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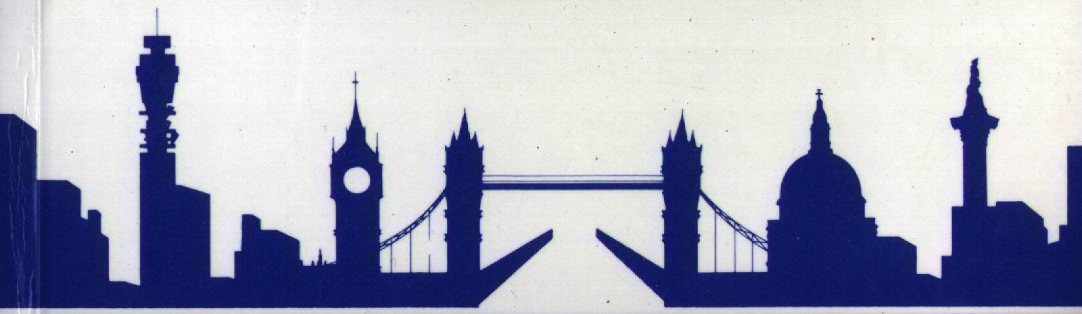

edited by Michael Blakemore

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AUTO CARTO LONDON

Volume 2

Digital Mapping and Spatial Information Systems

edited by Michael Blakemore

International Conference on the
acquisition, management and presentation
of spatial data

14 - 19 September 1986

Auto Carto London is a technical conference of the
International Cartographic Association

Published by Auto Carto London Ltd.

Any proceeds from the sale of this volume will contribute to a trust fund administered by the Royal Institution of Chartered Surveyors, and be used for such purposes as might advance knowledge in the areas encompassed by Auto Carto London.

ISBN 0 - 85406 - 312 - 9

Additional copies of the two volumes may be obtained at a cost of £40 from:

The Royal Institution of Chartered Surveyors
12 Great George Street
Parliament Square
LONDON SW1P 3AD
U.K.

Printed in Great Britain by
Whitstable Litho Ltd., Whitstable, Kent

The production of these proceedings has been
assisted by generous contributions from
the following:

International Computers Ltd.
Reading, Berkshire, U.K.

Laser Scan Laboratories Ltd.
Cambridge Science Park,
Hilton Rd., Cambridge, U.K.

Sysscan U.K. Ltd.
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FOREWORD

The problems of gathering papers from authors for any publication is a task fraught with anxiety. To do so with authors from across the globe is an exercise guaranteed to produce stress on all parties. The task of reminding, persuading, enforcing or diplomatically extending deadlines, telexing, telephoning and letter-writing, has fallen to Christine Philbin of Conference Services Ltd. The happiest witness to her unfailing tact and efficiency is the fact that these Proceedings are complete. All authors presenting papers have submitted a full written one (indeed, some have provided several revised versions over the past few months). The only abstracts are, as intended, for shorter presentations and are at the end of Volume 2.

In addition to the logistics of keeping in contact with authors, there has been the task of replacing some papers where previous authors had withdrawn. To do so at short notice, while maintaining the logical consistency of the overall programme, has required an extensive knowledge not only of the people who could be suitable, but also those available to attend the Conference. In this area the manifold international contacts of Peter Dale and David Rhind have functioned magnificently. Not a few of these papers were written under some pressure to meet the publication deadline, and in an era when we promote the proliferation of anonymous computer networks, this proves the continuing necessity of those traditional skills of communication.

The covers for the proceedings have been designed and produced by Lorraine Rutt and George Reeve of Birkbeck College. In Durham, Arthur Corner typeset the title pages, and Eileen Beattie processed the volume overviews. Many thanks to all of them.

Michael Blakemore July, 1986.

Digital Mapping and Spatial Information Systems

Volume Overview

While the majority of papers in Volume 1 concerned the developments in the methodology and technique, Volume 2 concentrates mainly on a wide range of applications. These range from those that mainly involve computer mapping, to others utilising complex geographic information systems. In geographical scales the studies go from individual townships to collaboration between the countries of the European Economic Community. Agencies involved are at local to national government, private sector consultancies, and utilities companies. The diversity of approaches and applications gives further weight to the need for viable international standards as debated in Volume 1, and highlights also the particular requirements of Auto Carto in the developing countries of the third World.

The initial section sets geographic information systems in an international perspective. At a municipal level **Bernhardsen and Tveitdal** show there to be positive cost benefits in digital mapping. Large volumes of data (some 20 gigabytes) are the concern of **Brand** who introduces the development of an integrated database for Northern Ireland. User needs have been identified, and the project is now at the stage of benchmarking proprietary geographic information systems. **Nag** illustrates the sorts of inter-agency collaboration that can take place in India, where the IRS-1 remote sensing satellite gives them better space technology than most Western nations. **Wiggins et.al.** use ARC/INFO as the GIS underpinning the CORINE project. This aims to integrate environmental information for the entire European Economic Community, with efficient data transfer between the development sites. Networks also feature importantly in **Green and Rhind** who detail the existence of a self-driven tutorial interface for ARC/INFO, which academics can access remotely using computer networks such as the U.K. Joint Academic Network (JANET) and British Telecom's Packet Switching Stream (PSS).

Land Information Systems (LIS are to a large extent synonymous with GIS) feature in several studies. **Williamson** notes that in Australia such systems are still dominantly parcel-oriented, since land valuation systems were the main development influences. In Sweden (**Andersson**) a particular factor of information systems are freedom of information - although there has been some speculation as to whether this will continue after the recent assassination of their Prime Minister. **Smith** assesses the possible benefits that would derive with the full computerisation of the resources in the U.K. Land Registry. With some 9.5 million plans and 400,000 index maps a pilot system in operation by May 1986 should ascertain the feasibility of such a scheme. On a more sanguine note **Burrough** questions why GIS technology is not a widely used as it could be, citing problems of data imprecision, and the conservatism of many applications areas. He also claims that Remote Sensing has been a drain on finance and brainpower, exacerbated by an existing lack of skilled personnel.

Adequate skilled personnel has as a prerequisite a capable educational and training process. **Cooper et al** complain that the retraining of cartographic technicians is hindered by the high cost of training, and increasingly limited budgets. **Tyrie** argues that it is vital to strengthens the training process in the higher education sector, while **Fortescue** outlines the plans within the Ordnance Survey stressing not only a concern for skills developing within the Agency, also in the school system - the necessary seed-bed of future technocrats. The introduction of computer assistance in an architectural design curriculum is supported by **Gimblett and Kelly** who stress that it assists in creative thinking by students, an analogy which would hold true with mapping. Specific examples of training programs are provides for the educational sector (ITC) by **McGrath**, and the Australian Key Centre for LI Studies by **Walker**. McGrath observes a growing market for employment in spatial data handling (a factor also noted by **Duru** in the context of Nigeria), but also proposes that in the same way that mechanisms are being derived for the exchange of digital data, so they should be also for exchanging information about teaching methods and course content.

Suitable training for countries in the Third World is addressed in four papers. **Taylor** stresses the utilisation of 'appropriate' technology using case studies of Nigeria, India and China. In some instances the standard capital intensive methods of digital mapping are less suitable than labour intensive ones - the inverse of most developed world situations. **Drummond and Stefanovic** list a series of problems incurred when transferring high technology to such areas; notably lack of finance, uncertain qualifications of the labour force, harsh environmental conditions, motivational and political uncertainties. An instance of cost-effective appropriate technology for Zambia is an IBM PC-AT system used for land evaluation purposes (**Anker et al**). Lastly, **Jeyanandan** introduces the development of L.I.S. in Trinidad and Tobago.

A series of sessions illustrate Auto Carto activities from the local to national levels. An LIS for the municipality of Vienna is the subject of the study by **Wilmersdorf**. In Canada, the experience of Burnaby is that computer mapping is only one element of digital spatial data usage, and **Wiebe** stresses that database facilities which enable efficient management, not just mapping, are crucial - a view concurred by **Mahoney** who hopes to see what he terms a 'Corporate Information Centre'.

Interrogation of spatial data is important also in the Canadian Department of Energy Mines and Resources electronic atlas (**Siekierska and Palko**). **Pearce** elucidates some of the staffing problems that can occur, using the system in operation at the Department of Mines in Western Australia. Data quality suffered initially since temporary staff were used for data preparation, and had a high error rate. Slow data capture and inconsistent data accuracies were some of the problems met during 10 years of digital mapping in Cheshire (**Gilfoyle and Challen**), where problem solving rather than research solutions were adopted. One of the staffing problems in the U.K. Military Survey (**Thompson**) is that at a time when new technology is being introduced it is difficult to reward staff adequately because the exigencies of the British economy, and career structures, mean there is a reduction in staff numbers, often inflexible recruiting methods, and a static salary structure. Storage structures which underpin activities in North Rhine - Westfalia are detailed by **Barwinski and Bruggermann**, and **Csillag et al** base their soil information system on quadtrees. Four papers specifically address developments in the U.K. The South Western Electricity Board (**Hoyland and Goldsworthy**) aims to have full automated mapping and facilities management by the early 1990s. The Wessex Water Authority has digitised its entire water supply network and developed a software system in-house. It now proposes to ask for tenders from GIS systems suppliers, though the authors bemoan the fact that 'the lack of digital map backgrounds in the U.K. is an impediment to developments'. A move to integrate Auto Carto between the Utilities is one role of the National Joint Utilities Group (**Ives and Lovett**), which is nearing the end of a five year trial set up in 1982 to link activities to Telecoms, Gas, and Electricity among others.

At an agency level, **Roberta Franklin** the activities of the Defense Mapping Agency in the electronic display of digital data, and **Dennis Franklin** explains their aim to have all-digital softcopy mapping by the early 1990s. At present some 50 million sheets a year are produced, and digital access will allow much more flexibility of production, such as specific feature wide extractions. The U.S. Geological Survey (**Starr**) has projected its requirements to 2000, which includes full production of the 1:24000 scale series, and revision of 5600 topographic quads each year. The USGS National Digital Cartographic Database will utilise advanced data structures that allow more sophisticated attribute and feature identification (**Guptill**), notably the use of name complexes that will mean feature names such as the Potomac River will include all elements that comprise it such as shorelines, islands, bridges etc. The Australian State of Victoria has a 1:25000 mapping programme (**McColl**) that was seriously disrupted in 1983 when a fire destroyed a substantial amount of equipment and data.

The photogrammetric updating of 147 sheets of the French littoral zone (1:25000 scale), comprising some 400,000 polygons, is studied by Grelot and Chambon. A prototype mapping system for the British Geological survey has been developed (Loudon) in advance of production systems, Hydrographic mapping in the U.K. is benefiting from a new coastal survey vessel with advanced data logging and processing facilities (Dixey, Gobey and Wardle). Sidescan sonar used in the Institute of Oceanographic Sciences (Searle and Hunter) is producing good quality contour mapping 15 times quicker than conventional bathymetric survey. The U.S. National Ocean Service (Lisle) maintains 1000 charts and is moving to its Mark II automated charting system. Key problem areas still exist in this field, and Drinkwater and Fielding stress those of generalisation and digitising. Added to that are legal liability issues, whereby a computer error leading to an erroneous symbol on a chart could result in loss of life. These legal issues are now concerning land surveyors as well, with the threat law-suits increasingly likely.

More methodologically oriented papers involve crucial areas of generalisation. Lodwick, Paine and Ratchinsky evaluate the various techniques of filtering used in enhancing Landsat imagery. A set of models are specifically developed for the generalisation of buildings, road and river networks (Meyer). A gradual move towards idealised fully automated algorithms is questioned by Monmonier who uses the analogy of 'training areas' used in supervised classifications in remote sensing. The deliberate human intervention he proposed may be better than some existing expert systems approaches. A new departure into fuzzy logic is proposed by Vicars and Robinson who see expert systems being useful in the derivation of hierarchical object structures for spatial data peculiar to each scale of mapping. These would then provide some of the 'rules' to be operated on. Lastly, Mark and McGranaghan examine the increasingly topical issue of in-car navigation systems with auto carto display facilities. They question whether this is not an overtly "technology-driven" application area, where the hardware can perform, but the users do not as yet want it to do so. Could it be that actual graphics in vehicles are not always the most useful data - in many cases procedural directions may be preferable.

The economic and commercial aspects of auto carto form a final set of papers. Woodsford carries out a comparison of digitising methods, particularly concentrating on the manual and scanning technologies. Weir and Swetnam stress that any investment must be the result not of costings on the basis of machinery and software, but on a much wider range of "informed" investment appraisals. They give procedures for so doing. The marketing of digital map data is a vital aspect of the U.K. Ordnance Survey's scales development; Leonard lists the marketing techniques they consider.

Marketing strategies are strongly developed in the private sector. Where agencies and bureaux are competing aggressively against each other there often is an incentive not to distribute data so that competitors can use them easily. The real importance is in the added value that market research can give to data sets. Thorpe gives an overview of the mainly military activities of Scicon, where systems for assessing intervisibility are important component of battlefield digital map usage. **Sheath** claims that 'a very sound map production has evolved' in the British Petroleum Exploration System. This has had a slow evolution over many years, which he claims has benefitted BP immensely. Two market research bureau in the U.K. are represented. Pinpoint Analysis (**Beaumont**) have much in-house software which is used effectively to communicate information concisely. Beaumont argues that "information overload is a real danger to efficient and effective marketing". CACI (**Harris and Pettigrew**) detail a mixture of proprietary systems and home-grown software in their study. The effort required in determining the logistics and timing of a major GIS development are given by **Dangermond and Sorensen**, here in the case of Baghdad in Iraq. Finally, innovative hardware utilisation and software development are manifested in the BBCs Domesday project (**Openshaw and Mounsey**). A laser disk stores 500 megabytes of digital data, 50,000 photographs and 20 million words of text. A minicomputer-based enquiry system has generated a vital information source for use primarily in schools (for which it is intended as a low cost database), but also in many commercial areas where such a well structured massive data set has considerable value.

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COMMUNITY BENEFIT OF DIGITAL SPATIAL INFORMATION

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ABSTRACT

A joint Nordic project is set up for the purpose of computing (quantifying) the community benefit of large-scale digital maps that include associated data, i.e. a computer-based technical information system of spatial data for municipalities.

The main purpose of the project is to develope economic methods for the calculation of the benefit derived from the introduction of digital spatial information system, to work out general information to be used by a switch-over to digital spatial information and to influence on Nordic policy in this area in a constructive manner.

The project is running for 1985 and 1986 and this paper gives the status of the project and our findings so fare.

Preliminary results show that the benefit - cost ratio for digital spatial information system lies between 3 and 7.

BACKGROUND

Municipal engineering is an important branch of social activity, basic to citizen needs, and consuming large economic resources. In the Nordic countries together the expenses involved in the running and maintenance of municipal technical utilities are estimated to more than 15 billion US$ per year.

The enormous values involved should imply that even modest improvements of effectiveness will be of great economic importance. Exact information about geographical location and status become levels of detail must be computerbased to be easy to handle, and in order to provide information standard and overview for more intelligent and coordinated efforts.

Preliminary investigation in Scandinavia points at a benefit-cost ratio of at least 3 for investing in good analog map system, i.e. each US$ invested would pay off three US$. There are reasons to beleive that the benefit-cost ratio for digital spatial information is considerably greater than this figure.

ECONOMIC CONDIERATIONS

Economic mehtods for the calculation of community benefit derived from introducing digital information system have been developed at the Stockholm School of Economic and Business Administration in cooperation with Moereforskning i Norway.

It is often a possitiv correlation between a change in technology and profitability. Instead of investing more money in an exisiting system it may be more profitable to change technology. Choosing time, dimensions and levels of ambition is important parameters of decisions in the introduction of digital geographic information system. The speed of change in technology is of crucial importance for the present day value of cost/benefit.

The choosen information system must be flexible in order to meet the users' different demands. At the start one has to concentrate on one simple task. This strategy will lead to the highest economic benefit.

RESULTS

The method of quantifiying community benefit of spatial information systems is mainly based on information about time saved among the users of products. The data was collected by means of personal interviews with principal users in various public services in the Nordic countries, USA, Canada and Italy. During 1985 approx. 35 comprehensive consumers interviewes have been carried out. A considerable quantity of written materials has also been collected.

The following strategy seems to be common when introducing digital systems:

1. Cost/benefit analysis, which is carried out proffessionally.

2. A pilot study lasting for 1/2 to 1 year.

3. Decision-making, taking into consideration both tangibles and in-tangibles.

4. Convertion of data, has to be carried out with great effort during a short period of time.

5. Operation and benefit period, incl. the development of new applications.

Data convertions are often made internally in the organisations.

It seems to be a common experience that the benefit is not realized until one category of data is fully converted. Preliminary investigations into the collected materials seem to lead to the conclution that the typical benefit/cost for digital spatial information system lies between 3 and 7. The benefit/cost ratio for a single effort as automation of map production is often estimated to 1, while a fully information system with links to asociated data have benefit/cost ratio up to 7.

In all organisations benefits are derived from an external coordination and exchange of information.

Usual areas of application:

Automation of map production, planning, project-making, water, sewage, electricity, gaz, telephone, roads, police, fire, property administration, statistics, public case procedures, marketing, taxation, land administration.

THE PRESENT SITUATION WITHIN THE NORDIC COUNTRIES

As a part of the project the present situation within the Nordic countries is registered. The producing of digital maps is today 30 - 50% of the total map production. Digital production of maps in scale 1:500/1:1.000 is regarded as simple.

Digital information systems with associated data are introduced in large towns and in privat utility firms. There are hardly any organisations that prosess complete data information system and the activity is still concentrated on producing the data rather than using it.

In the Nordic countries there are many small organisations and there is a great uncovered demand for low-cost graphic work stations.

It is expected that in a period of 5 - 10 years nearly 100% of the map production will be digital and a lot of geographical dataabases would have been established.

THE FOUNDATION OF A GEOGRAPHICAL INFORMATION SYSTEM FOR NORTHERN IRELAND

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Northern Ireland, small and compact, geographically well defined with a relatively simple administrative structure, has a unique opportunity to reap the advantages from the establishment of Geographic Information System. This paper describes the beginnings of the formation of the topographical part of the database, which will form the basis of such a system and the first part of this sophisticated spatial database. It identifies the benefits including financial ones that are to be gained within the Public Sector from the introduction of information technology including computer graphics. Here much of the information (in parts 80%), required for the proper management of municipal and utility functions or facilities and for the efficient provision of service to customers, is common. It will describe how in Northern Ireland user needs have been identified, and the organisational structure necessary to continue to do so has been constructed. This will assist in the acquisition and development of compatible systems to achieve maximum advantage. It also outlines the method of extension from a solely topographic database into an integrated system for the storage, exchange and use of spatially related data within the Northern Ireland Public Sector. This extends even to Remote Sensed data from the Northern Ireland Regional Remote Sensing Processing Centre, which is to be established in 1986 at the Ordnance Survey of Northern Ireland and ultimately interfaced into the topographical database.

CONCEPT

In common with many other organisations, the rapid growth in both the requirements for and techniques of information technology during the past decade, the Ordnance Survey of Northern Ireland began to look at the possibility of replacing its conventional map production (using largely manual techniques) with a computerised system. The concept involved the conversion of geographical data into digital form, their storage in computer systems and their subsequent manipulation and display. In late 1981 a feasibility study on the provision of a digital mapping and topographical database and its implications was begun. This concluded that the current topographic archive should be digitised over a ten-year period using a commercially available 'turnkey' system. This would provide a complete topographical database for Northern Ireland in digital form and establish the basis of a single integrated geographical information system.

Geographical information may be defined as all information that can be spatially referenced using a common system of geographic co-ordinates. All information, whether it be about a water stand pipe, a traffic incident or an unemployment record has one thing in common - a location. It is this positional location, often indicating causal relationships that is the common factor. All Ordnance Survey of Northern Ireland mapping is based on the Irish Grid (as it the modern mapping for the whole of Ireland), using a Universal Transverse Mercator Projection. The geographic position (co-ordinates) of any feature of the map is therefore the unique 'hook' to which all other data sets can be tied and so provides the common link between them. Thus the Geographical Information System would hold digital geographic data for, say, housing in any chosen areas, and a whole plethora of information - population, age structure, valuation, services networks, etc - would be related to the positional data. Many organisations already require positional data in digital form and as the system develops demand for this will grow. The possibilities that are provided by a properly constructed and managed Geographical Information System are almost limitless.

INTEGRATED APPROACH

The single most important feature in our thinking is that the system should produce a DATABASE - not simply a cartographic databank. Such cartographic databanks are fine for producing cartographic maps or digital 'backdrops' but are quite unsuitable for manipulation for other purposes. Our ultimate goal is a true Geographic Information System. Herein lies the essential difference in our approach from that taken by many organisations in other parts of the world.

To assist in achieving this goal Liaison Committees were set up bringing together the many public services concentrated in Northern Ireland government departments as well as other major organisations in the public sector. These included those bodies responsible for land registration, water and sewage, roads, planning and electricity services as well as police, housing, telecommunications, agriculture, forestry, economic development, health and social security. The function of these committees was and still is to advise on the structure and form of the topographical database and on the programmed population of it. They also carry out a vital role in the spread of information amongst members regarding the requirements of data exchange and the progress of computerisation within each organisation, and they have an increasing co-ordinating function.

This establishment of user needs was and is fundamental to our approach. From the beginning, the objective was the systematic introduction of an information system - and perhaps Northern Ireland is in a unique position to benefit from computer-based spatial data: It is a geographically compact area of some 14,000 square kilometres, with a population of approximately 1,500,000. Thus the database will be of a size that is relatively easy to manage. However, to put the size of the project into perspective, it is estimated that the topographical part of database alone will be about 20 gigabytes in volume. This emphasises the problems to be experienced elsewhere. Northern Ireland also has a comparatively simple administrative structure, where most of the local government and utility-type services are run directly and centrally by government departments. This leads to little or no geographical conflict in demand between requirements from different user sources. Thus we have a compact and simple environment within which to operate, to assist in the production of a single integrated system, with no duplication of effort in data capture and a ready sharing of data - providing an early start was made.

This latter point is vital because in Northern Ireland until recently most of the organisations concerned had not introduced computer technology except for financial and administrative purposes, eg, pay invoicing, customer records, etc. Therefore we have a clean page, so to speak, upon which to write without having the constraints of previous system procurement decisions and of data conversion. Large computer files of statistical information and cabinets and plan presses bulging with maps and written records are of limited use if accessing them is a clumsy business and they are difficult to relate to the real world. This especially so if they are prone to damage and costly to maintain.

Public utilities and other bodies base many of their administrative and service records on maps. The availability of suitably structured digital databases containing both graphic and non-graphic linked information will provide them with fast and flexible means of storing, retrieving and manipulating this information. Northern Ireland is determined that users of topographical information do not experience the incompatibility problems in utilising digital data now being encountered in many places elsewhere. For this reason it is important that all user organisations' systems are capable of linking into an integrated geographic information system. Compatibility is therefore the essential element.

Political support for this integrated approach has been forthcoming because the wisdom of avoiding duplication of the digitisation of topographic information by public sector bodies has been realised. This thinking extends even to other information used by public sector bodies where, in parts, 80% of that required for the proper management of municipal and utility functions and for the efficient provision of services to their customers, is common to more than one organisation. Information should only be collected or converted to digital form once, by the appropriate authority and to the proper standards, so that it may be used by all. It is thought that in Northern Ireland the Ordnance Survey is the natural originator of standards for production for digital maps, such standards being essential.

BENEFITS

Availability of a digital topographical database provides many already well-known benefits: Gone are the constraints of map sheet lines and of conventional content and output specifications; and there is the luxury of scale-free data that can be extracted selectively or used in conjunction with data from other sources.

The financial benefits are much more difficult to quantify - particularly as many of them accrue to other organisations, and not in the immediate future. We are in essence making a necessary investment in the infrastructure of the nation for the future. However the fact that many organisations worldwide, and an ever increasing number of them, have both the requirement and the justification to computerise their own graphical records for some applications, which in turn need a topographic base for full utility, indicates that these benefits are real. The main stumbling block or constraint for many is the non-availability of the topographical data and the cost of its provision not only in financial terms but in other resources including time. In Northern Ireland the financial justification is soundly based on non-duplication of data conversion and on the realisation and acceptance that additional and larger benefits accrue when the information systems of the entire Public Sector is linked, thus allowing the free exchange of information between those that require it. It is interesting to note that it has been conservatively estimated that the savings on the topographical data only could amount to some ten times the investment within the Ordnance Survey.

SYSTEM PROCUREMENT

The Ordnance Survey of Northern Ireland sought a computer-based system with the following broad objectives:-

- Capture and maintenance of the map archive in scale-free digital form over an initial ten-year period;

- Use of this digital archive for all map production;

- Creation of a fully structured topographic database to allow flexible extraction and manipulation of archive information by the Ordnance Survey and various other public sector organisations;

- Integration of the topographic database with other organisations' databases at their sites for convenient exploitation by them;

- Provision and development of all these services into the indefinite future.

Following evaluation of the output from a comprehensive series of Bench Mark Tests designed to identify suitable 'turnkey' systems, equipment was bought. The system configuration operates within a VAX environment, and as the database grows additional data storage will be acquired as necessary to hold the estimated 20 gigabytes of topographic information for Northern Ireland.

DATABASE

The design of the topographical part of the database is crucial. From the outset it was realised that ultimately a fully relational-type database would be required. Although there are a number of these presently available the full development of this type of database is still in its infancy. As a result it was decided initially to simulate a relational one to facilitate the eventual translation of data.

The major element of any investment into any such project is not the capital hardware or software part of the system but in the data itself. With a data capture period of up to ten years (a workload well in excess of 400 man years), the database structure must be very carefully designed to allow for portability and currency. In essence we are planning for a year 2000 system in the year 2000. Thus the design must be flexible enough to allow for the as yet unknown requirements of the future.

It is only on a project like this, when one dissects a map with its mass of information both specific and implied, that its value as a vehicle for the storage and transmission of information is fully appreciated. The topographical part of the data will have in excess of 140 main families of data, but it is intended that much of this structuring and its further breakdown will be done automatically by using computer files held by other organisations. For example, buildings could be classified by their usage or other attributes from information held in valuation records, eg private or government: dwelling or commercial; retail outlet or office etc.

THE WAY AHEAD

The basic task is to capture the map archive in digital form by 1995 or before, as it is intended, because of user demand, to accelerate this programme using a number of methods including automatic data conversion by raster scanning.

The first phase involved digitising the urban areas which are mapped at 1:1250 scale, these being the areas of greatest ground development and therefore the areas where public utility network information, etc, is most densely concentrated. The Greater Belfast Area will be available in digital form in 2 years time and by late 1989 the topographical information of all urban areas will have been converted. Rural areas will follow and throughout the ten-year data-capture period the stored digital information will be maintained up-to-date by direct input of automatically recorded field data. As well as the large-scale database, a small-scale database derived from the 1:50 000 series maps will be established in parallel within the first 3 years.

In addition, with the establishment of the Northern Ireland Regional Remote Sensing Processing Centre at the Ordnance Survey, remote sensed data from both satellite and aircraft will be available in digital form to assist in such studies as soil classification, agricultural crop and disease identification, pollution control, etc. Ultimately the Regional Centre will be interfaced directly with the topographical database system, thus providing a very powerful information tool. Airborne campaigns this year to capture data at five metre resolution of selected parts of the Province as well as data from Spot Image and the Thematic Mapper are underway, leading to a series of project orientated investigations.

Users, including the Ordnance Survey, will be able to access the system as soon as it contains data of interest to them. By then they will have developed their own compatible computer systems running a databases containing their own specialised data and it will be possible for users to manipulate the topographical data and their own as required for their unique purposes. A number of pilot schemes to be conducted in conjunction with our colleagues in the Water Industry, Land Registry, etc, will start this year as a beginning of the extension of the use of the system.

In addition, a project bringing together the Ordnance Survey, Water Service and the Institute of Hydrology is progressing. This contains topographic information, which includes relief, in the form of a DTM and river systems with the output of river telemetry stations. This will enable not only a series of graphical outputs of water quality, flows etc and all their derivatives, to be produced but also the opportunity to undertake computer modelling exercises. Other plans include a soil survey of Northern Ireland which will be 'digital', and studies to include the incorporation of Geological information in the system.

When several users are connected to the system, each of them will be able to extract data not only from the Ordnance Survey system but also from each other systems (subject to access privileges) and to manipulate the total data as necessary. As the number of users sharing information in this way increases, the system will constitute a continually improving Geographic Information System for the benefit of all.

A NEW DESIGN FOR THE U.S. GEOLOGICAL SURVEY'S NATIONAL DIGITAL CARTOGRAPHIC DATA BASE

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ABSTRACT

In analyzing the requirements for the U.S. Geological Survey's next generation of digital cartographic systems, several enhancements to the National Digital Cartographic Data Base regarding spatial data structures and data management systems were identified as key items. These included the development and implementation of a new data structure having enhanced attribute and feature identification characteristics to support product generation and analytical requirements and the development and implementation of an improved data management capability. A data base design incorporating these enhancements has been completed. Research and development activities pursuant to these design concepts are underway. A prototype of the spatial data base environment will be developed on a standalone workstation (32-bit supermicro) using relational data base software and anticipating a network of workstations connected to a central data archive.

INTRODUCTION

The U.S. Geological Survey (USGS) has been collecting information for the National Digital Cartographic Data Base (NDCDB) for almost a decade. The initial plans were for the NDCDB to consist of boundary, public land net, stream and water-body, and transportation data collected from 1:24,000-scale maps; and elevation data usually obtained concurrently with the orthophotoquad program. Over the years, other components have been integrated into the NDCDB including: planimetric data from the 1:2,000,000-scale sectional maps of the National Atlas of the United States of America; elevation data from the 1:250,000-scale map series; land use and land cover and associated map data; and geographic names data.

Recently the scope of the data base has again been increased to include digital cartographic data collected from 1:100,000-scale base maps. These data will provide nationwide coverage of transportation features (such as roads, railroads, powerlines, and pipelines) and hydrographic features (such as streams, rivers, and water bodies) by the end of the decade.

The digital planimetric data are produced and distributed in the form of digital line graphs (DLG). The DLG concept uses the principles of graph theory and topology to represent a graph as a set of nodes, lines, and areas that explicitly records the spatial relationships inherent in the graph. The use of the DLG structure in the NDCDB has helped to hasten the adoption of topologically structured data by the mapping and charting community.

Publication authorized by the Director, U.S. Geological Survey.

REQUIREMENTS FOR CHANGE

The USGS has embarked on a major development program to implement advanced technology and production procedures to satisfy National Mapping Program product and process requirements by the year 2000 with increased efficiency and acceptable operational costs. This program will exploit state-of-the-art technology available over the next 6 years, followed by an intensive production effort during the 1990's. The NDCDB will evolve to become the central focus of most National Mapping Division activities, including maintenance and revision of our basic map series and provision of data to geographic information systems.

The current NDCDB system, which manages an archive of cartographic data files, will have to be enhanced to meet the design goals of the future system. The major requirements for improvements and changes fall into four areas:

(1) Development and implementation of a data management facility within each Mapping Center to better support increased data production and product generation requirements.

(2) Acquisition and implementation of mass storage systems to support improved data storage and retrieval.

(3) Development and implementation of a new data structure and spatial data base management system having enhanced attribute and feature handling characteristics that will support expanded data production, product generation, and analysis requirements of the digital data.

(4) Development and implementation of an NDCDB data distribution subsystem to support the public sale of standard and derivative digital and graphic products.

CONCEPT OF OPERATIONS

To meet these requirements a concept of operations has been developed to define the future data base operations and data structure. The NDCDB is envisioned as functioning in two environments: archival and operational. The archival data base environment will consist of a central data repository, including information and indices about the data (metadata), and will support retrieval by cartographic feature and geographic partitions. The operational environment will provide data staging and tracking facilities for the movement of data between the archival and operational data bases. It also allow for the manipulation, analysis, and display of the spatial information in a data base context. The queries, retrievals, and uses are different within the archival and the operational environments.

Archival Data Base

The archival data base will consist of spatial data and metadata. The spatial data would be partitioned by series, quadrangles, and categories. These partitions are defined as:

Series: a partition by data content (imagery, elevation matrices, cartographic data) or scale (1:24,000, 1:100,000); interseries topological consistency is not required.

Quadrangles: partitions along latitude, longitude boundaries; matching across boundaries is required.

Categories: a logical subdivision of a series into classes of related data (transportation, hydrography); intercategory topological consistency is required.

Metadata are descriptions of the data content of the NDCDB. These descriptions apply to sets of records such as a quadrangle of a series and include such information as data source, processing history, and accuracy. The metadata also contain feature keys to quadrangle coverage. For example a key to all the quadrangles that contain the Potomac River would be maintained in the metadata. Queries are against only the metadata, not the spatial data. The spatial data would be retrieved by quadrangle multiples according to series, category, or feature designations.

Operational-Level Data Base

The operational environment will consist of two subsystems; a data staging and tracking system, and a spatial data management system. The data staging and tracking system provides facilities for the transfer of information between the archival and operational data bases and will manage the local storage of data in work at a production center. The operational-level data base will be initialized by quadrangle multiples of data from the NDCDB Archive. This downloading of data from the archive (where it will reside on a high-density mass storage device such as an optical disk or magnetic tape cassette) will probably occur over a local area network either to a local host computer or directly to a computer workstation.

The spatial data management system will provide the capabilities to manipulate spatial information with a set of data base tools. The schema used in this system will consist of the various feature, location, and topological components that make up a cartographic data structure. It is postulated that these data elements can be placed in a relational data base and used in the workstation environment. Data retrievals by feature, attribute, topology, or location will be required in the operational environment.

CARTOGRAPHIC DATA MODELS

To understand the conceptual design being proposed for the spatial data base management system, it is helpful to see the role of digital cartographic data as a model of reality. All maps can be considered as models of the real world. Future cartographic applications and activities will center around a spatial data base which is, like a map, a multifaceted model of geographic reality. Before such a spatial data base can be designed, there is, therefore, a need to define an efficient model of the geographer's abstraction of the real world.

The key here is to define and develop abstract global descriptions for digital cartographic and geographic data. This issue of data abstraction arises with respect to the identification of spatial entities. Definitions based on dimensionality of space (that is, points, lines, and areas) address the issue of feature description from only one perspective, that of object geometry. This is not sufficient.

To a user whose applications are to be supported by spatial analysis operations, individual points, lines, and polygons are but abstractions of the user's view of spatial reality. It would benefit the user if spatial entities and respective operators were defined at a user-logic level. Spatial reality from a user's view probably comprises visually or logically discernible geographic point, linear, and areal features (such as landmarks, roads, and counties), each with their respective descriptive attributes. We will term these spatial entities cartographic features.

More precisely, a cartographic feature is the set of points, lines, and/or areas that meet some specified attribute or spatial criteria. Examples include highways, by route number or by name; named complexes, such as Dulles Airport; unnamed complexes, such as a drive-in theater; and named natural features such as the Potomac River, including its shorelines, islands, falls, rocks, and mudflats. A spatial data base management system would allow the user not only to pose questions, but also to receive responses expressed in the user-logic level of abstraction, that is, in terms of cartographic features. The actual manipulations would occur at a lower level of abstraction, one that contains the geometric information about the spatial entity.

The representation of shape and location at the geometric and subordinate levels of abstraction are usually achieved by using either raster (typically using grid cells to enumerate spatial occupancy) or vector (using sequences of x,y coordinate pairs to represent boundaries) techniques. In this design, the geometric description of spatial entities will be presented in terms of a vector representation. However, it should be noted that the conceptual schema for the spatial data base management system separates the geometric descriptions of spatial entities from the feature description of the entity. In other words, alternate (or even multiple) geometric models can be used to describe the shape characteristics of the objects (point, line and area entities) of the cartographic model. For example, roads could be represented by vector line segments and county areas could be represented by quad trees (Samet, 1984).

In addition to modeling the geometry of cartographic features, the relationships of these features to each other need to be described in the model. One set of these relations describes the topology of the features (that is, relationships such as adjacent to, connected to, contained in, and bounded by). A second set of relations describes the class of objects that comprise a given cartographic feature.

In summary, the cartographic data model consists of spatial entities (objects), descriptive attributes for the objects, geometric descriptions of those objects, and the relationships among the objects. The concepts and terminology of the extended relational model RM/T (Codd, 1979; Date, 1983) have been used to develop the design for the cartographic data model. A formal description of this model is given in Appendix A. For data transfer this schema will be implemented in an enhanced digital line graph (DLG-E) format. The DLG-E will conform to the data standards guidelines being proposed by both the Federal Interagency Coordinating Committee on Digital Cartography (1985, p. 25-38) and the National Committee for Digital Cartographic Data Standards (Moellering, 1986).

DATA BASE OPERATORS

As described, the cartographic data model consists of the basic components (entities, designations, and properties) used in the extended relational data model. This then, allows relational data manipulations to be performed using the set of relational operators (select, project, product, union, intersection, difference, join, and divide (Date, 1986a)). Thus, the spatial data base management system has full manipulative power of the relational model available to process the descriptive attributes and the other non-spatial components of the cartographic data model. For the spatial (geometric) components of the model, it is proposed to use a set of spatial operators (Claire and Guptill, 1982; Claire, 1984). The commonly referenced spatial operators are listed in table 1.

Table 1.--Commonly referenced spatial operators (from Claire and Guptill, 1982).

OPERATOR	CLASS	OPERAND	RESULT	COMMENTS
LENGTH	Mon	1-cell	Nu	
AREA	Mon	2-cell	Nu	
BOUNDARY	Mon	2-cell	1-cell	Set of points that comprise limit of α
COMPLEMENT	Mon	n-cell	n cell	Set of points that are not members of α.
EXTEND	Mon	n-cell	2 cell	Set of points within a distance 'd' of α.
SEPARATION	Dya,sym	n-cell	Nu	Minimum of distances between points of α and points of β.
OVERLAP	Dya,sym	n-cell	B	True if α and β have at least one point in common
EQUALS	Dya,sym	n-cell	B	True if all points are members of both α and β.
CONTAINS	Dya,asy	n-cell	B	True if all points of β are members of α.
INTERSECTION	Dya,sym	n-cell	n cell	Set of points that are members of α AND members of β
UNION	Dya,sym	n-cell	n cell	Set of points that are members of α OR members of β
DIFFERENCE	Dya,asy	n-cell	n cell	Set of points that are members of α and not members of β

Mon : Monadic
Dya : Dyadic
Sym : Symmetric
Asy : Asymmetric
Nu : Numeric
B : Boolean
n-cell : 0-cell, 1-cell, 2-cell or combination
α, β : Operands

Spatial operators represent the basic and fundamental manipulations of spatial entities. The purpose of both the relational and spatial operators is to allow for the writing of expressions, which themselves serve many purposes, including data retrieval. The spatial operators are the analogs for spatial data to the set of relational operators used with non-spatial data. As such, spatial operators would be applied to various geometric components of the cartographic data model and relational operators to the remaining elements of the model.

Taken in concert, the relational and spatial operators provide full manipulative capabilities over all elements of the cartographic data model. They are the building blocks that may be aggregated in various ways to support the increasingly complex forms of geoprocessing. Thus we have both the data structure and the data manipulation components that are necessary for a spatial data base management system.

SUMMARY AND CONCLUSIONS

A preliminary design for the next generation of the NDCBD has been completed. The key features of this design are the creation of a comprehensive cartographic data model by adding a feature data element to the DLG schema and the separation of data base operations into archival and operational environments. It is thought that commercial relational data base management systems can be used to manipulate the non-spatial components of the data model. Spatial operators will perform fundamental geometric manipulations of spatial entities. These design concepts are being investigated and test implementations are underway.

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APPENDIX A
DATA BASE CONCEPTUAL SCHEMA

This description of the design for the spatial data base uses the general terminology of the RM/T data model (Codd, 1979), and more specifically, Date's "pseudo-DDL" formal expressions (Date, 1986b). The main elements of this semantic are entities (classified as being either kernel, associative, or characteristic), designations, and properties. Each entity (kernel, associative, characteristic) maps into a base table. Each designation maps into a field (foreign key) within the base table for the designating entity type. Each property maps into a field in a base table. Primary keys provide the only guaranteed record-level addressing mechanism in the relational model. Foreign keys provide the referencing mechanism in the relational model.

Pseudo-DDL description of the Spatial Data Base

```
CREATE TABLE N /* NODES(KERNEL) - DESIGNATE NG */
   FIELDS (N#, NG#, NAME, ATTRIBUTES,...)
   PRIMARY KEY (N#)
   FOREIGN KEY (NG# IDENTIFIES NG
           NULLS ALLOWED
           DELETE OF NG NULLIFIES
           UPDATE OF NG.NG# CASCADES)

CREATE TABLE L /* LINES(KERNEL) - DESIGNATE LG */
   FIELDS (L#, LG#, DIRECTION, NAME, ATTRIBUTES,...)
   PRIMARY KEY (L#)
   FOREIGN KEY (LG# IDENTIFIES LG
           NULLS ALLOWED
           DELETE OF LG NULLIFIES
           UPDATE OF LG.LG# CASCADES)

CREATE TABLE A /* AREAS(KERNEL) - DESIGNATE AG */
   FIELDS (A#, AG#, NAME, ATTRIBUTES,...)
   PRIMARY KEY (A#)
   FOREIGN KEY (AG# IDENTIFIES AG
           NULLS ALLOWED
           DELETE OF AG NULLIFIES
           UPDATE OF AG.AG# CASCADES)

CREATE TABLE F /* FEATURES(KERNEL)*/
   FIELDS (F#, NAME, ATTRIBUTES,...)
   PRIMARY KEY (F#)
```

```
CREATE TABLE NL /* NODES AND LINES - ASSOCIATE LINES AT A
          NODE */
   FIELDS (N#, L#, PLACE,...)
   PRIMARY KEY (N#, L#)
   FOREIGN KEY (N# IDENTIFIES N
          NULLS NOT ALLOWED
          DELETE OF N CASCADES
          UPDATE OF N.N# CASCADES)
   FOREIGN KEY (L# IDENTIFIES L
          NULLS NOT ALLOWED
          DELETE OF L CASCADES
          UPDATE OF L.L# CASCADES)

CREATE TABLE LBA /* LINES BOUNDING AREAS - ASSOCIATE LINES
          AND AREAS */
   FIELDS (L#, A#, ORIENT, DIRECTION, INOUT, PRIOR_L#,
          NEXT_L#,...)
   PRIMARY KEY (L#,A#)
   FOREIGN KEY (L# IDENTIFIES L
          NULLS NOT ALLOWED
          DELETE OF L CASCADES
          UPDATE OF L.L# CASCADES)
   FOREIGN KEY (A# IDENTIFIES A
          NULLS NOT ALLOWED
          DELETE OF A CASCADES
          UPDATE OF A.A# CASCADES)

CREATE TABLE FF /* FEATURES COMPOSED OF FEATURES -
          ASSOCIATE FEATURES */
   FIELDS (MAJOR_F#, MINOR_F#,...)
   PRIMARY KEY (MAJOR_F#, MINOR_F#)
   FOREIGN KEY (MAJOR_F# IDENTIFIES F
          NULLS NOT ALLOWED
          DELETE OF F CASCADES
          UPDATE OF F.MAJORF# CASCADES)
   FOREIGN KEY (MINOR_F# IDENTIFIES F
          NULLS NOT ALLOWED
          DELETE OF F CASCADES
          UPDATE OF F.MINOR_F# CASCADES)

CREATE TABLE FA /* FEATURES COMPOSED OF AREAS - ASSOCIATE
          FEATURES AND AREAS */
   FIELDS (F#, A#,...)
   PRIMARY KEY (F#,A#)
   FOREIGN KEY (F# IDENTIFIES F
          NULLS NOT ALLOWED
          DELETE OF F CASCADES
          UPDATE OF F.F# CASCADES)
   FOREIGN KEY (A# IDENTIFIES AREAS
          NULLS NOT ALLOWED
          DELETE OF A CASCADES
          UPDATE OF A.A# CASCADES)
```

```
CREATE TABLE FL /* FEATURES COMPOSED OF LINES - ASSOCIATE
             FEATURES AND LINES */
   FIELDS (F#, L#,...)
   PRIMARY KEY (F#,L#)
   FOREIGN KEY (F# IDENTIFIES F
           NULLS NOT ALLOWED
           DELETE OF F CASCADES
           UPDATE OF F.F# CASCADES)
   FOREIGN KEY (L# IDENTIFIES L
           NULLS NOT ALLOWED
           DELETE OF L CASCADES
           UPDATE OF L.L# CASCADES)

CREATE TABLE FN /* FEATURES COMPOSED OF NODES - ASSOCIATE
             FEATURES AND NODES */
   FIELDS (F#, N#,...)
   PRIMARY KEY (F#,N#)
   FOREIGN KEY (F# IDENTIFIES F
           NULLS NOT ALLOWED
           DELETE OF F CASCADES
           UPDATE OF F.F# CASCADES)
   FOREIGN KEY (N# IDENTIFIES N
           NULLS NOT ALLOWED
           DELETE OF N CASCADES
           UPDATE OF N.N# CASCADES)

CREATE TABLE NGEOM /* GEOMETRY OF NODES (KERNEL) -
               DESIGNATE NODES */
   FIELDS (NG#, N#, GEOM,...)
   PRIMARY KEY (NG#)
   FOREIGN KEY (N# IDENTIFIES N
           NULLS NOT ALLOWED
           DELETE OF N CASCADES
           UPDATE OF N.N# CASCADES)

CREATE TABLE LGEOM /* GEOMETRY OF LINES (KERNEL) -
               DESIGNATE LINES */
   FIELDS (LG#, L#, GEOM,...)
   PRIMARY KEY (LG#)
   FOREIGN KEY (L# IDENTIFIES L
           NULLS NOT ALLOWED
           DELETE OF L CASCADES
           UPDATE OF L.L# CASCADES)

CREATE TABLE AGEOM /* GEOMETRY OF AREAS (KERNEL) - DESIGNATE
AREAS */
   FIELDS (AG#, A#, GEOM,...)
   PRIMARY KEY (AG#)
   FOREIGN KEY (A# IDENTIFIES A
           NULLS NOT ALLOWED
           DELETE OF A CASCADES
           UPDATE OF A.A# CASCADES)
```

A PROPOSED BASE FOR GEOGRAPHIC INFORMATION SYSTEM FOR INDIA

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ABSTRACT

Attempts have been made by different organisations in India to organise data in order to develop a most suitable information system. These attempts were oriented towards specific use, such as natural resources, data management, thematic mapping and the like. In some attempts software have been developed for some specific purpose. Obviously, it is not an easy task to develop an information system for a country like India. The extent of the country along longitudes and latitudes is more than the average size of the countries. There are federal and state agencies for collection of data and preparation of maps. The geographic information concerning India is available from the following sources : (a) administrative set up : states, union territories, districts, sub -districts and villages; (b) survey sheets; (c) remote sensing imageries; (d) aerial photographs, and (e) thematic base of NATMO. There are other map series available which have been used for socio-economic mapping. By the end of 1986 the Indian Remote Sensing Satellite will be launched and then remote sensing data would be easily available. Considering the geographic bases available in the country, five levels can be identified for developing an information system for India. Some of the thematic maps at 1:1M scale can be used for initiating the Geographic Information System.

INTRODUCTION

Organising data for a large country like India is not an easy task at all. There are 29 states and union territories of reasonable size. Each of these states do not always have similar basis for data collection. As a result, the cartographic base and statistical contents vary considerably. On the other hand, the federal agencies for mapping and data collection follow moresoever homogenous policies for the entire country. The example of such data sets are population and housing censuses, livestock census, survey of industries, topographical sheets and thematic maps. India had developed space technology and soon remote sensing data will also be available from IRS-1. Some places have drawn special attention, and large scale maps and detailed information is available for these places. For priority areas, photographs at large scale can also be made available.

The geographic information of the country is available from the following sources :

(a) Administrative set up : The country is divided into 22 states and 9 union territories, or 418 districts, or about 3,500 sub-district administrative units known as tahsil, taluk, thana (police station), sub-division, or 605,224 revenue villages.

(b) Survey sheets : Covering the country on specific scales (e.g. 1:50,000 or 1:250,000) showing specific items, such as physical features with contour lines, rivers, settlements, general land use, transportation lines etc.

(c) Remote sensing imageries : Coverning the country on a scale of 1:1,000,000.

(d) Aerial photographs : Covering the country at various scales and photographed at different times. For specific areas, such as urban region or tea growing areas, large scale photographs are available.

(e) National Atlas & Thematic Mapping organisation (NATMO) base: Covering the whole country at 1:1,000,000 or 1:2,000,000 scales. The maps at these scales are on same base and can be compared.

Socio-economic base

Majority of the states have produced maps at 1" = $\frac{1}{4}$ mile scale maps for each of its administrative units at sub-district level, locally known as tahsil or police station or Majmuli maps (in short P.S. Maps). These maps show the revenue village boundaries and location of important settlements in the village with jurisdiction list numbers. Basically these maps are for administrative or revenue purposes, but have been widely used for mapping and data collection purposes. This is the only base available where the lowest level administrative boundaries are shown. There is no other source to provide this information. At one stage attempts were made to include village boundaries in the survey sheets (e.g. in Champaran district in Bihar state), but later it was given up. These maps have been widely used as pre-census maps and almost every district census handbooks contain these maps, however at modified scale. Due to the uniqueness of these maps, they provide a base for socio-economic mapping of the country. Since sub-district level administrative boundaries are available in the survey sheets, these maps can be linked with the overall geographic and cartographic base of the country. On the other hand, the P.S. map series can be linked with the age old cadastral map series at 16" = 1 mile or 32" = 1 mile scales. This map series at very large scale show property lines, built-up areas and plot numbers. Both the maps series are fairly accurate and reliable (Nag, 1984 A).

A district map on established geographic base can be developed showing administrative set upto revenue village level. A map of this nature can be used as a base for plotting 75-100 items of general and crop land use, or 80 items related to population and housing, or 135 items of livestock census for each unit shown in this map. Further, all the other information related to planning, development and administrative statistics can be mapped based on this framework. A base of this nature has to be included in the Geographic Information System (GIS) for considering socio-economic parameters.

Table 1 : Geographic Bases

No.	Geographic bases	Scale
1.	NATMO Thematic Maps	1:1,000,000 or 1:2,000,000
2.	Remote Sensing Imageries	1:1,000,000
3.	Survey Sheets	1:250,000
4.	P.S./Tahsil/Taluk/Majmuli Maps	1" = ¼ mile
5.	Survey Sheets	1:50,000
6.	NATMO Landuse Maps	1:50,000
7.	Air Photos	1:15,000 - 1:60,000
8	Cadastral Maps	16" = 1 mile or 32" = 1 mile

There are point based and line based information as well. For example, the metereological data and distribution of industries, universities, livestock markets etc. The location of such points are to be included in the base map for using the data. Similarly, the line based data, such as related to railways, road, waterways can be included in the GIS.

ATTEMPTS FOR DEVELOPING INFORMATION SYSTEM

National Natural Resource Management System

In 1982, it was felt that the country should adopt a comprehensive approach to the management of natural resources. As a result it became "necessary to have accurate inventories of resources such as land, water, forests, mineral resources, ocean etc to utilise this information in order to achieve maximum national benefit with least damage to the ecological system"(I.S.R.O., 1983). Considering the above necessity, Government of India recognised the need of establishing a National Natural Resource Management System (NNRMS). In the following year National Task Forces were appointed to look into the aspects related to :

(i) Agriculture

(ii) Cartographic representation of data

(iii) Forestry

(iv) Geology

(v) Natural resource information system

(vi) Oceanography, marine resources and costal studies

(vii) Soils and Landuse

(viii) Urban and rural studies

(ix) Water resources.

These task forces were required to study the present and the existing system of information genereation, data processing, management aspects highlighting the strengths and weakness; and identifying the specific elements amenable to remote sensing techniques presently and possible in the near future (I.S.R.O., 1984). Almost all the above task forces have submitted their reports which will help in building up Natural Resource Information System, the Task Force V. Obviously, the above activities are based on the potentialities of the Indian Remote Sensing Satellite-1. In addition to the above task forces, several 'end-to-end experiments' were also identified.

Natural Resource Data Management System

Another project with similar objectives was sponsored by the Union Department of Science and Technology, known as National Resource Data Management System (N.R.D.M.S.). The purpose of this pilot project was to evolve appropriate methodology for collection, collation, storage, analysis and dissemination of data on natural resources in a specific region in its totality. Here the data on human resources was also included. The aim was to evolve a standardised format in natural resources and socio-economic data could be presented in an integrated manner so that linkages among various hierarchical units, viz state, district, blocks and villages could be studied (D.S.T., u.d.).

This project also aims to develop an information system with grid of 2.5 minutes square of the entire area concerned. For littoral areas, econonic zone and deep sea area, the grid sizes were larger. Several indicators were identified to be included in six data sets. Software has been developed to generate thematic maps compatable with the geographic referencing system. Maps of different scales at 1:1,000,000, 1:250,000 and 1:50,000 were generated. The socio-economic information was collected from administrative sources and by selecting one village per grid with samole households. An integrated study in the Ghaghara -Gandak sub-basin for multiple data base was taken up.

RSDCATLG System of S.A.C.

Considering the possible increase in information sources which brings in various image reference schemes, it is becoming increasing difficult to make a selection of multi source data. "Operation users, for whom remote sensing is not of main interest, may not like to spend time in understanding image reference schemes and coverage patterns of various data sources" (Goel and Dasgupta, 1984). Space Applications Centre (S.A.C.) of the Indian Space Research Organisation has developed and implemented a RSDCATLG system based on VAX-11/780 computer for automated catalogue search facilities. The user can have the access of the availability of information based on relevant sources, period of collection and concerned geographical area (Goel, 1984). Geographic query is possible by refering the concerned area by all types of methods possible, e.g. survey sheet numbers, administrative boundaries; lines, points and polygons with longitude and latitude coordinates, etc. Software packages available with VAX-11/780 system were used for this purpose. Obviously, this system has been developed keeping in view of the possible information from IRS-1 and other satellites. Such designs would also help in developing the N.N.R.M.S. Task Force on National Resource Information System.

Data Bank of NATMO

National Atlas and Thematic Mapping Organisation (NATMO) has a data bank considering the nature of its work. This bank consists of a large variety of information in manuscript form, printed books and reports, mimiographed copies, air photos, imageries and maps. Mostly information is available for post 1951 period (NATMO was established in 1956). For example, classification of area, land use, and production of crops data is available from 1951-52 onwards. Similarly, information about livestock, agricultural implements, fisheries, and cattle is available from 1961 onwards. Printed data, such as census or health statistics is easy to handle. There are several other data bases pertaining to single or more than one maps of the National Atlas of India or thematic atlases. In the International Seminar on Environmental Maps and Atlases held in Calcutta in 1983, it was recommended that NATMO should develop a data bank on environment-related issues (Nag and Dutta, 1986). Though NATMO has one of the richest collection of data, practically no automation has been introduced in the whole process of building an information system (Dutt and Nag, 1985).

Some other institutions in India are also trying to develop their own information system with particular orientation to needs. These are National Informatic Centre and the Department of Environment and the like.

Remote Sensing Activities

With successful launching of Bhaskar-I, Bhaskar-II and Rohini, India is now planning to put IRS-1 in space later this year from Soviet Cosmodrome. Much of the success of the proposed information system will depend in the IRS which will provide real time data. The feature of the IRS is as follows :

Table 2 : Some Features of IRS

Bands	Microns	Sensitivity to
1	0.45 - 0.52	Sedimentation, discrimination of conifers
2	0.52 - 0.59	Green reflectance of healthy vegetation
3	0.62 - 0.68	Chlorophyll absorption of vegetation
4	0.77 - 0.86	Green biomass

Source : N.N.R.M.S. Bulletin, Vol. 1, No. 1, April 1983.

Table 3 : Anticipated daily through-put requirements for IRS data products.

Type	Format (mm)	Requirements
Browse products	70	400 band scenes
Standard products	240	60 band scenes
Precision products	240	40 band scenes
F.C.C.	-	20
C.C.T.s	-	4
Special products	-	4

Source : N.N.R.M.S. Bulletin, August 1983.

In addition to the IRS sources, India will get remote sensing data from SALYUT-7 TERRA Experiments, SPOT and Thematic Mapper (LANDSAT 5). The receiving station for Thematic Mapper is now ready and projects have already been identified based on this source of information.

PROPOSED BASE FOR G.I.S.

After assessing the sources of information, data bases, experiments on information systems, and possible sources of new information, it is worth considering the nature of a proposed base for India. For a sizeable country like the one in question with different types of data sets within its federal structure, a greater flexibility is required. Five levels of spatial information can be worked out according to the availability of data, potential sources, and mapping work already carried out. These levels are as follows :

(a) Level A - 1:1,000,000
At present, maximum information is available at 1:1,000,000 scale. The LANDSAT data is useful at this scale. NATMO has developed a geographic information base at the same scale. Whole country is divided into 15 plates and this base has been used for mapping of various aspects, such as administrative set up, physical aspects, population, transport and tourism, landuse, and cultural landscape. Some of the map series at 1:2,000,000 scale can be enlarged to this scale for additional information. These maps are on slope, rocks and minerals, rock types, rainfall, drainage, water resources, wild life and wet lands, forest types, density of rural population, crop regions, soil regions and working force. Some of the maps prepared by other institutions are based on this scale. NATMO has also developed a base where boundaries at sub-district level (3,500 approximately) have been matched with the geographic set up of the country.

If we consider a single map series at 1:1,000,000 scale, e.g. "Cultural Landscape", we will find that the following information has been mapped :

i) Boundaries-international, state, district with headquarters.

ii) Archaeological, pilgrim site or place of tourist interest.

iii) Airport and important settlements (towns and villages).

iv) Roads and their types.

v) Railways with station.

vi) Streams, dams, barrages, canals, waterways etc.

vii) Agricultural/rural landscape (irrigated, unirrigated, shifting cultivation and settlements).

viii) Industrial/urban landscape - predominant urban activity (primary, secondary, tertiary), mining and builtup areas.

ix) Pastrol/fishing landscape (grass, scrub, fishing areas).

x) Wild landscape (reserve, protected, unclassed forests, barren land).

xi) Airport, sea port, sea route, bus service, distance from point to point, rest house, temple, cave temple, Buddhist monument, mosque, tomb, church, palace, fort, ruins, view points, resorts of all types, power stations, bridge, ferry etc.

xii) Insets of important places.

On this base, other information files or data bases can be superimposed and corrected. This base can provide a useful framework to initiate Geographic Information System (G.I.S.) for India, It can be enlarged to the extend the details of data available for specific use.

(b) Level B - 1:250,000

From Table 1 it is apparent that survey sheets are now available at this scale. It is expected that with better resolution of remote sensing data, such as IRS or SPOT, mapping at this scale would be possible. NATMO is bringing out a series of District Land Use Maps at this scale. Village location can be shown at this scale, but the mosaic of village boundaries would be clumsy. The greatest advantage of this scale is the availability of air photographs.

(c) Level C - 1:50,000

Two important map series are available at this scale. First is the survey sheets, and second is the rural land use maps being prepared by the NATMO. At this scale village boundaries can be adjusted with the geographic features. Some air photographs are available at this scale. It is estimated that remote sensing data can be useful at this level as well. The advantage of this level is the availability of a uniform and accurate survey sheets. A lot of research and survey work is being carried out at this level.

(d) Level D - 1:15,000
The Police Station (P.S.) map series are approximately at this scale. Some detailed photographs for priority areas are also available at 1:15,000 scale. In addition, there is a plan to prepare survey sheets at this level basically for controlling flood in flood prone areas of northern India. Detailed physical features will be shown in such proposed maps.

(e) Level E - 1:5,000
No information source is available at this scale. The closest one is the cadastral map series. Maps at this level would be useful for high density areas, such as towns and cities. An urban area authority would like to have such maps showing derails of property lines and tax and planning purposes.

CONCLUSION

All these five levels can be integrated into one system with suitable hardware system and software packages. Hence, the proposed information system can be made scale free upto certain extent. The details of information available will indicate at what approximate level one can go. Probably, the whole process from 1:1,000,000 can be initiated and files of different thematic contents be developed step by step. To initiate a G.I.S. at this scale for the size of the country like India, it is not an easy task at all. But, technology to handle such a situation is now available and even larger countries have been successful in doing so (Nag, 1984 B). Some sttempts have been made in this regard which will guide the future course of action of developing a Geographic Information System for India.

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COMPUTING ASPECTS OF A LARGE GEOGRAPHIC INFORMATION SYSTEM FOR THE EUROPEAN COMMUNITY

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ABSTRACT

The CORINE programme has now been underway since 1985. Its purpose is to provide information on the environment of the entire European Community in a form suitable for assisting policy-making. Such data must be accurate, integrated and readily available to the personnel for whom it is designed. The system must be capable of dealing with large amounts of spatially linked data from many different data sources, in text, vector or raster form. Therefore the use of a Geographic Information System (GIS) is essential. This paper describes the use of an interim system as a 'test bed' for beginning the process of data acquisition and integration. The data sets available are soils, climate, topography and 'biotopes' - important areas for nature conservation. A data transfer format has been devised to provide for ease of transfer between various EC sites working on different mainframe computers. The interim system ensures that user needs can be defined and provides valuable user experience before a permanent system is installed. Other issues examined include the use of national and international networks and problems of data integration when incorporating existing digital data from disparate sources into a large GIS.

INTRODUCTION

The call for improved environmental and conservation policies has, in recent years, been loud and clear throughout Europe. Few countries have escaped the growth in 'Green Party Politics', marked by numerous public demonstrations. Both because of the international scale of the protest, and because pollution recognises no political boundaries (eg: acid rain, oil slicks, radiation clouds), a European Commission policy on the environment has been defined. This is implemented through the Directorate General for the Environment, Consumer Protection and Nuclear Safety (DG XI) who seek to codify and agree on environmental protection measures for adoption by the individual member states.

However, this process has brought to light a serious lack of both reliable environmental data and methodological principles on which to base predictions, assessments and recommendations. It is this deficiency which the CORINE programme has been set up to alleviate. Although formally launched in June 1985 by a decision of the Council of Ministers of the European Community (Official Journal No. 176 of

6:7:85), the first steps were made in the late 1970's with the 'Ecological Mapping' project (Ammer et al, 1976). By the early 1980's, the emphasis had moved away from using this prescriptive system, to a more interpretative approach utilizing a data base (France & Briggs, 1980). Two separate studies of the computer aspects of the database were also completed during this time (Rhind, 1981; Hanke et al, 1985) which set out comprehensive lists of the necessary facilities such a system should encorporate.

CORINE (an acronym for Co-ORdinated INformation on the European environment) is aimed at providing a 'spatially comprehensive and compatible database of all environmental descriptors which have, or may in the future have, relevance for policy' (Rhind et al, 1985). The facilities it must include are thus numerous and diverse in nature: cartographic, graphic and tabular output, area classification, the capability to detect and assess change, the ability to handle data at a variety of spatial scales and to model using many parameters. At the same time, cost must be minimal, but availability and ease of use maximal. Whilst needing to recognize and cope with different methods of data storage throughout the Community, it is hoped and expected that CORINE will facilitate the establishment of new standards of data compatibility between the different organizations.

This paper describes an evolutionary approach aimed at meeting all these requirements, concentrating on computing aspects of setting up such an interim system, rather than evaluating the cost, efficiency and success of its operation. While it is currently impossible to achieve all with one 'off the shelf' system, work is underway to come up with the best available solution out of one or more other systems. The authors are all contracted by the EC to work on the interim computer system. This paper reflects their views and not necessarily those of the Commission, Council or any individual in the employment of the European Community.

CORINE: A BRIEF OUTLINE

Embedded in this programme are three fundamental principles. The first is to use existing data wherever possible since the resources available are strictly limited. Linked with this is the second principle which has been the emphasis on collaboration wherever possible between the organizations of the different member countries. Both these goal have been achieved by running a number of separate projects in parallel to each other:

- An inventory of environmental information available in the EC which is required for CORINE is being created by Dornier System GmbH, Friedrichshafen.

- Co-ordination of the Biotopes inventory for the EC, which includes all areas for environmental conservation nominated by each member state, is being carried out by NERC - ITE.

- Work to study the possibilities of deriving the land cover of the EC from remote sensing data is currently being undertaken by SFERES, Paris.

- Collection and organisation of data on water resources in the Mediterranean and other specific regions is being carried out by the University of Strasbourg.

- A feasibility study into collating pollution data, including information about acid rain, from existing schemes and identifying areas where data are lacking is underway by CITEPA, Paris.

- Identifying areas threatened by erosion and therefore in need of protective measures is being carried out in Aquator, Pesaro.

- The interim computer system is using these data on an experimental basis to assess operational feasibility and also to ascertain the nature of the users' needs. It will form the basis of the specifications for a final computer system for CORINE, and is currently underway at Birkbeck College.

The compilation of data in different sites throughout the EC has the added implication of requiring a computer system with powerful data integration capabilities (Rhind et al, 1984). Utilising such diversified sources of data has also made it essential to establish a comprehensive, yet simple and easily understood, data transfer format (Wiggins et al, 1985).

The third fundamental principle on which CORINE is based is the need for data at many different spatial scales and levels of resolution: community-wide, by country, by level two region (Hudson et al, 1984), down to detailed analysis of areas of the order of magnitude of 1 km^2.

Detailed requirements cannot be accurately assessed until the users gain access to the system. This has involved the use of a European computer network and has revealed an acute need for training and education of the users as to what a GIS is and what it should be able to do. It is apparent from many of the early queries to CORINE by potential users (who often may be only 'occasional' users) that they simply do not understand the implications of using a Geographic Information System, as opposed to the more common database systems already available in the EC (eg, Chronos, which is used to handle time series data). This poses a number of potential problems:

- users may expect certain tasks, such as polygon overlay of a large database, to be 'easy and routine'. In many situations, this is simply not the case.

- users may not know enough to ask questions which take full advantage of the system.

At the same time, it has become obvious that potential for mis-use of the system, deliberate or not, is considerable and must be reduced to an insignificant level.

THE INTERIM COMPUTER SYSTEM

Introduction to the Interim System

The goals of CORINE - allied to uncertainty in detail of the user requirements - demands the availability of a system with great functionality and which is useable as a toolbox. As a result, ARC/INFO was chosen as the basis for the interim system. It has been developed by Environmental Systems Research Institute (ESRI), Redlands, California (Morehouse, 1985) and is installed on a VAX 11/750 in the Department of Geography, Birkbeck College (described in Green et al, 1985). ARC/INFO is particularly appropriate for the CORINE programme because it includes reliable methods of polygon overlay and data integration. It is also possible to convert digitized maps into any one of twenty-two standard projections. The system is flexible in relation to data entry, having numerous interfaces which facilitate the incorporation, validation, and editing of external sources of data as well as providing sophisticated on-line digitizing facilities. Because of this, it has been relatively simple to implement the data transfer format and also to develop macros for processing the PACE data (see below).

ARC/INFO is available, via JANET (Wells, 1984) and PTT network links, to the entire Community and beyond. Indeed, it is now regularly accessed from Brussels and Luxembourg. Furthermore, the use of such computer networks to link up different mainframes has also allowed small- to medium- sized operational data sets to be exchanged between the various sites in the project. Both the biotopes and climatic data have been sent to Birkbeck in this way. These network facilities have made it possible to set up two on-line demonstrators which utilize the facilities of ARC/INFO. ARCDEMO concentrates on the functions of the system, illustrating (through the use of graphics and text) the processing of raw digitized data through to the stage of creation of comprehensive maps which can involve overlaying data from different sources. Tabular, statistical summary output may also be produced (Green & Rhind, 1986). The second demonstrator, ECDEMO, is more specific to CORINE, using selections of the data already available on the project to show how such a GIS can meet EC needs. Both demonstrators have been found to be valuable assets for teaching potential users of the GIS.

Extensions to the Interim System

Work is also underway to evaluate and exploit the Map Librarian, a sub-system of ARC/INFO for the spatial partitioning, organization and archiving of large databases (Aronson & Morehouse, 1984). Preliminary results suggest that this map library will significantly speed access to the data by at least halving the cpu time required compared to that needed for a non-tiled database (Wiggins, 1986). An initial tiling system has been devised, based to a substantial extent on the political boundaries of the countries (figure 1). The biotopes data set has been inserted into this tiling structure on an experimental basis.

The Map Librarian makes extensive use of the ARCPLOT mapping package encorporated within ARC/INFO. This has recently been assessed and compared with other mapping software systems, in an attempt to

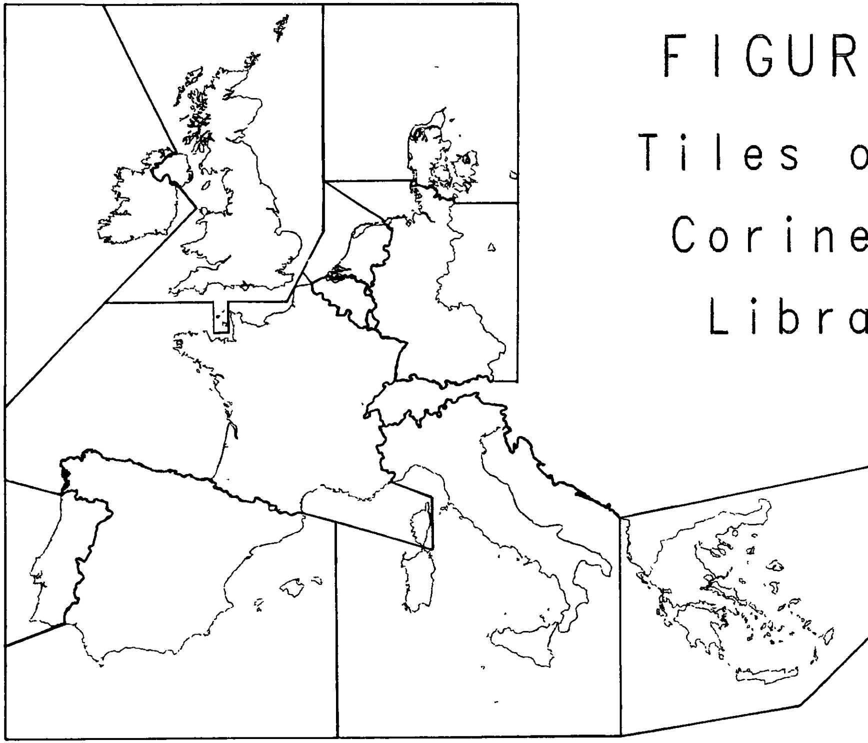


FIGURE 1: Tiles of the Corine Map Library

define the requirements of an 'ideal' mapping package, and thereby direct future developments (Hartley, 1986). Although ARCPLOT has its deficiencies, it also contains many other functions unique to the system. Hence, in general terms, it compares - even as a stand-alone package - with the best of contemporary mapping packages. The close linkage between it and the manipulation capabilities of ARC/INFO do, however, provide a variety of possibilities for ESRI to extend ARCPLOT, the most useful of which might be built in an Expert Mapping System.

WORK COMPLETED AND CURRENTLY UNDERWAY

Soils data

The first digitized data from the 1/1 million Soil Map of Europe is contracted to reach Birkbeck College in July 1986. It will be available to the EC approximately three months after its arrival. Already, however, a test portion of the map has been digitised at Birkbeck. This has allowed a key to be developed which subsumes variations in soil type (major and minor), texture categories and slope class, etc.; this will probably form the basis for the final key. At the same time, it has been possible to plot numerous maps from permutations of these data (see figures 2 and 3) and so devise a comprehensive set of shading symbols whilst, at the same time, recognising the hardware constraints involved in this plotting and in 'talking' to different terminals throughout Europe.

Climate data

Some data derived from meterological stations have recently been integrated into the database to join the small amount of digitized data from manually produced climatic maps. These data have permitted the integration of soils and climate data. Thiessen polygons have been generated using the UK climate stations as centroids. Each of these climate stations has a soil erosivity index derived from the annual precipitation and, following the generation of this tesselation, this value is allocated to the resulting Thiessen polygons. These polygons have then been combined with the test soil data to reveal those soils which are, according to the chosen criteria, in areas prone to erosion by water transport (Figure 4). Not only are the dominant soil types obvious in this instance, but the information pertaining to texture and slope classes can also be extracted.

Biotopes

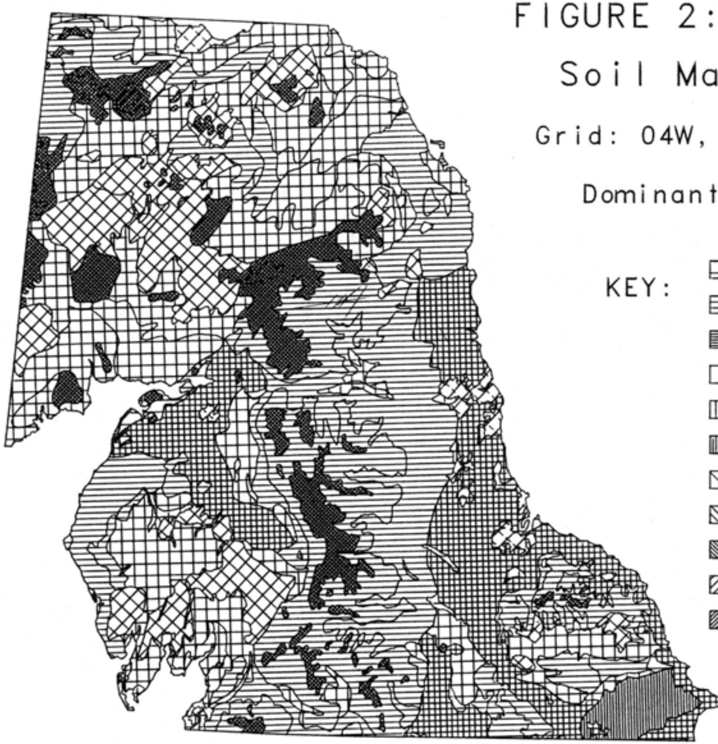
So far, the Biotopes-82 and SFF3 bird sites (Commission of the European Communities, 1981) for the EC 10 have been combined together to form the preliminary CORINE biotopes database. Attribute information in the files includes the latitude/longitude position, an assessment of scientific importance, a description of the biomes, species type, site altitude and protection status. These data have formed the basis for the first menu-driven interrogation system written for the project. It provides a step-by-step approach to analysing the data in a number of different ways and then permit a few simple calculations on the selected sites (eg: percentage of ecological sites in Denmark which are protected). In addition, the biotopes have been overlaid with an outline of Europe taken from the

FIGURE 2: 1:1 million

Soil Map of the EC

Grid: 04W, 54N x 00W, 56N

Dominant Soil Types



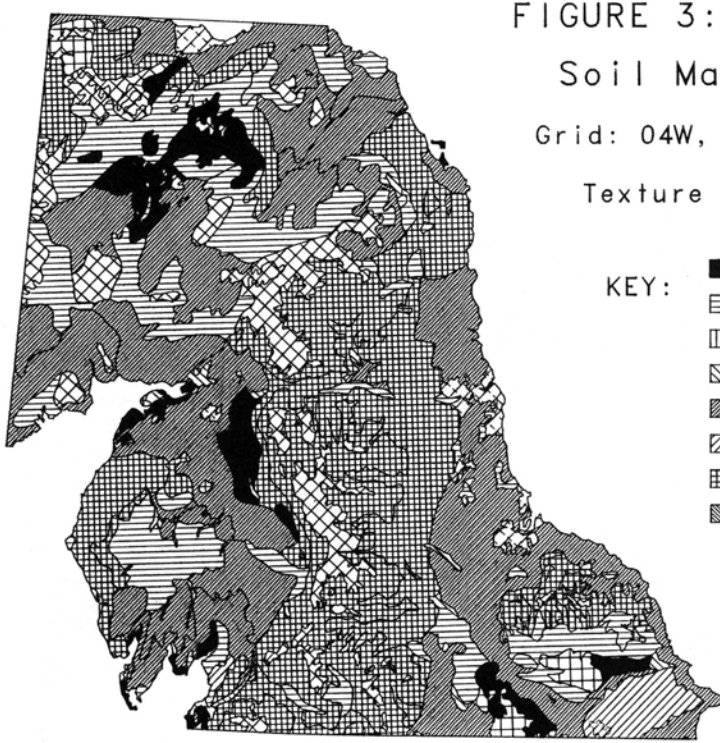


FIGURE 3: 1:1 million
Soil Map of the EC
Grid: 04W, 54N x 00W, 56N
Texture categories

KEY:

Coarse
Crse/Med
Crse/M fine
Crse/Fine
Medium
Med/M fine
Med/Fine
Med/V fine
Med fine
M fine/Fine
Fine
Fine/V fine
Very fine
'Urban'
'Fresh Water'
'Sea'

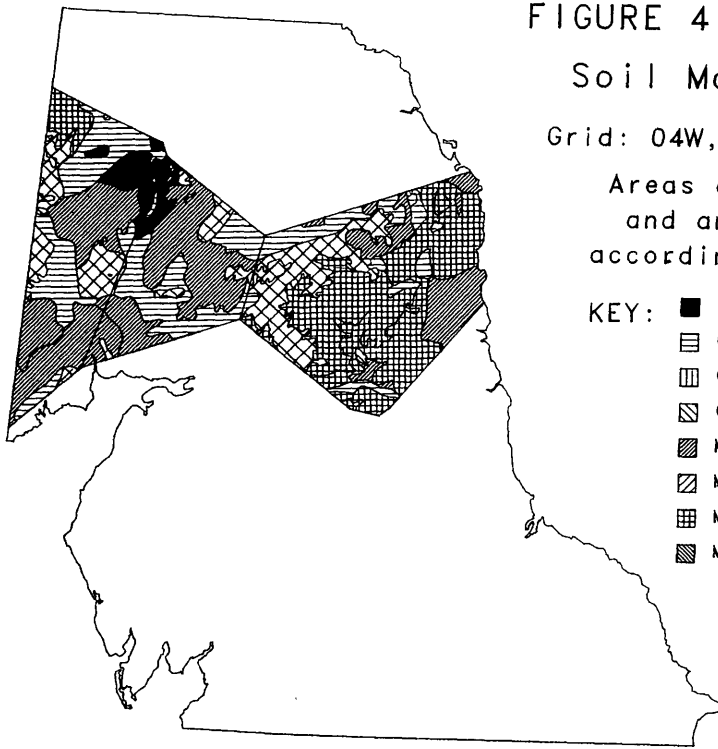


FIGURE 4: 1:1 million Soil Map of the EC

Grid: 04W, 54N x 00W, 56N

Areas of High Erosivity and annual rainfall according to Texture class

KEY:
- Coarse
- Crse/Med
- Crse/M fine
- Crse/Fine
- Medium
- Med/M fine
- Med/Fine
- Med/V fine
- Med fine
- M fine/Fine
- Fine
- Fine/V fine
- Very fine
- 'Urban'
- 'Fresh Water'
- 'Sea'

'European Community: Farming' map, successfully transformed from the raw digitised data into a Lambert conformal conic projection, and used for a series of topic maps (eg: peatlands, ecological sites, etc) (figure 5). This has revealed possible errors in latitude/longitude position (eg: peatlands in the Mediterranean Sea) and so provides a crude method for checking the data. Biotopes for Spain and Portugal are expected in the near future.

Topographic data

Successful negotiations with the Directorate of Military Survey of the UK Ministry of Defence have made the PACE data set (Howman, 1983) available to the project. This is derived from 1:500,000 and 1:250,000 scale maps and covers all of the EC as far south as Lyon. The data have been delivered to Birkbeck and are currently (April, 1986) being processed. This has involved writing a macro (PACEARC) which readily converts the data into ARC/INFO format, and is based on the standard CORINEARC procedures. Preliminary maps have shown the complex nature of the data (see figure 6), with over one hundred different attribute codes being used. In addition, the data contain no recorded topological structure, ie: they are 'spaghetti' files. Whilst of little consequence for simple cartographic reproduction purposes, this situation has significant implications for use of the data for database manipulation purposes and substantial effort will need to be devoted to the up-grading of the PACE data in this respect.

Other projects

The other projects are, in many cases, directed towards specific environmental problems, such as those arising from atmospheric emissions, water pollution and soil erosion in the Mediterranean area (see above). In progress too are a number of trans-frontier projects, which are designed to assess the problems of data compatibility between specific member states. All are being carried out by contractors from the different countries but the data collection is being coordinated at EC level and the implications for the growth of the CORINE data base are being monitored by the authors and colleagues.

Call for benchmarks

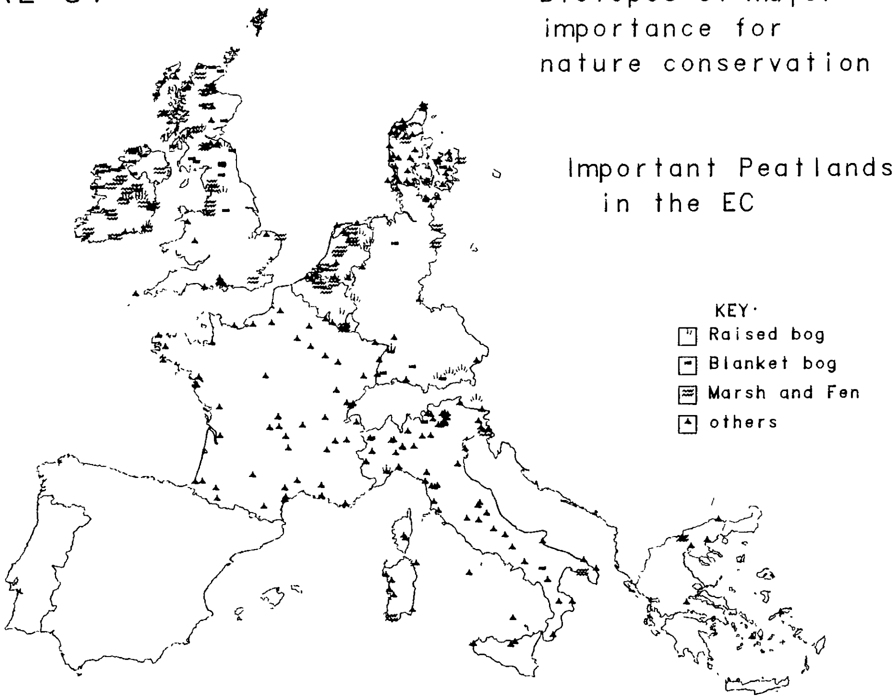
The requirements to be met by a 'final' system are now being defined and outlines of this are (at the time of writing) about to be circulated to commercial firms and other interested parties. A final specification and invitation for tender for the supply of such a system will be issued later in the year. One critical element of the evaluation will be the holding of benchmark tests using data supplied from the existing CORINE data base. To make these realistic, we expect to provide something of the order of 100 megabytes of data.

PROBLEMS

Many problems have already been discussed in earlier literature (Rhind et al, 1985). This paper therefore will simply provide an update on the problems encountered and anticipated.

FIGURE 5:

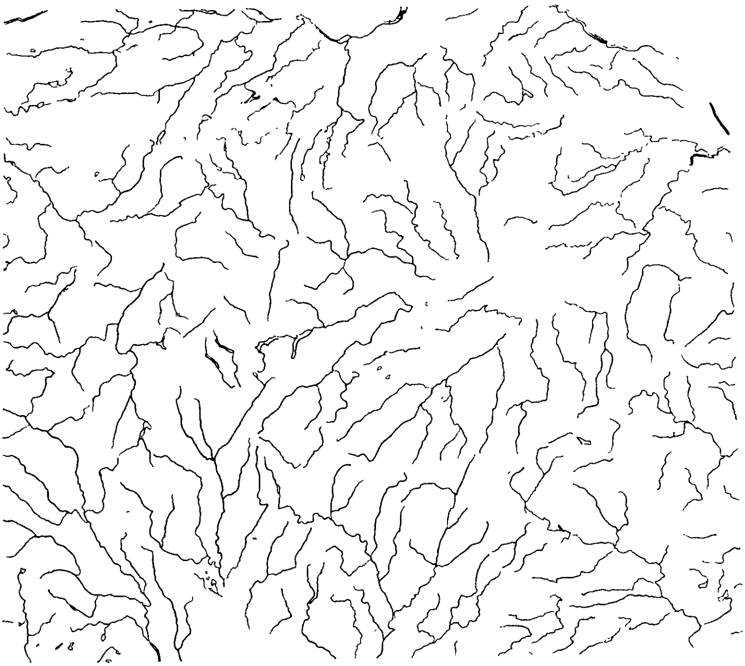
Biotopes of major importance for nature conservation



Important Peatlands in the EC

FIGURE 6: Specific Topographic Data

SHEET NN3002A
Approx. scale 1:500,000



Data volumes

The true size of the soils database remains unknown, but the existing topographic data alone are now expected to total over 200 megabytes in size when processing has been completed. Completion of this to include the Mediterranean area, inclusion of the soils data, extension of the climatic and biotopes data and incorporation of other data sets likely to become available in the next year ensures that the size of the on-line data base by that stage will be in the order of one gigabyte. Projections of data base size of 3 gigabytes within three years can now be made and a rapid escalation is anticipated thereafter as topographic data from the 1/50,000 scale maps digitized under the Digital Land Mass Simulation (DLMS) programme become progressively available.

Data structures

Accepting data in their original form was an inevitable consequence of using the PACE topographic dataset. This is not topologically structured and so represents only a large quantity of cartographic 'spaghetti'. Clearly, some possible retrieval and manipulation facilities are greatly simplified if topologically structured data are available (notably automated error checking and any queries involving adjacency between polygons). Given such data, it is relatively trivial to decant them into other data structures used by other systems. Yet most readily available data derived from cartographic sources do not come in this form at present: the consequence is that the final system is likely to need at least the power of ARC/INFO in infering topology from 'spaghetti'-type data.

Data validity

To date, and with the exception of the EC coastline and national boundaries, different versions of the same data set have not been incorporated into the database. Such a situation will shortly change (eg: the soils data will also contain a detailed coastline which should match that from PACE). Hence a significant effort will have to be devoted to ensuring that all existing data sets match to a small number of topographic base maps and that the permitted combinations of data sets are well-known and understood. Of course, 'covering up' the problem using raster data structures is a possibility but does not represent a truly satisfactory solution unless the pixels are of the order of 100x100m or smaller in size. Even then, this approach loses the benefit of having shape knowledge of entities (eg: sliver polygons) resulting from overlay of two polygon sets.

Data use

At the first meeting of the National Experts (April, 1986), who serve as advisors to the CORINE programme, there was a clear commitment on the part of all the member states to contribute. This enthusiasm was particularly evident on the part of the newer delegates - those from Spain and Portugal: within a few days of this meeting, on-line access was achieved by a Portuguese CORINE group.

Notwithstanding the expertise of those currently accessing the data, a major problem looms: the easier it is to access the data base, the less skilled and expert a user needs to be. Since many assumptions and factors (eg: source map scale) are built into the data, this may give rise to spurious results from nonsensical analyses. The answer to many such problems may well lie in the building of Expert Systems (Smith, 1985). Moreover, widespread use demands either very fast and widespread computer networks or local computer systems: one example of the latter has been produced by the BBC Domesday Project (Openshaw & Mounsey, 1986). Implicit in all this however, is the point made earlier about the fundamental need to educate all users, whether by on-site training or through the use of on-line demonstrators and tutors.

CONCLUSION

This paper has attempted to outline the development and work of the CORINE programme, designed to provide information for the policy makers in DG XI, elsewhere in the EC commission and beyond. It has concentrated largely on the current development of an interim computer system for this environmental database, and summarising the data being processed as well as the problems involved. No attempt to deal with points relating to the operation of such a GIS (constraints on users, cpu time, memory, efficiency, etc.) has been made. This analysis must really await the greater use of the system by users.

This current phase of the programme has been designed both as an operational phase and as an experiment. The early indications are that both aspects of the project are succeeding, and that the creation of a large GIS for the EC is a feasible enterprise. This phase of the project is due for completion at the end of 1986. Thus far, we have scarcely begun to tackle the problems of up-dating the data base and of examining the implications of analysing environmental data made available at different spatial resolutions. At a technical level, the use of optical disks, of parallel or vector processing hardware and specialist data bases engines, and of Intelligent Knowledge Based Systems are all topics which will inevitably need to be faced in the future.

ACKNOWLEDGEMENTS

The authors thank the following for their contributions to the work underlying this paper: H. Hanke, G. Schneider, M. Cornaert, K. Rudischauser, D. Rhind, D. Briggs and B. Wyatt.

GLOSSARY

ITE	Institute of Terrestrial Ecology
JANET	Joint Academic Network
NERC	Natural Environment Research Council
PACE	Production of Automated Charts of Europe
PTT	Post, Telegraph & Telecommunications agencies

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UP-DATING A LAND-USE INVENTORY

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ABSTRACT

In 1977 begun a land-use inventory of the French littoral. It consisted in a series of 147 large-format sheets at 1:25000 with about 50 categories for land and sea uses. The work has been completed by Institut Géographique National using computer-aided methods for producing maps and statistical data. By-products have been made at the same time. In 1982 a new air-photographic coverage has been made and photo-interpreted. The results were hand-drawn documents specially designed accordind to the up-dating digital process. Several difficulties appeared such as misfits between boundaries due to dimensional variations in base materials. Different kinds of products are proposed : modification maps, up-dated land-use maps, evolution maps, regional synthesis maps, statistical data, etc. This land-use up-dating stresses difficulties resulting from taxonomic changes : modifications appear as necessities in order to make the maps fit present decision-makers requirements which evolve between inventories. Will geographic information systems be able to take into account such a flexibility ?

INTRODUCTION

The "Inventaire Permanent du Littoral" (IPLI) is an interministerial organisation in charge of creating and maintaining analysis tools for the coastal area use in order to help in leading a protection policy in this area. The basic tool is a land use map at 1:25000 made from aerial-photographs interpretation and from subsidiary data compiled by local administrations.

The map states the situation at a precise time. Its inclusion into a management procedure forced to plan its up-dating and digital techniques were developed at the Institut Géographique National - France (IGN-F) in that respect. Despite precautions the up-dating process induces many difficulties.

INITIAL INVENTORY

The first inventory had been made from an air-photographic coverage dated on summer 1977. The communes sharing the coastline had been described through about thirty land-use categories and a maritime area with about the same 5-kilometre width had been described through ten categories. The polygons defining land and sea uses have been digitized in raster mode, as well as the administrative boundaries dealing with 1000 among the 36500 French communes.

Standard products have been (Grelot 1982) :
(a) a series of 147 A0-size sheets printed in four colours ;
(b) a statistical data file with the distribution of land uses within each commune.

Several by-products have been added such as small-scale maps (1:100000) directly drawn from archive files. Each one covers five to ten 1:25000 sheets and synthesizes land use in about ten categories.

UP-DATING DESIGN

As soon as the first inventory has been completed, a new photographic coverage was made during summer 1982. At the very same time the up-dating cartographic procedure was studied and showed a complex situation.

The 147 sheets consisted in 400000 polygons : for economical reasons it would not have been possible to interactively allocate a new attribute to each polygon according to its new characteristics. Moreover modifications often concerned polygon boundaries.

The sheets were not homogeneous. Although two years had been spent for defining the initial legend, new needs had been expressed when publishing the first maps and the specifications have been modified.

There were misfits between files and printed maps, due either to specification changes, or to hand-made editing on the films which were supposed to be recorded in the files, or to editing completed in the files after map publishing.

Through time the initial legend was regarded as not enough detailed. But instead of subdividing its categories, it has been decided to define a new legend only partially compatible with the first one : a change between digital situations can be either an actual change or only a legend change.

A last understandable change occurred : the studied area increased a little bit in order to contain communes close to the coastline or belonging to natural and ecological areas.

For making life difficult we decided that any thematic data (i.e. areal data, and as well linear and point data) and the city names and ancilliary data (i.e. coordinates, titles, map index, etc.) would be digitally drawn. It would reduce manual addings, photo-engraving operations and delivery times particularly when publishing by-products.

From printed maps and air-photos at both 1977 and 1982 summers, photo-interpretors drew an overlay using a copy of the first inventory black separate. This copy had topographic background and polygon boundaries. Only those polygons whose land-use categories had changed had to be drawn. Digitizing these overlays was not a difficult task. But the digital overlay of new and archive data created unpleasant surprises.

MAIN DIFFICULTIES

The first difficulties were due to misregistrations between boundaries. Distances were larger than a quarter millimetre which was the tolerance for graphic uncertaincy, and they reached one and sometimes two millimetres. They were not only due to bad-quality drawings but to dimensional changes in the films used as backgrounds. The backgrounds were supposed to be duplicated on polyester basis in contact frames but a few of them had been made again without respect to geometric considerations and had not been checked. Then we had to design a software package for areal fitting with two main steps : geometric transformation and new boundaries capture by old boundaries within a given tolerance (cf infra).

Decreases in minimum dimensions of polygons created a second set of difficulties, specially with quite-linear features (roads, channels, etc.) and quite-point features (houses, etc.) considered as areal features. Their minimum dimension has the order of magnitude of graphic uncertaincy. This aspect can be regarded as a fault in cartographic design when mixing location categories of features ; but it is mainly an incapability for distinguishing between thematic land-use mapping and topographic mapping, between photo-interpretation and photo-identification.

The new taxonomy created evolutions which were not real changes. They had no systematic characteristics and it was not possible to edit them by automated processing. They were eliminated at several stages in the production line by modifying the initial inventory. But methods which consist in writing again past history, which is philosophically suspicious, are lacking in consistency and in fiability. In our case, changes in the initial inventory are to be made all along the production line of derived maps : it looks more like arts and craft than like an industrial production line and it makes much heavier the project management. Four editing steps can be achieved after : (a) the checking plot, (b) the modification map, (c) the up-dated land-use map, (d) the evolution map. The maps will be described below.

Finally the graphic design of legends for the maps creates conflicts between the cartographers-producers and people responsible for the project who also are the map purchasers. They have not enough been trained in cartographic design and they do not clearly express their requirements in terms of colours, symbols, reading levels and main thematic appearance. They also suffer pressure from end-users who give financial support and who sometimes reject the layout of maps.

PROCESSING LINE

The processing line is subdivided into three components (cf figure in appendix) :

(a) areal data from photo-interpretation : only the features having been changed since 1977 are digitized ;

(b) linear data such as cliffs, docks, dikes, coastal pathes and other features drawn in linear symbols ;

(c) point data such as touristic harbours, houses ; city names are processed in the same way.

Areal data processing

A document with polygon boundaries is digitized by a drum scanner. Some editing eliminates small mistakes on an interactive workstation. 20 to 30 control points are selected when overlaying the initial file in order to calculate a geometric transformation which avoids main misregistrations. Polygons are identified and allocated a referring number.

A biquadratic distortion polynom calculated from control points is applied onto the derived vector file. The result is checked on an electrostatic colour plot, with different colours for initial boundaries and for final boundaries before and after distorsion. The final tolerance is a quarter millimetre.

Each polygon is allocated two attributes coming from two interpretation overlays : actual use with 67 categories and tide area with 6 categories. The attribute allocation is interactively performed on a digitizing table : many polygons are too small for automating this process.

Here the file describes the present situation for any polygon having been changed or created since 1977. It has to be superimposed to the initial file which is modified to take into account a few taxonomic changes.

Despite the distorsion polynom the registration is not perfect. A software package has been written for enhancing local fitting. It merges close boundaries avoiding small areas without any thematic significance. Priority is given to old boundaries during the capture process. The result is checked on an electrostatic colour plot. Attributes from initial and present files are automatically allocated.

Linear data processing

A line-work overlay is digitized on the drum scanner. After editing the file is attributed interactively on a digitizing table with eight categories.

Point data processing

The precise locations of point features and city names are recorded on a digitizing table with twelve categories and a five-digit identifier for each commune.

Graphic outputs

After these processings all thematic components have been digitized. A monochrome film is made on a laser plotter for checking. It contains patterns, screens, linear symbols, point symbols, place names, coordinates and legends. It has been specially designed for supporting ultimate editing.

Non-stop editing

Editing can deal with areal, linear and point features and is related to allocation mistakes or to geometric delineation mistakes.

Geometric mistakes are dramatic because the geometric consistency has to be maintained all along the inventories : that is the reason why editing is performed on interactive graphic workstations on which operators can display both old and new situations. We specially care about the preparation of editing materials because of their diversity and their number (up to 100 per sheet). They have to be checked, and we use an electrostatic colour plot drawing polygon boundaries and feature codes. We sometimes have to iterate these operations for avoiding omissions.

Further outputs show new mistakes which have not been seen on the check plot and which are corrected by the same process. It happens when producing the proof of the modification map : a new output has to be produced for each map.

Archiving
Only one file per sheet with areal data is archived. It gathers all data for both 1977 and 1982 situations. This principle will be expanded for further inventories.

Flexibility
The processing line has been built up for producing the first sheet but has been modified according to new events. It seems that flexibility is a critical element and has to be considered when designing any such complex production line.

PRODUCTS

As it has been made for the initial situation, the land use distribution is calculated for each commune with respect to the distance from the coastline : 0 to 2 km, 2 to 5 km, beyond 5 km. The results give an idea of evolutions and the system has a capability for producing more precise analytical data, such as the present situation of one or another initial category : we obtain some kind of evolution matrix (Grelot 1984) ; this capability has not been used up to now although it is an efficient criterion when designing evolution maps for both relevant taxonomic definition and main aspects to be graphically standed out.

The first graphic output is a check proof. For economical reasons it is a black-and-white film. But the great amount of legend categories and the small dimensions of polygons make the checking difficult and mistakes are forgotten which are seen on further outputs.

A modification map is systematically produced in two colours : screened black for the topographic background and violet fot thematic data. This map shows the 1982 land use in areas which have been changed, but does not give any detail on their former use.

According to changes and the interested expressed by local authorities (i.e. municipalities, departments, regions) through financial support, derived maps can be produced.

The 1982 land use map is printed in four colours. Its graphic design is close to the former map series but it looks more precise because of smaller patterns and smaller polygons : any graphic representation includes and may reflect subjectivity. The legend has been standardized for the whole series.

Evolution maps gather initial and present taxonomies for pointing out meaningful changes. They are printed in four colours and their legends may vary according to regions and changes. Evolving areas are drawn in alternate strips with light colours for initial situations and dark colours for present ones, and areas with no change only receive light colours.

Synthesis maps at 1:100000 are printed in four colours again with legends according to regions. They give some kind of mosaics like satellite imagery classifications but fortunately cluster reliability is much greater.

CONCLUSION

The products of the littoral inventory have been planned as soon as the first compilation had been mad in 1977-1981. But the difficulties only appeared during the up-dating procedure.

Taxonomic changes cannot be avoided. In order to really be a management tool, such an inventory has to be adapted to decision-makers worries. Industrial, touristic, agricultural, ecological pressures on the coastal zone vary through time according to circumstances which cannot be forcasted on long-range periods.

Faced with this phenomenon, cartographers will always try and build compability, then adapt products to compability restraints. Users on the other hand want everything immediately, arguing that nothing is impossible for computer processing. It is partially true but requires unexpected financial and time supports.

Technological choices modify the way problems can be solved. We choose raster mode, and automated processing prevailing the use of interactive workstations. What would have been interactive up-dating of 400000 polygons in vector mode, how long with how many workstations, including all checking and editing operations ?

Is automated cartography entitled to mistakes ? In other words, is it legitimate to keep mistakes in normal cartography because of editing costs, and to refuse them not only in data bases but also in automated printed maps ? Refusal results in iterating outputs up to a perfect map which causes overcosts and mainly disrupts and delays the production line. Imperfection acceptance requires users' training and obtaining an agreement before starting the work.

This kind of opportunities teaches a lot for designing geographic information systems. It points out functions to integrate to digitizing, processing and plotting stages. It also shows that these functions are quite fixed ; but on the other hand the data they process may change : in fact map readers are able to integrate a context to what they read and interpret, and then to adapt their conclusions according to interactions between these to sources, i.e. map and context. Will geographic information systems be able to provide such a flexibility ?

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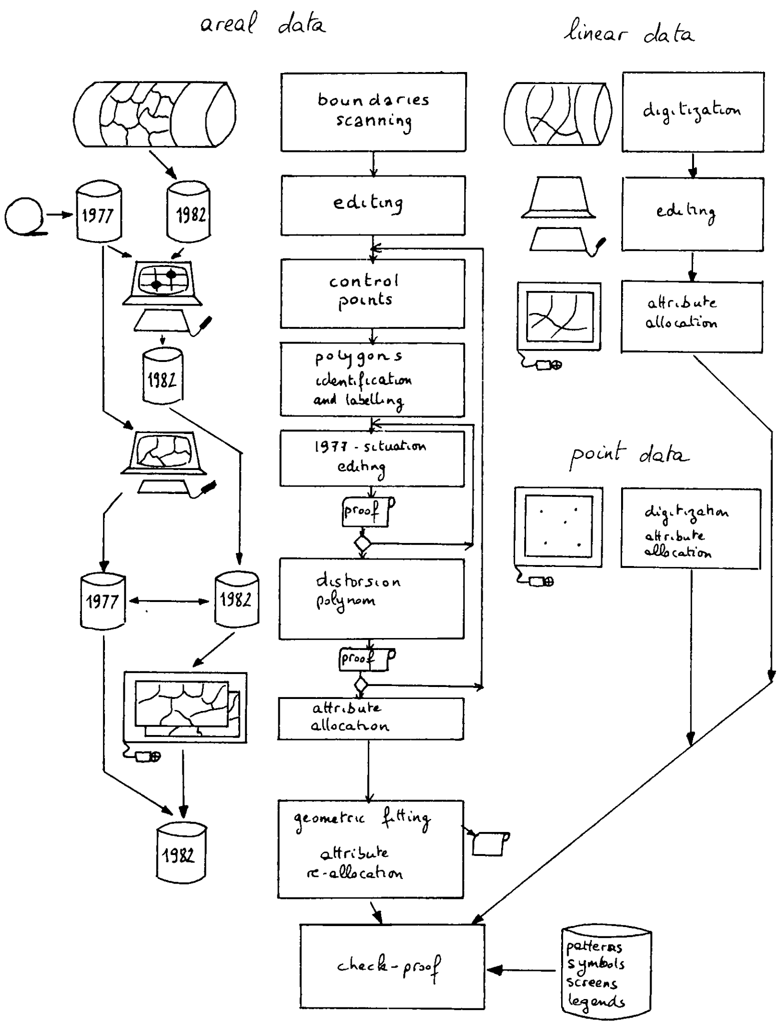
APPENDIX : PRODUCTION LINE OVERVIEW



TIR: A COMPUTERIZED CARTOGRAPHIC SOIL INFORMATION SYSTEM

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ABSTRACT

The constantly growing need for rational land use and management require adequate information on the soil. This leads to an enormous amount of soil data and maps. These data are being digitized, edited and incorporated into a digital data base. The data will be available in both graphic and digital form to assist large scale mapping of soils and monitoring of soil processes. To accomplish these tasks the SzATIR software has been designed and is being developed. SzATIR is designed to accept digitizer input, provide comprehensive expert system facilities and produce cartographic and statistical output. The distributed system is operational for an approximately 1o.ooo km^2 area /Pest County/ to search for either location or attributes and display results in a graphic and/or tabular form. Current system development is focused upon the enhancement of local modelling and editing functions, as well as to make this quadtree based thematic GIS compatible with other gridded data sources.

INTRODUCTION

1.1 Soil mapping information

The scientifically based planning and implementation of rational land use and management /amelioration, irrigation, drainage, agrotechnics etc./, ensuring normal soil functions and the maintenance or increase of soil fertility require adequate /i.e. well-defined, quantitative, territorial/ information on the soil /Várallyay et al. 1985/. A large amount of such information is available in Hungary as a results of numerous soil surveys, analysis and mapping projects accomplished is the last 5o years. The comprehensive and up-to-date synthesis, systematically controlled processing of this amount of soil profile data and maps require a computerized cartographic soil information system to enable soil scientists to establish and verify relationships among soil properties, soil caharacteristics and environmental factors or crop yields as well as to survey soil types and monitor soil processes /such as erosion, water-and plant nutrient dynamism, acidification, salinization, alkalinization, structure destruction, compaction etc./.

1.2 Geographic information systems

The recognition of the need for introducing computer technology in cartography lead to digital cartography. This means the formulation of the following basic features: /1/ the need for explicit coding of spatial relationships, i.e. for the definition of a topological structure, /2/ the need for numeric coding of attributes of map-elements, and /3/ the need for transforming spatial data to bit-streams for computers /McEwen et al. 1983/.
Based on these foundations new terminology, data standards, data formats, data quality could be elaborated in the early 80's, that facilitated the fast and wide spread of geographic information systems. Such systems generally consist of several /input, storage, retrieval and analisys, output/ subsystems, and are capable of cartographic information processing by computers /Marble 1984/.

DATA BASE SOURCES

2.1 Geographic /geodetic base

A number of thematic information systems have been designed in Hungary without a common geographic reference system /Csillag 1985/. The initiative for a Unified National Map System /UNMS/ was introduced and approved for all computerized cartographic applications in 1981 /Joó 1985/. The UNMS involves the regulations for projection, scale, topographic data content and quality, consequently opened the possibility for establishing the geodetic data standards and the geographic reference system /see Fig.1./ of the TIR /Hegedüs 1984/.

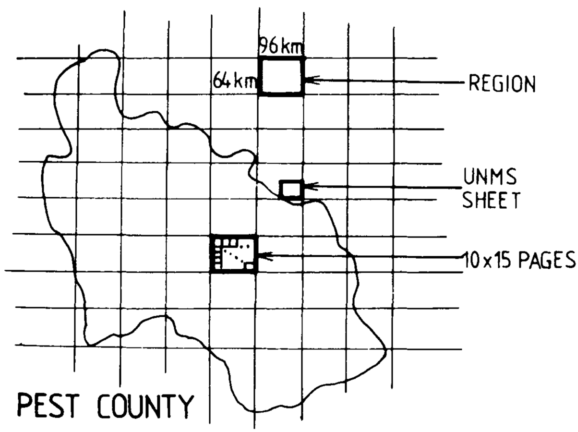

Figure 1. Pest county with the UNMS-grid, the experimental area and the geographic reference system of the TIR.

2.2 Soil data

The main sources of the TIR soil data base are as follows:

- 1:25.ooo soil maps of L.Kreybig's survey /1935-1955/
- 1:lo.ooo operational genetic soil maps of co-op farms
- data on soil profiles of the land evaluation program
- 1:loo.ooo agro-ecological maps of soil factors /Várallyay-Szücs 1978, Várallyay et al. 1982./

Table I. Soil data inputs of the TIR

Points	Maps
soil type	geomorphology
relief	slope categories
depth to humus horizon	slope exposures
texture	parent material
concretions	soil erosion
parent material	genetic categories
pH /H2o/	soil reaction and carbonate status
pH /KCl/	water-soluble salts
hydrolitic acidity	depth to humus horizon
exchangeble acidity	organic matter content
carbonate content	soil texture
water.soluble salt content	total water capacity /VKT = pF O/
ion composition of the aqueous extract	field capacity /FC=pF 2.5/
EC paste	wilting percentage /WP=pF 4.2/
alkalinity against phenolphtalein	available moisture content /AMR=FC-WP/
organic matter content	saturated conductivity
humus-stability index	unsaturated conductivity
clay-mineral composition	mean depth to water table
particle size distribution	max. depth to water table
sticky point according to Arany	min. depth to water table
thickness of capillary fringe	groundwater concentration
fine fraction %	ion composition of the groundwater
specific surface	
CEC	
base saturation /T-S/	
exchangeable cation composition	
Na^+ / $/Na^+ + K^+ + Ca^{2+} + Mg^{2+}/$	
SAR	
infiltration rate	
saturated hydraulic conductivity /K/	
unsaturated capillary conductivity	
characteristic points of the pF-curve	

The input data on soils /see Table I./ are divided into two parts:

- POINTS : characteristic properties of the soil profiles /borings/, identified by their UNMS coordinates;
- CONTOURS: physico-geographic soil maps of 1:25.ooo scale, while lines are used only coding geographic information.

The digitization of point-data /apprx. 4 Mbyte/ was completed in 1985, while the input process of map-data /apprx. loo Mbyte/ is currently going on.

COMPUTATIONAL FEATURES

3.1 System description

A distributed system has been developed: both the data storage and manipulation are shared between the host mainframe and the local microcomputer /see Fig.2./. The SzATIR software controls all GIS procedures from data capture through data storage and analysis, retrieval to data presentation. The entire software was designed by Egyszög Ltd. and has been implemented in FORTRAN and COBOL.

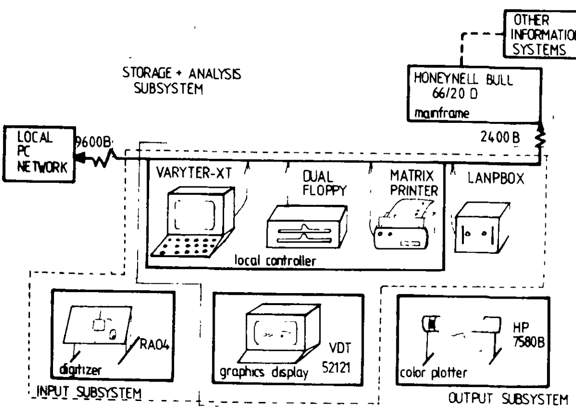

Figure 2. TIR - system scheme

2.2 Data capture

Point, line and region data are hand digitized from sheets, with o,5 mm resolution /64ox96o pixels/ according to the flow-chart on Figure 3. Three levels of error checking are performed:

- the catalogue, containing the complete list of polygons /identifier, colour, number of arcs/ provides control of structural-syntactic errors,

- the work-files, containing record-headers for all arcs of each polygon and its neighbours, facilitates the control of semantic errors,
- visual inspection helps the operators on both graphic devices to easily follow the input procedure.

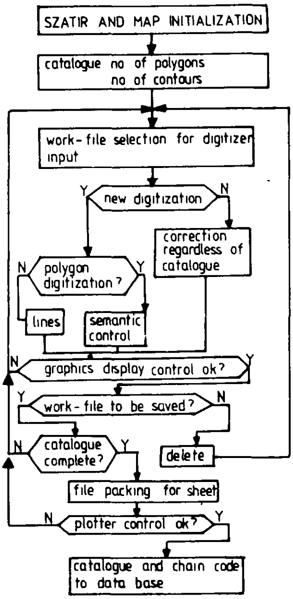

Figure 3.
Data capture flow-chart of the TIR

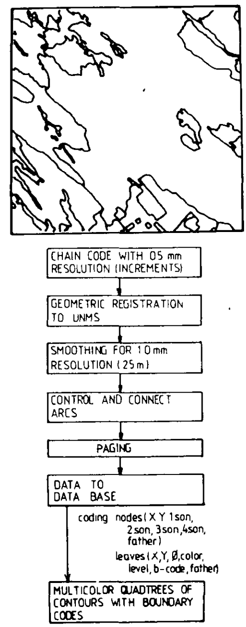

Figure 4.
Procedure for contour-data to enter the data base

3.3 Data base management system

There are two controversial requirements concerning data base management:
- to minimize storage space for the compensation of the slow modem (cf. interactivity), and
- to optimize map/data processing capabilities.

These requirements lead to the combination of chain-code and quadtree representation.

Quadtrees of regions are constructed by pages (256x256 pixels): first boundaries are encoded and then regions are converted, similarly as described by H.Samet (Samet 1980). Levels of the quadtree are coded in the page-relative coordinates of the lower-left corner of the nodes. The efficiency of this type of storage and union-intersection operations on it for binary images were pointed out by (Dyer 1980). Currently experiments concern the establishment and test of an effective multicolour quadtree-based DBMS (making use of colours and boundary-codes, i.e. 4. and 6. subfield of leaves' codes: see Fig.4.), in spite of the generally applied binary ones.

3.4. Data retrieval and query

Data can be retrieved from the data base using its query language. The initialization of the query starts with area selection: the highest acceptable level is a region, and a country, a set of pages or a polygon can be defined for restrictiong unnecessary data, as well as depth intervals (for point data). Readout is executed when data or map types (connected with any of the following logical operators: &, +, \ ), and specific conditions (data type → R → number, where R can be any of the following relations: =, \ =, >, <, >=, <=) are listed. Additionally SzATIR, certainly, accepts data from tapes of previous runs. Map mainipulation is allowed for previously defined maps (and their combinations with logical operators), and there is a sequence of commands for recording a map. An arbitrary set of points can be defined by conditions on data-types, value-intervals, previously defined sets and maps, as well as by locational functions (e.g. nearest n).

```
TARTOMANY= 54;
SOKSZOG   = 6440.7858,
            6954.7866,
            6952.8420,
            6400.8420'
ADATOK    = PHH2O,
            CACO3,
            HUMUSZ,
            HUMUSZVAST1,
            FIZIKFELESEG;
PONT      = K1&K2;
GOODSET   = CACO3 5&
            PHH2O 7.6&PHH2O 6.5&
            PHKCL 6&PHKCL 7%
            HUMUSZ 2&
            HUMUSZVAST1 30&
            FIZIKFELESEG=03+FIZIKFELESEG=05,
GOODMAP   = /EROZIOS+
            /DEGRADALT;
SZAMOSSAG;

A GOODSET    HALMAZ PONTJAINAK SZAMA:  955
=
STATISZTIKA PHH2O GOODSET,

GYAKORISAG.............................  278
ATLAG..................................   7.22
SZORAS.................................   4.52
SZORASNEGYZET..........................  20.98
RELATIV SZORAS.........................   0.63
MINIMUM................................   6.51
MAXIMUM................................   7.60
TERJEDELEM.............................   1.19
```

- region definition
- polygon definition
- data type selection
- data source selection
- conditions: ranges to define a set of points
- restriction to the complements of maps
- number of points command
- statistics of a given type of data for the given set of points

Figure 5. Sample query for point data describing optimal agricultural fields in a given area

Data retrieval can be represented with a set of commands concerning the total number of points, area of a map, statistics for data types and/or maps (categories). In addition a plotter-ready raster code of any quadtree(s) can be received by the local controller and be plotted according to UNMS standards.

A limited set of help and technical control functions (reset, list valid commands, list valid syntax etc.) assist to perform interactive functions in a more user-friendly environment.

CURRENT STATUS AND DEVELOPMENT

4.1. Usage

The design and development of the TIR is a significant contribution to the solution of several soil mapping problems. The system itself not only provides an opportunity for data retrieval and analysis, but during its use, methodological benefits can be achieved either in soil science or in computer cartography.

The TIR in its present phase can be used

- in the planning and implementation of rational land use and cropping pattern, according to ecological conditions
- in estimating the necessity, the predictable impact and efficiency of the application of various agro-technical measures
- in its implementation and control on national, regional, farm and field levels
- in the prediction of unfavourable soil degradation processes
- in land and soil evaluation
- in the protection of the environment
- in soil science-agrochemistry-soil biology research, and
- for educational purposes.

4.2. Future development

One of the most attractive features of the TIR is the opportunity to introduce, test and verify various scientific models, that concern its data base. The enhancement of the local expert system functions of the GIS is a field of intensive R and D activity.

Another area of interest is the multidisciplinary use of the information system, that requires compatibility and communication with other (e.g. meteorological agrochemical) data bases.

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DIGITAL SPATIAL MODELS AND GEOLOGICAL MAPS

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ABSTRACT

An increasingly diverse user requirement, and the growing importance of subsurface geology, create a need for greater flexibility in the presentation of geological map information. Computer methods are used in map production, and in databases to assemble raw information. To gain the full benefits of computer technology, however, it may be necessary to represent in digital form the geologist's spatial model - his ideas of the distribution, structure, composition, origin and evolution of a set of rock units. Some requirements of a digital spatial modelling system overlap with functions of Geographic Information Systems, Computer Aided Design systems and interactive graphics. Other requirements, such as palinspastic reconstruction and prediction of geophysical responses, are specifically geological. A spatial modelling project within the British Geological Survey has concentrated so far on self-contained prototype programs. In looking forward to production systems with their need to link to other subject areas, it may be desirable to limit new software to specifically geological aspects.

Published maps of the British Geological Survey (BGS) at 1:50 000 scale show in colour the areas underlain by each stratigraphic unit, with some indication of its lithological characteristics in the marginalia. The map base shows topography including contours, and the intersection of stratigraphic boundaries with the surface relief, supplemented by symbols showing orientation of strata, gives an indication of the geological structure. Subsurface information, available in increasing amounts from seismic surveys, mining, boreholes and wells, is considered in preparing the surface maps, but cross-sections and subsurface contour maps are needed to depict the subsurface more fully (see Whittaker, 1985). Geophysical information, such as aeromagnetic and gravity data, geochemical, hydrogeological and geotechnical information may also be shown on separate maps. The geological information which is thus assembled is required by a wide diversity of users, by no means all professional geologists, who are concerned with land use, planning, resource estimation, environmental impact, civil engineering, etc. Special purpose presentations, such as environmental geology maps, may be prepared for such purposes.

The introduction of computer methods means that many of the maps are prepared with computer assistance giving a digital record as a by-product (see Mennim, 1986). Extensive databases have also been constructed within BGS to hold raw data, such as borehole records, in digital form. Determining the future directions in the development of appropriate computer techniques requires consideration of the underlying nature of the information. The conventional geological map is in itself a powerful tool for information retrieval. Having selected a map of the appropriate area and scale, visual inspection quickly retrieves information on the basis of location from National Grid lines or topography, or on the basis of stratigraphy from the colour key in the margin. More important, the map shows not just data at a point location, but also the geological context of the surrounding area with further help from the marginal cross-section. The pattern of regional variation is all-important in understanding the geology. The practical importance of this aspect of the map suggests that in a computer-based system, a Geographic Information System (GIS) could usefully supplement the database.

Before turning to the inadequacies of this solution, a further reason for considering a GIS may be mentioned. Data integration to link say, surface and subsurface geology with geochemical and geophysical data must rely on visual comparison. Differences in sampling location, sampling scheme and spatial resolution as well as a lack of well-defined operational definitions and a non-homogeneous population make most statistical analyses invalid. A wide range of techniques for rapid display of single and multiple datasets as maps, cross-sections, block diagrams and perspective views is therefore required. Experience has shown the need for trial and error in these complex displays, and a powerful interactive graphics capability is therefore necessary.

Underlying the geological maps is the geologist's conceptual spatial model, that is, his opinions on the location, form and composition of the rock units and their origin and evolution. The map, as a static two-dimensional document, is a rather inadequate representation of the complexities of a sequence of interrelated three-dimensional bodies and their changes in geological time. If the model itself can be represented digitally, then the full detail of the conceptual model can be captured and communicated. Maps can be derived as projections of the model, not the model reconstructed from maps. Retrievals and GIS functions could be based on the digital model. The digital geological spatial model has many of the characteristics of a GIS, and one interesting possibility is that the requirement could be met by extensions to existing GIS software. Extensions would be required in several areas.

Polygon overlay, for example, is required to generate profile maps in which sequences of stratigraphic units are categorized and mapped, as well as simpler tasks like determining areas in which formation A is overlain by B. However, stratigraphic units are classified hierarchically and boundaries may be recorded at one hierarchical level and retrieved at another. This can be handled readily with numeric codes, where it is known that a boundary between units 6132 and 7234 is also the boundary between the 6xxx class and the 7xxx class. Such a code with the numbers arranged in stratigraphic order can also accommodate searches over a range in stratigraphic time. Simple 'less than' and 'greater than' comparison can retrieve all units between, say, 6132 and 7234. However, a hierarchical numeric code is inevitably an inhospitable array into which it is not possible to fit batches of new codes. The BGS Stratigraphic Code, therefore, has a four-letter mnemonic form. It is translated for storage and retrieval within the model into a concealed numeric form which is of purely local application. Experimentation within BGS has so far been with self-contained prototype systems, but a subroutine to generate polygon identifiers from a set of stratigraphic units could give access to existing GIS polygon overlay facilities.

The need to extend GIS facilities arises also in capturing the geologist's interpretation. Conventional geological maps contain a large element of interpretation, and indeed much of their value to the user lies in their offerring a considered and authoritative assessment of the available evidence. Computer interpretation is clearly inappropriate, as the computer lacks the geologist's background knowledge of regional characteristics and their variation, of geological processes and their effects. However, it is possible to enable the geologist to express digitally at least some of the hypotheses that he develops about an area. By capturing his interpretation in the three-dimensional model rather than the two-dimensional map, a higher degree of consistency with all data sources, and thus greater accuracy, can be expected.

Geological interpretation is involved in interpolating complete surfaces from scattered data points. Contouring and gridding programs are widely available, some surprisingly expensive, some with the algorithims concealed for proprietary reasons, but none apparently suitable for expressing a geological interpretation. Interpolation must be local, for geological processes change abruptly from one area to another. It must be possible to force a simple pattern of lines of curvature and fold axes on the surface, so that the strain bears a recognisable relationship to the stress field. It must be possible to relate the form of successive members of a sequence of surfaces in a manner consistent with their depositional and strength characteristics. There should be a possibility of controlling the shape characteristics of a surface (steep-sided reefs, rounded sand bars, asymmetrical dunes). Fault patterns must be geometrically valid, consistent with adjacent areas, strength characteristics and stress fields. The secondary surfaces, such as faults and fold axial planes, generated by the structural deformation of the stratigraphic surfaces, intersect the rock units and have their own rules governing their geometry.

In this area, Computer Aided Design (CAD) Systems have more to offer than GIS. The piecewise parametric bicubic surfaces used in CAD (see Peters, 1974; Foley and van Dam, 1982) seem appropriate for representing structural surfaces, with their non-parametric equivalents more suitable for gently folded stratigraphic surfaces. The intersections of structural and stratigraphic surfaces are lines which can be regarded as patch boundaries shared by both surfaces, and meeting the constraints of both. This method of interpolation uses slope and twist values at each node, raising the possibility of adjusting these by geometrical transformation to match fold patterns and shape tensors while retaining the fit to measured elevations. In the CAD environment, calculation of thicknesses, areas, volumes, etc. is usually possible with reference to a sequence of surfaces. As matter is seldom created or destroyed during geological processes, and voids seldom exist at depth, such calculations can be the basis for a material budget during erosion, deposition and deformation - another test that geological hypotheses are internally consistent. As some suppliers in the CAD field have diversified into GIS and digital cartography, existing systems might be found to meet such requirements. However, there are further requirements for the geological model which make the off-the-shelf solution somewhat elusive.

Another requirement of the geologist is to be able to turn back the geological clock, to prepare palinspastic reconstructions of earlier episodes in the geology of an area. For example, a study in the Inner Moray Firth basin (Barr, 1984) has attempted a restoration of strata to positions they occupied in Jurassic and Cretaceous times by removing the effects of subsequent faulting. The quantitative estimates of amount and direction of extension obtained by these techniques lead to a better knowledge of the present-day disposition of these strata and assist in understanding the regional structural evolution.

Much geological data, from seismic surveys, mines, wells, boreholes and outcrops, provide direct evidence on the surface and subsurface geology relevant to the spatial model. Other data, such as geochemical analyses of stream sediments or gravity or magnetic data, do not provide direct information which uniquely determines the geometry of the strata. Instead, the initial view of the model may be based on other information, and the expected values of, say, gravity, determined from that model. If the expected and observed values are not consistent, an iterative modification of the model is required. Requirements of these kinds are unlikely to be met by general-purpose CAD or GIS software, and at the very least modular extensions to existing products will be required.

Geology is not an isolated world, and no discipline can expect to find self-contained solutions to technological problems. It is to be hoped that in time the civil engineer may call up geological models while working with cut-and-fill software for motorway design, or that the geologist can relate his field observations to digital elements in topographic maps. In general, there appears to be a slow change of emphasis from the map as the final authorative document to an expression of three-dimensional concepts in a digital model, from which maps are derived as projections of the model for a particular purpose at a particular time. If the map is eventually seen as a more ephemeral document, there must be a need to make the digital model widely accessible. There are obvious, but nevertheless troublesome, implications for ease of use, cost, portability and compatibility with display devices. If the gestation periods for GIS and CAD are any guide, the digital spatial model in geology has moved a short distance along a long road, and must take full advantage of all related work.

ACKNOWLEDGMENTS

Numerous colleagues have contributed to the ideas expressed here, which nevertheless reflect the views of the author, and not necessarily those of the BGS.

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DEVELOPMENT OF AN INTEGRATED MAP PLOTTING SYSTEM FOR HYDROCARBON EXPLORATION

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ABSTRACT

There has been a rapid growth of computer usage and associated database concepts and technology in the hydrocarbon exploration industry. This has led to a state where a majority of data used in the exploration process has been entered and stored in a multitude of databases. There is a need for much of this data to be plotted in combination by personnel from different disciplines. In the past each database was accessed separately, the files of retrieved data collected together and, after the addition of a framework, plotted. This was inefficient and caused many problems and failures due to data and parameter incompatibility. The paper traces the development in BP Exploration of a system which combines all the retrievals into a single driver, ensures the compatibility of the data and plots it with a range of symbology and high degree of cartographic presentation.

INTRODUCTION

Computer assisted mapping has been used in BP Exploration for the past 15 years. Initially there was little input from the cartographic group and the rather crude system that evolved reflected more the state of the art of computer mapping rather than its inherent limitations (Monmonier 1982). The system was largely ignored by the cartographers within the company until five years ago, when not only its potential, but also the potential for disaster if it was further ignored, was realised.

For most of its existence the system has been used for geophysical shotpoint mapping, but with the ever increasing computer usage throughout the company the whole range of earth science specialists and the cartographers themselves have realised its practicality. This has given further importance to the need for the system to be based on sound cartographic and geodetic principles.

This paper traces the development over these five years and concentrates on the present developments and those planned up to early 1987.

BACKGROUND OF THE PRESENT SYSTEM

The system was initially developed for BP's Geophysical Division in the late 1960's and early 1970's. It was run on the corporate UNIVAC mainframe computer, written in FORTRAN IV and used standard eighty character card input. The map framework generation program required cards containing spheroid and projection parameters and the framework and map sheet parameters. The projection computations were basically a digital form of the standard projection tables and only Transverse Mercator and Lambert projections were catered for. During the 1970's further projections such as Mercator and Oblique Stereographic were added, some enhancements were made to the framework generator, and the system fulfilled its basic role of shotpoint mapping.

The late 1970's saw a steady increase in computer usage and members of the Survey and Cartography Division began to make use of the system. However their input to the development side was limited to a few cosmetic enhancements. As late as 1979 the system was still based on card input and batch processing and combined with a very slow plotting system was tedious to use. At this time the seismic processing group perceived a definite requirement for non-batch processing and interactive screen input. This was developed and used for a short time on the UNIVAC but was moved to a DEC VAX machine in early 1980.

At this time BP Exploration set up its own independent Computer Division. An early decision was made to standardise on Digital Equipment Corporation (DEC) VAX equipment. DEC's minicomputer range and its world wide support offered the necessary environment for the then present needs and future development of Exploration computing.

Soon after this move Survey and Cartography Division realising the need for the computer-assisted mapping system to be based on sound principles, set a brief for one of their surveyors to look into all the coordinate handling applications within the computer environment and provide support for the development of these systems.

FIRST PHASE OF DEVELOPMENT

The main objectives of the initial phase of development was to provide firm foundations for coordinate data handling on which future developments could be based. Within these foundations would be:

* A wide range of geodetic processing and transformation routines.

* A storage system for datum and projection parameter data.

* Easy access to the above data and routines.

* An enhanced map production system and user interface.

* A storage system for topographic data.

Geodetic Processing Routines

The requirement to be able to efficiently transform coordinate data between different datums and projections was of prime importance. BP Exploration activities are world wide and cover a wide variety of datums and projections (it should be noted that the word datum is used to cover both a specified geodetic datum and/or a specified spheroid). It is a requirement within certain obvious limits that all of this data should be compatible but that the general user, although being aware of the incompatibilities, should not have to be aware of the processes involved in making the data compatible.

A general conversion interface with a large number of underlying conversion routines was needed that could be easily called by application software. The routines should cover forward and reverse geographical to geocentric conversions and all the forward and reverse geographical to grid conversions that were required for BP operations. Computer processing power had risen to such an extent, and was forecast to continue this rise, that the use of double precision and precise spheroidal algorithms to a large number of orders could be implemented without causing undue overheads in processing time. The interface should be capable of receiving input, deciding on the conversion route to be taken, calling the necessary transformation routines and returning the result. Figure 1 illustrates the interface design and operation and also the Earth Constants Data storage covered in the next section.

Earth Constants Data

It was considered that the attribute information necessary for any coordinate handling operation was complicated and outside the comprehension of the general user. In the past both small and gross errors had been caused because it was necessary for the user to input this data. What was required was a storage system for all the datum, spheroid and projection parameters and for the user to be able to access this data through one or two 'keys'. This would mean that for any coordinate handling operation all that would be required from the user would be the input data and 'keys' and the output 'keys'. From this developed what was termed the Earth Constants Database and the 'keys' consisted of a geodetic datum mnemonic and a projection mnemonic (a vertical datum mnemonic was optional). This means that as long as a graticule coordinate has a datum mnemonic attached and a grid coordinate has a datum and a projection mnemonic attached then the coordinate can be handled by any of the conversion routines.

Access to Coordinate Handling Routines

For the successful implementation of the above system the actual access must be as easy as possible. This was provided by the provision of a FORTRAN callable routine that could be called by any application requiring coordinate handling. The coordinate, the coordinate type and the mnemonics for input and the coordinate type and mnemonics for output were all that was required for the output coordinate to be returned. All processing and data retrieval was handled within the transformation system (Figure 1).

Conversion chain may be entered or exited anywhere (except obvious exceptions).
Direction must always be forward along the chain.
(N.B. Vertical Datum processing is also handled but omitted for clarity).

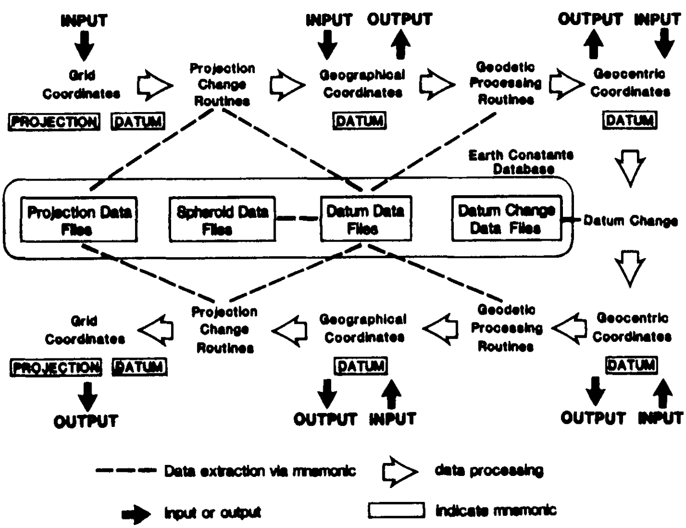

Figure 1 COORDINATE TRANSFORMATION PROCESS

Map Production

Although some use of the system within the Survey and Cartography Division is for straight coordinate manipulation with other than graphical output the major use made of it within Exploration is for map handling. This covers both digitising and plotting and although basic programs were available many enhancements were necessary.

The benefits offered by the coordinate handling system developed were great enough to easily persuade the involved disciplines to make use of them. It was probably an indication of the success of the design of the system that it was so easily accepted and integrated into the existing mapping system and other applications.

The existing routines that generated the map frame were extended to cater for the full range of projections covered by the new conversion routines. Few cosmetic enhancements were made as the actual 'look' of the map was considered at this stage to be acceptable for working purposes.

A new user interface was a high priority and a series of data input screens from which the program input cards were prepared was written. This consisted of a program to define what was termed the 'area of interest' and a second program that defined the map design. The area of interest program allowed the input of the top right and bottom left coordinates in either grid or graticule terms, the Earth Constants mnemonics and the scale. The map design program defined such items as the overlaying grid and graticule, the annotation, titles and label box information, and other such user defined features as a scale bar and a north arrow. The program had a series of hierarchical screens with an expanding amount of map design control being given the further the user progressed down the hierarchy.

Cartographic Database

Another high priority was the design of a cartographic database. This would hold topographic data that could easily be included as basemap data on application mapping. The system was developed in house so that full use could be made of the existing software, but it must also be noted that no suitable proprietary system that could be adapted for BP use was available at this time. The design and operation of this database is not covered here but described elsewhere (JONES,HARRIS,LOTT 1982).

SECOND PHASE OF DEVELOPMENT

Progress of Phase One

The Earth Constants Database, the conversion software and the plotting software and interface were in operation world wide during 1983. The new Geophysical Database was reliant on the system and other databases and newly planned databases also made use of it. The Cartographic Database development had experienced some teething problems but was in operation in head office in a prototype version by late 1984.

System Evaluation

At this stage the actual plotting system and the appearance of the produced maps had changed little. The basic foundations planned in phase one had been laid and would be built on in phase two.

The system faults identified in late 1984 and which were to be rectified in phase two were as follow:

* The constituent parts that made up the plotting system were unlinked.

* Due to this there was still no overall control throughout the process covering the parameters defined in the area of interest and mis-matching caused by data incompatibility still occurred.

* Different disciplines were using different sub-sets of the programs, causing unconformity and thus confusion among the users.

In essence these were the first steps toward an integrated map plotting system. The idea was to link the constituent parts by providing a high level user interface that carried control from one program to another and supplied certain defining parameter data to the individual parts. The development would also test the feasibility of accessing data from different databases from the one interface. If successful the system would provide the whole of Exploration with a single mapping system.

Early on it was decided that the system would in fact form a prototype for the third phase of development. This was due to the unknown user response to such a system and it was felt that this would provide invaluable assistance in the development of a fully integrated map production system. This meant that the development work only occurred on the interface linking the existing programs. Little or no work was carried out on the individual programs although for some users some of the constituent parts would be new.

The concept used for the system was based on hand map-drafting principles. The area of coverage and the projection to be used are first defined. The map framework and the map sheet layout are then designed. After this followed the data inclusion phase including topographic data and any application data that was required, with any coordinate conversion that was necessary handled by the system. Finally the output plot type is defined and the job run. The actual processing and data extraction was only to be made available in batch mode.

The system would ultimately be used in 10 to 15 overseas Exploration offices covering a wide spectrum of plotting devices. This required that the system had an installation process which catered for these differences. During the installation certain site configuration details were requested by the program which then wrote the parts of the interface which were site specific.

The system development went very smoothly and it was released to all Exploration sites that had suitable facilities at the end of 1985. The system was generally favourably received and a great deal of constructive user response was generated. The system installation proved exceptionally successful with only one site experiencing any difficulties during installation.

THIRD PHASE OF DEVELOPMENT

Phase Two Evaluation

Much of the user response generated following the release of phase two was predictable, although certain aspects of the criticism were surprising. For example one of the predictable criticisms was that the structure of the framework generation program interface was complicated and it was necessary to run through the program even if all the default values were to be taken. What was surprising from a cartographers viewpoint was the amount of the criticism and the overwhelming user view that only very rarely did they require any change to the default values. Another surprising response was that the different screen management systems used in the different parts of the system, which we considered a major fault, was considered as a very low priority problem.

The release of phase two had given the development team the knowledge that they were following the correct lines of approach in the development of a map production system. Phase three would provide the enhancements that would turn the system into the integrated map making process required within BP Exploration.

Phase Three Concepts and Development

The user response and various studies that were carried out during the release of phase two led to the definition of phase three as follows:

* The framework generation program, although not to be re-written, would be considerably enhanced.

* The user interface to the framework generation program would be completely re-written to provide a more streamlined operation and user friendliness.

* Much better on-line help facilities would be made available.

* The constituent parts of the system would, as much as possible, look alike and data input would be standardised.

* A greater range of symbology for both point and line data would be made available and automatic key generation would be provided.

* An interactive graphics display of the map would be provided for suitable hardware, although no graphics editing capabilities would be included.

* A standard interface to outside databases and sub-systems would be designed to enable other users to link into the mapping system with relative ease.

An expansion of these concepts, and their implementation which is presently taking place is as follows.

The complete user interface including the cartographic database retrieval would be re-written. One screen management system would be used and it would follow an agreed standard. It is hoped that although different screen management systems may be used within the sub-systems the modern flexibility of these systems will allow them to look as one to the user.

A far greater flexibility will be allowed as to how the user progresses through the interface. At the highest level the user can define the area of interest and can then opt for a completely automatic generation of a basemap. This will include topographic data and be known as a standard BP Exploration basemap. Each overseas site will be allowed to alter the standard format during installation so that it meets local requirements. This move is of great importance as when hand drafting techniques are employed then the cartographer designs the map for the specialist. A computer-assisted system should also follow this principle. This will allow the specialist more time to concentrate on the inclusion of his own specific data rather than having to waste time worrying about the map design. On the other hand the system should also allow a cartographer a quick pathway to the lower levels of the system and provide a high degree of flexibility in the map design. User response from cartographers in many locations has identified areas where greater interaction is needed. These include label box design, location map generation and symbology.

However these last options will generally be generated automatically. The location map will cover an area around the map limits, will highlight the actual map sheet area and will include very small scale topographic data. The key will be generated from a standard symbol table and will include all symbols that are used on the map sheet. Each sub-system will pass this information back to the main interface including user defined symbols. In the existing system the title and label information have been input during the framework generation stage. User response has identified this as a major fault requesting that this input should be after entry to all the sub-systems. In fact much of this information will be passed back from the sub-systems themselves.

The sub-system interface will be defined in precise terms. This will enable future sub-systems to interface with ease. The mapping system passes information such as the area of interest and map registration parameters to the sub-system. The user then works within the sub-system defining the specific data that is required on the map. On completion the sub-system passes back such information as to the map overlays that have or will be generated, the symbols that are to be used and title and label details. Any number of sub-systems can be entered any number of times and the ability to include previously generated data will be given.

Help facilities which were very poor in the existing system would be much improved. Virtually all the help that was available was provided as information on the input screens. This made the screens over-crowded and as only new users generally needed this information it was unnecessary for the majority of users. Two levels of help will be provided. There will be a help option on the menu which will give a general overview of each input screen and a help key on the keypad which will give field specific help depending on where the cursor is situated.

Phase three will therefore provide a fully integrated computer-assisted map production system. The world wide release should take place during the first quarter of 1987 and the available sub-systems will be the geophysical and geological databases. This will mean that the majority of explorers within the company will be relying on the system for their mapping requirements. This has given the development an importance that is well identified and it is felt that the planned system will fully meet these requirements.

Future Developments

Future developments of the system perceived at present will include enhancements to the appearance of the output, the ability of the user to carry out some interactive editing of the map and the ability to include raster data. The use of colour will greatly improve the appearance of the map and will in fact be possible within phase three. However the colour electrostatic technology is such that it is not seen that this will be available to the general user for some time to come. Colour infill for electrostatic plotting is at present too process intensive to be available to the general user and for automatic colour infill generation some alteration to database structures will be necessary. However these facilities are presently available through the Survey and Cartography Division.

The ability for the user to be able to edit the data that he has included on the map sheet is also seen as a future requirement. Editing of data outside the users discipline, except for deletion, will not be allowed. This development is very hardware dependent but with the move towards provision of locally linked graphics workstations throughout the working environment this is seen as a near-future development. Again this facility is presently available within the Survey and Cartography Division.

The inclusion of raster data is seen as a 'slightly further in the future' development. This is mainly due to the problems of processing time and output media. Processing power will steadily increase thus overcoming the first problem and it is hoped that colour electrostatic plotting will develop so that output using this process will be viable. It is envisaged that an earlier development will be the the ability to display raster data as a map overlay on a graphics workstation.

Conclusion

Computer-assisted mapping has slowly evolved within BP Exploration rather than experiencing the sudden explosive development that has accompanied many computer application developments. In retrospect this has been highly beneficial and a very sound map production system has evolved. The speed of the evolution has been slow but it must be remembered that it is taking place in a full working environment. It is imperative that any system, such as a mapping system, that is relied upon as heavily in everyday company operations is developed in this manner. The integrated map production system that has evolved is a robust and practical system that is based on sound theoretical principles and that has been enhanced through user input. This has meant that the user can at present, and will in the future, have confidence in the map making process and can place trust in the mapping of his specialist data.

ACKNOWLEDGEMENTS

The author wishes to express his respect and gratitude to all those, too numerous to mention, who have been involved in the development of the above mapping system over the past 15 years.

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DEVELOPMENT OF DIGITAL CADASTRAL AND TOPOGRAPHIC MAPS - REQUIREMENTS, GOALS AND BASIC CONCEPT -

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ABSTRACT

In North Rhine-Westfalia basic social facilities gain a special importance because of the impact of the densely populated and industrialized state on our environment. For their installment surveying and mapping offers current, detailed and exact maps in different scales. The possibilities of map production by analoguous means are exhausted. Further developments can only be expected by the use of digital production methods. The technical prerequisites for the installation of these methods are guaranteed. In the future the map user expects a more flexible availability of topographic-cartographic informations. To the conventional map series further editions should be added with other user-friendly graphic symbols and contents. But additionally the surveying and mapping agencies have to be prepared for the rapidly growing demand for digital informations of the earth's surface. Therefore, we have to strive for the realization of a Land Information System (LIS), which can support the acquisition, storage and provision of cadastral, topographic and user-oriented data. In the nation-wide project, the preparations for a digital cadastral map, the so called ALK, are nearly completed. For topographic maps in scales 1 : 5 000 and 1 : 25 000 first experiences were gained in data acquisition and data output. Suited storage models are being tested.

SURVEYING AND MAPPING IN NORTH RHINE-WESTFALIA

Prerequisites

North Rhine-Westfalia is the most densely populated state of the Federal Republic of Germany. During the industrialization periods many people were employed in the Rhine and Ruhr district; meanwhile large conurbations were developed in these districts. According to the growing population the demand for housing areas, areas for transportation, private and public institutions for education, culture etc. increased. Especially in North Rhine-Westfalia the demand for industrial areas is considerable, because of softcoal mining, mineral coal mining, steal production and chemical industry. In order to supply the areas required and to secure certain living conditions as well, the development of basic social facilities were considered very important.

Means of planning were developed and applied successfully in a wide range. Since society became more and more aware of the close relation between conurbations and natural resources, the provision of these social facilities also gained a new dimension since we do not want to endanger our own future.

Official map series

In these circumstances updated, exact maps in various scales become the important basis of all environment-related measures starting with the inventory and planning up to the realization. The constantly growing demand for maps for administrational or industrial purposes could be met up to now by the different official topographic maps offered by the surveying and mapping administrations.

Official maps of North Rhine-Westfalia

map series	number of sheets	revision cycle	application examples
cadastral map		permanent	- property register - town planning - utility base maps
1 : 5 000	8629	5 years	- "German Basic Map" - town planning - road planning
1 : 25 000	270	5 years	- regional policy - environment protection
1 : 50 000	72	5 years	- trail maps - military maps
1 : 100 000	19	5 years	- regional maps - traffic maps
photo map 1 : 5 000	8629	6 years	- environment protection - archaeology
photo map 1 : 25 000	270	5 years	(program started)

In contrary to the cadastral maps which are continuously updated, the maps in scales 1 : 5 000 to 1 : 100 000 have a revision cycle of 5 years. The photomap, scale 1 : 5 000, is renewed every 6 years, the photomap, scale 1 : 25 000, every 5 years.

Present production and distribution of maps

The development of a map, beginning with a mainly military function in the beginning of last century up to its present status as environment-related basis for the prevision of social facilities, was accompanied with a fundamental change of the production method of maps. Only by means of this change the growing demand for maps could be satisfied. Thus, the use of transparent foil since the middle of this century enabled an even stronger differentiation of cartographic objects according to their colours, and depending on various foil-combinations different map editions were possible. Even the production of thematic maps on the basis of topographic maps became very simple by adding a thematic foil, variations in scale, colours and sheet lines were possible as well. Still today the use of transparent foil influences the cartographic production method. According to present map production, map editions basically different of the ones we know today, can only be realized by a high expenditure of personnel, time and money.

Future requirements

In spite of the high standard of our official map series, they are more and more criticized:

1) The map symbols should correspond to the knowledge of modern semiology. The basic graphic elements: area, colour and raster should be used more frequently.

2) Different groups of users need different types of maps.

3) The reliability and updating of maps does not meet the demands of the user.

4) The possible combinations of situation and a special theme are limited by the number of foils used.

This means that map users do not only want updated and exact maps but a more flexible presentation of the available topographic-cartographic information. The conventional map editions should be complemented by further editions with user-oriented graphic symbols and themes. Recently new editon possibilities have been introduced in the Federal Republic of Germany. The surveying and mapping agency of North Rhine-Westfalia also took part and introduced two edition possibilities for maps in scale 1 : 25 000. These editions each with a different graphic representation and theme are meant for two different purposes. The first purpose, the map as planning material and scientific research basis, shows a geometric documentation of the earth's surface as complete as possible. In contrast to the conventional edition another graphic means - the area - was used in addition to new and more map colours. The second purpose, the map as a means of orientation, stresses all elements necessary for the orientation outside and does without any information useless for orientation. This can be seen by the different representation of housing areas and the addition of streetnames. In this edition the graphic elements: area, colour and raster are used more often than in the conventional one.

In addition the surveying and mapping administrations have to face an increasing demand for digital information of the earth's surface. New information systems are being developed for different purposes related to the earth's surface. The surveying and mapping administrations developed the program system "Digital Cadastral Map", a parcel-oriented information system of high accuracy, which is meant to be the basis of user-oriented information for large scale maps. The development of topographic-cartographic data-banks has only just begun. We want to realize a Land Information System (LIS) for the acquisition, storage and processing of topographic data as well as user-oriented data.

DIGITAL MAP CONCEPT

I have already mentioned that the use of transparent foil for cartographic production meant a new step of cartographic evolution and thus enabled surveying and mapping administration to meet higher demands of former times. The next step of cartographic evolution has begun with the development of computerized information systems, which we also want to use for the production of official maps. Only thus we shall be able to meet the increasing demands of the future. Below, I want to describe the development of a Land Information System which we have begun in North Rhine-Westfalia.

Structure of the Land Information System

A Land Information System comprises all information on our environment for a defined region - a township, a county or a state. It is different from other information systems because of a geometrical, a 3-dimensional component of each information. This enables direct access to information of a certain region but also demands special geometrically oriented storage-structures which are difficult to handle by conventional data-management-systems.

All objects stored in a Land Information System need geometrical description based on coordinates. Therefore, special importance has to be given to a homogeneous, highly accurate horizontal and vertical control point net which serves as basis of the Land Information System. The surveying and mapping agency of North Rhine-Westfalia successfully uses methods of satellite geodesy, the Global Positioning System (GPS), in order to achieve this aim.

The horizontal accuracy neccessary for practical purposes also influences the choice of scale usefull for cartographic representation. An information system for 3-dimensional data will, therefore, be devided in scale sections as long as automatic generalization is still impossible. For official mapping the following scale sections are planned: scales 1 : 1, 1 : 5 000, 1 : 50 000, 1 : 250 000 and 1 : 1 million. These so called "Digital Land Models (DLM)" are based on each other and are meant to be the basis for all user-oriented information in the fields of planning, statistics, environment protection etc.

The surveying and mapping agency of North Rhine-Westfalia has to develop the "Digital Cadastral Map" (DCM), and together with the different cadastral administrations, to realize this project and install the Digital Land Models, scales 1 : 5 000 and 1 : 50 000. The other scales belong to the responsibility of the Institute for Applied Geodesy.

The Digital Land Model is object-oriented, and comprises the original information of the earth's surface, not the already deducted information of the map. The Digital Land Model can be divided in two components: a "Digital Situation Model" (DSM) consisting of all informations about the horizontal position of the objects and a "Digital Terrain Model" (DTM) consisting of all informations of the terrain modulation of a region. The DLM can be used to develop "Digital Cartographic Models (DCM)" which are the digital equivalent to our analogous maps.

DLM, DCM and official map series

Digital Cadastral Map (DCM)	-	Cadastral Maps 1 : 5 000 - 1 : 2 000
DLM 5	DCM 5	German Basic Map 1 : 5 000
DLM 50	DCM 25 DCM 50 DCM 100	Topographic Map 1 : 25 000 Topographic Map 1 : 50 000 Topographic Map 1 : 100 000
DLM 250	DCM 200 DCM 500	Topographic Map 1 : 200 000 General Map 1 : 500 000
DLM 1000	DCM 1000	International Map of the World 1 : 1 000 000

The development of a DCM is necessary since a map cannot be produced automatically from the original DLM because of its complex map symbols. Manual corrections of the DCM at an interactive workstation are necessary in order to guarantee a correct graphic representation. In special cases these corrections might be relatively extensive, therefore, it seems adviceable to store the corrected DCM also to reduce the time expenditure for the next map revision.

In order to handle such a Land Information System all surveying and mapping administrations agreed on certain standards. The first step was the edition of a uniform object-catalogue for all objects represented in official maps. The catalogue for cadastral maps is already completed, for medium and small-scale maps it is being revised.

In the second step to standardization a data-model was developed. According to their shape the objects were classified in point-shaped, line-shaped and area-shaped objects, and additionally for each object the details relevant for representation were given. E.g. for the object 'parcel' the details relevant for representation are parcel boundary and parcel identifier.

In a third step this data model was considered the basis of a standard-interface necessary for data exchange, the so called "Uniform Data Bank Interface" (UDBI).

Further standards define the graphic representation of map objects and individual names of map objects (e.g. parcel identification, building identification). These elements can be used to link informations of the data file with files which do not contain any geometrical information.

Because of practical reasons for the organization of the DLM maps will be the primary source of information. Only for revision purposes it seems useful to use the countryside itself as main source but it also depends on the scale of the model revised. The DCM (equivalent to maps in scales 1 : 500 - 1 : 2 000) is based solely on original surveying informations, the DLM 5 (equivalent to the map scale 1 : 5 000) is partly based on original surveying informations and partly on aerial photos; the models of smaller scales are based on aerial photos only but are controlled by field checks if necessary.

The special advantage of a Land Information System is the variety of its products. Besides conventional official maps a whole range of different map editions will be available. Maps of each scale, of any map section, of any contents desired, and of any graphic representation demanded can then be offered to the user. Because of the linkage between all geometrical data files and those of other thematic information thematic maps can easily be produced.

Digital production methods

The organization of the Land Information System consists of two seperate parts: the storage of data on the one hand and the processing of data on the other. Not only the producer of this program-system (the surveying and mapping agency of NRW) shall be able to use all data stored but also the other users,(e.g. all cadastral administration i.e. townships in NRW). Therefore, a standardized, central large-capacity computer is used. But we do not plan to store all possible DLM in the storage of this central computer. Especially the models for the cadastral maps, will be stored decentralized in computers of each township concerned since in NRW the cadastral functions are carried out decentralized by the administration of each township county or community.

Similar to the storage of the DLM data processing is also carried out decentralized e.g. in the cadastral administrations of each township or the departments of the surveying and mapping agency in charge of a certain map scale. Because of these complex programs and the integration of the different operations an interactive graphic workstation should be used. The data flow between the central computer and these interactive graphic workstations is guaranteed by the standardized interface mentioned above, the so called "Uniform Data Bank Interface".

In this development stage of the LIS the surveying and mapping agency of NRW uses the special hardware configuration - figure 1 -, without scanner/ rasterplotter.

This configuration is based on the special necessities of the program-system for the Digital Cadastral Map. The central unit is a SIEMENS-computer; the data bank for the Digital Cadastral Map is tested with a multipurpose data bank program-system and will soon be available for general use. In the departments of the surveying and mapping agency of NRW in charge of the production of different map scales vector based graphic computer systems are used for decentralized data processing.

The interactive graphic workstation will be the most important tool of the user. This workstation was developed especially for the requirements of the DCM-project. It is, as already mentioned above, a vector-based system equipped with additional functions, e.g. for data acquisition, data revision and for data application (automated drafting or computing). These functions can easily be modified according to the wishes of each individual user.

This interactive graphic workstation is based on the international graphic standard, the so calles "Graphical Kernel System" GKS, which also implies a special organization of software - figure 2 -.
This software is specially oriented according to cartographic requirements consisting of different sections for a graphic data bank, which enable the use of digitizers, menu-functions and complicated graphic representations. Thus, this workstation can be applied for many fields:

- cadastre
- soil evaluation
- mapping of land use
- regional planning
- development planning
- mapping of cables and pipelines

This program-system proves the capacity of the GKS also for complicated graphic applications and shows in every day programming and application the advantages of such a graphic system.

It is based on the highest level of the GKS, therefore, its portability is limited to computers, where GKS of the highest level can be implemented. The programs are written in FORTRAN 77. According to principles of software engineering a special programming structure was developed to enable the programming of the components of the basic system and the application components.

This vector-based graphic interactive workstation for the digital cadastral map meets all our requirements. But using this workstation for smaller scales soon shows its bounds. We estimated that data acquisition for a DLM 50 (equivalent to the maps scales 1 : 25 000 to 1 : 100 000) of North Rhine-Westfalia with conventional digitizing methods based on the maps, scale 1 : 25 000 and the momentary staff-capacity would take about 10 - 15 years. A second problem arises by the automated drafting of one sheet of the map, scale 1 : 25 000. According to our experiences this takes about 50 hrs (without contour lines) on a CONTRAVES-plotter with light-head.

A solution of these problems could be the use of scanners for automated digitizing and of raster-based plotters for automated drafting. But we are not yet sure about how much acquisition expenditure scanners would actually save. The development of special software designed for the recognition of patterns and structures has only just begun. These programs still leave many details to manual correction and addition especially considering the relatively complex symbols of topographic maps.

The use of a raster-based plotter shows immediate efficiency, instead. The problem of converting raster-data to vector-data is already solved, thus, the raster-based plotter could directly replace our vector-based one. An additional advantage of the raster-based plotter is, that it easily drafts areas of solid colour and screened areas.

Because of the advantages of raster-based graphic data processing the surveying and mapping agency of NRW considers to supplement the configuration with an efficient raster-based high precision plotter. We expect great advantages for the reproduction of maps, especially for colour seperates and map printing. By means of this new high-precision plotter we hope to introduce data processing techniques in the production process of topographic maps and orthophoto maps. We also expect that the raster-based techniques expedite the conversion process of the analoguous cadastral map to the digital cadastral map and in general also the development of a LIS in NRW.

FIRST EXPERIENCES

Since 15 years the surveying and mapping agency of NRW is using methods of graphic data processing. Not all developments which we started were successfully, and we also thought to manage the problem of automated generalization, meanwhile, we are sober to think that we are farer away of the solution of this problem than ever. We turned to closer problems: the processing and computing of mass-data of a LIS, the acquisition of topographic and other environment related data for cartographic data-banks, and their output in an either digital or analoguous way. Therefore, we finally developed an interactive graphic workstation as modern tool for all applications concerning a Land Information System by applying many experiences we gathered with other previous systems. We used it e.g. to assist the revision of 100 maps, scale 1 : 25 000 by digitizing, controlling and correcting interactively 1,1 Million points in 4000 hrs. The workstation was used successfully for the production of thematic maps, for digitizing of cadastral maps and for the development of a digital terrain model. Today we can offer a mature, multi-functional interactive graphic workstation, which is compatible to all computers designed for high-standard graphic data-processing because of the GKS and its pure modular structure.

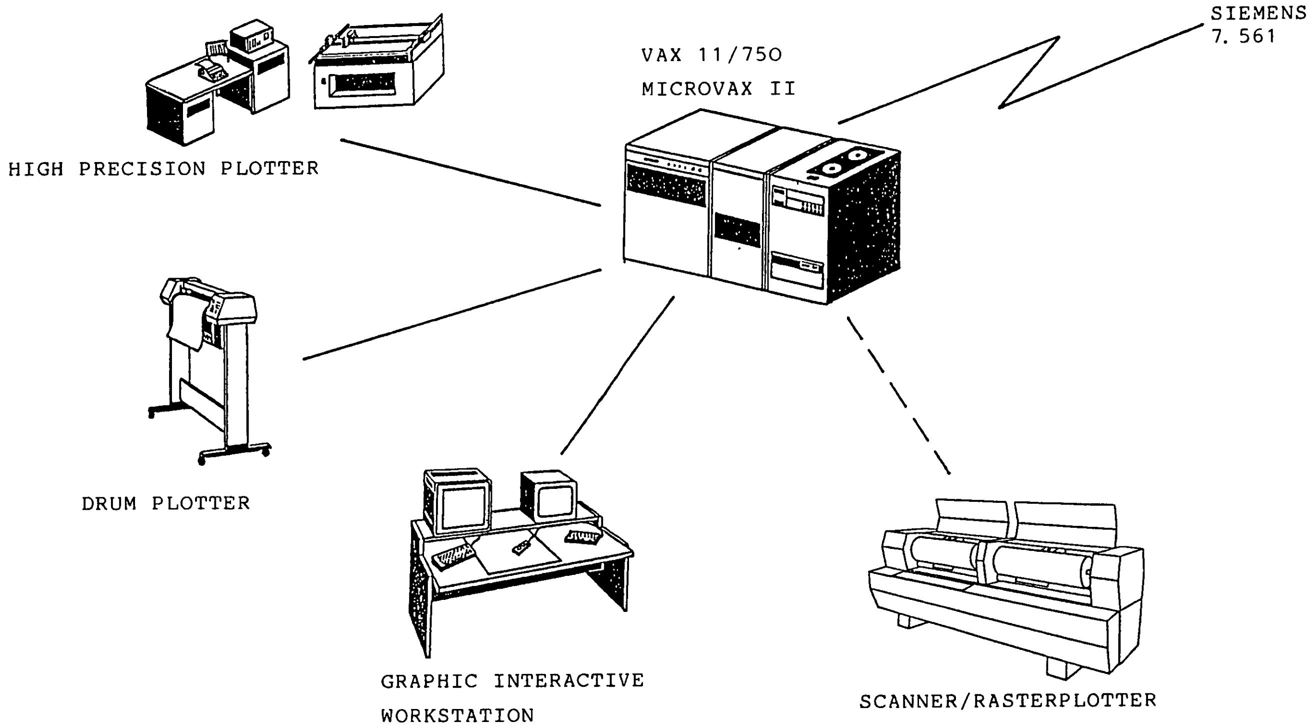

Figure 1: Hardware Configuration

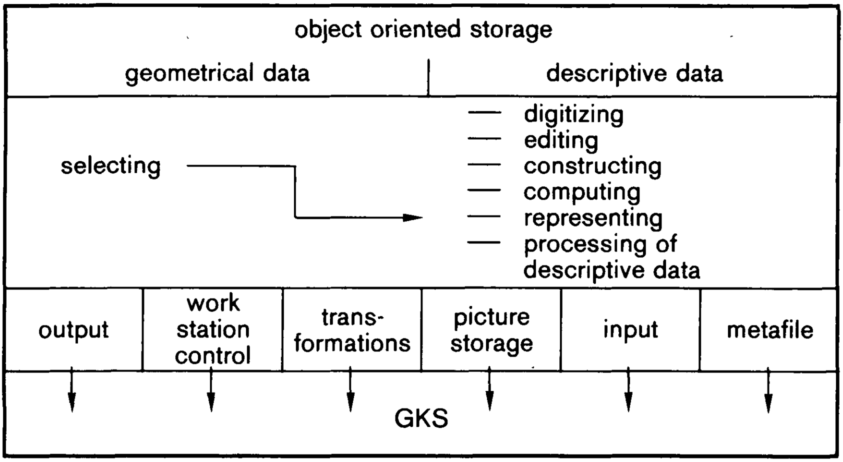

Figure 2: concept of the interactive graphic workstation for the digital cadastral map

TENDEX: A COMPUTERISED DATA BASE OF MINING TENEMENT INFORMATION

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PERTH WESTERN AUSTRALIA

ABSTRACT

The Department of Mines in Western Australia is responsible for the registration and processing of application for mining tenements.

In a period of reasonable mining interest and activity, the number of applications lodged in the Department are in excess of 10,000 per year, rising to between 60,000-80,000 in a boom year.

Tendex is a computerised data base holding the most important attribute data against approximately 35,000 tenements. It was designed as the first step in a building block approach to an eventual large data base managment system of tenement information, and scientific data connected to a geographic base.

This paper outlines the philosophy, method and results of the Tendex system.

IMPORTANCE OF MINING TO THE STATE

The importance of mining to the economic well being of Western Australia can be gauged from the fact that in 1984 the value of minerals extracted was almost $4.7 billion (Aus) of which the Government collected more than $180 million in royalties, rent and fees. (See Fig 1)

The Western Australian Mining industry contributed 30% of the total value of overseas trade for Australia and more than 80% of the value of W.A. mineral production is exported. (See Fig 2)

There are currently 5 different types of tenement that maybe applied for to carry out exploration and mining under a new Act introduced in 1978.

- EL - Exploration lease
- ML - Mineral lease
- PL - Prospecting licence
- GPL - General purpose lease
- ML - Miscellaneous licence

ROYALTY REVENUE

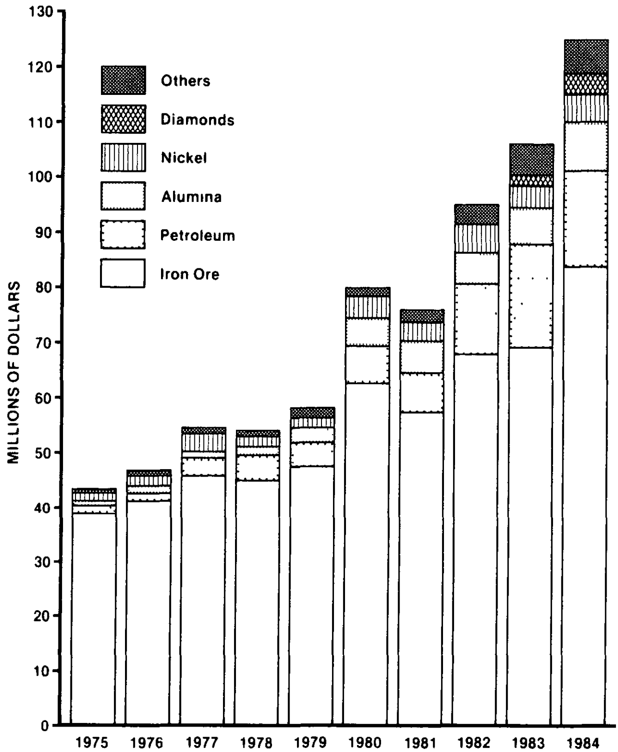


Figure 1

VALUE OF MINERAL PRODUCTION

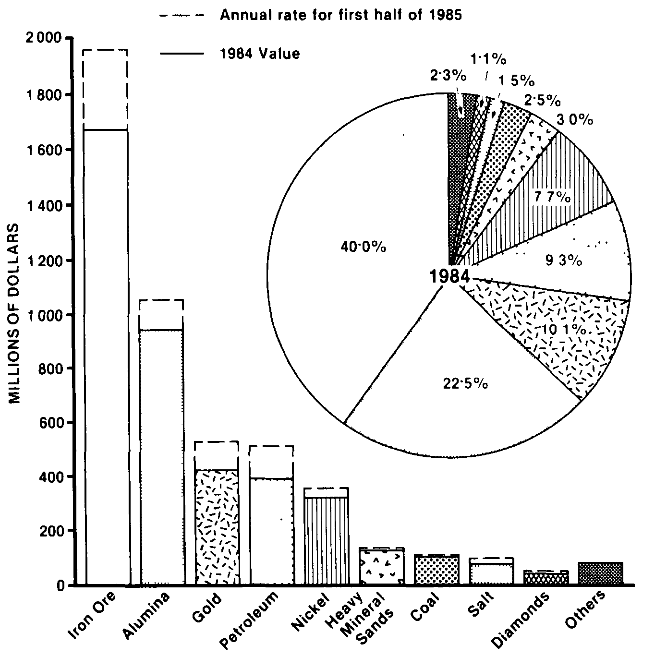


Figure 2

Prior to that, more than 40 different types of tenements could be applied for under the original Act of 1904.

At the end of 1985, more than 35000 tenement applications under the 1978 act had been lodged in the Department and approximately 394000 under the 1904 act.

Each tenement may have up to 70 items of information related to it, such as the name and address of the holder, Departmental file number, area, plan name and other legal dealing attributes.

Since the beginning of this century and until recently all tenement information was recorded by hand in large leather bound volumes.

Because of the vastness and remoteness of Western Australia, a system of registration offices was established in remote areas where tenement applications may be lodged in the field to avoid the long trip to Head Office in Perth, capital city of Western Australia. (See Fig 3)

A duplicate set of registers is kept in each outstation covering tenement applications in that particular region.

All tenements are plotted onto plans at various scales although mostly at 1:50 000 and a duplicate set of plans is maintained in each outstation similar to the registers.

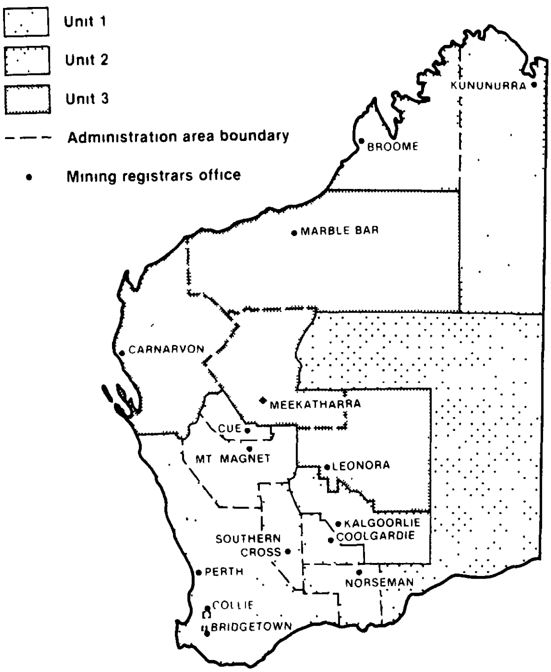
The Department is required to service the public and the mining industry by providing up to date information on all aspects of current applications and in particular, evidence that ground is available for pegging.

The massive amount of information requiring recording, plotting and processing has severely strained the ability of the Department to maintain manual systems.

In 1981/82 investigations were carried out into ways of computerising the information so that more efficient methods of recording and processing the tenement data would enable a better service to be provided to the industry and the Department.

When an application for a mining tenement is lodged, it is allocated a file number and a tenement number. The State is divided into Mineral Fields for the purpose of administration and as the names are quite long a 2 digit code is used to precede the tenement member. Thus, a tenement applied for as an Exploration Licence in the Marble Bar District would carry a number like this - E 80 3962.

REGISTRATION OFFICES



APPLICATIONS

1-1-84 TO 30-6-85

UNIT 1

TENEMENT	NUMBER	AREA (ha)
PL	1 873	211 488
EL	291	3 184 000
ML	260	37 655
MISC.	52	1 121
GEN	6	155

UNIT 2

PL	1 717	225 866
EL	435	6 327 500
ML	199	17 890
MISC.	94	6 744
GEN.	21	404

UNIT 3

PL	2 155	262 720
EL	444	6 411 300
ML	309	46 510
MISC	143	6 144
GEN.	35	591
TOTAL	8 034	16 740 088

PL = PROSPECTING LICENCE
EL = EXPLORATION LICENCE
ML = MINING LEASE
MISC. = MISCELLANEOUS LICENCE
GEN = GENERAL PURPOSE LEASE

Figure 3

The application form (See Fig 4) contains all the data necessary for processing and in the event of disputes arising, marking off time and date may become an important issue.

The type of data on the application form and the following legal transactions were ideal for computerisation and it was eventually decided to proceed with building a data base.

Although the Department did not have a computer, the Central Government Computing Centre had sufficient space on a Vax 780 and terminals were installed in the Department and connected by land line to the central computer about one kilometre away.

The Department decided to proceed with building a data base and staff were trained and much enthusiasm prevailed.

Due to inexperience with data base management systems, no structuring of the data was attempted and it was decided to simply take up all the data and work out any reporting functions at a later date.

The data take up began in 1983 for a system known as MTIS (Mining Tenement Information System) with all data based on the tenement number.

Temporary staff were engaged and the data were taken direct from the source documents, the hand written registers where the information was recorded most of the time, and certainly in the last 20 years, under pressure of continuous high level mining activity and the original entries were never checked.

By mid - 1984, there were obvious signs of trouble. The error rate of data entry was very high and added to the errors in the original data, the whole validation process became unworkable. It proved conclusively the need for data to be checked and validated before entry.

All data entry ceased and a working group investigated the problems and finally concluded that the original plan to take up so much data was too ambitious and recommended that a severely reduced system should proceed. At the same time, a project manager, missing from the first exercise was appointed to co-ordinate all the activities and to design and establish a new system.

During 1984, an IBM 4341 computer was installed in the Department and some data had been transferred to it from the VAX 780.

Form 21 WESTERN AUSTRALIA
Mining Act, 1978
(Secs 41, 58, 74, 86, 91 Reg. 64)

APPLICATION FOR MINING TENEMENT

(a) Type of tenement
(b) Time & Date marked out (where applicable)
(c) Mineral Field

(a) EXPLORATION LICENCE — No. 45/526

(b) a m/p m / / — (c) PILBARA

APPLICANT
(d) Full name, (e) Address, (f) No. of shares — for each applicant
(g) Total No of shares

(d) & (e) CORDALE HOLDINGS PROPRIETARY LTD.
PO BOX 7249
CLOISTERS SQUARE
PERTH, WA.A., 6000

(f) Shares: 100

(g) Total 100

DESCRIPTION OF GROUND APPLIED FOR
(h) Locality
(i) Datum Peg or Starting Point
(j) Boundaries

(h) DE'GREY

(i) Datum situated 30.30 km @ 277° from Trig R134

(j) Thence 19.0 km brg 126° thence 6 km brg 036°
Thence 7.0 km brg 306° thence 1.8 km brg 216°
Thence 12.0 km brg 306° thence 4.2 km brg 2 16°
back to datum

(k) Area (ha or km²) (k) 92.40 km²

(l) Signature of applicant or agent (l) [signature] DATE 21.2.86
ELIZABETH A. SMITH

NOTE
Where a general purpose lease—S 86 (1) or a miscellaneous licence—S 91 (1) is being applied for the mining lease or mining tenement to which it relates should be stated

TYPE	NUMBER

OBJECTIONS to this application may be lodged at the Mining Registrar's office at MARBLE BAR
on or before the 23RD day of MARCH 1986 and the
hearing will take place on the 18th day of APRIL 1986

OFFICE USE

File No: 4742-86.

MINING REGISTRAR
24 FEB 1986
MARBLE BAR

18 MAR 1986

FEES PAID	$	c
Application	500	00
Rent	1,848	00
Survey Fee		
TOTAL	2,348	00

$12 00 RENT SHORTFALL

Received at 11:30 a.m.
on 24-2-86
C J EDWARDS
(Mining Registrar)

Map ref
Plan DE GREY
Scale 1:100 000

11021/3/81—100M—L/439

FIGURE 4

NEW SYSTEM

Although there were several options available in developing a new system, certain constraints were imposed by the Department that had an influence on the final decision.

The constraints were that no extra staff would be available and that in view of the time that had elapsed with the previous system, development time should be as short as possible.

Although a massive amount of data had been taken up, it was unreliable and it was decided that the task of validating would be too great as compared to starting again. However, two small sub-systems had been maintained and although not validated, they provided the important data of a mining tenement such as the Department's file number, the tenement number, the name and address of the holder and some survey details including the plan name.

These two systems, although on different computers and not related, provided an opportunity, if combined, for a small interim system to be developed that would allow a phased approach to the eventual large data base.

The systems had been maintained daily by two separate divisions of the Department but in unsupervised and ad-hoc way.

A complete print out of all information was made which was then validated with the source documents (registers) and corrected. Plans were then made to combine the systems under the name Tendex, an acronym for Tenement Index.

A number of other essential data items were identified and finally, it was agreed that Tendex should contain the following data items:

Tenement Number
Holder's Name
Holder's Interest (Active or Inactive)
Holder's Address
File Number
Status (Live or Dead)
Locality
Description of Datum Point
Mark Off Time
Mark Off Date
Lodgement Time
Lodgement Date
Date of Grant of Tenement
Date of Death of Tenement

Reason for Death of Tenement
Local Council or Shire (by code)
Public Plan
Area Applied for
Related Tenements
Comments
1: Million Index Map
Survey Instruction
Date of Survey
Surveyed Area
Diagram or Original Plan
Standard Plan
Surveyors Name
Surveyors Field Book

Because of staff restrictions, an officer of the Cartographic Computing Section of the Surveys and Mapping Division was seconded to the project and with a contract programmer, began the job of writing programmes in the Focus language, a software package that was purchased with the IBM computer.

During the review of the previous MTIS system, it was realised that the Department would ultimately require a huge date base of its information that would include the following:(See Fig 5)

1. All the data listed in Tendex
2. Additional legal Transactions with tenements
3. Production reports
4. Royalty payments
5. Mineral statistics
6. Land rehabilitation information
7. Financial information such as rents, fees
8. Technical reports on operations
9. Geological information
10. Data related to petroleum wells
11. Data related to water bores
12. A range of graphical data including maps

The original philosophy of Tendex was that it would form an interim limited system only until the full data base was developed. It would provide useful experience for users in the general handling of a computerised system and would provide answers to the most common enquiries made by the public and government ministers. It was agreed not to expand it beyond the limits previously set unless there was a good reason to do so.

FUTURE DATA BASE

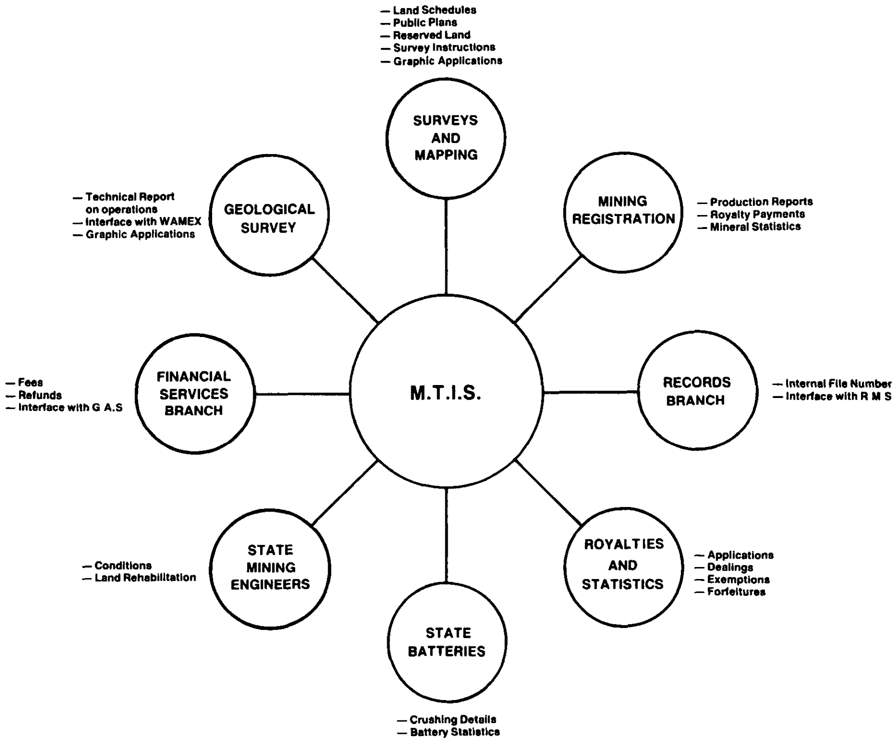


Figure 5

When Tendex became a live operational system, work would begin immediately on designing the large MTIS data base and although the data from Tendex would be used, the programmes and system would be discarded.

Preliminary planning for Tendex began in February, 1985, and the system became live on November 1st, 1985.

Almost immediately a number of enhancements were requested from users. A steering Committee had been set up initially to monitor the planning and all enhancements were examined by the committee to decide whether they should be included. Where it was seen that they system would be improved, the enhancements were built in.

DATA ENTRY

Data entry is carried out daily by two operators on separate input terminals. Entries are made from the tenement application forms that are lodged daily in the Department and those that are received by mail from the outstations. Transactions that take place after lodgement of these forms such as approvals, refusals, transfers, surrenders etc, are entered from internal forms that record such data.

The data base is up to date with all information at the end of each day.

At the end of every data entry session, an automatic print out is produced of all data entered for that session. A senior officer uses the print out to validate all data against the source documents.

DATA ENQUIRY

Many sections of the Department use the data daily and the public and mining industry presently make enquiries by telephone and through public counters in the Department and through the 15 outstations.

Although the system is still under test (as of March) it is expected that between 20 and 30 terminals will be eventually operating to handle all such enquiries. The outstations will also be progressively brought on live for enquiries.

Enquiries can be made via the file number, the tenement number or the name of the holder and any or all of the data can be read on the screen or printed out if required.

Programmes have been written for a number of report functions that are required frequently; such as:-

(i) List all the tenements by type on a particular plan

(ii) List all tenements owned by Company X in all districts or a particular district.

(iii) List all tenements approved between two given dates.

Other similar and more complex functions will be added as users became more confident with the whole operation.

BENEFITS

Tendex has provided faster access to a wide range of data for multiple users that previously took much time and labour to obtain from the manual records.

When the system is available to the public, these benefits will increase particularly with answers to telephone enquiries.

However, there have been many side benefits that are worth mentioning. The need for accurate and up to date information to be computerised, has forced the Divisions of the Department to tighten up their existing records and manual procedures and to introduce checking stages for all data entry.

It is expected that manual registers in one Division will be discarded very shortly and time consuming manually compiled reports will be discontinued in another Division.

DISADVANTAGES

The Department runs a number of other computer systems based on the Focus data base language but the huge amount of data in Tendex has placed a strain on the storage and processing capacity of the IBM.

It was found that only 4 terminals could operate together on Tendex and the response times were too slow to consider a public system.

In addition, it was realised that in its present form, the IBM would not be able to carry the capacity of the next stage, the development of MTIS.

A computer consultant was engaged to recommend a solution and gave 5 options to be considered. The important criteria was to have a public system available as soon as possible and the option taken was to rewrite the programmes into COBOL language and run the system under CICS, (IBM Customer Information Control System); doing it in two stages.

The enquiry system required internally and for the public would be done first with expected completion by May 1st and followed by the update function, expected completion by June 30th.

At the same time, the opportunity will be taken to correct a number of design faults in the original system, brought about by the pressure to complete it quickly.

It is expected that at the completion of the modifications, the Department will have an excellent up to date data base of mining tenement information that can be accessed through 20 to 30 screens including at least one outstation.

GRAPHICS

One of the most important requirements of the Department is to provide graphical information about mining tenements and this is currently done through the mapping system.

However, it is planned to support TENDEX and ultimately the MTIS, with a graphic system.

There are two main options that have been considered:

(i) A complete capture of all tenement boundaries plus the topographical and cadastral bases

(ii) A limited capture only of the boundaries of the very large tenements, a centroid or co-ordinate value of all other tenements and a main framework only of topographic and cadastral information

The first option, while considered to be the best, is beyond the Departments resources in the next 10 years. The second option could be achieved in one year and would provide very useful spatial data as almost all enquiries about tenement data includes a "where is it" question.

Much of the surveyed data has been captured on other systems in the Department both manual and computer, and much of the main topographic features have a co-ordinate reference in a names file of another department.

The proposed plan is to manually digitise the centroid of each small tenement, (by eye only) and to digitise the boundaries of the large exploration tenements. This will be done from existing plans and as new tenements are plotted, a co-ordinate value will be read and entered into the data base. A complete plan or portion only could be printed out to support an inquiry. (See Figs 6 ,7)

A land information system is being developed in other State Government Departments and in the long term it is expected that the cadastral and topographic data base of that system will be interfaced with the MTIS and will be on line to the Department.

The Department is also involved in geological mapping but at this stage, there are no plans to computerise any areas although it will be one of the long term considerations.

Other future possibilities include the loading of parts of the data base onto a video-tex system to provide greater and faster access for the industry.

A problem in placing computers in the outstations, is combating the erratic fluctuation of power that occurs and the problems of dust. Many outstation areas of Western Australia are like being on the edge of the Sahara Desert where heat and red sand prevail. The use of Video-tex could solve this problem.

The Departments wide range and variety of information will undoubtedly fill a very large management data base in the future.

The development of Tendex has created the first foundation stone and the next few years will see this added to with what promises be exciting use of new technology.

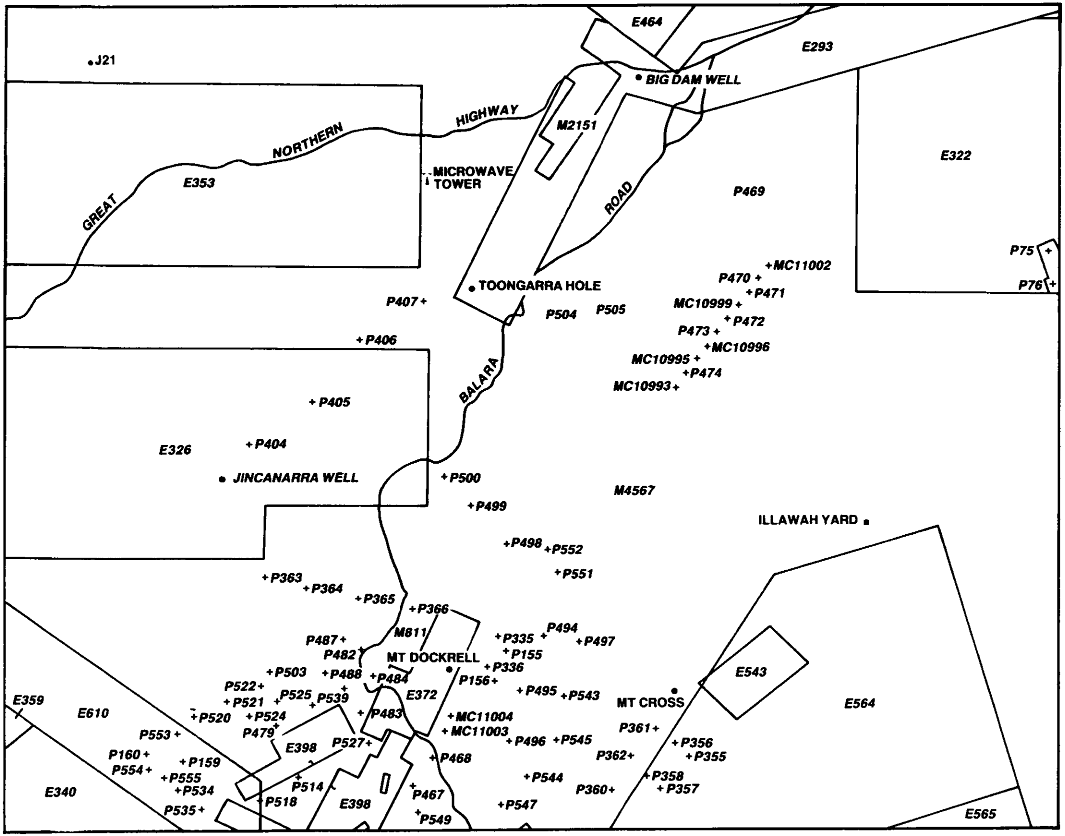


Figure 6 **MAP OF TENEMENT CENTROIDS**

DOCKRELL

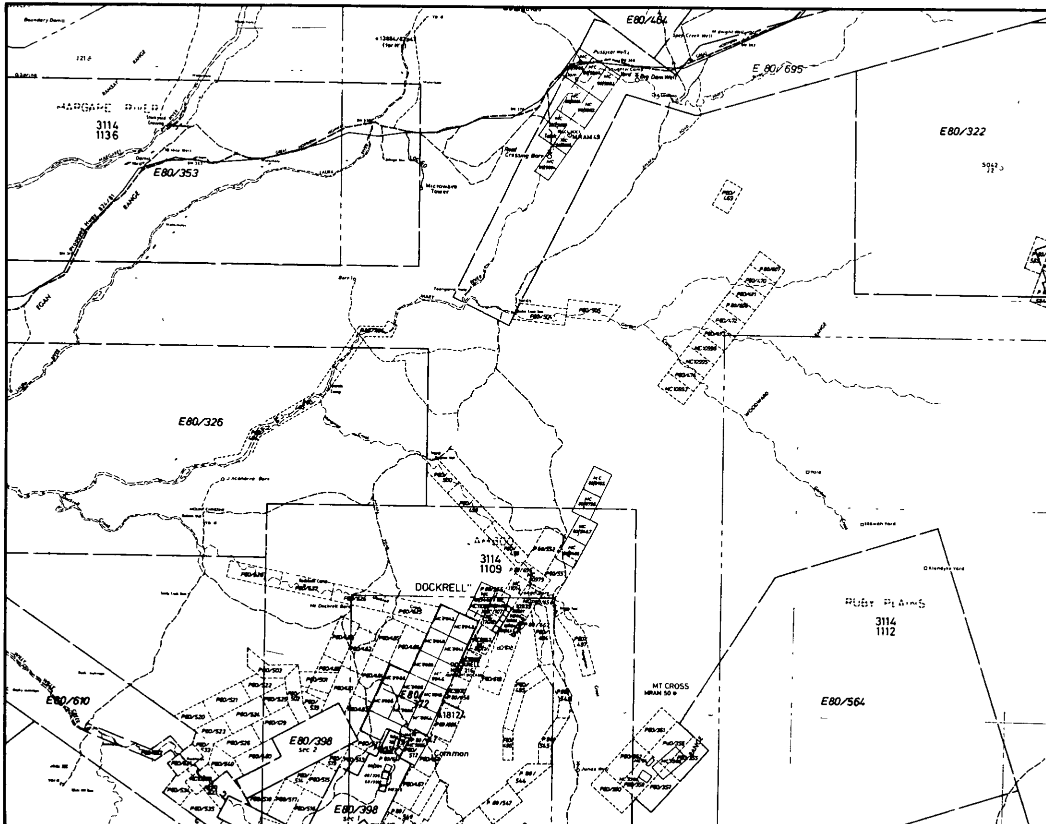


Figure 7

ACTUAL TENEMENT MAP

THE BURNABY EXPERIENCE WITH COMPUTERIZED MAPPING

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ABSTRACT

In 1976 the Corporation of Burnaby decided it was time to review its maps. We found that the old maps which had been produced prior to 1939 contained many errors and that the maintenance of our maps was very costly because of the variety and number of documents which were involved each time a correction and/or addition had to be made. It was also at this time that our Federal Government began talking about converting everything to a metric standard. Recognizing that the other utility companies, which serve our Municipality, would be faced with similar problems, we put forward a proposal to undertake a joint project to explore the computerized approach to map production and the handling of a broad spectrum of facilities information.

The pilot project (BJUMP) proved conclusively that computerization was a viable alternative to manual remapping and now, after some ten years of experience, we have come to the realization that the maps are only the tip of th iceberg. A greater benefit of having such a system is the spatial data base which allows us to use the system as a powerful tool for analysis and not just as a record keeping system.

CORPORATION RESOURCE

For the past 35 years, computing systems have been used by municipal governments to maintain financial records, issue cheques, record inventories of equipment, etc., in essence, most communities have a computer of some description. However, during the past eighteen months, we at Burnaby have been studying our information needs throughout the Municipality and with the assistance of our consultant, R. Liley and Associates, have concluded that more than 70% of the information maintained by Burnaby has a spatial or geographical relationship. Burnaby now considers **INFORMATION AS A CORPORATE RESOURCE** and as such, it should accommodate individual and departmental needs and be accessible by all. Although the current recession has put a very definite emphasis on restraint in every facet of our operation, the elected officials continue to demand a higher level of service and additional information to keep them well informed. It is our conclusion that the only way to meet this demand is with high tech information systems.

During the early 1970's we at Burnaby became increasingly aware that our 50-year old maps, plus or minus a few years, no longer were adequate for the level of detail and accuracy required in a 1970's organization.

Although maps seem to be taken for granted and recognized as important documents, no one seemed prepared to budget for a new set of composite maps. It continually seemed that the cost of producing new maps was high and the benefit was "it only looked better".

Over the past ten years this perception has changed in Burnaby and we have come to recognize the importance of accurate maps. What brought about this change?

JOINT VENTURE

The Municipality of Burnaby is one of twelve communities making up the Greater Vancouver Regional District. Each of these communities, plus a number of private utility companies operate facilities within the Regional District and have historically drawn their own maps. Although each of these jurisdictions had different requirements for accuracy, level of information and purpose for the information, there was one common denominator; each agency is concerned about the same geographic area.

This lead us to believe that possibly other map users within our Municipal boundaries were also beginning to realize that they needed new maps.

The two major map users besides the Municipality are B.C. Hydro, representing gas and electric facilities, and B.C. Telephone, and upon enquiry we confirmed that both utilities were facing the same need to remap and, in fact, had already started to explore the application of computer assisted techniques.

At the same time, during the summer of 1975, the Canadian Federal Government indirectly came to the Municipality's aid by suggesting that Canadians would henceforth convert to metric measurement as part of Canada's push towards a closer trading relationship with the European community.

Recognizing the fact that we were having difficulty convincing our management to budget for manual remapping and the fact that two other prime map users in Burnaby were already involved in a remapping program with the use of computer assisted techniques, we proposed the formation of a task force composed of members from each of the major map users to investigate the feasibility of creating one common base map, with the aid of computers, to be used by each agency. In turn, each agency would enter their respective facilities onto the system so as to be available to all users.

The task force completed a feasibility report in 1976 January, which concluded that computer assisted mapping would:

(1) be approximately three times faster than the conventional manual approach;

(2) be less expensive, especially as the work volume increases;

(3) be easier and quicker to maintain and update;

(4) provide an "end" product which would be a total information base with infinitely more flexibility than the conventional map.

PILOT PROJECT

Formation

Although the CAM approach appears to be far superior to the manual approach, it must be pointed out that much of the data on the existing maps and the time, cost and performance projections were not very definitive, and that to obtain more meaningful information a significant amount of mapping would have to be performed using a CAM system.

From the foregoing conclusions came the recommendation that the participating agencies undertake a one year pilot project using a computer assisted mapping system to obtain more definitive information regarding manpower, equipment costs and overall benefits for computer assisted map conversion and maintenance.

The task force spent almost a year establishing the parameters of the pilot project, doing preparatory work such as field survey and photogrammetry, selecting a system supplier, negotiating with labour unions representing operators from each of the participants, selecting and training operators, and convincing their respective managements that the computer assisted mapping technology was sufficiently advanced to recommend the leasing of such a system for the pilot project.

Some of our more successful arguments were that firstly, our Federal Government was recommending that the country would convert to metric measurement and secondly, that some of the other large map users were "leaning" very heavily towards the use of computer assisted technology and we did not want to fall behind. A third argument, which may very well have been the most convincing one, was that in the long term there could be some staff reductions.

The Burnaby Joint Utility Mapping Pilot Project (BJUMP) began operation in 1976 December when we took delivery of a Synercom ST-700 mapping system. For the next fourteen months members of BJUMP worked with the technology to assess all facets of computer-aided map production and maintenance.

Level of Accuracy

Many papers have discussed the question of what level of accuracy one should aim for when developing base maps. We concluded that the agency with the highest accuracy requirements should be responsible for base map development, production and maintenance. In most instances this would be the municipality. Very early in the pilot project it became apparent to all participants that to digitize directly from the existing maps would not give us the ±1 meter level of accuracy which we had set as our absolute minimum.

Our decision was to use coordinate geometry to enter each line mathematically. For the sake of saving time we chose to use photogrammetric methods to obtain our required control points. The latter consisted of survey monuments, survey pins, gas valve and manhole covers, etc., which had been painted to ensure identification.

These "targets" were all identifiable on aerial photographs, and by using analytical aerotriangulation were given Universal Trans Mercator (UTM) coordinates. (UTM coordinates are true rectangular coordinates on a grid parallel to a central meridian, which in Burnaby is 123 degrees west and perpendicular to the equator.)

Using these photogrammetrically derived control points and the original air photos, we were able to produce orthophotos which show the targetted control points, all of which can be used when digitizing directly from the orthophotos. This procedure increased our accuracy to something in the order of ±0.2 m.

This method was the primary source for base map production in BJUMP. In some areas where there were difficulties in reconstructing the irregular and curved cadastre from the orthophotos, a method using coordinate geometry (COGO) was employed and the resulting maps are virtually of legal map plotting accuracy.

Although this decision contributed to a reduced rate of production and increased costs, we can now look back and state that it was well worth it as the benefits definitely outweighed the added costs of production delays.

Some of the benefits of having produced higher quality maps are that:

(1) we can extract and rotate any portion of the base map as necessary to suit the required orientation for construction plans and profiles;

(2) we can merge individual sheets or portions thereof and produce composites of a larger area at reduced scales;

(3) we will be able to use the information stored in the system for the future preparation of design plans,

profiles and cross sections; and

(4) we will not have to remap to improve accuracy because each facility will be referenced to true world positions.

DEVELOPING THE BASE MAP

Agreement

With the completion of BJUMP in 1978 February the Municipality exercised their option to purchase the Synercom system and established a work schedule to produce a complete set of new base maps which would serve the needs of the many users in our community.

The other two participants in BJUMP also gained the information they needed to convince their Board of Directors to purchase their own CAM systems, which each one has now done. Having purchased their own respective systems for province-wide mapping, each of the utility companies entered into an agreement with the Municipality to provide us a copy of their utility information in digital form in exchange for updated base maps from the Municipality.

Features

Some features of the Burnaby system which I would like to mention are map components, property identifiers, facets, versatility with respect to conversion between imperial and metric measurements and versatility with respect to isolating randomly sized "windows".

Maps contain three basic elements, namely, lines, symbols and annotation; our task is to develop a cartographic base showing the cadastre in a format that is acceptable and useful to a variety of users.

Illustrations 1, 2, 3 and 4 show how we have built our base in order that each user is able to display the cadastre in a form that he or she requires.

In Burnaby we have assigned a twelve-digit property identifier to each of the approximately 43,000 properties. This identifier consists of three basic elements; the first four digits represent the name of the street or avenue, the next four digits represent the civic address and the last four digits are reserved for the suite number. Using this number one can then get such information as the complete legal description, the street name, and the property owner's name. Other non-graphic statistics will be available in the future as other departments come on-line.

The creation of a uniformly sized facet (50 cm by 80 cm at a scale of 1:1000) covering an area 500 metres by 800 metres eliminates the problems of eighteen random sized strip maps as well as the problems of overlaying a strip map or portion thereof

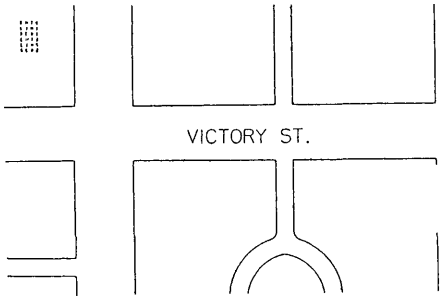

Figure No. 1

Block lines and street names

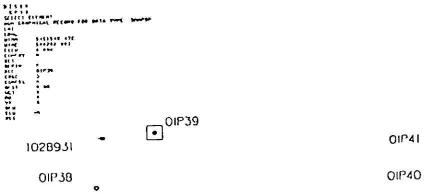

Figure No.2

Survey control information

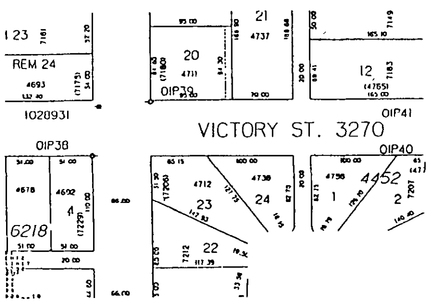

Figure No. 3

Civic addresses, dimensions
and legal descriptions

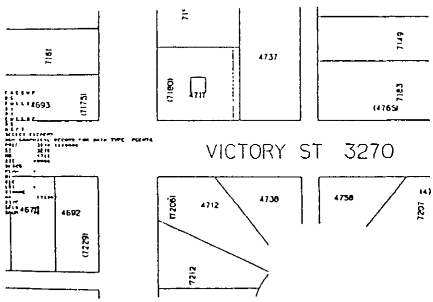

Figure No. 4

Attribute information
pertaining to 4711 Victory St.

with a contour and/or facilities map. However, the user is not restricted to displaying only predetermined facets as the system has the capability of plotting any area, whether it be a part of one facet or whether it spans a number of facets. This allows the user to zero in on an area as small as a survey monument and display it at an enlarged scale.

The system also has the versatility to convert information which was entered in imperial units to metric units, and vice versa. It can also adjust the scale almost infinitely between 1:200 to 1:1,000,000.

FACILITIES

With the completion of our base maps, we now have the skeleton which is necessary to support facilities information, contours and countless other geo-based information. This phase is the core for an effective and efficient engineering office in a local government setting. We must have good quality up-to-date information which is readily accessible. We are currently involved in data entry (again using coordinate geometry) for the conversion of our facilities information such as waterworks, sewers, drainage, roads and street lighting networks to the computer assisted system. our current projection is to have this phase completed by the end of 1987.

Let's now look, in a little more detail, at exactly what we mean by facilities information. As an example, I will use a portion of Burnaby's waterworks system. The basic element in a waterworks distribution system is the water main or line which is generally located within the public road allowance. The second element is the water main fittings such as valves, service connetions, hydrants, meters, bends, adapters, couplings, etc., and the third element is the annotation relating to each of the fittings. This could include such information as size, type, date of installation, position (open or closed), number of turns required to open, manufacturer, reference number and condition. Everything, except the annotation, can be displayed graphically.

With all the aforementioned information loaded into the system, the computer can now exercise its capability to draw a map of Burnaby, or any chosen portion thereof, showing only 150 mm diameter water mains; or giving us a complete listing of all streets which have a water main less than 150 mm in diameter; or providing a complete tabulation of all asbestos water mains, including sizes and lengths. As you can see, this is the type of information which would be invaluable when preparing a water main replacement program.

As each of the facilities is entered into the system, we will have similar applications for each of them. To make such an analysis manually would have taken many weeks at a high cost. By using the system, the results were produced in minutes and at a fraction of the cost. This is significant to our community because the infrastructure of water mains, sewers and roads is the backbone of the Municipality and a large percentage have been in service for over thirty years. It is therefore reasonable to project that much of our infrastructure will have to be replaced within the next ten to fifteen years.

However, facilities are not restricted to our physical infrastructure. They may include land use zoning, traffic accident details, crime statistics, population distribution, property ownership and much more.

MANAGEMENT INFORMATION SYSTEM

Although we are continually finding new uses for our automated mapping facilities management system, we must look beyond this to the broader subject of information management. At Burnaby we are in the process of developing an integrated information management system. We recognized that the computerized mapping technology was changing to concentrate on spatially-oriented data bases. We also began to recognize that the fragmentation of information systems was costly and prevented us from taking advantage of the inherent synergy of an integrated information management approach.

In order to further study the feasibility of developing a plan for integrating all of the Municipality's information systems the Municipality, in late 1983, retained the consulting services of R. Liley and Associates. The consultants report entitled "A Strategic Plan for Information Management" (Liley, 1984) included the following recommendation:

> "Information systems were required to support overall Municipal operations and management decision-making."

The report also presented a new configuration for Burnaby's electronic information network as illustrated in Figure #5 and outlined a system design concept based on the following premises:

(1) access to the computer systems will be provided throughout the Corporation. In most cases the manual systems will be replaced by a computer system;

(2) many of the applications will cross departmental boundaries and pervade the operation and management of the Corporation;

(3) individual applications will be conceived around data bases. This approach, rather than the more traditional one of appending data bases to specific applications, should significantly increase flexibility and result in systems which have longer term viability for the Corporation.

ELECTRONIC INFORMATION NETWORK OVERVIEW

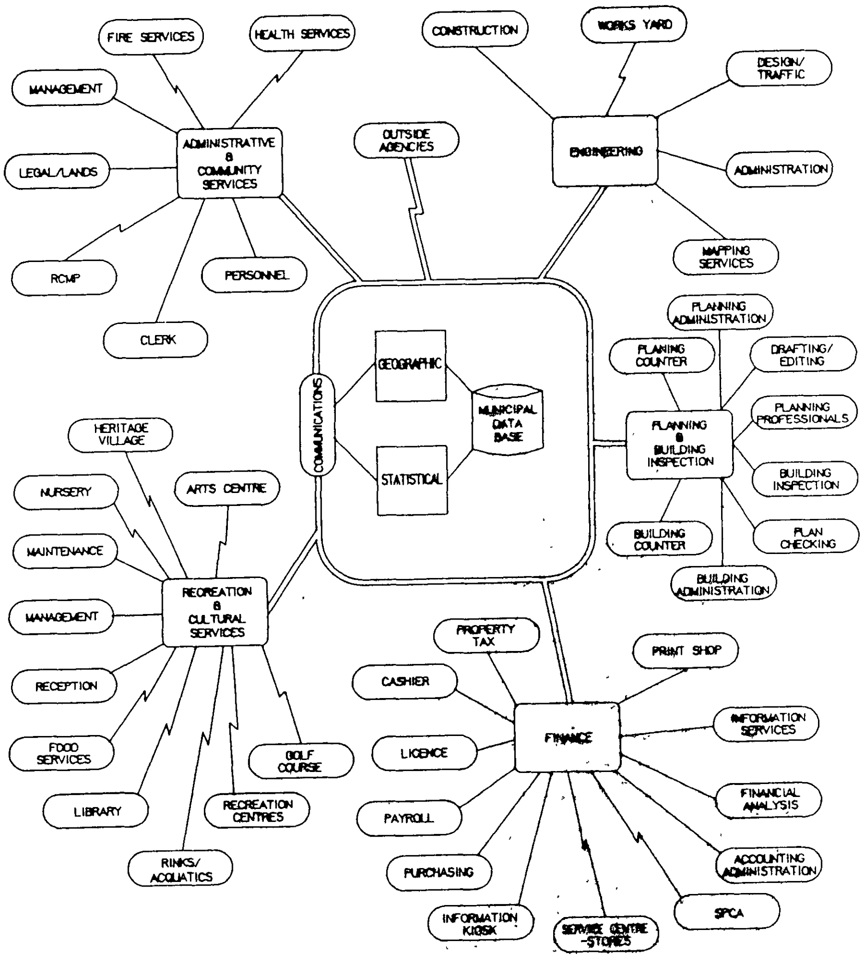

FIGURE NO. 5

Having come through the various stages of this evolution, Burnaby is only now beginning to reap some of the many benefits which will improve productivity and services at all levels. Benefits such as on-line inquiry through a single work station, paperwork simplification, staff cost avoidance, the ability to respond to a changing environment, the ability to control and manage costs, improved levels of service and management control. In addition there will be many intangible benefits such as the availability of more complete and better information for decision-making and planning, job enrichment as employees come in contact with the computer and greater reliability of information.

CONCLUSION

The Corporation of the District of Burnaby has been a leading user of information systems in local government. The Municipality has pioneered the use of automated mapping and, by virtue of having a digital map of the Municipality, has been able to proceed to the next logical step of marrying non-graphic geobased data to the mapping system. It is now moving successfully into the total integration of Municipal Information Systems, having recognized that information is a key corporate resource and should be managed as such. The use of electronic data processing to handle the routine day-to-day business of the Municipality will of itself realize significant benefits in terms of productivity and quality of services offered. The information that is captured through transaction processing will also provide significant benefits in terms of performance planning and measurement. However, the synergistic benefits arising from the integration of systems will potentially outweigh the routine benefits provided by automation of the normal transaction processing. This integration is vital because the majority of municipal data is geobased.

ACKNOWLEDGEMENTS

I would like to thank Harry Christie for his assistance in preparing this paper and for the opportunity to participate in Auto Carto London.

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A LANDINFORMATION SYSTEM (LIS) FOR AN URBAN REGION

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1. ABSTRACT

Urban regions are marked by a high density of objects on the surface and below. The management how to make use of the available space is a continous process of planning, execution and administration. The knowledge of the local relationship is an important prerequisite for controlling these processes. The paper describes the state of the art of an geographic system in operation in the municipality of Vienna (Austria). In detail a description is given of the production line starting from different types of data collection until the automated production of multipurpose cartographic output such as standardized large scale maps, special and thematic maps. The features of the data bases and the ways of maintaining them are mentioned as well. As a long range objective it is envisaged that all geographic data processing should be automated by ADP and fully supported by computer graphics. Therefore a detailled model of the urban region has to be stored in the near future comprising a broad variety of data with geographic relationship.

2. DATA COLLECTION

2.1 Requirements

Basically it is envisaged to include step by step the inventory of objects which are described already in different types of graphic documents. Priority is given to the capture of topographic data. Underground objects and town planning themes will be inserted subsequently.

According to the needs of users data are captured with the utmost accuracy of geodetic data, the highest degree of geometric detail, classification and keying facility.

Therefore it is likely that the central data base will be able to fit all requirements and it can be prevented, that separated and redundant data must be maintained for special purpose.

2.2 Data sources

2.2.1 Field measurements

2.2.2.1 Digital tacheometry. The most accurate method of data collection is applied in the road area, where available space is scarce and conflicts of interests have to be solved frequently. The council of Vienna decided to survey the complete network of streets in order to get reliable data in these sensible areas of the town. The final result will be a complete framework of precise geographic data.

Features of this measuring method are:

- Coding in the field
- partitioned data set per street segment
- generating derived geometric elements (e.g. parallel lines for rails, walls; completing rectangular objects, composing segments)
- highly automated dataflow from the field to the plotter (linework included)

The remaining bloc area is filled up by photogrammetric measurement (2.2.2).

2.2.1.2 Survey plans. The large archives of maps and survey plans represent a useful stock of geodetic data. By manual digitising of existing analogue documents, mostly road planes 1:200, additional data are obtained. The digitised data are adjusted by control points. The final datafile resembles that of a field measurement in the tachometric mode.

2.2.2 Photogrammetric measurements. In the early stage analogue documents of a stereoplotter had to be digitised completely. Now, the photogrammetric model is measured analytically and stored during the interpreting process. These digitised data represent a supplement of the skeleton built up by ground survey.

2.2.3 Existing maps

2.2.3.1 Manual digitising versus scanning. Due to the vast extent of analogue sources digitising is still the bottleneck of geographic data processing. Efforts in the last years had been made to automate the digitising process. Scanning and a subsequent vectorisation has successfully proved its feasibility in several applications.
Although scanning does not signify a fully automated data capture - interactive postprocessing is still necessary - it is a fact, that it can alleviate the nearly invincible task of compiling the vast amount of existing analogue documents.

2.2.3.2 State of the art of scanning methods. In practice the range of economic scanning is dependent on the graphic quality of the document and its complexity in terms of lines, symbols and text. Recognition of lines together with a rough classification according to the line width and line pattern can be an economic counterpart to manual digitising. Further advantages are expected by more sophisticated pattern recognition for symbols and text. Then scanning will become more economic due to increased possibility of automated classification and keying.

The recent production line makes use of manual offline digitising, scanning, interactive editing or a combination of those methods.

2.3 Assembling of different data sources
In the last processing stage of data collection all these different kinds of source data have to be checked, merged and harmonized.

2.3.1 Geometric adjustment. This complex task is done partly automated (within a tolerable range) partly interactively.
Digitised or scanned data are adjusted by means of control points.
Manual digitised and scanned data are composed.
Photogrammetric data are adjusted to identical ground survey data.

2.3.2 Overall coding system. For each measuring device a special coding system is used to minimize operator´s input. After checking automatically the codes additional data are derived. In the final stage the isolated coding systems had to be fitted into a comprising overall coding system.

3. USING THE DATABASES

3.1 Types of databases
3.1.1 Local reference system. In the first step a reference system was built up covering the whole area of the city. It is based on a hierarchical order of areas ranging from district to the bloc (census tract, bloc) and a street network (crossing point as nodes).

3.1.2 Topographic database. Is still in the process of building up. It represents a detailled description of topographiy separated into features combined with an geographic inventory of objects. It contains

- geodetic data
  partly threedimensional of different qualities (according to source data)
- classification of object groups (layers)
- identification keys (postal address, pylon, etc.)
- object names (text)

3.1.3 Thematic data basis

- land use
- planning zones
- protected areas
- environment cadastre

3.2 Access to the geographic database Retrieval paths

Apart from the selection by coordinates there are a set of user oriented selection modes:

- postal address
- street segment
- street name
- bloc code
- census tract
- layer code
- identification key of objects

Among these are interconnections and pointers to other regional keys:

postal address to its bloc and to its street segment, or to its constituency.

3.3 Geographic data connection

The keying facility of the geographic database allows the linkage to other data basis storing statistical and technical data.

e.g. density of population
  growth of population (e.g. forecasting the number of children of schoolage for the demand of teachers and classroom)
  density of built up areas
  traffic system (local coordination of road construction works and excavations in the road)
  medical care of the population
  environmental aspects
    annoyance by noise
    provision with areas for recreation

4. CARTOGRAPHIC OUTPUT

Despite the advantage of digital data for processing analogue representation of geographic information will be needed further on. Even its range of application is growing fast, as graphic output is the adequate output format. A powerful graphic capability by ADP is therefore an important prerequisite of such an information system.

4.1 Standard large scale map

In areas with ground survey the base map starts with 1:200 (the map sheets follow the street network). Smaller scales continue with 1:500 (sheets gridwise), 1:1000, 1:2000, 1:3000 up to 1:5000 (1:10000 is produced by reproduction). Sample map see App. 1.

4.2 Special maps

District maps or any other special purpose plan or map. Parameters are:

- window
- layers
- legend (symbolisation, line and area pattern, text fonts).

Sample map of lightning system (wiring chart) see App. 2.

4.3 Thematic maps

The keying facility enables the user to link other data bases in order to examine special relationship of data. This feature causes a fundamental change: the time consuming task of collecting statistical data and of referencing to their local distribution is obsolete. Automated geographic data processing reduces the "response time" for the production of thematic maps, so that maps become an up-to-date image. Recently obtained data of administration can be transferred quickly into cartographic images as useful means for the day´s work.

e.g. Controlling of registered obstacles in the traffic system makes use of thematic maps: an overview of excavation and construction work in the stage of execution and planning can be published within few days.

5. UPDATING

5.1 Geographic mail box for updating

A prerequisite for an effective revision of a geographic data base is the observation of all changes in a region and to recognize them as soon as possible. There are many signals in public administration which give hints to future changes: changes of parcels (cadastre), planning and building permission of future construction activities on the surface and underground. These signals are obtainable by tapping existing files of the administration. Those activities which will be later on a case for updating (e.g. construction of demolition of buildings, changes in the zoning etc.) are stored in the mail box. Finally different types of changes are linked with their relevant geographic reference (e.g. postal address, parcel number or street segment) and stored in a mail box. If a map sheet is plotted additional news are available to the user, referring to the changes in the area of the map sheet since the last updating of the data base for each layer. These news can be delivered in alphanumeric way as listings but also in graphics. Thematic maps with geocodes symbols can be produced automatically displaying type of changes, the responsible authority where to find further information etc.

5.2 Temporary update

In those cases where a quick updating with less accuracy is necessary, a prerelease of an up-to-date database is built up. Site planes, maintenance reports can be used to generate provisional cartographic data which are labelled especially.

5.3 Final update

Similar to the building up of the geographic database maintenance of its data makes use of different sources as well.

5.3.1 Field surveying. Additional to the input of the data collection codes for updating and the reference to existing points by junction points allows an automated insertion of a new object or a part of it (in development).

5.3.2 Aerial Survey. For those areas where less accurate data are needed, photogrammetry contributes her part of geodetic data.

5.3.3 Processing for updating. The software development is aimed towards a maximum degree of automation. Automated data flow from measuring equipment to the insertion into the data base is envisaged. It is evident that this cannot be

realised totally. Interactive computer assisted activities will reduce manual interferance to a minimum. Not to mention that a lot of auxiliary function of updating can be automated: Checking that all update cases were executed (data of the mailbox can be compared with corresponding files of objects).
Adjustment of new geodetic data with old data, logic checking, uniqueness of identification keys, admissible range of identification keys.

5.4 Distribution of recent geographic data
Computer assisted revision of geographic data is expected to cut down the response time of map revision essentially. But in the final stage it is important that data can be transmitted to all users fast and in such a way that it need not processed manually. Apart from the distribution of analog documents the transmission of cartographic data can either be handled by ADP via a digital interface.

5.5 Responsibility
As above mentioned layering of objects is designed user oriented in such a way that the responsibility for updating of geographic data can be distributed on to those authorities which have the duty to maintain those objects.

5.6 Aspects of time
Updating of the city map of Vienna had been done periodically adjusted to the aerial survey interval. This proceeding will be changed to flexible periodes, dependent on the priorities of the users of the data base.

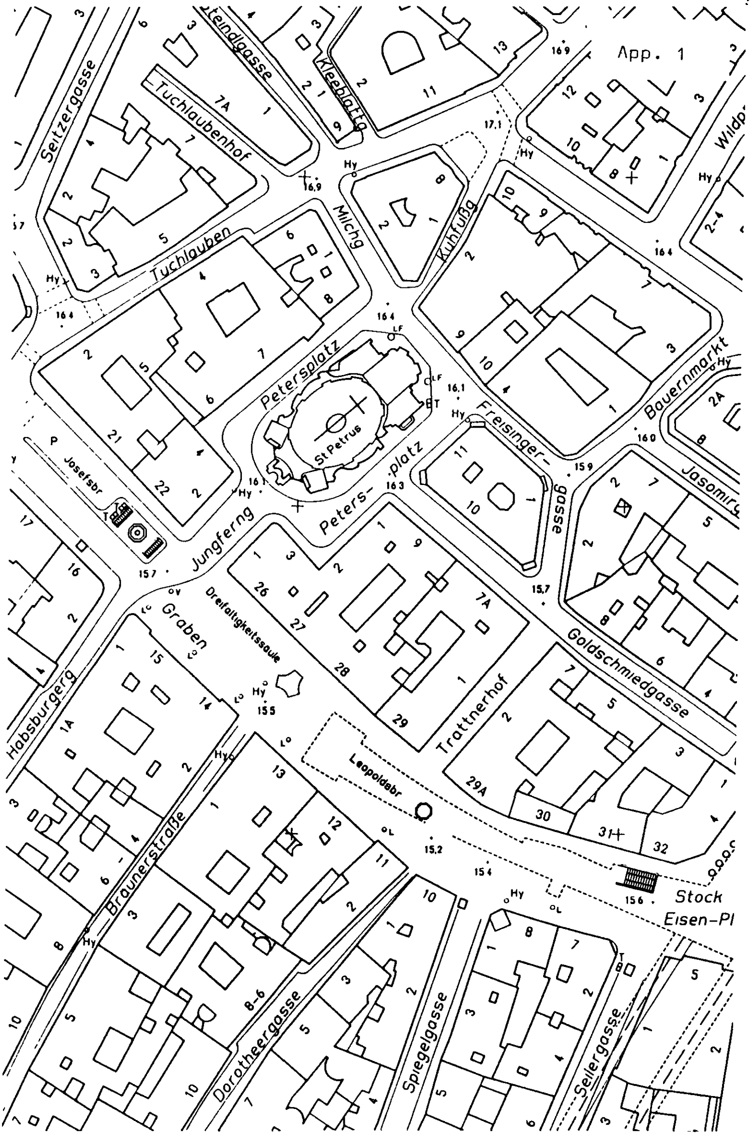
6. CONCLUSIONS

The Land Information System described above is desinged as a comprising source for geographic information. By means of an increasing use of the keying facility the data base becomes more and more a powerful tool for geographic integration of distributed data. An "inquiry bank" for local planning, executing and administration is therefore available.
Especially spatial coordination among several branches of authorities and offices - today a time consuming and cumbersome activity - will be supported by automated retrieval and combination of relevant data.

As a powerful userinterface information can be oblained in graphics manifolded according to the purpose. Either a general description of the local situation (basic map) or a special application oriented graphic (thematic map).

Advantages of this development are:

- increased quality of data
- multiple usage of geographic data
- integration with other data bases
- automated processing of local relationship and distribution
- flexible data exchange
- flexible output
  the data base represents an abstract storage without fixed linkeage a specific cartographic representation.



Weiterverwendung nur mit Quellenangabe: MA 41 - Stadtvermessung
Digitalisiert u. automatisch gezeichnet MD-ADV

Weiterverwendung nur mit Quellenangabe: MA 33 - öff. Beleuchtung
Digitalisiert u. automatisch gezeichnet MD-ADV

THE SWEDISH LAND DATA BANK

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ABSTRACT

The Swedish Land Data Bank System has been developed in order to rationalize handling of data on real properties and land. The system replaces earlier manual systems for property and land registration. It interacts regulary with other EDP-based information systems and serves as a land information system (LIS) in a broad sense. The system is being steadily extended to cover all parts of the country. The costs for design, implementation and maintenance of the system are covered by reduction of costs for property and land registration.

1. INTRODUCTION

With an area of 174,000 sq.miles (450 000 km^2), Sweden is the fourth-largest country in Europe. Half its land surface is covered with forest. About 10 % is farmland. Lakes dot the countryside. A long mountain chain follows the border in northwest. Sweden has a population of 8,3 million, with 90% living in the southern part of the country, mainly in urban areas.

The country is divided into about 3,5 million real properties. Most properties are owned by private land owners, but also companies, municipalities, the Church and the State own land. Registration of the division of land into real properties (property registration), and of the owners (land registration), has a long tradition in Sweden. It has been performed in a systematic way, covering all kind of properties and every spot on the ground, since the beginning of this century.

No changes in the division of land can be made without having it registered at the local property registration authority. There are in all 55 authorities. They handle 50,000 registration cases per year. Transfer of ownership has to be registered in the same way at the local land register authority. The number of land register authorities are 95. The number of land register cases, including applications for mortgages and similar, are 2 million per year.

In the early seventies the Swedish Parliament decided, on proposal from the government, to replace the earlier manual systems for property and land registration with a new, EDP-based system, the Land Data Bank System. The purpose was to improve the old systems and to make the registration process faster, cheaper and more effective. The Land Data Bank would at the same time serve as a land information system (LIS), storing easily accessible data on land. The Central Board for Real Estate Data (CFD) was established as an central agency under the government to develop and build the new system, and, later on, to implement and maintain the system.

The system was introduced as a pilot study in one county (Uppsala county) running parallell to the manual systems for a certain time. It was legally empowered to operate in that county from 1976. Since then it has been implemented step by step in other counties and cover for the time being 40% of the country. Recently it was decided to speed up the implementation process. Half the country will be covered in 1987 and the system will be implemented for the whole of Sweden in the beginning of the nineties.

2. SYSTEM DESIGN

Property and land registers serve basic functions in the society and have to be build upon well defined and stable regulations, which are uniform for the whole country. This has led to the creating of the Land Data Bank System as one system for the entire country. It has proved to be advantageous also to run the system on one computer. The structure of the data bases is, however, decentralized. This means that data from different regions (counties) are stored in physically separated bases, which operate independently.

The system comprises 15 logical data bases. A Swedish data base management system (DBMS) - AROS/ROSAM - is now being used. The DBMS is partly tailor-made for the purpose of the Land Data Bank System and therefore much more effective than standard products used in the beginning of the project. Also the application software is tailor-made to a great extent. In all, some 100 man years have been put into system design and development. These efforts have been fully compensated through a more effective system than what could be reached by standard products. The number indicated includes penetrating of regulations, preparing of procedures and training materials, documentation, etc.

3. DATA CONVERSION

A major part of the data in the Land Data Bank is derived from the manual property and land registers. On an average 900 characters are captured per real property, 400 coming from the property register and 500 from the land register.

Experiences show that the data capture preferably should be performed by specialists, exclusively concentrating on the task. Preparation and cleaning up of the manual property register takes on the average 3 minutes per real property. Corresponding work for the manual land register is 5 minutes. Also the transfer to an EDP-readable medium takes 3 and 5 minutes respectively. A minicomputer system (key-to-disc system) is used for this purpose. Registration is performed by two independent operators. The system checks that the registered data is identical and plausible. There is no need for manual checking.

The total costs for the data conversion from the manual registers amounts to about 60 SEK per property. The figure includes costs for the development and maintenance of the data conversion system, and loading of the data bases.

Another 40 SEK per property are used in order to collect certain information which can not be found in the old registers. Examples are: coordinates and map references, street address of the property, assessed value of the property, plans and regulations affecting the property, and address of the owner.

The figure just mentioned also includes reformation of the identifiers of the properties. A uniform system is implemented. The identifiers consist of the name of the municipality as a first part, the name of the district within the municipality or the name of the block as a second part, and property number (lot number). Examples are: Stockholm Bromma 4:3 and Stockholm Mercurius 5.

4. USE IN PROPERTY AND LAND REGISTRATION

The Land Data Bank System replaces so to say over-night the manual systems. It is legally empowered from that time and the State guarantees the correctness of its registers.

The local property and land register authorities are connected to the system on-line via "leased circuit connections" in the public telephone network. Handling of cases is carried out as a dialoque between man and machine, where the computer takes over routinework and check-ups. Diary sheets and other documents needed in the daily work are printed out on local printers. Official documents such as certificates, mortgage bonds etc., intended for the applicants are printed out at the central computer and distributed therefrom. Calculations of stamp duties and fees are automated.

For the people at the registrars' offices this means that the working environment has been improved. Heavy ledgers and register books are not needed any more. Boring matters of routine have disappeared. Type-writing etc. has been exchanged for decision-making.

For applicants and others interested in having cases handled without delay the system speeds up the process tremendously. In principle an application - say for a title or a mortgage - delivered at the registrar's office before noon will be dealt with and decided upon the very same day. Applications for extracts of the registers, mortgage bonds etc. are automatically printed out when ordered from a terminal. The applicant receives the results of his application by mail within a few days.

Banks, brokers, municipalities and other users of land information can have a direct access to the system by renting terminals from the CFD which are linked into network in the same way as the terminals at the register authorities. It is also possible to connect userown equipment, normally used for other purposes within the office, to get access to the Land Data Bank System. In this case "called circuit connections" in the Nordic public data network are used. A third alternative, so called VIDEOTEX-connections, will be available from July 1986. Users, who have a local terminal network of there own can get access to the system via a computer to computer linkage.

The user pays a rental varying from 2 500 SEK (leased line including equipment etc.) to 25 SEK monthly. In addition to this the user is charged a transaction fee, varying between 1,50-3,00 SEK per question.

5. LIS IN A WIDER SENCE

Terminal connection gives a direct access to the data in the data bases. The principal search arguments on-line are the identifiers of the properties. Also unreformed identifiers and street addresses can be used. In batch-processing, however, searching can be done on any information stored. Coordinates are frequently used, for example to produce list of properties (and owners) within an specific area. The area can be delimited arbitrarily on a map. Coordinates can also be used for analyses of geographical data (distance analyses) and for presentation of statistical data (thematic maps).

In batch-processing also civic registration number or names can be used as search argument.

The Land Data Bank System interacts regulary with the Population and the Land Taxation registers - both are based on EDP - in order to update owneraddresses and assessed values of the properties. The connection offers possibilities to combine data in these registers with the coordinates in the Land Data Bank. Production of population maps and other kinds of thematic mapping is since long an established field of activity within the Land Data Bank System.

6. SECURITY AND INTEGRITY

In order to ensure good security in the Land Data Bank System there are several security systems operating independently. Physical protection of stored information is ensured through regular copying of the data bank. Backup copies are stored in several different archives.

Authorization to change data is checked on several levels. There are lockouts connected to the entire chain of databases, line network, offices, terminals and persons. For information retrieval there is a simalar arrangement, even though the number of authorized persons is considerably larger in this case. Information retrieval in the data network can be done only unit by unit. Furthermore, retrieval can be performed only from a known terminal in a known place.

It is a basic principle in Swedish legislation that citizens have the same access to information as authorities have. The entire register content is open. The same rules apply to the Land Data Bank System as to the earlier manual registers. Also the right to use developed programmes is fundamentally open.

Another major principle is that programmes for data processing can be developed solely for the purposes the system is aimed for. This applies also to distribution of information.

In spite of the fact that the information in its entirety is public and accessible unit by unit on-line from terminals, there are limitations as far as retrieval of processed information is concerned.

The responsible agency - for the Land Data Bank System it is the CFD - has to carefully observe questions concerning security and integrity. Based upon the existing regulation system the CFD has the right to reject requests for compiled information and declare the requested compiled data secret. This means that the data itself is still open unit by unit but the compilation will not be executed. There has been no need for the CFD to use the right to declare data secret so far. Nor has up to now anyone lodged a complaint for integrity reasons.

Data law and other regulation systems developed for EDP-handling seems to have worked comparatively well for the Land Data Bank System. These questions must, however, be treated as parts of the development of a system of the kind the Land Data Bank System represents. Openness and easy accessibility to data must be a guiding ingredient when developing an information system. Otherwise it should be questioned whether the system shall be built at all. On the other hand, limits must be drawn in order to protect security and integrity. Existing rules and developed technique must balance one another in a concurrent system.

7. ECONOMY AND EFFECTS

The investments being made for the Land Data Bank System as regards development, data collection etc., are more or less twice as high as the annual cost of a manual system. In spite of these investments, the Land Data Bank System is profitable within a relatively short period. Savings are made through reduction of staff and reduced costs for premises at the register agencies. Considerable economic effects can primarily be seen at large agencies while short-term realization of profits at very small agencies is more difficult to achieve.

In a wider sense the system is economically beneficial to society as a whole by achieving a higher degree of service as regards accessibility of data, increased amount of information, shorter turn-around time and so on.

8. FUTURE STEPS

The property and land registers within the Land Data Bank System give fairly detailed information on the properties: origin, location, area, value, owner, mortgages, easements, survey measures, plans and regulations. It has been proposed to create a third register within the system, a register on buildings. The idea is mainly to automate manual registration procedures concerning buildings in the same way as property and land registration procedures have been automated.

One reason to use the Land Data Bank System for this purpose also is the close relationship between properties and buildings. Certain data on the buildings, e.g. coordinates, are already stored in the system. Another reason is that the registration process and flow of data are similar and that the experiences of that kind of system which has been implemented for property and land registration are so positive.

Investigations show that todays cost of registration and transfer of data can be reduced. Establishment of the building register, however, has not been decided so far.

DIGITAL MAPPING IN LAND REGISTRATION, AND ITS RELEVANCE TO THE POSSIBLE DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM IN THE UK

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ABSTRACT

This paper examines the results of a technical study carried out by Her Majesty's Land Registry relating to the possible use of the large scale digital mapping published by the Ordnance Survey, as the basis of a future computerised land registration mapping system. The study confirmed technical feasibility, although a detailed examination of costs and benefits did not fall within the scope of the study, and these were not rigorously evaluated. An initial experimental interactive graphics system was further developed into a prototype production system which has now been installed in a land registry, and is being used in live operation, in order to study cost/benefit and organisational implications. First results from this pilot study will be described at the Conference. A UK government appointed committee of enquiry has been considering how geographic information in the UK should be handled in the future. This paper considers the relevance of a computerised land registration mapping system to the possible future development of a comprehensive geographic information system in the UK.

INTRODUCTION TO H.M. LAND REGISTRY

HM Land Registry is a government department which administers the system of registration of title to land in England and Wales. Registration of title to all land is not yet complete, but in areas such as London, more than 98% of the land is registered. About 7000 HMLR staff are employed in 13 district land registries, and at a headquarters office in London. Approximately 1400 staff are engaged in cadastral surveying and cartographic work.

The primary official records created and maintained by HM Land Registry are the register, the filed plan and the public index map. For each registered title there is held a register, identified by a unique title number, which provides a description of the land, the name of the owner and any incumbrances on the land, such as mortgages, restrictive covenants etc. The title to registered land is guaranteed by the State.

Under modern practice, every registered title has its own official filed plan. The Registry also maintains a series of large scale index maps showing the position, extent and title number of every parcel of registered land.

First registration of unregistered land in England and Wales takes place on the first sale or long lease after the area in which property is situated is declared by statutory instrument to be a compulsory registration area. Registration of land for the first time is therefore of a sporadic nature, but after land becomes registered, all dealings are subject to registration.

Before completion of a purchase of land, a purchaser or his solicitor will initiate an inspection of the public index map to determine whether a property is already registered. If it is not, a deed of conveyance is prepared, and an application for first registration is made. After registration, a land certificate containing copies of the register and filed plan is issued to the landowner. A sale of registered land is carried out by the execution of a transfer in a simple form, which is then completed by registration.

THE EXISTING MAPPING SYSTEM

The Map Records

The 9.5 million filed plans and 400,000 index maps and index map sections held by HMLR are, by statute, required to be based on the Ordnance Survey map. In practice, both the map records are almost invariably at the largest published scale (ie. 1/1250 in urban areas, 1/2500 in rural areas) although filed plans may also be produced at 1/500 or larger scales. Surveys to update the filed plans or index maps are undertaken by both OS and Land Registry surveyors.

The published Ordnance Survey maps used are topographical maps. Land Registry staff add cadastral information to the maps or map extracts in the form of colourings, symbols and annotations. The extent of land in each registered title is shown on both index maps and filed plans by a red edging around the inside of the land parcel boundaries. Where boundaries are undefined by physical features, they are plotted from the plans and descriptions in the deeds, and dimensions are added where necessary. In rural areas, complete published OS maps may be used as index maps. In urban areas, the OS map detail is divided into index map sections. The borders of index map sections are edged in green, each red edged parcel is marked with a red parcel number, and each map section plan is bound into an individual stiff covered B4 sized book with a parcels index, which indicates the title numbers of land comprised in each numbered parcel. Apart from red edgings, parcel numbers and title numbers, other colourings are not normally added to index maps. However, filed plans may show a variety of colourings, dimensions and annotations.

The Street Card Index

HMLR also holds a very comprehensive series of card indexes of the roads or streets shown on all its index maps. The card indexes provide a quick and easy means of identifying the index map or map section on which any property falls.

Basic Mapping Procedures

When an application for registration is received, the procedures employed by HMLR plans staff are as follows:-

(1) the correct index map is identified, and withdrawn from the map store.

(2) the plans and descriptions in the deeds are examined, and any inconsistencies between deeds and OS map detail are investigated and resolved.

(3) the property description is drafted for the register, and the official filed plan is prepared, together with a copy for the land certificate.

(4) the land is indexed on the public index map.

(5) the new filed plan and the index map are refiled.

In addition, on the sale of part of a registered title (ie a mutation), the land transferred is edged and numbered in green on the vendor's filed plan and land certificate plan.

Plans staff also process applications for official searches of the index maps, office copies of filed plans, and carry out a wide variety of maintenance and map revision tasks.

THE PROBLEMS

Generally the existing mapping system operates well, but there are a number of significant and recurring problems which may be summarised as follows:-

(1) intensive use of manpower resource in filing, retrieving and keeping track of map records in use.

(2) maintenance of map records, both in terms of their physical condition and their level of update.

(3) duplication of effort in indicating identical extents of registered titles on filed plans, their certificate copies and on the public index map.

(4) maintenance of consistent cartographic standards.

(5) inflexibility inherent in a system where one map or plan may be required for use by several staff at the same time.

COMPUTERISATION OF THE REGISTRATION SYSTEM

Developments which have been undertaken by HMLR to computerise its records may be considered under two broad headings, as described below.

Computerisation of the Register

The Land Registry has for some years been engaged in the design and development of a computer system for the creation and maintenance of its register records, the provision of searching and copying services, and the related handling procedures. It is the intention to implement an on-line distributed processing system based on a 'host' and 'satellite' configuration. The 'host' mainframe computer will be an IBM 4381 situated at one of HMLR's offices at Plymouth. Each district land registry will be a 'satellite', using an IBM 4361 computer, and will be linked to the host at Plymouth using BT Kilostream links. The system will be introduced into HMLR on a progressive basis. Full implementation will take place at the Plymouth District Land Registry in the latter half of 1986, and will then be introduced successively to other land registries.

Digital Mapping Technical Feasibility Study

HMLR has carried out a two year technical feasibility study into the possible use of OS digital mapping as the basis of a system for holding its official filed plan and public index map records on a computer. The study commenced in early 1983, when a specification was drawn up of HMLR's requirements for a turnkey package which could be used for trials and experimentation. Intergraph was finally selected as the supplier, and a hardware/software package was installed at HMLR in the Autumn of 1983.

The hardware consisted of a VAX 11/730 computer with additional processors to speed graphics processing, with 2 Mb main memory, 2 x 84 Mb fixed disc units and a tape drive. The CPU was linked to a 2 screen monochrome/colour graphics workstation with a digitising table, and an 8 pen plotter. The basic system software used was VMS. Intergraph IGDS software was used for interactive graphics and file manipulations, and the linking of graphics to database entries. A small experimental network database was created, using Intergraph DMRS data management and retrieval software. Like the manual card index and filing system, the experimental database provided broadly similar, but much enhanced facilities for searching for properties on a digital public index map, and for retrieving digital filed plans of registered properties for display or plot.

A report on the project produced in February 1985 indicated that the use of digital mapping technology for the preparation and maintenance of HMLR's filed plan and public index map records was technically feasible and that benefits were likely to accrue in the following areas:-

(1) Speedier, more comprehensive and less labour intensive system of storing and retrieving map records.

(2) More effective maintenance and security of map records.

(3) More efficient and less labour intensive system for production and up-date of map records.

(4) Production of map records at consistent high standards of cartographic quality and accuracy.

(5) Possibility of providing on-line access to map records by external users in the longer term.

The terms of reference for the feasibility study did not include the full evaluation of operational efficiency and cost feasibility of using a digital system. Accordingly, it was decided that a two year pilot study would be mounted at a district land registry, using converted map records for one of the local authority areas served by that registry. A full scale feasibility study would also be mounted to investigate the implications of converting HMLR's entire mapping system to digital in the long term.

THE PILOT STUDY

The local authority area selected for the pilot study was the district of Corby in Northamptonshire, having a population of 51,500, and a total land area of 80 square kms. Using 'OS translator' software supplied by Intergraph, Ordnance Survey digital mapping was converted to the Intergraph format. The 108 Ordnance Survey feature codes were reduced by holding them on 6 levels on the system, although all original feature codes remained separately identifiable if required, as they were translated into Intergraph colour codes.

Further system and software developments took place from February 1985 to May 1986 to provide the present pilot digital mapping system incorporating the following principle features.

The OS map detail is divided into map sections, each of which is held in a separate graphic design file. As in the manual system, map section boundaries are designed to follow road centre lines, streams, and other permanent boundary features. As each map section is created, the roads and house names and numbers within each section are entered into the database.

Land Registry graphical information in respect of each registered title is created interactively, and linked to the database. As in the manual system, the extent of each registered property is indicated by a red edging which follows the inside edge of the topographical features demarcating the boundaries of the property. Each registered property also has its parcel number, together with any required colour references (by coloured hatchings, edgings etc.) to show the extents of areas of land affected by easements, restrictive covenants etc.

A diagram giving an outline of the database structure is shown at Annex A. The data retrieval software is utilised as an enhanced form of street index under the manual system. Suitable macro command procedures have been prepared which enable a workstation operator to enter a property address, and then initiate search routines which result in the correct map section being displayed automatically on the screen. The initial display is in the index map format, that is to say, all registered properties are shown edged with red and labelled with their parcel numbers. By 'highlighting' any individual edging or parcel number with the cursor, information on the database entries relating to the title in question are also displayed (ie. title number, tenure etc.). The database structure also enables the correct map section to be selected directly through the Land Registry title number, if the property is registered and the title number is known, and provision has been made for searching by reference to a Unique Property Reference Number (UPRN) if this facility proves to be required for more general application in the future.

Under the digital system, the public index map sections and filed plans are no longer held as separate physical documents in paper form, but all form part of one integrated land information database. The database software provides the means of searching to enable the required information to be retrieved and displayed automatically. Normally there is no requirement for hard copy of public index map displays, but the system provides the means to display the appropriate graphics for any individual title, and to plot colour copies in a 'filed plan' format with appropriate Land Registry headings and annotations. These are used as copies for the proprietor's Land Certificate, and also for office copies requested by intending purchasers. An example of a 'digital filed plan' is shown (in monochrome) at Annex B.

The pilot system commenced live operation in May 1986 and is being used to provide information for the assessment of potential costs and benefits to HM Land Registry. The pilot system is also of a more general interest, as a land information system capable of expansion or integration into a more comprehensive geographic information system.

GEOGRAPHIC INFORMATION SYSTEMS IN THE UK

At the present time, the position in the UK is that a large number of land information systems are in existence, most of which are not automated or interrelated to any degree. A UK government appointed committee of enquiry has been considering how geographic information should be handled in the future. It seems doubtful whether there will be a move to combine the functions of the many different organisations into a single, or small number of authorities concerned with land use and administration, or who otherwise deal with data capable of spatial referencing. The most likely possibility appears to be that individual systems may be referenced or be capable of being referenced to a common spatial framework, and that appropriate standards may be established and accepted for data definition and formatting for interchange of information between systems and sub-systems. As to the latter, even within HMLR, this problem exists as between the proposed computerised register and map databases, although we believe this problem can be resolved without any great difficulty.

In the UK, the Ordnance Survey map with the National Grid referencing system is widely regarded as being the common spatial framework to which UK geographic information systems should be related. This leads one to consider certain features of HMLR's pilot digital mapping system which may have a wider interest and application in the context of the development of interrelated geographic information systems. These may be summarised as follows:-

(1) The system is based on the Ordnance Survey map, and should thus be capable of being related to

other systems referenced to the same base map.

(2) The data retrieval system developed at present provides the OS map extract on which a property falls (whether registered or not), if it can be described by postal address, or nearest street name. The system is capable of being developed to permit searching by an agreed UPRN of a parcel.

(3) A public index map search will, for registered land, generally speaking provide the legal extent of ownership of a land parcel, which is of great interest to all those concerned with land use and administration.

(4) In some cases, the map detail shown on the HMLR database will be more up-to-date than published detail, as later detail will have been digitised in by HMLR from the Ordnance Survey SUSI service (Supply of Unpublished Survey Information) and from surveys carried out by OS and HMLR surveyors for registration purposes.

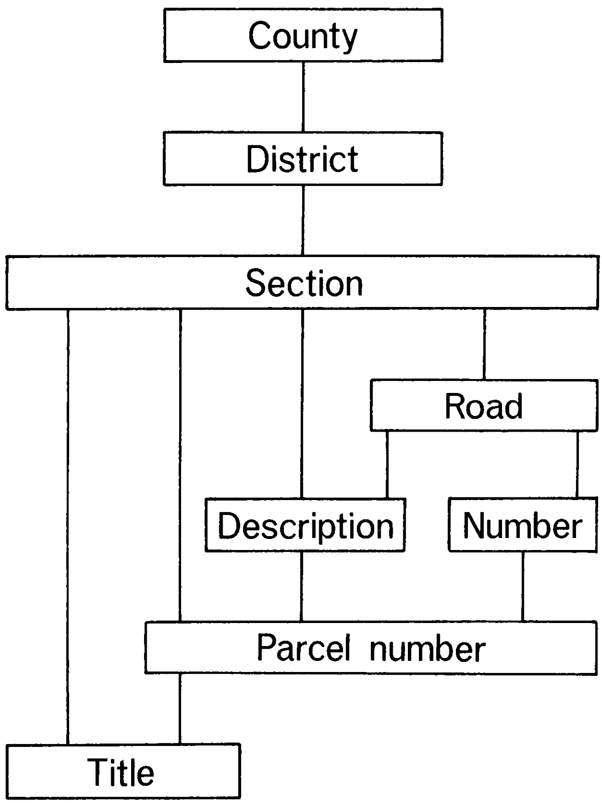
(5) Under the present law, the register is private, and access is normally restricted to registered proprietors and those having their authority to inspect the register. However, there is some possibility that the law may be changed in the future. With the establishment of appropriate links between the Land Registry's register and map databases, landowners' names and other information could be accessed quickly and easily by the public, as is already possible in many other jurisdictions.

CONCLUSIONS

Computerisation of HM Land Registry's register and mapping records appears to offer many benefits and advantages, primarily by way of improved speed and quality of service to the public, and accessibility for on-line users in the long term. Whilst these benefits are of immediate interest to those concerned with conveyancing, the introduction of computer technology may in the longer term also provide the basis of a key sub-system in a comprehensive geographic information system of the future.

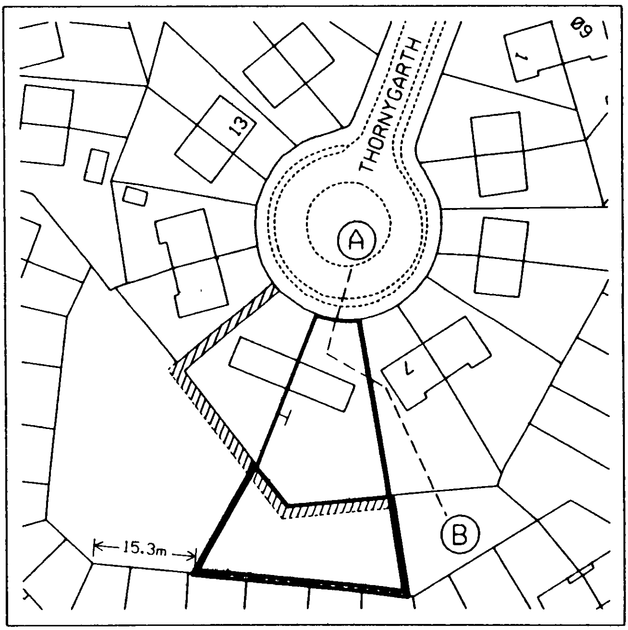
The views expressed in this paper are those of the author, and do not necessarily represent the views of HM Land Registry.

H.M. LAND REGISTRY DIGITAL MAPPING DATABASE STRUCTURE



Title No	Freehold / Leasehold	History details	Office copy Parameters

H.M.LAND REGISTRY	TITLE NUMBER **TY10136**	
ORDNANCE SURVEY PLAN REFERENCE NZ2861	SECTION B	SCALE 1/625
COUNTY TYNE AND WEAR	DISTRICT GATESHEAD	CROWN COPYRIGHT



Example of a formatted copy of an official filed plan. Bold markings such as edgings, hatchings, broken lines, circled letters and dimensions are shown on the original in a range of colours.

FIVE REASONS WHY GEOGRAPHICAL INFORMATION SYSTEMS ARE NOT BEING USED EFFICIENTLY FOR LAND RESOURCES ASSESSMENT

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ABSTRACT

Current state-of-the-art geographical information systems appear to be ideal tools for all forms of land resources assessment and rural landuse planning. Yet in contrast to land information systems, utility applications and topographic mapping, GIS are not being used for land resources assessment as effectively nor as widely as possible for at least five major reasons. These are:
1. The dynamic but often imprecise, complex and stochastic nature of many natural phenomena is poorly captured and handled by current GIS methods using simple Boolean logic, map overlay and conventional thematic mapping techniques.
2. Many current soil science, ecology and land evaluation methods currently use only single site-specific data.
3. GIS for land resources assessment are too expensive.
4. A shortage of skilled personnel.
5. Remote sensing and image analysis have taken investment away from more direct methods of land resources assessment.

INTRODUCTION

At first sight, current, state-of-the-art geographical information systems are ideal tools for all forms of land resources assessment and rural landuse planning, both in developed and in developing countries. Yet in contrast to land information systems, utility applications and topographic mapping, apart from certain notable exceptions, GIS are not being used for land resources assessment as effectively nor as widely as possible. There are at least five major reasons why this is so. They are:

1. The dynamic but imprecise, complex and stochastic nature of many natural phenomena is poorly captured and handled by current automated methods of classification, Boolean logic, map overlay and conventional modelling and thematic mapping techniques (c.f. Burrough 1986).

2. Many current soil science, ecology and land evaluation methods pay more attention to data located at specific points (monitoring) than to spatial distributions.

3. The limited markets and thus restricted profit motives for appropriate system development are reflected by the high capital costs of many commercial systems.

4. The lack of skilled personnel, particularly in third-world countries, and the technology gap between system designers and potential users.

5. Remote sensing and image analysis have diverted much finance and brain power away from more direct methods of land resources assessment.

1. Describing natural phenomena

Any system of land resources assessment is totally dependent on the quality of the data that are used for making statements about the feasibility or otherwise of various kinds of land use. In most kinds of land resource assessment, quantitative or otherwise, data collection is often carried out separately from data analysis. Various data collection technologies (field surveys, remote sensing, sampling methods) are used to build a database of information that is considered to be relevant and necessary. This database is today often available in digital form on a computer.

It is axiomatic that the database will not serve its purpose unless it enables the user to retrieve and manipulate the data it contains in the ways required for the purpose at hand. For natural resources analysis it is essential that the fundamental concepts used by the field scientist to describe and collect basic units of data are appropriate for the problem at hand and are not dictated by the structure of an information system.

The field scientist usually organizes landscape data in terms of 'phenomenological' units - mountains, terraces, solifluction layers, soil series, textural horizons, catchment areas, geotopes and so on, that he has attempted to recognize as physical entities that can be uniquely described. These phenomenological units are then very often meticuously described in terms of their non-spatial attributes, which are organized in classes, and their spatial extents, which are represented by polygon boundaries on thematic maps. The net result is a database in which the fundamental units or building blocks are stylised abstractions of reality (Figure 1). Note that these units imply a static, or unchanging landscape; dynamic landscape change must be treated separately.

If natural landscapes could always be fully described by the data model given in Figure 1, we would have few problems. The basic units of natural landscapes would then be very similar in structure to the well defined and well delimited parcels and land units that can be managed so well in current land information systems. Unfortunately, reality is often otherwise. There are three aspects that should be considered, namely the nature of the spatial boundaries, the problem of internal variation, and the problem of dynamic change.

Boundaries. In practice a cartographic boundary may describe a) an abrupt change in the value of a phenomenon, b) intervals along a trend or c) a chance occurrence resulting from adjacent observations just happening to fall on opposite sides of an a priori class boundary (Figure 2). Clearly, whether a boundary is type a), b) or c) will have severe implications for the outcome of analyses using map overlay techniques in GIS.

Also, most boundaries on thematic maps of natural resources such as soil or vegetation have been interpreted either from field observations, or indirectly from aerial photographs or remotely sensed images. Because of the complex nature of landscapes, and the variation in the skills of the surveyors, the resulting interpreted boundaries can be drawn in many ways (c.f. Bie and Beckett 1973). Note that the average density of boundaries on soil maps, for example, seems to owe more to the scale of the paper map on which the survey was compiled, than to inherent differences in terrain (Burrough 1983, 1986).

Spatial variation within boundaries. The thematic map model assumes 'homogeneity' within boundaries. For some phenomena, in some landscapes, this may be a reasonable approximation of the truth, but in other situations it is clear that there is considerable spatial variation within the mapped units. In recent years there have been major advances in ways of describing spatial variation (e.g. Nielsen and Bouma 1985, Webster 1985), but these methods have not yet been incorporated into most commercially available geographical information systems. It is only with respect to methods for modelling landform, using digital elevation models, that commercial systems have provided exciting and powerful new tools for handling continuous variation in spatial data.

Conceptual units and Boolean logic. Most information systems currently available use sharply-defined conceptual classes or spatial units as basic entities. These entities are at the heart of relational databases which use of Boolean logic for data manipulation and retrieval. Many 'expert systems' having strict rule-based logic use the same basis of well defined data entities and the same is true of current qualitative land evaluation methods (e.g. McRae and Burnham 1981). "Pattern invoked programs" (Negoita 1985) are activated whenever certain conditions hold:

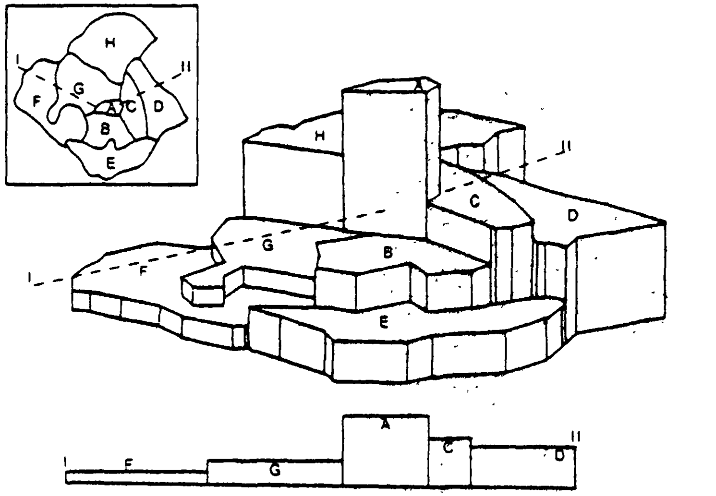

Figure 1. Many thematic maps of natural resources imply discrete, stepped distributions enclosing homogeneous areas.

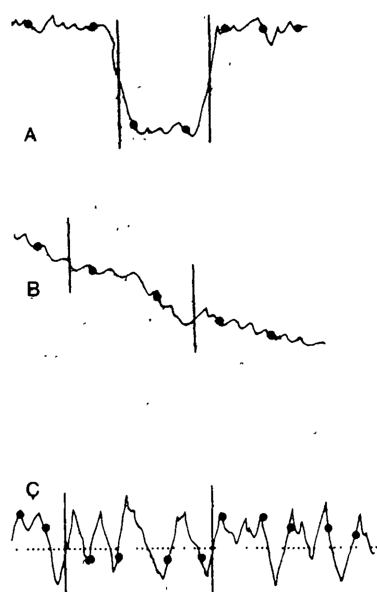

Figure 2. Three variants on soil boundary location from point observations.
A. abrupt change,
B. splitting a trend,
C. Sampling variation - observations happen to sample points falling on opposite sides of a classification boundary.
• sample sites.
'True' variation.

Condition IMPLIES action

This is usually coded by IF ...... THEN statements: For example, IF soil is non-alkaline AND slope < 5% THEN site is suitable for irrigation. Many systems of land evaluation, including the FAO 'framework' (FAO 1976), are based on this kind of logical equivalence.

Although these conventional methods of reasoning have brought us a long way, studies of the spatial and multivariate variation of soil and other natural resources are demonstrating that the simple concept of discrete, basic, homogenous units is inadequate for further progress in quantitative land resource assessment. We cannot be completely certain that all statements made about the data units are 'true'in the sense of being exact and precise. We know that it is impossible to determine the value of soil, water or other properties exactly - Table 1 - (c.f. Beckett and Webster 1971, Pleijsier 1986), we know that spatial variation of soil occurs within map units (c.f. Nielsen and Bouma 1985), and we know that map unit boundaries may reflect anything from abrupt changes in soil through attempts to divide a trend, to chance effects caused by noise.

Table 1. Variation in the estimated values of soil properties when the same samples were analysed by a number of well-known international laboratories using the same methods.#

Soil Property*	Number of labs.	Minimum	Maximum	Mean	Standard deviation
Clay % (11)	37	9	60	39.84	9.67
Clay % (19)	37	19	36	26.16	3.88
pH-KCl (11)	43	5.8	7.5	7.11	0.31@
pH-KCl (19)	43	4.3	6.0	5.24	0.26@
Exch K (11)	38	0.04	0.77	0.32	0.15·
Exch K (19)	39	0.26	4.55	2.00	0.73·

\# Data from Pleijsier (1986).
* Numbers in parentheses give the sample identification numbers: 11 is from the B horizon of a saline/calcareous/gypsiferous soil from Syria, 19 is from the A horizon of a typic argiustoll from the USA. @ means and standard deviations for pH are for measured values, and not via transformation to H+ concentrations. · Means and standard deviations for Exch K calculated ignoring single extreme values of 2.00 and 16.66 meq./100g oven dry soil, respectively.

So, we conclude that the basic units of information in natural resource data are not always well defined, but may be diffuse or 'fuzzy' (Figure 3.). For many years field scientists have been using imprecise terms such as 'moderately well drained' or ' few mottles' or 'steep' to express their findings, yet they have been forced by the conventions of logical data analysis to define them in terms of strict intervals. Modern information theory, linked to geographical information, can provide an answer.

Fuzzy logic When working with quantitative variables, we can use discriminant analysis or maximum likelihood methods to establish the degree of statistical probability that any individual soil observation belongs to any given class (e.g. Webster and Burrough 1974). When working with logical statements, we can use the concept of possibility or of a 'certainty factor' (CF, CF -1 < 0 < +1) which indicates the certainty with which each rule is believed (Negoita 1985, Zadeh 1965). Inexact reasoning is based on the construct:

IF A (to degree x) THEN B (to degree y)

Such constructs can be applied to decisions involving phenomenological data and situations in which there might be more than one correct decision. As Figure 4 shows, the intersection of two fuzzy subsets (be they spatial or conceptual) will yield very different results depending on the levels of the certainty factors that are chosen. The answer obtained from intersecting two sets no longer has to be 'yes' or 'no', it could also be 'maybe'. In 'eyeball' studies of land evalution, the levels of the certainty factors are determined intuitively by experience; skilled 'experts' will make better choices than novices. Because our current methods of data collection and data structures do everything possible to avoid the real problems of the inherent fuzziness of landscape and spatial variability, methods of natural resource evaluation that use discrete units and strict rule-based logic cannot perform as well as we would like.

Propagation of errors in GIS. Many commercially available systems allow the user to set up cartographic models, which are essentially flow charts governing the transformation or selection of basic data in order to draw conclusions. Because of the limited facilities for recording information about within-unit variability (even if the information was available, which it often is not), these models pay no attention to the propagation of errors. Consequently, only one result (usually in the form of a beautiful graphic product) comes out of the computer; there is no information about possible margins of error.

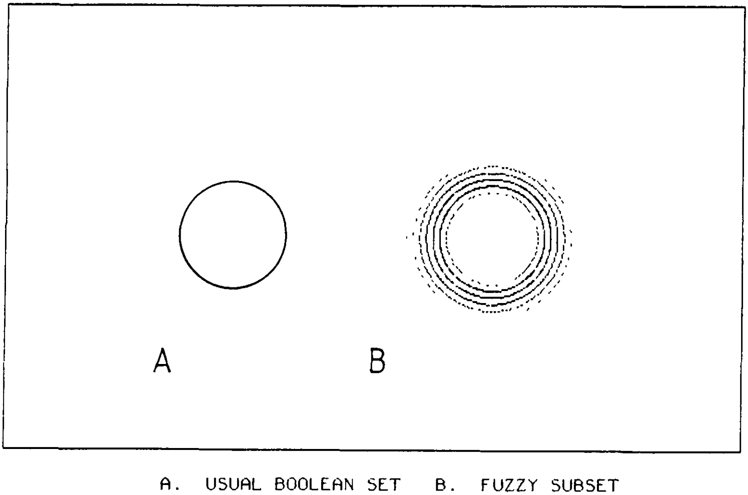

Figure 3. Comparison of a normal Boolean set with a fuzzy subset.

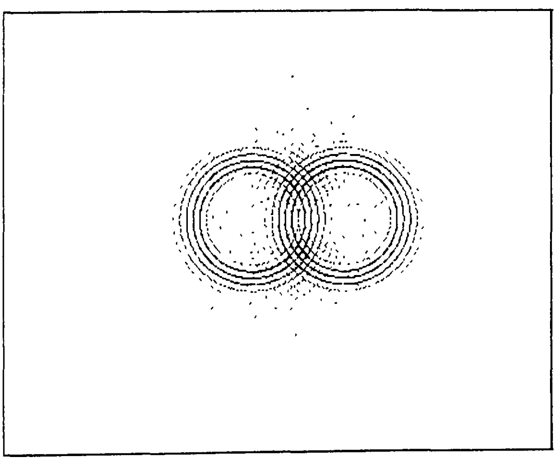

Figure 4. The intersection of fuzzy subsets.

Statistical methods of analysing error propagation have been available for many years (Parratt 1961, Burrough 1986) but so far have found little application in standard GIS methodology. Few users seem to realise the implications of error propagation, however, believing that the quality of the results of a GIS analysis are determined by the cartographic quality of the end product. For example, if an empirical GIS model requires six terms, each having a relative error of 10%, to be multiplied together, the result will have a relative error of 24%. Few natural resource data can be determined with an accuracy of ±10% at a price resource survey agencies can afford.

2. Site-specific studies

Because of the complexity of many natural resource phenomena, there has always been a tendency to study them intensively at a few, 'representative' sites, from which conclusions are drawn and extrapolated over large areas. Examples are the study of soil erosion along specific transects, the monitoring of environmental quality or the modelling of crop production at given locations. There is a great challenge now to find new ways in which detailed, local studies can be applied to whole landscapes. Because of the limitations imposed by the basic 'building block' approach outlined above, in which 'second-hand' resource data are used for extrapolation, it seems sensible to approach the problem by integrating the data collection and data analysis phases into a single system. Such a system would also have to include dynamic models of the movement and spatial variation of air, water and pollutants in order to allow proper extrapolation in time and space. It is a challenge to the natural resources disciplines to develop the necessary strategies that can be used effectively here so that the new methods can be incorporated in the next generation of GIS.

3. System costs

Geographical information systems are expensive tools. The high costs of hardware, good software and skilled personnel have restricted the widespread use of GIS and also have restricted critical assessment of their worth. Manufacturers have very naturally been prepared to invest in areas where there has been a chance of good returns, and it has been attractive for them to use the same technology and software for land information systems (i.e. well-defined parcels with simple attributes and high quality graphics) as for natural resources. It is only recently, with the arrival of small, cheap but powerful processors, and good raster display systems, that more people can work with natural resource data in ways that have not been dictated by CAD/CAM system design.

4. Training

The high costs of systems linked to the rapid changes in technology have meant that until recently, only students of natural resources in the richest countries of the world have be able to receive training in GIS. Because until recently, few received training, the acceptance of GIS, and understanding of their potential have been retarded. As more people become aware of the potentials, it is to be expected that within the natural resource disciplines there will be trends away from the original qualitative approach of classification into static spatial and conceptual units towards more emphasis on quantitative, dynamic understanding of complex natural processes.

5. Remote sensing

Remote sensing and image analysis are natural parts of any geographical information systems used for natural resource assessment, yet in the past, they have often functioned as independent disciplines having little in common with the field sciences. Their technical nature has attracted many able scientists who have found the intellectual challenges of computer science more stimulating than those provided by field work. Many government agencies, particularly the military, have invested much larger sums in remote sensing than in basic research in natural resources, yet fundamental understanding of the patterns of distribution and the processes at work in natural resources is absolutely essential for the proper use of remote sensing as a tool in resource analysis. Rather than continue to invest large sums and skilled persons in further refinements in image classification and analysis, let us attack some of the fundamental theoretical and practical problems of describing and modelling the complex, dynamic aspects of our natural resources base upon which all life depends.

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TRENDS IN LAND INFORMATION SYSTEM ADMINISTRATION IN AUSTRALIA

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ABSTRACT

Current land information system (LIS) activities and trends, at the Commonwealth, state and local government levels in Australia, are briefly reviewed. The reasons for the pre-occupation with parcel (cadastral) data are discussed while recognising that the challenge for the next decade is the integration of resource, environmental and soci-economic data into parcel-based systems. LIS models are reviewed with particular emphasis on LIS administration in the Australian context.

INTRODUCTION

Reforms in the cadastral and land information system (LIS) areas have been occuring at an increasing rate in Australia during the last decade. By necessity the reforms have been directed almost solely at the parcel based areas and have been centred around major institutional and administrative reforms.

It is fortunate that Australia has well developed systems for land registration, and cadastral surveying and mapping. By comparison with many other countries, Australia's government institutions for administering these systems are extensive and well established. Such systems, together with the associated institutional arrangements, form the foundation for the present LIS initiatives in Australia.

The reasons for the present reforms are many and diverse, and include:

- an increasing requirement of governments and government departments to be more effective, efficient and accountable;
- the trend to rationalise existing cadastral arrangements to better meet the needs of a modern LIS;
- the impact of advanced technology on the collection, storage, manipulation and display of digital, spatial, land-related data;

- an increased environmental awareness by society and governments in general, which has resulted in a requirement for more complete and up-to-date data about land; and

- a general trend for governments to demand better and more timely information for decision making.

Within this context, this article briefly reviews LIS activities in Australia at the three levels of government, namely the Commonwealth, state and local levels, together with the efforts being undertaken by the utility and service authorities. While recognising that "land administration" is a state responsibility in Australia, the general administrative arrangements for LIS in the states are discussed. In conjunction with this discussion, trends in LIS are outlined. Even though most efforts in Australia are directed at parcel-based LIS, considerable thought and effort is being expended on integrating resource, environmental and socio-economic data into a broader LIS. The paper reviews the present pre-occupation with parcel-based data and looks at efforts to integrate these other forms of data. Theoretical and applied LIS models are briefly discussed.

For a general overview of LIS activities in Australia, reference should be made to the Report of the Working Group on Statewide Parcel-Based Land Information Systems in Australasia (Williamson, 1985a).

LIS ACTIVITY IN AUSTRALIA

Since "land administration" is the responsibility of the States in Australia, most activities in the LIS area have been traditionally undertaken and initiated by the respective state governments. On the other hand, the Commonwealth Government is becoming increasingly interested in specific land-related information and at the level below state governments, local governments, and utility and service authorities are rapidly establishing LIS and facility information systems (FIS) respectively.

Commonwealth Government

In 1983 a Commonwealth Inter-Departmental Steering Committee was established to investigate ways and means of implementing co-ordination of land-related information within the Commonwealth Government. At the instigation of the Prime Minister, a National Conference was held in 1984 endorsing the co-ordination of Commonwealth land-related data and the compilation of a directory of such data. As a consequence a National Co-ordination Committee on Land Information Exchange was set up, comprising the chairmen of existing Commonwealth, state and territory land information system steering committees to plan, develop and promote a national strategy. A full-time Commonwealth Land Information Support group was established in the Australian Survey Office in 1985. Its tasks include the updating and maintenance of the LANDSEARCH Directory, the first edition being published in late 1985.

State Government

During the last decade each state or jurisdiction in Australia has developed or has commenced developing a LIS strategy. A central component of these strategies has been the establishment of some form of LIS support group or unit. The primary role of these units is co-ordination and advice. They are established in a range of different administrative structures and have different responsibilities and levels of authority (see following section).

The major LIS activities at the state level are:

- establishing a COMPLETE inventory of land parcels, each parcel being identified by a unique identifier;
- establishing a graphic data base or digital cadastral data base (DCDB) to complement the textual data base of the above parcels;
- improving the conveyancing/land registration and cadastral surveying/cadastral mapping systems to update the above parcel data;
- establishing a centralised policy and decision making unit to direct LIS developments;
- developing standards for the exchange of textual and spatial data, and nomenclature;
- understanding existing systems and quantifying user needs;
- preparing a land information directory.

Local Government

There is considerable awareness and activity at the local government level concerning LIS developments. It is becoming increasingly recognised that local government is one of the major growth areas for LIS applications. In a sense this is obvious considering the vaste amount of land-related data that is created and maintained at the local government level. From a practical view point, the most desirable way to maintain the integrity of data is to update it at its source. In a statewide LIS this means a major input by local government. In the Australian context this will see the state systems giving overall co-ordination, setting standards, providing basic parcel data in the form of ownership data and spatial data (cadastral maps/DCDB) and in providing digital topographic data. The state systems may also be involved in collating and processing socio-economic, resource and environmental data for specific user needs.

In Australia there are over 30 local government organisations which are committed to a LIS strategy. In general these organisations manage upto 100,000 parcels with populations of upto 500,000 persons. The systems vary greatly in sophistication and design. Some have a strong emphasis on land information management, financial management, corporate planning and land administration, while others emphasise graphics and CAD. Some systems are only textual or graphic, while others are a combination.

Systems utilise IBM, Intergraph, Prime, Digital and ICL systems. They use such packages as GDS from ARC Cambridge, Easinet etc., for graphics and INFO, PICK and CODASYL for the data base management system. In addition there has been considerable experimentation in the smaller organisations with micro computers for both textual and graphic applications.

Utility Authorities

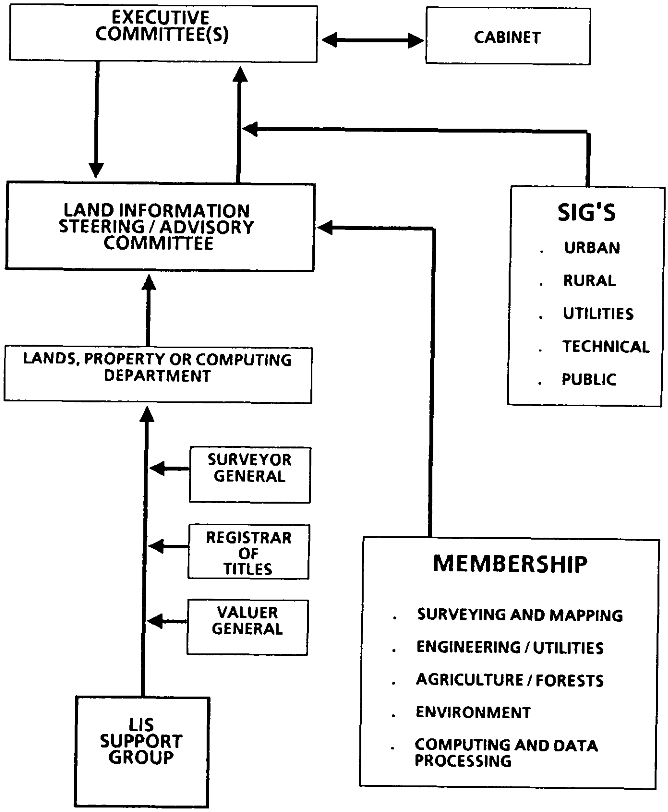
In one sense the utility authorities have taken the lead in applying the latest technology in developing facility information systems (FIS) in Australia. Since these organisations tend to be self funding and more autonomous than local or state governments, they appear to have had more access to funding.

Two examples of such authorities are the Sydney Water Board and the Melbourne Metropolitan Board of Works. Both organisations serve over one million properties. Both are developing sophisticated FIS with extensive and flexible, textual and graphic data bases. The Sydney Water Board is developing its system around the IBM IFIS and the Melbourne system around Intergraph.

TRENDS AND ADMINISTRATIVE ARRANGEMENTS FOR LIS

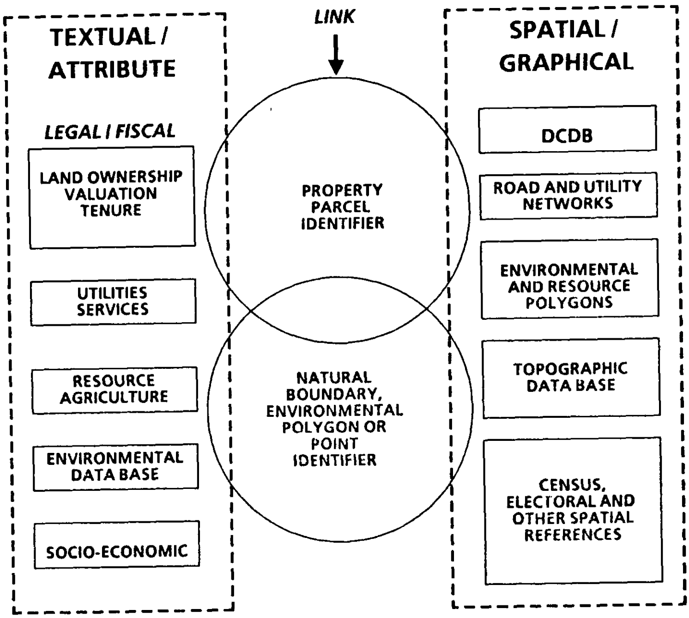
As mentioned, the overall co-ordination of LIS activities in Australia generally falls upon the states. The Commonwealth Government does have a co-ordinating role to some extent although its efforts are directed primarily at Commonwealth land-related data. The local government and utility authorities in general take their direction from the respective state government although they are virtually autonomous within the constraints of their legislative mandate.

Even though no two administrative LIS structures are the same in the Australian States, there is considerable commonality as shown in Figure 1 which depicts a general administrative infrastructure for LIS in Australia and in Figure 2 which depicts in schematic form the generalised concept of LIS in Australia (Source: Williamson and Blackburn, 1985).



GENERAL ADMINISTRATIVE INFRASTRUCTURES IN LIS IN AUSTRALASIA

FIGURE 1



SCHEMATIC OF GENERAL LIS CONCEPT IN AUSTRALASIA

FIGURE 2

The major effort in Australia over the past decade has been establishing "complete" textual and spatial data bases of land parcels in the respective state or jurisdiction. In creating these data bases, most States have started with an existing valuation base. By linking the computerised valuation roll into the title registration system, the integrity of the data is gradually increased. To some extent the development of the textual data is undertaken seperately from the development of the spatial component in the form of a DCDB. In general this is the approach taken by South Australia, Queensland, Victoria and Tasmania. Western Australia (and the planned initiatives in New South Wales) are placing more or at least equal emphasis on the spatial component (cadastral survey and mapping). The Northern Territory and Australian Capital Territory are also placing equal emphasis on the textual and spatial side, however, in these cases the basic cadastral mapping is in general complete, the result being that the creation of a DCDB is not as critical.

It should be recognised that even though many states have developed or are developing LIS, this does not mean that the systems are complete in the sense of a modern cadastre. For example South Australia's LIS does not as yet provide for a spatial component, other than by reference to existing charts or cadastral maps which themselves do not give complete coverage (however a DCDB is being developed). Ideally every parcel or piece of land on a cadastral map should have a unique identifier which has a corresponding series of records in associated registers (according to the basic cadastral concept), however in most states this has not been achieved.

From an institutional or administrative point of view, two trends have been evident in Australia over the past decade. The first concerns the centralisation of the administration of land-based departments and the second concerns the establishment of LIS administrative structures.

With respect to the centralisation of land administration, all States have taken slightly different approaches. Prime examples of this are Victoria and South Australia. In Victoria, the major parcel-based systems are now combined into the Department of Property and Services. This Department includes:

- LANDATA (the Victorian LIS unit)
- Division of Survey and Mapping
- Titles Office
- Valuer General's Office
- Government Computing Service

The natural resource based systems are all combined into the Department of Conservation, Forests and Lands.

In South Australia, the present Department of Lands incorporates the offices of the Registrar-General, Surveyor-General (including the State mapping function) and the Valuer-General. It also includes the Land Operations Division which is responsible for all Crown lands management, and the Land Information Unit which has the role of overseeing all LIS development in the State.

Another example of this trend is N.S.W. where the Department of Lands (within the Ministry of Natural Resources) includes:

- Land Titles Office
- Crown Lands Office

. Central Mapping Authority

. Western Lands Commission

. State Land Information Council

Some problems arise in New South Wales because the Valuer General is in another Department and that the cadastral mapping function in the State is poorly co-ordinated.

In general, these administrative developments are following a trend towards moving closer to the modern cadastral concept (Williamson, 1985b).

Whereas all initial LIS developments were directed at parcel-based land administration systems, all LIS strategies have adopted a broad definition of land information to include natural resource and socio-economic data. The linking of such data to the parcel-based systems is potentially the biggest challenge facing LIS. The overall model now developing for the total LIS of the future is a "dynamic information network".

INTEGRATION OF PARCEL-BASED AND RESOURCE/ENVIRONMENTAL DATA SYSTEMS

As mentioned one of the biggest challenges of the next decade will be the integration of parcel-based and resource/environmental data into a LIS. This integration is the basis of much of the discussion about the role and form of LIS and GIS. Within such discussions it must be realised that in general the two systems have quite different data sets. Some of the differences are as follows:

Parcel-based data (LIS)

- usually large scale
- polygon data defined by discrete vectors
- polygons dynamic and require a very high degree of accuracy and integrity
- maintenance of polygon data base part of large administrative institutions heavily controlled by legislation

Resource/environmental/socio-economic data (GIS)

- usually small scale
- often grid-cell data

. boundaries of data sets are usually statistical

. boundaries of data sets are usually not dynamic

. high integrity of data usually not necessary

. usually incorporate less structured systems for data maintenance

All states in Australia have recognised the need for the integration of resource/environmental/socio-economic data into a broad LIS, but few major developments have been achieved in this direction. Western Australia and Queensland however, have undertaken some interesting pilot studies integrating such data using complex polygon processing packages. South Australia on the other hand is the only state that has developed a model to incorporate environmental/resource and socio-economic data into the South Australian Land Information System using a nodal approach (Figure 3), as described by the South Australian Government:

> "Today the LIS is viewed as a series of procedures and standards that allow for the integration of land-related data from a variety of individual systems (whether digital, manual or graphic) that form the State's corporate data resource. Conceptually the total LIS can be viewed as consisting of four major data bases and a myriad of peripheral systems. These primary data bases are:
>
> . Legal/fiscal
>
> . Geographic
>
> . Environmental
>
> . Socio-economic.
>
> This "nodal approach" is seen (in South Australia) as an effective balance of the centralised/decentralised concept and the most practical and cost effective method of achieving an integrated system". (South Australian Department of Lands, 1985)

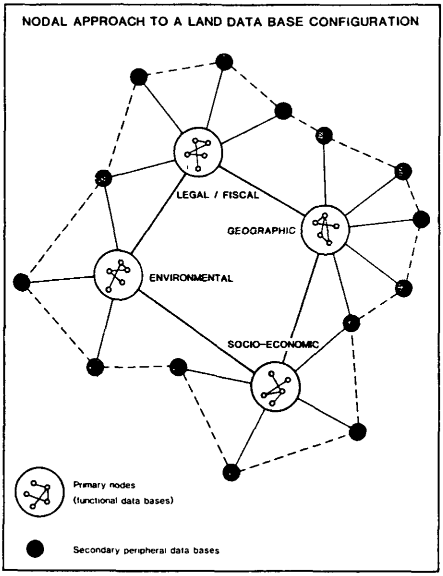


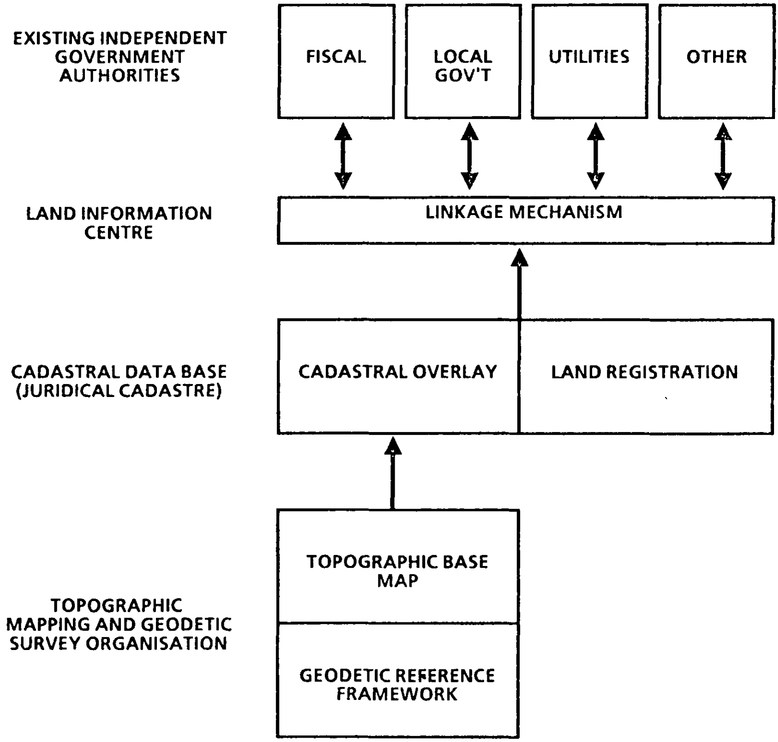
FIGURE 3

On the other hand it must be recognised that in the land administration area, parcel based data is the foundation of the LIS, particularly for state government, local government and utility authorities, as reinforced by the Western Australian Land Information System (WALIS):

> "The results of the questionnaires have already reaffirmed that all areas of the WALIS community continue to recognise that the Legal and Graphic cadastres are the foundation upon which they can build their land management function". (Hyde, 1985)

LIS MODELS

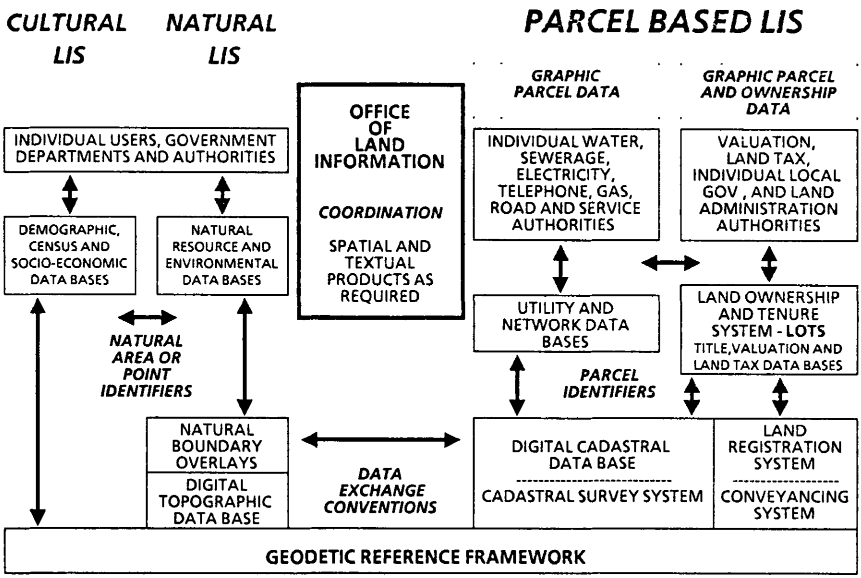
Over the years many theoretical LIS models have been proposed (Williamson, 1983). Unfortunately many do not recognise the very important and central role that cadastral parcels play in the land administration process. In addition most do not recognise the fundamental role that cadastral surveying/ cadastral mapping and conveyancing/land registration play in the maintenance of the parcel based component of a LIS. Following is a generalised model for a parcel based LIS (Figure 4) which incorporates these principles.



THE CADASTRAL COMPONENT OF A STATEWIDE LAND INFORMATION SYSTEM

FIGURE 4

The most crucial challenge however, is applying such models in the real world. Figure 5 shows such an attempt with regard to the South Australian Land Information System.



A SCHEMATIC MODEL OF THE SOUTH AUSTRALIAN LIS

FIGURE 5

CONCLUSION

The land information system concept has been embraced by the three levels of government in Australia, namely Commonwealth, state and local government, in addition to the utility authorities. All states have developed a LIS strategy and introduced administrative arrangements to manage the statewide LIS. In general, the states recognise the equality of the textual and spatial components in such systems. It is the role of the state to co-ordinate most LIS activities since the state has constitutional, legislative and consequently administrative control over land matters. As a consequence LIS initiatives have been most evident at this level although it is recognised that local government, as a major user and contributor of land related data, is a growth area for LIS developments.

Australian land information systems are predominately parcel-based. In many cases they have grown out of valuation systems alghough they are now usually maintained within the "legal" parcel system. This development is similar to the European trend over the last century for cadastres to develop from a fiscal to legal focus.

The Commonwealth and most state systems recognise the need to integrate environmental/resource/socio-economic data into a LIS. However, the parcel based systems are still the major driving force behind all LIS developments in Australia. The integration of these different forms of data is one of the major challenges in the future.

Australia has had much experience over the last decade in establishing operational LIS systems (see Williamson, 1985a). Interestingly the vaste majority of problems encountered in developing such systems have not been technical but people related. Institutional and administrative problems have been the major limitations in establishing useful land information systems which serve the needs of the community. In general, however, Australia has made many positive achievements in the LIS area, particularly regarding the successful establishment of LIS administrative/co-operative structures. In this regard Australia has valuable experience to offer other countries or jurisdictions heading down the LIS path.

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DIGITAL MAPPING AND FACILITIES MANAGEMENT IN A UK WATER AUTHORITY

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ABSTRACT.

The Wessex Water Authority is responsible for all aspects of the 'water cycle' over an area of some 10000 km^2 in South-West England. Following an early entry into digital mapping (DM), the entire water supply network was digitised by mid-1985. At this point, a state of the art system was acquired, with the primary objective of applying the technology to further aspects of the Authority's operation, with access to the data becoming available to all levels and functions. This paper is in two parts. The first introduces Wessex Water and its approach to information technology; it then goes on to chart the history of digital mapping in Wessex and look ahead to its continuing expansion. The second part explores three specific topics in greater detail, based on experience acquired to date: specifying DM requirements, data capture and operational applications.

1. WESSEX WATER AUTHORITY AND MAPPING.

1.1 ABOUT WESSEX

Wessex is one of the ten Regional Water Authorities set up in England and Wales in 1974. It has responsibility for all aspects of the water cycle, including supply and distribution, land drainage, sewage treatment, pollution control, river management and recreation. The residential population served is over two million, but this increases during holiday periods. Other salient statistics: length of supply mains 17,200 km; average daily quantity supplied 378 ML; total length of sewers 11,300 km; length of main rivers 2355 km.

Since its establishment, Wessex has acquired a reputation for its strong commitment to the use of Information Technology where it can be shown to bring positive benefits. In addition to Digital Mapping, the main theme of this paper, extensive use is made of digital communications, telemetry and Computer Aided Design.

Following an extensive survey, a digital communications network for voice, computer and telemetry data has been established linking all major offices. This provides up to 2 Mbits/sec capacity using a ring configuration to maximise resilience. By means of this, all major locations can obtain access to the centrally-located mapping processor.

The telemetry system covers all significant operational sites with over 350 out-stations. All supply and most sewage treatment sites are unmanned and monitoring and control is carried out by control rooms. One of the main uses is the management of the network, for example in regulating pressure to minimise leakage. Network simulation is used extensively and this will be linked to mapping in the near future (see 1.3 below).

Although systems capable of both Digital Mapping and CAD were evaluated, it became apparent that the optimum solution for Wessex was to install the most effective systems available for each application while at the same time providing links between them for the transfer of data. The CAD system runs on the IBM 'look-alike' mainframe and is the basis of all major new works design carried out by the Authority.

1.2 THE FIRST PHASE, 1979-85.

With considerable foresight, Wessex first made the commitment to Digital Mapping in the late 1970s. Although it was not possible at that stage to achieve the full benefits of the inchoate technology, it was appreciated that rapid developments would soon bring these to fruition.

When Wessex was established in 1974, it assumed the responsibilities of numerous predecessor bodies such as river boards, water boards and rural district councils. As a consequence of this, the map-based records - which the Authority is under a statutory requirement to keep - were particularly heterogeneous, with a wide range of accuracy, symbology and coverage. One of the many benefits of the digital mapping data capture exercise was that it imposed a valuable discipline which ensured that all records met a common standard of accuracy and completeness. Indeed, the number of man-hours spent on digitisation roughly equalled that spent on site surveys and correction of records.

At the time of its inception, developing digital mapping meant exactly that; "off-the-shelf" hardware was acquired and it was then linked up by Wessex staff. Concentrating solely on the water supply function the emphasis was placed on data capture. The necessary software was also written in-house, for example, allowing for the stretch and skew of maps and enabling records based on the old 'County Series' maps to be digitised according to the Ordnance Survey National Grid. At a later stage, software for data extraction - for example, according to street name, or summing lengths of main by their properties - was developed.

By 1984, digitisation of the supply network on the in-house system was largely complete. Increasingly, however, a sense of frustration was being felt that this substantial database was not realising its full potential. In particular:

(i) direct user access to the system was limited;

(ii) map boundaries were present, as with paper maps, and these constituted a major limitation;

(iii) there were no facilities for map backgrounds;

(iv) the handling of attribute or non-graphic data was limited;

(v) the extension of the software to cater for sewers, rivers and other aspects would require several man-years of development and even this would fall short of what had become commercially available;

(vi) interchange of data with other systems was difficult - this included not only Wessex' mainframe applications (CAD, network analysis etc) but also plant data from other utilities.

The intermediate stage involving the acquisition of a replacement for the in-house system was lengthy and detailed, as befits such a major capital investment. It is the subject of a separate section (2.1) of this paper.

1.3 1985 ONWARDS.

In spring 1985 a DM/FM system was selected by the Authority which it was believed came closest to meeting the multiplicity of requirements in both the short and longer terms. The chosen configuration was a VAX 11/750 processor, centrally located adjacent to the mainframe, with initially two workstations, one for development and one for operational trials. A further two workstations were acquired in spring 1986. In addition, there are a number of 'enquiry stations' based around the IBM-PC. All hardware is linked via the communications network (see 1.1). The option exists to upgrade the system in a number of ways.

In addition to the central system, an essential part of the overall contract was several items of custom-built software. Firstly, this provided the ability to transfer from the old system the digital supply network data which represented a substantial investment in man-years of effort. Secondly, it made possible the two-way exchange of maps between DM and the Authority's CAD system; for example so that background maps could be shared between systems. Thirdly, it provided direct links between the mapping and mainframe computers, for a number of reasons, some of which are discussed below.

The clear intention when Wessex made its investment in Digital Mapping was to realise the benefits as rapidly as possible. To this end, a number of developments are now taking place in parallel, each of them selected to maximise cost-effectiveness.

Water Supply. The database inherited from the in-house system is beginning to be used as the definitive plant record. Operational staff have been given the software 'tools' to update this record as changes are made to the network. Time series data, which was previously recorded manually, relating to bursts and similar incidents will shortly be added. In this way management will be able to quickly review the 'burst history' of the network and the replacement programme can be more accurately tuned to the condition of the assets. In the longer term, the considerable attribute database - including diameters, materials, C-values etc - is expected to provide the static network data for network analysis, thus giving the usual benefits in terms of reduced redundancy and inconsistency of data.

Recovery (Sewerage). Digitisation of the sewers in one of the major urban areas of Wessex is expected to be complete during the third quarter of 1986. In addition, a number of methods of inputting sewer and manhole data 'on site' are in use - these are discussed in section 2.2. Sewers represent a major asset, much of which is now in a state of disrepair. Wessex, like other UK Water Authorities, is drawing up a sewer rehabilitation programme and information on sewer condition is a vital input to this. Digital mapping provides a means for recording this information logically and consistently and also collating and presenting it in a format appropriate to management's requirements.

River Management. The relationship between abstractions, discharges (including pollution) and river flow is fundamental to the achievement of the Authority's objectives. River data will show the numerous sampling and extraction points and the upstream/downstream relationship of the network. Using the links to the mainframe computer, where an extensive archive of water quality data is kept, it will be possible to explore the temporal and spatial distribution of water quality.

2. EXPERIENCE TO DATE

2.1 SPECIFYING DIGITAL MAPPING REQUIREMENTS.

The acquisition process for the replacement mapping system in Wessex was both lengthy and rigorous, involving two distinct stages. In the first stage, all likely suppliers - a total of fifteen - were asked to respond to an outline specification of Wessex' requirements. The responses to this provided sufficient indication of which suppliers came closest to meeting the complex specification, and a shortlist of three was drawn up for closer examination. The requirements for true facilities management - rather than drafting capabilities alone - and for links to other systems proved to be most exacting.

The three suppliers remaining from the first stage were subjected to a three-part evaluation exercise: mapping benchmark, computing benchmark and site visits. The first of these called for the display of maps from both Ordnance Survey and the Wessex in-house system; graphical data capture, editing and display; and the use of attribute data. The second looked at aspects such as remote operation; operating system and security; data exchange between systems; and the effect of multiple usage on timing and performance. Finally, suppliers were asked to arrange visits to existing installations which they believed would closely parallel the proposed operation in Wessex 2-3 years after installation.

An essential input to the initial specification and the content of the second-stage evaluation was a knowledge of the Authority's requirements wherever mapping is likely to be applied. As always in such situations, a middle course has to be sought which stimulates the interest of potential users without "promising the earth". In this respect the in-house system in Wessex - or a similar pilot exercise - is invaluable, providing exposure to the concepts at all levels of the organisation, without the need for heavy capital investment.

A low-budget pilot has the advantage that lessons can be learnt or mistakes made without unduly serious consequences. Indeed, the shortcomings of Wessex' in-house system made a major contribution to the specification of requirements for its replacement. Potential applications were clear but could not be realised, and this could be demonstrated to users. At the higher level, senior management were able to come to terms with the concepts and implications of digital mapping and their commitment was the greater because of this.

2.2 DATA CAPTURE.

A major dilemma facing those wishing to invest in Digital Mapping relates to the capture of data. This usually involves a lengthy and expensive commitment of resources, whilst at the same time the true benefits cannot be realised until a substantial database is built up.

One way to break this 'vicious circle' is by means of a low cost combined pilot and data capture exercise as discussed above. The data can thus be loaded on to the system without a major capital investment beforehand. At the same time, the discipline imposed by the need for accurate and consistent data provides a validated database which represents a considerable improvement in the quality of data available to the user; this regardless of the outcome of the pilot.

Equally, many organisations will already have geographically-based data - perhaps on mainframe - which is suitable for display on a mapping system. Links between systems, of the type already discussed, can be utilised. For example, in the case of public utilities, the billing system may include a location reference (in the UK, the postcode). In this way the geographical database can be enriched rapidly and effectively.

At the other end of the spectrum, many organisations find that their records of plant are in a very poor condition or cannot be relied upon for their accuracy. In the UK, records of the sewer network - some of which may be over 100 years old - sometimes fall into this category. Wessex now has a well-proven suite of programs for the capture of sewer and manhole data, based on the 'Husky' hand-held computer. The operator is able to visit the site and is led through a series of questions which ensure that the data is input direct to digital storage in the computer. This can later be transferrred direct to a floppy disk on a desk-top computer, and thence to either the mapping or mainframe computers. The Ordnance Survey National Grid - which provides a unique reference for any point in the UK - provides the 'key' which enables plant to be shown in its correct geographical location on the mapping system using the grid reference input on-site.

2.3 OPERATIONAL APPLICATIONS.

Because of the existence of an established database, Wessex Water was able to move relatively quickly to a situation where digital mapping could be applied operationally. This section aims to highlight some of the experience gained from that.

Firstly, background maps should be made available wherever possible. Although street-name look-up facilities can act as a substitute in some circumstances, a high proportion of applications call for a knowledge of the location of plant relative to distinct geographical features. This is particularly true in the case of public utilities, much of whose plant is at or below ground level. Many potential users of mapping have had years of experience of paper maps based on backgrounds, and a similar product on screen also has psychological benefits. Unfortunately, to date less than 15% of the UK has been covered digitally by the national mapping body, Ordnance Survey. Many users therefore find themselves in a dilemma, with the choice of either waiting for O.S. or having digitisation carried out in-house or externally.

Secondly, training potential users needs to take into account their intended use of the system. Only those involved in system development need to have an overview of the entire system and its capabilities; specific users must be shown how their particular requirements can be met and how this brings an improvement in current practice.

Finally, digital mapping can offer a wide range of capabilities and hence applications. These must be prioritorised so that the greatest benefits can be achieved first: specific users should be 'targetted' and their commitment assured.

CONCLUSIONS

DM/FM is a powerful tool which Wessex believes will be applicable to all geographically related functions.

A low-cost data capture exercise makes it easier to justify investment in DM/FM.

The bulk of Wessex' requirements were based on experience of the pilot system and its limitations.

Geographical data is available from a number of sources.

The lack of digital map backgrounds in the U.K. is an impediment to developement.

The author would like to express his thanks to the Wessex Water Authority for permission to give this paper. Any opinions expressed are those of the author alone, not of Wessex Water Authority.

THE DEVELOPMENT OF AN AUTOMATED MAPPING SYSTEM FOR THE ELECTRICITY DISTRIBUTION SYSTEM IN THE SOUTH WESTERN ELECTRICITY BOARD

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ABSTRACT

The Electricity Supply Boards of the United Kingdom are required by statute contained in the Electric Lighting (Clauses) Act 1899 to maintain records of underground mains and services. The South Western Electricity Board had by 1981 accumulated 19,000 record maps of urban and rural networks based upon Ordnance Survey map background and normally held on translucent material for reproduction. The maintenance of this stock of records in this form is a significant manual task comprising updating and replacement of the ageing archive. In 1981 consideration was given to the transfer of these records and the associated map backgrounds to digital form to eliminate this task and to establish an associated data base for design and general facilities management concerned with the Board's assets. The paper describes the project trial which was undertaken to evaluate this possibility and which formed the basis for an investment appraisal which subsequently led to a Board-wide installation of computer graphics equipment to provide an automated mapping and facilities management system by the early 1990's.

INTRODUCTION

The South Western Electricity Board supplies the south west peninsula of the United Kingdom from Bristol to Lands End. The area, some 14,400 square kilometres, contains more than one million electricity consumers supplied from 28,000kms of overhead network in the rural areas and from 16,200kms of underground cables in the urban areas. The Board's general management is based at its Headquarters in Bristol and four regional managed units are located at Bristol, Taunton, Exeter and Redruth in Cornwall. There are also subsidiary offices at Bath, Weston-Super-Mare, Barnstaple, Torquay, Plymouth and Bodmin.

The statutory requirement to maintain records of the distribution system has been met by the creation of 19,000 record maps, made up of 11,000 records at 1:2500 scale in rural areas, and 8,000 urban records at 1:500 scale or larger.

The average life span of such records held on translucent, often diazo, material is of the order of 20 to 30 years. As time passes the film can darken or be damaged by handling or alteration, which affects legibility when such records are copied. In 1981 it was assessed that 10,000 record maps required replacement. Records showed that the rate of replacement of urban records at 1:500 scale was 13 maps per draughtsman per year and that with the then employed numbers of draughtsmen the replacement task was increasing rather than diminishing. Even if the numbers of staff were increased to overcome the backlog it was evident that there would be an ongoing residual replacement task requiring 30 draughtsmen.

The introduction of a computer-based map record system could break this cycle and it was envisaged that if the appropriate data base concerned with the electrical attributes of the distribution system could be associated with the records, a facilities management system could be provided.

Whilst such concepts were clear, the costs, timescale of achievement of the transfer, impact upon staff and other issues could not be assessed. It was decided, therefore, that it would be proper to establish a working trial to develop procedures and practices, and to evaluate the productivity gains that computer graphic systems could offer. In due course a full investment appraisal would be made. Fortunately some years before, a limited trial of computer graphics equipment had been undertaken in the Board's Plymouth Office and although that system was crude by comparison to equipment available in 1981 it did mean that there was some working experience of such systems amongst the Board's engineering and computer staff. The project trial was begun in the Board's Somerset Office at Taunton in the Autumn of 1981.

The Somerset Trial Project

Following a review by the Board's computer staff of computer graphics equipment available in 1981 a turnkey contract was signed with Intergraph (Great Britain) Ltd to supply a DEC PDP 11/23 processor, two LSI monochrome workstations, a pen plotter and associated equipment. A project team of distribution engineers, computer staff and operators was established and supervised by a small senior management team. The Project Team was given terms of reference which were:

"to become fully conversant with the equipment; to establish standard working practices within mapping systems, system diagrams and a data management retrieval system; to seek to demonstrate the productivity gains; to monitor all work undertaken and to report in such a manner that senior management might consider the wisdom of further investment."

The central processor was installed in an air-conditioned room but the workstations were installed in the drawing office so that staff would become accustomed to such equipment since this marked the introduction of computing equipment into locations where working practices had varied little over many years.

The operators, chosen on the basis of their aptitude and interest in such development, were trained initially by the equipment suppliers but much of their ability was as a result of a self-learning process. Computer support staff also received specialised system support training from Intergraph.

The area of project study chosen was Glastonbury in Somerset. This town had a mixture of urban and rural networks and was fairly typical of those encountered in the south west. No Ordnance Survey (O.S.) digital mapping was available for the area but this was not seen as a disadvantage since it was envisaged that there would be times in the future when SWEB staff would undertake limited map digitising tasks. The project area was covered by 109 records at 1:500 scale and 15 at 1:2500 scale. The scope of the project was established as:

- the attainment of operator efficiency; storage, retrieval and use of digitised data.

- the establishment of standards for symbols, text, line weights.

- the creation of file registers and access systems.

- the creation of new records.

- the establishment of protocol and procedures surrounding the computer system in terms of back-up to files, system recovery and security.

- the establishment of an engineering data base associated with the map record of the distribution system.

- the application of computer graphics to other drawing office tasks concerned with schematic diagrams.

- the production of standard 'in house' user manuals of procedures which could be the basis for training other operators if the project was launched Board-wide.

Regular monitoring of the progress of the trial during the following 18 months, together with close liaison between the operators, the project team and senior management ensured that these goals were achieved.

THE RESULTS OF THE TRIAL

Firstly, the study area was hand digitised from O.S. chartpaper originals or enlargements therefrom, and a series of mapping symbol cells and user commands for their manipulation, was established as also were text sizes, line weights and symbology etc. Originally six levels were used, reducing finally to two - road names and remainder. Even during this limited exercise, digitising techniques learned reduced production time per map from 19 to 10 hours.

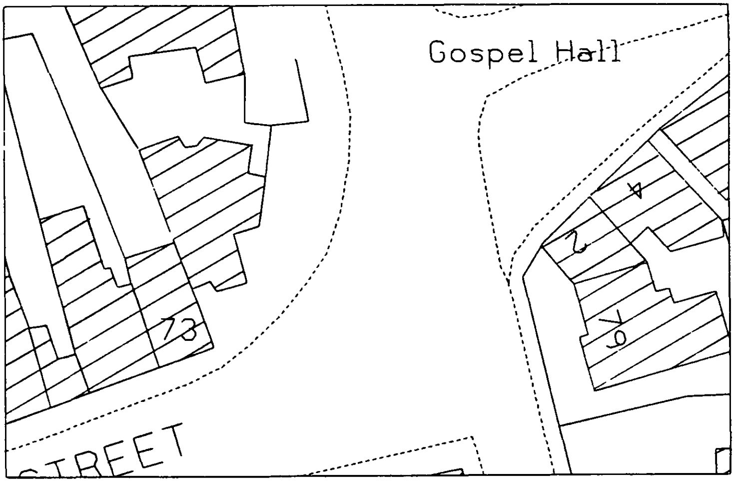

Figure 1 illustrates a section of such a map background within the project area.

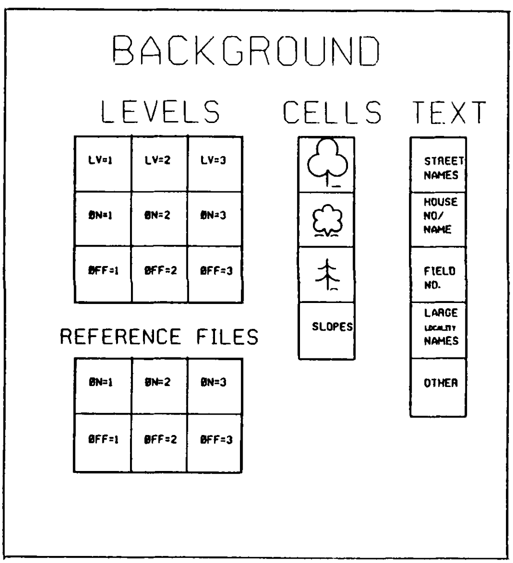

Figure 2 shows the menu developed for the operator to use in this process.

Experiments during the trial showed that the use of skeletal background information with limited features of house outlines and very little background data was unsatisfactory from a user point of view. Also, although considerable improvements in output were achieved, it became clear that if the Board were to attempt to create its own mapping base as well as to capture the asset record the task would extend well into the next century.

The next area of development concerned the capture of the digital record of the mains distribution system. Again cells, user commands and menu were established for the mains distribution system including text sizes and line symbology. At the same time procedures were established which associated plant data with spatial referencing thereby producing an interactive database. These enabled the route of the distribution of electricity to be traced from the source to consumers, present analysis of common information, separate levels of voltage and use the record maps at a variety of scales for new construction, maintenance, fault location and so on.

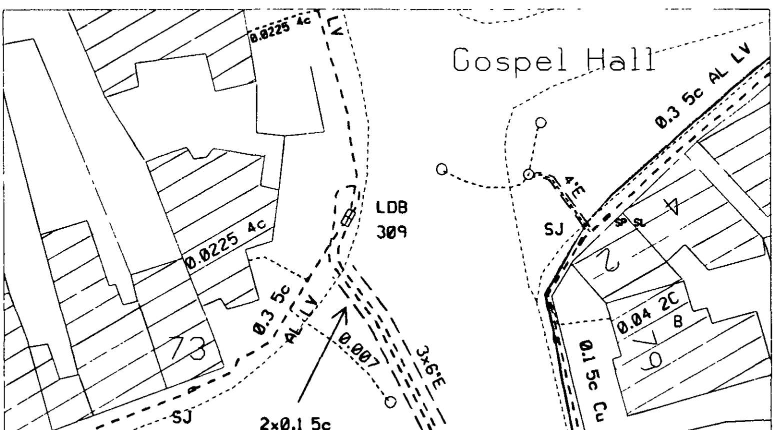

Figure 3 illustrates the product of this work in which the asset record has been superimposed upon the digital map background. It should be realised that this overall picture can be simplified by switching on and off various levels.

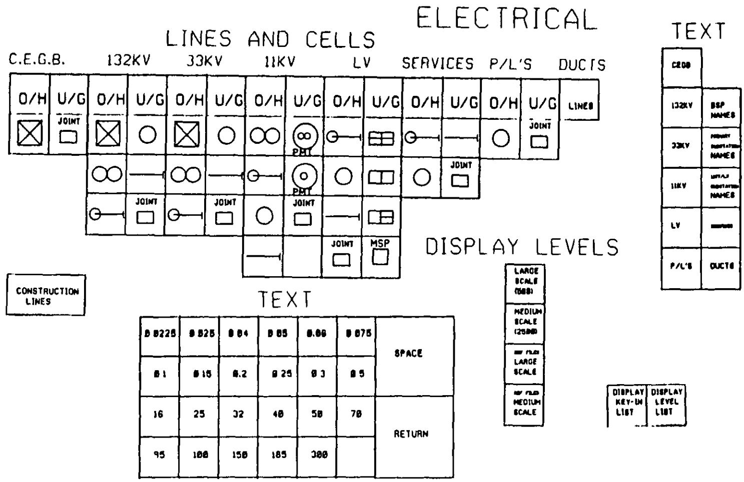

Figure 4 shows the menu used by operators to develop such records.

At the conclusion of the project the Project Team prepared User Guides to enable additional operators to be trained for the applications developed. It was also decided that Intergraph equipment would be used for the main task.

THE INVESTMENT APPRAISAL FOR PROCUREMENT OF A COMPUTER GRAPHICS SYSTEM FOR AUTOMATED MAPPING AND FACILITIES MANAGEMENT IN SWEB

The project development thus far described proved that the advantages envisaged were achievable and provided the basis for an investment appraisal to determine whether there was a cost benefit in adopting such a course of action. In preparing such an appraisal there were two central issues to be considered which were:

- that digital map backgrounds could be obtained for the whole of the Board's area at a rate and for locations determined by the Board's programme.

- that the Board could regulate its progress and rate of investment in computing equipment such that the overall programme would be completed within an acceptable time and also that early investment would not be quickly outdated by technological advance.

The Procurement of Digital Map Backgrounds

Throughout the project period the Board maintained a close liaison with Ordnance Survey so that O.S. were aware of the Board's intentions. In 1984 O.S. digital coverage of the south west was 75 1:1250 maps and 1273 1:2500. This represented only 150 urban and 636 rural sheets out of the total of 19,000 records! The Board gave a commitment to O.S. that if its investment was approved it would purchase every digital map that was produced.

With the best of O.S. intentions, it was obvious they would not match requirements and in consequence the Board explored many avenues to obtain digital maps. These included hand digitising map contractors and scanmapping. Trials showed that the most successful and economic souces were scanmapping systems which produce vectorised maps with two or three levels of data. The use of scanmapping is not without its problems. Enlargement from the original scale needs to be restricted if distortion of the images is to be avoided. It has not proved practical to scan SUSI sheets. The file storage for scanmaps can range from three to five times that for O.S. maps of equivalent density. Some editing of scanmaps is necessary. The final conclusion was that from O.S. or scanmap sources, a mapping base to match our programme could be obtained.

The Programme for Record Transfer and Investment Appraisal

It was recognised that the transfer of 19,000 detailed record maps to the automated map would be a formidable task. The period in which the task could be completed is a function of the number of years chosen to complete the work, the number of workstations purchased and the number of operators employed. It was decided that a period of 10 years for completion of the programme would be acceptable in terms of expectation and motivation. The assessment of digitising progress rates in the trial enabled the number of workstations required to be calculated from this decision with some phased for later introduction to allow for technological improvements.

The investment appraisal was based on the following factors:

- additional staffing cost for a conventional redraw of out-of-date records and the continued employment of staff to maintain the archive after this period.

- the phased purchase and replacement of computing equipment for record transfer to digital form, software support and digital map purchase.

- staff savings in other activities as facilities become available.

The study covered a 15 year period commencing at the beginning of the project trial, and gave the following results using present values derived from a 5 per cent discount rate. (A 5 year replacement of computing equipment was assumed.)

Equipment Cost	-	£4.67M
Additional Staff Costs	-	£3.33M
Other Savings	-	£1.59M
Net Present Value of Benefit	-	£0.25M

CONCLUSION AND THE FUTURE

As a result of the Project Trial and Investment Appraisal, the Board has now equipped each of its four regional offices with Intergraph systems comprising DEC VAX 11/751 processors, workstations and the appropriate memory and disc storage. Remote workstations have also been installed at Head Office and the Plymouth Local Office, these being connected to the processors by kilostream links. During 1985 and 1986 some 25 operators were trained. In the initial year whilst the staff were developing their skills some 500 records were digitised and the programme for the current year anticipates that some 1750 records will be transferred. This work is supported by purchase of digital map tapes from O.S. where available or by purchase of scanmaps.

At present when a record has been transferred to digital form a master copy is added to the file and used conventionally. Once significant coherent areas of network have been completed the hard copy records will be withdrawn and the computer system will be used for all purposes. At this stage mainframe compatible workstations will be introduced to provide the necessary interface between the graphics system and its data base and the related data held within the Board's other computing system. As necessary additional memory and disc drives will be purchased.

The present and future integration of the automated map/facilities management system into the Board's day-to-day business procedures is now overseen by a Steering Group of senior staff. The emphasis of this work is now concerned with development of procedures for the design of, extension to or reinforcement of the distribution system and the support of maintenance work on plant, cables and overhead lines. Procedures have also evolved for many other frequent tasks in the Board's drawing offices including the design of civil structures, office design, electrical wiring diagrams, schematic diagrams. Whilst such activities did not form part of the main justification for the investment made there is no doubt that such applications assist the general justification of the investment and increase staff involvement.

The Board has committed itself to a future in which a significant portion of its facilities management will be based upon the automated map. The decision to go forward in this manner was made from a careful assessment of the potential and costs of such systems and would recommend such an approach to any other business considering embarking on a similar path.

EXCHANGE OF DIGITAL RECORDS BETWEEN PUBLIC UTILITY DIGITAL MAPPING SYSTEMS

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ABSTRACT

There is a need for Public Utilities to exchange information concerning their mains and plant records. The introduction of digital records systems in the utilities offers the opportunity for exchanging these records in digital form. This paper describes the work being done in this area, particularly that at Taunton where records are being exchanged between individual utility digital records systems. The Taunton trial has highlighted a number of key issues relating to commonality of digital base maps and their updates, and also relating to the data exchange formats.

BACKGROUND

The Requirement to Exchange Records

There is an existing practice for Public Utilities to exchange records in connection with major operations covered by the Public Utilities Street Works Act, 1950 (PUSWA).

PUSWA governs the relations between the undertakers (Public Utilities) on the one hand and the persons or bodies who own or control the highways on the other. It also provides a code to regulate the relations of undertakers amongst themselves when the operations of one undertaker interferes with or affects apparatus belonging to another. Before the commencement of any major works there must be an exchange of a notice and records indicating the proposed works. There are, however, two exceptions. Emergency works may be carried out immediately with the details being provided subsequently and for minor works, particularly services, there is only a requirement to serve a notice with no provision of records.

The present procedures covering the implementation of PUSWA impose a considerable clerical and drawing office task for the organisations involved. The introduction of digital records will not directly affect the statutory obligations to provide a notice but it does offer the opportunity to make improvements in the exchange of records.

The requirement to exchange records is not simply to fulfil a legal obligation, but it is necessary for the protection of operatives involved in street works and to limit the damage to underground mains and plant. A survey conducted by the National Joint Utilities Group (NJUG) in 1981 indicated that the national cost of mains and plant damage was of the order of £14 million per annum. Prior knowledge of the location of other utilities mains and plant will also lead to benefits in the planning of street works.

A review of street works activities has recently been completed for the Department of Transport, reference HORNE (1985). Whilst not actively promoting the exchange of digital map based records, it has identified the need for more computerised information on street works.

NJUG Trial at Dudley

Recognising the opportunity which digital records offers for exchanging information, NJUG set up a five year trial in 1982. This was located at Dudley and covered an area of 50 square km, some 250 map sheets. The principal objectives of the trial are:-

(i) to establish standards for the interchange and display of digital mains records
(ii) to gain experience in the methods and techniques involved in the joint use of digital records and map backgrounds
(iii) to reduce the level of utility damage and to investigate the implications for PUSWA

All four utilities (electricity, gas, water and telecom) and the local authority are participating in the trial. Each has digitised its own records over a common map base, which was provided in digital form by Ordnance Survey. The system is based on a shared central processor to which the individual utility workstations are connected.

Whilst the trial has not yet been completed, some interim conclusions have been identified. The use of a shared processor system implies that the operational units of the individual utilities need to have coincident boundaries. In practice, this is not the case and even at Dudley comprimises have had to be made. Consequently, further developments in exchanging digital records between utilities need to be based on a different technique; exchange between individual utility digital mapping systems is seen as a suitable alternative.

The Dudley trial has a major advantage in using a shared map base thus automatically ensuring registration between the individual utility records. In exchanging records between systems, this question of registration is very significant.

The NJUG trial has been important in creating co-operation between utilities on the question of exchanging digital records to assist in street works.

TAUNTON JOINT UTILITIES TRIAL

Introduction

In 1983, the utilities in the South West agreed to investigate areas for co-operation through the exchange of records. It was necessary for initial work to involve a very limited scheme in order to minimise costs, resources and the timescale to implement the pilot project.

Initial Taunton Trial

The Taunton Joint Utilities Group (TJUG) was established and a trial was set up at the end of 1983. The initial participants were South Western Electricity Board (SWEB), British Gas South Western, Wessex Water and British Telecom; subsequently the local authority (Taunton Deane Borough Council) was also included.

The initial trial was based on a 1 sq.km. area in the centre of Taunton. Taunton was chosed as this was the location of the initial SWEB digital records system. The Ordnance Survey agreed to support the trial by including the urban area of Taunton in their digital map program.

The utility records for the initial trial area were digitised by SWEB and a hard copy of all the records was provided to all utilities. At this stage, only SWEB had a digital records system available in the Taunton area.

For the trial area, utilities had prior knowledge of the location of all underground mains and plant to assist their operations. For major works, it was only necessary to confirm that these records represented the most up-to-date situation. SWEB, besides undertaking the initial digitising also maintained all utility digitised records in the trial area.

Whilst the initial trial was set up and was operating satisfactorily, it was evident that the trial area was too small. It was agreed to expand the trial area and to introduce the exchange of digital records to overcome the overheads in managing hard copy maps inherent in the initial trial.

TJUG Phase 2

In July 1985, the trial was expanded to cover a third of the Taunton urban area,6 square km. The objectives set for phase 2 of the trial included:-

- (i) to expand the procedures set up in the initial trial for monitoring damage to underground mains and plant in the trial area with the longer term objective of assessing the reduction in damage arising from improved, more timely records information.
- (ii) to examine the alternatives available and the implications for the exchange of digital records.

Two utilities, electricity and gas, had digital records systems operating in the trial, whilst systems in the other utilities had not been incorporated at that stage.

At the time of setting up the second phase of the trial, Ordnance Survey had not digitised a large enough continuous area adjoining the initial trial area. Consequently, 12 Ordnance Survey digital maps were used together with 7 map sheets of vectorised scanned maps, all at 1/1250 scale. No problems were encountered in integrating these two forms of digital map, however, the scanned maps required some updating as they had been produced from published map sheets.

Identical versions of the digital base maps were installed on the electricity and gas systems and all utility records were digitised. Hard copy plans were again produced for all utility records as an interim measure prior to digital records systems being available for all utilities in the trial area. In order to reduce the paper burden, some rationalisation of the hard copy output was achieved so that four A1 sheets were prepared for each 1/2 x 1/2 km quadrant :-

(i) Telecom and Gas at 1/1250 scale
(ii) Water and Sewer at 1/1250 scale
(iii) & (iv) Electricity at 1/500 scale

The format of the joint sheets is illustrated - fig. 1.

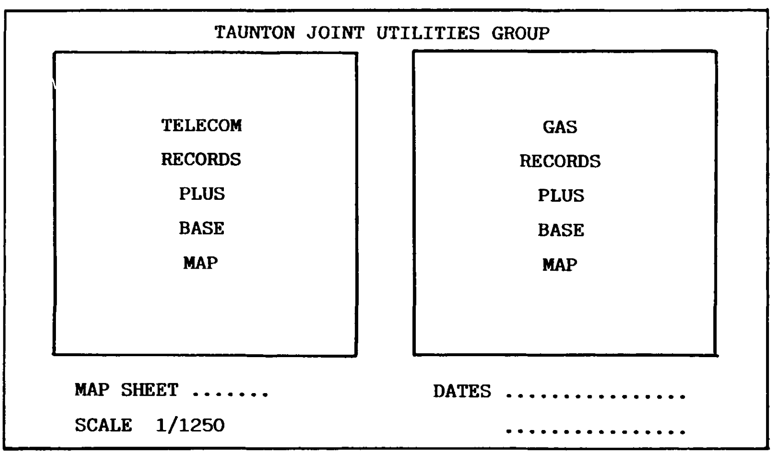


Fig.1 TJUG joint hard copy format for Telecom and Gas

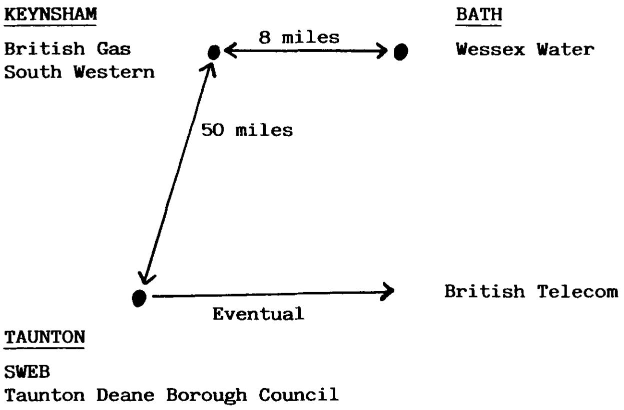
For electricity and gas, digital records for all uitilities were exchanged between the systems using magnetic tape transfer. This exchange excluded the base map.

Progress at Taunton has been necessarily slow since a second operational system was required to reduce the workload on SWEB before the second phase commenced. Also work at Taunton is being undertaken as an adjunct to the existing operational priorities for digital records in the utilities, as opposed to Dudley where the exchange trial is the only priority for the system. This point is demonstrated by the two preceding papers by Wessex Water and SWEB, references Bolland (1986) and Hoyland (1986). This should not be construed as a criticism but as a comment on the realities of the way digital records are being introduced by the utilities.

The hybrid operations involving both digital and hard copy records at Taunton again reflect the situation where utilities will move into digital records with differing timescales and priorities.

<u>TJUG Future</u>
The Taunton trial will expand to incorporate the whole of the Taunton urban area and also to include the other utilities digital records systems.

Not all the utility systems involved in the Taunton trial are located at Taunton, indeed the method of operation does not require that they are closely located. This enables the trial to accommodate the differing needs of utilities for digital records and also their different operational boundaries. The location of the systems is shown diagramatically in fig. 2.



<u>Fig. 2 - Diagrammatic location of systems in TJUG</u>

Operations at Taunton have identified a number of major issues which are considered in the next section.

MAJOR ISSUES FOR THE EXCHANGE OF DIGITAL RECORDS

Digital Base Maps

In order to be able to exchange digital records between systems and for these records to be correctly registered in each system, it is essential that identical copies of the base map are used by all utilities.

This has major implications for the future outside the area of the Taunton trial, since utilities will work in areas according to their operational priorities and it is unlikely that these will be coincident. The Taunton trial, where all utilities are working together, is aiming to produce standards for the exchange of records which utilities can work to in the knowledge that they will ultimately be able to successfully exchange records when other utilities have digitised their records in a specific area.

This vital question of the provision of a common base map goes beyond the question of the supply of base maps. The issue of the incompatibility between the needs of utilities for digital maps and the Ordnance Survey digital program has already been discussed, reference IVES (1985). The question which has yet to be addressed is the provision of updates to digital maps and the form of these updates.

At present, Ordnance Survey has digitised some 25,000 large scale maps in Great Britain, unfortunately only 250 of these in the Dudley trial area are being kept up to date. Consequently, utilities are having to maintain their digital base maps themselves. When this situation is considered with the need for identical base maps in utilities digital records systems, a substantial problem is revealed.

Under the controlled conditions at Taunton, updates of the digital map base can be satisfactorily achieved, however, in other areas this may cause substantial problems. Should utilities not be able to achieve commonality in base maps, and their update, then records are unlikely to be able to be registered correctly in other systems and a major area of benefit of digital records will be lost.

At Taunton, areas of base map change are identified on a copy of the latest version of the geography, namely the supply of hitherto unpublished survey information (SUSI) from the Ordnance Survey. The area of change is digitised and the merged with the digital base map. In this way, only the records in the area of change need to be adjusted, in the remaining part of the map the records are untouched as they remain correctly registered.

Records Updating

The present operations are based on the principle of each utility holding a copy of each others records. These records need to be kept up to date and checks are required to ensure that the data is not 'lost' or corrupted.

At Taunton, utilities issue a new copy for their records in a 1 km square where there is an amendment to the mains and plant details. This is felt to be the best way to control the data. An amendment process based on passing details relating to a particular piece of main is likely to be difficult to control and would lead to errors, which would be unacceptable.

Data Exchange Format

The format of the data being exchanged between systems must comply with the following:-

(i) The format must be transportable across a range of manufacturers systems and must be independent of the way in which a particular utility system is set up, i.e. in terms of resolution and units.

(ii) The large volumes of data associated with utility records, particularly electricity, require the data transfer to be efficient and not rely on processes that are onerous.

The first requirement effectively rules out transfers in the internal format of a particular system, which would only be able to take place in a few instances.

A universal exchange format is available since all systems in the utilities must be able to read digital map data in Ordnance Survey format. Working on this, NJUG and Ordnance Survey agreed, in early 1985, an expanded feature code structure for the proposed new Ordnance Survey transfer format (OSTF) for digital map data, which would allow codes for utilities mains and plant data.

This would appear to be a most suitable format, unfortunately it has two major drawbacks :-

(i) The Ordnance Survey has been unable to implement the host format (OSTF) for its own map products in the intervening period , since the proposals for the exchange format were published in February 1985. This failure has compromised the major advantage for utilities of using OSTF format which would have meant both base maps and other utilities records formats would have been common.

(ii) Being a universal 'high' level format does lead OSTF to be inefficient in terms of the processing power required to transform it into systems internal data formats, and vice versa.

Consequently an intermediate format would seem desirable in order to reduce the processing for data translation. A suitable format already exists, namely Standard Interchange Format (SIF) developed by Intergraph and widely used in USA.

SIF is used as the data transfer format in the Taunton trial.

Data Exchange Mechanisms

At present, data exchanges between systems in the Taunton trial use magnetic tape media.

There is nothing inherent in the present operations which would inhibit direct connection of the host processors. The question of controlled transfers over a data link or of interactive linking into other systems will be a matter for individual utilities to resolve in the future. Interactive linking would have the advantage of not requiring utilities to hold copies of each others data, but such an operation would require acceptable response times for data requests and would also need to determine the availability of the service, for example out of normal working hours.

CONCLUSIONS

The main conclusion deriving from both the Dudley and Taunton joint utility trials is that utilities can co-operate to exchange digital mains and plant records.Exchange using digital records greatly improves access times to data and reduces the clerical overheads inherent in the process of exchanging hard copy records. More timely availability of data will lead to better information being available for short lead-time operations, including emergency work.

In addition a number of conclusions have been drawn from the operations at Taunton involving exchanges between individual utility digital records systems even though the trial has yet to be completed.

1. An identical digital map base must be installed in each utility system to ensure the correct registration of records. This is seen as a major problem with the current lack of availability of a single source of digital maps in the required timescales.

2. It is also essential that each utility holds the same updates for the digital map. Unlike conventional maps, there are no digital map updates available, except on a limited basis at Dudley.

3. A universal, efficient data transfer format is required. The intermediate format SIF is seen to be the most suitable, although transfers using Ordnance Survey data formats could be used if SIF was not available on a particular system.

ACKNOWLEDGEMENTS

The authors would like to thank British Gas South Western and South Western Electricity Board for permission to present this paper and also colleagues within the joint utilities trial at Taunton.

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DIGITAL MAPPING - AN INFORMATION CENTRE

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ABSTRACT

British Gas South Eastern has used the experience gained in its Digital Mapping trial to study the end users data access requirements and the use of information in geographic and alpha numeric form. The paper studies the historical use of maps, map based records, conventional mapping and existing alpha numeric data systems. The developments that have given the planning and operational engineer access to geographically based information through low cost workstations, "the Engineers Information Centre" are also examined. Many of the non-engineering departments within the organisation also hold map based records and the advantages of linking these to a single map base to form the "Corporate Information Centre" are discussed.

INTRODUCTION

Digital Records

Digital Records are referred to as AM/FM in North America, an abbreviation of Automated Mapping and Facilities Management. This North American jargon sounds impressive, but its meaning is not clear in the United Kingdom. AM/FM broadly is defined as computer aided cartography (AM) and the management of the business or information that can be made from records that are associated with the map (FM). To explore the potential benefits offered by Digital Records within the Gas Industry, we need to understand why the Industry maintains map based records, what these records are and what other existing records systems are used to store information.

The largest map user in British Gas is the Distribution Department which is responsible for 210,000 Km of underground plant held as records on some 90,000 large scale map sheets. These map records are the key to an Information Centre. The other map based records maintained by the Engineering Department, together with existing alpha numeric computer files, form the basis for creating a fully integrated Digital Records System.

HISTORICAL USE OF MAPS

Early Recording

Towards the end of the Nineteenth Century, the small Gas Companies had information requirements similar to today's organisation, though naturally, this information was much smaller in volume. As gas mains were laid, their position and depth were recorded relative to existing geographic features often in "Book Form" as sketches and not to scale. Annotating the sketch were details of the pipe, its diameter, material, its length and other information, who laid it and, sometimes, the cost of labour and materials. These records were ideally suited to their purpose as the same person was often responsible for the planning, construction, maintenance of the gas supply system and service connections to customers. Under these circumstances, these books could almost be considered to be personal information systems.

Early Planning

The need to plan the gas supply to a town and the expansion in terms of the number of staff involved meant that the book records became inadequate as a planning tool because it was impossible to maintain an overall perspective of the network or see any geographical relationship between one street and another. Some form of map base had to be used. Map sheets at 1:2500 scale were chosen and the main's position drawn from the book records.

Due to the limitation of scale, not all the information from the books could be recorded on the map. Consequently, the line of the main, diameter, depth and some principal locations were all that could be transferred to the map to retain legibility.

Two Early Record Systems. These two record systems, book and map, had to be maintained in parallel. A straightforward task, though subject to error even if under the control of one person. The introduction of more than one person maintaining the records became the source of accumulated potential error.

Towards Today. During this century, the Industry's needs and expectation of its map based records have changed and developed. Today, many map based systems of recording are maintained, often witn record transposition from one system to another, in order to meet the demands for information that a modern utility imposes from its record systems.

CONVENTIONAL MAP BASE

Large Scale Maps

The master records of the Gas Network are held on paper or polyester film 1:1250 and 1:2500 scale Ordnance Survey. The maps show the route of buried plant and use line styles to differentiate between mains of differing pressures. They also indicate a limited range of other features. The Ordnance Survey National Grid at these large scales also provides a convenient, though not ideal, referencing system. To disseminate and communicate using the information, several mapping systems are maintained, each type containing the line of the main as a common entity and added details appropriate to its user needs. To achieve the aforementioned, there is a fundamental need to record the plant's relative geographical position to the surrounding geography and to maintain that record to ensure the plant's relocation at some time in the future.

As-Laid Drawings

The use of multiple line widths and styles at 1:2500 scale to represent mains means that it is impossible to draw them in their true geographical position when one or more are laid adjacent in the same street. To overcome this congestion, as-laid records at 1:500 scale or larger are produced by photographically enlarging the large scale Ordnance Survey maps and scaling the mains position from on-site measurements.

Detailed Sketches

Adding dimensions to large scale maps can cause congestion of information. Placing sufficient detail at complex junctions and mains connections can lead to confusion when trying to interpret the map on site. Detailed sketches, often freehand, are made and referenced from the map for these complex areas.

Other Large Scale Map Records

The Transmission System is recorded in addition to the master map on large scale maps, normally covering rural areas and contains precise locational information. Smaller scaled maps are used and maintained for Pipeline Act details and wayleave plans.

Planning

A separate system exists to enable expansion of the Gas Network to be made into areas of new housing or expand within established areas. This is achieved by using the developer's plan and adding the proposed gas mains. New building developments are photographically reduced and incorporated into the existing record at the appropriate scale when the developments are completed. In some cases, when the supply of the hitherto unpublished survey information (SUSI) is made available by the local Ordnance Survey Office, this is also incorporated into the map. If this updating system is used, the Gas Industry's mains and plant will need to be repositioned on the map to fit the new geography. This ensures that the relative position of the mains, plant and geography is retained.

Out-of-Hours Cover

To provide copies of the mains records to staff outside normal office hours, the large scale map sheets are microfilmed. The resulting fiche are distributed to appropriate personnel. A regular updating programme ensures that the sheets on which changes or additions are made (which represent approximately ten percent every six months) are refilmed and exchanged in the field.

Network Analysis

The analysis of pressure, consumer load, flows and their behaviour under various climatic conditions is used today in the operation and planning of gas supply networks. Large scale based records of plant are maintained for this purpose as separate drawings from the master record which, for operational reasons, are normally kept in various offices.

Conventional Map Base Summary
The volume of information that can be held on a map is limited by scale and the need for clarity. To overcome these difficulties the Industry maintains several map based systems at various scales, each containing detail appropriate to the user's needs. Transposition from one system to another causes progressive loss of accuracy and is labour intensive. The need to amalgamate records and maintain one map based system is clear.

ALPHA NUMERIC COMPUTER SYSTEM

Management Information in Engineering
In the late 1970s details of all mains that were maintained by the Distribution Department were transferred onto an alpha numeric computer system known as M.I.N.E. (Management Information in Engineering). This transfer required all mains to be defined as administrative units within a street. Each mains unit consisted of a section of main of the same material, joint type, age and approximate position, subject to a maximum length. A unique number identifies each street and each unit number within the street, together with a description of where the unit starts and finishes. A total of fifty items of information are held against every street and mains unit. This system enables management statistics to be automatically generated. To achieve this, job instructions are issued through the computer and information about completed work captured in alpha numeric form.

Planned Mains Units. As new mains are planned, they are described as planned mains units then added to the alpha numeric record. When the main is laid, its status is changed. This system is adopted for various operational reasons, changes to the proposal are sometimes made on site which may result in new units being created or destroyed and proposed mains are more easily altered if held at a different status.

The system has been very successful. The information being used is, by its very nature, geographically based and the system will be enhanced by the provision of direct access through a computer map.

Network Analysis
The large scale maps are used to show the position of nodes to define network analysis units. These contain data on the pipes: length; material; size and potential load. The unit definitions are held in alpha numeric form, which is subject to continuous revision as the network changes.

Details of gas demand are generated from Customer Account files and the flow and pressure between nodes is calculated across the system, taking into consideration the major factors that affect the gas network. Alterations can be made to establish the predicted change that will occur when one or more of the basic network design criteria are altered.

The output is normally in alpha numeric form. This is not ideal and often requires relating to a map or schematic network diagram for clarity.

Other Computer Systems
The Industry maintains other computer systems in non-engineering departments, such as Customer Service, Sales, Customer Billing. Many of these often contain a geographic association, which will be discussed towards the end of this paper.

The two major engineering systems, M.I.N.E. and Network Analysis, are naturally geographically based and form the basis of discussion here.

DIGITAL MAPPING TRIAL IN BRITISH GAS SOUTH EASTERN

British Gas South Eastern commenced a Digital Mapping Trial in July 1983. A multi-disciplined Project Team was formed and digital mapping equipment purchased. The aims of this project were to:

1) Substantiate the benefits of digital mapping.
2) Measure the impact on Engineering Standards.
3) Establish computer guidelines for digital mapping.
4) Research the secondary capabilities of digital mapping.
5) Investigate the effect of digital mapping on the organisation.

The Horsham District in the Sussex Area was chosen for the trial. This was selected for several reasons - the District's proximity to Gatwick Airport meant that major residential and commercial developments were taking place; the mains network was expanding; the District was an example, in miniature, of the Region's Engineering activities; total coverage of the District by the Ordnance Survey of maps in digital format.

Statistics of the Trial District
The Horsham District consisted of:

46,000 consumers, 600 Km of main, 7,600 M.I.N.E. mains units and 240 large scale digital map sheets in a gas supply area of 135 Km^2.

Prototype Design
An extensive and detailed analysis of organisation procedures and use and maintenance of the existing conventional maps. Following this analysis, a prototype digital mapping system was designed and demonstrated to all levels of staff and management. It was this prototype that formed the basis of our subsequent developments.

Procedures and programs were written to assist the take-on or conversion exercise to bring the digital Ordnance Survey maps up to date and transfer the mains and plant record.

Fundamental System Design

Colour. Underlying our whole design was the fact that colour was a fundamental requirement. The rapid identification of different categories of gas mains, other utilities plant and various geographic features can be made by the operator due to the ease with which feature recognition can be achieved through colour differentiation. The scope of design offered by colour also adds significantly to the arguments in its favour.

Geography and Mains Files. It was found necessary to aid and increase data flexibility to ensure that mains could be easily identified for inter-utility exchange and network analysis. To achieve this, geography and mains needed to be separated in the computer system. Maps are held as conventional map sheets. Mains are stored as logical networks geographically related but not stopping at map sheet edges.

Base Map. The digital map had to be capable of displaying, in a readily identifiable form, data relating to Existing, Proposed and Historic geographic features in any combination. These may be referred to as "time" structures; each must contain details of kerbs, street names, buildings, fences, house names and numbers, all of which must be capable of being turned on or off in the display.

Mains and Plant. As with geography, the mains and plant had to be capable of displaying existing, proposed and historic information, in any combination. Within each mains "time" structure, mains of various operating pressures must also be displayable.

Data Base Attachment. By drawing the mains onto the computer file as mains units and forming a link between them and the associated alpha numeric record, the first major step was taken to establish the "intelligent map". In addition to the graphic information normally held on a conventional map, it was now possible to use this to gain access to all the information held in the system.

DIGITAL RECORDS UPDATING

The processes and procedures used to control and validate the take-on exercise are well documented (Cross, Branch 1984) (Mahoney 1985). These basic conversion techniques form the core of the system used to maintain the digital maps and associated plant records. The updating of one record which will automatically adjust all associated data is a long term objective. The immediate task is to use digital records updating as the key system that can ensure all geographic data and associated alpha numerics are in unison. To achieve this, it is necessary to install software and introduce administrative procedures.

Under the manual recording systems, when new mains are laid dimensions are taken that locate the main relative to geographic features. These dimensions are recorded on "freehand" sketches from which the 1:2500 or 1:1250 records are updated. Copies of the updated record are used by M.I.N.E. and Network Analysis to update the appropriate records.

Four separate systems, often in separate locations, are thereby maintained. Digital Records form the link to ensure that the records are now related and validated. This is achieved through the use of customised facilities.

Site Recording
Dimensions between plant and geographic features are recorded on site onto a 1:500 scale screen dump which has been taken from the screen printer prior to the site visit. This saves the time taken to make an on-site "freehand" sketch and confirms that the features being measured from are on the map.

Input of Dimensions. The dimensions are drawn onto the dimension levels of the plant file using specifically designed user commands that emulate the measurement methods. The completion of all dimensions for a defined area is automatically notified and logged by the system. As with all information, it can be selectively turned on or off when using the system and is accessible to all users.

Local System Management
All work on the system is logged and work allocated to individual operations by a Local System Manager (the Senior Draughtsman). The log is flagged to indicate new sketch information and, when M.I.N.E. is updated, the data base change will also be logged to enable the amendments to the associated mains and plant graphic to be made.

Network Analysis Updates
Developments are being undertaken to create a dual noded mains network on the digital record system. The mains will be drawn only once, and any updating of the M.I.N.E. data base must also adjust the related Network Analysis records.

Common Update
When Network Analysis updates are incorporated, a total records update process will be in operation. A fully automatic update system is now being worked towards.

THE ENGINEERS INFORMATION CENTRE

The first stage in developing an Information Centre has been achieved by linking the geographic information to its associated alpha numeric. If developments cease at this stage, the records could be made available to appropriate personnel; it could have all the advantages of being one centrally held and maintained record. Digital Records, having collected the data, give the opportunity to present map based information in a form more readily understandable by the user through simplified and structured system enquiry methods.

A re-assessment of the need for hardcopy output often shows that the task which the output is requested for can be performed on the graphic VDU. This is particularly relevant to the Planning and Network Analysis user.

Rapid Access and Terminal Use

The geographic based information needs of the user must be fully understood to enable rapid (within 30 seconds) VDU response to enquiries. Conventionally small scale paper maps covering large geographic areas are often used to identify the large scale map, which is then used to find a particular street or property (which may be drawn on more than one map sheet).

The automated system provides direct access to the geography for a street by asking the user to enter the street name. The system returns the appropriate geography (even if it appears as more than one conventional map sheet). Access is then given to the relevant graphic and alpha numeric information available for that street.

User Operations

Presenting the user with geography on the screen poses several questions: What is it used for? What is the end product? Will other information be displayed against it? When will another enquiry be made?

Answers to these questions enable three user categories to be identified. In turn, this allows the type of terminal to be identified for the particular user.

The Limited User. Many enquiries take place to identify items, such as mains associated with properties, planning proposals, site dimension recording and Public Utilities Street Works (PUSWA) enquiries. This user requires data for a short amount of time; the task is performed and another request is made. Low resolution graphic terminals are adequate for these tasks. Within Utilities, these will represent a high percentage of the terminals attached to a graphic network.

Professional User. Access to geography, associated M.I.N.E. and Network Analysis information allows the engineer to use the system for detailed data base enquiries; the results being displayed against the appropriate geography or graphic. This is particularly applicable to the planner and operational engineers.

This system use will require a high resolution graphics screen, full graphic manipulation facilities and access to all alpha numeric data.

Record Maintenance User. The maintenance of the map base requires access to the geography as map sheets (which form a convenient method of filing geographic data in the computer). Access is required to mains and plant records, with the appropriate software to manipulate and amend the graphic and associated records. The need to digitise geographic information from Developers, Utilities and Local Authorities requires a full size digitising capability. The accuracy of the digitising surface must allow accuracy to an order of magnitude greater than required for the geographic base. This terminal is the "standard" graphic workstation of the past few years, which deals with large volumes of data for full detailed manipulation and amendment.

They will represent a small percentage of the overall workstations on graphics network required within the Gas Industry.

Engineers Data Base Enquiries

To facilitate the need of the engineer for operational, planning and managerial information, extensive use of the data base and customised graphic commands will be made. Tutorial menus must be developed that will automatically build data base search programs from selected criteria without the requirement of the engineer to master complex enquiry languages. When the appropriate geographic features have been selected, and the data base report criteria defined, the geographic area is identified against which the program will be run. The results of the enquiry displayed against the graphic must be clear and unambiguous. To achieve this, customised display features would be provided. Specified features may be highlighted if they have met a search criteria; for others, reports with completed data boxes on the graphics may be required.

The areas where these techniques are appropriate show the diversity of such enquiries. Examples of these areas are:

- Mains Planning
- Service Planning
- Network Analysis
- Wayleaves
- Structure Plans
- Boundary Data
- Plant Maintenance
- Plant & Mains Location
- Historic Information
- Archaeological Sites
- Hazard Categorization
- Activity Monitoring and Analysis

Engineers Information Centre Summary

Information is easily assimilated when presented in graphic or pictorial form. Allowing the engineer to use simplified rapid access methods, can make information available in the most readily understandable form, using highlighting, colour, linestyle and reporting features. To achieve these results conventionally, alpha numeric reports would be generated and subsequently interpreted by cartographic staff using manual drawing presentation techniques.

The type of terminal on which these enquiries are made is dependent on the principal user requirements, which range from general enquiries to the planner and operational engineer. The advantages and benefits of data base enquiries are only attained by advanced software customisation. These capitalise on holding and maintaining one record and making it available to all users.

CORPORATE INFORMATION CENTRE

The Engineering Department is recognised as the major user of geographic based information. Consequently, developments to date have naturally concentrated on the engineers' use of mains, plant and other associated alpha numeric records. Once this has been completed, the opportunity will exist to incorporate the geographically associated alpha numeric system currently used and maintained by other non-engineering departments. Maintaining only one map base for the organisation and providing customised updating processes for departments' own overlaid data, will provide wide ranging benefits to the organisation.

Customer Service, Sales, Marketing, Accounts, Transport and Market Research Departments all use maps for various purposes. Information in "picture" form is more easily and accurately assimilated and analysis will show that beneficial facilities can include the areas of gas availability to potential customers, vehicle route planning, meter positioning, planning sales campaigns, potential sales area relating to Local Authority structure plans, land ownership and wayleaves, demographic and strategic studies. This list is by no means exhaustive but provides an insight into the way that Digital Records can be used to interface and make available data for the whole organisation.

To maximise the advantages provided by integrating the whole organisation's geographic and alpha numeric data, direct access to the geography encompassing an individual property must be made available, and eventually the analysis of large areas will require a change in the type of display available.

CONCLUSIONS

Digital Mapping for the Utilities should not be viewed as an end product but as an avenue into the technology of the next century, not only in the way it records its underground investment but by manipulating and questioning that record to make better and more cost effective management decisions. To gain the maximum benefits of introducing Digital Mapping, a long term view must be taken of an Organisation's geographic based information. The initial design should be flexible enough to allow for future usage of the system. Digital Records are more than automated cartography; there are benefits in using the computer to draw mains records on maps, the break-through comes by linking the records to other alpha numeric data systems within the Organisation. Digital Records can be customised to provide rapid access to geographical information and present enquiry results in an easily understandable form on terminals appropriate to the users needs.

ACKNOWLEDGEMENTS

The author would like to thank British Gas South Eastern for permission to present this paper and to colleagues within the Industry for their helpful and constructive comments.

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MARK II: THE NEXT STEP IN DIGITAL SYSTEMS DEVELOPMENT AT THE U.S. GEOLOGICAL SURVEY

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ABSTRACT

The National Mapping Division, U.S. Geological Survey, has begun a major new system development effort called MARK II that has as its goal the implementation of advanced technologies and production procedures that will satisfy projected requirements of the National Mapping Program through the year 2000. At that time, it is planned that the National Digital Cartographic Data Base will be fully operational, with its contents based essentially on digital data. These data will represent the 7.5-minute, 1:24,000-scale map series, as well as other smaller scale series, and will be the central focus of the Division's mapping activities. To accomplish this ambitious goal, a series of development tasks are being implemented to (1) expand and improve mass digitization capabilities, (2) modify data structures to support increased content and access requirements, (3) develop digital revision capability, (4) develop product generation capability for standard, derivative, and digital products, (5) improve quality control, and (6) support advanced analysis and applications. Development of the MARK II system has begun, and implementation over the next few years will lead to full production of 1:24,000-scale digital data in the early 1990's.

INTRODUCTION

Since the mid-1970's, the National Mapping Division, U.S. Geological Survey, has been collecting digital data from the cartographic source materials produced by the Division. The Division has continually been involved in the development and implementation of new and improved systems and procedures to expand and enhance digital data production capabilities. In 1980, the existing production system and its capabilities for digital cartographic and geographic data production underwent a major review, and a series of production improvements and recommendations were made and implemented. Only minor system modifications were allowed, as the system then was considered to be stable and maintainable over the short term although it was recognized to be inadequate to meet the long-term requirements for

Publication authorized by the Director, U.S. Geological Survey.

digital data. The opportunity to gain several years of experience, while allowing technology to advance and become more cost effective before launching the next development phase, was judged to be worth these initial investments.

To address these long-range requirements and to continue the development of the Division's digital systems, two studies were conducted in 1985. One addressed the programmatic issues of transforming an ongoing production program from a traditional graphic operation to a digital environment, while coping with an increasing requirement for revision of the basic cartographic series of the country. The second study addressed the technical aspects of this transition. Upon completion of the two studies, an integrated development/production plan was adopted to guide the National Mapping Division through the remainder of the century. This next generation digital production system is called MARK II.

SYSTEM OBJECTIVES

The development plan for MARK II addresses both the programmatic and technical issues involved in the transition of the Division's cartographic operations.

Production Objectives

The production objectives for the Division through the 1990's include the completion of the cartographic coverage of the country and improvements in product quality and in the establishment of more effective map-revision procedures. The long-term development includes a transition from the traditional cartographic production processes to a digital production environment. The near-term objectives involve the completion of approximately 4,600 1:24,000-scale quadrangle maps. In addition, approximately 9,000 existing quadrangles are now judged to be substandard and will be updated to improve positional accuracy. Also, maps with inappropriate contour intervals and those with content deficiencies will be corrected.

The long-term production objectives for MARK II address the development and implementation of specific capabilities and capacities. These goals are divided into three timeframes:

1. By the year 1990

   For the 1:100,000-scale data base (approximately 1,800 map sheets)

   - Complete digitizing of the major categories.

   For the 1:24,000-scale digital data base (approximately 54,000 map sheets)

- Complete digitizing of 50 percent of the Public Land Survey system and boundaries.
- Complete 50 percent of the digital elevation models.
- Implement a production capacity of 4,000 quads/year for digital line graphs.
- Develop contract options for as much as 50 percent of the required production capacity.
- Implement a digital revision capacity of 2,000 quads/year.
- Implement an initial capability to produce high-quality cartographic products from digital data.

2. By the year 1995

- Complete digitizing of 100 percent of the Public Land Survey system and boundaries.
- Complete 50 percent of the other 1:24,000-scale digital line graph categories.
- Increase production capacity to 5,600 quads/year for digital line graphs.

3. By the year 2000

- Complete digitizing of 100 percent of the 1:24,000-scale digital line graph categories.
- Increase capacity to revise 5,600 quads/year.
- Implement capacity to produce 5,600 high-quality maps a year from the National Digital Cartographic Data Base.

Development Strategy

The development strategy proposed for MARK II addresses the major production capabilities to be designed, developed, and implemented to meet the program objectives listed above. These objectives are:

- Development of advanced mass digitization systems, to especially concentrate on the collection of the heavily symbolized 1:24,000-scale source data.

- Development of improved data verification and testing procedures, concentrating on the development of improved automated data checking. This also includes the completion of data standards.

- Development of techniques and processes to produce topographic and thematic graphic products from data contained in the National Digital Cartographic Data Base.

- Provision of digital data suitable for analysis and application by geographic information systems and related technologies.

- Development of an improved production management system to efficiently task and track the multiple production activities of the MARK II system.

- Enhance the National Digital Cartographic Data Base operations and its structure to ensure the data are maintained for optimum utilization by the production system.

MARK II SYSTEM DESIGN

The MARK II effort will result in the implementation of advanced technology and production procedures in the National Mapping Division production centers. To accomplish this and to provide an orderly implementation of newly developed capabilities, the MARK II production system has been divided into four functional components, each under a component manager and designed to address a specific portion of the production process. Each of these components has been further subdivided into a series of development modules, currently numbering 46. Each module then consists of a set of defined and assigned tasks.

MARK II SYSTEM COMPONENTS

Data Production Component

The data production component addresses all phases of data collection, editing, processing, quality control, and revision prior to entry of data into the National Digital Cartographic Data Base. This component is the largest and most complicated portion of the system to be developed. It includes the requirement to develop efficient mass digitization and automatic feature-recognition capabilities for traditional cartographic symbolization and the requirement to develop methods for feature extraction from imagery. Implementation will have to be skillfully managed in introducing new equipment, software, and procedures into an already operational system.

Data Base Component
The data base component is designed to implement improvements in the National Digital Cartographic Data Base to enable a central data repository to support substantially all of the Division's production activities. In order to do this, the development of two levels of data bases are planned: (1) operational data bases located in each production center to support ongoing center production and product generation requirements, and (2) an archival data base to provide a central repository for data to support the operational data bases. These data bases will be linked with high-speed data communication systems to transfer data between data bases and to support the public sale and distribution of products. Additional information about the design and operation of these data bases can be found in "A New Design for the U.S. Geological Survey's National Digital Cartographic Data Base" (Guptill, 1986).

Product Generation Component
The product generation component is designed to provide a capability for producing a variety of standard and derived cartographic products, both graphic and digital.

Production Management Component
The production management component is designed primarily as a two-way interface between the MARK II production system and the National Mapping Program production requirements and authorization systems. This interface will include reporting mechanisms among various systems, establishing production tracking within the data base management system, and ensuring that MARK II activities are appropriately related to the requirements for digital and graphic products.

MANAGEMENT STRATEGY

The implementation of a comprehensive management strategy is critical to the overall success of MARK II. The management of MARK II includes the organization of the development effort, and the establishment of a development cycle.

Management and development of the MARK II effort is being accomplished within the current organizational structure of the Division rather than by establishing a separate organization. The only new position that has been established is the Program Manager for MARK II developments. This position has been placed within the research staff with full responsibility for the overall coordination and management of the development effort. The effort has been divided into components and modules, and component management has been assigned to existing staff offices. Module responsibilities have been assigned throughout the Division, with 60 percent of the work assigned to mapping centers and 40 percent assigned to staff offices.

The cycle established has been divided into two phases -- design and development. The design phase begins with the assignment of component and module tasks and ends with the approval of the component and associated module designs. The development phase begins with the approval of the component designs and ends with the implementation of the developed capacities into the production centers.

The primary review and approval authority for the designs has been assigned to a Division Configuration Control Board. This new senior-level management board was established to review and certify the initial design of the system and control the subsequent configuration of the hardware and software systems developed.

CONCLUSION

The design, development, and implementation of the MARK II system represents a major development activity within the Geological Survey that will exploit state-of-the-art mapping technology resulting in a highly responsive digital cartographic production system. We believe that the timing of this effort is appropriate and necessary to meet requirements, the state of available technology will support the effort, and the future needs of users of these data will be fully met. The development of the MARK II system will assure that the long-term goal will be met, that is, to enable the National Digital Cartographic Data Base to support the product and process requirements of the National Mapping Program. Attainment of this goal will allow the Division to be responsive to national requirements for up-to-date cartographic data and map products that are produced more quickly and efficiently.

REFERENCES

Guptill, S.C., 1986, A New Design for the U.S. Geological Survey's National Digital Cartographic Data Base: Auto Carto London, England, September 1986, Proceedings.

DIGITAL MAPPING: FACT OR FICTION!

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ABSTRACT

The Defense Mapping Agency has passed the point where we provide only the traditional paper maps and charts used by the Armed Forces. Many of the traditional, manual, labor intensive production processes currently in use are no longer cost effective in supporting present readiness requirements. DMA is now heavily into the production of digital data to support the navigation and guidance requirements of new advanced systems. To meet the ever increasing sophistication of these new systems, as well as updating our capability to support our traditional products, DMA is in the midst of the most ambitious modernization in the history of cartography. While the all digital softcopy production system is today still a fiction, the Defense Mapping Agency has committed itself to make this fiction a fact by the early 1990's.

DMA MISSION

The Defense Mapping Agency (DMA) was formed in 1972 from a consolidation of separate Service mapping organizations. It employs approximately 9000 people in over 50 locations around the world with headquarters at the U.S. Naval Observatory in Washington D.C. The major production sites are the Aerospace Center in St. Louis, Missouri and the Hydrographic/Topographic Center in Brookmont, Maryland. The Aerospace Center is charged with supporting aerospace navigation while the Hydrographic/Topographic Center is charged with topographic mapping and the hydrographic charting of the seas.

Current production processes for paper maps and charts are labor intensive and therefore very costly. Nevertheless, DMA has the requirement for the annual production and distribution of more than 50 million copies of paper maps and charts for military and Merchant Marine use which will continue for many years to come. In addition, requirements for crisis response, increased accuracy, flexibility, and the worldwide commitment for DMA products have driven DMA to evolve from labor-intensive manual production processes to an interactive computer graphics emphasis as a means of decreasing production costs as well as increasing productivity.

The automation of feature extraction tasks, to the extent they can be accomplished, will help reduce costs. The resources required for information extraction and the relative benefit to be gained from automation can be expressed in Fig 1. If DMA could use more image based products in the generation of our products (no feature extraction, no symbolization, etc) the manpower and calendar time requirements would, of course, be greatly reduced. It is only as we build to the abstract (traditional map and chart products) that causes a high expenditure of resources for the symbolic representation of the map/chart feature data. This relationship is reflected in the accumulated effort curve in Fig. 1. Hence, the goal of automation.

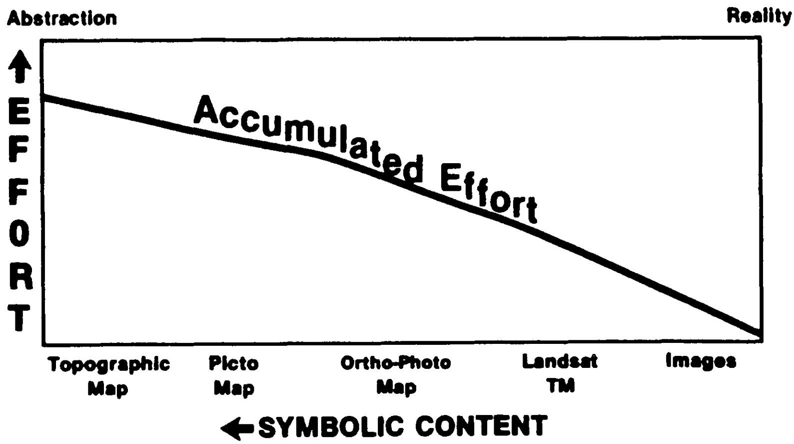

FIG. 1

MODERNIZATION

To support increasing demands for DMA products, a major expansion of the Agency's extensive computer capability has been undertaken. This modernization effort has the goal of a 50% reduction in production hours and a 75% reduction in production throughput time for the generation of currently defined products.

Computers will be applied to all map/chart production process, including source analysis, data collection, compilation, editing, maintenance, storage, and output. Many of the technologies and techniques (hardware, software, production processes) planned for the modernization are already in existence today. They will be integrated into a softcopy production system for the digital manipulation of map/chart data from initial source analysis to final reproduction. Advanced digital workstations will be developed to handle digital, graphical, and textual data. These workstations will be the cornerstone of DMA production in the 1990's. Cartographers will be able to maintain strict interactive control over the development of digital data into the required format for output - either for insertion into the cartographic data base or for the generation of product masters according to specifications of the map/chart or special digital product required.

Critical to the successful implementation of the modernization is that DMA implement a standard computer operating environment to include hardware, software, operations and maintenance. Common hardware (mainframes, minicomputers and components for interchangability) and commercially available software, will provide for increased system reliability, reduced software maintenance, simpler operations and training and a better configuration management control over continually evolving system growth.

Development of a DMA all-digital capability will also require a transformation of existing production line techniques and significant training of personnel. In addition, a sophisticated on-line information management capability will be required, along with state-of-the art laser and fiber optic communications capabilities for transfer of expected massive volumes of data. It is essential that these developments be designed to be cost-effective given system and program requirements. Furthermore, evolving technologies that offer significant improvements in cost/performance over the baseline system will continue to be of interest for subsequent exploitation.

Effective management policies for modernization will address responsibilities for developing plans, programs, and schedules to enhance DMA's capability to exploit data extraction from source materials and to enhance product generation from the MC&G data base. Rule sets are to be designed to aid the production planning process for the translation of user requirements into production assignments. They would specifically address user requirements vs resource availability. A Multi-Product Operations (MPO) concept is being designed into the modernization program and extraction specifications will be essential to its success. Source selection would be based on the most stringent extraction requirements for all DMA products within a specific geographic area. DMA could collect data from a single source and, in a single extraction process at the workstation, satisfy multiple products assigned within that area. The integrated MC&G data base would then support all product requirements.

Finally, the softcopy production system will be geared towards a topologically consistent digital data base to include all cartographic feature and attribute data required to support DMA paper, film and digital products. The digital data base will have an expected data volume of 10^{17} pieces of information, with possibly 10^{13} bits accessible in near real time to multiple users. To understand the complexity of this undertaking, try to imagine every house, field, road, stream, fence (i.e., every feature in the data base) being available to the cartographer at his work station.

Special attention must be given to controlling any divergent growths of digital data base requirements. Differences among data specifications for current and projected users of our digital data base must be resolved. Successful data base interoperability among DMA users will require implementation of a "standardized" digital data base. DMA must develop and implement this digital data standard in its modernization and then "encourage" users to conform to it. It should be noted that user impact on DMA resources is very nearly proportional to the proliferation of unique formats requiring tailored composition and non-standard accuracies. Validation of such esoteric requirements can cause a significant displacement of the level of production resources available to DMA to support our standard product requirements. Emphasis must therefore be directed toward innovative means to significantly reduce the time required to produce the digital data base. Because of limited production resources, DMA can realistically only generate and support one major set of digital data. DMA cannot maintain a responsive and cost effective production posture if required to transfer its data to unique user requirements. All future system developments should address our data format and content (unless required at a higher resolution than we can realistically provide) for exploitation.

To address the immense data base issue, DMA development is centered on efforts related to data base structures and the computer architecture to handle the spatial data efficiently. Further exploration of data base management systems will be required to develop spatial query capabilities for data bases which may be geographically dispersed and which must deal with concurrency, integrity, and multi-level security.

RESEARCH AND DEVELOPMENT

Continuing expansion of this country's strategic arsenal and increased force readiness requires DMA to continually expand its capabilities for weapons systems support. DMA's role in research and development has been expanded accordingly, and significant advances have kept the Agency at the forefront of some of the most radical changes in state-of-the-art technology in digital data processing, photogrammetry, cartography, geodesy and photography. The Agency, however, is still a long way from solving the total digital production problem. For this reason DMA continues to support R&D programs in the areas of automated feature analysis and mass database management. With respect to the feature analysis problem, automated feature extraction is an important DMA goal. DMA has developed an in-house research test bed which adapts techniques developed by researchers at various academic institutions and has contracted with a number of universities to explore various areas of image understanding. These problems encompass automated recognition of both man-made and natural features, change detection, and the knowledge base to properly identify these features and insert them into the spatial data base.

Automated change detection is another important goal. It is desirable to be able to identify changes between images, and between images and graphics files. There are ongoing developments in the modernization effort that are also expected to achieve a high degree of automation in elevation data extraction.

Modernization is addressing this by evolving a framework addressing a number of processes central to the automation of feature extraction, and a knowledge-based system is being built to address feature identification and attribution requirements. Rule sets will also be developed to aid the cartographer in his development of the data. Rules will be developed to support both data extraction and product finishing functions. Data extraction would include processes to be executed during photogrammetric and cartographic feature and terrain extraction. Product finishing would address those processes for the extraction of data from the MC&G data base to support rule-based product symbolization. Included would be such automated cartography functions such as line generalization, names placement and symbol generation. Such a system of rules must interact with both a human analyst and a spatial knowledge base.

DMA's major interest for a near term solution is in cost-effective, interactive approaches to the processes of image segmentation, region measurement and feature identification and attribution. The initial focus should be on effective interactive techniques. Final modular software design would allow for new algorithms to be easily plugged in. Past experience with many algorithms designed for total automation have shown that awkward manual clean-up is often required. If efficient interaction is designed from the start a better system will result. DMA needs to orient to specific objectives. We do not have the resources to test every algorithm that could possible relate to every situation. DMA needs to develop benchmark testing materials to evaluate current production facilities as well as commercial development. A new generation of sophisticated systems are being developed to automatically perform the functions of pattern/symbol/character recognition, feature tagging and spatial coding. Viable benchmark data would form the basis against which proposed evolutionary changes could be effectively evaluated.

The mass database management objective includes developments in storage media, database structures, data compression, interoperability and interactive data base storage, access and management with a variety of user interfaces. Successful development of these capabilities is crucial to cost effective support of future requirements for digital data production. Storage of digital data is another major problem and continues to be the subject of a vigorous research and development effort. Optical disk and high-density magnetic cartridges are under study, along with other techniques. Another critical component in support of new navigation and guidance systems is the ability to provide adequate digital databases that describe a variety of types of surface information. Both static and time-varying information such as texture, thermal and near-infrared properties, precise geometric properties, population and traffic density patterns, and atmospheric weather data may be required in addition to traditional feature attribute descriptors. Along with new types of feature descriptors, increased resolution and level of detail will also be required. Numerous technical problems must be solved in the areas of artificial intelligence, image understanding, telecommunications, and digital production techniques. DMA has accepted this challenge and is actively pursuing university, government, laboratory and commercial contractor support.

FEATURE EXTRACTION

The introduction of the digital working environment in the early 1990's will facilitate increased levels of automation. In this environment the feature analyst will use digitized imagery at a softcopy workstation instead of film and optical equipment. The analyst will have computer-based automatic and interactive aids for extracting features.

This digital production environment will make it possible to incrementally introduce new levels of automation. Maturing research in several areas are candidates for incorporation into the production process. Automated symbolic change detection will help the analyst rapidly evaluate new source material. Automated analysis of airport scenes and automated extraction of transportaton networks such as roads and railroads are two domain specific areas of research showing promise.

DMA is addressing the feature extraction problem in a Technology Base Program because of the potentially high payback to be achieved from a modest increase in capability. In the longer term, the major focus of the DMA Technical Base Program is to automate the information extraction function by introducing knowledge-based techniques and by developing machine intelligence systems. DMA has a joint program with the Defense Advanced Research Projects Agency to extend the image understanding technology into intelligent machine applications. The efforts include the development of expert systems, a natural language man/machine interface and automatic creation of a spatial knowledge/data base. Also, fiscal year 1985 was the first year of an exploratory development program of research in computer vision for which DMA has direct management responsibility. This program is addressing many of the problems which must be solved in order to achieve the ultimate goal of development of a robust fully automated feature extraction system. These problems include improvement of line detection algorithms, exploitation of multispectral data, increasing computer processing speed and efficiency, and the development of artificial intelligence techniques specific to MC&G feature analysis from imagery.

It should be noted that current industry research in the feature extraction problem tends toward recognition of specific features (i.e., vehicle on road, ship in port, etc.) and industry subsequently tends to discard any additionally extracted information as noise. It happens that this noise, the road itself, the house next to it, the vegetation across the road, etc. is actually the data DMA requires for input into the MC&G data base.

Approximately 80% of the cost of our current Feature Analysis program is in the feature analysis interpretation problem. The hardest job is the interpretation of unique significant features. We know that the feature is a bridge, but what kind of bridge is it? A manual, labor intensive feature interpretation production process is our current solution to this requirement. Should DMA achieve even a modest increase in capability, this increase applied to an approximate 5000 man year estimate for Level II (cultural feature data at a scale of 1:50,000) coverage for cities currently in our Level I (250;000 scale) data base, would effect a significant savings in both manpower and equipment resources.

DMA has developed a Feature Analysis Coding Standard (FACS) to include all attributes required for products. FACS will contain a standard code assigned to each feature in the extraction specification. A FACS coding system also exists for attribution. FACS will support the density of features required in each product specification and the rules for collection of data to support MPO operations. These rules will have to be followed to achieve a seamless data base from adjacent areas collected under different product specifications. Collection of MC&G data independent of these rules, will obviously yield mismatches to adjacent data sets in terms of feature connectivity and feature densities. There will undoubtebly be some feature and density requirements that will be exceptions based on the spatial properties of the data (i.e., sparse areas, overcongested areas, representation of data in built up areas, etc.). These exceptions should be allowed.

ADDITIONAL AREAS FOR EXPLOITATION

The Terrain Analysis Data Base (TADB) being developed by DMA will support trafficability, cross country movement, and most MC&G requirements in the tactical arena. Some gaps do occur, however (i.e., soil types, slopes and grades, river velocity and other items not available from current techniques of feature extraction from the digital sources), and DMA will need to address these areas. DMA is planning a scale of 1:50,000 for its TADB. The U.S. Army has a recently identified additional requirement for 1:12,500 scale data for terrain analysis data. In addition, a systematic approach is needed for the rapid preparation of local-area, demand-driven digital terrain databases. Efficient methods are required to get this information to the user. Knowledge-based applications are long term potential solutions.

A number of computer scene enhancement techniques such as synthetic breakup and fractals should also be considered as potential methodologies to support simulation and terrain modeling requirements. Synthetic breakup is a technique to put realism into the scene where precise metric capability is not required. It would allow maximum use of our Level I culture data to support varying product requirements via the synthetic break up of large aerial features into smaller ones based upon original feature attributes. Real features would not be discarded and unrealistic feature representations (due to changes in scale, feature density, etc.) could then be represented in a realistic manner. Current labor intensive production resources limit the collection of high-resolution data to small geographic areas of interest and the production of large area, high-resolution databases will continue to be unattainable without both adequate source data and automated feature extraction techniques. Synthetic breakup will have its greatest utilization in areas where feature density is sparse and Level II culture data collection requirements will be no more expensive than for Level I.

Terrain modeling in an important element for representing feature data. Fractals offer a promising approach. Fractal sets have recently become popular for the description of natural features used in image analysis, image simulation and topographic modeling. As with synthetic breakup, fractals are considered a potentially cost effective means for providing additional background data where metric quality is not required. An approach is to generate metric quality data for unique features required for navigation by the users, and then fill in the remainder of the scene with non metric data. Fractals are a potential mechanism.

Application of remote sensors such as Landsat, airborne active/passive scanners and synthetic aperture radar to digital data collection represents a new and promising generation of technology that can be exploited to improve digital data production at DMA. Forthcoming multisensor imagery from systems such as the French SPOT and the U.S. EOSAT will be at a 10 meter pixel resolution. Such imagery will support many map and chart requirements as well as support production planning for maximum currency.

An additional advantage of multispectral imagery is that the interpreter has the option of single-band black and white or color composites (the color assignment and bands used being options) and ratios of any combination of bands. He also can use various grey level assignments and classification systems to aid in interpretation. The greatest advantage of space-derived images is the greater synoptic perspective. Just as the aerial camera expanded the cartographer's perspective for analyzing the character of the earth's surface, space imagery enlarges this perspective even more.

Another goal is to expand multi-source registration capability to include visible, Landsat, radar and any other sensor and graphical information. We want to be able to generate conjugate points automatically (correlation, edge matching, etc.) in order to synergistically exploit these sources for MC&G product support.

A sensor with a specialized standoff role is the side-looking airborne radar (SLAR). From high altitudes, SLAR antennae can collect self-generating radar energy from either side of the aircraft. The film is not affected by poor weather conditions where persistent cover precludes conventional photography. Radar provides its own controlled source of illumination and can be used at any time regardless of sun illumination. Radar images are especially useful for emphasizing topographic relief because of the strong shadowing effect that can be obtained.

Synthetic Aperture Radar (SAR) imagery from SEASAT and Shuttle Imaging Radar systems will also support many mapping requirements. Good stereo viewing calls for a limited change in position of the images and texture while good metricity calls for greater changes in imagery. The system would have to be tasked for optimal data collection against any validated requirement. Effective use of multi-source data will be important to our goals of automating feature extraction and change detection.

Finally, there are ongoing developments to merge digital source data with our Digital Terrain Elevation Data to generate synthetic low level perspective scenes from any point at any angle. A major need is to simulate selective DMA cultural feature data on these perspective scenes in order to provide a greater level of realism for planning, training and simulator applications.

CONCLUSIONS

DMA is being tasked to support an ever increasing number of higher resolution requirements from our users and the question is how can DMA practically and cost effectively support such requirements? In order to maintain a viable production status in the future, DMA must ensure the use of standard DMA products to support new operational doctrine, new systems or modifications to existing systems. The use of standard DMA products is essential to minimize disruption of MC&G production commitments to established operational requirements. New MC&G support requirements must be defined early in the concept definition phase of system development. As each new system progresses through the development and acquisition process, the required DMA product must be identified and the appropriate resources allocated to support it. Any proposals for unique, non-standard product support must be reviewed to determine viability of the requirement and to consider possible alternative means of satisfying the requirement.

DMA has embarked on an ambitious modernization program to automate its production processes. DMA will also continue to utilize laboratory, university, and commercial assistance in the interpretation of MC&G requirements and for the development of alternative products, production concepts, and techniques for providing the required MC&G support at minimum cost. Full automation, however, will not be an achievable goal at this time. The feature analysis/feature interpretation problem will be with us through the 1990's. R&D goals have been initiated to continually address this problem, along with the investigation and development of efficient methodologies for exploiting multi-sensor imagery. On-going developments in knowledge-based systems will be monitored for subsequent exploitation by DMA.

The state-of-the-art development of our modernization will be a great step forward for DMA. DMA must not lose the momentum gained through this effort. We must be ever cognizant of the requirements of our mission and expend the energy and resources required to achieve it. The critical role of the human operator in the production of digital data is not expected to change. The cartographer of the 1990's will require skills and familiarity with computers, knowledge of mapping, charting and geodesy, an understanding of source materials and an understanding of production processes. The DMA digital mapmaker of the future will be ready and capable to implement applicable any and all improvements into the established framework of our modernization program.

THE DEVELOPMENT OF DIGITAL TOPOGRAPHIC MAPPING IN A STATE GOVERNMENT AUTHORITY

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ABSTRACT

In February 1983, the Graphical Photogrammetric Section of the Division of Survey & Mapping was decimated by a fire. In the re-equipping which followed, the Division acquired extremely modern equipment to continue the 1:25,000 topographic mapping program. Also included in the re-equipping phase was a digital mapping system to be used for a research project into digital mapping. Amongst various projects undertaken, the main development has been the creation of a small scale digital map of the State of Victoria. This product combines topographic information , mapping information, administrative and thematic information into a graphics data base across Victoria. A user interface has been developed to enable the data to be accessed easily, utilizing special menus and interrogation routines, and plot files or digital data sets may then be obtained.

NOTE: The views expressed within this paper are entirely those of the author and do not necessarily reflect those of the Division of Survey and Mapping.

INTRODUCTION

This paper centres mainly on the activities of the Digital Topographic Mapping Research Project (DTMRP) of the Research Section, and the Graphical Photogrammetric Section, both within the Division of Survey and Mapping, which forms part of the Department of Property and Services. The Division is a member of the National Mapping Council and is the official Victorian State Mapping Authority. The State of Victoria is located in the south-east corner of Australia and covers an area of 227,600 square kilometres and a population of approximately 4.5 million. These figures represent just under 3% of the total area of Australia with around 30% of the nation's population.

The Division's mapping programs presently involve the concurrent production of 1:25,000 standard series topographic mapping and 1:25,000 / 1:2,500 cadastral mapping. The Division is currently in the 4th year of an Accelerated Mapping Program which sees the production of around 120 topographical maps per year using internal and contracted production systems. The Accelerated Mapping Program is expected to run for a total of 8-10 years and was placed into operation because of the pressing need for a large scale mapping coverage to support functions such as long term economic, future development and rural planning needs. Full 1:25,000 topographic coverage of Victoria will consist of 1640 sheets.

DATA CAPTURE CAPABILITIES

In February 1983, the course of the Division, as far as topographic mapping was concerned, was well entrenched in a traditional program relying on equipment which had been in service for quite some time. The data capture program undertaken in the Graphical Photogrammetric Section relied on 18 stereoplotting instruments (Wild A8, A7, B8, B8S and Kern PG2). The section also had 10 major ancillary items such as Wild TA and Kern AT plotting tables to support these instruments. This equipment represented a replacement cost of approximately $A2,000,000.

In the early hours of Monday, 28th of February 1983, a fire detector signalled an alarm in the Government Offices complex at Treasury Place, Melbourne. Due to an incorrectly labelled indicator board, the fire units were led to the wrong area of the building. One and a quarter hours later, a fire was reported in the section of the building immediately below the Graphical Photogrammetric Section. This area housed chemical laboratories which serviced several Government Departments.

The fire proved extremely intense with explosions and heavy fumes caused by a range of chemicals stored in the laboratory. The fire was contained within an hour but explosions and minor ignitions continued throughout the day. These were caused by water contact with ruptured chemical containers.

Extensive damage was done to the building which is unusable to this day. The Graphical Photogrammetric Section suffered the greatest loss with either total destruction of, or serious damage to each of the 28 major equipment items. The damage was caused by a mix of direct fire, heat distortion, water damage or chemical vapours. This resulted in the total loss of the Division's togopraphic compilation capabilities and potentially severe disruption to the Accelerated Mapping Program.

Immediate problems of the accommodation of the staff involved and the restoration of some form of productivity were faced. Two stereoplotters were made available at the Royal Melbourne Institute of Technology, 4 stereoplotters were provided by the Army Survey Regiment and National Mapping also loaned 2 stereoplotters, in order to enable the resumption of the compilation process.

Equipment Replacement

An investigation into the re-equipping of this section was then carried out. Of the destroyed and damaged equipment, only 1 Wild B8, 2 Kern PG2's and 3 Wild TA plotting tables were restored. Only a very short time frame was allowed for the selection and replacement of the destroyed machinery.

The total mapping requirements of the state were again to be supported using both high and low order instruments. This also added an opportunity to cater for future developments in the areas of digital mapping and automation, especially with the emerging LIS/GIS technologies gaining prominence on the state scene. However the production of graphical 1:25,000 topographic maps was to remain the highest priority.

The destroyed equipment was replaced in two stages to supplement the equipment on loan and to enable some production to be maintained during this period. The equipment obtained through the phased acquisition process was:

2 Wild BC1 Analytical Stereoplotters
2 Wild TA2 Precision Digital plotting tables
7 Wild AG1 Analogue Stereoplotters
4 Wild TA Digital Plotting tables
2 Kern PG2 Analogue Stereoplotters
1 Wild OR1 Orthophoto System

Three of the AG1 stereoplotters were outfitted with Wild RAP computer based enhancement systems. Serial line communications were also installed between the 3 AG1-RAP systems and the BC1 analytical systems. At this stage, it was decided that an investigation into digital topographic mapping should be commenced within the Division, to take place within the Research Section.

THE DIGITAL TOPOGRAPHIC MAPPING RESEARCH PROJECT (DTMRP)

The DTMRP was established in late 1984 as a small research and development project. Two staff members were permanently attached to the project, with a third position being filled on a rotation basis by trainee draughting staff. An Intergraph Digital Mapping System, based on a VAX 11/730, was purchased to provide a focus for the operations of the

DTMRP. A single screen, monochrome graphics workstation, coupled with a large format, high precision digitizer formed the crux of the graphics system. The workstation was interfaced to a Wild AG1 to enable direct capture of digital data from aerial photography. The acquisition of this system along with the BC1 and AG1-RAP systems represented a major step for the Division into digital mapping.

After a period of familiarization with the system, the investigation proper was commenced. The initial terms of reference of DTMRP were to investigate the requirements of a digital topographic data base at a source scale of 1:25,000 for the state of Victoria. To this end, tests of direct stereoplotter digital data capture and manual digitization were commenced. Evaluations of the equipment, the data acquisition methods and the canvassing of user requirements (either actual or projected) were pursued.

A Digital Victoria

However, in May 1985, under the direction of the Surveyor-General, the DTMRP project team began studying the requirements for the creation of a small scale digital map of Victoria. A report detailing the possible source materials available, and the processes required for the creation of a digital product at a nominal scale of 1:1,000,000 was prepared. This special project is designed to be the initial mapping product of the Division.

Upon acceptance of the project team's recommendations, the DTMRP resources were committed to the development of the small scale map, known within the project as VICMAP. A recent map product developed within the Division was chosen as the base from which the topographic data could be digitized. A 1:1,000,000 tourist map had been developed in 1983, and the source base was available in the form of 4 1:500,000 base sheets. Stable based proof copies were prepared for the manual digitization process.

The standard projection used within Australia is the Australian Map Grid (AMG), a version of the Transverse Mercator projection based on the Australian Geodetic Datum. The coordinates used are metres, with zones of 6 degrees width and a central scale factor of 0.9996. This projection was however, not suitable for the VICMAP files as Victoria is split by a zone boundary. This raises considerable problems when trying to display the outline of Victoria within the one file using this coordinate system. One option considered was the use of geographical coordinates. This was also not chosen as there is a considerable distortion of the "accepted" image of the state outline as shown on the Transverse Mercator projection.

The projection chosen for the VICMAP task has been dubbed "Pseudo-AMG". It is a Transverse Mercator Projection which was created specifically for the small scale map of Victoria in 1981. It has a central meridian of 145 degrees east (which runs through Melbourne) and a central scale factor of 1.000. The zone width is unlimited enabling the State of Victoria to be digitized within a consistent coordinate system. Coordinates for control have been computed to the nearest metre from reduced AMG equations. Routines were developed to enable the conversion of the "pseudo" coordinate data to geographicals or AMG if so desired.

Using a classification of features based upon generalized topographic criteria for representation at the scale of 1:1,000,000, a digitization program was commenced. The initial data capture effort was concerned with the main topographic layers of information, the hydrographic pattern and the road network.

The positions of all population centres were also digitized during this program. A file of town names was developed through a map preparation process. Town names were placed in order of half degree squares. Coordinates corresponding to a position in the adjacent half degree square (to the east) were used to place all the town names into the file by software processes. It was then a simple, logical editing process to place a town name in its proper position to annotate the town location correctly. This proved to be a more efficient process than the operator keying in the name during the digitization process.

System development has been performed by DTMRP staff throughout the project. Software processes were developed to place various information layers into the system. The boundaries, names and numbers of the 1:25,000, 1:50,000, 1:100,000, 1:250,000 map sheets covering Victoria were placed into the graphics data base files by software processes. The current status of the 1:25,000 topographic mapping program is also held within the system.

Proofing of the content of the topographic data was done by the Cartographic Drawing Section to ensure that a complete coverage of topographic features was held. All information within the graphics data base files is feature coded and structured to enable manipulation and display of individual feature classes if so desired. Routines to ensure the correct codes are held throughout the digital data sets were developed.

Thematic and administrative information is also being incorporated into the VICMAP files. Land administration in the form of the Parish overlay for the state has been manually digitized. This proved to be a lengthy process. The parish data had been drawn against a 1:1,000,000 map of

Victoria, drawn in 1966, which was known to contain positional inaccuracies. To confound this problem, the parish base did not fit the base perfectly.

A careful map preparation and analysis process enabled the identification of many "control points" for the parish overlay. These were clear boundary intersections where known coordinates were available, and points that could be confidently matched to detail within the digitized topographic framework of stream and road patterns. The digitization of the parish network, containing 2004 parishes, was then performed by concentrating upon small, localized areas and performing a digitizer set up for each particular area. A computer file containing the 2004 parish names along with associated centroids, was used to place the names within the graphic file. The parish names are being thoroughly checked to ensure correct placement and also to counter problems with the size of the text in relation to the size of the parish itself.

Digital information was obtained from the Division of National Mapping, a Federal mapping authority, for use within VICMAP. The local government areas and the federal electoral boundaries within the State of Victoria were obtained from National Mapping. The data provided was still in a "raw" state and consequently some editing of the data was expected. This information was placed into the graphics files by software processes. It was found that a considerable editing effort was required for this data. The topographic base of stream and road networks, and the parish system were used as references to control the structure of the local government and federal electoral boundaries. As the vast majority of local government boundaries follow either a parish boundary, a river or a road, conflict frequently occurred. In all such cases the structure of the topographic base was adopted. Using the monochrome screen, we were quickly forced to adopt a system of exotic line styles and weights in order to discriminate between the lines we were looking at on the graphics screen.

The state electoral boundaries and various state department administrative regions are being manually digitized and will provide a comprehensive base of administrative information. This will prove to be of enormous use to state departments, especially those that require staff to be operating in the field, and already interest has been shown in the utilization of this information. The information stored within the VICMAP graphic data files is shown in Table 1.

TABLE 1

TOPOGRAPHIC BASE	OVERLAY INFORMATION	MAPPING INFORMATION
control	local government areas	1:25000 boundaries
coast	parishes	1:25000 names
lakes	counties ##	1:25000 numbers
rivers	federal electoral areas#	1:50000 boundaries
streams	legislative assembly ##	1:50000 names
minor streams	legislative council ##	1:50000 numbers
highways	post codes ?	1:100000 boundaries
secondary roads	various state departments	1:100000 names
minor roads	administrative boundaries ##	1:100000 numbers
unsealed roads?		1:250000 boundaries
railways?		1:250000 names
state boundaries		1:250000 numbers
cities		
towns	1:25000 status data: - on program]	
villages	(topographic program)- compiled]	quarterly
localities	- provisional]	updates
major islands	- printed]	
minor islands		

\# - currently undergoing digitization or editing
\## - to be commenced
? - possibly to be included

One important factor being ensured is that the various thematic layers form a consistent, homogeneous base of information across the state. In all cases the structure of the topographic base has been adopted as the controlling framework upon which the other layers are established.

Output Capabilities

Wild TA2 high precision flat bed plotters are used to provide a range of high quality cartographic outputs, including the preparation of scribed negative plots. Considerable effort has been put into the development of a plotting optimization package to make more efficient use of the available time on the TA2 plotting tables, which are generally dedicated to the operations of the BC1's. Also developed has been a package to provide optimised positive/negative photographic plots on a Gerber flat bed plotter, which is available on a contract basis. The optimizing package was developed in order to minimize the movement of the pen turret with the pen or scribing tool up. The package strings together adjacent line strings or locates the nearest line string for plotting.

High quality cartographic products, derived from the VICMAP data, have already been provided for use in a state government commission into the re-structuring of local government in Victoria. The commission's activities have a very high public and political profile, and consequently are operating on a restricted time frame. Therefore, when maps were required for use by members of the commission as working tools and for inclusion in published reports, manual methods for the production of such documents was impossible in the time available. However, using the data stored within the VICMAP project, many different maps were provided in a large range of scales and formats within a short time frame.

The other main product of this project is the digital information itself. The data can be provided in various formats, the most notable being the Australian Standard for the Interchange of Feature Coded Digital Mapping Data, AS 2482.

To enable the use of the data by people with little experience with the computer graphics system, menus and software have been developed to enable the 'tailoring' of the images or data sets required. Interrogation procedures have been set up to enable the location of areas of interest by the entry of items such as : map name or number, town name, parish name or local government name.

APPLICATIONS AND FUTURE DEVELOPMENT

The creation of the VICMAP graphics files has opened up a new avenue of customised mapping for the Division. There has not been such a comprehensive and consistent base of information available before and it is consequently generating considerable interest. Effectively the VICMAP project can be seen as a small scale GIS.

The ability to provide customised products in a variety of formats is of great benefit. Conventional processes are not practical in many cases because of the photographic processing required, the inflexibility of the layout and the large times involved for creation of special layouts. The performance of the product and the system has been tested well by the work done for the Local Government Commission.

Planned developments to the VICMAP system include the creation of generalization routines to enable the derivation of smaller scale digital products. The mounting of the VICMAP product information on a PC sized machine is also being considered for use in areas such as education. There is also a number of projects with which the DTMRP may become involved. The development of a National Wilderness Inventory is being pursued at two levels, national and state. The Victorian effort is at the forefront of the current proposals and the participation of the Division, utilizing the DTMRP system and National Mapping, in a joint venture with staff of the Arthur Rylah Institute and the CSIRO is progressing.

Also under consideration is a major pilot project studying the rural salinity problems. This project would require the digitization of quite a number of 1:25,000 topographic maps, as well as numerous thematic and natural resources overlays. Such a project would have obvious benefits, enabling a reasonable introduction to the task of the creation of a digital topographic data base for the state of Victoria and the requirements of a state-wide GIS.

The major agencies in Victoria that manage land related programs all hold the belief that the 1:25,000 topographic coverage being developed by the Division of Survey and Mapping will provide the best base for the creation of a GIS to handle the long term needs of Victoria.

Another in-house project which may be of great benefit, would be the establishment of the translation of raw data files created on the BC1 systems and the AG1-RAP systems into a structured format on the Intergraph system. With still a third of the state to be mapped, this process could prove to be of inestimable value to the long term requirements of the state.

CONCLUDING REMARKS

The Division of Survey and Mapping is actively progressing into the new age of mapping with the acquisition of high technology equipment to conduct its topographic mapping program and the Digital Topographic Mapping Research Project. The equipment that is now in use has a great capacity to be of enormous value in the production of a state wide digital data base of topographic information.

The development of the small scale digital product has shown some of the benefits that may accrue from such a data set. A second workstation providing colour graphics display is being added to the Research Project, due to the success of the VICMAP project. This is planned to cater for the use of VICMAP both in-house and by external users. Involvement in future projects will only confirm that there are many benefits to be achieved from the use of digital mapping data.

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MANAGING THE TRANSITION TO SUPPORTING THE PRODUCTION OF DIGITAL GEOGRAPHIC PRODUCTS IN MILITARY SURVEY

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ABSTRACT

Since the early 1970's Military Survey has been increasingly involved in meeting the demand for digital geographic data required to support a wide range of defence applications including navigation and weapons systems, command and control information systems, and training simulators. The data, in the form of elevation matrices and vector or raster feature data, is required to varying densities and accuracies covering a wide range of equivalent map scales, and particularly between 1:50,000 and 1:500,000 scales. The diversity of applications of the data also presents severe problems in developing a range of digital products which will satisfy a wide range of defence needs.

The increase in demand for digital data has not been matched by a comparable reduction in requirements for conventional maps and other graphical products. It has not therefore been possibly simply to transfer resource from conventional to digital products. There have also been problems, common in most organisations, that the introduction of new technology and production methods are not without difficulty. Additionally, there are a variety of constraints on the organisation with increasing pressure to reduce manpower and other costs, and inflexibilities in the recruitment, classing and grading of staff on a more-or-less fixed salary structure.

The paper discusses some of the problems associated with the introduction of instruments and processes to support the production of digital products. It will cover the main managerial concerns and issues surrounding the transition to a new digital production system. It will also outline attempts to achieve a better definition and rationalisation of customer requirements, and describe the main technical concepts by which productivity is to be optimised.

INTRODUCTION

Military Survey is a branch of the Royal Engineers. Its role is to provide the Armed Services with the land maps, aeronautical charts and other survey data which they require in peace and war. It is essentially a role that depends on peacetime activities similar, in many ways, to those of the Ordnance Survey. The area of responsibility for Military Survey is however worldwide, with geographic information collection and standard series production work carried out on a continuous basis. In an emergency or war situation the whole emphasis is re-directed to rapid response tasking. To give an indication of the Military Survey operation we currently have to meet specific requirements for some 15-20,000 printed maps and charts and hold stocks of over 30 million sheets. The range in scale of product stretches from town plans, through 1:50K and 1:250K to 1:500K and 1:1M. There is now a significant requirement for digital geographic products amounting to perhaps 20 per cent of their paper equivalent and increasing rapidly.

Military Survey has been involved in the production of digital data for more than 15 years, with development work stretching back to the early 1960s. This has been a period of evolution with digital systems, and the requirements on which they were based, arriving on an ad hoc basis. The ideal, certainly perceived early on, to develop along the long held principle of survey of going from the whole to the part was just not possible due to the sheet size of the projects that would have resulted, the funding problems and not least the technology itself which was insufficiently advanced.

To date in Military Survey the most significant digital production system was developed to meet a defence requirement for Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data (DFAD) incorporated in the Digital Landmass System (DLMS)(1). This project was conceived in the early 1970's to provide continuous radar navigation scenes in advanced aircraft simulators, but now has much wider applications. The second system, Production of Automated Charts Europe (PACE)(2), was designed partly to satisfy a defence requirement for up to date air information, and partly to achieve economy of map and chart production. This saving was possible due to the range of related products that existed over the central European area. Our success in meeting these two programmes has relied extensively on the Laser-Scan Fastrak automatic digitising system(3) which has been progressively developed, and tailored to the needs of these two programmes.

I believe we have now arrived at the time when we have to consider the full implication of the technology we have so readily embraced. There is no indication that the defence requirement for paper maps will diminish, while there is the certainty that the requirement for digital geographic data is increasing exponentially. There will continue to be pressure on resources; therefore not only do we have to consider the impact of technology on the requirements of our users, we have to apply that technology to enable considerably improved production efficiency and higher standards of service to the defence user.

In mapping the transition from map production to supporting the production of an increasing range of digital geographic products requires that we:

a. identify and analyse the defence requirement for digital geographic information.

b. design and develop appropriate digital products.

c. establish standards for the exchange of data and digital products.

d. develop and implement appropriate production capability, the "multi-product operation".

In addition, of course, there are the many other management initiatives that have to be taken in developing and implementing any new technology system. In this paper I will not be discussing matters such as the defence procurement system or training for example.

THE DEFENCE REQUIREMENT

When we talk of the defence requirement for geographic information we look fundamentally at the terrain, and the impact that the terrain can have on military operations. The terrain is not only the land surface but the natural and manmade features on or beneath the surface. All these we can describe by attribute or attribute value, and we can also add related military or air information pertinent to the conduct of the battle. The schematic of the terrain in Figure 1 illustrates this concept. The military therefore requires knowledge about the terrain in one or more of the following forms:

a. in descriptive form such as a map or display where the image is clear and unambiguous to the human eye.

b. as discrete positional data, where the relationship established between two points or a number of points is unambigious, as in navigation systems or elevation models.

c. as relational terrain data, enabling its analysis and evaluation with other data pertinent to the conduct of military operations.

The emerging applications for the use of digital geographic information can be summarised under the following four headings:

a. **Navigation and Guidance.** The requirement here is for positional data and map displays which support the navigation of the air or ground vehicle, and which will be linked to the integral navigation system of the vehicle which may include terrain referenced navigation systems.

b. **Surveillance, Targetting and Weapons.** The requirement in the first instance is terrain data to support surveillance of the battlefield for the acquisition of targets. Once identified the relative position of the target to the weapons system must be determined. Additionally terrain data is required in planning the siting of some weapons systems.

c. **Command, Control and Communications.** The state of the art in information technology itself is driving this requirement for army and airforce command and control systems. The need extends from simple background map displays to the sophisitication of terrain analysis databases.

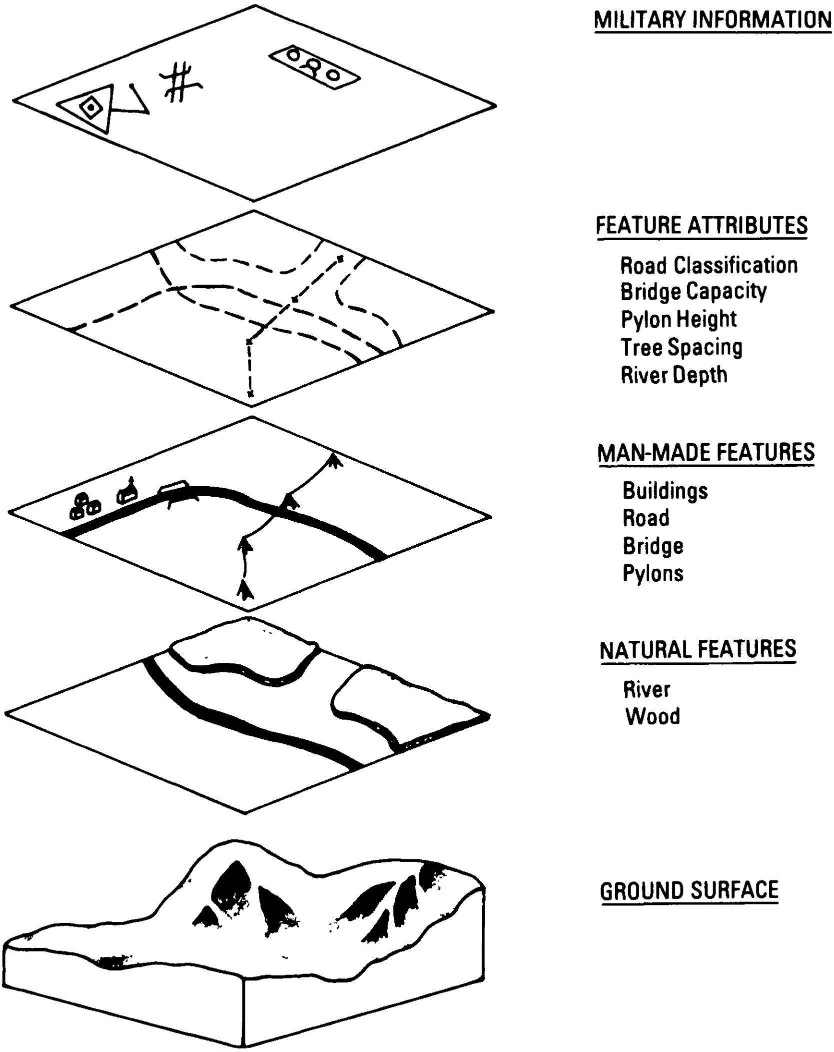

Figure 1 - Terrain Data

d. **Training Simulators.** The use of simulators for training (eg the Tornado simulator for which DLMS was developed) offers better training at reduced cost for many weapons systems and battle group trainers. The data required includes elevation data, map displays and radar or visual simulation.

Additionally we have our own need to apply the digital technology to provide the digital data required and to improve our production efficiency, as for example with the PACE programme.

A major element in defence requirements is the need for interoperability - of weapons systems and command and control systems, within battle groups, within and between the Services and between nations, such as in the NATO alliance. In the geographic field this manifests itself in the need to establish, nationally and internationally, standards for mapping and now digital geographic information. This I discuss later.

DIGITAL GEOGRAPHIC PRODUCTS

The digital geographic products that we are now producing or designing for future use derive directly from the requirements for geographic support. They can be categorised from the simple to very sophisitcated database products. These are discussed below.

Map Displays. For most evolving systems a simple background display is requested. Data storage capacity is a limitation, as is the availability of data over large areas. Expedients have been adopted, such as projected map images or video maps, and there is a multiplicity of products emerging. These are inflexible as compared to a fully digitised map where there are options for selection of data to be displayed.

Elevation Data. Terrain elevation data is probably the most readily available, and is used in a wide variety of applications. It is relatively easily produced from contours or by direct photogrammetric compilation, is easily structured (or modelled) and manipulated to produce, for example, obscuration diagrams and perspective views.

Feature Data. Both the natural and manmade features, on and below, the ground surface are included. Features can be digitised as point, line or polygon, with the addition of a feature attributes. Such data is readily used for displays and map replication. For more complex applications data needs to be structured.

Radar/Visual Simulation. This requires elevation data and feature data. The latter can be selective as in the case of radar simulation, when only radar significant features need be incorporated in the product data base that can be generated. However the coding of the features is based on a complex specification. For visual simulation all visible features will, presumably, need to be digitised. Such a product data base will need to handle radar and other types of simulation as well.

Terrain Analysis. Todays terrain analysis maps are inflexible, limited in application and difficult to use. They are therefore not greatly used and their importance is overlooked. The creation of a digital terrain analysis data base will overcome the major problem of accessing and evaluating all types of information about the terrain in real

time. More extensive feature types and attributes will need to be incorporated than for other applications, and the data will need to be properly structured. This is a demanding relational database application.

The examples of digital geographic products I have given above will, I hope, serve to illustrate the wide range of applications that have to be satisfied. Many users are already developing their own variants and there is the danger of a proliferation of digital geographic data that it will not be possible to support in the future. This reinforces the need for data standards. It also places priority on defining the range of products that it will be possible to support, and defining the production capabilities required. These matters are discussed in the concluding two sections of this paper.

Given that the necessary data standards will be defined and agreed, there remains the need to establish the range of products that can be produced and maintained by Military Survey. As we have seen these range from simple graphic displays to complex relational databases. It we are to succeed we have to look at our whole production process so that we can achieve the required product range within the constraints of available resources. The solutions we are proposing centre around optimising our use of digital technology, and developing the use of the multi-use database concept. This is discussed in the concluding section.

DATA EXCHANGE STANDARDS

The need for digital data standards is now universally accepted. How we are to achieve them is another matter. Such standards are going to be needed for digital work within organisations, and between organisations; and on a national basis and also internationally. There will be the need to exchange data between organisations, and although this can be arranged on a one to one basis many problems will be eased if a universally recognised standard can be agreed. There are also important implications for equipment manufacturers so that interfaces between equipment and systems of different manufacturers can be easily interfaced, and in the defence field so that weapons and other systems can be supported by the appropriate geographic data.

There are already a number of initiatives taking place in Military Survey, and with our NATO partners, as described in reference(1). The Ordnance Survey has now set up its Working Group into Digital Data Standards, and on a national basis data standards is a matter of active concern to the governments

Committee of Enquiry into the Handling of Geographic Information in the United Kingdom (the Chorley Committee). From all this activity one can look for positive results in the not too distant future.

For its part Military Survey started a Data Structure Study in 1984 which reported in May 1985. The aim of the study was to develop a structure capable of supporting advanced military requirements. The results of the study have provided the basis for defining some of the essential features required of a data exchange standard. The study also addressed the need for economy of production.

The main results of the Study were for a database system, based on 3 functional elements, to be developed. These elements are:

a. **Spatial data** - edge/node structure.

b. **Attribute data** - the data that describes the spatial data.

c. **Source ID data** - in a multi-product environment the maintenance of data integrity is considered essential. The Source ID data is designed to provide a full audit trail capability to support this requirement.

Two additional systems, a Geo Cell Management System and a Toponymic Database were also recommended to provide the management support needed for data maintenance.

A major conclusion of the Study was that such a database system is capable of development to support the Military Survey requirement for digital geographic data production. The concepts for such a multi-product operation are discussed in the final section.

THE MULTI-PRODUCT OPERATION

In conventional map production in general, for each product that we produce we have a separate production flow-line. There may be similar operations performed on a number of flow-lines, but in essence from the appropriate source material we extract information, cartographically process it and end up with a map product. This is illustrated at Figure 2. Different products may be related to each other, for example deriving smaller scale maps from larger scale maps, but nevertheless this requires a different process and production flow-line. Similarly we may modify a product as in the case of overprinting additional information eg at powerline and obstruction information for helicopters printed on a 1:50,000 map base. This procedure is manpower intensive, it is expensive and very time consuming. This is particularly so for a family of scale related products where there is no possibility for all the maps to be produced within a short period of time, but rather over a number of years for a particular area.

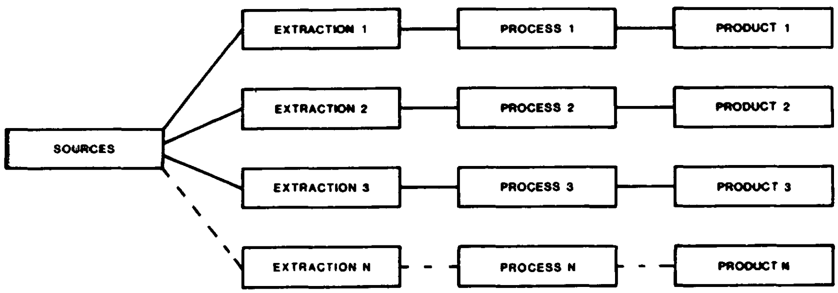

Figure 2 - Conventional Map Production Flow

In the future we are not only going to have to maintain production of map products but also digital products. Many of these digital products will relate to the map product and will be extracted from information on the map products. Nevertheless this is a significant additional workload and to approach it by adding further production proceses and flow-lines would involve an enormous increase in resources. Furthermore, it would be extremely difficult to achieve the required consistency of content and currency across a product range produced in this way. Therefore the system proposed for the future provision of digital geographic data by Military Survey had led us to look at the concept of the multi-product operation shown in Figure 3. The concept of a multi-product operation is that of capturing and storing a database from which many different products can be derived. The Military Survey multi product data base might be one scale free source data base or, more likely a series of scale related data bases. The concept envisages supply of data or data products to a number of user systems each requiring digital geographic data. Between the Military Survey data base and the user system a transformation process will be necessary, which will manipulate the data and output it in a form that the user system can accept directly. The concept is illustrated at Figure 5.

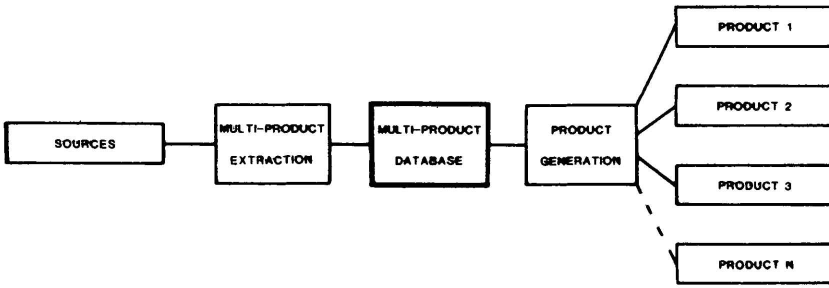

Figure 3 - The Multi-Product Process

The user system will be a type of defence system that requires digital geographic data in a particular format. The user system might consist of just one equipment or application for which a specific product would have to be produced and supplied, or it might consist of a number of user systems or equipment which could be supported by a single digital product. In terms of the system diagram at Figure 4 this does not matter but it may well influence how the data is physically supplied. Therefore there will be many different user systems, some of which will be able to accept the same data sets and others that will require totally different data.

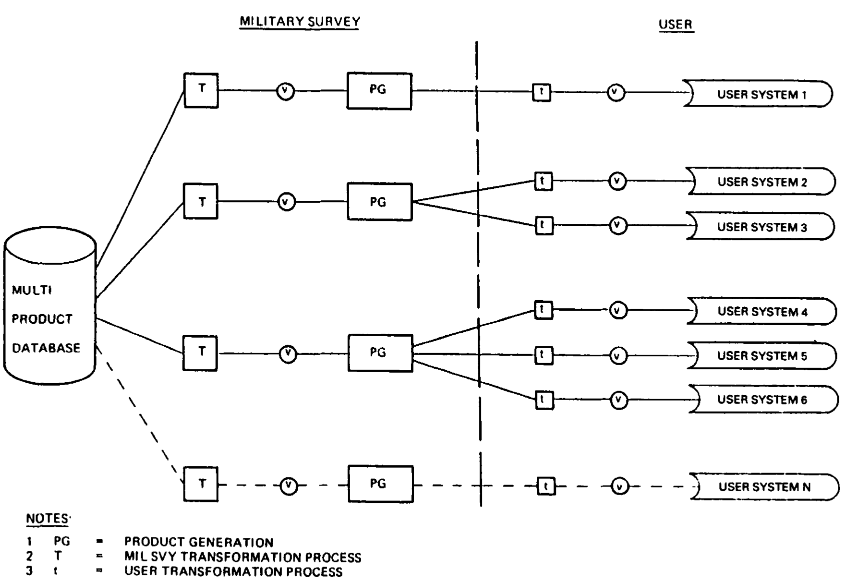

Figure 4 - Multi-Product Operation Supply System

To bridge this gap between the Military Survey data base and the user system we have to consider the transformation process, or processes, which will be required. In the concept shown at Figure 4 we envisage that transformation of data will occur at two stages. Firstly will be the transformation of data after extraction from the Military Survey multi-product data base and conversion to a specific product, or as we are called it "product generation standards" (PGS). The PGS is then available to the user system and a second transformation is performed to convert the data into the specific form required of the user system. The main variations on this basic theme are illustrated in Figure 4. An alternative concept would be to produce a single Military Survey digital product which is then passed to the user to make this own extraction and transformation to specific systems. We have discarded this approach.

In carrying forward the multi-product concept, the problem will be how to arrive at the "ideal" range of Product Generation Standards. To some extent it will be an evolutionary process, as is the case at the present time with the products that we are already supplying. However if the necessary economy in production resources is to be achieved it is essential that this matter be addressed sooner rather than later. The Military Survey Data Structures Study established the feasibility of the multi-product operation approach. As a follow on to this Study Military Survey are now undertaking a number of Technical Design Studies which will lead to the development of the Military Survey data base and, then to the definition of a number of product generation standards required to meet existing and perceived user requirements. Once these product generation standards are defined they can be adopted by users for the design of their systems, and this in itself will encourage progress towards standardisation. Present plans are for the Technical Design Studies to be completed during 1986, followed by development of the Military Survey data base for implementation during the latter part of 1988.

CONCLUSIONS

In this Paper I have outlined the major problems facing Military Survey management in moving from the era of conventional map production to the production of digital geographic data. The major management issues centre around what users require, the development of appropriate digital products and digital generation standards, and at the time establishing standards for the exchange of data and digital products. The major challenge now is the development and implementation of a multi-product data base for Military Survey to support the multi-product operation.

I have not discussed in this Paper management issues which fall in the domain of normal project management. These include such things as training. These should not be overlooked, and it remains a major management responsibility that such things are done thoroughly if one is going to succeed in the main objective of introducing the new concepts of production which I have indicated.

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FOURIER FILTERING OF LANDSAT DATA FOR INFORMATION EXTRACTION IN SURVEYING AND MAPPING

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ABSTRACT

Various spatial filtering techniques have been developed to process digital Landsat data. This research aimed to filter the same digital data within the frequency domain, and involved the use of the Butterworth lowpass and highpass filters. The lowpass filter is used primarily for the reduction of noise whereas the highpass filter is used primarily for edge enhancement. The analysis of these two filters was based on a comparative approach, utilizing what had already been accomplished in the spatial domain. It was found that the Butterworth lowpass filter did an inferior job of reducing noise and keeping data distortions to a minimum than did the spatial filters. Also, the spatial filters clearly defined edges to greater detail than the highpass Butterworth filter. However these results only apply to the frequency filters used in this research. It cannot be inferred that all frequency techniques would be inferior to spatial filters.

INTRODUCTION

In the realm of general digital image processing, two-dimensional Fourier transforms are used for enhancement, compression, texture classification, smear removal, quality assessment, cross-correlation, and a host of other operations. In particular, the Fourier transform of an input image can be used to ascertain the spatial frequency content of that image. Other spatial filtering to modify an image or to analyze a spatial structure can often be performed conveniently in the frequency domain. The goal of restoration is to process a degraded image so that, in accordance with some criterion, it resembles as closely as possible some ideal image. Alternatively, the aim might be to enhance the details of the image to enable the maximum amount of information to be extracted from the image.

An example of this involves research into the extraction of surveying information, currently being undertaken in the Division of Surveying Engineering at The University of Calgary. A large amount of surveying and mapping information involves linear features, roads, railroads, cut lines, field boundaries, etc. In extracting these features from Landsat data, for example, the additional spatial component, represented by the linear element, can be used to assist in the delineation and interpretation process.

The work involves an analysis of a study area in the upper Kananaskis Valley of southwestern Alberta, located in part of the Rocky Mountains comprising a segment of the Calgary, Canada Landsat scene (see Figure 1). The test data set consisted of 600 by 600 pixels, from which a 256 by 256 pixel subset was taken. All the necessary corrections had already been applied to the original data to account for such things as haze correction, radiometric errors and sixth line banding. Then, the data were rectified to ground control using a second order polynomial, and nearest-neighbour resampling was carried out, based on a 50 by 50 m U.T.M. coordinate grid. As well, principal component analysis (PCA) had been performed, resulting in the first and second principal components containing 99 percent of the total original four band variance (Paine, 1984). These principal components were combined to produce a classified data set on which comparisons between the spatial and frequency domain filters were performed (Paine, 1983).

FREQUENCY FILTERING

The main difference between frequency filtering and spatial filtering is that the former is usually done in the global context, applied to the image or data set as a whole, whereas the latter is usually applied locally, to a sub-set of the data. Examples of spatial filters are the Means, Median, Mode, and Five-Nearest-Neighbours filters which act on the local 3 x 3 box of data, and the Minimum-Variance and Gradient filters, which act on a rotating 2 x 2 box of data (see Paine, 1986).

Frequency filtering involves spectral analysis using Fourier transforms. The Butterworth high and low pass frequency filters used in this research are global, linear filters. A linear filter is one which assumes no periodicity in the signal, and therefore can be more generally applied. There are several alternate linear filters that can be used within the frequency domain. Examples are:

1) Recursive Frequency-Domain filters,
2) Interpolating filters,
3) Wiener filters, and
4) Exponential filters.

Another approach to filtering is to use non-linear filters. Two of the more common non-linear filters are the Maximum-Entropy method (MEM) or the Maximum-Likelihood method (MLM). The MEM and MLM differ from conventional linear spectral analysis filters because they avoid the assumptions that the data set is periodic and that the data outside the record length are zero (Haykin et al, 1979). The MEM or the MLM show considerable promise for estimating the spectra, especially when the length of the data set is limited. However it should be noted that the computational effort involved with the non-linear filters is extensive and therefore they are not as widely used as the linear filters.

An alternative method of filtering noise or smoothing a data set is by looking at the phase relationships between the Fourier coefficients at particular frequencies. The basis behind this method is to determine the coherency measure, which is the quantitative measure of the phase agreement among the phases of various Fourier coefficients at a given frequency (Dave and Gazdag, 1984). The coherency measure assumes a value of unity if all of the Fourier coefficients of a given frequency are in phase, and a value of zero if their phases are randomly oriented (Dave and Gazdag, 1984). Thus it can be shown that the coherency measure attains a higher value for those frequencies that are less contaminated, and as a result the coherency measure is correlated more strongly with the signal component than with the noise component. The result, then, of multiplying the coherency measure with all of the Fourier coefficients will be an increased signal-noise ratio and thus a smoothing of the noise from the data set.

FILTERING TECHNIQUE

The first step when working with Butterworth filters in the frequency domain is to remove any trends that may occur in the data set. Trend removal is necessary in the Fourier analysis process and may be accomplished by fitting a surface through the data set and calculating the deviations from that surface (Davis, 1973). With this data set it was found sufficient to use a first order surface for this purpose.

The next step is to take into account the fact that the data set is defined by a finite interval. The Fourier transform is derived for a continuous function defined from minus infinity to plus infinity, or an infinite sampling interval. If the sample does not have an infinite sample interval, it will not satisfy the conditions necessary to recover completely an under-sampled function. This is known as aliasing. In order to get around this problem of aliasing, the finite sampling area can be represented by a function known as a window. A window and its Fourier transform are shown graphically in Figure 2. The window used in this research was the Hamming window. The circular pattern of the final data sets is due to the windowing process, because all outer corners of the 256 by 256 data set are damped down to zero (see Figure 3).

After windowing is completed, the next step is to decompose the data via a Fast Fourier Transform algorithm. The FFT is used because the data are sampled on a regular grid, allowing significant savings in computational time. Then, once the data set has been decomposed to the frequency domain, different filters can be applied to the data to try to remove random signals that can be attributed to noise. As well, filtering can be used to enhance the image.

The transfer function of the Butterworth filter of order N and cut-off frequency located at a distance D_0 from the origin is defined by (Gonzalez and Wintz, 1977):

$$H(u,v) = 1/(1 + 0.414 * (D(u,v) / D_0)**2*N \qquad (1)$$

where
- $H(u,v)$ .... transfer function,
- $D(u,v)$ .... distance from the point (u,v) to the origin of the frequency plane,
- N .... order of Butterworth filter used,
- D_0 .... distance to cut-off frequency.

The cut-off frequency defines the radii which encloses various percentages of the information that will be filtered. For low pass filtering, the frequencies inside the radius are referenced, for high pass filtering the reverse is true. The process of trying to decide what the cut-off radius should be is a difficult one, and is most easily done on a trial and error basis. The effect of the different cut-off frequencies is compared and the one that produces the best result, without losing or altering the data significantly, is chosen as the cut-off frequency to be used.

It should also be noted that since H(u) has frequency components that extend to infinity, the convolution of these functions introduces distortions in the frequency-domain representation of a function that has been sampled and limited to a finite region (Gonzales and Wintz, 1977). This implies that, in general, it is impossible to completely recover a function that has been sampled in a finite region.

Finally, when the filtering process has been completed it is necessary to bring the data back to the spatial domain. This involves running the frequency data through several reversal algorithms, which include inverse FFT, inverse windowing and inverse trend. The filters can then be evaluated.

RESULTS OF FILTERING

In order to evaluate the filtered data sets, an unfiltered data set was used. Comparison was on the basis of:

1) Degree of generalization, which means that the image is smoothed so that areas become more homogeneous.
2) Degree of enhancement, where composite areas are created by merging discrete segments that are in close proximity. As well, linear features, such as edges and boundaries, are modified to become more distinct within the image.
3) Information distortion, which implies the movement of linear features or boundaries, the addition of erroneous information, or any significant loss of information.

The unfiltered classified data set shows both lack of generalization and boundary definition (see Figure 4). However this data set is considered distortion-free. Noise in the data can be regarded as masking the image, so the filtering process aims to produce a sharper image.

Lowpass Butterworth filters at 99, 95 and 90 percent energy level are displayed in Figures 5, 6 and 7, respectively. The 99 percent filter shows little generalization or enhancement compared to the unfiltered data set. Also there is little distortion of information. On the other hand, the 90 percent filter shows much generalization and smoothing, to the extent that some information is lost and erroneous information added. The lowpass Butterworth filter at 95 percent gives optimum results. This filter does a very good job of removing the noise from the image, showing that it has good generalization properties. As well, there is good enhancement resulting from merging of new areas. Boundaries and linear features have become more discrete, however there is some addition of information, implying distortion along boundaries. It is clear that the Butterworth filter with a 95 percent energy level gives the best overall representation.

The 95 percent Butterworth lowpass filter can be compared with the Minimum-Variance spatial filter used by Paine (1986), which is displayed in Figure 8. Both the spectral and spatial filters have good enhancement properties and generalize the data very well. Also, noise reduction is good in both cases. The major difference between these two methods is the superior boundary definition of the spatial filter. Also, the 95 percent lowpass filter tends to add information to the image.

Of the three energy levels used (90, 95, 99 percent) in the Butterworth highpass filter to try to enhance edges, the 95 percent level did the best job of defining the edges or linear features (see Figure 9). The 90 percent level caused the edges to thicken to the point where they were not clearly definable. On the other hand, the 99 percent level filter did not define the edges well enough.

The 95 percent Butterworth highpass filter can be compared with the Gradient filter used by Paine (1986) for edge enhancement (see Figure 10). In comparison, the 95 percent highpass filter performed rather poorly. The noise in the highpass filter masked the edges, whereas the spatial technique highlighted the edges very well and edge information can easily be extracted from that image.

CONCLUSIONS

The aim of this research was to utilize filtering techniques in the frequency domain in order to evaluate their usefullness for information extraction in surveying and mapping. It was found that the filters used were adequate, however not as good as spatial filters. Some explanations as to the apparent poorer performance of the Butterworth filters could be:

1) Errors were known to exist because of the prior classification process, and
2) The Butterworth filter is basically a global filtering technique as opposed to a local or regional spatial filter.

With a global type filter each pixel is being treated the same, in that a cut-off radius is chosen and the same degree of filtering is applied universally. With the local filter, each pixel is treated separately and is dependant upon the pixels immediately surrounding it. In this way each pixel is changed according to a majority rules type of philosophy. This implies that any partial errors introduced by the classification process will be taken care of, because these errors will be locally restricted and will not be propogated.

This research, however, did not cover the complete spectrum of filters that may be employed in the frequency domain. A logical extension would be to investigate frequency domain filters that act more like the local filters used in the spatial domain. These might give a more accurate representation of the data set. As well, one could begin to look at power spectrum plots and select the frequencies that contain the majority of the information in the data sets. Also, by utilizing bandlimited filters it may be possible to get more acceptable results.

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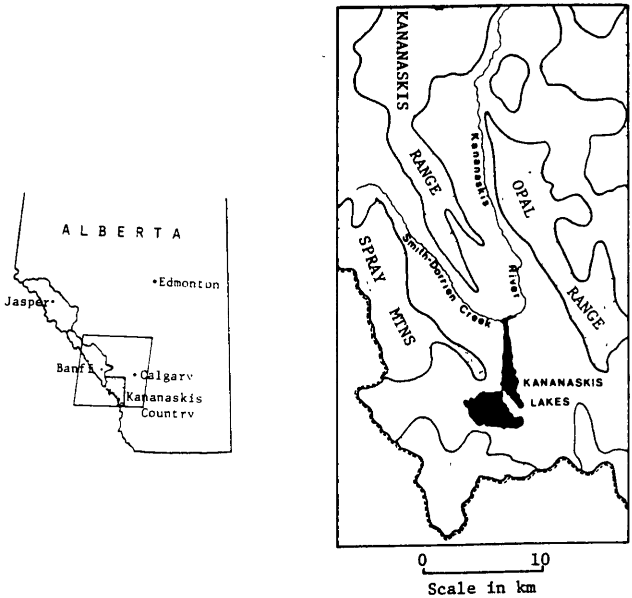

Figure 1: The Kananaskis Valley in Alberta

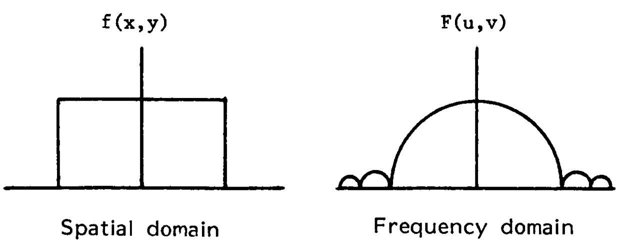

Figure 2: Window function and its Fourier Transform

Figure 3: Circular pattern of Hamming window

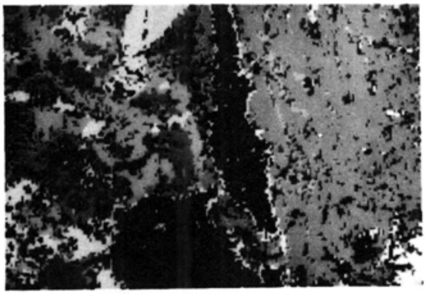

Figure 4: Unfiltered classified data set

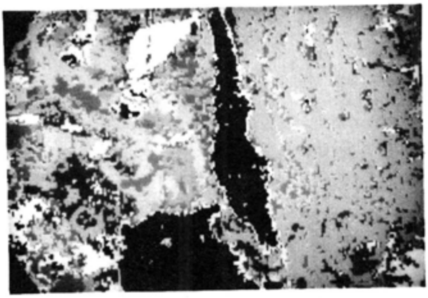

Figure 5: Lowpass Butterworth filter (99 percent)

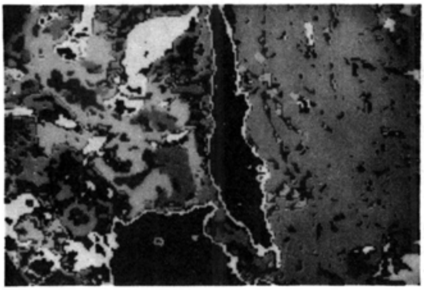

Figure 6: Lowpass Butterworth filter (95 percent)

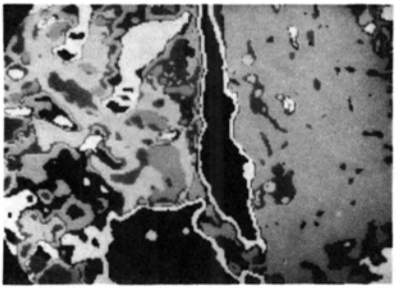

Figure 7: Lowpass Butterworth filter (90 percent)

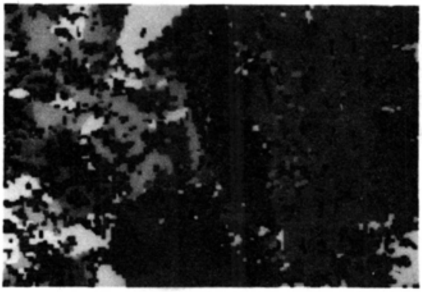

Figure 8: Minimum-Variance spatial filter

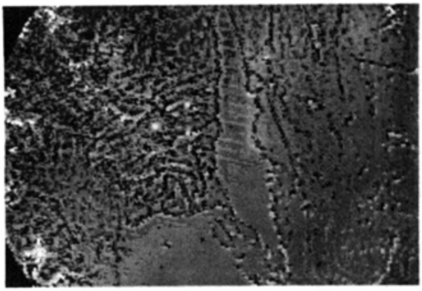

Figure 9: Highpass Butterworth filter (95 percent)

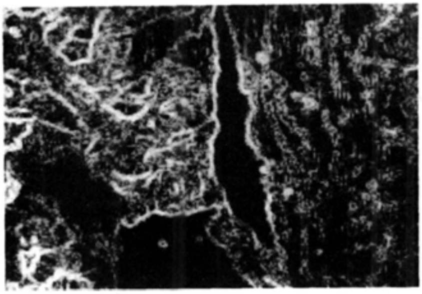

Figure 10: Gradient spatial filter

SOFTWARE-DEVELOPMENTS FOR COMPUTER-ASSISTED GENERALIZATION

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ABSTRACT

Automated data processing has meanwhile been introduced to most of the branches of cartography. Only few institutions are engaged with the problem of computer-assisted cartographic generalization. Members of the Institute of Cartography of Hanover University (IfK) are working on several research projects dealing with developments of algorithms and computer programs for cartographic generalization. These programs are the elements for creating of cartographic information systems. Base of such information systems are Digital Landscape Models (DLM), which are derived from large-scale topographic survey by digital data flow and its processing. An essential process for creating of Digital Landscape Models of a lower resolution from those of a higher one is the computer-assisted generalization. Developments on this topic which have already been made at the IfK can succed in a system for complex model generalization. The emphasis of these investigations is the generalization of the German Basic Map at the scale of 1 : 5,000 (DGK5) and the Topographic Map at the scale of 1 : 25,000 (TK25). This paper shows the development of an expert system for complex cartographic generalization which is composed of the a.m. components.

INTRODUCTION

To be able to meet the demand of the different special disciplines (geoscientists, environmental scientists, military, a.s.o.) for digital information related to location, the official surveying and mapping has been entrusted with drawing up a computer-assisted topographic-cartographic information system. It consists of different information sources and methods of information gaining, a cartographic data base as well as methods of information disposition of digital models and cartographic descriptions (see fig. 1).

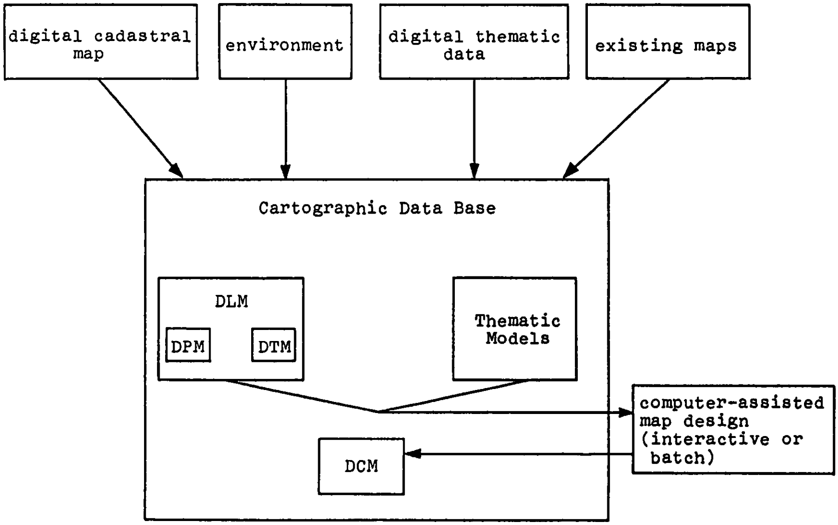


Fig. 1: Cartographic information system

The cartographic data base shall be drawn up by taking over data from different sources (e.g. digital cadastral map, digitized maps or remote sensing data). The Digital Landscape Model (DLM) and Thematic Models will be created by model generalization. In the first mentioned, Digital Landscape Models, there are the visible and non visible objects of the surface of the earth in their area relation in quality and quantity. They consist of the Digital Planimetric Models (DPM) and the Digital Terrain Models (DTM). The information of the DLM are prepared for the cartographic representation in a Digital Cartographic Model (DCM), which is also a part of the cartographic data base. As an example the object "street" should be mentioned, which is stored in the DLM with its axis and its quality characteristics, in the DCM it is stored with its symbols. The process of displacement is just only used in the DCM.

Investigations of the IfK deal with the development of an expert system for all generalization procedures, which are necessary for deriving a DLM of lower resolution from one of higher resolution in a first step and a corresponding DCM in a second one. This expert system named GENEX (GENeralization EXpert system) consits of the entire special knowledge of a cartographer.

Fig. 2 demonstrates a possible model configuration corresponding to existing topographic map series in the FRG.

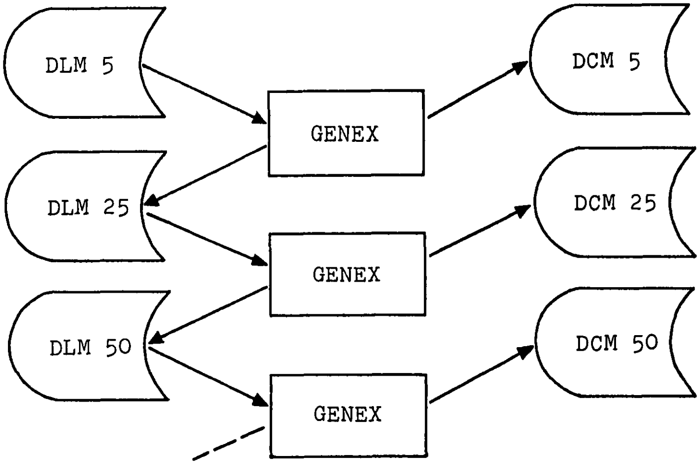


Fig. 2: Possible system of models corresponding to existing topographic map series in FRG

Essential components for the model generalization are the moduls GEBGEN and ACHSE for the generalization of areal features (e.g. buildings) and linear features (e.g. streets). They will be presented in the next chapter with their statements and efficiency.

GEBGEN - A PROGRAM FOR GENERALIZATION OF BUILDINGS

STAUFENBIEL (1973) has developed a procedure for the scale transition from 1 : 5,000 to 1 : 25,000, which has been transformed into programs by HOFFMEISTER (1978).

GRÜNREICH (1985) has extended this program for the generalization from 1 : 1,000 to 1 : 5,000 using graph-theoretic algorithms. Thus an initial step for the automatic data flow from the large scale topographic land survey to the Digital Landscape Model 1 : 25,000 or 1 : 50,000 has been undertaken.

In the following the individual program steps for a generalization of scale 1 : 5,000 to 1 : 25,000 will be shown. During this generalization procedure data will be taken from a digital data stock which could have been originated from a data flow from a basic data file 1 : 1,000 using the geometrical conceptual generalization according to GRÜNREICH or also from a manual digitalization of the German Basic Map 1 : 5,000.

Data preparation

- Conceptual generalization by feature codes (OSKA)
- Determination of outline contours of building standing closely together

Data processing

- Parameter input (e.g.threshold values for minimum lengths, - areas and - distances)
- Individual steps of generalization:
  - typification according to the offical style sheets (e.g. churches, chapels)
  - selection and enlargement: omission of buildings the area of which is smaller than the minimum dimension or enlargement of objects of extraordinary importance
  - recognition and compilation of typical parts of a building (e.g. circular arches, pillars of a church - see fig. 3), whose geometrical structure does not clearly come out of the digital data stock (generalization steps see fig. 4)

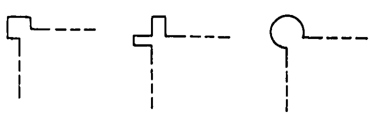


Fig. 3:
Typical parts of buildings needing preprocessing

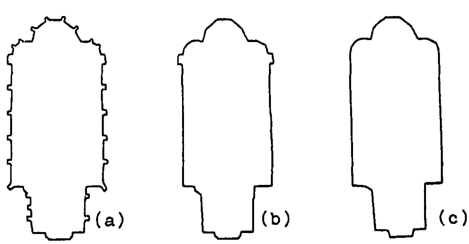
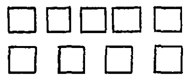


Fig. 4: Digitized data (a), first generalization step (b), generalization result (c)

- simplification of building contours
- combining of buildings whose distance inbetween is smaller than the minimum distance (see fig. 5)
- simplification of those objects having originated from combination



Forming of minimum sizes by leaving out the smallest object and equidistant distribution of the others

Fig. 5. Combining of serial objects (generalization result bottom row)

The generalization products resulting from this program may form the object classification "building" of a Digital Planimetric Model (e.g. DPM50) while choosing the corresponding minimum dimension for the requested resolution.

The following figures illustrate the generalization result for the scale 1 : 25,000 from the manually digitized German Basic Map 1 : 5,000 in an example from the city of Hannover.

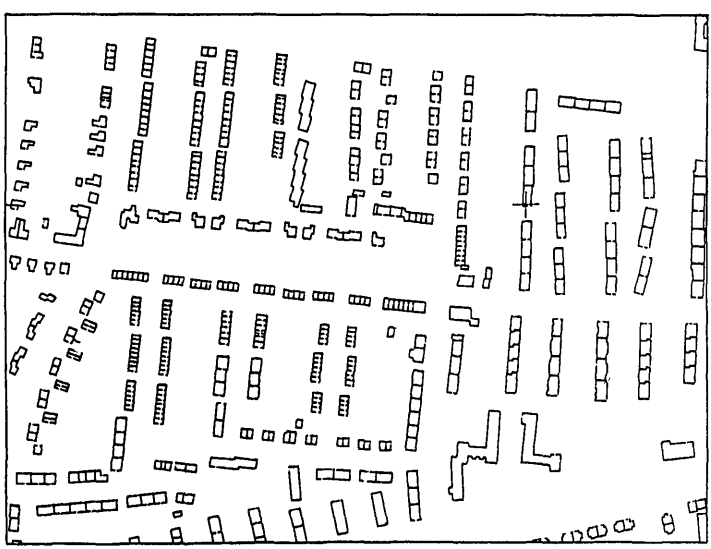


Fig. 6: Digitized data (buildings) of the German Basic Map 1 : 5,000

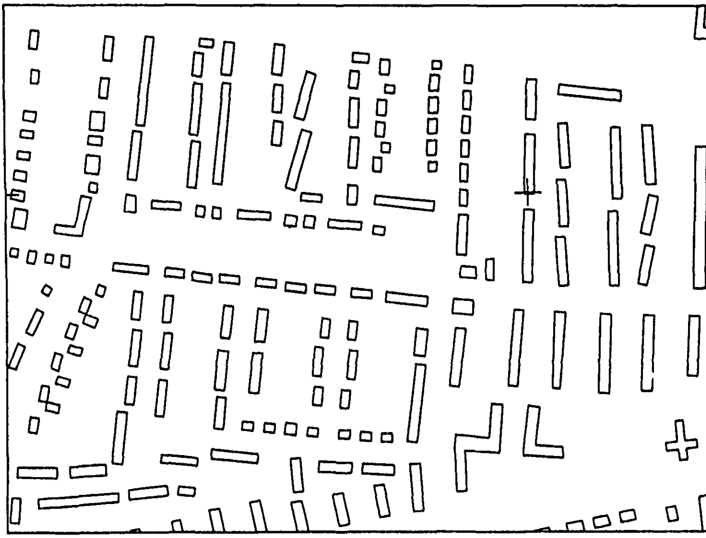


Fig. 7: Generalization result for the Topographic Map 1 : 25,000

ACHSE (AXIS) - A PROGRAM FOR GENERALIZATION OF TRAFFIC WAYS AND RIVERS

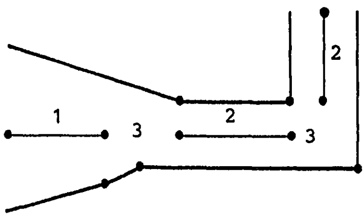
Besides the buildings and other individual features which are defined in a DPM by their individual point coordinate and an attribute there are more large groups of features - the traffic ways and the rivers, i.e. linear features, which are often symbolized in a map by double-line signatures.

While storing this group of features and also processing (generalization) the determination of their middle axis is very important. The essential factor of a procedure which has been developed by MENKE (1983) is the geometric construction of the axis elements "middle parallel", "angle divisor" and "intermediate piece".

The program ACHSE deals with digital information about the both sides of a street or a river. Also in this case the information may originate from a topographic survey as well as from digitizing of the original map.

Steps of processing

- Section by section determination of the elements of the middle axis of the type "middle parallel" and "angle" divisor" (fig. 8)
- Determination of the missing intermediate pieces (fig. 8)
- Simplification of the middle axis (polygone) with an element of the program GEBGEN



1 angle divisor element

2 middle parallel element

3 intermediate piece

Fig. 8: Elements of the middle axis

For the graphic edition of the features dealed with symbolizing is possible by a feature code:

- widening or narrowing along the supposed relation lines
- emphasis of especially broad roads if there are information about the original feature widths according to the relation lines
- objects whose widths exceed a supposed minimum width within certain sections, remain unchanged within these sections
- clearing of junctions and smoothing of irregularities of the object border lines arisen from the widening algorithm:
  - vector-raster-conversion and window building
  - area filling
  - raster-clearing of details
  - raster-vector conversion
  - filtration of the "stair"-effects arisen from the raster-vector-conversion

The introduced method of clearing of junctions and elimination of loops as a consequence of the widening furnishes results which could also have been obtained by methods of vector data processing. It is, however, evident that optimal results for the whole tested area can be achieved by relatively simple raster operations.

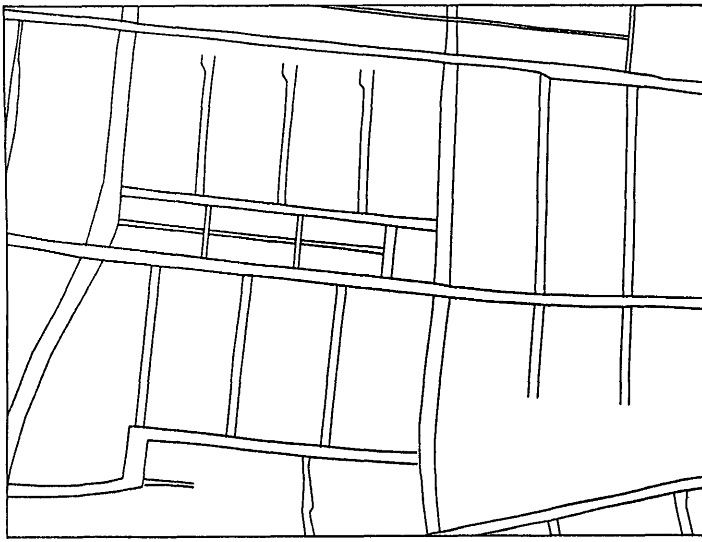


Fig. 9: Digitized data (street boundaries in the German Basic Map 1 . 5,000)

Fig. 10. Program results from ACHSE (street axis)

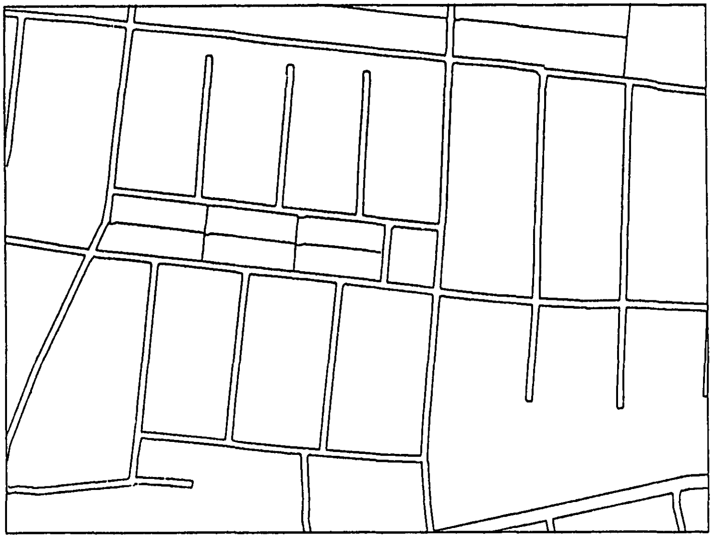


Fig. 11: Symbolized streets for DCM

COMPILATION

The moduls present elements of a complex system, which is at the moment still in the state of development. Data processing is done by hybride methods; as the final result in the DLM's of high and medium resolution the storage of geometric object information in vector-format is being planned.

An algorithm for realization has also been installed (LICHTNER 1976) and has been realized in a computer program. The further development of GEBGEN and ACHSE assists at the installation of a DLM25 or DLM50 and therefore this paper is especially devoted to this problem. The statement of displacement will be put on an existing DLM and will be an element for forming the Digital Cartographic Model (DCM) to match.

The realization of this plan, the installation of Digital Landscape Models with an automatic data flow from the topographic survey up to models of different resolution and the derivation of the resulting Digital Cartographic Models will probably need some more years of developing and will only be possible step by step with provisional solutions.

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TOWARD A PRACTICABLE MODEL OF CARTOGRAPHIC GENERALISATION

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ABSTRACT

A system for fully automatic cartographic generalisation must be able to deal with severe reductions in map scale by preserving the salient characteristics of geographic features while avoiding overlapping symbols. An "intelligent database" treating features as assemblages of landscape units can further reduce the complexity of the generalisation algorithm. A hybrid data structure is needed to allow the algorithm to track features and detect overlap. Skeletal representations of key features can guide the selection of features and displacement of symbols. A supervised approach, similar to supervised classifiers for remotely sensed imagery, affords a practicable means of choosing options and setting tolerances.

INTRODUCTION

Attempts to evaluate the cost effectiveness of programs for collecting digital cartographic data must recognize two levels of use. Primary applications are those uses the program was designed to serve. Because primary uses commonly relate to the mission of the agency supporting the project, their benefits generally are comparatively easy to assess. Secondary applications are less predictable, and often serendipitous. But although their benefits are difficult to define and measure, in the long run secondary uses might well yield a greater return on investment than primary applications. Included in the broad range of secondary uses are applications in which the data are related to other thematic coverages, are used at some future date as a base for generating change data, and are generalised to yield smaller-scale displays and other less detailed derivative products.

This paper addresses the use of computer-assisted cartographic generalisation to extend the utility of digital geographic data. It presents and explores several principles essential to the design of an operational system for cartographic line generalisation. And it recommends strategies in feature-coding to extend the applications of digital data to a wider range of uses at smaller scales.

HYBRID DATA STRUCTURE NEEDED

Perhaps the most obvious requirement for an operational generalisation model is a hybrid, vector-and-raster data structure. Although point-symbol data can be generalised in vector mode and areal data in raster mode (Monmonier 1983), linear features would require elements of a raster structure to represent their proximity to neighboring features. An operational model must recognize that generalisation involves three processes: selection, smoothing, and displacement.

Vector-only approaches, such as the widely used Douglas algorithm (Douglas and Peucker 1973), are successful only where scale reduction is comparatively minor and the density of features is sufficiently low so that overlap--or worse, criss-crossing--tends not to occur. These algorithms address only the need for feature smoothing, and then only by a process of point removal (Van Horn 1985). It is perhaps symptomatic of the operational limitations of vector-only algorithms for line generalisation that in demonstrations and evaluations, such as the exhaustive comparative study by McMaster (1983), these algorithms are applied only to isolated strings of points unencumbered by encroaching neighbors. Yet, solutions acceptable for well-spaced features may prove inappropriate for neighboring features, such as parallel railways, roads, streams, and contours sharing a steep-sided valley or water gap, as shown in Figure 1.

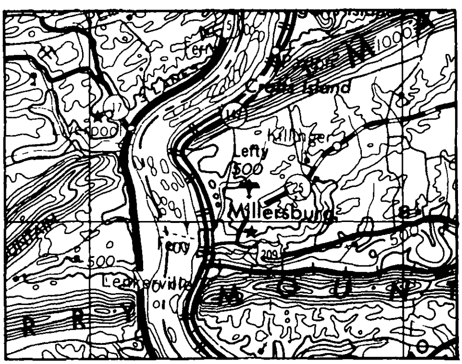

FIGURE 1--Crowded linear features, such as the river, roads, and railway sharing this watergap, require separation if overlap of symbols is to be avoided. [From Harrisburg, Pa., U.S. Geological Survey 1:250,000-scale topographic map, 1969.]

In contrast, efforts at generalising lines in raster mode can yield equally embarrassing results. In an investigation of the potential of raster data for shifting apart close features that might otherwise overlap, Wilson (1981) demonstrated that a high local feature density can produce unwarranted wrinkles in an otherwise smooth feature, as in the generalised map on the right side of Figure 2. This example includes only the boundaries of New York State (with Long Island excluded) and the Adirondack Forest Preserve, the state's principal railway lines, and the New York State Thruway from Buffalo to New York. Note the indentation in the east-central part of the region, where the mutual displacement of the road and railway produced an inward dent in the Forest Preserve boundary. Iterative raster-mode algorithms that examine only a small part of the map at once cannot easily preserve salient trends in linear features.

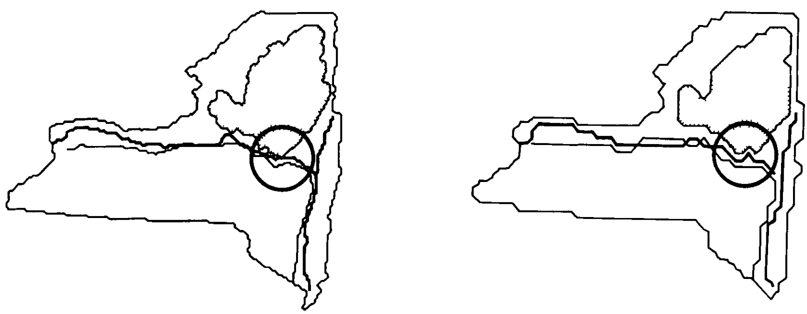

FIGURE 2--Original (left) and generalised (right) versions of raster-mode representations of selected linear features in New York State. Circle identifies dent in Forest Preserve boundary produced by mutual displacement of railway (heavy line) and road. [Redrafted from Figures 4.30 and 4.32 in Wilson (1981).]

Vector-mode displacement of cartographic features has been partly automated but seems doomed to the interactive guidance of a human cartographer. Most of this effort was carried out in the 1970s in West Germany, largely in the Department of Topography and Cartography at the University of Hanover (Lichtner 1979). Efforts have focussed on the generalisation of topographic maps, with scale reduced by factors of 1/2 to 1/4. Advances have included a series of algorithms for displacing a stream from a road, a road from a triangulation station, and a road from itself on a double-hairpin bend (Schittenhelm 1976). Where the scale reduction is moderate, say, from 1:50,000 to 1:200,000, a human cartographer enters displacement vectors to direct the shifting apart of parallel linear symbols (Christ 1976). Where the scale reduction is comparatively minor, as when the street grid on a 1:25,000-scale topographic map is generalised for portrayal at 1:50,000, apparently only interactive checking and occasional minor adjustments are needed (Leberl, Olson and Lichtner 1986). For more severe scale reductions, though, considerable human intervention would be needed to help these algorithms cope with densely packed features.

Generalization for severe scale reduction has been programmed in raster-mode for the less demanding case of land-cover polygons, reduced in detail from 1:250,000-scale digital data for presentation at 1:2,000,000 (Monmonier 1983). As shown in Figure 3, a raster-mode algorithm can cope with the need to remove clutter by eliminating some features and merging or thickening others. But land-cover polygons can be divided, whereas roads and railways require continuous symbols of uniform length, and must either be displaced to avoid overlap or eliminated altogether. Raster data can afford a convenient means of identifying contested parts of the graphic plane but cannot efficiently and independently deal with all pixels representing a long, thin, uniformly wide polygon.

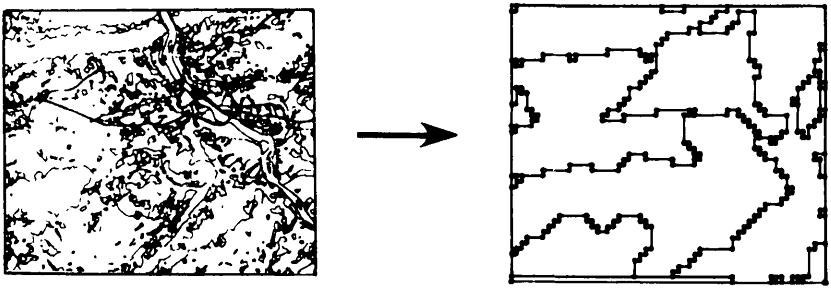

FIGURE 3--A raster-mode generalisation algorithm can remove the clutter inherent in the boundaries of land-cover polygons reduced from 1:250,000 to 1:2,000,000 (left). Elimination of thin, graphically unstable features and merger of nearby polygons with the same land cover yields a far less cluttered set of boundaries (right). [From Figures 13 and 18 in Monmonier (1983).]

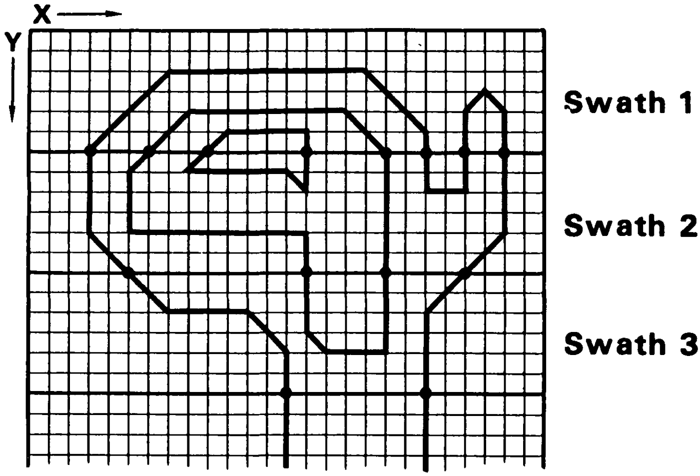

FIGURE 4--Elements of the vaster data structure, a hybrid combining a raster organisation of horizontal swaths aligned with the rows of a grid and a vector organisation of chains representing sections of each linear feature falling within the swath. [Adapted from Figures 2a and 2b in Peuquet (1983).]

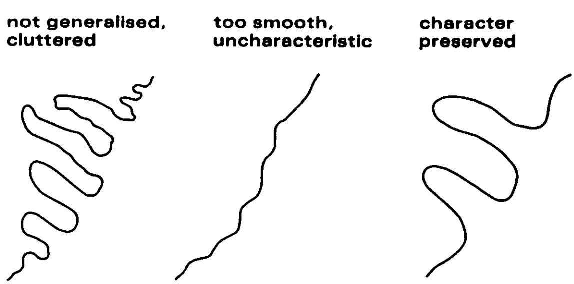

FIGURE 5--A severe change in scale might warrant the selective elimination of some features of a given type and the enlargement of others. For example, a reduction in the number of inlets not only prevents clutter but preserves the character of a fjorded coast. Merely smoothing the coastline yields a symbol with less information about the form of the coast and its geomorphic history.

A hybrid data structure, such as the "vaster" structure examined by Peuquet (1983), might promote the efficient identification and resolution of overlapping symbols. The vaster structure divides the raster grid into a number of swaths, several rows wide (Figure 4). Vector chains represent portions of linear features falling within the individual swaths, and the initial nodes of these chains are recorded as scan-line data. Chains can be followed easily between neighboring swaths, and adjoining chains can be detected easily within a swath. For feature displacement, though, elongation of the swaths in one direction (as in Figure 4) seems inefficient--displacing horizontal features upward or downward in horizontal swaths is inherently simpler than displacing vertical symbols in the same data structure. A more appropriate hybrid structure might subdivide the grid into square units, instead of long, thin swaths. Perhaps a vector-quadtree hybrid--call it a "vectree" structure--is warranted.

LANDSCAPE UNITS IN AN "INTELLIGENT DATABASE"

What might be called intelligent databases will greatly simplify cartographic generalisation. By "intelligent" I mean that the data would specify a feature's membership in a landscape category relevant to scale reduction. Perhaps the classic example of where this might be appropriate is a fjorded coastline. Points around each embayment should be similarly tagged, as should headland points between fjords. With these data a generalisation algorithm might efficiently preserve the geographic flavour of the coast at smaller scales by retaining and widening some fjords while eliminating others. Figure 5 illustrates how a cartographer trained in geomorphology would both promote graphic clarity and retain salient physiographic traits. We should expect no less from an operational model. Yet common sense suggests that much of the requisite intelligence might more efficiently be added to the data than to the algorithm.

An intelligent database might represent useful linkages between social and economic elements of the landscape. These linkages, which often are implicit in digitally encoded data on land use, land ownership, and administrative areas, are just as frequently missing from electronic representations of the street and road network--to mention but one common type of digital map. In the United States, for instance, route numbering of state highways is often the vestige of a haphazard, incremental strategy of roadbuilding, and individually numbered routes need not reflect the principal lines of travel between interacting cities along the same route. In contrast, the newer and more heavily used Interstate network would almost always warrant selection whenever roads are to be shown: its corridors are comparatively smooth and direct, and its links are usually the principal intercity routes. Moreover, its numbering scheme differentiates intercity routes from beltways and spurs, which might need to be suppressed for very-small-scale displays.

One general-purpose geographic database that would benefit from the identification of landscape units is the U.S. Geological Survey's digital line graph (DLG) data (Allder and others 1983). These quadrangle-format files of vector data represent hydrographic, boundary, transportation, and other "culture" features shown on large-scale topographic maps. Linear data for streams indicate flow direction and braided or artificially confined channels. But addition of simple stream-order numbers indicating branching structure and network geometry (Richards 1982) would be highly useful in identifying minor tributaries, which might readily be eliminated for clarity when scale is reduced.

Overlaying DLG data and the Geological Survey's land-use and land-cover data might permit a rule-based generalisation algorithm to discern the relative importance of some linear features. For example, short roads solely in residential areas are likely to be side-streets, whereas longer roads through commercial and industrial areas might well be thoroughfares. But such assumptions are problematic and far from foolproof. Specifying this kind of intelligence directly in the database would benefit cartographic generalisation as well as applications in transportation planning, computer-assisted highway navigation, and real-property assessment, among others.

"EXPERT GUIDANCE" FOR A RULE-BASED SYSTEM

Relative importance can be specified for individual points as well as for entire features. SAS/GRAPH, an American software package for data graphics and simple statistical maps, uses this approach to guide the generalisation of its county, state, and country boundaries--each point has a "density level" derived by applying the Douglas point-elimination algorithm five times, with the tolerance incremented in steps to yield five progressively more generalised sets of points (Carter 1984). A point-tagging strategy seems less suitable, though, for a large cartographic database with many features, some of which will have to be not only smoothed but displaced.

A plausible solution might be to provide a highly generalised version of the map at a greatly reduced scale. Designed by an experienced cartographer or geographer, this skeletal set of carefully selected, smoothed and displaced features could then guide the computer-assisted generalisation of the data for a range of intermediate scales. Deveau (1985) employed a similar philosophy in generalising coastlines. He controlled the degree of generalisation by finding first a "smallest sufficient subset" of points to express a feature's salient character and then eliminating details falling within the tolerance used to specify the degree of generalisation. A rule-based system might use a smallest sufficient subset of features and landscape units to guide the selection of features and to suggest directions for their displacement.

A "SUPERVISED-GENERALISER" APPROACH

An intelligent database and the guidance of a smallest sufficient subset of feature characteristics should simplify the design and implementation of an operational algorithm for fully-automatic generalisation. But experience with the comparatively simple raster-mode generalisation of land-cover data suggests that the user will need to select and set an unwieldy number of options and tolerances (Monmonier 1983). Particularly prominent among these choices are the relative priorities for selecting various types of geographic features, and for preserving their character and conserving positional accuracy. The map author must be cautious in setting specifications for the algorithm--at any given reduced scale markedly different generalisations might be produced from the same database. A "supervised" strategy, similar to those used to classify remotely sensed imagery, would be useful in allowing the cartographer to work out the choice of options and tolerances with "training data" for one or more known areas. Trial runs could be used to calibrate the algorithm to assure mapped patterns appropriate to project goals and presentation constraints. Once calibrated, the generalisation model could be applied to a much larger region.

An expert-systems methodology might also be useful. A computer could, no doubt, be programmed to examine a series of generalised maps prepared at various scales to meet specific presentation goals, and to establish a set of options, tolerances, and decision rules likely to yield suitable results for similar goals when applied to similar data. But this level of sophistication seems unwarranted because most, if not all, needs might be met with a far simpler "supervised-generaliser" approach based on good data. Intelligence in the data can obviate the need for highly elaborate algorithms.

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GENERALISATION FROM LARGE TO MEDIUM AND SMALL SCALE ORDNANCE SURVEY MAPS USING EXPERT SYSTEMS TECHNIQUES

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ABSTRACT

Definitive procedures have been developed which are effective to varying degrees in specific areas of generalisation. In many cases, however, the variables involved such as change in style, are difficult to quantify and to manipulate with precise rules or 'hard' logic. The approach proposed here is one in which the 'hard' logic of established methods are combined by the 'fuzzy' logic techniques used in expert systems

Introduction.The Ordnance Survey (O.S.) has evolved a set of unique styles throughout its range of topographic maps which both define and characterise the British landscape. In this the O.S. are considered by many to lead the world. Automating these stylistic nuances is, however a very different matter. The large scale 1:1250 map series is the obvious starting point for the generation of digital data and the 1:625000 route map has led to an accomplished end product coupling a full digital database with an output module capable of producing a map of publishable quality. The medium scales however have remained elusive and although the 1:50000 series in particular is desirable in digital form it appears to be uneconomic as an independent commercial product. There is a clear need for a bridge from the existing digital data, now burgeoning, to this scale and thence to smaller scales which are stylistically and structurally related. This paper outlines an approach to this problem which is intended to accommodate the impressions involved with the stylistic change while maintaining inherent topographic accuracy. The following sections briefly describe the techniques that have been developed for automated generalisation and outline generalisation to date in a computer-oriented or "information Science" way and finally describe recent research.

GENERALISATION

Manual approach. The professional cartographers approach is typically full of a mixture of aesthetic design assessments combined with clear analysis of the requirements and data, a characteristic of the Cartographers art which makes computer cartography so demanding.

Figure 1b depicts a simplified view of the process concerned. A key to the symbols used is given in Figure 1a. This shows the dependence of the end product on the professional cartographer's expert judgement in using libraries of cartographic symbols and the like.

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Figure 1b depicts a simplified view of the process concerned. A key to the symbols used is given in Figure 1a. This shows the dependence of the end product on the professional cartographer's expert judgement in using libraries of cartographic symbols and the like.

The prime feature of O.S. 1:50000 maps is the road network and this is obtained for by photographic methods from larger scales to form the framework of the new map. This is then redrawn in a style suitable for the new scale according to the cartographer's judgment. The remainder of the map is then constructed by a carefully assessed selection of the remaining features which are adjusted where necessary to fit and to give the "right" impression.

Automated approach. If the generalisation process is to be successfully automated it is clear that it must be fully understood in order that it can be turned into computer managable form. To attempt to do this we took Figure 1 as our starting point and generated a "Data Flow Diagram" (DFD) (Weinberg, 1980) of the equivalent automated processes involved (Figure 2) for programming into the computer.

It is in the computer equivalent of the photo-reduction process that there has been most work. The Douglas-Peuker algorithm (Douglas & Peuker, 1973) in particular derives the most characteristic generalisation of linear features and is particularly suited to the generation of strip trees (Harris, 1981). It envisaged that these techniques would be applied to the reduced linework at the target scale.

Other approaches to map generalisation. The generalisation problem is particularly challenging for the Ordnance Survey because of the legacy of established map series and the reference data supporting them. Countries mapping large areas accurately, possibly for the first time using modern techniques of photogrammetry and remote sensing have the opportunity to create styles which can cover all maps from about 1:10000 downwards. This does not trivialise the representation or the generalisation problem but it does make the process more amenable to hard logic rules.

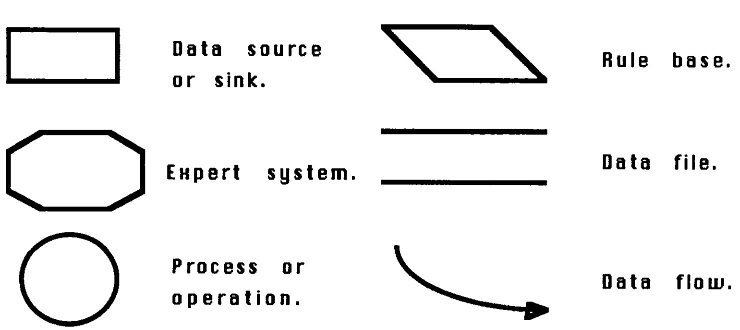


Figure 1a. Key to Data Flow Diagrams.

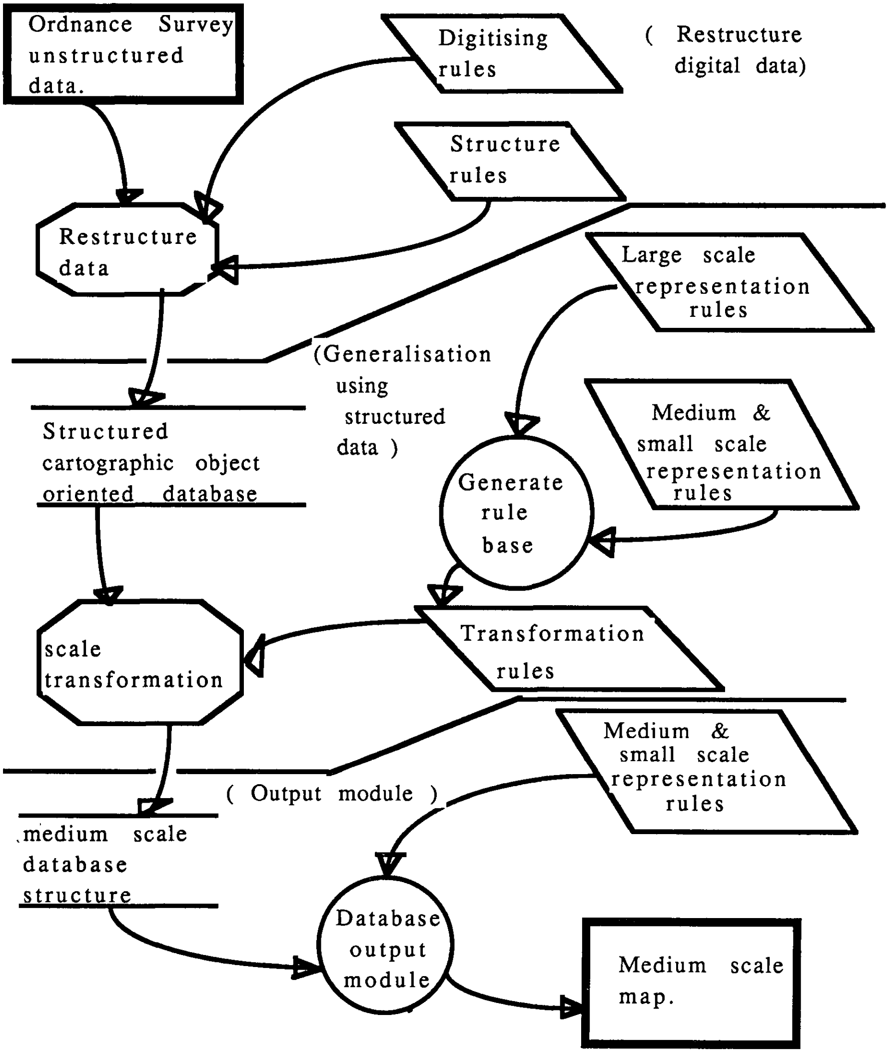


Figure 2. Data Flow Diagram of scale reduction using expert systems structure.

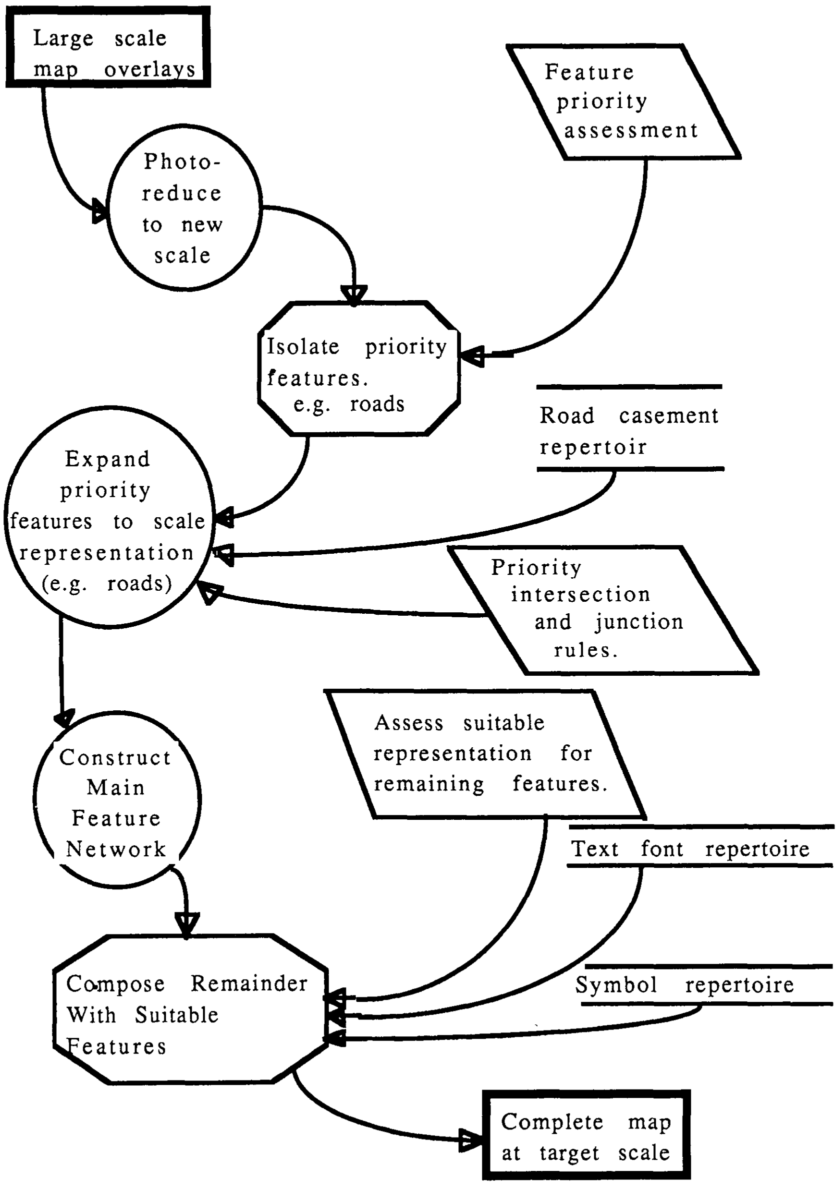
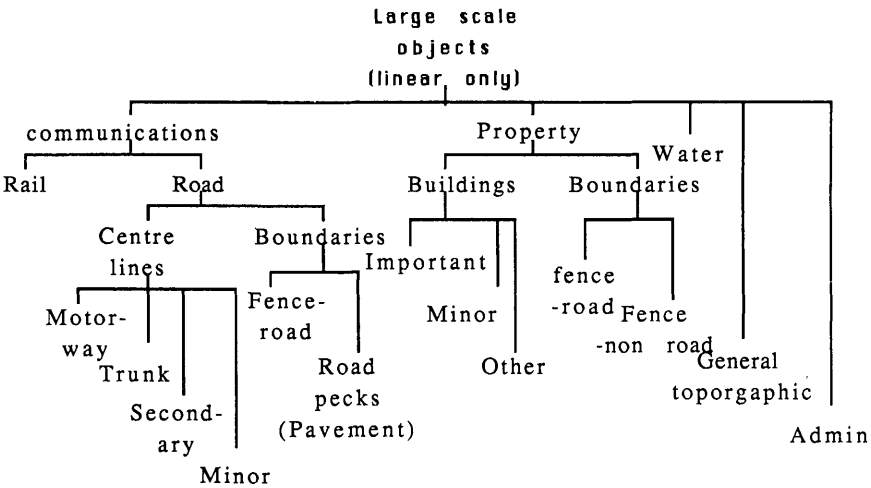


Figure 1b - Data Flow Diagram for manual scale reduction with generalistion



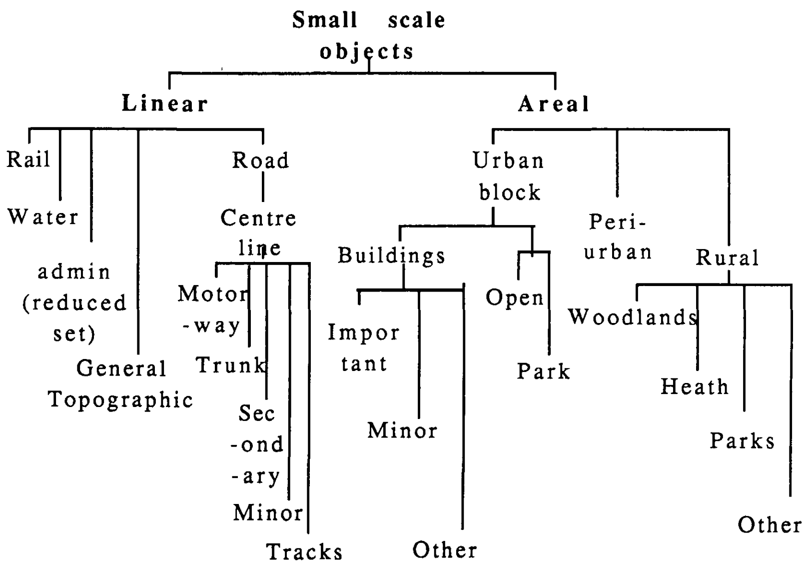


Figure 3. Map data structures at large and small scales.

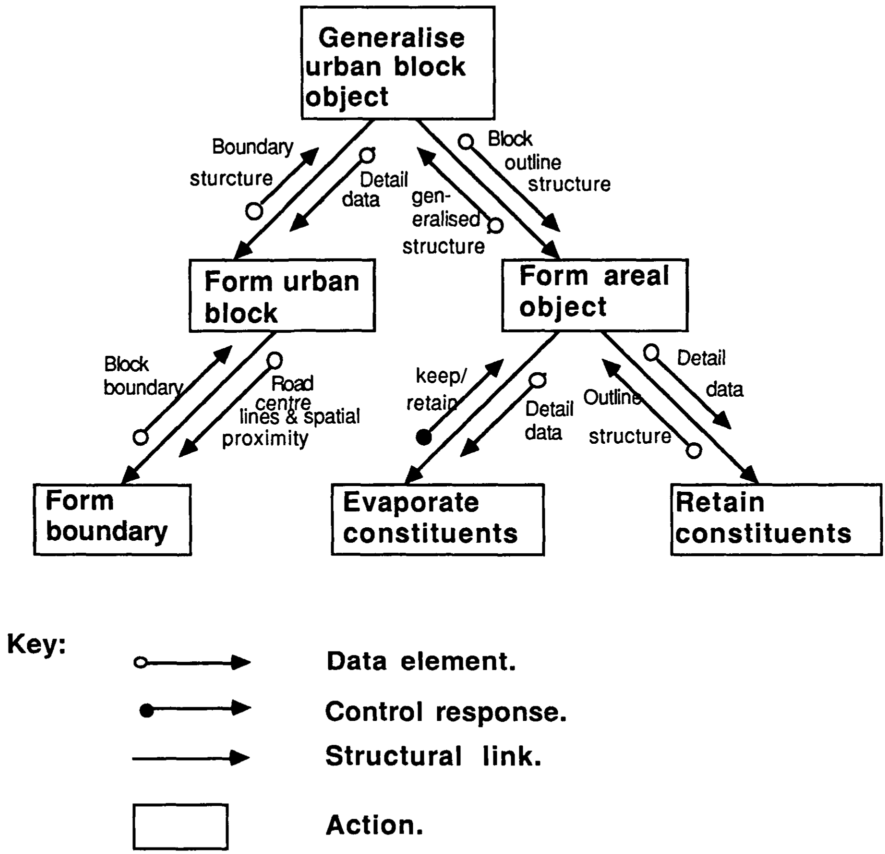


Figure 4. Transaction Analysis diagram for transform of an urban block.

concerned with the application of rules, fuzzy or otherwise, which map these objects and as a by-product their representations, into new objects at the target scale. One consequence of this approach is that objects, however defined, reflect the generalisation rules that operate on them.

Turning now to the rules we identify three basic types:

i) those that apply to basic objects. e.g. an object appears at one scale but not at another.

ii) those that modify the spatial and symbolic representation of an object.

iii) those that govern the spatial and symbolic aggregation of groups of objects into new objects.

The first set may be thought of as simply filtering the data by feature. Similarly the second could use existing line and area generalisation algorithms to filter the spatial representation of objects. The third set is the most difficult to handle and is the focus of most of our effort to date.

Object generation. By considering those objects present for the same area at different scales it is apparent that new composite objects are present at the smaller scale. The rules for composition of these are similar for both urban and rural areas although the former is the more complex. The assumption made is that the structure of the O.S. 1:50000 series is based on the road network and the remaining features are adjusted to fit the representation at this scale. Only the process for constructing an urban block is discussed here; the process for rural areas are very similar but slightly simpler. The structure of the data at both large and small scales is shown in Figure 3.

The process of transformation applied to urban data. The rules of representation at the source and target scales are well defined (Harley, 1973) and a correspondence is set up between them, the structures being defined so as to determine the creation of objects at the smaller and the treatment of their constituents from the larger scale. This defines the rules for collection and assembly into objects at the target scale. For instance an urban block at O.S. 1:50000 is defined by a combination of the application of administrative boundaries and the density of urban objects at the detatiled level of the larger scale. It containes essentially only three types of areal object; general housing, open spaces and parks, their boundaries being generated by approximation from the larger scale data. Exceptions are the presence of special buildings which are placed and presented as accurately as possible at the expense of the remaining data if necessary.

Detailed low level processing. Spatial referencing and road type information present in the O.S. digital data are used to assemble all road features to define the block and a centre line constructed. Features such as pavements and dual carriageway outlines are taken into account at this point.

Our approach. Several points from the preceding section are immediately obvious. Firstly Figures 1 and 2 are generalisations in themselves. Secondly current research on automated methods have concentrated almost exclusively on the low level spatial properties of the data forming the map. Thirdly few hard and fast rules are present, the majority are a matter of judgement in the manual case and loosely defined or "fuzzy", in the automated case. This indicated to us at an early stage that straightforward programming techniques would not suffice - a way of describing the "fuzzy" nature of the algorithms involved was essential. We therefore decided to investigate the variety of tools available in the area of Artificial Intelligence, in particular "Expert Systems". Current work has therefore centered on the use of an expert system (E.S.) shell (POPLOG) that was already available at Reading University, and which provides many features such as E.S. skeletons, LISP, Prolog, graphics and interfaces to other procedural languages.

GENERALISATION USING EXPERT SYSTEMS

The map as a hierarchy of objects. The availability of base data in a fully structured form with access to all relevant attributes is crucial to any attempt to model the generalisation process. As mentioned previously current techniques tend to be centred on the detailed lower levels of the map data rather than with high level objects. Our approach is based on that taken by the cartographer- predominantly top down - modified by occasional iterations at various levels. We thus start with the process:

Generalise (Map1 at scale 1 -> Map 2 at scale 2)

and commence to decompose this by breaking down the map into its component objects at the next level down. At large scales this could be into rural, peri-urban and urban areas. Each peri-urban and urban area object is broken down further into block objects delineated by the road network. These blocks could contain lower level objects such as houses and gardens, public buildings, parks, works, water bodies, etc. This process can be continued until the lowest level of object corresponds to the O.S. "feature". It is for this reason that fully structured data is required.

Restructuring Ordnance Survey digital data. The format of the digital data currently available was based on the ideas current in the early seventies which can be restructured with modern cartographic database software using spatially referenced attribute records and facilitates the restructuring process. The method being to bring together, spatially, the possible objects to which any line could be a component. Inference derived from the digitising standards would be applied to generate the attributes necessary for the component to fulfil all its functions.

THE GENERALISATION PROCESS

The object oriented view. Our technique is independent of the issue of feature representation. What we are doing is describing the map by a hierarchical object structure peculiar to each scale. The process is

The objects which comprise a block are generated and combined to form one of the composite features at the new scale and a boundary constructed between them. This will be modified however by the presence of special features, usually significant buildings, whose outline and position will be as exact as possible subject to modification from a generalised road boundary. This process produces a structure appropriate to the new scale and style which is the output by a specialised output module. These steps are represented in figure 2. The block translation procedure is represented by the transform analysis diagram in Figure 4 (Weinberg, 1980).

CONCLUSION

We consider that the above represents a fresh view view of a long standing problem central to the issues of the automation of cartographic design, albeit in a highly specific area, and a promising research project. There are also potential applications to data structures and datatransfer standards for medium and small scale maps.

ACKNOWLEDGEMENT

We thank Dr John Townshend, Director of NuTIS, for permission to publish this paper and Roger Anson of Oxford Polytechnic for invaluable discussions on the Cartographers methods of generalisation.

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"CARTOGRAPHIC INFORMATION SYSTEMS AND EMPLOYMENT GENERATION IN RURAL AFRICA"

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ABSTRACT

Even though there is increasing unemployment in Africa, there are various avenues for trained modern cartographers to become self employed. The prospective self employed graduate avails of periodic access to the urban based computerised work station operating a standard WILDMAP or similar equipment where he analyses the problem and data peculiar to his rural environment and task. The client could be the Federal, State or Local Government, private contracting, engineering, real estate, mineral prospecting organisations, institutions and private companies. A selected set of areas easily exposed and simplified for clients are presented. The need for international cooperation in this area of employment generation is stressed because of its novelty and technicality. The creation of International as well as National Institutes for Spatial Information Technology is also suggested.

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Rising unemployment, age-selective rural exodus and explosive rates of urban population growth, which have beset African countries during the last decades, have also been accompanied by widespread famines (Onibode 1986). In Nigeria, the drop in mineral oil prices to ₦9 a barrel signalling an unanticipated disintegration of the protective shield of OPEC membership, has created a state of economic consternation characterised by uncontrollable inflation and high rates of unemployment among both the highly skilled and the uneducated (Ekugun 1986, Abiola, 1986, Muhammed 1986).

Dramatizing disappearance of jobs are government rationalisation of salaried positions, personnel retirement, cutback of import quotas for private industries needing imported raw materials thus creating underemployment, closure or merger of universities and university departments in Nigeria as well as widespread retrenchments and layoffs (Ekugun 1986). Crude activity rate (percentage of total African population in the labour force) has dropped from 42.8% in 1950 to around 37.5 per cent even though labour productivity (Agriculture) has remained at a low constant rate of 17 percent (UN, 1979). In Nigeria the average number of persons employed in manufacturing industries had dropped from 309,070 in 1978 to 293,290 in 1980 even before many factories then closed down due to lack of imported raw materials and spare parts (UN 1982 p 447). Crude oil prices which stood at $34 in 1981 have pulmetted to an unprecedented low value of $9 a barrel. During the period, significant increases in foreign exchange reserves were recorded among oil producing countries with the exception of Nigeria (TABLE 1, IMF 1982):

TABLE 1

CHANGES IN FOREIGN EXCHANGE RESERVES (BILLIONS)

Country	Change In Billion SDR	Comment
Saudi Arabia	3.0	Increase
United Arab Emirate	0.3	"
Indonesia	0.6	"
Kuwait	0.2	"
Nigeria	-1.1	Decrease

(1981 Figures)

The net increase in foreign exchange reserves for Africa as a whole during 1981 was 0.3 billion SDR which shows that Nigeria fell below the mean for the continent in spite of substantial oil exports (IMF 1982).

Age selective rural-urban migration is closely linked with the urban population explosion which persists in spite of urban unemployment (Table 2):

TABLE 2

AFRICA: Urban Population Change

Year	1950	1960	1970	1975	1980	1985
% Urban	14.8	18.4	22.9	25.6	28.7	32.1 %
Total Urban	33	51	82	n.a.	137	n.a millions

SOURCE: UN Department of International Economics & Social Affairs, Population Studies No 85, p 59

In spite of the increasing urbanisation, employment in the urban industrial and service sectors in Africa has been decreasing in several countries since 1960 (Frank 1967). This was spotted by Frank (1967) claiming that in spite of increasing urbanisation, employment in the urban industrial and service sectors in Africa has been decreasing since 1960. Barbison (1970), Callaway (1968), Lewis (1967) and Kilby (1969) have subsequently recognized the growing rural to urban migration in spite of urban unemployment caused in part by recent salary reviews. Harris and Todaro rightly conclude that attempts to increase urban employment without a concentrated effort to make rural life more attractive will only increase rural to urban migration by the increased probability of securing urban employment. (Harris and Todaro 1968, 1970, Duru 1974).

In Nigeria, unfortunately, this thesis has been understood too literally, particularly by economists and planners applying non-African classical labour surplus models which have but tangential bearings on the Nigerian situation (Williamson 1985, ILO 1984, ElGhomery 1984, Uphoff and Wignaraja 1984).

Universitites are the foremost producers of highly skilled labour (M'Bow 1979). This essay therefore makes an apriori assumption that university based departments will seek to establish a sufficiently precise relationship between course content and chances of post-graduation employment. Such parameters as technical content (T) studio and practical exercises (S), field task exposure (F), in-service or industrial attachment (I), relevance to income generation or financial risk minimisation (G), relevance to conservation and infrastructure protection (P), concentration on health (H) and concentration on law, order and social justice (J) may be considered as aids in assessing the potential employment generation function (Py) of any subject area. With these, a mathematical model can be formulated of the form

$$f(Py)\ \phi(T,S,F,I,G,P,H,J) \quad .... \quad (1)$$

In the case of Cartography, there immediately arises the problem of definition. The International Cartographic Association Commission II deviated from its Education Commission's earlier, cautious and restrictive view of the discipline. (ICA 1968, ICA 1972). From a position of not wanting "to compete or interfere with the other established mapping sciences" it now proceeds to define cartography as "The art, science and technology of making maps together with their study as scientific documents and works of art (Keynen 1973). ICA Commission II further defined "maps" as including "all types of maps, plans, charts and sections, three dimensional models and globes representing the earth or any celestial body at any scale (Robinson 1978 p 5). This point of view, re-echoed by Piket who stresses "a new inventory of all aspects and components of our Earth" is described by Keates as "the concept of the general public" already adopted by the United Nations conferences and publications (Piket 1975, Keates 1985). These views clearly transcend Raisz's 1948 view that "The surveyor measures the land, the cartographer collects the measurements and renders them on a map and the geographer interpretes the facts thus displayed. (Raisz p. xi). Such neat and precise division, if it ever existed, has now been overridden by an avalanche of innovations in the fields of auto photo mapping, remote sensing and computer-assisted airbourne and space-bourne spatial data capture and handling systems.

In Nigeria, none of the 28 universities offers cartography as a seperate degree programme (Duru 1985). Nonetheless contents of cartography courses offered reflect the current ICA conception of the field of study as "the art and science of map making .... the totality of scientific, technical and artistic activities aiming at the production of maps and related presentations on the basis of data (field measurements, and aerial photographs, satellite imagery, statistical material, etc) collected by other disciplines" (ICA 1980 p. 4). To be fully relevant to the task of national development, the modern cartographer must be freed from the image of "someone who draws", Keates (1985, p 27). Cartography must also cease to be conceptualised as "the hand maiden of geography", surveying, or any other field since they all have their own central concerns which now differ from that of modern cartography (Thrower and Jensen 1976 p 34). The act of drafting a map is no more cartography than typing is authorship (Robinson, 1960, p.3). Modern cartography is the art, science and technology of spatial information capture, storage, and transfer using a wide variety of equipment, media, processes and tools and following a standardized worldwide graphic or conventional symbolism. Taylor's awareness of this leads him to suggest "a new cartography".... "an emerging discipline" (Taylor 1985, p 3). Kadmon terms it "4m cartography" (Kadmon 1984, p 291). Automated or computer-assisted cartography refers to that aspect of modern cartography that embraces recent developments in computer technolocy and telecomunnications technology, especially in data acquisition, spatial data base and information system creation with or without inferface manipulations. So defined it can then be hypothesized that cartography's employment generation potential in rural Africa is significant.

The ILO's stated primary objective of "achievement of full employment (in member countries) by the year 2000" has run into such serious set-backs that the organisation may need to invest in accelerated research efforts in that direction to meet its deadline (ILO 1984). Other external bodies as well as donor nations and humanitarian organisations need to re-examine their assumptions about the major constraints on real development and employment generation in African countries. This may lead to policy modifications that will favour international collaboration in high technology projects and applied research especially in computer-assisted cartography.

In Nigeria such application of modern artographic information technology calls for integrated functioning of one or more data receiving and read out ground stations. The target groups are rural based teams of agents, self-employed field operators, namely graduates, whose university training in cartography has been enhanced to include modern cartographic skills such as

(i) Real time data acquisition and analysis,
(ii) Basic remote sensing,
(iii) Digital image processing and interactive editing,
(iv) Fortram, Basic and Assembly language programming
(v) Image quality evaluation, image reconstruction, restoration and enhancement,
(vi) Statistical analysis of spatial data,
(vii) Mathematical modelling of physical elements including isometric block diagram creation
(viii) Photo-interpretation and photogrammetry,
(ix) Electro-optical instrumentation, and
(x) Field survey principles and instrumentation.

The objective is to adapt Spatial Information Technology "the eyes and ears of peace" through an appropriate organisational framework to generate self emploument for unemployed intermediate and high level manpower. Envisaged also are jobs in compugraphics instruction contracts.

The ground stations in each country should be capable of processing pre-recorded information and where possible be equipped with the facility to receive remote sensed data from some of the 150 (or more satellites in orbit (FAO 1981). The equipment could, for example receive imagery directly from environmental satellites especially the Nimbus series and also the U.S Heat Capacity Mapping Mission (HCMM) systems designed primarily for applications in rock, soil and vegetation studies among others (Barret 1981). Other environmental satellite systems which can serve as data sources include, Essa, Tiros-N, Cosmos, Nimbus, Noaa and Meteor series. For these and in the case of all other satellite systems, access to tracks, coverage and dates of transit is a necessary pre-requisite.

Earth Resource satellite imagery should also be picked up by equipment at the data readout ground stations. HCMM which was launched in 1978 with a 16 day lag in coverage, a resolution of 500m in the visible spectrum (0.5 - 1.1µ) and thermal infra-red can indeed be considered also as an Earth Resource satellite. Similarly, Landsat-C (1978) and Landsat-D (1981) with a higher resolution of 30m in 7 multi-spectral sanning (MSS) bands as well as the later 1984 French SPOT polar orbiting satellite with a 20 meter resolution in 3 bands (0.5 - 0.6, 0.6 - 0.7, and 0.8 - 0.9µ) and transmitting both vertical and oblique imagery in a periodic cycle of 26 days should also be considered. Access to these either directly or through pre-recorded recent tapes and also the imagery processing and analysis equipment make ground stations quite expensive although costs can be cut by use of micro computers such as APPLE II. There must therefore be a committment on the part of national governments and large private prospecting and construction companies to use the station. An appropriate organisational framework should be devised to ensure that the field operators are not side-tracked by consulting or construction companies who should obtain comprehensive or selective data for the local regions through the field operating agents of the Ground Stations.

Costs may be minimised through the use of mini-computers such as the POPII/70 Digital Equipment with one megabyte of MOS memory. This is most efficiently integrated in the new WILDMAP interactive remote sensed data base and mapping system. The system builds up a data base for the digital production of maps and plans at medium and large scales. It effects a computer-assisted simultaneous restitution and digitizing using stereo-plotters and stores up geographic data and descrptive texts in the data base for a comprehensive land information system. It is thus able to build up cadastrial archives of properties, and public utilities of various types. It facilitates the management of such and other data needed for various land reforms, drainage and irrigation works among other uses. Its interactive capacity makes revision, updating and unification of spatial data from various sources easy. The aesthetic and fiducial quality of its automatic draughting of plans at any scale and its flexibility in acceptance of additional software qualify it for the title of "the best stereo photogrammetric interface and supporting software available at the time (Boase and McRitchie 1983). This system can support the interactive graphics work stations, two stereo-plotter work stations with automatic plotting tables, a flat-bed plotter, eight general purpose terminals and one Textronix 4010-1 graphics terminal. It can also support at least six CRT's. Its software consists of those of the famous INFORMAP system namely the MAP/IN, INFORM and C060/1 in addition to the CAP/IN a photogrametric input addition and theCIP which is basically contour interpolation programme. With these systems the employment generating agency can make available to its agents plans of public utilities, multipurpose cadastral plan, rating maps- land information systems; planning data for plant pipelines, conduits, and ducts; technical and scientific earth-space-related computations, commercial and transportation calculations as well as a wide range of statistical assessments and evaluations. It has been suggested that in view of the key role played by cost, a start should be made with a "system relying entirely on visual interpretation (Barret, 1981, p 9).

On the contrary, by using such newer modern digital equipment, colour controlled multi-spectral imagery analysis as well as geometrically rectified hard copy prints improved by contrast stretching and high contrast filtering can be achieved quite economically.

Information needed for regional development and resource exploration at relatively low costs must be accurate, comprehensive and timely. Such information needed in Nigeria includes major classes of land use major land capability classes, physical properties and characteristics of geological formations particularly for engineering sites such as major bridges, flyovers, cloverleafs and cause-ways; abutments, spillways, and outlet works, reservoir area delimitation and micro-contouring; road relocation and re-alignment designs, transmission line and major pipeline tract design and mapping.

Exact technical cartographic rendering will prove a big asset. Information is also often demanded by Ministries of Mines, Power and Transport on orientation, pattern and condition of faults, fractures, joints, bedding planes cleavages and schistocity, especially in foundation areas and tunnels and steeply inclined routeways and cause-ways. Distribution and areas of surface water, construction materials and rock outcrops are also required by various arms of government.

Also to be easily documented in Africa are stability of reservoir rocks siltation/sedimentation, valley side erosion, gullying and stream overloading, inundation, delineation and extent of areas likely to flood or actually flooded areas, flood monitoring, flood hazard assessment and flooding impact of new constructions. Others include vegetal cover, fire threats to plantations and forest reserves, squatter encroachment in forest and nature reserves, determination of new sites for forest and game reserves, conservation mapping, cropping patterns, water flow , water depth, location of new dam sites, wind speed, wind direction and estimation of precipitation. These and other related aspects of spatial information have been called for in recent times.

Examples include the 1978 Nigerian Government consultancy contract award (No, NIR/75/058) later updated with another related contract award (No. NIR/77/008). In spite of the pitiable spatial information situation at the time, the contracts sought exceedingly wide and ambitious targets. One target was "national policy on Watershed Management and Erosion Control including the institutional and legal framework necessary", while the other added "the Development of Forest Management Capability" (Onyagocha 1980). Terms of reference were:

1. "Assess the country's problem of erosion and watershed degradation and consequent problems of droughts and floods, silting and damage, or hazards to human settlements and the physical infrastructure;

2 Assess the country's present capability to solve problems of erosion and offer training in erosion control and watershed management.

3 Assess the country's need to rehabilitate land affected by strip mining and other development projects

4 Make recommendations concerning the role of the Federal Department of Forestry and the State Forest Services in erosion control and watershed management,

5 Prepare a proposal for an institution-building project in erosion control and watershed management at the Federal level. The programme of work .... should emphasize .... a multi-disciplinary approach.

6 Prepare a report summarizing the information collected under 1 - 4 above".

These prove existence of potential jobs.

International Partnerships In Spatial Information Technology

The disgust expressed early in March 1986 by the Nigerian Minister for Works and Housing that the Ministry's directors operate from offices in the capital city is perhaps misplaced since no field data collection centres are as yet in existence (NTA 1986). The minister should instead be oriented to receiving and paying for accurate field information from spatial information specialists (graduates) renting the computerised services of a Central Ground Station and awarding major contracts to such a station. This calls for a prior existence of a number of well equipped environmental and spatial information companies employing a few experts and operating as joint ventures between foreign partners and local experts. These will create jobs for many trained cartographers. To give to the trained cartographer wishing to be self-employed, the professional protection and prestige currently enjoyed by surveyors, architects, engineers and urban planners there is a need for creation of an International Institute of Spatial Information Technology which admits experts to its fellowship (FISIT). This will enhance the prospects of emergence of (NISIT's) National Institutes of Spatial Information Technology for cartographers in various countries including Nigeria.

CONCLUSION

The study has shown that even though there is increasing unemployment in Africa, there are various avenues for trained modern cartographers to become self employed. The prospective self employed graduate avails of periodic access to the urban based computerised work station operating a standard WILDMAP or similar equipment where he analyses the problem and data peculiar to his rural environment and task. The client could be the Federal, State or Local Government, private contracting, engineering, real estate, mineral prospecting organisations, instutitions and private companies. A selected set of areas easily exposed and simplified for clients are presented. The need for international cooperation in this area of employment generation is stressed because of its novelty and technicality. The creation of International as well as National institutes for Spatial Information Technology is also suggested. Graduate unemployment and potential presence of jobs, indeed justify a call on Electro-Optical Manufacturing companies encouraged by approriate UN agencies to invest in Spatial Information Technology and Management in partnerships with local experts.

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DESIGN EDUCATION: A METHODOLOGY FOR INCORPORATING COMPUTER TECHNOLOGY INTO THE DESIGN CURRICULUM

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ABSTRACT

Computer hardware capabilities have dramatically increased over the past ten years in terms of processing power and graphic capability. Costs have decreased to the point where educational institutions can now afford to buy such systems. Unfortunately, research exploring methods to aid educators in incorporating computer technology into the design curriculum has not kept up at the same rate. This paper examines through a comparative analysis two methodologies that integrate computer technology into the design environment. 3-Dimensional representation and abstract /volumetric form are used to explore composition as a tool to aid the designer in developing alternative design solutions. Specially designed interactive software is used to aid the student in evaluating a design by converting abstract form into realistic imagery. The results of the research indicate that the most effective way to teach students to design using computers is by reinforcing the fundamentals of design theory while introducing a palate of graphic commands. With the addition of specialized software, abstract form can be easily replaced for realistic imagery. The results of this study strongly suggest that the integration of an evolving design theory, coupled with the power of computer technology not only encourages but fosters the creative thinking process by providing the designer more opportunity to evaluate, revise and incorporate new ideas into a design, emphasizing abstract representation.

INTRODUCTION

One of the major challenges currently facing design educators today is how to effectively incorporate computer technology into the design curriculum. The design professions are currently caught in a major transition between traditional styles, philosophies and communication techniques and the technological advances in society. On one hand computer hardware capabilities have dramatically increased over the past ten years in terms of power, available memory, graphic resolution and data storage. Costs have decreased to the point where educational institutions can now afford to buy such systems.

On the other hand applied research by design educators is on the increase. Research related to the fundamentals of design theory is exploring and testing traditional design philosophies in an attempt to better understand the intuitive nature of the design process.

Technology is aiding this investigation by providing designers with the tools to systematically dissect work and synthesize vast amounts of information. The investigation and use of innovative technology is crucial to this research. Education, merging design theory with the new technology is the main cog in the wheel that will turn out a new generation of design professionals.

At Ball State University, College of Architecture and Planning we are attempting to develop tools that can be used to aid the design process. The goal of this research is to develop and test a methodology for teaching architectural design at the post-secondary level that integrates the fundamentals of design theory with computer technology.

In light of the above goal, the following research questions direct the research design:

1. Can we effectively teach design students the fundamentals of design theory using two and three-dimensional computer graphics to derive abstract /volumetric form?

2. If so, is it possible to use specialized software that aids in teaching a student to visually and methodologically evaluate and resolve design problems in abstract form rather than a preconceived design solution composed of randomly placed detailed design elements in three-dimensional space.

RESEARCH DESIGN

The research design addresses the above research questions by examining the results of a comparative analysis using two entirely different approaches to incorporating computer technology into the design studio. This study uses the power and flexibility of the Intergraph computer graphics system throughout this study. The first methodology involves reinforcing design theory as the students learn to use graphic commands and manipulate images on the Intergraph computer graphics system. The premise is that students will think more in design terms when using the computer to design rather than as a glorified drafting tool. In contrast the second methodology involves no reinforcement of design theory rather teaching students the basic functions of the computer drafting with related project work.

The first class (herein referred to as Class A) was comprised of fourth year undergraduate design students, one instructor and one graduate research assistant. There were no pre-requisites for entrance into this course. Students have been exposed to a limited amount of design theory and traditional graphic communication skills. The students had no exposure or experience on a computer graphics system. The class was to meet four times a week for a 3 hour period throughout the entire 10 week quarter. A total average of 120 hrs of studio and instruction during this time was provides. The design medium was the intergraph workstation, generic IGDS command menu and specialized software for design manipulation and evaluation.

A design vocabulary incorporating design theory was introduced to class A as they were taught the basic drawing commands on the Intergraph system. The class was introduced to 2-dimensional drawing commands and used these to create abstract compositions. After a period of 2-3 weeks 3-D drawing was introduced. In all, 5 weeks of instruction and constant reinforcing of the design vocabulary through the drawing of abstract/compositions, color theory, etc. was undertaken before the major design projects were started. The remainder of the 10 week quarter consisted of two design projects, developed using only the capability of 3-dimensional drawing.

3-Dimensional representation and abstract/volumetric form are used to explore composition and spatial relationships to aid the designer in developing alternative design solutions. Only after the design decisions have been made is the student introduced to specially developed software that converts abstract form into realistic imagery.

The second design studio (herein referred to as Class B) consisted of fourth and fifth year undergraduate design students and two instructors. The class met once a week for a 6-7 hour period for the entire 10 week quarter. In all a total average of between 60 and 70 hours of class time for the quarter was spent. The students in this design studio had been exposed to design theory in previous design studios. The only requirement for the course was that each student must have taken one of the introductory 2-Dimensional computer graphics courses offered each quarter. The premise here was that if the students had already been exposed to design theory and had certain level of experience at two-dimensional drawing then the instructors could start to teach three-dimensional drawing from day one, utilizing the advanced capabilities of 3-D drawing in the design studio.

The course consisted of approximately 7 weeks of training in 3-dimensional drawing, user command, menu generation and view control and manipulation with exercise to practice drawing commands throughout this period. The remaining weeks consisted of a design project. Both studios were closely monitored during the entire quarter. No specialized software was used during the design process to aid a student in evaluating a design.

ANALYSIS OF RESULTS

Figure #1 was the first of the projects undertaken by Class A to apply the methodology in the research. Figure #1 is an example of the abstract drawing using the commands to systematically draw each of design vocabulary. They were as follows; transition, sequence, transparency, irregularity, pattern, dispersion, concentration, contrast, dominance, order, disorder, balance, imbalance, rhythum, repetition, gradation and radiation. This exercise clearly illustrates how easily the students grasped the concept of control and manipulation of views, placing of primitive graphic elements and manipulation of this graphic elements. The students began to closely associate command selection with design terms order, disorder, circles, shapes etc. and element manipulation like copy parallel, to create order or disorder.

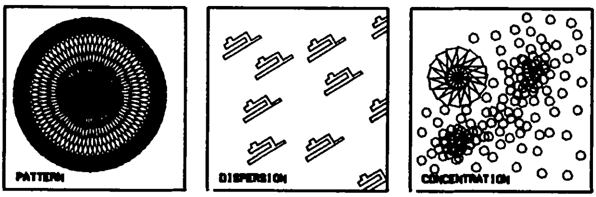


Figure #1 - Abstract Drawing of Visual Vocabulary

Figure #2 is representative of the second design exercise using four of five of design terms and commands used to draw these design terms to create a composition. The result of this exercise clearly indicates how each of the students are beginning to think more in abstract design terms with ease in manipulation of that image.

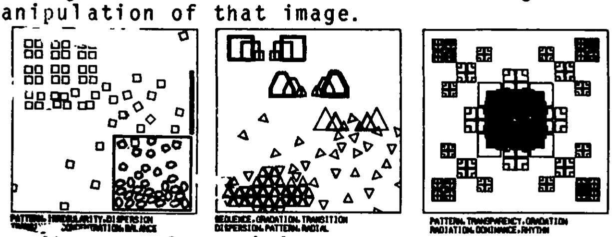
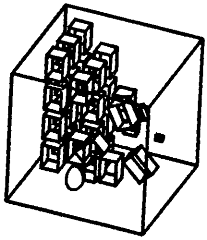
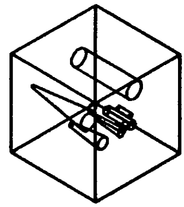


Figure #2 - Abstract Compositions

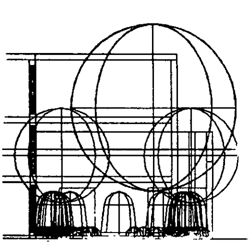
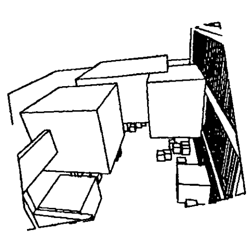
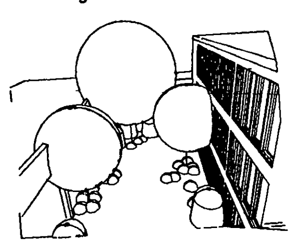
The Intergraph system is invaluable as a tool in aiding the student to envision a design in 3-dimensional space. Figures #3 & 4 reveal how easy it is to move around and design in three-dimensional space once they have learned the basics of element placement and manipulation in 2-dimensions. With the dual screens and four views on each screen, the designer can design in any of the views and reference any of the adjacent views when developing a design. Figures #3 & 4 illustrate the creation of three-dimensional abstract form within a three-dimensionally contrived space. The students quickly grasped how to manipulate 3-d views and set the active Z or three-dimensional plane while dealing within a volume. The students were able to explore the spatial relationships between abstract volumes in three-dimensional space.

Figures #3 and #4 - Three-Dimensional Abstract Compositons

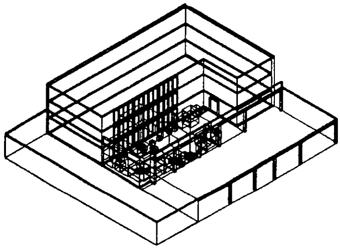
The real value of the Intergraph system for design not only lies in its ability to aid the designer in generating abstract volumes and concisely working out the interrelationships of these volumes in three-dimensional space but in its ability to aid the designer in evaluating the design in abstract form or realistic image. Evalution of the design before it was constructed or after it was designed has still been an area not well researched in design schools.

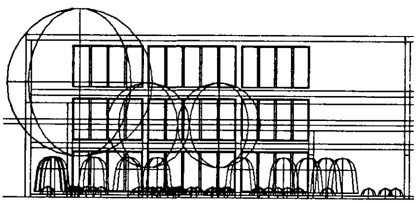
The results of this research show that the true power of the computer is its ability to visually display in three-dimensional space many alternative views of the same design. Figures #5,6 & 7 illustrate the use of the hidden line software to quickly generate various perspective views of the site by selecting the position of the viewer and the target to be viewed in any location within a cone of vision on the design plane. This provides the designer with a method to quickly evaluate and resolve any conflicts in the design early on in the design process. Further evaluation can be made later on in the design project once the abstract /volumetric relationships have been resolved by exchanging abstract volumes with detail design elements ie. details of design elements, trees, benches, facades, textures, patterns etc., to create a realistic image of the design.

Figures #5,6 & 7 - Hidden Line Perspective Views of Design

The results of this research as illustrated in figures #8 & 9 show how easily abstract design can be developed into a realistic detail design. Once the major design decisions have been made at the site scale, the designer is forced to look at design at a very detailed level. Since each volume in abstract form represents a real image that the designer envisions in the design, than it is easy from outside the design plane to divide the design into smaller detailed components. These components are created as three-dimensional cells, stored in cell libraries then by activating a user-interface replace function, each volume is quickly exchanged with the appropriate detailed cell. Any abstract form that is a closed shape and converted into a cell can be simply replaced. The detailed cell library can contain as many detailed compostions that represent a real detailed image as the designer can draw. The designer knowing for example that a volume is to represent a wall may have many styles and types of facades stored as cells and by using this replace function simply continually exchange facade for facade until the appropriate continity and image of the design the designer to trying to convey is achieved. This provides the designer with a tool to quickly evaluate the character of a design at whatever level of detail from various view points they desire.





Figures #8 & 9 - Converting Abstract Design To Real Images

Figures #10 & 11 take the evaluation of a design one step further. Figures #10 & 11 illustrate how to use a plant simulation routine to evaluate planting in a design. Figure #10 illustrates the design at the initial planting stage.

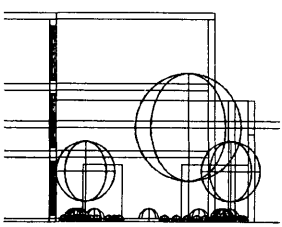


Figure #10 - Planting Plan At Time Of Planting

Figure #11 illustrates the what the design will look like 25 years down the road. The plants are grown exponentially, providing a fairly accurate representation of the degree of change that will occur over the lifetime of a project. This routine is extremely important in the evaluation of the design as a means of ensuring the character of the design is maintained or changes accordingly over a number of years.

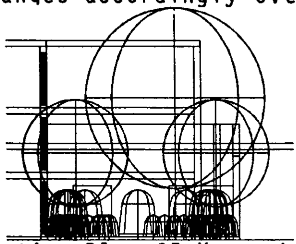
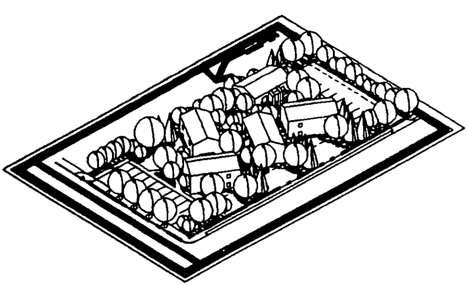


Figure #11 - Planting Plan 25 Years Later

Class B on the other hand was off to a quicker start in the design studio using three-dimensional drawing. Figure #12 illustrates a comparison of two representative examples from each class. Figure #13 were a result of two separate design projects constructed to examine three-dimensional form between weeks 6 and 7 of the quarter. A review of Figure #12 from Class A illustrates a greater amount of complexity and quality in designing in abstract volumes than in Figure #13 from Class B. The advantages that representative case Class A shown in Figure #12 has over that shown in Class B ,Figure #13 is that more time can be spent dealing with abstract design or design basics because specialized software can quickly transform these abstract ideas into realistic images. at this early stage. Volumes used in Figure #12 were developed into cells that can be replaced with real imagery. This method provides the designer with greater flexibility in evaluating a design. The designer can easily exchange these volumes as cells for a realistic image as many times as required with as many styles as there are cells to replace. The exchanging, re-evaluating and shifting of volumes around and then re-evaluating again, provides the designer with a extremely powerful design tool.



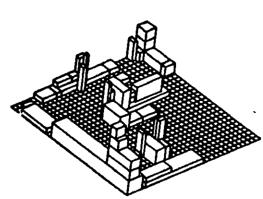


Figure #12 - Result of Class A Figure #13 - Class B

DISCUSSION AND SUMMARY

In order to truly evaluate the effectiveness of using computer technology to design or teach design one must first examine the nature of the design process in a traditional sense to determine the most suitable role computer technology plays in aiding the design process.

According to Greenberg (1984) in referring to the nature of the design process used in architectural design says that the first three phases of the design process involve problem identification, formulation of plan or strategy for approaching the problem and an attempt to create a realization or solution. Greenberg (1984,p.150) states:

> Only in the fourth stage, when there is a preliminary solution to the problem, is it possible to evaluate the results of the design. The evalutions clearly influence the next step and thus the entire design process consists of this iterative cycle, where the entry of the next iteration may be as far back in time as the initial step. Repetition through this loop is a learning process, and new ideas are continually absorbed or inserted (and perhaps later rejected) by the architect.

In light of the above discussion on the nature of the design process by reinforcing design theory through the introduction of graphic commands the designer with the aid of specialized software can spend more time developing and resolving design solutions in abstract form. This was illustrated in in Class A where the students created many more design alternatives with more freedom without getting bogged down in design detail. The student gains new perspectives of the design from re-examination and re-evaluation of the design than was the case in Class B. A Intergraph system can without a doubt speed up the first three phases of the design process as outlined by Greenberg (1984), which theoretically provides the designer with more time to design. But software like created and used in the Class A design studio used in conjunction with dynamic manipulation and various rotation commands clearly aids the designer in developing a design and evaluating throughout various stages of the process.

Having previous knowledge of computer aided drawing and without reinforcing of design theory as in Case B tends to restrict rather then enhance the design process. Students in the senior years or the design curriculum without a doubt have a preset methodology for solving design problems. This makes the transition from traditional design methods to designing with computers extremely difficult. Results of this study also indicate that without the introduction and constant reinforcing of design theory a computer tends to restrict rather then enhances creativity. This was the case in Class B were a very small palate of graphic commands and element manipulation techniques were actually used by the students out of a wide range introduced. Design theory was not the impetus reinforcing the broad range of the graphic commands. Too often the student will rely on a small range of graphic commands that they feel comfortable with, which tends to force a design solution. This serves only to restrict the design process rather then allowing the integration of computer graphics and creativity to determine how a design will evolve.

In summary, the key to the success of Class A design studio was not in teaching students how to use the basic functions of the Intergraph system nor was it in lecturing about design theory but the amalgamation of the two. The results of this study lend support to the discussion on the design process. The results of this study strongly suggest that the integration of an evolving design theory, coupled with the power of computer technology not only encourages but fosters creative thinking and learning through the evaluation process. This is due to the fact that the designer is forced to think more realistically about fundamental design issues, interactively resolve design conflicts, can explore more design alternatives with on going evaluation and re-evaluation of the design without worrying about detail. The learning process is excentuated by the continual incorporation and refining of new ideas throughout this process.

However, results also indicate that it is only after the student feels comfortable with designing on the computer that they can truely think and design creatively. Then and only then does the computer become part of the designers vocabulary which encourages them to visually and methodologically resolve and evaluate design solutions at the early stages in design development.

CONCLUSIONS

The results of this research indicate that the most effective way to teach students to design using computers is by reinforcing the fundamentals of design theory while introducing a large palate of graphic commands. With the addition of specialized software, abstract form can be easily replaced with realistic imagery. In addition this study illustrates that by incorporating the fundamentals of design theory when teaching the basics of 2 & 3-dimensional computer drawing, the design student:

A) Learns how to design by associating basic elements and element manipulations with particular components of the design theory.

B) With little or no computer experience and with minimal design training can learn a great deal about the fundamentals of design through three-dimensional volumetric /abstract form.

In addition this research illustrates that specialized software to transform volumetic form into realistic imagery without a doubt aids the student in designing and evaluating a design. Through the use of specialized software to transform abstract/volumetric design a student can spend more time in dealing with abstract form dealing more with design basics such as spatial relationships, scale etc. early on in the design process without worrying about how they are going to present their ideas, detailed design and working drawings. Too often is the case where sophisticated hand drawn graphics over weigh the design process and concealing the flaws in a design. In addition growth simlation software provides the student with a tool to quickly evaluate plant design solutions early on in the process.

The results of this research clearly indicate that students with minimal experience in design and no experience on computer can be effectively taught to design using a computer. It is important that the initial faculty to student ratio must be of approximate size as to allow a maximum of four to one student to teacher ratio. The larger the student to teacher ratio the more difficult it is to teach design using the computer.

FUTURE RESEARCH

Future research incorporating computer technology into the design curriculum should address the following issues:

1) A long range research project (over 5 years) should be initiated. This project should start in the first or second year of a students design education before they are exposed to design theory with an introductory level of graphics and follow through the entire time the students are enrolled. This would give us accurate data to properly assess how much the computer aids in the design process.

2) Plant growth simulation routines should become more sophisticated and vegetation symbols should change in form, driven by a database that will very accurately simulate growth according to climatic conditions.

3) Include in the evaluation procedures the simulation of other design components such as building facades etc.

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THE CHALLENGE TO EDUCATIONAL ESTABLISHMENTS: PREPARING STUDENTS FOR A FUTURE IN LIS/GIS

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ABSTRACT

Basic considerations arise from the requirements for education and training in spatial information systems. They are the implications of the terminology; the levels and categories of staff needed and the educational preparation desired; aspects of the educational challenge; and the importance of defining objectives in such teachng. Several conclusions resulted from ITC's evaluation of the needs for educational programmes in land information systems. The perception of need for such systems is expanding rapidly, and personnel qualified to manage their design, implementation, operation and maintenance will be in critical demand. There will be a variety of disciplines for which the educational programme must cater, and heterogeneous backgrounds will be encountered. Although a single course will not suffice for this one functional level of personnel, a common structure based on the concepts of systems engineering will be an advantage. An outline is given of the curriculum for the first specialisation, and the essential differences between it and the other two specialisations are noted. The paper concludes with points for discussion: the need to identify completed manpower forecasts, the value of a 'clearing house' for exchanging information on programmes and courses, ensuring there is full coverage of the educational needs, and developing an informal referral system for student applicants.

INTRODUCTION

Educational establishments are increasingly challenged by society, and by governments acting on its behalf, to provide programmes which are relevant to society's needs. One such need is for personnel able to function creatively, effectively and efficiently in the many land and geographic information systems which exist in, are undergoing development, or are proposed for, the public and private sectors. An assessment of the size and segmentation of the market for digital spatial data in the USA, including GIS applications, has been provided recently by McDermott (1984). Satisfying the personnel requirements of this and similar expanding markets, and overcoming the lag between the recognition of need and the initiation of appropriate programmes which often occurs in academia, is a major challenge. It is also a growth centre for the educational world, to which the small number of responses thus far range from three day "crash courses" as a function of continuing education to a four year undergraduate baccalaureate degree programme. The purpose of this paper is to identify and consider matters which arise from the requirements for education and training in spatial information systems.

BASIC CONSIDERATIONS

Terminology and implications for education

The purpose of raising the subject of terminology is not to add to, discuss, or modify existing definitions of LIS and GIS; nor to argue whether one is a subset of the other. Recent contributions, including papers by Hamilton and Williamson (1984) and Marble (1984), will provide the semantic purist with ample material for consideration. Rather it is intended to recognise key aspects of the discussion and terminology which have implications for educators.

1. Spatially-referenced land-related information systems demand inter-disciplinary cooperation. The disciplines which should be represented will vary with the questions which a system should help answer in order to facilitate planning and decision-making.
2. Such systems should be strongly user orientated. This requires a thorough understanding by those who will design and manage the system of the political, legal, economic and social factors which may influence the development; and a commitment to investigating, understanding and responding to user requirements.
3. The land parcel is clearly the basis of some information systems, and the legal or fiscal attributes of the parcel are vital to specific parcel-based systems. Equally clear is that there are systems for which the parcel is not relevant, and for which other polygons or grid cells represent the basic element.
4. Procedures and techniques of data collection, structuring, manipulation, presentation, management and maintenance are central to spatially-referenced information systems, whether in manual, automated or hybrid forms; and sound knowledge of possible techniques which might be employed is important. The degree of importance will, however, depend upon the level at which the individual is expected to function.
5. Information systems will have consequences for staffing and funding, and these must be understood by those responsible for design and management.

Levels and categories of staff for which education and training is needed

The purposes, design and components of a specific information system will determine the level, categories and numbers of staff needed to ensure its proper functioning. Each solution will be unique, and the nomenclature and responsibilities of the personnel will be decided accordingly. Given the theme of this paper, however, an attempt will be made to identify appropriate levels of staff, suggest generic categories, and describe functions.

The levels of staff are A. Management; B. Technical Support; and C. Operation. The categories of staff, and their functions, are shown below.

Level	Category	Functions
A	System Manager	To assemble and analyse user needs, develop design concepts, oversee procurement and installation, manage the system, maintain contact with users, and define necessary changes to the system
A	Data Base Manager	To design data structures and formats, and to manage the creation, utilisation, maintenance and expansion of the data base(s)
B	System Analyst/Designer	To transform concepts into detailed system design, evaluate proposals, undertake benchmark tests, supervise installation, conduct problem analysis, and design changes to the system
B	Programmer	To programme utilities, algorithms and interfaces
B	System Engineer	To ensure the smooth running and maintenance of the components of the system
C	System Operator	To operate the individual components of the system for data collection, processing and presentation
C	Terminal Operator	To input high volume text data (where appropriate)

Education or training, and work experience, desired

For each category of staff which has been identified an outline will be given of the academic preparation and work experience considered desirable.

Category	Academic preparation	Work experience desired
System Manager	BSc or MSc in discipline appropriate to the type and functions of the system; and post-graduate course in LIS/GIS or image processing	In the discipline, and in the applications of computing within the discipline
Data Base Manager	BSc or MSc in appropriate discipline and post-graduate course in LIS/GIS; or MSc in Computing Science	In the discipline, and preferably with spatially-related data base

System Analyst/Designer	BSc, Computing Science	Analysis of user requirements and system design
Programmer	BSc, Computing Science (for senior level); post-secondary diploma in computing (for junior level)	Programming for spatially related data
System Engineer	BSc, Computing Science or Electrical Engineering	In computer installation, operation and maintenance
System Operator	BSc and/or diploma in land surveying, photogrammetry, cartography, remote sensing, or computing	In digital mapping, computer-assisted cartography, digital image processing or computing
Terminal Operator	Secondary schooling completed, and preferably diploma in computing	

Tentative conclusions on the educational challenge

A wide range of spatially-referenced, land-related information systems already exists at various stages of implementation and with differing degrees of sophistication. They serve the needs of legal and fiscal cadastres, utilities management, local authority and municipal planning and management, land use in its many manifestations, or combinations of interests. Others will surely follow, and continued attempts will be made to develop functioning linkages between systems and data bases. In the light of this situation, and the functional levels and categories of staff which have been recognised, the following tentative conclusions are reached on the challenge facing educators.

a) Management level

1. Knowledge of the appropriate user discipline, and a thorough grounding in the concepts and techniques of LIS/GIS, are equally important to system managers so that the relevance and proper functioning of an information system can be assured.
   There is, then, the question of whether a single course offering in LIS/GIS can deal adequately with the range of disciplines and applications which can be anticipated.
2. Managers of spatially-related data bases with a first or higher degree in Computing Science would be better prepared for an LIS/GIS environment if the curriculum in Computing Science permitted insights into the earth sciences, and perhaps carefully selected social sciences.
3. The role of Geography as an integrative discipline warrants careful consideration when education in LIS/GIS is under discussion.

b) Technical support level

The conclusion noted in 2. above could also be applied to the category of System Analyst/Designer.

c) Operational level

The curricula of those disciplines traditionally concerned with spatial data collection, processing and presentation should be reviewed to ensure proper emphasis is placed on the requirements and use of spatial information, and the appropriate methods of collecting data and converting it into the information needed.

Teaching in LIS/GIS

Educational theorists consider it highly desirable, if not essential, to define with precision and clarity a small number of objectives for each programme, course, and teaching unit; and to express the objectives as a graded series of practical and intellectual tasks. The subject matter of the programme, course or unit, and the choice of teaching method(s), should be such as to contribute to the fulfilment of one or more of the defined objectives. Whether such theory is applied in practice will depend largely upon the teacher's own knowledge and understanding of the processes of learning, and methods by which to achieve success. For prospective managers of land information systems, there is an interdependence of disciplinary interests and techniques of data collection, organisation, processing, storage, extraction and presentation. The former are reflected in the questions "why", "for whom", "what", and "when", and in other contextual factors. The latter consists of a wide variety of technologies, processes, and their applications. Reflecting this interdependence of interests and techniques, and achieving an appropriate balance between these two major components, are judged to be particular and difficult challenges to the designers of an educational programme in LIS/GIS which is intended for present or future management level personnel. Given this context it would seem that the carefully structured statement of objectives, and accompanying steps in curriculum planning, are highly desirable means to the end required.

LIS AT ITC

Photogrammetry was the founding discipline at the Institute. It was joined later by disciplines which utilised aerial photography for data collection and interpretation: Natural Resources (soils, forestry, rural surveys and integrated surveys), Earth Sciences (geomorphology, geology, geophysics and mineral exploitation), and Urban Surveys. Cartography and the Image Processing Laboratory were added in the 'Seventies. The majority of courses are offered to post-graduate and MSc students, though in three departments students may follow technologist or technician courses. In 1985 there were 389 students in residence. Post-graduate diplomas and MSc degrees were awarded to 230 and 31 students respectively. Several factors prompted an evaluation in 1984 of the needs for educational programmes in land information systems, and the following conclusions were reached.

1. The perception of need for such systems is expanding rapidly. This is in response to reports in the technical literature; conference discussion; the singular or combined efforts of consultants, software houses, and equipment manufacturers; and the interest of the World Bank in seeing improvements to land registration, property assessment, the collection of taxes upon land, and the upkeep of urban infrastructure.
2. There will be an early and critical need for personnel qualified to define and analyse the requirements for and functions of such systems, and to manage their design, inplementation, operation and maintenance. It was accepted that other levels and categories of staff will also be required. In the first instance, however, the need for managerial staff will be pressing. The planning group decided, therefore, that the initial focus should be upon an educational programme for actual or potential management level personnel possessing university degrees; and that the programme should have a strong user or demand orientation.
3. There are three main problem areas in which spatially-related land and geographic information plays a key role:
   a) A legal and/or a fiscal cadastre which can serve as the foundation for a multi-purpose cadastre
   b) Municipal information requirements for planning, decision-making and management
   c) Project, rural, regional or national development planning, decision-making, management and monitoring of change
4. The educational programme should attempt to cater to a range of professional interests in land information systems - representing the survey and earth sciences, natural resource disciplines, and urban and regional planning - and to respond to the needs of the problem areas identified above. As a consequence it could be expected that the programme would have to accommodate heterogeneous academic backgrounds and work experiences.
5. Given the considerations noted above, the extreme position of there being a single course dealing with the whole spectrum simultaneously would not be acceptable. It would of course be impossible to provide a tailor-made course for each participant. The compromise should consist of a small number of specialisations. In order to avoid unnecessary duplication in teaching, the curriculum should be planned in such a way that there would be elements common to the several specialisations.
6. The specialisations would require a common structure within which to operate, combining where appropriate and diverging where necessary to reflect the professional interests and problem areas of relevance to the students. The common structure should be founded upon the concepts of systems engineering, and take the following form:
   a) Defining the functional problem of the information user to be solved, and the processes on which a solution depends

b) Analysing the specific environment of the problem, and the conditions and constraints it imposes
c) Specifying the information needed for the solution of the problem
d) Defining the data required to derive the information needed
e) Examining and assessing the means of collecting, structuring, storing and processing data into the information required
f) Solving the functional problem

Planning proceeded with the intention of offering a one year post-graduate course in the first specialisation (or problem area), the Cadastre/Land Registration, to commence in October 1985. An outline of this specialisation is given in Table 1. Though the Institute has a firm base in disciplines concerned with data gathering, manipulation, analysis, presentation, and utilisation for problem solving, to realise the full scope of the first specialisation has necessitated cooperation with other institutions. The substantial contributions of colleagues from the Department of Geodesy, Technical University of Delft and The Netherlands Cadastral Office have demonstrated the importance of "networking" between institutions. Other specialists are also participating. Such "networking" may prove to be necessary for other educational institutions embarking upon a course or programme in LIS/GIS unless, of course, the variety of disciplines required are already represented in the individual institution. "Networking" does, however, demand careful coordination in course planning and execution, a lesson which has been learned by ITC and its collaborators. The first specialisation is underway at ITC with 10 students selected from 55 applicants. All ten have degree qualifications in surveying and previous work experience.

Planning is underway so that the other two specialisations may be offered in 1986, in Municipal Data Management Systems and Rural Data Management Systems respectively. Much of the content of subject groups 1-4 (inclusive), as outlined in Table 1, will differ substantially from that of the Cadastre/Land Registration specialisation; and will be offered by the three departments at ITC concerned with Natural Resources, Earth Sciences and Urban Surveys. The section on data gathering techniques (6.2 of Table 1) will be modified to reflect the relevance to the two specialisations of small-format aerial photography, air-photo interpretation, and remote sensing; and the reduced roles of land survey, photogrammetry and valuation. Common subjects will account for approximately one-third of the time available; and in each of the additional specialisations emphasis will be placed upon practical projects related to the student's home country or to a project on which ITC staff are working overseas.

TABLE 1

LIS SPECIALISATION IN THE CADASTRE/LAND REGISTRATION

SUBJECT GROUP	SUBJECTS	HOURS LECT/PRACT
0 Preparatory Subjects	Maths, Statistics, Programming, Surveying, Photogrammetry, Cartography	133/74
1 Introduction to LIS	Definitions, theory, applications, models	32/-
2 Defining the problem area	Land, the economy, transfer, security, planning	36/-
3 Environmental characteristics	Political, cultural, legal, socio-economic, technological, institutional	50/38
4 Info required by problem area	Cadastres, parcels, identifiers, linkages, confidenticality	20/-
5 Data required to derive information	Data types and quality, technical and legal	26/-
6 Technology		
6.1 Georeferencing	Systems and conversions	8/-
6.2 Data gathering	Land Survey; Valuation; Photogrammetry; Photo-interpretation; Remote Sensing; Socio-economic, admin. and environmental data; digitizing existing graphics	157/98
6.3 Mapping Techniques	Metric and semantic data, standards, methods of presentation	64/70
6.4 Data Base Technology	Requirements, data systems, models, DBMS	50/50
6.5 Data to Information Processing	Data types and sets, editing, manipulation, analysis, modelling	28/34
6.6 Functional design	Admin. and graphic parts of cadastral data base	10/30
7 Resources required	System specification, selection, personnel needs, education, re-training	26/-
8 Existing systems	Overview of selected systems	10/8
9 Systems engineering	Applied to design/implementation of LIS	15/-
10 Case Studies	Case study and computer simulation	25/20
11 Final Project	Project to integrate all subject matter	-/240
		690/662
	TOTAL	1352
	Directed studies	302
	Technical visits	80
	Assessment	40
	Statutory and other holidays	120

CONCLUSION: POINTS FOR DISCUSSION

Whether one shares Humphries' (1984) view that "hopefully, the educational problem is a passing one....." will reflect one's optimism or otherwise. Perhaps few would question his statement that "a concerted effort and the fullest possible cooperation between the tertiary institutes, employee and employer" will be needed. In the broader international context the second part could, however, be expanded to include the multilateral and bilateral funding agencies which support external educational studies. What follows here is the author's perception of points which warrant discussion between educators in LIS/GIS.

1. The signs suggest that the market for personnel educated or trained to fulfil specific functions in LIS/GIS will grow in the coming ten years at a rate in excess of the supply from educational institutions. The author is aware of a forecast of personnel requirements which has been made in one country. Presumably there are other forecasts. Knowledge of their existence and contents would assist the planning of new programmes and courses; and would help prevent the serious imbalances between demand and supply which have been experienced in some disciplines. What is needed, then, is the identification of national manpower forecasts which have been completed, and initiation of such in other places.
2. A workable mechanism must be devised for the exchange of information on current and proposed programmes and courses in LIS/GIS. Word of mouth, the occasional paper on an educational matter, and the chance sight of an announcement in a journal or brochure, are unreliable forms of communication. For the purpose of exchange a 'clearing house' is desirable, which might be the responsibility of an educational institution or association, or a professional body. It could, of course, be at national level; and in the larger developed countries this might be appropriate. But for many developing nations the needs for specialised education or training in LIS/GIS will have to be met externally. This suggests that an international 'clearing house' would be useful.
3. It is the jealously guarded prerogative of educational institutions to devise and offer programmes. This the author defends, particularly in the face of a growing tendency for governments to influence - and even direct - what will be taught. Yet the 'clearing house' suggested above could play a valuable role in helping to ensure that full coverage of educational needs in LIS/GIS is provided for the levels and categories of staff proposed in this paper. Being able to determine easily what courses are offered, where, and to whom, could help identify potentially serious gaps in coverage and, equally, substantial overlaps.
4. Finally, enrolment in an LIS/GIS programme will be influenced by many factors, both student-centred and institutional. The latter will include staff and equipment constraints, and could lead to qualified applicants not being admitted to a specific course. Knowledge of alternative programmes, and of

the availability of places, would be an advantage to those responsible for admissions. For this purpose an informal referral system would be useful, particularly in the context of the limited number of programmes and places to satisfy what is clearly a growing international demand.

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DIGITAL MAPPING AT THE AUSTRALIAN KEY CENTRE FOR LAND INFORMATION STUDIES.

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ABSTRACT

The paper describes the establishment of and development plan for the Australian Key Centre for Land Information Studies, located at the Queensland Centre for Surveying and Mapping Studies, Brisbane. The Key Centre pursues education, training, and industrial development in the fields of Land Information Systems, Digital Mapping, and Remote Sensing, and has an opportunity to investigate and develop interfaces between these areas. Details are given of the already significant facilities available at the Centre, together with planned facilities and details of a number of case studies completed and in progress, primarily in the digital mapping area.

INTRODUCTION

The Australian Key Centre for Land Information Studies was established in 1985 by a grant from the Australian Government in response to applications from leading academic institutions throughout Australia. This followed the formation of the Queensland Centre for Surveying and Mapping Studies which was created in the same year by an academic and scientific amalgamation of the surveying departments of the University of Queensland (U.Q), the Queensland Institute of Technology (Q.I.T.), and Darling Downs Institute of Advanced Education (D.D.I.A.E.). This amalgamation has created the largest and best equipped school of surveying and mapping education in the country and has enabled the centre to achieve "critical mass" with respect to research and development activity. The Key Centre is supported by the Research and Development Section of the Queensland State Government's Department of Mapping and Surveying, and by the University Departments of Geography, Regional and Town Planning, and Computer Science, and the associated departments at Queensland Institute of Technology and Brisbane College of Advanced Education.

Aim and Objectives.

The aim of the centre is to provide a Key educational facility specialising in Land and Geographic Information Systems, with their associated input, processing and output systems, covering Australia and the Asian Pacific region.

The aim will be achieved by the offering of formal and continuing education courses, from para professional to doctoral levels; training; industrial research and development; and consultancy.

The Key Centre is multi-disciplinary, and attracts students, educators, and researchers from such areas as computer science, geography, regional and town planning, and government and law, as well as surveying and mapping.

Facilities.

The Key Centre has access to equipment on the two major campuses and at the State department of Mapping and Surveying. A planned build-up of specialist equipment dedicated to the Centre's objectives is in progress and will continue over the next two years. In addition equipment manufacturers are cooperating in making equipment available over short and long terms for special purposes such as short courses.

1. Major laboratories :-

Function.	Location.
Land information systems	U.Q./Q.I.T.
Remote sensing	U.Q./D.M.S.
Photogrammetry	Q.I.T./D.M.S.
Cartography	Q.I.T.

Both campuses have extensive computing facilities, including PDP, VAX, and IBM mainframe computers. Networking is available through the linking of various systems on and between the major campuses.

2. Major equipment :-

Land Information Systems :-
Input:
Monochrome terminal workstations 3
Colour terminal workstations 2
Digitiser, AO 1
Tapedrive 1
(Shared facilities of Computervision, Australia)
Processing:
CDS 4000 Computervision computer 1
(32 bit, 600 Mb hard disk)

Output (Cartographic):
G.D.S. drafting system on VAX 780 computer 1
PALLETTE drafting system on VAX 780 1
Graphics terminals 8
Flat-bed plotter 1
(All above shared facilities of QIT campus)
Plotter/Digitiser (in PLANICOMP environment..... 1
Flat-bed plotter 1
(Shared facility of Computervision, Australia)
Line-printers 2

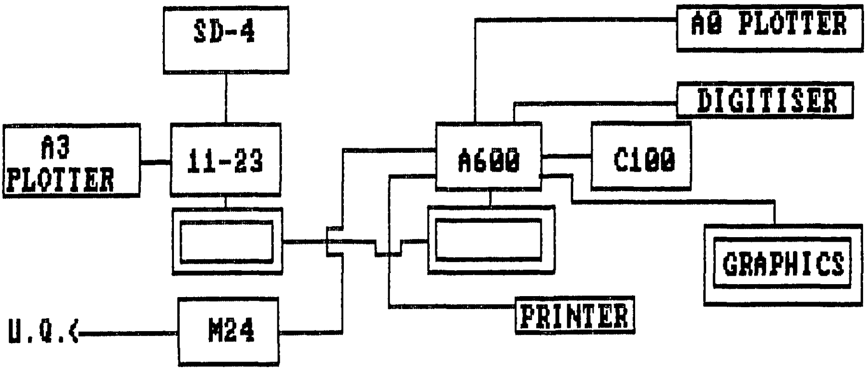
Remote Sensing :-
Digital image processing systems :-
1. Micro-Brian, implemented on IBM AT computer (currently one system, 3 more to be acquired)
2. U. of Q. system developed in-house by Dr. G. Dowideit, based on Ramtek/PDP 1144, plus SLIP
3. SLIP/Comtal/Vax system at State Dept. of Mapping and Surveying.

Optical image processing systems :-
1. I2S multi-projector system
2. Binoccular 4-chip viewer.

Photogrammetric :-
Analytical stereo-plotters :-
Zeiss Planicomp, with A0 plotter 1
QASCO SD4, with A3 plotter 1
Analogue stere-plotters, numerical o'put 4
Analogue stereo-plotters, graph output 6
Orthophoto instrument, Zeiss O-3-P 1
Metric terrestrial cameras 4
Access to following instruments through the Queensland Department of Surveying and Mapping :-
APC IV analytical stereoplotter
Zeiss Orthocomp analytical orthophoto instrument
Computer supported analogue plotters
Related computer software :-
PATMR - robust aerial triangulation by models
PROSA - progressive sampling of terrain models
HIFI-PC - terrain modelling by finite elements, with profiling and contouring capacity
PLANIMAP, -digital mapping system on PLANICOMP

DIGITAL MAPPING SYSTEM

The elements of the digital mapping system of the Key Centre, located at the Q.I.T. Campus, are illustrated in Figures 1 and 2. The core of the system is a Zeiss Planicomp C130 analytical photogrammetric plotter, supported by a QASCO SD4 analytical photogrammetric plotter, and three digitally encoded analogue photogrammetric plotters.



QIT DIGITAL MAPPING SYSTEM
Figure 1.

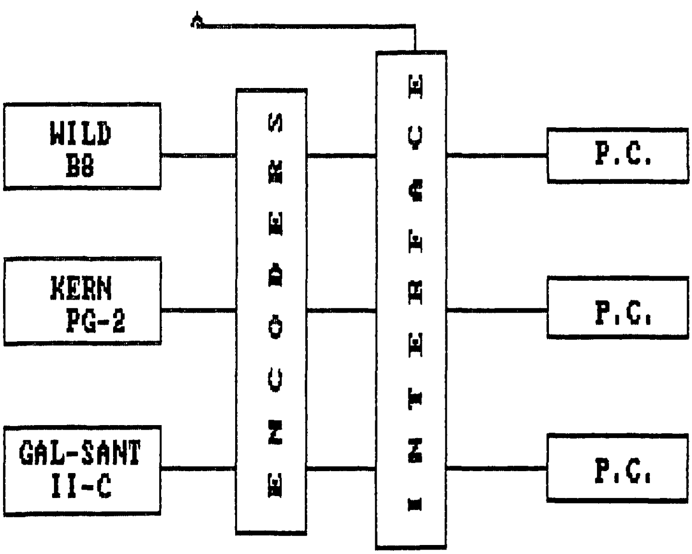


Figure 2

The Zeiss Planicomp

The Zeiss C130 planicomp is controlled by a Hewlett-Packard 1000 Model A600 mini-computer. The operations of the Planicomp are performed by some 80+ programs, organised in three levels A,B,C, programs from a higher level (A,B) being able to run concurrently with one from the lower level. Thus it is possible for instance to change model or plotting parameters, inspect or modify control information or direct output to the screen or plotter and return immediately to pending photogrammetric operations on the instrument. It is also possible to carry on program development or normal computer management operations on the H.P. 1000 while running the Planicomp. Input peripherals include a H.P. drum plotter/digitiser, an additional Aristogrid digitiser, and an input link from the QASCO SD4 analytical photogrammetric plotter. Output is to H.P. hard disk or cassette, to 20 cm floppy disk via the link to the PDP 11-23, or to 13 cm floppy via the link to the Olivetti M24. Data can be tranferred off-line via 20 cm floppy to the Q.I.T. central DEC10 or VAX780. A selection of some planicomp facilities is listed at Table 1, and the standard mapping programs sequence at Figure 3.

PLANICOMP FACILITIES

INPUTS	PROCESSES	OUTPUTS
C-P PHOTOGRAPHS	AFF. FILM CORR'N	POINT RECORD
DIAPS/NEGS	RADIAL DIST'N	TIME INC. REC.
COLOUR/PAN	REFRACTION	DIST/HT INC. REC.
FILM/GLASS	EARTH CURV.	PRIM. & SEC. INCS.
FORMAT<240 MM	AFF. MAP CORR'N	VAR. OUTPUT FORMS.
240 MM PORTIONS	INST. CAL. DATA	VAR. OUTPUT MEDIA
	ORTHO/PSEUDO VIEW	LINE, CIRCLE,
	BIN. L/R VIEWING	CURVE, SYMBOL,
	INDEPENDENT/INTEG.	TEXT, GRID,
	PHOTO MOVEMENT	PARALLELS, SQUARE/
	ORIENTATION WITH	POLYGON COMPL'N,
	NUMERICAL ANALYSIS	TO SCREEN OR PLOT.
	TRACING, PROFILING,	
	POINT AND SPLINE	
	MEASUREMENT	
	BRIDGING AND A.T.	
	ADJUSTMENT	
	AUTO POINT	
	POSITIONING	
	EXTENSIVE DATA	
	HANDLING FACILITIES	

Table 1

PLANICOMP PROGRAMS SEQUENCE

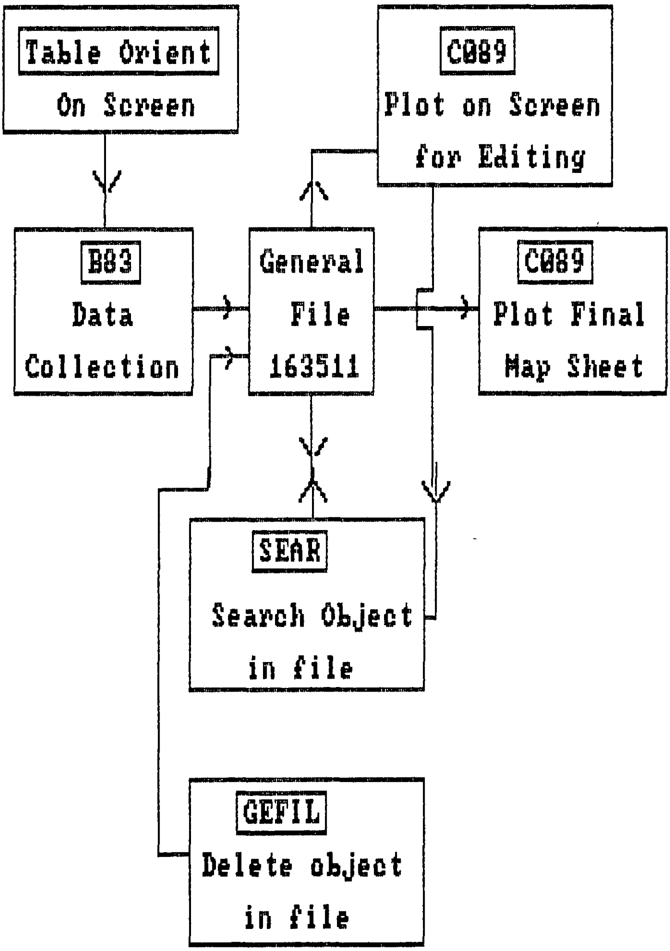


Figure 3

The QASCO SD4 Analytical Stereoplotter

The SD4 is a low-cost medium accuracy analytical plotter designed and built in Australia by the Queensland Air Survey Company. The instrument has been in use in the Surveying department of Q.I.T. for four years, and has now been integrated into the digital mapping system of the Key Centre. As can be seen from Figure 1, the plotter is controlled by a PDP 11-23 computer which incorporates a 20 cm floppy disk drive and a 20 Mb hard disk subdivided into eight user areas plus a system area. Photogrammetric movement is by two joy-sticks, although the conventional handwheels and foot-disk can be supplied. The basic accuracy of the instrument is dictated by the fact that photo-stage movement is by stepping motors with a 6 micrometer step, giving a measuring accuracy of about 10 micrometers. All operations are controlled on the basis of a 'job-file' in which photographic and photogrammetric parameters are entered for a particular model or series of models- this file is then called on by the system to control for instance the range of photo-stage movement for automatic positioning during relative orientation, or control point identification during absolute orientation. Model coordinates throughout are at 'ground scale', initially estimated from the job-file parameters and finally established by absolute orientation.

Digitisation density in the the SD4 is determined by the dimensions of a 'rejection cube' selected by the operator - dimensions in Easting, Northing and Height are specified, defining a parallelepiped with origin at the coordinates of the last record - another measurement will not be recorded until the floating mark moves outside the 'cube'. Alternative patterns of grid or profile with specified alignment are available in optional software packages.

The SD4 has been found to be extremely valuable in the teaching of analytical photogrammetry, being easy to use in a short time - necessary for intensive practical exercises - with easy-to-follow on-screen menu operation and useful printouts of results. It has been used for classwork in all photogrammetric operations, including analogue and analytical aerial triangulation, contouring for orthophoto production, and detail plotting in both aerial and terrestrial mode. In addition it has been used in more advanced project work and consultancy, primarily exploiting its capacity in using terrestrial photography in various formats.

Analogue stereoplotters

The development of the three analogue plotters into an integrated unit as shown in Figure 2 is planned over the next two years. All the instruments are fitted with encoders but currently only the Wild B8 is interfaced with a micro-computer (Apple II+) and controlled by an operating system (SPADD). It is proposed to re-write the operating system in Fortran and use modern 16-bit micro-computers as controllers.

DETAILS OF DIGITAL MAPPING PROJECTS

1. Micro-terrain mapping

In order to support a research project of the School of Australian Environmental Studies at Griffith University, Brisbane, mapping was required of soil terrains in a rainfall-simulation flume. The research was aimed at modelling rainfall erosion parameters for various soils and rainfall types, and mapping with 5 mm contours was required after each 'event', the terrain being planar before the simulated rainfall. Photography was with ordinary high-quality 35 mm cameras from a photographic distance of 1.5 m. The digital mapping was performed on the Planicomp, camera parameters being determined by the "bundle orientation" technique. In this technique a normal relative and absolute orientation is performed to give initial parameters for the bundle orientation. In addition, best estimates are entered for the camera parameters focal length, principal point coordinates, and distortion curve. The program then performs an iterative bundle orientation with additional parameters, finally creating a new spatial model based on the results. Digitisation was by contours with output on the drum plotter. For future analysis of the results it can be noted that the Planicomp inludes the programs HIFI with which interpolation onto a regular grid can be made, and also PROSA - progressive sampling - with which interpolation can be optimised into areas of greatest variation. The use of these should enable comparison of the various digital outputs from the mapping. The project is ongoing.

2. Preliminary Evaluation Program for SPOT(PEPS)

Dr. E. Clerici, Head of Department of Surveying, Q.I.T. is the Principal Investigator in a PEPS project with the following reference - "An investigation of SPOT stereoscopic imagery for application to Digital Terrain Models (D.T.M.) and the production of orthophotos and conventional line maps at medium to large scales in Australia". The measurement of the DTM will be carried out on the C130 Planicomp, and the orthophotos will be produced from conventional photography on the Z2 Orthocomp. A necessary preliminary to the project is the development of a new LOOP (analytical plotter feed-back) program for the Planicomp enabling the measurement of coordinates from 'pushbroom' imagery as opposed to the conventional central projection geometry of photography. This has been completed by a post-graduate student and at the time of writing the supply of imagery is awaited. Under the terms of this project further details cannot be reported until any data or results have first been reported to the PEPS Secretariat.

3. Beach Protection Mapping

Historical mapping over some 25 km of beach on the Gold Coast, Queensland was performed to assist in the detection and monitoring of beach movement over the period 1930 to 1979. Selected photography of 1930, '35, '44, '56, '62 and '79 was mapped digitally on the Planicomp C130, 35 models over 7 sites being mapped. The flexibility of the analytical plotter was exploited in the use of a wide range of input imagery, photography from Williamson-Ross (7"x5"), Eagle IV, Eagle IX, RC8, RC10, and F24 (5"x5") cameras being used. Although specific calibration data on the older cameras was not available, distortion curves characteristic of the lenses were used with satisfactory results. Control was based on ground survey lines run for the 1979 photography, and passed back through time by transfer using common detail, which was always available. Thus all data was relative to the 1979 control.

Three modes of data acquisition were employed :-

1. A digital elevation model at 10 m interval.
2. Profiles along the ground survey lines, and at +/- 100 m along the beach from them.
3. 1 m contours and detail.

The ability of the Planicomp to "move to" points of given coordinates, and to profile in given directions was of great value. Graphical output was limited to the detail and contour plots, the whole of the digital data being transferred to the Beach Protection Authority's VAX, filling 12 DSDD Olivetti floppies along the way.

Digital Mapping of an Ocean Going Sailing Hull
(Smith 1985)

In the run-up to the America's Cup, ocean sailing is a hot topic in Australia. An interested sixth-stage student decided to jump on the bandwaggon by doing his final thesis-project on a related theme. Hull profiles and water-line length are important inputs (among many others in this complicated process) in determining the rating of an ocean racing yacht. In the past these measurements have been obtained by tedious operations with plumbobs, strings, and tapes; more modern techniques, including the use of lasers, have been suggested for introduction in 1987. The method used in this project was that of terrestrial photogrammetry using a metric camera and the C130 Planicomp. Due to time and logistic constraints, one side only of the yacht, a 12 m standard class sloop, was photographed and mapped, the hull being covered by two overlaps at a photographic distance of 9.5 m from the yacht centre-line with a 100 mm focal length lens. Digital data was acquired in the form of contours in the vertical plane. A great advantage of the analytical photogrammetric approach in this case is that, once the data has been acquired, output in any plane can be plotted, such as contours in elevation, or cross or longitudinal sections. The contours were digitised in 'spline' mode on the Planicomp, which is advantageous for data density - in this mode, point-wise recording along the contour is performed and the program constantly computes a spline fit and stores the data in the form of the spline parameters. A disadvantage of the mode, as opposed to direct tracing, is that care must be taken to increase the recording density where there are abrupt direction changes, and in extreme cases to digitise also break-lines and process the data through the HIFI program.

An interesting logistic aspect of this project was the necessity to give the hull of the yacht 'photogrammetric texture'. This was achieved by painting a random 'squiggle' pattern across the whole hull, alledgedly with an easy-to-remove water paint. However, when the time came to remove the pattern it was found that the paint was not so easy to remove as advertised, and many man-hours were spent restoring the hull to its pristine white.

CONCLUSION

An outline has been given of the establishment and objectives of the Australian Key Centre for Land Information Studies, located at the Queensland Centre for Surveying and Mapping Studies, Brisbane, Australia. The Key Centre is one of seven Centres established in various disciplines by the Australian Government in 1985 with the view that the concentration of teaching and research effort flowing from such centres would be an important factor in assisting higher education institutions respond to emerging national needs and forge closer links with industry. The Key Centre at Brisbane is well placed with respect to equipment and expertise to achieve such objectives in the areas of Land and Geographic Information Systems, Remote Sensing, and Digital Mapping.

Reference:
Smith, S., 1985, Terrestrial Photogrammetry Applied to Ocean Going Sailing Racing Hulls, Thesis-Project Report,Brisbane, Queensland Institute of Technology.

THE COST CONSTRAINT IN AUTOMATED CARTOGRAPHIC EDUCATION AND TRAINING FOR TECHNICIANS

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ABSTRACT

Much emphasis in training to date has been placed upon developing the skills of postgraduate research workers or those of digitising operatives. The College recognises the need to develop the skills of technicians and higher technicians in automated cartography. However, high capital costs and recurrent expenditure to up-date and replace equipment coupled with substantial operating costs are likely to limit what can be achieved. The authors hope to encourage discussion of the industry's requirements and how these may be achieved.

INTRODUCTION

Luton College of Higher Education has developed a unique and highly successful course leading now to the Business and Technician Education Council Higher National Diploma in Geographical Techniques. Students from the course find employment in many fields where applications of automated cartography are increasing rapidly, particularly in petroleum exploration and development, the public services and planning, and in field survey. With the exception of the last, the majority of our students tend to be cartographic illustrators rather than cartographers in the strict sense. Although from the outset computing has formed part of the course the emphasis initially was placed on data processing applications and has shifted only gradually towards computer assisted cartography. The course teaching staff believe the time is now right for a aubstantial investment in technician training.

BACKGROUND

The course is a sandwich structure, the students spend the first and third years in College and the second out gaining industrial experience. Through a programme of regular visits to students' employers, from information coming via students visiting College, through contacts with former students after completing the course the staff maintain close liaison with developments in the industry. It was deliberate policy not to become involved in automated cartography early in the history of the course but to establish a reputation for a broadly trained, adaptable student well grounded in cartographic skills and possessing sound knowledge of basic survey and data processing techniques. This has been achieved, but we are becoming increasingly aware that students completing the course will require practical experience in automated cartography at a high level.

The structure of our course as currently approved by the Business and Technician Education Council (BTEC) enables us to provide this training developmentally and to differing levels through the preliminary stage, the core of the course and options taken at the highest level. Students are introduced to computer cartography early in the course but at present do most of their developmental work at the beginning of the third year on their return to College from industrial experience. More students are encountering automated cartographic systems during their work experience year and our first year curriculum is under almost constant review.

By abnegating computer cartography in its early development we tried to avoid committing the College to heavy expenditure on expensive and rapidly obsolescent equipment whose capabilities were frequently limited. As the equipment enters the third generation we feel that expenditure can now be justified.

THE OBJECTIVES

The requirements for technician training are different from those for operatives or for research workers but provide linkages between these groups. The technician requires a wider range of skills than a machine-minding operative; a higher technician requires managerial skills to organise work and ability to solve problems which may arise both from the machine and in its products. The higher technician may require the ability to carry out all tasks performed on the job and to switch between jobs, changing for example from one contract to another whilst supervising a shift.

Our objective of a Diplomate who can successfully switch tasks may well involve a high level of understanding of computer operation and the use of user-friendly and less friendly systems and possibly machine languages as well as more common languages. We do not consider a knowledge of programming essential when the student completes his or her course. Programming is a specialised task beyond the course and carried out in employment to meet specific requirements. It is knowledge of the applications and limitations of programmes we regard as important.

We hope to provide worthwhile experience of an interactive computer system or systems, using both the student's own data as well as other data. To be able to produce maps using existing frameworks and to design within the limitations of existing programmes. There is a need to be aware of the different types and outputs and the different methods of plotting. Most of this will go on in the third year because we remain committed to a firm understanding of the basic graphic cartographic principles taught in the first year.

ATTAINING THE OBJECTIVES

The teaching staff have submitted to the College a number of options costing between £5,000 and £300,000. The lowest price is for a simple system to demonstrate the principles to students. The highest price is for the ideal of 10 interactive workstations capable of working on a single problem simultaneously through a central 'teaching console' yet also being capable of independent work for student and other projects. This is our primary objective, how can we attain it?

In terms of cost,£300,000 is a greater investment for a single course than the College has ever made. Our estimated running and replacement costs equal our present Departmental income covering 35 staff in Science.

Obviously it will require special funding, we believe that this can be obtained from the Department of Education and Science; the Natural Environment Research Council; Industry, as well as local sources. In return we would expect to share the facility with other Colleges and with Industry. We already share other facilities with a Polytechnic and are extending this agreement. We have expressions of interest from local cartographic firms to use equipment if we get it. However, in education buying capital equipment is treated like purchasing a house - how many of you would buy your auto-carto equipment with a mortgage over twenty years? Would any manufacturer or factory lease us equipment on an annual payment we could afford? Used equipment is superficially attractive but spares and maintenance costs become prohibitive.

THE TRAINING PROCESS

Having obtained equipment and found how to use it we need to apply it. Our validating body, the Business and Technician Education Council (BTEC) will need convincing that CAC or Auto Carto is more than button pushing and screen or printer watching and requires high level skills. Our present course is in four stages, three of which would require modification for Auto Carto. In the Preliminary Stage - the first term in College - there would be an introduction to computer graphics as part of a general computer course. We cannot yet rely on all students entering with a sound knowledge of computers and computing. This should provide the basic motor skills of keyboard, loading and running and some understanding of capability of CAC.

In Stage One - the rest of the first year, students would work as groups on assignments and exercises set by staff but in-putting some of their own data and observations. This would be regarded as Level III by our validators.

Stage Two is the industrial experience year where exposure to CAC is likely to remain variable for years to come. Hardly any of our 25 or so employers have no computer assistance be it only a self-rectifying KROY machine or a typesetter; only the largest can afford full-scale interactive automation.

At Stage Three - the third year of the course emphasis would shift towards student directed project work - examining applications and developing them further, exploring designs and styles of mapping and graphing, making innovations. To provide time for this other things in the course may have to have less time. To begin some of this work may be done by small option groups but given the rate of expansion of the applications we could not hope for it to remain so for long.

CUSTOMER NEEDS

We serve two groups of customers. You,whom we serve directly by training technicians and secondly your customers whom we serve indirectly. You are interested in the quality of training we give our students we know that they are accepted throughout the cartographic industry and want to keep it that way. It is these technicians and higher technicians who will produce the products that keep your customers happy. We know that they may not necessarily be using 'hard copy' maps in the future but whatever they have it will require good design and sensible production. This is a very important development in cartographic illustration and we intend to go with it.

EDUCATION AND TRAINING FOR AUTO CARTO

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ABSTRACT

The paper examines the needs for education and training for staff involved in Auto Carto generally; and draws attention to the requirement for operators, technologists and professionals; it examines in detail the training being given in the seven operations where Auto Carto is currently being practiced in the Ordnance Survey, this includes automatic drafting, computations, digital input from field survey instruments, the field update system, photogrammetric digital data capture, digital mapping and interactive editing; it attempts to look into the future with the introduction of new technology, to identify possible additional training needs; and it suggests some initiatives which could be taken to meet these forecast needs.

DEFINITION OF AUTO CARTO

Auto Carto is not a discrete discipline with well defined parameters, but is a generic term for a range of disparate functions which have a common purpose, namely the creation of digital data which can be used by the cartographer to aid map production and by other users to meet a variety of requirements in the field of Information Technology (IT). Auto Carto is considered to cover three main functions;

As a tool to aid map production, without necessarily creating a bank of digital data

As a means of creating, revising and enhancing databases of digital topographic and allied data for use in cartography

As a means of extracting data from such databases for use in map production or for providing such data to users in forms suitable for their requirements

THE EDUCATION AND TRAINING NEEDS

As with all technical disciplines, Auto Carto can make use of staff with varying skills and knowledge. At one extreme staff may require only simple manual skills to operate equipment without needing to know how it works; and at the other extreme staff may require extensive professional or technological knowledge and skills, which will enable them to manage, plan, develop, install, trouble shoot, maintain, and repair highly sophisticated electronic equipment operated by a multi-discipline staff. A production agency cannot decide on its training requirements until it has established the correct balance of staff needed to carry out its particular task. This balance may vary from agency to agency depending on both the task and the type of equipment used.

In broad terms, however, there will be a general need for broad based induction training for all the staff, and then varying levels of technical training for the operators, and education and training for technicians, technologists and professionals, appropriate to their responsibilities.

HOW CURRENT TRAINING NEEDS ARE BEING MET IN THE ORDNANCE SURVEY

For the purpose of this paper, seven operations have been grouped together under the broad umbrella of Auto Carto. The work is carried out in different divisions within the department and with different equipment. This has resulted in separate training needs in each area, and separate training programmes. These seven operations are:

Automatic Drafting using a Kongsberg 1216 four pen drafting table. The main task is the plotting of Instrumental Detail Surveys (IDS). Edit plots are drawn on paper and final plots directly on to plastic documents. Errors detected at the edit stage are corrected by amending the plot files before final plotting. Other plotting tasks include photogrammetric surveys, grids and graticules. The Kongsberg plotter is also used as a measuring device for checking lower order survey plots.

Computations The task is to compute minor control surveys and Instrumental Detail Surveys on a Vax 11/850 computer from digital data received on cassette tapes. Editing may be necessary.

Digital input from Instrumental Surveys The task of Instrumental Surveys is to provide horizontal, vertical, and detail control, and to present it in digital format on cassette tapes.

The Digital Field Update System (DFUS) The task is to pre-edit and digitise to current OS specification, detail surveyed at 1:1250 and 1:2500 scale on the Master Survey Drawings (MSD) and to replot the new detail on to the plastic MSD.

Photogrammetric digital data capture The task is to plot map detail photogrammetrically and at the same time collect digital data which is subsequently manipulated, coded and edited for input to a database.

Digital map production The task is the initial data capture and revision of digital maps using source material at 1:1250 and 1:2500 scale; including pre-editing and feature coding. For maps going forward for publication, additional text and symbols are required.

Interactive editing of digitised map data The task is to use interactive edit stations to correct errors which have arisen during the blind digitising process.

Continuation training in the Ordnance Survey

Apart from the appreciation training for managers, all the other courses are followed by a period of on-the-job practical experience. During this time the trainees will meet the range of problems which arise during normal working practices. Line managers and supervisors act as instructors and counsellors during this stage of the training.

The following tables list the range of in-house training courses which have been developed to train the staff in these seven operations.

TABLE No 1

Type of Course	Equipment	Level of Student	Course Objectives The student should be capable of:
AUTOMATIC DRAFTING COURSE Duration 20 Days spread over 3 months 75% practical	KONGSBERG 1216 4 pen drafting table VAX 11/750 Computer TEKTRONIX 4663 2 pen edit plotter	Basic Grade Surveyors or Draughtsmen (Operators) Higher Grade Surveyors or Draughtsmen (Supervisors)	Using the Tektronix plotter for production of a range of edit plots on paper Using the Kongsberg 1216 for plotting IDS and other forward or reverse reading work using etching ink on plastic documents Correcting computer files
COMPUTATIONS FOR MINOR CONTROL AND INSTRUMENTAL DETAIL SURVEYS Duration 27 days spread over 3 months 65% practical	VAX 11/850 Computer with 440 megabytes of perm-anent disc store LINE PRINTER DOT MATRIX PRINTER TAPE DECK INTERACTIVE TERMINALS	Basic Grade Surveyors or Draughtsmen Higher Grade Surveyors or Draughtsmen	Using the Vax 11/850 computer Creating, amending and deleting edit files Carrying out traverse computations Carrying out Bearing and Distance computations
INSTRUMENTAL DETAIL CONTROL COURSE Duration 25 Days 60% practical	DIGITAL RECORDERS EDM SETS THEODOLITES TOTAL STATIONS	Basic Grade Surveyors Following basic survey training	Supplying and monitoring detail control using up to date equipment and modern booking procedures, including digital data capture
MINOR CONTROL COURSE	DIGITAL RECORDERS EDM SETS THEODOLITES	Basic Grade Surveyors Following IDC Course	Supplying and monitoring horizontal control using up to date equipment and modern booking procedures, including digital data capture

TABLE No 2

Type of Course	Equipment	Level of Student	Course Objectives The student should be capable of:
LEVELLING COURSE SECONDARY & TERTIARY Duration 25 days 60% practical	LEVELS DIGITAL RECORDERS	Basic Grade Surveyors Following IDC Course	Supplying and monitoring vertical control using up to date equipment and modern booking procedures, including digital data capture
CONTROL COURSE Duration 20 days 60% practical	DIGITAL RECORDERS EDM SETS THEODOLITES	Senior Grade Surveyors Higher Grade Surveyors	Supplying and monitoring horizontal, vertical and detail control using up to date equipment and modern booking procedures, including digital data capture
DFUS OPERATOR TRAINING Duration 7 days 45% practical	MICROCOMPUTER DIGITISING TABLET FLATBED PLOTTER CASSETTE TERMINAL	Basic grade Surveyors and Draughtsmen Higher Grade (Team managers)	Pre-editing a copy of an MSD for digitising by DFUS Using the DFUS facility to update MSDs Plotting the data and completing the MSD to current specification Downloading the digital data for subsequent archiving
DFUS FOR SURVEYORS WHO WILL INPUT TO THE SYSTEM Duration 2 days 20% practical	MICROCOMPUTER DIGITISING TABLET FLATBED PLOTTER CASSETTE TERMINAL	Basic Grade Surveyors Higher Grade Surveyors	Annotating detail Positioning names clearly A basic knowledge of the DFUS facilities A basic knowledge of feature coding Presenting fieldwork unambiguously for subsequent digitising by the operators
DFUS APPRECIATION FOR MANAGERS Duration 4 days 25% practical	AS ABOVE	Section Managers Senior grades Area Managers	A practical knowledge of digital mapping and DFUS procedures, and a limited experience on the equipment

TABLE No 3

Type of Course	Equipment	Level of Student	Course Objectives The student should be capable of:
COMPUTER AIDED PHOTOGRAMMETRIC MAPPING COURSE Duration 10 days 70% practical	PHOTOGRAMMETRIC PLOTTING INSTRUMENTS PDP 11/75 GRAPHIC EDIT STATIONS	Higher Grade Surveyors and Draughtsmen Following basic training in their own discipline	Understanding basic computer technology. Relative and absolute orientation, scaling and levelling a model Capturing data digitally Operating a graphic edit station
DIGITAL MAPPING COURSE Duration 13 days 73% practical	DIGITISING TABLES	Basic Grade Draughtsmen Following basic Carto training	Pre-editing large scale maps for digitising, colour coding, names collation, and preparation of the digitising documents. Digitising and feature coding large scale maps at 1:1250 and 1:2500 scale. Correcting digitised maps. Completing positives ready for publication.
DIGITAL MAPPING FOR CARTO ASSISTANTS Duration 13 days 73% practical	DIGITISING TABLES	Cartographic Assistants	Interpreting pre-edited documents. Digitising and feature coding large scale maps at 1:1250 and 1:2500 scale. Completing positives ready for publication.
INTERACTIVE EDIT STATION TRAINING COURSE Duration 10 days On-the-Job	INTERACTIVE EDIT STATIONS ARC INTERACTIVE EDIT STATION	Basic Grade Draughtsmen Following training and practical experience as digitisers	Correcting any digital map using either the MADES (LITES) or the ARC interactive edit stations

Validation of Training in the Ordnance Survey

Wherever possible, validation exercises are included in the training courses, to enable the instructors to monitor the progress of the trainees. It is standard practice for validation reports to be sent out six months after a formal training course, for the student to comment on his progress and to confirm that continuation work has taken place; and his line manager to assess the level of post course achievement.

Training patterns for the future in the Ordnance Survey

It has become quite evident that future training for Auto Carto must be in modular form. Students require a broad base which will prepare them for the ever changing technology they can expect to meet throughout their working lives, and to teach them to be computer literate. This background training will be followed by a series of specialist modules to train them specifically for the task they will be required to perform in their work area. As they move from area to area throughout their career, or as new technology is introduced into their own area, they will require further retraining modules.

Ordnance Survey has identified two different types of trainee. The first are the staff who have been with the department for many years, trained to the conventional mapping processes, who are not computer literate, and are somewhat reluctant to learn new concepts. The second type are the new young generation to whom computers are second nature, and who understand the jargon and are not frightened to use computer technology.

The immediate training requirement is to change the attitude of the older generation and to encourage them to be more willing to accept the new technology. The background training for these people will probably be provided by appreciation courses specifically tailored to their varying levels of skills and knowledge, whilst the follow up specialist modules could continue on similar lines to those already outlined above.

In the case of the younger generation who already have greater computer skills, it should be possible to consider new training patterns for the future.

FUTURE NEEDS FOR EDUCATION AND TRAINING IN AUTO CARTO

In the opinion of the author, there is a specific requirement for broad based education and training in Auto Carto which is currently not being met. Education establishments and user departments should get together to develop an education strategy for the future.

Education in Auto Carto should be included in foundation training, and be an integral part of cartographic, B TEC and Higher B TEC courses. It should be practicable to develop appropriate modules in computer science and Auto Carto covering such subjects as basic language - computer practice - computer graphics - handling spatially referenced data - file creation - interactive editing - database structuring etc.

It is doubtful whether external courses will be suitable for all specialist training modules, as each manufacturers equipment presents its own training requirements for the operators, and each organisation has its own specifications and working practices. It is probable that the larger organisations will run their own courses on lines similar to those at the Ordnance Survey. Smaller departments may continue to use education establishments, who will need to give both the students and their own staff, access to up-to-date systems, so that they will be aware of the latest developments.

SOME SUGGESTIONS FOR FUTURE TRAINING INITIATIVES

Central training facilities are expensive to run, and it may be possible for those with the facilities to offer courses on repayment to other organisations.

Distance learning is becoming more acceptable and it may be possible to encourage education establishments to consider developing courses for Auto Carto, or build specific Auto Carto modules into other carto related courses.

Manufacturers could be encouraged to work more closely with education establishments on the introduction of new hardware and software so that trainees and teachers are more aware of developments.

Manufacturers could be persuaded to offer more training facilities.

The staff of education establishments could make more effort to keep up-to-date by arranging attachments for staff to work in production departments, and the reverse.

Greater co-operation could be encouraged between education establishments to share resources and ensure viable numbers on specialist courses.

There is a need for standardisation in Auto Carto so that knowledge and skills can be used more widely.

The use of digital map data in schools could be encouraged so that youngsters are educated in IT.

Education and Training in Auto Carto is at a watershed, and there is a need for all the interested parties; users, education establishments, manufacturers, and schools to get together and develop a new education and training strategy for the future.

CONCLUSION

The pace of technological change demands flexibility and adaptability on the part of the workforce, and we need to develop and teach new training skills and techniques to meet the challenge.

TEACH YOURSELF GEOGRAPHIC INFORMATION SYSTEMS: THE DESIGN, CREATION AND USE OF DEMONSTRATORS AND TUTORS

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ABSTRACT

In the UK - as in many other countries - interest is growing rapidly in the nature and capabilities of Geographic Information Systems (GIS). Given the relatively small number of systems currently in use and, in particular, the very restricted number of individuals who have used GIS for a wide range of applications, a conflict of interests arises. It is desirable that education and training is provided on demand and that ad hoc queries are answered: yet the provision of this advice and teaching falls at present upon the most skilled and expert proponents and diminishes their capability to develop or exploit GIS in other ways. The increase in demand for training can - in principle - be satisfied by the creation and use of a computerised tutor which deals with the fundamental concepts of GIS. ARCDEMO is a demonstrator - a primitive tutor - developed to show the capabilities of the ARC/INFO GIS, and its design and implementation is described. The system contains both text and multi-colour graphics, sections of which can be viewed in sequence or selectively from a menu. Operations covered by the demonstrator include: automatic data validation and correction; projection change; selective retrieval of spatial data; map overlay; and network analysis. A second demonstrator, called ECDEMO, was developed from the basic structure of ARCDEMO but illustrates an environmental data base established for the European Community. We describe the extent of use and successes and failures of these demonstrators and, on the basis of this experience, we set out desiderata for fully-fledged tutors, suggest the contributions which could be made by knowledge-based systems, outline the machine and human resources needed for running such tutors and conjecture the merits of an international collaborative project to set up a GIS tutor with appropriate national data sets.

INTRODUCTION

The interest in Geographic Information Systems (GIS) has grown rapidly over the last few years. Thus far, however, systems are still relatively few and generally difficult to access. Moreover, many users or potential users are still low on the learning curve so far as the advantages and limitations of GIS are concerned. As part of a Natural Environment Research Council (NERC)-funded project to produce a conceptual design for a GIS, a survey was conducted to evaluate NERC user requirements (Green et al., 1985b). To us, one of the most surprising aspects of this survey was the low level of understanding shown by most earth scientists when questioned on the functions and capabilities of a GIS: this was all the more surprising because we have good reason to believe that those individuals are generally more aware of computer-based analysis of spatial data than researchers in other disciplines or many involved in 'production' organisations. At the same time, the small Birkbeck group was being inundated with requests for visits, demonstrations and explanations. It was decided, therefore, that the best way to educate people was to create a small on-line computer demonstrator to illustrate some basic GIS concepts and functions. Computer-based training (CBT) was considered preferable to other means for a variety of reasons, some of the most important of which are given below:

(i) A computer-based demonstrator, especially one available over telecommunication links, could be accessed by a large number of users relatively easily. Although widely distributed, most NERC Institutes are on the Joint university Academic NETwork (or JANET, see Wells, 1985) and would be able to use the system through this link: all universities in Britain are linked to this network.

(ii) Individuals could work through the demonstrator at their own pace and skip sections which they initially might not be able to comprehend or found irrelevant to their needs.

(iii) By using interactive colour graphics in addition to text, the principles behind GIS might be more easily understood than if they were presented in a paper or by seminar; users also seem more inclined to explore systems if colour graphics are used.

(iv) By incorporating a mail facility, users of the demonstrator could provide feed-back on the aspects of GIS with which they found difficulties and the demonstrator could be continuously updated to improve its teaching capabilities.

COMPUTER BASED TRAINING

Computer Based Training or CBT has also grown in importance in recent years, its use is now spread across many fields. Characteristically, it has been successful where large numbers of people need to be trained in routine tasks and it has a high initial cost: Austin-Rover, for example (according to Kaewert 1986), claim that it costs them 35,000 to train 600 people in a particular function using CBT but that the alternative, traditional, means of training might well cost more and be less effective. Moreover, there is some evidence to show that information is learned more rapidly, more predictably and retained longer than with traditional methods: one British credit card company trains its basic grade staff using CBT in one third of the time required by traditional methods.

The ideal situation for CBT, then, appears to be where numbers to be trained are insufficient in any one place at any one time to justify heavy investment of teachers, where students vary considerably in their abilities and hence pace of learning, and where individual, anonymous tuition is appreciated (as by many professional, status-conscious staff). All of these are common situations in GIS training.

What is also evident, however, is that CBT is most useful when viewed as a complement to rather than a substitute for an instructor. Human communication skills remain important in encouraging students and in perceiving why a particular student is misunderstanding a topic. Even in the latter situation, however, progress has been claimed in the development of prototype CBT systems which, based upon cognitive modelling concepts, monitor the students progress, develop a fund of knowledge about student reactions and vary the training accordingly.

DESIGN CONSTRAINTS AND OBJECTIVES IN CREATING A GIS DEMONSTRATOR

The design of the demonstrator was bound by a number of constraints and objectives. The most important objective was to construct a system that was easy to use and could be freely accessed by academics and by NERC employees. Other considerations dictated that the system should:

(i) Use minimal disk space and computing resources and run on the departmental VAX 11/750 computer under the VMS operating system.

(ii) Be easy to use. From the outset, it was certain that the system would be used by some people with very little, perhaps no, computing experience. For this reason, instructions would have to be clear, simple and unambiguous.

(iii) Be robust. To test empirically a system's response to every possible request is almost impossible, but the demonstrator had to be as near fool-proof as possible. Fragility of a product designed to introduce a user to GIS would be counter-productive. This ensured that the system had to be rigorously tested, be based on a simple structure and that interrupts and possible error conditions had to be trapped and handled appropriately.

(iv) Be flexible. A structure which allowed people to view examples sequentially, or look at individual sections on request and to review pages of test or graphics was considered desirable.

(v) Provide high resolution colour graphics and text information. With this, those users with high quality displays would be able to gain an accurate impression of what is possible.

(vi) Support as wide a range of graphics and non-graphics terminals as possible. It was clear that, although the system needed to support high resolution colour graphics, it was possible that many people might be accessing the system using low resolution black and white terminals operating at low baud rates. For this reason, the graphics would have to be simple and easy to draw. Indeed, as many users might not have access to graphics terminals, it was decided that both graphics and text-only sections be included in the demonstrator.

(vii) Require minimal human resources to construct, implement and support. This was so critical that, in the early days, we chose the networked facility rather than distributing tapes because of our minimal resources.

THE STRUCTURE AND FORM OF THE DEMONSTRATOR

To provide free access to the demonstrator, the system was installed on a computer account with no access restrictions (no password, etc.) the system being automatically activated after logging on. This ensured that the minimal of instructions had to be given for the system to be accessed but, correspondingly, placed great importance on the prevention of users 'breaking out' into other parts of the VAX computer system. For this reason, all Control-Y and other interrupts are trapped and redirected.

The demonstrator is currently machine-dependant, at least so far as its host is concerned: it consists of a set of VAX files containing DCL commands and text or graphics to be displayed. This decision is not a major constraint: VAX computers are widely (almost ubiquitously) used throughout Britain for GIS work and, furthermore, the remote user logging on to our computer is generally unaware of the type of computer in use. It would, however, be a relatively straightforward matter to port the software onto certain other computer systems.

To comply with point (vi) above, it was decided that the demonstrator should have two main sections. The first consists purely of text information displayable on any 'dumb' terminal. The second section, which could only be used by those having access to a graphics terminal, consists of both text and multi-colour graphics. The graphics produced by the system are designed to support mostly Tektronix and 'Tek compatible' terminals and uses the Tektronix Interactive Graphics Library (IGL) routines. To make the system flexible, it was decided that a hierarchical menu-driven structure would be most appropriate. This was modified, however, to allow the user to 'walk through' the demonstrator in sequence (see figure 1). The following sections are accessible from the main menu:

Introductory Text Section
This section consists of a number of pages of text which give an overview of the ARC/INFO system, how to access the system, and under what conditions it should be used. It does not require a graphics terminal. Here, as in all sections, pages of text are limited to 80 columns by 24 rows i.e. to meet the worst possible case so far as alphanumeric terminals are concerned.

The Graphics Demonstrator
The graphics demonstrator consists of a number of examples depicting some of the main functions of a GIS (Green et al, 1985a). The examples are accessed from a sub-menu and can be viewed in sequence or selected individually. Each example consists of text - never more than two pages in length - describing the function, followed by a number of illustrative graphics 'pages'. Most of the graphics are produced from plot files rather than being created interactively, having the advantage of requiring few system resources and allowing those users who are most able to work more quickly through the package.

Mail and News Facilities
The provision of a mail facility, exploiting the VAX MAIL utility, enables users to make comments and suggestions. Some modifications have been made to the demonstrator in the light of these replies: these are discussed in a later section. First-time users of the system are encouraged to leave their name and address, which are then read into INFO and used to produce a mailing list to keep people informed on new up-dates, conferences, etc. A frequently up-dated bulletin board is also provided to allow people to keep track of forthcoming events and news.

THE COMPOSITION OF THE GRAPHICS DEMONSTRATOR

When called from the main menu, the graphics demonstrator first displays a table listing the types of terminals supported and prompts the user. After the terminal type has been specified, a sub-menu is displayed which lists the examples held in the demonstrator. Any example can be selected from the menu, or all can be gone through in sequence. It is also possible to 'step back' to a previously displayed page of text or graphics, or to skip further stages in an example and continue with the next example or to return to the sub-menu. Currently, the graphics demonstrator is composed of eight sections, each one of which is summarised below.

Data Structuring and Validation
The section illustrates the process of 'cleaning' an unstructured 'spaghetti' digitised file. The first frame shows digitised lines (arcs in ARC/INFO terminology), control points (tics), and the flagging of possible topological errors at unconnected line intersects nodes. Subsequent frames show how software can be used to remove automatically the 'overshoots', to 'snap' together undershoots, to geometrically transform and then to generalise the mapped data.

Data Enhancement
The generation of corridors or 'buffer zones' around features is used in this example to show how a GIS can enhance existing data. The example involves the creation and display of a corridor where width varies around roads of different class (figure 2).

Data Integration
Using the buffer zones generated in the previous example, this section shows the intersection of these areas with others depicting land use (figure 3). Further frames in this section show the intersection of postcode sector boundaries for the same area with land use zones and the subsequent selection of the portions of land use zones falling within a single postcode sector.

Data Retrieval
The section originally initiated an interactive dialogue session with INFO, a relational data base management system coupled to ARC; the former is used to generate a report summarising the results of the integration of postcode sectors and land use given in the previous example. This example also serves to demonstrate how INFO handles thematic data associated with a map and introduces the concept of relational file structures.

Data Manipulation
The ability to manipulate map data is one of the most useful aspects of a GIS. Comparing maps draw at different scales and using different map projections is the most basic of map manipulation requirements. Taking the example of map projection change, this example shows the transformation of a simple map of the continents of the world through a series of azimuthal, polar and Mercator projections (figure 4).

Network Analysis
Network analysis is becoming increasingly important in GIS for the modelling of flows, for planning the distribution of services and the allocation of resources and for route finding. Taking the example of service centre allocation, the frames show how different parts of the road network in the centre of London can be assigned to specified centres based on a travelling time criterion.

Data Structure Conversion
With the advent of an increasing number of mapping and information systems, the ability to transfer data between systems is becoming more important. The ARC/INFO system has a number of two-way interfaces for data conversion to a number of different formats and has been further enhanced by some of its users. The interfaces available on the Birkbeck version include DIME, DLG, DMC, GIMMS, and a GRID structure. The ability to convert to and from a grid structure is one of the most useful facilites. The demonstrator shows the effect of converting a map to grid format (i.e. rasterizing the vector data) and then converting it back to vector format (figure 5). Parameters were chosen so as to ensure some difference is discernable between the initial and final products!

This section also includes a plot illustrating the creation of Thiessen polygons (Dirichlet tessellations) abstracted from point data i.e. space is partitioned so as to allocate all locations in space to the nearest data points (figure 6). The resulting polygons are then available within ARC/INFO and can be treated as if they had been digitised.

Graphical Symbolism
The last section in the demonstrator illustrates the various types of graphical symbolism which can be generated automatically by the system.

Examples of point, line, area and text symbolism are displayed in a selection of bright colours, chosen so as to map to shades of grey on a monochrome terminal.

THE OPERATION OF ARCDEMO

Originally installed in September 1985, ARCDEMO became available over JANET in November 1985. All Geography, Geology, Planning and Computer Science departments in Britain were circulated with the JANET address and login details, heads of departments being asked to pass these to individuals who might be interested in such a facility. Between then and end-March 1986 there were over 250 logins; over 150 people have left their names and addresses. Originally designed as a semi-interactive system, ARCDEMO was modified in February 1986 to replace sections requiring processing by ARC/INFO with plot files and with static text. These modifications were made to allow the system to run faster, to prevent file access conflicts under INFO version 9.2 with many people using the system at once, and to enable the system to be used as a stand-alone package. The demonstrator now characteristically uses no more than 2 to 3 % of the cpu on our VAX 11/750. In addition to being located at Birkbeck College, ARCDEMO has now been installed on VAX computers at the universities of Reading, Leicester and Sussex where it is used as a teaching aid; it has also been run on a micro-VAX at DEXPO by DORIC, the company marketing ARC/INFO in the UK.

Due to the success of ARCDEMO, another system, ECDEMO, was produced to be used as part of a major project to create an Information System on the State of the European Environment (Rhind et al 1985, Wiggins et al forthcoming). This system was designed to show how ARC/INFO was being used to validate, edit, integrate and map a variety of European data sets including soils, topology and climatic data. The system has the same structure as ARCDEMO and has been used by other institutions involved in the project and by the project coordinators in Europe over international packet switched computer networks. It differs from ARCDEMO in a number of ways, including the need to offer the user text in any one of the different official languages now in routine use in the European Community.

LESSONS GAINED FROM ARCDEMO AND ECDEMO

These include:

(i) What is obvious to the system creators is frequently arcane to the user. Hence even early system testing must be done by a sample of users, rather than the system designer/creator.

(ii) Many of the difficulties relate to trivial matters which should be answered locally - such as clearing the graphics screen. This implies a need for a hierarchical release of the system to local experts, then a more general release.

(iii) Boredom rapidly results from too much text appearing on the screen.

(iv) Each example must be clearly focussed and should not extend beyond say five 'pages' or screenfuls.

(v) The response rate is important: users are frequently unhappy if it takes more than about 45 seconds to fill a screen with a graphic. It is highly desirable to give reassurance (e.g. sending messages such as '... sorry for the delay I'm still calculating the results') when nothing obvious is happening on the screen.

(vi) Simplicity is essential, if an instruction can be misinterpreted it will be misinterpreted. Only thorough testing, however, can detect some more subtle misconceptions.

(vii) Despite the problems listed above, it has proved entirely possible to run a demonstrator of this type at 2400 baud; running at 300 baud is acceptable for text but not for graphics.

(viii) The happyness of the user with the system appears to be related to the quality of the terminal being used: colour and a resolution of at least 600 x 400 seem desirable.

(ix) The operational reliability of existing networks makes use of a demonstrator hosted in a centre of expertise a technical possibility.

DESIDERATA FOR A GIS TUTOR

Based upon our experience with ARCDEMO and ECDEMO, we believe that a genuine GIS tutor should:

(i) be hierarchical in structure and at least have a comprehensive overview of GIS functionality. This may be provided by an ARCDEMO-type superstructure. It may also usefully include sections on GIS-related concepts e.g. on data structures and data volumes.

(ii) interact with the user by seeking responses to simple questions (e.g. 'do you require further explanations of this ?').

(iii) provide locally relevant examples, with all dialogue in the local language. Thus the design must be highly modular, with local examples slotted in as appropriate. Despite this, cross-references must be made e.g. to the need for 'clean' vector data before overlaying polygons.

(iv) response in manner appropriate to the facilities locally e.g. less complex graphics should be transmitted to a monochrome terminal attached to a 300 baud line than to a multi-colour terminal running at 19.2 kb.

(v) trap user errors and log these, together with a note of the most frequently used sections of the tutor, to build up knowledge of the users. This provides some scope for the use of Intelligent Knowledge Based System approaches.

(vi) provide 'help' facilities at any point, together with a glossary of terms used and a keyword-searchable bibliography.

(vii) be readily capable of expansion to include local details e.g. of the particular tasks carried out in the 'production shop' running the tutor.

One difficulty which we anticipate is that of generalising the tutor: it is easy enough to create one which relates directly to one specific system such as ARC/INFO. At this stage, however - and especially since no known system provides a full range of vector- and raster-based operations - the concepts and approaches embedded in different systems would have to be included in any ubiquitously usable tutor. In the absence of a GIS command language analogous to UNIX, this is likely to cause difficulties.

FUTURE DEVELOPMENTS

In-house Developments

Under an agreement with NERC, the structure of the ARCDEMO demonstrator is soon to be extended and modified to include further GIS functions, covering sections on edge-matching, sliver polygon removal, and map library concepts. Major new sections on remote sensing, topographic and thematic data handling are also to be included, along with an interactive bibliographical system, an index of active individuals in GIS and a glossary of terms. This development will make it more general, allowing the input of sections derived from other systems. In addition, the demonstrator is to be modified to allow closer monitoring of how people use the system. This should give an indication as to which of the various aspects of GIS specifically interests users. In particular, we intend to produce different versions of the demonstrator to monitor users responses to different types of system interface.

Possible International Developments

In addition to the within-UK developments above, we believe there is much scope for international collaboration in creating GIS tutors. The obvious vehicle to achieve this is the International Geographical Union (IGU) Commission on Geographical Data Processing and Sensing, which has been active in the area of GIS for twenty years and has established a world-wide net of contacts. Our suggestion is that this should take place in two phases, the first creating and distributing of a prototype and, if successful, the second proceeding to a full-scale operational tutor. Our experience indicates that a prototype tutor could be produced to meet the less ambitious of the desiderata set out in an earlier section well within an 18 month timespan, particularly if it built upon experience thus far. Clearly, such a development must be proceeded by agreement on the overall objectives to be met and the structure and design of the tutor and not all the work could be achieved on a voluntary basis: the proposal therefore has some funding implications. Nonetheless, these may be relatively small, despite the need for international collaboration - we now routinely make use of computer messaging facilities to the USA and to mainland Europe and such communication is very inexpensive. In short we can now use computer facilities to expedite international collaboration to teach others about computerised facilities.

An informal proposal to this effect has been forwarded to the Chairman of the IGU Commission, Prof. Duane Marble, and proposed at the Commission-sponsored meeting in Seattle in June 1986. Details of the status of this proposal will be given orally at Auto Carto London.

CONCLUSIONS

To the best of our knowledge, ARCDEMO is the first freely available, networked computer demonstrator using computer graphics in the UK. Clearly, as a teaching tool, it is somewhat primitive; however, we believe that Computer Aided Learning and Computer Based Training have an important roles to play in the development of GIS and automated cartography, especially if combined with expert systems. We claim no great prescience for this insight: Fraser Taylor, for example, in his book on Education and Training in Contemporary Cartography stated,

> "... we must look for complementary methods of educating the current map user ... the use of computer-aided learning may be useful, although again few such packages exist." (Taylor, 1985, p. 21)

Our own experience with large numbers of users suggests that it is worthwhile to devote considerable resources to creating and making readily available tutors and demonstrators and we expect to see many other developments in this area.

ACKNOWLEDGEMENTS

Thanks are due to the Economic and Social Research Council for the funding of the purchase of the ARC/INFO software. Part of ARCDEMO was written in the course of a project financed by the Natural Environment Research Council. Thanks to Jo Elliot for assistance with the figures. We also thank Jack Dangermond and his ESRI colleagues for much assistance over the last three years. Finally, we thank all those who sent us helpful suggestions on ARCDEMO by use of the mail facility.

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Figure 1 .

PAD>CALL A5163000

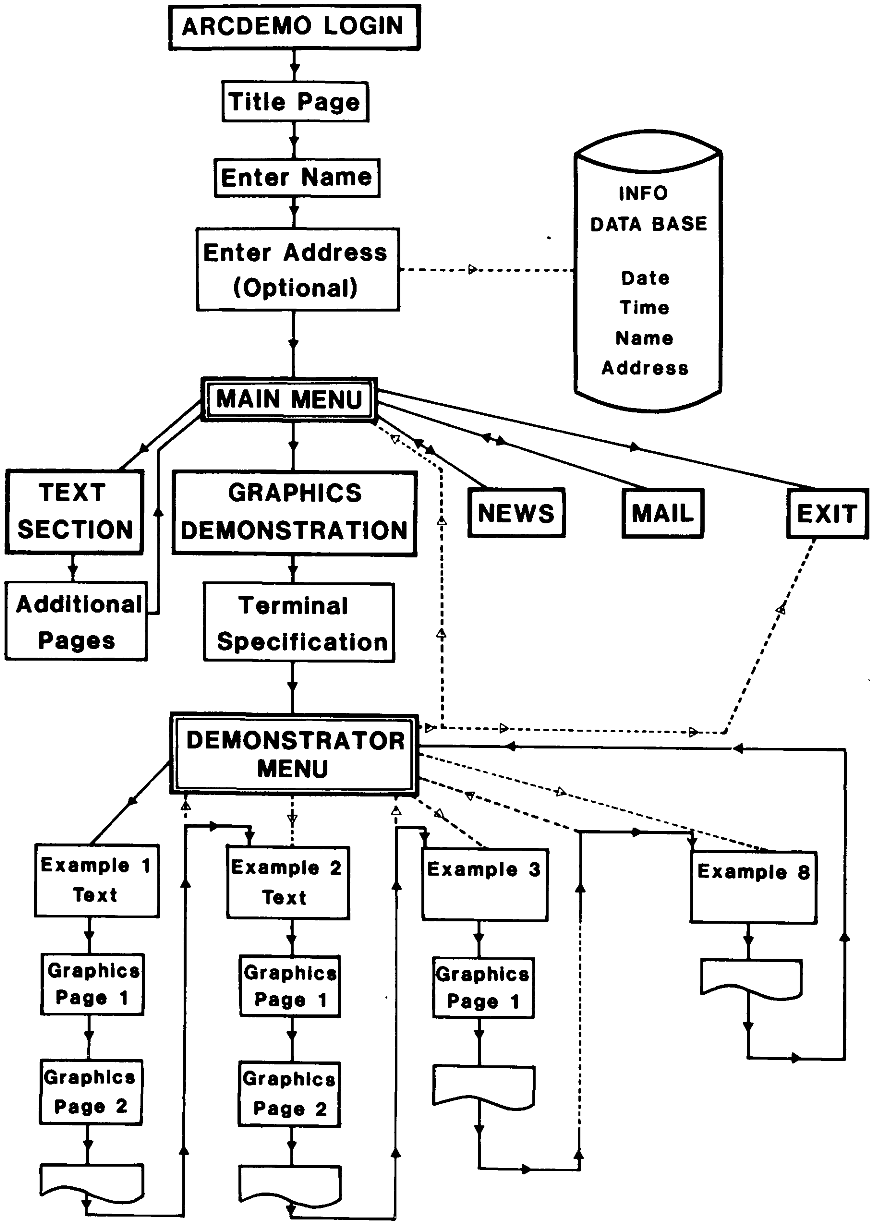


Figure 2.

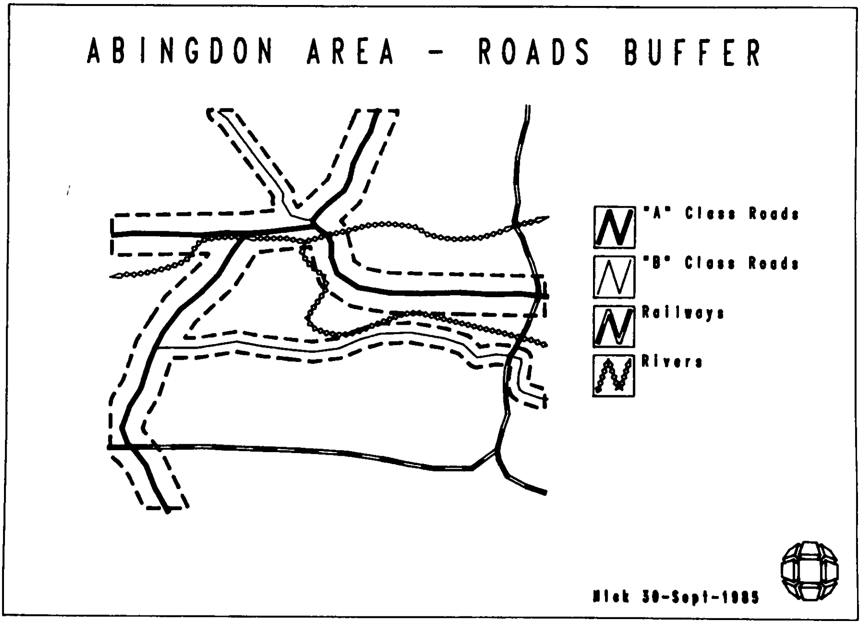


Figure 3.

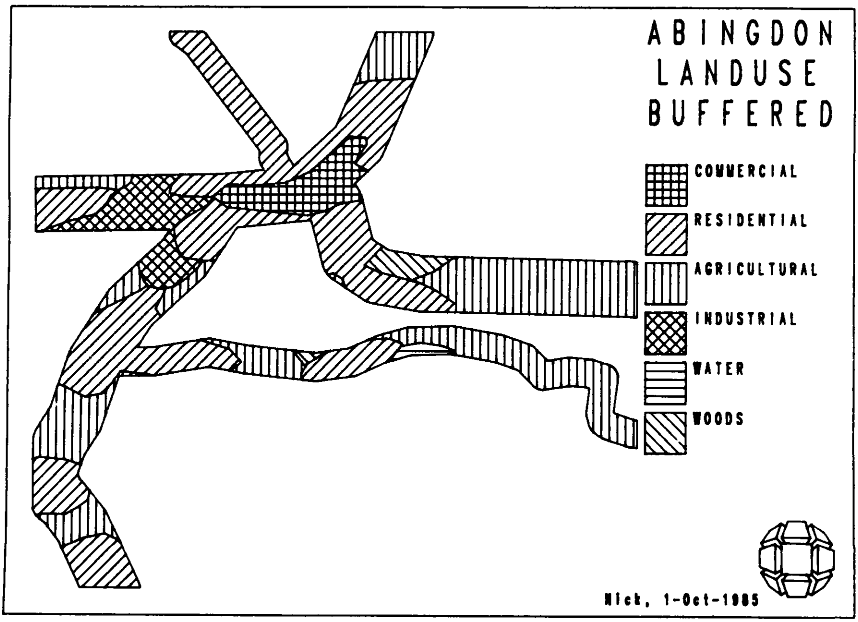


Figure 4.

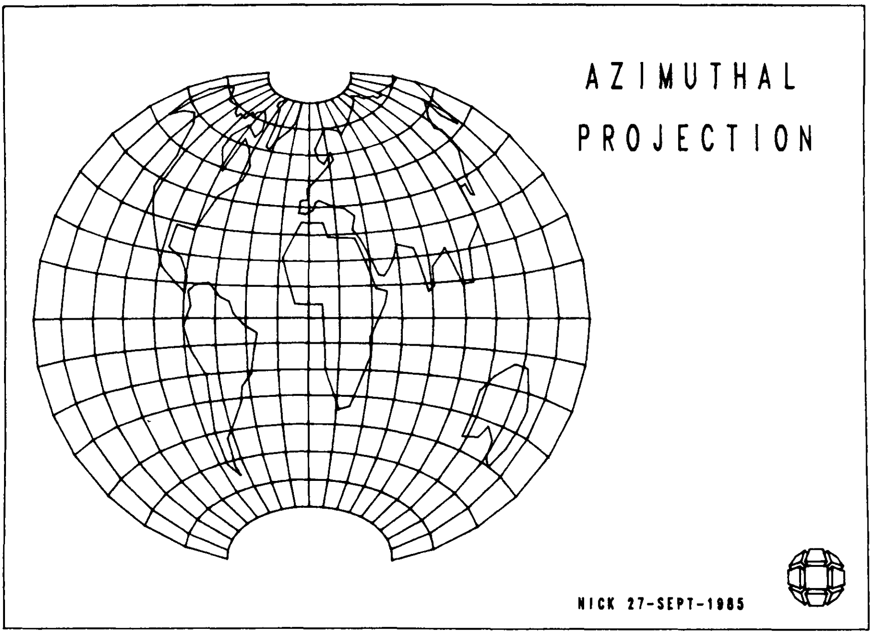


Figure 5

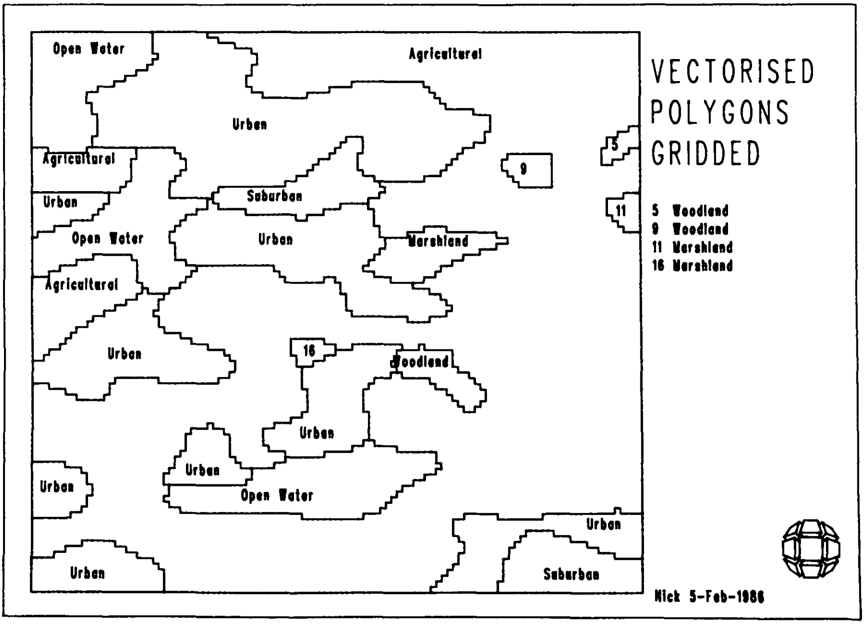
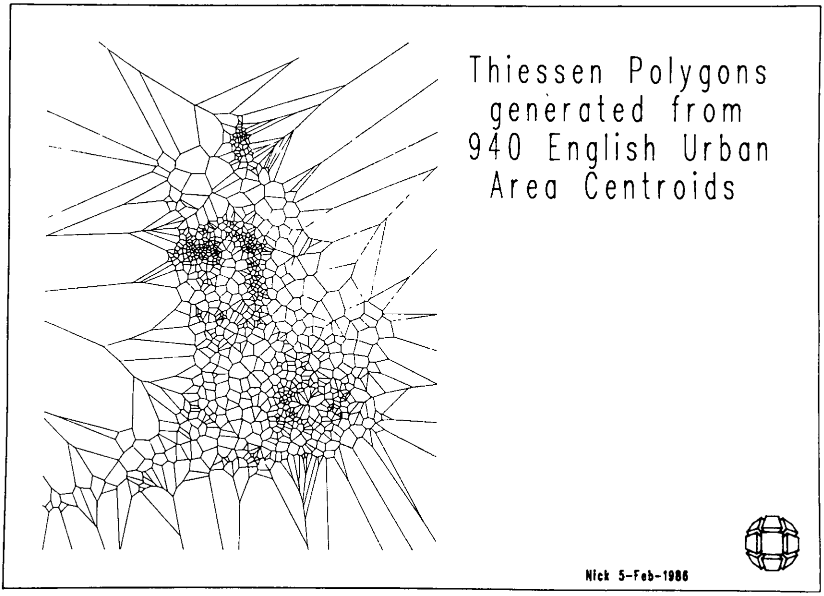


Figure 6.


Thiessen Polygons
generated from
940 English Urban
Area Centroids
Nick 5-Feb-1986

LIS EDUCATION VERSUS TRAINING: a surveying perspective

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Abstract

There is the ever increasing need for data to be captured, manipulated and displayed as fast as possible in a form for people to understand and use. The technology of land information systems is attempting to do that. This technology has largely been developed within computer science departments. The handling of land information is done by geographers, planners, environmental engineers and many other disciplines. The overall management of land information, from the data collection phase to the use of the information, logically lies with the professional surveyor.

To have intelligent use of information systems future LIS professionals, present-day students, will require university education. Not only must they be trained in the technology but they must know how to adapt, how to assess accuracies and how to find the optimum solution for a given application.

A university course in LIS must include both the technology and management aspects of LIS. The basics behind the technology, the applications and the social aspects, must all be addressed. This will enable true LIS education for the demanding need of our information age.

If the opportunity is grasped, it may well lead to that expanded professional role of surveyors in society that has been the subject of so much introspective analysis of the last decade and more.

Introduction

In this paper I will use the terms land information and geographic information systems as synonymous. A geographic information system, by definition, has data attached to a geographical locator. Such a locator is not necessary in a land information system although they usually do have them. Spatial information system is an all-encompassing term, which neatly separates such information systems from management information systems. The latter are the text information systems which have no map type data display or structure.

Confusion also arises as to land information management versus land information systems. Land information systems is the technology. This is the knowledge of how the data is in the system. It can mean an in depth understanding of how specific data types are coded and understood by the computer. This is where computer science is essential. Land information management is the whole picture: a knowledge of the system, enough of how it works so that effective use can be made of it, enough so that the accuracies and limitations are known and can be adjusted for.

For most people, it seems, the various facets in land information systems (LIS) are self-taught. There are few curricula available that offer courses sufficient to give a thorough background in this area. Where should such courses be taught? Do we want LIS education or LIS training?

Education or Training?

College courses can train in the technology, which is an acquired skill, but rarely do they go into essential professional and managerial functions. This is the difference between training and education. One can be trained in the technology, but its effective use lies in the creativity and understanding of the individual. A thorough understanding requires a thorough education. Education can be thought of as training in a way of thinking. Universities are for education. Therefore LIS education lies with the universities.

Is a person working in the field of LIS a professional? What is a professional person? Generally, a professional is thought of as having a university education (Personally, I do not accept this definition.). Therefore a socially sanctioned professional in LIS must have a university degree. Should this be in LIS? Or can other disciplines encompass the subject?

What University Department is the Home for LIS Education?

Which departments in the university could claim LIS? Let's look at familiar departments which seem appropriate:

(a) A geographic information system implies, by its name, that it should be in a geography department. Some university departments of geography have woken up to the idea that they can have quantitative and qualitative data that can be manipulated by this new technology. However, geography departments often shy away from the computational and computer aspects of information systems that require a fairly rigorous quantitative background to understand them. Geography departments, therefore, are very much involved in the application of land information systems, as they are primary users of land data.

(b) Computer science departments are involved in the development of hardware and software, often with little regard for the application of their technology.

(c) Typical land and resource management programs, whether they are in planning or environmental studies types of departments, mainly deal with public policies, valuation and economics. They are involved in the social (benefit and problem) aspects of LIS.

For education in land information systems a little of all of the above disciplines is needed. Any course which hopes to educate the professional in LIS must contain significant parts of each of the subjects of geography, computer science and land management. The degree to which a course is tailored towards the analytical mind determines the 'systems' aspect. The degree to which the professional and social elements are taught governs the 'management' aspect. It will be difficult in any one degree programme to include sufficient of both areas. A solution is to provide interdisciplinary courses, say, geography and computer science, survey engineering and land management.

Another logical home for information systems whose primary focus is in the manipulation of land data, and which require precise positioning of that data, is in the realm of the surveyor and in a true surveying department. Surveying does, already, include elements of all of the above disciplines. Surveyors' "basic training gives them a valuable balance between technology and management".[1] As Koo states "computers and information technology has influenced land surveying more than most other engineering sciences".[2]

Surveyors must therefore remember their roots and broaden their present data collection role into land management.[3] The surveyor has traditionally gathered the data for management decisions. It makes sense that the management information be gathered in the way most effective for input into a land information system. To do this requires a knowledge of the questions that will be asked of the system (output) and the way in which the data can be gathered (input).

It is the knowledge of these two ends of a land information system that a surveyor has. By putting the two ends together the surveyor moves from a mere collector of data to the realm of management. It is not only a problem of where to put the land boundaries, but the economic, ecological and political consequences of what to do with the land unit. This is land management.

Basis for LIS Curriculum

I am not going to list courses that should be taught, rather the ideals behind LIS education.

To use the technology for land information systems we must go to the fundamentals of learning about and managing land resources in addition to training in the technology itself.[4] We must not be technology driven. It is easy to be forced into concentrating on the technology: instructors can get caught up with the transient technologies, students want to learn about the instrumentation and methodologies that they think will make them more marketable. New technology is exciting. Canadian universities that teach LIS technology in their survey engineering departments include Calgary, New Brunswick and Laval.

Courses in the technology are essential, but students must not believe automatically what comes out of their automatic device - EDM or computer. The user should have a knowledge of what the right answer should look like. Let automation give us speed and precision to 15 decimal places, but we must know what that really means. A person can be trained in the use of the technology, but must have the educational basics to know what they are doing.

Physics is the root of the technology. Mathematics is the language. Understanding technology and how and where to use it, assessing its value and relevance, are some of the prime objectives in LIS education. This can only be done through a balancing of the technology with the basics and with equal emphasis being given to social considerations of LIS. When working out a mathematics or programming assignment, the student has a good idea of when the answer has arrived, so continues working until the solution appears. With, say, a law assignment such is not the case, so it can more easily be put aside without a proper answer. We should try not to let this happen. As much effort must be put into logical analysis of all facets.

The two most important professional attributes (other than professional responsibility) that any person should have are:

i) critical thinking: logical; structured; systematic; analytical; precise.

Students must learn to think around a subject, to question, to have insight into things and to develop initiative. Not only must they have a scientific approach to thinking, but also different approaches gained through a more liberal education. Gracie states "As professionals, we must be able to think at different frequencies on the intellectual spectrum".[5]

ii) effective communication: written; oral.

Anyone working with land information systems will have to deal with people from diverse background: computer science, land use studies, resource management, government and the accredited professions. This requires an ability to converse with people, as well as being able to document one's own work.

The technology in LIS is in the automation of data collection and in the system themselves - the hardware and the software. What automation does not do are the typical managerial functions: acceptance of proposals, contractual arrangements, feasibility studies, responsibility and potential for negligence, dealing with people, both staff and clients. A computer can be used in many functions, but it is just a grown-up calculator. It cannot make decisions; it does not have inductive reasoning, no intuition, no instinct; it does not have the ability to improvise or to create something new, nor to apply old methods to a new application without more input.

The user of the technology, and the manager of the data, still has to analyze, interpret, make decisions and act on those decisions. Thus, the person educated in land information management must have the knowledge and creativity to effectively use the data, as this is something that the technology alone cannot do.

Students of LIS must be trained to lead. Technology can give them the confidence in the tools that they use, so that they can seek further application of the technology with vision—and initiative. They must understand that their work is a service to society, know the technology of the day, apply it intelligently and build upon it.

LIS at the University of Toronto

The geography department at the University of Toronto has a course in geographic information systems and one in computer cartography. There, the emphasis is on the use of the systems for geographical applications. The computer science department offers a degree in computer science for data management, and also runs courses in graphics, data structures, and information systems analysis and design. However, these are generally not for spatial data. The computer science department is also involved with expert systems, computer vision and artificial intelligence, all of which are on the fringes of LIS.

There is a gap in LIS education: the bridge between the technology and the application. This can be filled by the survey science programme at the University of Toronto. Here we take the basic knowledge of the land and its law and meld this with information systems as a management tool, to enable effective control of the land and its resources.

We want to broaden the outlook of our surveying students. It is a common malady that the surveying profession is seen simply as one where a "bush hog" is bashing in a survey marker. The survey science programme is advancing with the new ideas and technologies that are entering surveying. At the same time the basic background in the essential aspects of the profession are not forgotten. However, to attract students in LIS, we must make the subject known to the public and to high schools. This needs effort on behalf of the surveying profession and the university.

Conclusion

Cooper[6] states that the removal of observing as the surveyors' primary activity gives them the freedom to develop and use other skills:

i) There are those with an analytical bent who can write programs, devise data transfer and processing systems and design survey procedures (LIS).

ii) Those who wish to synthesize, who can take the route of economics and management, can ensure the accuracy, maintenance and proper use of data relating to the land (LIM).

Together, they can inform society about the extent, shape, resources, use and value of the land. This is land information: as such, it is the surveyor who should be educated in land information systems and management.

This is going back to surveyors as they were in the time of the exploration and opening of Canada. Since then they have gradually lost many areas of their profession. It is time to get these prospects back.

The changes that are taking place in the profession of surveying are also changing the focus of the university courses that must lead the way to the future. At the University of Toronto, students are given a good grounding in the basics relevant to surveying; taught the essentials of technology, data collection, analysis and evaluation. They get professional training in the art and science of using land-related information. They are taught the limitations and accuracies of the technology so that they can effectively apply it.

As with most of the other disciplines at a university, there is just not the time to teach everything we think a student ought to know. The emphasis on interdisciplinary studies should be stressed. Education in land information systems must rely heavily on its basic disciplines - mathematics, computer science, geography, land resources and management.

Such a curriculum in land information systems cannot exist without the technological training and the fundamental understanding of the applications of that technology. It is not a compartmentalized subject and it brings out the universal nature of knowledge. Our education system, unfortunately due to time and logistical constraints, tries to make each subject stand in isolation. This is never so, and LIS education must bring that out.

Let automation give us speed and precision, but we must still know what the result means and how best to use the answers we obtain, to ask better questions, to obtain better answers and to better serve the society that we live in.

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A SURVEY INFORMATION PROCESSING SYSTEM FOR HYDROGRAPHER

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ABSTRACT

HMS ROEBUCK, the Royal Navy's latest coastal survey vessel, is equipped with an advanced data logging and processing system. The system is designed to aid all aspects of hydrographic survey from planning to final fair sheet production. It includes a variety of graphics displays which enables the surveyor to monitor on-line the data being collected. Sophisticated computer processing and cartographic capabilities allow the final data to be presented with a new degree of flexibility in a variety of forms.

INTRODUCTION

The Fair Sheets recording the results of hydrographic surveys undertaken by the surveying service of the Royal Navy are a principal source of field data for Admiralty charts. They are themselves a cartographic product which forms an archived public record. Although there have been many developments in both surveying equipment and techniques, the painstaking preparation and presentation of these documents has remained a highly labour-intensive activity largely unchanged for the last 100 years.

Initially, the use of automation to assist in the progress of coastal surveys touched only on the areas of position computation and plotting the ship's track. However, with the impetus from oil and gas exploration a new generation of computer-based navigation and surveying systems has become available in the commercial sector. The construction of a new coastal survey vessel, HMS ROEBUCK, launched in November 1985, has allowed the Hydrographic Department to take advantage of these advances and install the Royal Navy's first automated logging and processing system for bathymetric surveys. Designated the Survey Information Processing System (SIPS) it has been developed to suit Hydrographer's particular needs in association with Qubit UK Ltd as Ministry of Defence contractor.

The objectives are to improve survey accuracy and presentation; to ease the handling of the voluminous amount of data involved; and to reduce the repetitive aspects thereby allowing the surveyor to spend more time on the exacting task of quality control of the survey. This paper concentrates on the way the System's graphic and cartographic capabilities help achieve these aims for the surveyor at sea.

EQUIPMENT

SIPS is designed to provide a real-time aid to navigation, data logging and onboard processing. To meet this task it is divided into two subsystems, one for data acquisition and one for data processing.

Data Logging System (DLS)

This is located on the bridge and is centered around a Hewlett Packard HP1000 mini-computer. There is an A0-size flatbed plotter, a terminal and two strategically mounted high-resolution colour displays: one for the officer of the watch, another for the helmsman. The computer is interfaced to a wide variety of navigation and surveying sensors, such as depth measuring echo-sounders, heave compensator, gyro compass, logs, sonar and a variety of electronic position fixing equipment (Fig 1). Observations from all these inputs are logged onto magnetic tape cartridges for transfer to the Data Processing System.

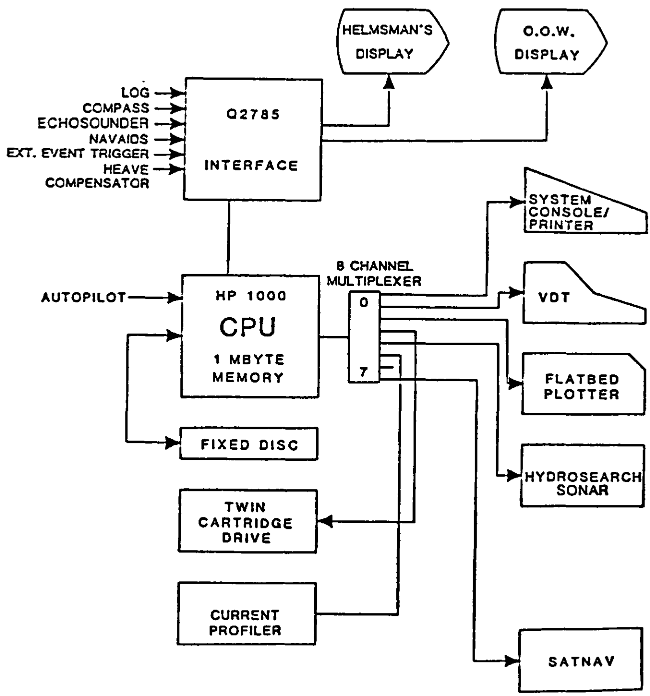

Fig 1 Data Logging System (DLS)

Data Processing System (DPS)

This is based around a separate, identical mini-computer located in the chartroom. It differs from the DLS in having a faster A0-size drum plotter, a high-resolution graphics terminal and a digitising table (Fig 2). The output is a set of processed data on cartridges and a variety of hardcopy cartographic products.

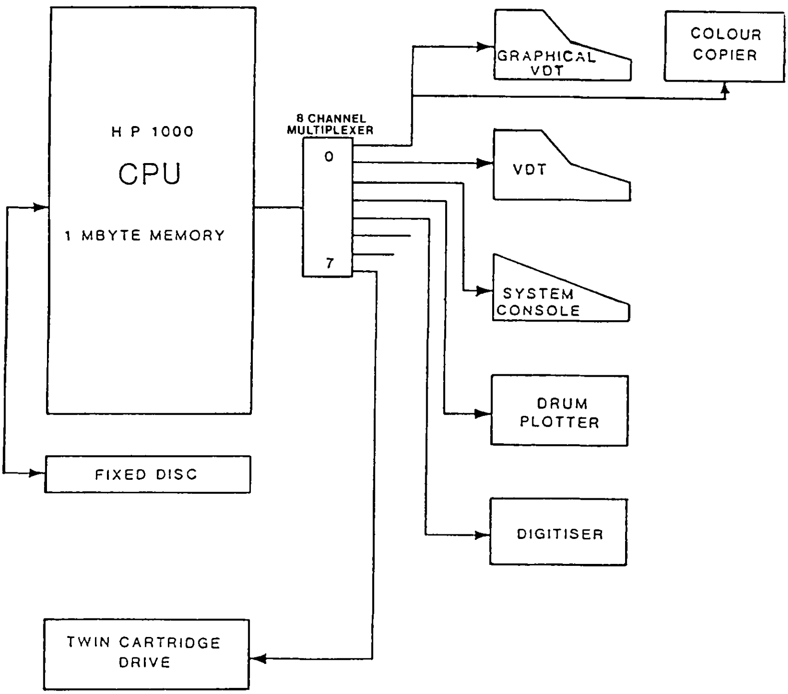

Fig 2 Data Processing System

SYSTEM DISPLAYS AND OUTPUT

The use of SIPS divides into four functional areas: survey planning, surveying (real-time navigation and logging), data analysis and reduction, and presentation of results. Displays can be either ephemeral on one of the video monitors or onto hardcopy. Hardcopy documents can be generated in the planning phase and predominate in the final presentation of the results of the survey. The visual displays are used principally whilst navigating, when constant updating is required, and for interactive editing during data processing.

Survey Planning

The planning phase can be carried out on either system but normally will be done on the chartroom equipment. The lines along which the ship will survey are automatically generated in grid terms, given the area to be surveyed, the spacing between the lines, and the first line to be run. Files are created of, for example, hazards, features requiring investigation, navigation marks and the coastline, using either the digitising table or by keyboard entry. Symbols are drawn from a library of standard Admiralty-style chart symbols. Base sheets, optionally with navigation lattices, can be plotted with this information.

Whilst none of this is particularly novel onshore, onboard it gives the ship significant operational flexibility both in the production of planning documents and in the way information can be displayed. Additionally, amendments to the surveying plan can always be made on-line without disrupting the main task of logging.

Surveying; Real-time Navigation and Logging

Data collection for a routine bathymetric survey may well involve the simultaneous collection of data from up to a dozen different sensors. Monitoring the incoming data in the past has been limited to spot checking the reading of an individual piece of equipment and the production of a trackplot on a plotter. SIPS firstly records the raw readings from these sensors for later processing and secondly, it integrates and processes the data on-line, presenting relevant information to the surveyor. The presentation is achieved by means of a series of textual and graphical displays. Textual displays are used to summarise the data currently flowing into SIPS. A series of graphical displays affords an easily assimilated summary of navigation information, coupled with the more critical data from the sensors such as depth, course and speed.

The principal display that will be used by the helmsman is the left/right indicator (Fig 3).It provides the ship's track superimposed onto the planned profile, against which the ship's position has to be constantly monitored. Meanwhile, the Officer-of-the-Watch can be evaluating the accuracy of the position fix using an error ellipse display (Fig 4) which gives a visual presentation of the lines of position emanating from the various navigational aids. Position fixing remains one of the main problems in hydrographic surveying and demands constant checking. SIPS provides the information for the surveyor to judge its reliability and then to take steps to obtain the best position calculation for the ship.

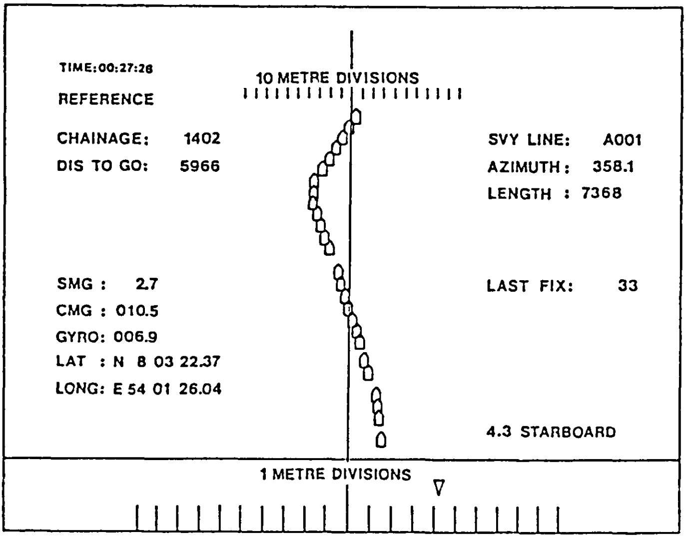

Fig 3 Left/Right Indicator Display

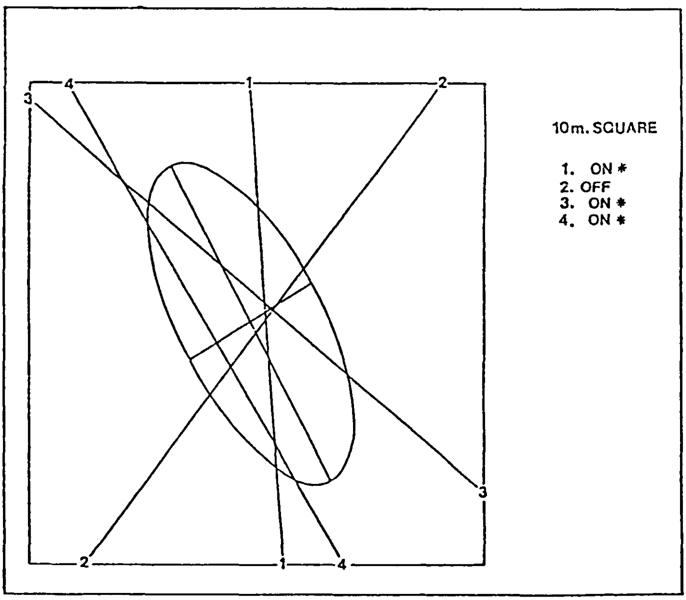

Fig 4 Error Ellipse Display

The information input during the planning stage, such as hazards, the coastline and shoals requiring investigation, can be displayed on the screen, together with the survey lines to be followed or the track already completed. Alternatively a target display can be chosen centred on, for instance, a wreck or natural submarine feature requiring investigation (Fig 5). This display includes a series of range circles centred on the pre-selected point at the chosen scale. Again, cartographic information on file can be added to the ship's position. For investigation of wrecks a very large scale can be selected and as well as the ship's position that of a second ship's position (required in wreck sweeping) or a towed sonar can also be displayed. All this aids the precise manoeuvring necessary in this type of operation.

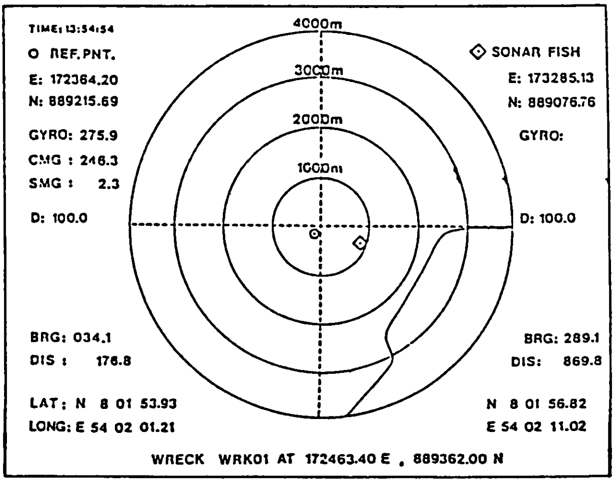

Fig 5 Target Display

In practice these displays are also backed up by a continuous small-scale hardcopy plot of the ship's track, plotted together with any wreck contacts discovered, but it is the visual display unit that has now become the focal point for the surveyor on the bridge.

Together, these displays provide regularly refreshed information for controlling and scrutinising the survey processes as the survey progresses. The variety of display options enables the surveyor at sea, for the first time, to monitor the quality of his observations properly using quantitative data.

Data Analysis and Reduction

The extraction of depths from analogue echo-traces and their reduction to a common vertical datum are exacting and time-consuming. The depths are then in time-honoured fashion 'inked-in', first on collector tracings then on final 'fair sheets'. A further disadvantage is that there is inevitably a degradation in accuracy resulting from some of the subjective procedures and the manual transcription of data. This can now be eliminated by manipulating the raw digital survey data. With the introduction of computer processing the aim is to remove some of the sources of error and to speed up the production of the final survey results.

Depths may have to be logged at 10 values per second to ensure pinnacles are not missed. The result is a vast amount of data which inevitably contains spurious or redundant information. The object of processing is to produce a reduced, valid, manageable data set. Procedures are still being refined but the underlying philosophy is that they should achieve a balance between software and human intervention. The surveyor has the opportunity to select parameters for the various filters used in the processing, and subsequently has the ability to verify and edit the computer's choice.

The first element to be processed is the ship's position. The values used can be those computed whilst logging, but as raw data is collected there is the option, for example, to re-configure or adjust calibration values. Once a 'best position' has been computed the ship's track can be smoothed to remove spikes in the data, for instance those caused by outside radio interference or perhaps the malfunction of a particular shore transmitter. The results are viewed on the screen, checked and, if necessary, interactively edited before the optimum track is plotted onto a base sheet.

Armed with the best ship's track the next stage is to remove erroneous return signals, caused perhaps by fish or aeration, from the logged bathymetry.

The data is processed by viewing the depth profile on a graphics terminal. The horizontal and vertical scales can be adjusted to suit the variation in, and density of, the data. The computer has a 'first go' at finding the errant returns, but the software is not left totally to its own devices. The operator has to set values used in the selection algorithms. This choice affects the effectiveness of the automation and gives the surveyor more control, or at least the feeling of having more control. Additionally there is the option of editing the automatic selection, by moving a cursor along the profile and tagging or deselecting soundings. At the very least the software draws attention to areas of data that require special consideration.

At this stage one of the prime objectives has been achieved. There is now a file containing only accurate positional and valid depth information. The bathymetry has been corrected for the ship's heave and the file contains the appropriate tidal values required to reduce the observed depths to a common vertical datum. However the data has still to be presented in conventional forms for both the end-users and for the surveyor's own use in quality control. The profiles that have been viewed on the screen can be plotted out, either on a large scale to overlay the echo-trace or on a small scale for a whole survey line's worth of data. If the information is required in plan form, the depth dataset has to be reduced still further to plot it at a reasonable scale. Chart-making and surveys are based on the principle of presenting shoal depths critical for navigation. This has to be reconciled with giving as representative a picture of the seabed as is possible. Further software routines aim to do this firstly by selecting minimum and maximum soundings within a 'window' set by the operator. Having chosen the scale of plot and sounding size, 'infill' depths are then selected, or depths are removed if there is likely to be a clash. As before, the surveyor can view the profiles on the screen (or plot the profiles) and edit the choice of soundings if necessary.

So far these methods have only dealt with data along individual lines. A normal survey has areas of intense investigation, as well as check lines run perpendicular to the normal survey direction. This extra information may contain critical depths which are required in the final data set. Another software routine compares soundings in two dimensions from adjacent or crossing survey lines, selecting the shoal soundings where there would be a clash at the chosen plot scale.

So we now have the means firstly to achieve valid data, and secondly to reduce the information into a manageable dataset. This is the starting point for the conventional cartographic products.

Presentation of Results

The currently accepted international convention on nautical charts is to show depths as individual spot values, supplemented by only a limited number of contours. This forms a constraint to which the presentation of hydrographic survey data must for the moment work, continuing to produce sheets of soundings for a chart compiler to use (Fig 6).

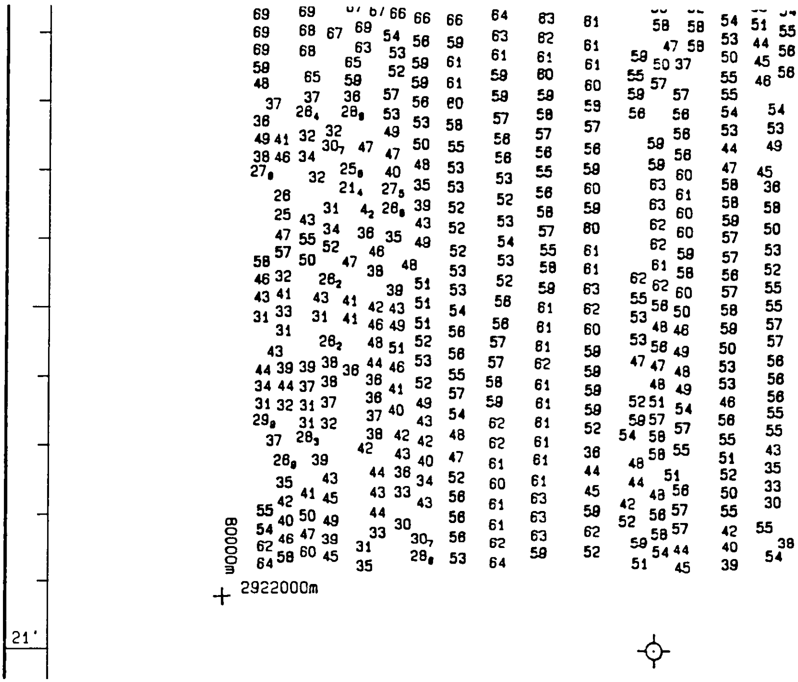

Fig 6 Automatically Plotted Survey Fair Sheet

Automated cartographic methods can enhance presentation, speed up production, give more precise and consistent results, and allow much more flexibility in the final product. The starting point is the base sheet which can be generated, as in the planning stage, complete with textual title information and features plotted with a range of Admiralty style symbols. The track of the ship and the projected track of a sonar fish (a body towed some distance behind the ship) can then be plotted, allowing the surveyor, and later the office, to assess the thoroughness of the survey and sonar coverage.

But it is in the plotting of bathymetry where most improvement lies. Depths can easily be plotted rapidly onboard not only at the required survey scale, but at enlarged scales in areas of detailed investigation, for example. The eight pen plotter allows the depths to be shown in colour bands which can be used to distinguish contours or highlight seabed features. Three-dimensional plots, viewed from whichever direction required, are produced either on the screen or paper. On a practical level these are an excellent 'long stop' for detecting spikes in the depths. At the Hydrographic Department they should aid the chart compiler in assessing the adequacy of his depth selection.

Other options allow surveys to be compared with previous work, plotting the result as a depth-difference choropleth chart; this is particularly useful in the sedimentation studies carried out by the Department. Of more use onboard is the comparison that can be done where survey lines intersect. Cross lines are run as a matter of course to check on the main sounding profiles; the system outputs a plot of depth differences at the line intersections. An excessive value flags the necessity to check, for instance, that the tidal adjustment is correct.

CONCLUSION

Our philosophy at present is determined by the crucial role the surveys play in safety at sea. The surveyor needs to maintain a watchful eye over all that the machine is doing, though in time experience with the system and the confidence that is built up, may reduce the amount of human intervention.

HMS ROEBUCK is currently undergoing extensive trials to refine the operating methods of SIPS. Undoubtedly SIPS will improve the accuracy of survey and greatly improve the flexibility with which the data can be presented. It is expected that certain timeconsuming tasks will be reduced allowing more time to be spent on quality control as well as speeding up the rendering of surveys. The final product will now include digital data ready for potential future exploitation.

The real-time video graphic and cartographic presentation of information is drastically changing life at sea for the surveyor. For the first time he will be provided with a proper measure of control over both his observations and the way they are presented.

THE HYDROGRAPHIC DEPARTMENT AND THE REQUIREMENT FOR DIGITAL HYDROGRAPHIC DATA

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ABSTRACT

Recent events point to an emerging requirement for bathymetric data in a machine readable form, primarily to support the digital chart. The Hydrographic Department has developed expertise in the use of automated cartography as part of its paper chart production process. This paper details the current thinking on how these computer based methods must be modified in order to supply data to meet the new requirement. It also describes the experimental work undertaken at the Hydrographic Department, including the production and maintenance of a trial data set, and a method of data coding which automatically matches the level of generalisation of displayed detail to the selected scale. The paper reviews initial moves within the international hydrographic community to identify and find solutions to the problems which must be overcome before digital hydrographic data can be used for navigation at sea.

INTRODUCTION

It is almost impossible to read a nautical journal these days and not find some reference to the electronic or digital chart as a general concept, as a system under development, or as a first generation piece of equipment usually intended for a specialist market, eg fishing.

It is difficult to predict in detail the outcome of current technical activity and debate, and it is of interest that there is, as yet, little demand for the digital chart from navigators. It does, however, appear axiomatic that as we enter the 'information age' there will be a requirement for chart data to be made available in a digital form. Furthermore, we believe that it is incumbent upon hydrographic offices to start planning for this eventuality now, and in this paper we outline the United Kingdom Hydrographic Department's initial moves in this direction.

Before describing these activities, a word about nomenclature would appear to be in order. The term electronic chart is often used to describe a comprehensive electronic navigation and information display system, which will display a vessel's position against a background of chart data, possibly with radar information superimposed. Electronic chart is also used in a more limited sense to describe the chart data displayed by such equipment. To avoid the inevitable confusion which can arise from the dual use of the term electronic chart, we prefer the term digital chart to describe the chart data, ie for that element of the electronic navigation and information display system which will be provided by hydrographic offices.

CURRENT CAPABILITY

In considering the digital chart, the Department has been able to draw extensively on experience gained from the use of its existing 'digital flow-line' which plays a major role in the production of paper charts (Drinkwater 1985). A major element in the chart production process is the conversion of the detail appearing on hand drawn chart 'compilations' into the reproduction quality images which will appear on the printing plates. When performed using traditional manual methods, this activity is both time consuming and labour intensive.

Using the digital flow-line, compilation detail is converted into a machine-readable form using off-line digitising tables. A verification plot of the data is then produced and examined for errors, which are subsequently corrected using interactive editing equipment. An increasing amount of routine editing is now performed automatically by software (Drinkwater 1986). The contents of the edited data file are output to a flat-bed plotter equipped with light head, which produce reproduction quality images of the digitised data on film. These film positives provide the image for the printing plates.

INVESTIGATIVE ACTIVITY

Our first investigative activity was the production of six digital chart files, using as source a series of 1:150,000 scale paper charts covering the south coast of England. The purpose of the exercise was to identify the problems likely to be encountered when capturing, storing, updating and selectively extracting such data and, from the experience gained, establish reliable working methods. Fifty-eight types of charted detail were selected for inclusion in the data files. It should be stressed that this is merely a representative data set; it was not our intention at this stage to decide which charted detail should be included in the digital chart. Similarly the level of generalisation used when encoding linear features was a convenient compromise rather than our considered view on how such features should be stored in the digital chart. The data are arranged into twenty software layers, the rationale behind this being that the user will be able to select the combination of layers most suited to his particular needs. (Restricting the number of layers to 20 merely reflects the limitations of our current editing and display software).

Examples from this data set are illustrated by figures 1 and 2. Both figures cover the same sea area, bounded by a coastline to the north, and include 2 depth contours (20 and 30 metres) and navigational lights. This information was obtained by selecting layer 1 for coastline, layer 5 for 20m depth contour, layer 6 for 30m depth contour and layer 13 for lights. In addition, figure 1 includes detail from layer 10 (soundings), layer 12 (buoys), layer 14 (light sectors) and layer 15 (pilot station). In lieu of layers 10, 12, 14 and 15, figure 2 shows the position of all known wrecks (layer 11).

The production of the trial data files has revealed several areas where modifications to our existing methods were required. It soon became obvious that digital techniques developed for paper chart production do not always meet the data encoding requirements of digital charts. For example, all depth contours appear on the printed chart in the same line style, with the appropriate depth values indicated by contour labels. In the digital chart each contour value eg 10m, 20m, 30m etc must be allocated its own feature code to enable software to perform selective extraction and display. This, and other similar considerations,

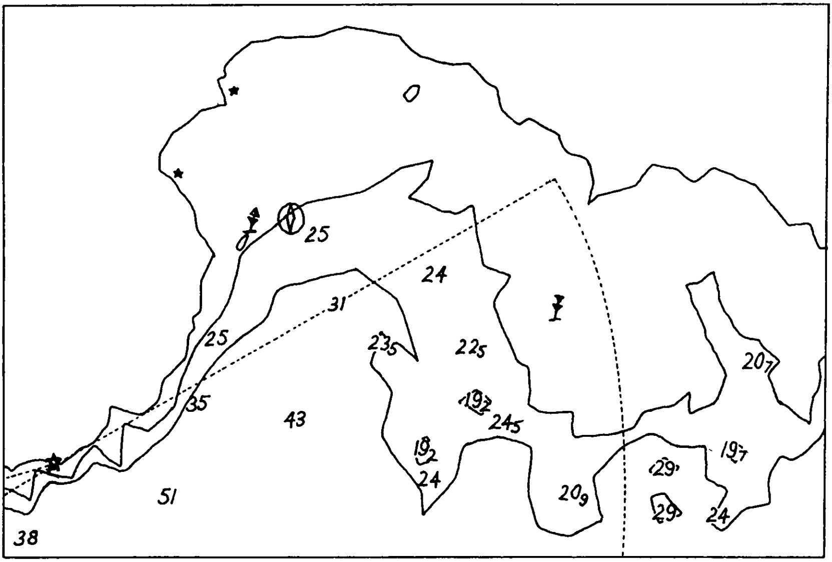

Figure 1

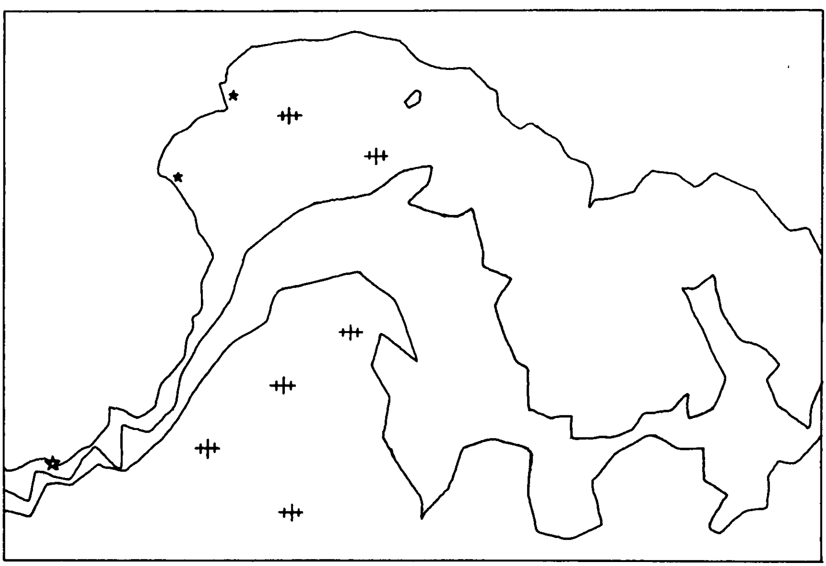

Figure 2

resulted in the creation of a new feature code menu specifically for the digital chart. Depth contours provide another good example of departure from 'conventional' charting practice. On the paper chart, cartograpic considerations often result in the localised omission of contours. In an area of steeply sloping seabed where contours lie very close together, it is often only possible to chart the shallowest and the deepest contours, intermediate ones being terminated on either side of the congested region. The digital chart will require all contours to be continuous - as we cannot predict in advance which ones the user may wish to select. Remaining with depth contours, it was necessary to establish a convention regarding the direction of digitising to enable software subsequently to determine on which side of the contour the deeper (or the shoaler) water lies.

Another indication of the difference between paper chart and digital chart digitising techniques is illustrated by the example of a lighthouse situated on an island. If the island is of very small extent, all that will appear on the chart is the symbol for a lighthouse without any encircling coastline. This is standard cartographic practice and does not confuse the mariner - he fully appreciates that the lighthouse must be standing on dry land and is not floating in the sea! Hence all that is encoded at that particular location in conventional chart production is the lighthouse symbol. For the digital chart, however, where the mariner may, for some reason, wish to omit the lighthouse from his display, it will be necessary to encode both a lighthouse and a symbol for a small island at the same location.

Requirements such as these illustrate the fact that the digital chart cannot be produced by simply digitising the paper chart of the relevant area, and that the preparation of the necessary source document - which could be an annotated version of the paper chart - will not be a trivial task. We must not lose sight of the fact that when reading a paper chart the mariner uses his interpretative skills to reach conclusions (as in the case of the non-floating lighthouse in the above paragraph), the spatial relationships between objects being an important input to this process. If he chooses to display a less than complete picture, then as many as possible of these relationships have to be built into the data set to enable software to emulate these human decision-making processes.

Not surprisingly, the study also revealed that the software associated with the production digitising flow-line did not satisfy all our new requirements, particularly in the areas of data update and data extraction. The ability to update is particularly critical for hydrographic data, being directly related to safety of navigation. The existing series of paper charts is updated each week, by the distribution of a free volume of so-called 'Notices to Mariners', describing the amendments to be made by the navigator to his charts. In the case of more complex changes the navigator is provided with a 'block correction' or chartlet, to be pasted over the affected area. Any professional digital chart series will require an analogous updating service. To this end we have established a method for updating our experimental data files for Notices to Mariners. Our initial data extraction capability was based solely on X, Y coordinates. We have now developed the ability to extract within specified geographical limits. The extraction routines operate on either selected feature codes or the contents of complete layers. Hitherto, each chart has been considered as an independent data file. The retrieval software is now being amended to access multiple chart files, so enabling the creation of new data files which cross chart file boundaries. The production of digital chart data sets brought with it the requirement to digitise textual information, something which had not been attempted hitherto. The capability to handle text has now been developed and as an added benefit has been implemented in our production digitising flow-line (Drinkwater 1986).

We have also been looking at data selection and data generalisation. The proponents of the digital chart make much of the fact that the user will be able to vary the display scale to suit his changing requirements. In reality, such freedom will depend upon two major considerations:

a. The availability of data at suitable scales. Just as hydrographic offices would not contemplate publishing a chart at a scale of say, 1:10,000 based upon a hydrographic survey conducted at a scale 1:50,000, so must the electronic display system be prevented from displaying data at an inappropriately large scale.

b. The ability to control the degree of generalisation. If a data set is to be used to support a wide range of display scales, then the controlling software must ensure that the density of data displayed is commmensurate with the chosen scale, increasing automatically when the display scale is enlarged and decreasing when the display scale is reduced. The level of generalisation used to depict linear features, such as a coastline, must also be amended automatically as the scale is varied.

Without such generalisation there is a danger of the mariner being presented with a uselessly scant representation of his surroundings or, conversely, a confusingly detailed one. The selection made by the controlling software will have to be at all times conducive to safe navigation and moreover, produce a display which is cartographically acceptable. (It is appreciated that conventional attitudes towards what is and what is not acceptable may have to change as we move into the digital age). Certain features are scale dependent but others are not, and cannot be dispensed with if the display is to be of any use to the mariner, eg certain soundings must always be shown irrespective of scale, whilst others can be safely discarded below a certain scale. Similarly, the points required to satisfactorily depict a coastline are dependent upon the scale of display: major headlands are significant at any sensible scale, minor undulations are insignificant at the smaller scales.

In theory, what is required is software which will simulate the compiler's thought processes when he decides on the level of detail to include in a chart of a particular scale. As far as we are aware, no such software exists. We therefore considered the possibility of qualifying each element in the digital data set with a 'scale of display' indicator. This ensures that although the real time selection of display detail is performed by the software, the results of this process have been pre-determined when constructing the data set in the hydrographic office. One way of generating a correctly coded data set would be to prepare a set of source graphics, one for each scale range, and digitise from these, allocating to each point the appropriate scale range indicator. The drawback to this method is that many points will be common to several graphics and so must be digitised more than once. This would involve duplication of effort in both the production and the maintenance of the data sets.

An alternative method makes use of a single data set. Firstly the important points on the smallest scale graphic are identified. These points are then indicated on the next largest scale graphic, on which are also marked the additional points considered significant at that scale. This process is repeated at each successively larger scale to produce, on the largest scale, a digitising guide indicating the scale of display appropriate for each feature. The advantage of this approach is that there is only one digitising source (the largest scale graphic for each area) and each point is digitised once irrespective of the range of scales over which it is suitable for display. Figures 3 and 4 are based on data derived from such a data set. Figure 3 shows a small scale depiction of the approaches to a harbour. Using the same data set, but specifying a larger display scale figure 4 is produced. Being at a larger scale this covers a smaller geographical area and it will be seen that the software has chosen a greater number of soundings, and that linear features such as coastline and depth contours are shown in greater detail than in the small scale example.

INTERNATIONAL APPROACH

Many outstanding items need to be resolved before the digital chart can be accepted as an effective replacement for the paper chart. These are the subject of debate by such bodies as the International Hydrographic Organization's (IHO) Committee on Exchange of Digital Data (CEDD), the North Sea Hydrographic Commission's (NSHC) Electronic Chart Display Systems (ECDIS) Working Group.

The primary question concerns the content of the digital chart. Should it contain all that is currently shown on the paper chart, less, or even more? The first generation of electronic chart systems operate on a very limited sub-set of chart information because of limited display resolution and data storage capacity. It is our view that this is not acceptable if the system is to be considered as a replacement for the paper chart. It is our contention that such a digital chart should contain all the detail shown on the equivalent paper chart, and this view is supported by others (Ligthart 1985). It is even conceivable that additional data may ultimately be included to support, for example, the real time tidal adjustment of depths and the generation of user-specified depth contours. It would also seem logical to consider including data from existing nautical publications which currently supplement chart detail.

There is common agreement that the digital data itself should be supplied by the national hydrographic offices in order to ensure the quality of the electronic chart data base. But system manufacturers will bear the responsibility for the integrity of the data if they subsequently process it, eg convert the format to that required by their particular equipments. The hydrographic offices will be responsible for obtaining and collating new information, and will update the electronic chart data base accordingly, but the means of supplying the update information to the user is still the subject of debate.

The selection of a suitable medium for supply of digital hydrographic data goes hand in hand with the development of a data format. It is clearly desirable that an internationally agreed format should be devised. CEDD has produced a proposal for an chain-node format, including a comprehensive feature/attribute coding scheme, for presentation to the XIIIth International Hydrographic Conference in Monaco in 1987.

The proposed format is intended for the exchange of large volumes of hydrographic data on magnetic tape between hydrographic offices. A simplified version of this format may be more suitable for use with electronic chart systems, but this cannot be produced until the requirements for such systems are more precisely defined.

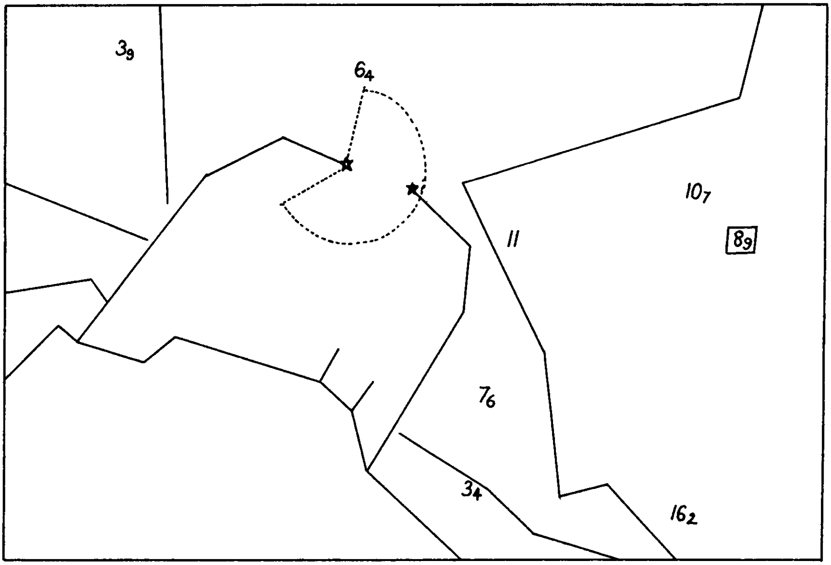

Figure 3

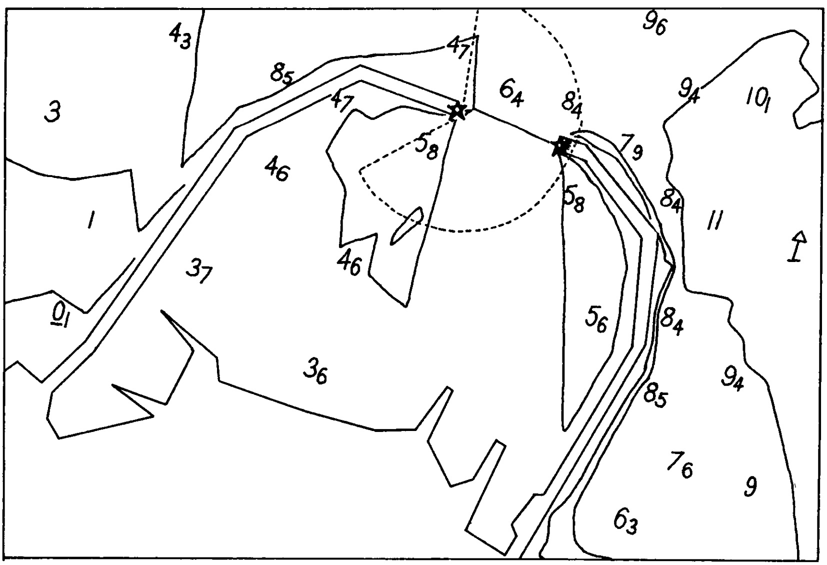

Figure 4

Consideration is also being given to the possibilities offered by telecommunications, particularly the supply of data to vessels at sea, and to this end a Canadian study is in hand to devise a format for this method of data transfer.

The other major area of discussion is that of the technical specification of the electronic chart systems. Systems of varying degrees of sophistication will emerge, each aimed at its own particular part of the market. There is a danger of some systems offering complex data manipulation capabilities which are not compatible with safe navigation. For example, care must be taken to ensure that the flexibility offered by a layering system of display is not abused by the navigator, who is not, after all, a cartographer. While the ability to select only those layers immediately relevant to his own vessel may produce a less cluttered display, the prudent navigator would also wish to display any information which may affect the navigation of other vessels in the vicinity.

Other aspects under consideration are: the standardisation of symbolism, the constraints which should be built in to prevent chart data being used at inappropriate scales; the means of recording a vessel's track and selection of data for accident investigation purposes.

From the above it should be clear that the problems of introducing a digital chart service are organisational, legal and financial, as well as technical. It is the aim of the Hydrographic Department to assist in finding answers to these questions, having as its overriding consideration the safety and convenience of the mariner.

The views expressed are those of the authors and do not necessarily represent the views of the Ministry of Defence, or of the Hydrographic Department.

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THE NATIONAL OCEAN SERVICE DESIGN FOR AUTOMATED NAUTICAL CHARTING SYSTEM II

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ABSTRACT

The National Ocean Service (NOS) has the mission of providing nautical charts and related information for the safe and efficient transit of the Nation's coastal waters and marine inland waterways.

In 1975 the National Ocean Service initiated the design of a computer-based system to provide for the storage of nautical chart information and automated assistance to the cartographer for compilation of nautical chart products. The Automated Nautical Charting System was implemented in 1978.

Efforts commenced in late 1984 to design a replacement system which would provide not only the functional capability and capacity to handle the requirements of nautical production, but also the needs of other users for nautical charting data.

The conceptual view of the next generation system, the Automated Nautical Charting System II (ANCS II), recognizes the fact that the nautical chart is only one of the many marine products that may be produced from a digital, chart-independent, data base of marine information. It is designed to benefit from the separation of the data management and chart production functions to lessen the impact of each function on the other. Another benefit is the reduction in the amount of time that data are unavailable (i.e., locked-out) to other users during chart compiliaton.

The NOS suite of 1,000 nautical charts may contain as many as seven or eight overlapping charts at different scales for certain areas. The design of ANCS II will incorporate in the automated chart compilation process the principal of update "through the scales." That is, application of digital marine information from the largest to the smallest scale using the set of information from the previous larger scale, thereby improving the efficiency of the system and ensuring greater standardization of chart products.

INTRODUCTION

The National Ocean Service (NOS), under the United States Department of Commerce, has the responsibility of providing nautical charts, related marine publications, and information required for the safe and efficient transit of the Nation's coastal waters and inland waterways. NOS marine products directly support national commerce, development of offshore resources, and defense of the Nation's coastal areas.

In 1975 the NOS initiated the design of a computer-based system to provide for the storage of nautical chart information and automated assistance to the cartographer for compilation of nautical chart products. This design culminated in the implementation of the Automated Nautical Charting System (ANCS) in 1978.

Technological advances in automated mapping and charting equipment coupled with the introduction of new automated mapping concepts have yielded capabilities far beyond those envisioned in the original ANCS. Therefore, a modernization effort, termed ANCS II, has been designed to reap benefits from state of the art hardware and software. In addition, ANCS II will expand well beyond the concept of a chart product support system to that of a broad information system for the support of multiple products and users of digital navigation data.

The ANCS II is designed to have the capability and capacity to handle the total requirements of NOS nautical chart production and the requirements of external users of digital marine information (to the extent the latter can be identified and defined). The ANCS II has a modular design to facilitate incorporation of new requirements and will allow for enhancements that cause as little impact as possible on production operations.

The ANCS II is part of an overall nautical charting moderization program and as such will directly support and be integrated with two major NOS data processing systems currently under development: the Shipboard Data System III (SDS III), a digital hydrographic data acquisition and processing system to be deployed on NOAA hydrographic survey vessels, and the Integrated Digital Photogrammetic Facility (IDPF), a shore based photogrammetric data processing system for compilation of digital topographic and photobathymetric survey manuscripts. Both systems will rely heavily on the contemporary information contained in the ANCS II data bases.

DATA MANAGEMENT

The NOS is responsible for charting approximately 2 million square miles of coastal area. This area contains more than 40 million cartographic features of interest to charting and navigation. The management of this vast amount of information to meet the growing demand for digital navigation related products, as well as to enhance charting productivity, is central to the mission of NOS.

The current data management system, which was designed to support paper chart production, is not amenable to the changes required for a focus on digital data dissemination. In order to accommodate this change in emphasis, a change in the data management concept was required. That change required the logical separation of two distinct functions:

- o The management and maintenance of marine navigation information, and
- o The management and maintenance of chart graphic information.

Early thinking saw the inherent properties of both incorporated within the physical processing confines of one large data base system. However, experience with ANCS has proven that, because of the distinctly different demands and requirements associated with each, the two functions cannot be adequately performed without performance degradation of each other.

The daily processing of source information and the timely update of the marine Navigation Information Data Base (NIDB) will continue unaffected by the demands and requirements of scheduled product maintenance at the Chart Graphic Data Base (CGDB). The CGDB will rely on the contemporaneous nature of the NIDB and in the purest sense will be considered a user of the NIDB. The following text describes the major components of the ANCS II design and the functions of each.

SYSTEM COMPONENT DESCRIPTION

The ANCS II design diagram (figure 1) reflects the five major activities and information flow.

- o Document evaluation - the determination of the validity of the source document and the level of usefulness of the included information. This is a data certification process.
- o Data selection - the process of automated evaluation and selection of specific information from the contents of the valid source document with interactive selection approval by the cartographer.
- o Data base maintenance - the process of updating the existing data base of navigation information by interactive addition and deletion of selected features and associated information.

AUTOMATED NAUTICAL CHARTING SYSTEM
ANCS II

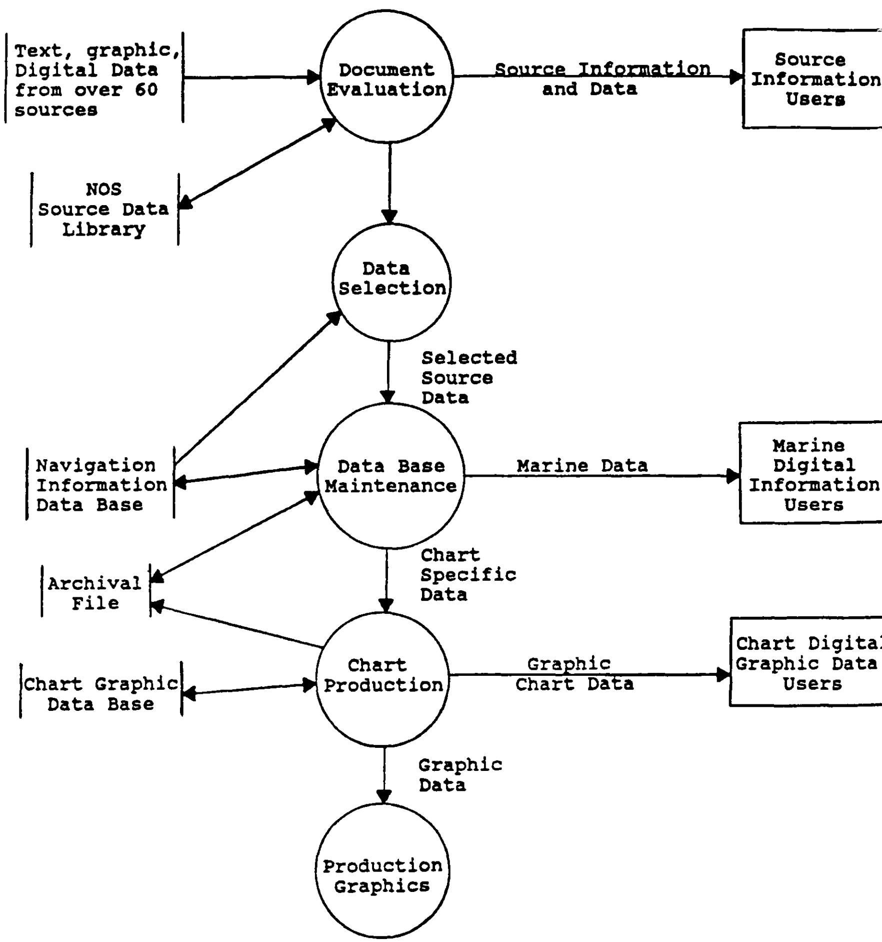

FIGURE 1

- Chart production - the process of automated compilation of the chart graphics from digital information and the storage of the digital graphic representation.
- Production graphics - the creation of graphic reproducibles.

Document Evaluation

Document evaluation is one of the major concerns being addressed in the design of ANCS II. The current ANCS system does not provide interactive facilities to assist the cartographer during the registration, validation and subsequent processing of new information. ANCS II has been designed as an interactive environment to assist the cartographer in a predefined evaluation process and to serve as a management tool for: a) the tracking of documents, b) recording events during evaluation, c) data selection and reduction, d) application of documents and their contents, and e) scheduling of resources.

Information affecting NOS charting products is received by NOS from over 60 different sources. About 80 percent of the documents received are from sources external to the Agency. The information received from external sources and new source information acquired by internal NOS hydrographic and topographic surveys and field examinations will be inspected and an entry created in a Source Document Index File (SDIF) describing characteristics of the document and the information it contains. ANCS II, utilizing an interactive process supported by the index of previously received and evaluated source documents, will assist the chart specialist in the determination of the validity of a new external source document. This determination will be made by comparing the new document against existing and other new documents which have been entered into the NIDB. Redundant documents and those that do not contain information useful to charting will be rejected or redirected to the appropriate office. Internal source documents are entered directly into the NIDB.

The source document and its contents are incorporated into a Source Data Library (SDL) for storage and subsequent retrieval of source information as required. The Library is a repository for both physical documents and digital storage medium indexed by document number, document type, and date.

Data Selection from External Source Documents

The cartographer will initiate the process of source information selection and application by an interactive query requesting information on a particular source document or the geographic area of interest. The cartographer will be informed of the availability and status of newly entered source documents and presented, if requested, with a display of a graphic index containing a general feature outline of the area and relevant document limits. Using the graphic index and SDIF information, the cartographer will interactively build and qualify a request for retrieval of the required new source information, if in digital form, and current NIDB data for the area. Automated assistance in retrieval request building will aid in keeping the volume of data retrieved from the data base to a minimum and improve the human interface.

After the retrieval request has been accepted by the user, the data retrieved will be copied to a working file. Source document data residing in the SDL, already in digital form, will also be copied into a working file. Digital data retrieved from the SDL will undergo an automatic transformation sequence to convert the control and translate the contents of the digital source document to the same coordinate system and graphic characteristics as that of the data base. The source document line data will be generalized, the soundings will be preselected, and the depth curves created. If a source document is not in digital form, the retrieved data base work file will undergo the equivalent transformation so that the information can be displayed at the work station in the units and with the control of the physical source document for digitization and data selection from the source document.

The transformed digital source document file and the data base work file are then overlaid and displayed at the work station. Automatic editing is performed to the extent that document features are added and corresponding data base work file features are deleted. The user can revise the automatically edited work file and perform other editing to tie linear information and revise the disposition of features for which a predetermined editing sequence has not been established. If the source document is not in digital form, the work station will allow precision entry of features into the data base work file.

Upon completion of the editing session, the user will have the capability to generate a textual or graphical representation of the proposed transactions prior to update of the data base. The user will have the capability, prior to acceptance of these transactions, to restore or undo any edit performed.

Documents vary over a wide range as to content, form, size and complexity requiring various degrees of precision for digitization and cartographic sophistication for evaluation and selection. In order to utilize resources efficiently, ANCS II will provide a variety of work stations, each best suited to a particular task.

Data Base Maintenance

During the NIDB update process, a Feature History File (FHF) and a Notice to Mariners File (NMF) will be updated based upon the transactions. Should a feature be deleted for any reason, it will be moved from the data base to the FHF for permanent storage. Should an addition or deletion, either through automatic editing or manual editing, result in a critical difference between the current representation of the data base and the transaction applied to the data base work file, the items of a critical nature, flagged by the user, will be copied to the NMF. An entry made into the SDIF is updated to reflect the current evaluation and data base application status of the source document. The NIDB will be updated to reflect the status of the data base.

The NIDB is a geographically oriented digital data base consisting of geographic positions of features and their associated attributes. The NIDB will provide the capability to efficiently access a logical subgrouping (as shown in table 1) of features, which with the present system, is a difficult task.

<u>Chart Maintenance</u>

After information is applied to the NIDB it becomes available to the Chart Production Subsystem (CPS) for application to the nautical charts contained in the CGDB.

The CGDB is a digital data base containing the information required to produce the published chart graphic for the approximately 1,000 NOS nautical charts. The data consists of a link to the NIDB and instructions for producing the graphic attributes needed by the cartographer to make cartographic decisions during the compilation processes. An interactive retrieval initiated from the NIDB will retrieve only new features entered since the last chart update or a specified date. The retrieval will be qualified by geographic limits; usually the limits of the largest scale chart in common with the NIDB revisions. Any features previously retrieved for chart application will not be included in the current retrieval. This eliminates the possibility of NIDB features being retrieved and applied more than once to a chart.

The features retrieved are transformed into the proper chart symbols based on the coded information in the feature record. The largest scale chart parameters govern the portrayal characteristics of the data retrieved; scale, control, and screen orientation (for skewed charts). Additional processing performs line and symbol generalization, and converts all NIDB depth values to the units of measurement on the chart (soundings). Initial application is rule based, but will allow the cartographer full latitude to apply the final portrayal of data.

The link between features in the NIDB and the CGDB is the geographic position which was entered into the NIDB and the system derived feature code. The CGDB will record both the

PROPOSED MIDB FEATURE CLASSIFICATION

Classification Code

1. NAVIGATION

   A. Aids

      1. Lights
      2. Buoys
      3. Daybeacons/Markers
      4. Radio Aids
      5. Fog Signals

   B. Demarcation

      1. Boundaries
      2. Administered Limits
         Cautionary/Information
      3. Anchorages
      4. Recommended Routes
      5. Channels/Dredged Areas

   C. Marine Assistance

      1. Stations/Other
      2. Facilities

2. HYDROGRAPHIC

   A. Bottom

      1. Soundings
      2. Depth Curves
      3. Bottom Quality
      4. Cleared Areas

   B. Features in Water

      1. Manmade
      2. Natural

3. TOPOGRAPHIC

   A. Coastline

      1. High Waterline
      2. HWL Associated

   B. Culture

      1. Prominant Structures
         Behind HWL
      2. Other Feat/Limits
         Behind HWL
      3. Structures Over
         Water

   C. Natural

      1. Limits (Surface)
      2. Drains (Non-Nav)

   D. Relief

      1. Contours
      2. Features
      3. Spot & Trig Stations

4. CHART SPECIFIC

   A. Nomenclature

      1. Legends
      2. Blocked Text

   B. Scales

      1. Other Scales
      2. Magnetic Variation

   C. Symbols/Annotation

      1. Feature Enhancement
      2. Chart Format
      3. Generated Data

TABLE 1

position at which a feature is to be displayed and the original geographic position, so that the link is uneffected even if the feature symbol is moved for cartographic reasons. Features deleted from the NIDB are retrieved with the new features and matched with charted symbology having the same geographic position and symbol code. All matches to be deleted are graphically presented on the edit display for cartographer approval. All new features are added to the chart allowing the cartographer to eliminate excessive features. Features retained are spatially oriented to avoid overlapping other symbology. Coded text extracted from the NIDB record is displayed in the correct font and character size for the symbol to which it is attached. The cartographer will abbreviate the text, if necessary, and orient it to best describe the feature: arc, stacked, or sloped. The system will make the basic attempt to assign the best location and configuration of the text. Text that cannot be coded will be available in the record on demand to allow the cartographer to create additional text.

After application of the features to the largest scale chart, the system will model the selected contents of the initial application and any features retrieved not within the limits of the initial chart for subsequent application to the next smaller scale chart in common, and the procedures will be reinitiated. This continues until all affected charts have been revised. Encoded in the basic design of the CGDB will be the rules for through-the-scales application of features. The results of this process yields uniformity and consistency.

Graphic Production

The updated graphic representations will be subsequently retrieved for color plate production on the SCITEX Response 280 system where esthetic corrections will be performed to ready the graphic for raster plotting of negatives and positives. The CGB will also support internal and external special requests for high resolution graphics.

SUMMARY

The current Automated Nautical Charting System was designed in 1975, primarily to support the automated compilation of the paper nautical chart. The system has limited capability to respond to the increased requests for digital chart information.

The modernization of technology and the conceptual approach taken by the ANCS II effort will allow the National Ocean Service to meet the need for digital charting products of the future and enhance the productivity of the nautical charting process.

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THE USE OF GLORIA LONG-RANGE SIDESCAN SONAR FOR DEEP-OCEAN MAPPING

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ABSTRACT

The Institute of Oceanographic Sciences´ sidescan sonar GLORIA has been used for many years to aid bathymetric, physiographic and lithologic mapping of the deep ocean floor. The major advantages of the system are high tow-speed (up to 10 knots) and wide swath (up to 60 km), providing a rapid surveying capability. GLORIA does not measure depth directly, though depth can sometimes be inferred from shadow lengths. More often, GLORIA data are used to guide the manual contouring of widely spaced soundings. Contour maps thus produced are a great improvement over those made conventionally. While not quite as accurate or detailed as those produced by SEABEAM, they still provide a great deal of information on detailed depth, morphology and physiography that cannot be obtained from a conventional bathymetric survey, and do so with survey rates of ten to fifteen times that of SEABEAM. Recent advances in digital recording and image processing allow improved accuracy and presentation of the data, mainly by the application of slant-range correction and user-controlled time-varied gain. The latter can be selected interactively to match best the features under study. We are now experimenting with various ways of combining sidescan and bathymetric data in the same digital image.

OCEAN SURVEYING

There are very few deep ocean surveying techniques which permit the bathymetric mapper to see the shape and extent of the features he is trying to contour before he even puts pen to paper: sidescan sonar is one. At the Institute of Oceanographic Sciences (IOS), a long-range sidescan sonar has been developed that will insonify the seafloor over a double-sided swath up to 60 km wide at a speed of 10 knots. Originally developed for scientific purposes (Laughton, 1981), GLORIA (Geological Long Range Inclined Asdic) has shown its potential as a survey tool, producing results from which bathymetric, morphologic and potential resource maps may be produced (EEZ-SCAN Staff, 1986).

GLORIA Mark II (Somers et al., 1978) looks to both sides at once. It consists of a neutrally buoyant torpedo-shaped vehicle towed 40-50 m deep and 300-400 m behind the survey ship. The vehicle houses the dual sidescan transducer arrays which operate at frequencies around 6.2 and 6.8 kHz. Maximum range depends on the sound velocity profile and water depth, and in deep water can be up to 30 km. More information about the present system and past surveys can be found in Laughton (1981) and Somers & Searle (1984).

Shipboard sonograph processing

Signals are recorded onto magnetic tape, which are then replayed to produce a photographic hard copy. During replay a correction for "slant range distortion" is applied. This distortion arises because the images are produced by recording the travel-time of sound not along a horizontal surface but along the diagonal path from near-surface instrument to deep sea-bed. This makes the cross-track scale non-linear and distorts seafloor features. For 5-km-deep water the apparent displacement is about 2 km at 5 km range, but falls to 0.6 km at 20 km. The distortion is calculated and applied digitally assuming straight rays and a horizontal seafloor whose depth is given by the ship s echosounder. Any departures from these assumptions have small effects compared with errors in navigation.

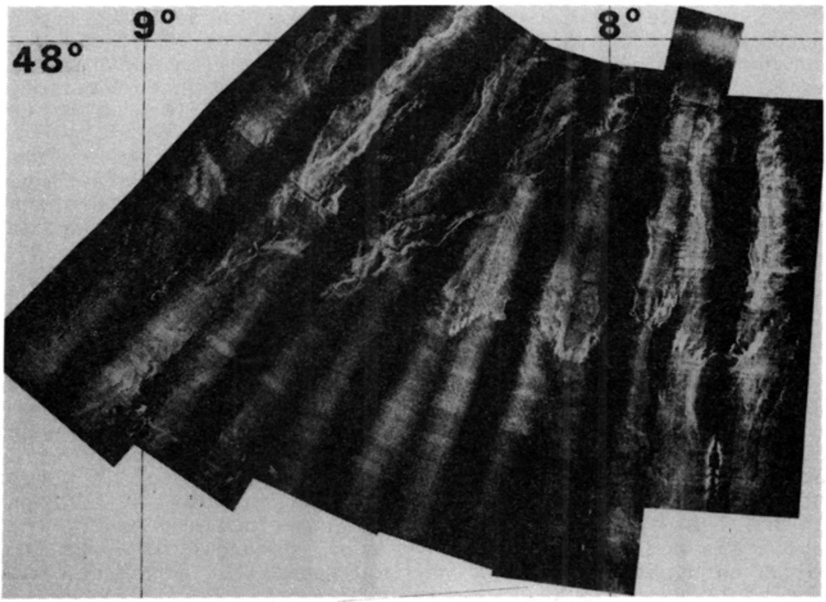

Figure 1. GLORIA sonograph mosaic over Meriadzek Terrace, northern Bay of Biscay continental margin (after Kenyon & Hunter (1985). Sonographs have been slant-range corrected but are otherwise unprocessed.

The photograph is then "anamorphosed" to correct for variations in ship's speed. Such variations result in a variable ratio of along-track to across-track scales. Until very recently the effect was corrected at sea by rephotographing the images through a special camera in which both object and film moved at speeds selected to give the required amount of stretch, though now this correction is also applied digitally during tape replay by replication of scan lines a variable number of times depending on ship's speed. For an average ship speed of 8 knots a stretch factor of about 3 is required. Finally the resulting photographic negative is printed to the required scale (usually between 1:200,000 and 1:500,000).

The sonographs are mounted along a plot of the ship's track and a mosaic is built up (e.g. Figure 1). In general features can be correlated between adjacent tracks, but errors can result from the varying viewing direction and because of navigational inaccuracies. Navigation is usually by Transit satellite, Loran-C or Pulse-8. Earlier errors due to slant-range distortion have now been eliminated.

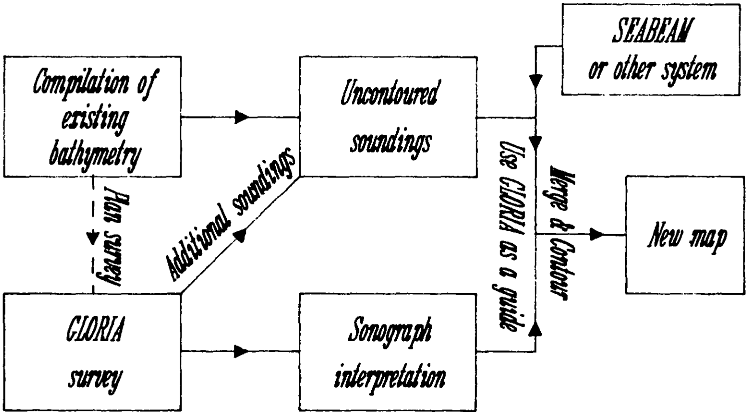

Figure 2. Procedure for creating a bathymetric map using GLORIA data.

Sonograph interpretation for mapping purposes

We illustrate the mapping procedure (Figure 2) with reference to an area on the continental margin west of Land's End (Figure 1). Before the start of the GLORIA survey an initial compilation of the proposed study area is usually made, and based on this the directions and spacing of the track lines are planned. In Figure 1 the tracks fan out almost perpendicular to the continental slope, owing to the increase in range as the depth increases.

The sonograph image is a map of different levels of acoustic backscattering from the seafloor. Signals are produced not only by topographic features but also by the variety of bottom deposits often found on areas of little or no relief (e.g. Kidd et al., 1985). Basalt flows and rocky terrain produce high levels of backscattering, whilst smooth mud produces very little.

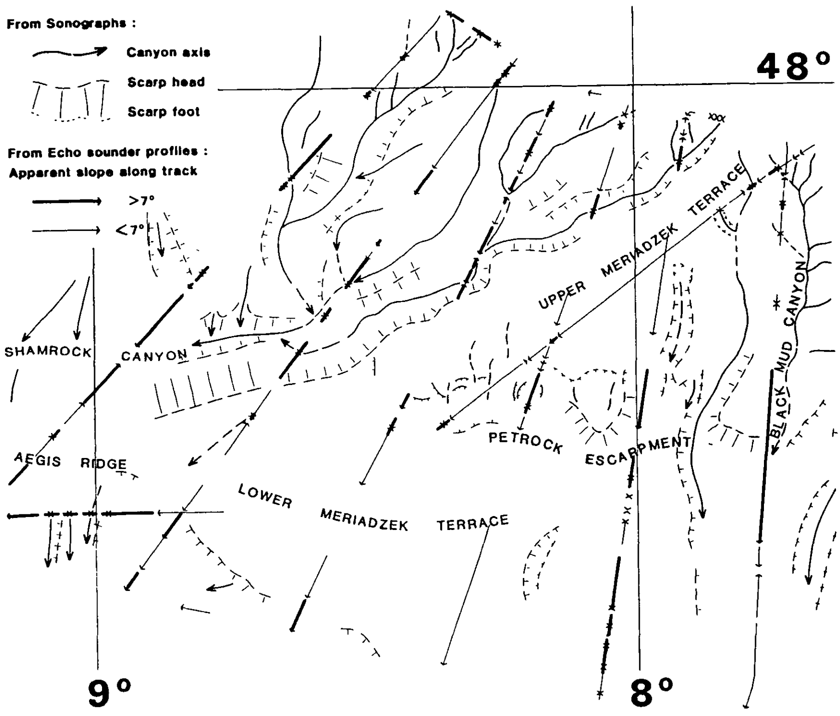

Figure 3. Interpretation of the area of Figure 1 based on echosounder profiles and GLORIA sonographs (after Kenyon & Hunter (1985).

Interpretation of the sonographs is carried out by overlaying the mosaic with a sheet of film and extracting the outlines of the relevant features. To identify the types of features reference is made to echo-sounder and seismic profiles and to any existing maps. Other information such as the seafloor gradients can also be included on the overlay as in Figure 3.

The final stage in the mapping is to merge the compilation of sounding information, supplemented by soundings collected during the GLORIA survey itself, with the interpretation of the sidescan data. Now the contours passing through areas between sounding lines can be interpolated with far more confidence than has been hitherto possible, resulting in more accurate maps such as that presented in Figure 4.

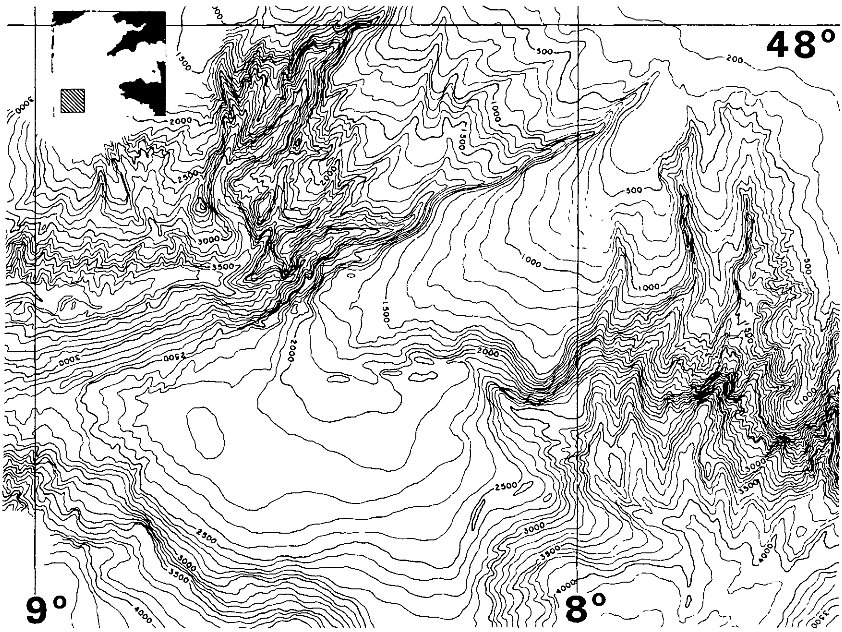

Figure 4. Bathymetric map, contoured in metres, of area shown in Figures 1 and 3 (after Kenyon & Hunter (1985).

The GLORIA data here reveal a more complex pattern to the distribution of the canyons than could be determined by echo-sounder alone. Multibeam scanning systems such as SEABEAM produce high-resolution maps which would also reveal the same pattern, but would take around ten times as long to cover the same amount of ground. However, a combination of the GLORIA coverage of an area with even a few SEABEAM passage tracks to give information on the contour complexities can produce an accurate map of a large area in a fairly short time.

An idea of the quality of GLORIA-aided mapping can be obtained by comparing figure 3 of Hey et al. (1980), produced conventionally, with figure 6 of Searle & Hey

(1983), which was contoured from conventional soundings but guided by an 18-hour GLORIA survey, and figure 6 of Hey et al. (1986) over the same area produced from a two-week SEABEAM survey.

POST-CRUISE IMAGE PROCESSING

Sidescan sonar images normally suffer from two types of distortion: geometric and intensity distortion. The geometric distortion comprises the slant-range distortion and the anamorphic distortion which have already been discussed and are now routinely corrected during data acquisition.

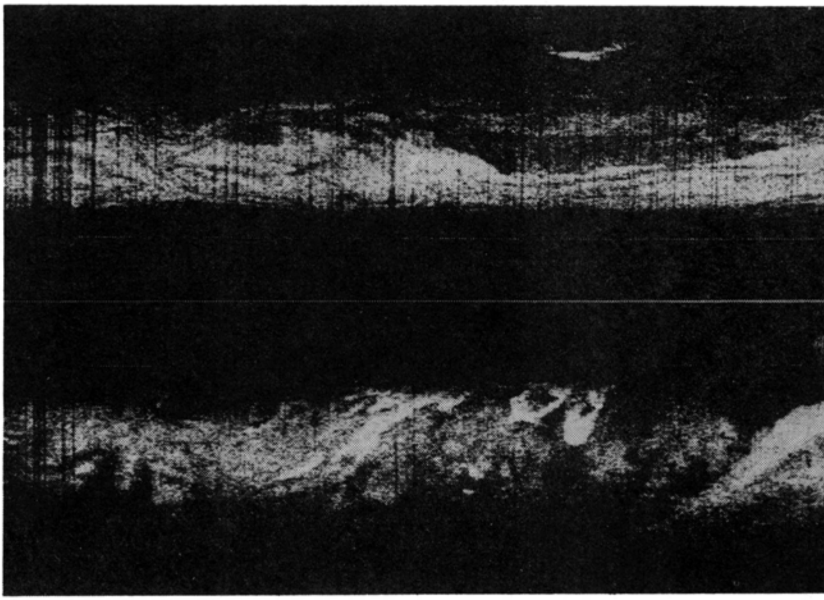

Figure 5. Single GLORIA image from the Saharan Slide study area, northwest African continental rise. Image has been photographically anamorphosed but is otherwise unprocessed. Image area is 50x60 km; ship's track runs horizontally along centre (port beam to the top). Straight lines parallel to track are bottom echoes from vertically beneath the sonar.

Intensity distortions

Even after the image has been geometrically corrected, it is usually seen that recorded intensities are greatest at mid-range (about 10 km horizontal range) and fall off at greater and lesser ranges (Figures 5, 6). This has the

effect of producing very uneven levels of illumination and contrast, which may obscure important features and also make very difficult the publication of mosaicked images. We can now correct for this effect during post-processing, and hope soon to be able to apply the corrections during data acquisition.
The intensity distortion arises from several different effects, of which the most important are the sonar beam shape (i.e. the variation in sensitivity with direction), the geometric spreading of the beam (inverse square law loss modified by any focussing or defocussing due to refraction), physical attenuation of sound in the water, and effects of changing angle of incidence. All except the first of these are monotonic variations, and a very approximate correction for them is applied during data acquisition by a hard-wired time varied gain. Even so, there is a rapid fall-off in intensity beyond 15-20 km.

The beam directivity is not at present corrected for. The beam has a null response between the main lobe and the first sidelobe, and this typically falls at a horizontal range of about 2 km. Although the first sidelobe illuminates the seafloor vertically beneath the ship, there is an effective "blind zone" on unprocessed images that is some 4-5 km wide. Post-cruise processing can materially enhance the data by reducing the width of this zone and by extending the effective outer limit of the beam.

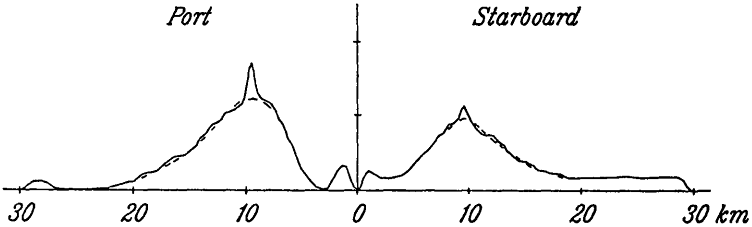

Figure 6. Observed profile of intensity in a GLORIA swath from the Madeira Abyssal Plain, eastern North Atlantic (continuous line). Ordinate is in arbitrary units. Profile produced by averaging 33 pixels along track and 17 pixels across track. Broken line shows the smoothed version used for correcting other images.

We do this by first empirically estimating the effective sonar response, i.e. the average intensity as a function of range. This can be done either by averaging a large number of line scans (the equivalent of several hours of surveying) over a variable area, or by averaging a relatively small number over a restricted area where the seafloor response is very uniform. The US Geological Survey has used the former method to correct its very variable data from a large survey off the US west coast (EEZ-SCAN Staff, 1986), while we have used the latter method over the Saharan Sediment Slide in the eastern North Atlantic (Searle & Kidd, 1984; Kidd _et al_., 1985; Figure 6).

In Figure 6 the spikes near zero range represent the first bottom echo from the seabed directly beneath the ship, and those at 10 km represent the second bottom reflection. Note that the beam pattern is rather asymmetric (owing to the use of slightly different frequencies and unmatched electronics on the two sides), and that in spite of the averaging the profiles are still not completely smooth. A final smoothing was applied by hand (broken line in Figure 6), and zero-level elements were replaced by small non-zero ones, to provide a "standard profile". The images from the Saharan Slide area were then corrected by dividing each image scan by the standard profile, to produce images with a broadly uniform level of illumination (Figure 7).

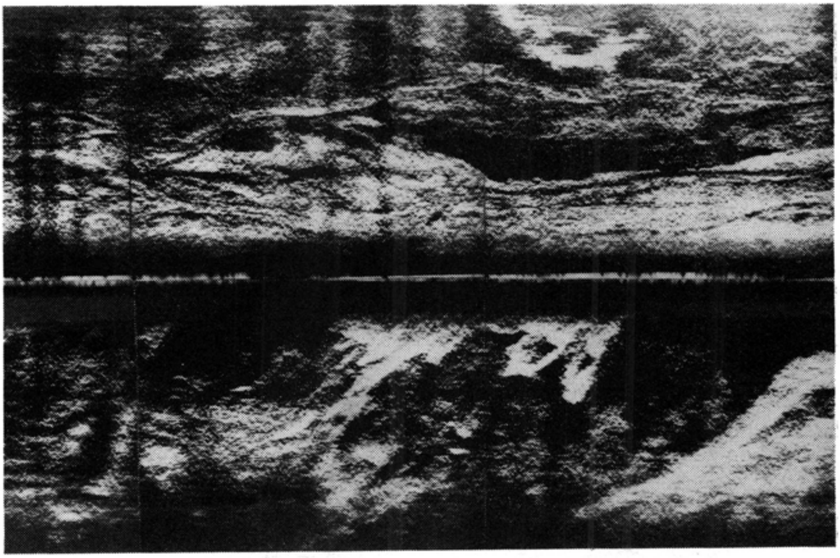

Figure 7. Processed version of image shown in Figure 5, after corrections for slant range distortion, intensity distortion and destriping.

The process also enhances low-level signals near minimum and maximum range, extending the effective minimum range from about 4 to 3 km and the maximum from 15 to 20 km.

Experience so far suggests that different versions of the standard profile are applicable to different geological terrains, probably mainly because the function relating backscattering intensity to angle of incidence is different for different lithologies. Indeed, we are almost certainly losing some of the lithological information in the images by determining the correction empirically, and we are now working on a more objective version of the standard profile.

The last intensity correction is to "de-stripe" the image, i.e. remove any line dropouts. These are recognised by comparison with the average of a number of scans on either side, and replaced by a suitable mean value.

Other processing

The processes described above are carried out on a line-by-line or image-by-image basis. However, once these corrections have been made, it is often desirable to mosaic the individual images together into a large scene. To date that is still done by hand, but we hope soon to develop routine methods for computer mosaicking.

With the advent of digital mosaics there will come the exciting possibility of combining GLORIA images with other types of data. The most useful combination is likely to be sidescan with bathymetry; this could be achieved, for example, by using hue and saturation in a colour image to represent depth, and intensity to represent the sidescan signal. It is also possible to make digitally a perspective view of the shape of the seafloor and to project the sidescan image onto it, so that one sees the image as though pasted onto a relief model. Another possibility is to generate a shaded relief map from detailed bathymetry (e.g. SEABEAM). If the appropriate direction of illumination is used, the result looks rather like a GLORIA sonograph: in fact it represents that part of the sidescan image that arises from topography alone, ignoring any lithological variations. (A good example is the Galapagos "Propagating Rift" in the eastern equatorial Pacific, imaged by GLORIA in Searle & Hey (1983, figures 4 and 5) and as a SEABEAM shaded relief map in Hey et al. (1986, plate 2)). Preliminary experiments with all of these techniques have been carried out and show considerable promise. In principal it should also be possible to subtract the topographic signal from the complete sonar one to obtain the signal due to the lithology alone, but we have not yet attempted that.

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THE EXPLOITATION OF DIGITAL DATA THROUGH ELECTRONIC DISPLAYS

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ABSTRACT

As recently as 1981 the majority of the production at the Defense Mapping Agency (DMA) was in the form of traditional paper products such as maps and charts. The emergence of sophisticated and miniaturized computers and computer processes is revolutionizing cartographic techniques at DMA such that over half of the Agency's products are now in digital form in support of computer based planning, charting, and weapons systems. DMA is in the process of building and loading a very large digital data base, with the potential to be exploited in more ways than currently defined Department of Defense applications. Objectives to be achieved are: increased productivity, standardization, quick response to user needs, cost savings, flexibility, and universal application. Optimal exploitation of the DMA digital data base, originally designed to support the output of feature data in a format suitable for lithographic reproduction, will require a reevaluation of the constraints and opportunities inherent in electronic display technology. This paper will address the potential for DMA to develop a digital data base that can indeed be exploited for universal applications on electronic displays.

BACKGROUND

A prime mission of a mapping and charting organization should be to present and to communicate its product to the user in the best way possible. In the past, and for many current products, lithographic printing was the "best way" to satisfy user requirements. The traditional format of the paper maps and charts produced by DMA reflect considerable effort by planners and cartographers to design stable products which still serve a multitude of users and uses. These products have integrated the requirements for feature selection, density, symbology, and scale for optimal portrayal of the contemporary conditions of the environment on a stable two-dimensional medium. The results of these efforts have been accurate depictions of all pertinent factors, easily interpreted by the user regardless of the purpose or use.

The need for mapping, charting, and geodetic (MC&G) products for computer-based planning, training, and weapons systems has forced DMA to change from an analog to a softcopy emphasis.

This transition from analog to digital mapmaking has progressed to where more than half of DMA's efforts are now directed towards the production of digital products, some being used directly by on-board computers of "smart" weapon systems. The cruise missile and other systems such as the Firefinder artillery-locating radar, the Pershing II terminal guidance radar, and a wide range of mission planning simulators and command and control systems all depend upon DMA digital products.

All military units, from infantry patrols to the most modern weapons systems, require products of the Defense Mapping Agency. Requirements for digital data (even from the users of traditional map and chart information) are becoming more and more sophisticated. Users will need up-to-date cartographic information without waiting weeks or months for the normal distribution process to work. Modern users will require electronic map and chart information quickly, and will also require access to the digital database for supportive cartographic information.

Techniques that could be applied for presentation of digital MC&G information on electronic displays are available today. A three-dimensional perspective scene is relatively simple to output, either to an electronic display device or to a lithographic printing process. Since most electronic displays cannot replicate the resolution of the lithographic process, an analysis of the two outputs might lead one to conclude the electronic display to be a degradation of the paper product. However, the creative potential of the Electronic Chart becomes apparent when one considers the dynamic applications available for real time interaction with the displayed data sets. Parameters of a displayed scene can be changed by means of simple inputs, and real time sensor information can be overlaid and combined with the MC&G digital data base for timely and flexible responses to user needs. Thus the EC becomes a cost effective and versatile tool capable of supporting a multitude of modern day mapping, charting, and planning requirements.

MODERNIZATION

DMA is in the midst of a complex modernization program to achieve greater productivity and to meet increasingly sophisticated digital data base requirements. DMA will have on line in the 1990's a virtually all-digital production process, developed through utilization of high-speed computers and computer data exchange systems. The rapid emergence of extremely sophisticated computer technology has been the catalyst for this revolution of cartographic techniques. Computers are being applied to all phases of the production effort, from source analysis to product generation. DMA is also developing advanced digital workstations to handle digital, graphical, and textual data. These workstations will be the foundation for DMA production in the 1990's. This all-digital production system will dramatically reduce the present labor-intensive compilation processes inherent in manual map/chart production, resulting in significant productivity increases and improved user responsiveness.

The all-digital production system will be geared towards a "product independent" digital data base to include cartographic feature data required to support all DMA paper, film, and digital products. Working at advanced digital workstations, DMA cartographers will develop the digitized data for insertion into a cartographic data base or for lithographic or digital product generation

With the modernization, DMA has begun to generate the required data base(s) to support user digital requirements. If DMA cannot, because of limited production resources, provide these digital data, users will be forced to collect their own or, in some cases, even to do without. Users who generate their own digital data, whether by customizing existing data bases or digitizing paper maps and charts, run the risk of inadvertently introducing errors into their applications. Errors in the data could lead to faulty system development and subsequently negate an entire development or deployment effort. Furthermore, data bases generated by multiple users could create a standardization nightmare for any subsequent data exchanges. Thus, it is imperative that DMA succeed in its modernization program and provide accurate, up-to-date cartographic data to its users. DMA should then consider the most effective distribution and display methodologies for digital information. Standards for both the telecommunications and the electronic portrayal of the digital data need to be addressed. Telecommunications requirements are being addressed by DMA, but are outside the scope of this paper.

ELECTRONIC CHARTING

Electronic output is a logical follow on to the development and initialization of a DMA digital data base of MC&G information. What do we mean by an Electronic Chart (EC)? The standard product would be MC&G data provided by DMA for display on a screen. This would provide the controlled base over which the user would then superimpose information from his own real-time sensors. A real time radar image superimposed over a DMA data set would considerably enhance the usefulness of the EC display. Any uncharted or misplotted features would be immediately identifiable since they would be displayed simultaneously with the DMA data.

As an example, one could use an EC display as a vehicle navigation system where automated steering and collision avoidance become practical for the real time alignment of the vehicle's position. Another example of an EC is the digital hydro chart currently operational in the Navy's PHM class Hydrofoil Ships. Coastal charts in digital form are stored in the ships' computers. They are skewed to match real-time radar returns of the coastline against the stored charts. Then when a hostile reading, such as a fast-closing ship, comes up, this data is displayed on the screen with a warning bell or whistle, and evasive maneuvers follow. There can be numerous variations of this scenario. Aircraft applications are obvious, and ground forces are moving rapidly into this area as well. A company commander in the field will continue to need DMA paper maps, but the commander back at battalion HQ will be using a computer display.

DMA must support the commanders of all armed forces with data at the same accuracy they now get with paper maps and charts. Users will need basic DMA map data on that display and will need to enhance it with real time information, possibly even in a three-dimensional format. EC users will need to be able to select instantaneously from a number of maps or charts and then, in turn, be able to zoom in rapidly on the area of concern.

EC PRODUCT REQUIREMENTS

DMA does not make an EC digital product, per se. DMA generates the Mapping, Charting, and Geodesy (MC&G) data that provides the metricity to support the interaction with user on-board real-time sensor imagery.

The U.S. Army, the Air Force, and the Navy are independently developing a number of electronic display systems to support planning and tactical operations. These are in response to individual service requirements and will all require DMA to provide the digital MC&G data necessary to drive them. For example:

> The U.S. Army has developed the Digital Topographic Support System (DTSS) to support Corps, Division, and above planning and operations. DMA digital data base requirements include a 1:50,000 scale product, including terrain analysis overlay data, to support operational areas and a 1:12,500 product to support testing, training, and development areas. Other systems include an All Source Analysis System (ASAS) for intelligence fusion, a Battlefield Management System (BMS), and a Night Navigation Topological System for helicopter navigation support.

Air Force developments include the Automated Mission Planning System (AMPS) to support pre-mission planning on a simulator and to provide on-board threat navigation support, the B1B simulator, and the optical disk store for the AV-8B Harrier aircraft.

The Navy has implemented a Hydrofoil Collision and Tracking System (HYCATS) on its PHM class hydrofoil patrol vessels. Displayed are ships position and threats overlaying DMA-provided coastal and harbor data. Other systems requiring medium scale DMA digital sources (bathymetric, shorelines, threats, etc.) for input are the Submarine Advanced Combat System (SUBACS) and the Aegis system. Aegis is projected to be operational in 1987 and will provide a 42-inch screen for the real time display of task grouping, shorelines, and hazards, and will support anti-aircraft defense.

Each service requirement will have to be fully understood by DMA cartographers in order to generate a useful digital product for maximum exploitation on each proposed display device.

DESIGN GOALS

An ideal goal in the design of EC products to support these developing service requirements is that the systems they are displayed on be user friendly and responsive to the requirements for which they were developed. Operations controls must be easily learned, the hardware ruggedized for stand alone field operations, and the system hardware and software be easily maintained. DMA input into the EC product would be standardized MC&G digital data sets capable of being transformed into highly readable and understandable displays. The success of any EC program development will only be as successful as DMA's capability to provide the data to drive it. The success of the total EC program requirement will be driven by the success of the standardization effort. Unless DMA can generate a standard for universal use, the cost of production and the subsequent transformation of the data sets to support specific user requirements could become prohibitive.

Generic display components of EC systems must be standardized as much as possible to reduce production, maintenance, and training costs. Display hardware design and content must strive for graphic simplicity. Complex displays can be erroneously interpreted and used by human operators. This could negate the effectiveness of the product design. The EC should also operate with minimal operator intervention. Hardware and software parameters should be designed to display current situations unless expressly overridden by the operator. A display where the vehicle position remains centered on the screen would be a useful format, since it offers the maximum view of the surroundings. This would also allow the user to maintain some of the perspective currently designed into the DMA paper products.

MC&G DATA SETS TO SUPPORT ELECTRONIC CHARTS

The basic coding dimensions for symbolic representations in a static mapping format are shape, color, and size. Symbols in a dynamic mapping environment can exploit color and be caused to blink, fade, highlight, vibrate, etc. Blinking, for instance, can be exploited in electronic charting applications when an object is of target interest or when an occurrence will cause a change in a real-time display.

In support of new and upcoming navigation and guidance display systems, DMA must be able to provide adequate digital data bases that describe a variety of types of MC&G information. In addition to the basic requirements for traditional MC&G feature data at an increased resolution and level of detail, there will be requirements for time-varying information such as texture, thermal, and near-infrared properties; population and traffic density patterns; atmospheric weather data; etc. All attributes will be required in DMA Feature Analysis Coding Standard (FACS) feature descriptors. Data from these various sources must be fused in the EC display so that information can be quickly assimilated and reduced to meaningful conclusions in command and tactical situations.

For an EC to be effective, the digital data requirements necessary to drive the product need to be identified and validated prior to actual system development. Digital data production can then keep pace with system development for implementation of an operational product. The digital MC&G data set required to support the proper portrayal of the data on an electronic chart display would include:

Feature types and attributes (FACS coding) to adequately represent the required environment.

Symbology to assure feature types and conditions displayed will have universal interpretation to all users.

Data density sufficient for the optimal representation of the product requirements.

Scale to realistically portray the essential information.

The most important aspect for successful implementation of an electronic chart concept is standardization. This means adopting a standard for symbology, feature contents, density, scale of display, resolution of display, etc., and, most importantly, a means to ensure that any developed standard can be universally implemented.

Variable resolution requirements could make the EC product a challenge to derive from standard data bases. If the data base is indeed product independent, data captured at a single scale, not coincident with the EC product, would require the application of either generalization or enhancement refinements. DMA currently produces products that could require both applications, e.g, for navigation scales (Harbor and Approach Charts) that could have extremes of scale above and below the data base scale. Developers, as well as users, must be aware of the danger of using digital data at a larger scale than that at which it was collected and validated for insertion into the data base. To do so would imply a greater level of accuracy to the data, which could lead to disaster if accuracy is a critical requirement. How to insure that this will not occur is a critical issue to be worked.

EC PORTRAYAL

Electronic charting has the potential to provide new approaches to mapping problems that have been virtually unsolvable on hardcopy media. An example is the problem of representing superimposed surfaces (i.e., sea surface, ocean bottom, and objects in the intervening space) on the mapping medium. Another example could be the concurrent and detailed depiction of air space, flight corridors, and terrain.

Electronic charts should resemble paper maps and charts with minimum feature density. This traditional appearance would facilitate acceptance of the EC by the user and make it easier to use. To insure that all EC systems receive the same basic information for portrayal, it is essential that the digital data be derived from the same data source using standard algorithms whenever possible.

Electronic maps will allow for flexible viewing. Perspective views of terrain can be extremely useful in terrain visualization where viewpoint is critical. Interaction with perspective views will allow users to specify altitude, azimuth, and distance, as well as to zoom, pan, and rotate.

Animation of the data can provide a way to show predicted or real-time changes in the geographic area of interest.

The display should permit the user to tailor the screen contents to his liking by means of scale change, zoom and pan, deselection, etc. Moving map capabilities would allow users to travel within a mapped area, zooming in for large scale information and zooming out for a birds-eye view, to support cross-country and trafficing requirements.

The results of 3-D perspective models, predictive models, and quantitative calculations performed by the computer can be displayed on electronic charts. Based on terrain analysis information, an overland route for an army tank can be generated and displayed in real time. The display would minimize trafficability risks (off road soil conditions, tree diameters, water barriers, etc.) and exploit other factors (navigable roads, etc.) subject to the constraints of the parameters of the tank. Time, distance, and most importantly, a wealth of stored geographic information too complex for adequate display in two dimensions, can be factored into the computations for the real time display.

Reference grids can be useful additions to displays. Electronic charts can generate virtually any kind of grid overlay to enhance the usability of the displayed data.

We must remember that the effects of an EC product may not all be positive. It may be one thing to have a 1;20,000 scale paper chart and quite another to permit only the display of a 5-inch sized CRT section of that chart at any given time. As an example, Harbor and Approach Chart scales are selected in such a manner as to provide maximum aid to navigation. The CRT-displayed portion would eliminate a vital aspect (total picture) of the chart, and a selectable scale capability would only partially solve this problem.

Data resolution can also vary within the digital EC product. This can cause scaling difficulties if a vehicle, such as a ship or tank, moves into a product area digitized at a different scale. Whether moving from a large scale to a small-scale area, or from a small-scale to a large-scale area, scale selection is difficult. Multi-scale presentations can cause feature distortion (jagged or sparse depending on the scale), and the display of data at a higher resolution (than digitized) implies positional and contextual accuracies that cannot be supported by the data. Windows within displays, side-by-side displays, and superimposition are potential remedies to these problems.

DISPLAY TECHNOLOGIES

The applications described above will depend upon available display system technologies. DMA is currently committed to CRT technology for internal softcopy exploitation of its digital data bases. Note, however, the user potential for 1990's EC utilization of other flat panel devices. The two technologies emerging as the leaders are liquid crystals and electro-luminescence.

Liquid Crystal Displays (LCD) are the most mature of the flat panel technologies. Because of their poor contrast and viewability, however, LCDs have made few inroads into large-screen applications. These afflictions should largely disappear with the advent of new techniques for activating the display. Reductions in cost will hopefully come with large-volume production (as in the case of the personal computer market driving the development of the optical disk).

The electroluminescent (EL) panel is also becoming competitive in the market place. With its pleasing amber radiance, light weight, and slender profile, EL displays have already made their debut in the personal computer market. ELs are active, emitting their own light so they can be viewed under almost any lighting conditions. ELs also have higher contrast, better resolution, and much wider viewing angles than LCDs. The panels' ruggedness, low power consumption (relative to CRTs), light weight, and good viewability are drivers for military (army and avionics) interest in this technology. Advancements expected include the advent of full color, new high-contrast designs that will make the displays readable even in sunlight, and advanced driver electronics that make panels more compact and energy-efficient.

Future growth of large-area flat panels will probably depend on a reciprocal relationship with portable computers. Advances in display technology should improve the appearance of portables, while any increase in portable sales would accelerate demand for displays.

SUMMARY

Display technologies and database capabilities are now mature enough to support producing electronic charts. The ultimate success of an EC will depend upon proper identification and validation of product digital data requirements prior to actual system development. This will allow DMA product support to pace system development.

Another important aspect for successful implementation of the electronic chart concept is standardization. Standards will ensure and preserve the critical significance of DMA supplied data. Digital data in a universally accepted standard format will provide DMA the capability for greater flexibility and increased responsiveness in support of user requirements.

Softcopy display design for an EC product is highly dependent upon the capabilities of the output device. Resolution constrains symbology and textual display designs. Electronic charting, however, expands the possibilities for symbolization and display manipulation through the dynamics of CRT technology. The capability for exploitation of a digital data base in conjunction with these dynamic displays will allow customized presentations geared directly to user needs for optimal user satisfaction. The user will be able to use DMA digital data in an EC of his own making. Note, however, that the dynamic capability for interacting with and changing the display contents can also pose dangers to users with non-cartographic backgrounds since inadvertent user manipulation and deselection of specific data (sets) could contaminate the user perspective designed into the total EC product and subsequently promote erroneous interpretation of the data.

Finally, a critical component in support of new planning, navigation, and guidance systems is the ability for DMA to actually provide adequate digital databases containing the required MC&G information optimized for electronic displays. Ultra-high resolution databases will be required in the 1990s with additional feature descriptors and resolutions. Current production resources at DMA limit high-resolution data to small geographic areas of interest. The required production of large area, high-resolution databases will be unattainable without both adequate source data and enhanced automated feature extraction techniques. The success of electronic charting applications of DMA MC&G data will only be as successful as our capability to load and maintain the digital data.

DMA is addressing the tremendous problem of automating digital data and chart production processes in the modernization program. More and more users will be demanding more and more sophisticated digital data, and ECs could allow DMA a means to exploit new approaches to satisfying those user requirements in the 1990s.

EFFECTIVE PROVISION OF NAVIGATION ASSISTANCE TO DRIVERS: A COGNITIVE SCIENCE APPROACH

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ABSTRACT

On-board computer-assisted navigation aid for drivers is an area of considerable research interest. Information on how humans learn spatial relations and how they communicate those relations to others should form the basis for such navigation aids. For example, both theoretical and empirical evidence from cognitive science suggests verbal (procedural) navigation advice may be more effective than a map (graphic output) displayed inside the vehicle. Probable reasons for this are discussed. Central issues related to navigation assistance for drivers are reviewed, and important directions for future research are suggested.

INTRODUCTION

Spatial navigation is one of the most basic abilities and essential survival skills of humans and most other animals. Human society often requires navigation in unfamiliar areas, and thus places strong emphasis on ability to give and receive directions for travel. Since spatial behaviour is such a central concern of geography, and spatial learning has been an area of geographic research, it is surprising that geographers and cartographers have devoted relatively little time to the study of the **communication** of spatial information which is embodied in formal and informal direction-giving, direction-receiving, and route-following.

In contrast, cognitive science has shown considerable concern with how people know and learn about geographic space; in fact, spatial learning is an important theme within cognitive science. Papers from the cognitive science literature by Kuipers (1978, 1983a, 1983b) on modelling spatial knowledge and learning, and by Riesbeck (1980) on judging the clarity of directions reveal important elements of the navigation process and supply a theoretical basis from which to proceed.

Recent activity in the study of human navigation has been sparked by technological innovation. Navigation aid systems for private automobiles are an area of commercial and academic interest, as indicated by a session at the recent Seventh International Symposium on Automated Cartography (Cooke, 1985; Streeter, 1985; White, 1985) and by various articles in the popular press. Such systems might be of particular interest in rental cars, and similar systems might prove valuable for taxicabs, delivery trucks, and emergency vehicles. On-board computer-assisted vehicle navigation aids for drivers are now available at moderate prices, and such technology will certainly become less expensive. Yet, several crucial questions remain about the content and form of the information they should provide.

We contend that information on how humans learn spatial relations, and how they communicate those relations to others, should form the basis for automated navigation aids for drivers. We therefore begin by reviewing in some detail a powerful model for cognitive representation of spatial knowledge, and by discussing some experiments which relate to the performance spatial navigation tasks. Then, we expose a number of issues relating to computer systems for the presentation of navigation information. Finally, we conclude by outlining what we feel are the major gaps in our knowledge of spatial learning and cartography, gaps which inhibit the design of systems and which provide many research opportunities for geographers and cartographers.

THEORETICAL BASIS: COGNITIVE SCIENCE AND SPATIAL KNOWLEDGE

Kuipers' Model of Spatial Learning

Benjamin Kuipers has developed a powerful computational theory for spatial knowledge. In particular, Kuipers' theory is concerned with the processes by which one learns about large-scale (geographic) space: "space whose structure cannot be perceived from a single vantage point, and which is learned by integrating local observations gathered over time" (Kuipers, 1983b, p. 1). This theory (implemented as a LISP program) was introduced as the TOUR model (Kuipers, 1978), and refined and expanded in a series of other papers. Kuipers' model accounts for a variety of states of partial knowledge in spatial learning, and Kuipers has claimed that "design alternatives **do not exist** at the level of the gross structure of the cognitive map" (Kuipers, 1983a, p. 358). Kuipers' model thus forms an appropriate theoretical basis for studies of the **communication** of spatial information for navigation and other purposes.

Kuipers' model organizes spatial information into three major categories:

> "**Sensorimotor Procedures:** Knowledge of a set of actions, and their sequence, required to travel from one place to another.
>
> **Topological Relations:** Knowledge of non-metrical properties of the external environment, such as containment, connectivity, and order.
>
> **Metrical Relations:** Knowledge of, and the ability to manipulate, magnitudes such as distance, direction, and relative position." (Kuipers, 1983b, p. 1).

For convenience, we will refer to these as **procedural, topological,** and **metrical** knowledge, respectively.

Procedural knowledge is based on two types of objects, **views** and **actions.** The term **view** is used to refer to the set of sensory inputs available at a particular place and orientation; the nature of a view allows one to determine whether or not two views are the same. An **action** is a motor operation that changes the current view (for example, a move or a turn). As one travels through large-scale space, one 'sees' a series of these views; some of these views are associated with actions such as turns from one street to the other. Procedural knowledge can be acquired by storing (i.e., learning) associative links of two types:

> "The link (V->A) has the meaning that when the view is V, the current action should be A.
>
> The link (V A)->V' has the meaning that if the action A is taken in the context of view V, the result will be view V'" (Kuipers, 1983b, p. 2).

A **route** consists simply of a series of (V->A) pairs. **Learning** such a route would consist of tranferring (V->A) pairs from short-term to long-term memory; such a route provides a **procedure** for getting from one place to another. It is possible to follow a route given only such an unordered collection of (V->A) pairs--following an action, the environment provides the next view, triggering the next action, et cetera. However, if links of the second type, namely (V A)->V', are stored as well, the person can 'replay' the trip in his/her mind, or explain it to someone else. As Kuipers (1983b, p. 1) has pointed out, storage of only (V->A) links would result in the not uncommon situation: "I can't tell you how to get there, but I can show you."

Kuipers proposes that many people assimilate information from procedural knowledge of routes and use this to build **topological knowledge** of large-scale space. At this level, a **place** is identified as the cycle of views after repeated turns at a point. Places may be common to more than one route. A **path** is a sequence of places, and often corresponds with a route. However, a path would not be a route if it has never been travelled in the real world, but only inferred from other experiences. Furthermore, places and paths are fixed features in the real world, whereas views and actions are sensorimotor experiences, and routes are procedures for navigation (Kuipers, 1983a, p. 356).

Paths are seen to **connect** places, and to **divide** space into **regions**. People with spatial knowledge at a topological level will usually know on which side of a major street (path) some known place lies, and will be able to plan new routes between places. However, the orientations of paths may be distorted, and places are not fitted into an over-all coordinate system. Sketch maps produced by people with this level of knowledge may have strong distortions, but often will be useful and fully functional for spatial navigation. Also, regions at one level of abstraction may be equivalent to places at another level.

Some individuals acquire spatial knowledge at the metrical level, wherein that knowledge is placed into the framework of a cartesian coordinate system. People with metrical spatial knowledge can point in the same direction that would be straight out their front door at home, and can provide estimated distances between places. Although not so stated by Kuipers, we feel that access to graphic, metrically-correct, maps almost certainly plays a key role in the learning of spatial information at this level.

Kuipers' Model and Spatial Navigation

We claim that it is useful to classify various forms of spatial information for navigation according to the three categories of spatial knowledge proposed by Kuipers. Verbal directions for getting from one place to another, presented in words either spoken or printed, represent information at a procedural level. Sketch maps with distortions (deliberate or other) represent a topological level of spatial information. Road maps and other planimetrically-correct maps represent a metrical level of information.

Clearly, procedural information (at least the next (V->A) pair) **must** be available in short-term memory in the brain of the traveller in order to allow the traveller to get from one place to another. If navigation information is provided at **any** level other than procedural (e.g., a map on paper or on a CRT), then one must do work to determine the relevant procedural instructions. This takes time and effort, may distract from other tasks, and may be subject to error.

Graphic Maps or Verbal Directions?

Interpreted this way, Kuipers' model accounts for the results of research by Streeter et al. (in press). Their study indicated that drivers may navigate more effectively when given verbal (vocal) directions, rather than a graphic map. Streeter and her co-workers compared four methods for receiving navigation during automobile driving. These methods are: (1) Standard road maps; (2) customized road maps (north at top); (3) verbal instructions from tape recorder; and (4) a combination of methods (2) and (3).

Performance of test subjects was evaluated in terms of travel time, number of errors, and other measures. They found, not surprisingly, that method (1) (the 'control' condition) produced the poorest performance. However, the best performance was observed when the subjects had only the tape recorder to guide them. (This method involved a customized tape recorder with two buttons: one to repeat the last instruction, and the other to play the next one.) Significantly, the 'customized map' group (method 2) had the second-worst performance level. It also seems that providing the subjects with maps in addition to the tape recorders (method 4) detracted from performance given the tape recorder only. Perhaps the map constituted a distraction, reducing the ability of the subject to concentrate on the tape; alternatively, by providing a means to recover from errors, it may have reduced the perceived **need** to concentrate on the tape.

The main result of Streeter's experiment appears to confirm the implication we have drawn form Kuipers' model, namely that provision of navigation information at the procedural level should be easier to assimilate than would be graphic topological or metrical information.

NAVIGATION AIDS FOR DRIVERS: KEY ISSUES

In this section, we present a number of issues related to the provision of navigation aids to drivers. Many of these issues lead to two or more alternatives. An ideal system might provide all of these alternatives, as user-specific options selected either explictly or through a series of computer-administered questions or tests. However, provision of such a wide range of options would probably make a system unduly cumbersome. Furthermore, users may not fully understand the differences among choices presented, and may be intimidated by a system which presents too many 'complicated' choices.

Form of presentation

Perhaps the most fundamental issue in computerized navigation aids for drivers involves the mode of presentation: should the information be presented in graphic form (as a map), or in verbal form (as procedural directions)? Both theory (Kuipers) and empirical evidence (Streeter et al.) suggest that verbal directions may be more effective than maps, but anecdotal evidence suggests that some users would not want to 'trust' a computer to give them directions. (They would, however, trust a map drawn by the same computer!) Furthermore, a system to provide verbal directions **must** include an algorithm for route selection, raising several new issues.

Finally, in a post-travel survey of 27 people provided with both verbal directions and a map to a novel destination, 7 preferred the verbal directions, 10 preferred the map provided, 2 rated them as equal, and 8 did not use either (Mark and McGranaghan, in prep.). This small sample suggests that there is no strong consensus of preference on this issue. Streeter and Vitello (in press) found that "self-described good navigators like and use maps... whereas poor naviagtors tend not to use maps [and] prefer verbal directions" (Streeter and Vitello, in press, ms. p. 1).

Graphic Design

If the data are to be presented graphically, then one is faced with all the usual issues of map design, under the constraints of the display technology and intended use. One point of interest is the orientation of the map. Should the map be presented with north at the top (north-up mode), or with the direction of travel at the top (heading-up mode)? Informal surveys suggest that people may prefer a north-up presentation most of the time, but a heading-up presentation for complicated situations.

The use of CRTs for on-board map presentation raises the issue of optimal colour and illuminance contrast among map symbols. Recent research on choropleth map perception (McGranaghan, 1985b) suggests that such maps should be presented on a light background. Does this effect apply to line symbols employed in road maps? The issue must be addressed within the context of changing ambient illumination in the driver's compartment.

Route Selection

As noted above, the computer must perform route selection in order to provide verbal directions between arbitrary origins and destinations. Route selection advice could also be a useful component of a graphic presentation of navigation information. Finding 'any' route to a goal (destination) would seldom be adequate, and so the route search procedure must either find an optimal (shortest) route, or at least find an adequate heuristic approximation to the optimal. Choice of an appropriate state-space search algorithm is one issue in such a system.

Another issue is the cost function which the search algorithm attempts to minimize. Naively, one might simply find the shortest path, minimizing the total metric length of the path. However, shortest paths often are difficult to navigate along. Elliott and Lesk (1982) have suggested algorithms which attempt to find minimum effort paths; to accomplish this, they include in the cost function heuristic differential costs of, for example, left- and right-turns. Alternatively, Mark (1985) proposed that 'ease of description' is a useful heuristic component of route cost. His approach minimizes the weighted sum of the metric path length and the length (number of elements) of the verbal description of the path.

Positioning issues

Whereas paper road maps do not provide drivers with absolute position information (a 'you-are-here' symbol), it seems obvious that this would be useful in a computer mapping system. A 'you-are-here' symbol could move about on the computer map, or could remain at the center of the map frame, with the map window moving accordingly. Such a system could determine absolute positions through the use of Loran or of a navigation satellite (signal-dependent positioning); current civilian Loran and satellite technology, however, do not provide sufficient accuracy at present for such an application. Alternatively, the navigation system could be based on 'dead reckoning', sensing headings and distance travelled (autonomous positioning); given an initial location and heading, the computer could keep track of the current position, correcting it through the relation of turning points to road intersections in the data base. Of course, position at the start of the trip is essential for verbal (procedural) route description. If the system kept track of position during the trip, it could detect errors and provide directions to correct them.

Data issues

The total quantity of data needed to support a navigation-aid system is very large; for example, the road network of the San Francisco Bay area requires between 7 and 10 megabytes of data storage space (Zavoli et al., 1985). Both data-structuring and data location are significant issues. It may in fact be possible to incorporate spatial concepts, based on cognitive models, into the design of data-structures themselves (McGranaghan, 1985a).

Two distinct data location strategies are available: in one, all data are kept in the vehicle (on-board data-base); in the other, data are transmitted to the vehicle as needed (broadcast data-base). The on-board strategy has the advantage of independence. Furthermore, it avoids an additional data link in the system, another place for error.

On-board data storage raises the issues of the storage medium and the data structure. White (personal communication to M. Gould, 1986) states that cassette tapes represent the only currently-available storage medium which meets the requirements of on-board systems. However, this may soon change, as Schipper (1984) describes a system based on Compact Disc (CD-ROM) technology. The CD-ROM would seem to have many advantages. For one, optical disks support random-access data retrieval, whereas a cassette tape provides only sequential access. Secondly, a cassette can store about 3.5 megabytes of information, and thus 3 cassettes are needed to store the aforementioned San Francisco Bay area data set (Zavoli et al., 1985); in contrast, the data capacity of a CD-ROM is about 500 megabytes (Chen, 1986). In addition, CDs are not subject to damage by water or magnetic fields, have no moving parts, and do not wear out with repeated access (Chen, 1986).

Although on-board data systems might be more stable than broadcast systems, the latter do offer one notable advantage: such systems can be constantly updated, and can provide data on ephemeral features such as construction hazards or even accident locations and traffic jams. Of course, a hybrid system could use on-board data for a base map and broadcast data for time-dependent information.

Use of Maps During Trip Planning, Rather Than During Travel
Mark and McGranaghan (in prep.) found that, of 29 subjects travelling to a novel destination near an area familiar to them, 18 consulted navigation aids during trip planning, whereas only 9 used them during the trip itself. This effect may be even more pronounced for unfamiliar areas. When people travel to a new or unfamiliar city and then drive around (in either their own car or in a rented car), the need for some form of navigation aid becomes much greater. Mark and McGranaghan (in prep.) found that 42 of 48 subjects (87%) "always" attempt to obtain a map of a new city when travelling, and that 31 subjects (65%) try to obtain such a map **before** they travel. Evidently, travellers represent important consumers of navigation information.

Specific Needs of Different User-groups
Yet another set of issues relates to the different needs of different types of users. For private cars, system use might be similar to map use. Many drivers use road maps in their home areas, largely when outside their neighbourhoods. A survey of 54 drivers found that 33 of them (61%) keep one or more local road maps in their cars (Mark and McGranaghan, in prep.). However, consultation of either maps or a digital system might be expected to be infrequent for drivers in their home areas.

Emergency vehicles, delivery vehicles, and taxicabs represent another class of potential users. Whereas drivers of these vehicles typically would learn their areas quickly, and thus have little need for autonomous on-board systems, broadcast traffic- and road-condition data could be very useful for these users. Also, algorithms to determine destination sequences and perhaps route details would be helpful for variable, multi-destination delivery situations.

RESEARCH NEEDS AND FUTURE DIRECTIONS

Kuipers' model of spatial learning, and its apparent confirmation in Streeter and others' study of 57 subjects, suggests that the use of a graphic (map) presentation in existing driver navigation aid systems may be premature. However, more research will be needed before one can recommend to industry the adoption of a verbal-procedural basis for such systems. Furthermore, the relative importance of the 'verbal-vs.-spatial' and 'aural-vs.-visual' differences between Streeter and others' maps and tape recorded instructions must be explored. It is quite possible that both differences are important. When the navigation aid is a graphic map, the actions to be taken (procedures) must be derived (extracted) from the map by the user, even if the route to be taken is shown distinctly; thus, procedural directions may be easier to follow simply because the driver is not required to do as much work. Secondly, the use of the aural sensory input channel may be less distracting from the predominantly visual tasks involved in actually driving the car. Thus, experiments which compare aural verbal instructions with verbal directions given on a printed script or a CRT or LED screen should also be performed.

ACKNOWLEDGEMENTS

We wish to thank Michael Gould for his comments on an earlier draft of this paper.

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CANADA'S ELECTRONIC ATLAS

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ABSTRACT

The availability of display systems with high quality graphics and powerful processors capable of efficiently handling large amounts of data has made feasible the development of interactive electronic mapping systems. This presentation will report on the Electronic Atlas of Canada, a microcosm of a National Atlas Information System that is being developed to support the National Atlas of Canada program in the Geographical Services Division, Surveys and Mapping Branch, Department of Energy, Mines and Resources. The Electronic Atlas is a user-oriented geographical information system, that permits on-line retrieval and analysis of information which is stored in a database. Selected information can be displayed according to user specifications or it can be analyzed using a variety of quantitative methods that have been incorporated into the Electronic Atlas system. The system is capable of performing a variety of cartographic and analytical functions, such as user-controlled generalization, animations or simple simulations of predicted distributions of time-dependent geographical phenomena. The Electronic Atlas system's design has been based on an open architecture concept, which allows the possibility of incorporating new developments in technology and of continuously augmenting its overall capability. The structuring of the database is data-dependent as opposed to function-dependent; i.e. the organization of the database is primarily influenced by the inherent characteristics of the data, which increase the longevity of the system. This paper will discuss the approach taken in the development of the Electronic Atlas system and will describe major functions that have been already implemented in the system and those that are being considered for implementation in the near future.

INTRODUCTION

The Geographical Services Division, Surveys and Mapping Branch, Department of Energy, Mines and Resources is investigating how evolving computer technologies could facilitate the National Atlas program. An important step in this direction is the development of an Electronic Atlas. The Electronic Atlas is an experimental computer system with an interactive raster graphics display. It is being developed in order to increase flexibility in the manipulation, analysis and creative use of National Atlas information. The Electronic Atlas will form a part of a National Atlas Information system, which is being established in the Geographical Services Division.

A schematic representation of the major components of the National Atlas Information System and their interrelationships is presented in Figure 1 (McGuire, 1986). The central component is the database. It will be established and maintained by geographical research and cartographic sections. The majority of information in the National Atlas is based on data collected by other departments. Thus, national standards for the exchange of information with other government and private agencies will be developed. The Database will be kept up to date through a revision cycle that is appropriate to a given information type. A user liaison program will be established that will contribute to the establishment of priorities for the development of data sets, system functions and revision cycles. The National Atlas Information System will permit an integrated approach to data management and will optimise the provision of up-to-date geographical information at the national level.

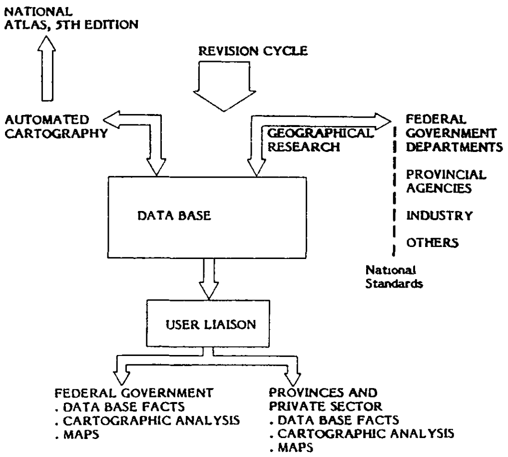

Fig. 1 National Atlas Information System

In order to examine issues relating to the implementation of the system described above, a prototype Electronic Atlas System has been developed (Siekierska, 1983). This paper provides a brief description of the current functional capabilities and the organization of the Electronic Atlas database.

CURRENT FUNCTIONS OF THE ELECTRONIC ATLAS SYSTEM

The Electronic Atlas functions can be subdivided into two major types; namely, cartographic and analytical. Cartographic functions are used for the creation of maps and for the display of information. Analytical functions are used for the analysis and the interpretation of information.

Examples of cartographic design functions are:

- **Design of thematic overlays**

  This function permits the user to specify the display criteria for a given subject. It allows the selection of symbols and the specification of generalization rules. Moreover, it permits the selection of attributes for thematic data analysis, and specifies the level of measurement for such analysis.

- **Structuring of maps**

  This function permits the user to select the information stored in the system database in order to combine it to create customized maps. This function also assigns visual priorities to the display of information and specifies the number of colours that can be utilized for an individual overlay or for a set of overlays.

- **Manipulation of colours**

  The Electronic Atlas provides several capabilities for assigning colours to particular map elements. Colour manipulation can be static, which means that individual colours may be selected, or it can be dynamic, meaning that the user selects initial and ending colours of a given scale, and all intermediate colours are calculated automatically by the system. Manipulation of colours in the Electronic Atlas also allows for the use of special effects such as animation or blinking of selected features on the screen.

- **Generalization**

The National Atlas maps are published in a number of different scales ranging from 1:2 million to 1:30 million, the main scale being 1:7.5 million. Therefore, generalization is an important function of the Electronic Atlas. In conventional cartography, generalization is usually associated with the scale reduction process. In electronic mapping generalization is a reversible process, meaning that one can also obtain the effect of "degeneralization". In the process of degeneralization, when enlarging selected portions of a map, one can display additional details that were visually suppressed at the smaller scales, but that exist in the database. In the Electronic Atlas, generalization functions are based on the cartographic theory of visual threshold generalization (Ratajski, 1973). This theory advocates the conversion of symbol types whenever a visibility threshold has been reached. For example, the system automatically converts area symbols into point symbols when during the scale reduction process, an area becomes too small for acceptable legibility. In the Electronic Atlas, such conversions can be based on the spatial characteristics of features, as well as on their thematic values. In both cases, the size of threshold values is controlled by the user.

Examples of analytical functions are:

- **Database query**

This function permits the display of attributes, that is the numerical or textual data associated with each map element. Such queries can be either graphical or numerical. Users can graphically select, on the electronic display, a map element about which they wish more information. In the numerical query function, the user selects the range of values and the system searches for elements that satisfy the selected criteria. The Electronic Atlas also permits progressive searches. This means that a set of map elements can be queried repetitively and all elements found in consecutive searches can be highlighted in distinct colours.

- **Selection of class intervals**

Thematic values associated with the map elements can be grouped into classes and displayed by unique colours. There are several methods implemented for selection of class intervals. Class interval values can be specified during the stage of overlay creation in the design of the thematic overlay function, or they can be selected interactively on the display monitor. To facilitate interactive selection of class intervals, the system calculates the basic statistics from the data such as means, standard deviations, quartiles or frequency distribution histograms.

- **Simulation modelling**

Besides delivering information that has been entered into the database, the Electronic Atlas system allows the derivation of additional information with calculations using values already existing in the system. Such capability permits the generation of hypothetical occurrences; for example, to mapping the depletion of natural resources or predicting population growth. The Electronic Atlas allows two types of simulations. One involves historical reconstruction, for example, the territorial expansion of Canada. The other permits the "prediction" of the future evolution of certain processes, for example, the depletion of natural resources.

As well as the functions described above, there exists in the Electronic Atlas a range of additional functions that facilitate the positional and thematical data entry, the updating of information, or design of graphic display. Some examples are scrolling of the map-viewing area, creation of map insets, or positioning of text. Further, the Electronic Atlas incorporates most of the functions typically found in Geographic Information Systems. To these belong graphic and numerical derivations of intersections and unions of information that reside in different map overlays, the calculation of areas and distances, and the calculation of basic statistics. All of these functions are implemented for use by non-computer experts.

FUNCTIONS CONSIDERED FOR FUTURE IMPLEMENTATION

To enhance present Electronic Atlas capabilities, several research and development projects have been initiated to explore new functions and analytical capabilities in order to increase the utility of the database for decision-making in both the public and private sectors. The areas currently under investigation are topological queries, elastic space modelling and a cartographic expert system.

These software modules are being developed either in-house or in cooperation with the private sector, other government departments and universities.

- **Topological queries**

Unlike the attribute queries, that involve searches using thematic information, topological queries are based on the spatial or geometric properties of geographical or cartographic data. Here, the spatial relationship of the object in space plays a predominant role. The main interest is to find the objects that are in neighbouring relationships. Such objects can be directly adjacent to each other (i.e., share common boundary points) or they can be indirectly related spatially (i.e., be in the vicinity of each other).

Currently the Electronic Atlas system development team carries out the implementation of all basic topological queries such as features near a point, near a line, near a polygon, within a polygon, and adjacent to a polygon. Further, it will also include more advanced conditional queries where the specified command can be overwritten by spatial constraints (for example, find all cities that are within a certain distance from a river, excluding those which are located in forested areas). Such functions are being implemented using computational geometry and raster mode processing methods.

- **Elastic space**

Elastic space is one of the geographic data modelling facilities that is currently under development for the Electronic Atlas, in cooperation with the University of Alberta. The concept of elastic space expands the traditional geographical space based on geodetic distances. It includes other units of measurement based on socio-economic indicators, such as cost, distance, travel time or volume of flow.

The elastic space simulation program accomplishes two tasks. Firstly, given an initial distance between points and a set of indicators, the program finds the distance function that best fits the non-spatial distance. The calculations of such distances are based on the Minkowski's space distance formula (Muller, 1984). Secondly, it displays the modified point locations and a legend showing a locus with isolines according to the calculated distance function.

This simulation can be used to evaluate the influence of non-spatial parameters, e.g. travel time on the development of related geographical phenomena.

- **Cartographic Expert System**

Cartographic expert systems aim at capturing certain aspects of cartographic expertise, usually acquired through education and experience. In the Electronic Atlas System the cartographic expert system module will be based on the set of rules to be used as a guidance in map creation, design and display.

A Cartographic Expert System currently under development, in cooperation with the University of Alberta, is designed to make decisions in the design of electronic maps. For example, given a set of map purposes from the user, it will identify the optimum cartographic specifications (such as scale, projection and symbology) for map construction. This is made possible through the production rules built into the system.

In addition to software development projects, other commercially available packages are being evaluated in order to assess their applicability to the Electronic Atlas system.

ELECTRONIC ATLAS DATABASE DESIGN

The Electronic Atlas database has been specially designed to handle cartographic data. Digital cartographic data have three aspects. One is the spatial position of objects in geographical space. In the Electronic Atlas these are represented by positional files. The second is the thematic values associated with each geographical object. In digital cartography these are usually referred to as attribute files. The third aspect is the cartographic representation file, which consists of sets of symbols and rules of data display (for example, generalization rules or colour manipulation rules). In the Electronic Atlas, these three types of files are stored permanently in the database and are utilized to derive the output files. The output files are temporary or permanent raster mode display files. It is possible to derive an infinite number of raster files, each created according to specific user requirements, through unique combinations of positional, attribute, and cartographic representation files.

The output files are in raster mode. They consist of hardware dependent pixel array files that utilize 8 bit memory planes and a set of Video-Look-Up (VLU) tables. The memory planes and VLU tables provide links to the attribute data by assigning different colours to different thematic variables or their values. The extended use of memory planes and VLU arrays will result in higher "intelligence" raster file processing, which means that many more attribute values can be associated with individuals pixels. Thus, some operations such as generalization or topological queries can be initially performed on the raster files.

Digitization of cartographic data results in very large data sets, consequently, such databases have to be optimized to assure efficient processing. In the Electronic Atlas this has been achieved by subdividing all position dependent files into smaller units, which are derived by a regular grid overlayed on the map. Greater efficiency of processing is obtained by utilizing grid directory files that permit the identification of objects within each grid. Thus, it is possible to by-pass all non-relevant data during processing.

The design of the Electronic Atlas database has been primarily influenced by generic cartographic data types, of the kind encountered in the National Atlas maps. This takes into consideration, to a lesser extent, types of functions that are going to be performed with such data. This approach ensures the stability and longevity of the system. In order to permit quantitative manipulation of data, the design of the database accommodates the fundamental topological properties of cartographic data, namely, the connectivity of lines and the adjacency of polygons. All other topological relationships can be derived by processing the positional or raster files. For example, the proximity relationships can be obtained by calculating the relative distances between map elements using computational geometry or raster processing methods.

The Electronic Atlas database use an in-house-developed Database Management System that is optimized for cartographic data handling. Through a system of menus it provides a convenient user interface. It allows a broad range of database queries; all performed in an interactive mode. Finally, through the high integration of positional, thematic and cartographic representation files, it permits a convenient method of derivation of user-designed electronic maps.

The Electronic Atlas System's design has been based on an open architecture concept, which gives the possibility of incorporating new developments in technology or of continuously augmenting its overall capability.At present, the Electronic Atlas prototype system runs on a LSI 11/73 computer with 256 KB main memory supported by 65MB disc storage. The graphic processor used is a LEXIDATA 3700 system with 12 memory planes and a medium resolution screen. This system uses the RSX 11/M operating system and the programming language is PASCAL.

FUTURE DIRECTIONS

The Electronic Atlas will form a part of the National Atlas Information System. The National Atlas Information System will be based on the central database concept that will provide a focal point for all activities of geographical research and cartographic production. It will facilitate an integrated approach to data management and assure the provision of high quality information for use by other federal departments, provincial and municipal governments and the private sector. The focus of the Electronic Atlas will be the creation of customized electronic maps and the provision of geographic information through the modern electronic media. Its fortes will be the continual updating, in predefined revision cycles, of a current geographical database, and the extent of quantitative data manipulation. The latter will complement conventional mapping with the capability of numerical evaluation of geographical information. When completed, the Electronic Atlas will provide an innovative and comprehensive geographical knowledge base of Canada at common map scales to support decision makers in the public and private sectors of Canada.

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GRAPHICAL DISPLAY AND MANIPULATION IN TWO AND THREE DIMENSIONS OF DIGITAL CARTOGRAPHIC DATA

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ABSTRACT

This paper describes aspects of the work done within Scicon on the use of digital map data, normally displayed in two-dimensional map or chart form, to provide both two and three-dimensional displays and derived interpretations of the map data.

INTRODUCTION

Within both the civil and military mapping organisations digital cartographic data capture, display and manipulation is expanding, such that the creation of digital geographic databases is becoming a prerequisite for the new generation of civil and military communications, command control and information systems.

Scicon's work has been committed to the establishment of suitable databases of this material for efficient retrieval, manipulation and display in both two and three-dimensional form in conjunction with user information of asset deployment. To this end Scicon have produced the product "VIEWFINDER" which this paper briefly describes.

The generation of the three-dimensional information and derived mappings of slope, aspect and intervisibility become available by the combination of contour or randomly sampled height data of the region, with the associated topographic or culture features which make up a conventional map. The following sections highlight the processing of digital map data pertinent to terrain shapes from various capture modes, with the databanking of the culture features for use in a mission planning, communications planning, navigation and asset deployment environment.

1. Digital Terrain Data Capture Sources

In the following paragraphs three sources of digital material will be described which form the basic inputs to digital terrain modelling systems.

Discrete Samples

This source of digital terrain data is the most important and it is to this variety, which the remaining sources reduce during processing.

This type of data is represented by a single triplet of numbers which define the location in three dimensional space, of a point on the surface under consideration.

This surface may be any single valued function which represents a land surface, a sea surface or perhaps an underground surface formed as the interface between two types of rock.

To adequately represent this function, in three dimensional space, the location and height/depth of a suitably large number of points on the surface must be measured, or sampled.

It is important to define the surface with the correct number of sample points, such that:

a) The surface is correctly sampled with respect to the Sampling Theorem.

b) The minimum number of samples are obtained that are necessary from an economic standpoint.

c) The total area of the surface under consideration is sampled at a density (sample/unit area) commensurate with both sampling theorem and economic considerations.

The Sampling Theorem states that the highest frequency, or shortest wavelength components involved in the Fourier Transform of the surface must be sampled at least twice per cycle.

This theorem can be interpreted as saying that if the surface is made up of long wavelengths, eg. rolling hill-sides, then the samples can be taken, on average at a separation less than half the distance between the tops of the hills. If, however, the surface is very undulating and irregular, with very steep sided valleys, then the surface must be sampled at a rate, at least twice per cycle of the shortest wavelength undulations and irregularities that are required in the model of the surface.

Under the constraints of the Sampling Theorem and with a knowledge of the detail that is required on the surface, then the number of sample points required to define the surface can be estimated.

Similarly, the cost per sample, in terms of survey equipment, mapping or photogrammetric resources, man effort, etc, involved in the data collection, can be divided into the available budget, to indicate the number of samples that are possible.

If the budget for data collection does not allow sufficient sample, as dictated by the Sampling Theorem, then the specification of the detail over the whole surface area may have to be relaxed, or the area of coverage reduced.

It is clear that these two factors are in conflict and their implications must be carefully considered prior to undertaking detailed sampling of the surface.

The best known examples of discrete sample points on surfaces are:

a) Soundings on Hydrographic Charts, where the depths of the ocean has been measured at a sequence of sample points taken along the path of the survey vessel, as it moved over the ocean surface. This path may have been organised on a criss-cross basis to provide the sampling rate determined by the considerations given above. This would be typical of a detailed hydrographic survey of an area, or it may be a routine measurement taken of the depth of the ocean alorg the course of a vessel for safety and monitoring purposes.

b) Bore hole data is obtained by mineral prospecting companies in their investigation of sub-strata for oil and mineral bearing rocks.

In each case the resulting information representing the surface is formed from random sampling of the surface in the three axes of the coordinate system, and this is recorded as discrete point information represented at (X,Y,Z) triplets.

i) Photogrammetric Sampling

This source of digital terrain data is obtained via the analysis of photographic images of the surface obtained from aircraft or satellites.

The area being investigated is overflown by a survey aircraft, which takes a series of overlapping photographs of the region. The resulting photographs are, subsequently analysed in stereo viewing systems connected via shaft encoders to digital recording equipment. The human operator focuses the stereo viewing system onto the three dimensional image created by two of the overlapping photographs. By this procedure a particular level, or height value is selected. Then by skilful manipulation of the 3-D image under his view a series of points, of the same height value are identified; as a continuous curve defining a contour line. This procedure is continued until the required set of lines are identified covering the area of interest to the required detail.

This material is captured, in a digital format, as a string, or series of strings of (X,Y) coordinates, all associated with a particular Z value, representing the contour height.

On older photogrammetric equipment, without digital interfaces, map output will then require digitisation.

ii) Existing Contour Maps

This source of terrain data perhaps represents the largest source as a very large number of maps already exist in printed form. The contours on these printed maps have often been created by photogrammetric methods, without the digital interface, and a variety of discrete sampling methods followed by human contour threading to define the shape of the surface.

To convert these existing maps into a digital format requires the process of digitisation. This is achieved using a variety of techniques each of which have associated advantages and disadvantages.

a) Hand digitising - whereby a human follows the contour lines by hand on a flat digitising table, coding each line in turn with its height.

b) Mechanical line following - whereby a laser controlled automatic machine follows the shape of the line and associates the code either automatically or by human voice or finger keying.

c) Scanning - whereby the paper map is scanned in a raster fashion with a flying spot to identify each "pixel" on the map containing contours. These pixels are subsequently converted to vectors and their corresponding height codes associated.

When the contours are in digital format they are again as a string or series of strings of (X,Y) coordinates all associated with a particular Z value representing the contour level.

iii) Conversion of Contours to Discrete Samples

Photogrammetric and digital map data generally occur as line strings of (X,Y) coordinates with an associated Z value for the contour level.

It is necessary to convert these line strings into discrete samples by associating the particular Z value for the line string, with each component point of the line to form (X,Y,Z) triplets.

It can be seen that this form of discrete data point input is formed from random (X,Y) data but quantised Z, to produce the triplets required for further analysis.

2. Digital Terrain Model Creation

VIEWFINDER provides a comprehensive data reduction facility for the class of problems relating to surfaces in a three dimensional space. To use these facilities it is necessary to convert the array of input (X,Y,Z) data points into a more suitable representation of the surface which can be efficiently and effectively processed by computers. The most convenient representation of a surface for such processing is in the form of a set of height values on a uniform square grid distribution.

The numerical approximation, from the irregularly distributed points to height values on a regular grid, provides an efficient and accurate transformation which generates a representation of the surface that exactly fits each of the input data points. This is achieved using a least square error plane fitting technique.

This is based on the selection of the nearest set of, at least eight, sample points distributed in the eight quadrants around the matrix node under consideration. From these points the least square error plane is calculated to pass through the input points from which the value of the node is then interpolated. This process is continued for the whole area to produce the digital terrain matrix.

Uses of Digital Terrain Models

Once the matrix has been calculated it can be used for a large variety of purposes. The following paragraphs give a number of examples, which are not exclusive.

i) Calculation of Contours

From the matrix the shape of the contour figure field can be produced. This can be done by using linear interpolation through the grid cells, or alternatively approximations to a smooth surface that is based on derivative estimates at grid intersections. The latter produces a more desirable result and the validity of the matrix can be checked by this algorithm whereby the contours interpolated from the matrix can be compared with the input data (see Figures 1 and 2). Similarly, the conversion of input contours in feet, to output contours in metres can also be performed.

ii) Calculation of Cross Sections

From the matrix of terrain height, the height at any desired location on the area of interest can be interpolated. This is done by linear or curve fitting algorithms, but instead of computing the (X,Y) position for a given height, as for a contour, the height is calculated for a set of (X,Y) coordinates which define the vertical cross-section, or profile through the surface. Generally only two (X,Y) coordinates are specified, to define a straight line cross section but a number of straight line cross sections can be combined together to define a cross section through the surface, along a curved line.

3. Three Dimensional Views

From the matrix of terrain heights, representations of the shape of the surface can be generated in three dimensional space.

i) Orthographic projection

An orthographic view represents the surface that contains no distortions due to the distance of the point on the surface from the observation point since the eye point is deemed to be at infinity.

Profiles parallel to the X or Y axes are drawn each of constant length (representing the width of the matrix), while the length of the matrix is represented by the set of profiles set back and offset from each other along a line at 45° to the horizontal.

ii) Perspective projection

A perspective view of the terrain matrix produces a three dimensional representation that contains a distortion due to the distance of the object, from the observation point, or eye point.

A perspective view of the matrix looks very similar to the equivalent orthographic view, particularly if there is not a significant difference between the ranges of the set of points on the surface and the eye point.

Perspective views of the surface provide a means of presentation of the matrix information that is particularly easy to comprehend. If the eye point is taken "onto the matrix" then views of the surface that correspond closely with the actual scenes observed from the equivalent eye point on the ground, can be calculated. Compare Figures 3a with 3b which were computed using the Scicon VIEWFINDER Perspective View facility.

Having defined the eye point, it is then necessary to define the direction of view and the angle of the cone of vision around this direction.

4. Line-of-Sight Diagrams

Using the digital terrain matrix, diagrams can be generated which display the area of the ground that can be seen from a particular eye point, either on or off the matrix.

i) Star Diagram

If the location of the eye point is specified in the three dimensional coordinate system of the matrix, as (X,Y,Z), then a series of cross sections through the surface can be calculated. For each of these sections, the (X,Y) coordinate of the eye forms the start point, while the end point is chosen such that radial lines in the X,Y plane from the eye point are generated at a set angular separation for the whole 360° around the eye point.

For each cross section the eye point is positioned at the correct height (Z) and lines of sight from this point onto the surface are produced, thereby identifying the points on the cross section that are visible, and the points that are occluded.

The disadvantage with this type of line of sight diagram is that as the range extends so the resolution of the image degrades.

ii) Intervisibility Matrix

The intervisibility matrix does not exhibit the disadvantage of the Star Diagram, since every node on the Digital Terrain Matrix is analysed to determine if it is visible or not from the defined eye point. Within the VIEWFINDER system the intervisibility diagram is computed for each perspective view simultaneously. Such that a comparison of nodes visible on the 3-D view, with those displayed on the intervisibility plot, provide an easy means of establishing the range of features on the surface from the eye.

Figure 4 shows the corresponding intervisibility plot for Figure 3b.

5. Slope and Aspect

From the digital terrain matrix, the angle of slope of the ground can be calculated and displayed either as contours of constant slope or by colours.

The VIEWFINDER System calculates the maximum angle of slope at each grid node and the aspect of that slope. The aspect of the slope is the direction with respect to North that a sample of liquid would move under the influence of gravity down the angle of maximum slope.

The direction of the colour coded vector indicates the aspect of the slope as measured from the direction of North.

6. Further Discussion of the Use of Perspective Views

Manipulation of Perspective Views

From the above description, it is clear that there are three important parameters to be be defined in order for a 3-D image to be calculated:

a) The eye point
b) The direction of view
c) The cone of vision around the direction of view.

Consider the manipulation of these parameters to advance the use of digital terrain modelling for military applications in general prior to a more specific discussion of military applications which follows in the next section.

i) Change of cone of vision

If the eye point and the direction of view have been defined then the scene in view is equivalent to that obtained by looking through the viewfinder of a normal camera system (see Figures 3a and 3b). If the camera system was fitted with a widely variable focal length lens, or zoom lens, then by changing this focal length an ever more detailed picture would be obtained. The change of focal length directly changes the solid angle viewed through the viewfinder of the camera.

By manipulation of the solid angle around the direction of view the VIEWFINDER system can simulate this widely variable focal length lens, such that the angle of view can been changed from 90° to 1° and a small region of hillside, at a large range, "fills the field of view" of the camera.

ii) Change of eye point

The previous section discussed the manipulation of the cone of vision as a smoothly varying parameter. To follow this philosophy with the eye point, as distinct to stochastically changing the observation point to produce random views, the VIEWFINDER system is capable of generating a connected sequence of views as a simulation of an observer flying or moving via some vehicle over the terrain.

If the sequence of views are presented as a moving picture on film or television, then of the order of 15 to 20 frames must be displayed per second to produce smooth continuous motion.

This requires considerable computing power and other specialised hardware, to generate such animation.

7. Addition of Texture and Culture

To increase the realism, in the computer generated scene, it is necessary to include both the texture of the surface and other details, generally man-made objects, which make up the set of features on the terrain surface.

This requirement necessitates the classification of the various regions of the surface, such as:

- vegetation - woods - deciduous
  - coniferous
  - mixed

  - crops - corn
  - potatoes
  - mixed

- soil - clay
  - sand
  - rock
  - silt, etc

Having established the types of surface cover, and their textures, the boundaries of these areas must be digitised, and the facets of the three dimensional view filled in with the required colour and texture, up to the required boundaries.

Much of the data for culture addition to DTMs is acquired from photogrammetric sources but also from vertical or oblique aerial photographs. This is currently a slow and labour intensive process and research is being carried out in a number of centres to automate it. Approaches include the use of artificial intelligence techniques (AI). Only the major simulator companies currently offer any working systems with culture addition, but with the advent of low cost array processors and high-speed graphics devices, these capabilities become available at significantly less cost than full mission simulators.

8. Defence Applications of Digital Terrain Model Techniques

VIEWFINDER is a planning tool which will become an essential aid to intelligence and operations staffs particularly before hostilities, but which will provide increasing assistance during operations as defence forces acquire further ADP capabilities.

Deployment Options

The deployment of friendly forces is reactive to the perceived threat. The elements of surprise available to an enemy indicate that the plans of friendly forces should be secure, effective and flexible. This implies the rapid investigation of several deployment options. In the previous section it is explained how the system is able to interact with queries and demands from the user. This provides the facility for preliminary reconnaissance without the need to undertake a cross-country or helicopter mission.

Provided friendly intelligence has acquired data on the deployment of hostile assets, (primarily, surveillance and target acquisition equipments, and EW sensors), it is possible to identify whether an area is under surveillance or shielded by natural features or culture (woods, buildings, etc). The risk of occupying an area can be estimated and, if necessary, the appropriate responses can be determined: ie. accept the risk if low, eliminate the hostile surveillance, or move to a less vulnerable location.

VIEWFINDER allows the detailed deployment of assets to be made by Commanders before a postion is occupied. For example, the position of a radar site can be adjusted to provide maximum protection of the main lobe consistent with the best coverage of the threat; artillery can be deployed to avoid crest clearance problems; Remotely Piloted Vehicle (RPV) missions can be planned so that the communications links are established precisely when required.

Subordinate commanders can be briefed in detail during a period of tension. Any adjustments to the operation order can be evaluated, enabling the transition to war to proceed smoothly.

Scicon do not consider that any system of this nature can replace the need for a Commander, whenever possible, to view the ground and the environmental conditions which apply currently. However it is believed that preplanning using VIEWFINDER will enable a Commander to confirm his thinking, and to make whatever tactical adjustments he wishes, in the light of the detailed technical assistance at his disposal. This would provide a more cost effective utilisation of time and resources of the Commander and his staff.

During hostilities, VIEWFINDER is available to the planning staffs for preliminary evaluation of other phases of battle, and to operations staffs for real time mission planning. This would provide quicker reaction, a wider choice of options, and greater threat to an enemy via the increased flexibility which sound planning allows.

The following brief descriptions provide specific sceanrio examples of the application of VIEWFINDER to these planning tasks.

i) <u>Sensor System Siting</u>

The deployment of a ground surveillance radar on a terrain feature highlighted on a map will be displayed.

The task of the radar is the surveillance from the top area of the feature of an adjacent road which is visible across the valley.

The problem is to achieve surveillance without compromising friendly radar positions from the hostile EW assets which might be sited on the high ground to either side of the road.

It is essential to protect the radar by its careful siting, and an analysis of the slides which will be shown will provide a number of interesting locations.

The results show what cover is available: light blue is the best area for observation; dark blue the worst. Postions where light blue adjoin black are clearly optimal for both observation and protection from view.

The data derived provides sufficient high quality information upon which to issue deployment orders with realistic six-figure grid references. Tactical adjustment by the local commander will provide the fine tuning on the ground, but this is only necessary over a very localised region of ground.

ii) <u>Communication Planning</u>

The VIEWFINDER system is ideal for communications planning either for securing optimum paths where the use of high ground and relay is permitted or for identifying alternative paths which could diminish the probability of hostile intercept.

In this example, the requirements of a Remotely Piloted Vehicle (RPV) system are analysed. Its mission planning will include periods when it flies autonomously, employing its on-board guidance, also periods when it verifies its flight path by correlation of the actual track with the expected track, and periods when real time transmission is required. In order to communicate with the Ground Control Station (GCS), a communications path must be established at specific intervals in the mission.

Slides will be shown which illustrate:

- RPV mission highlighted on 1:50k map.

- Intervisibility from RPV above target area to potential GCS.

- An oblique 3-D view from RPV to a selected GCS.

It will be seen that the RPV height, the technical requirements of the sensor package, and the ability to shift control from one GCS to another can all be pre-planned with ease. The GCS can be sighted anywhere out of the occluded areas and within friendly territory.

iii) FGA Mission Planning

This example illustrates part of a mission plan for two FGA sorties. Two Harrier aircraft are being used against defended localities. The localities are defended by a surveillance, early warning radar and four SAM 7 missiles.

The slides shown will provide an assessment of the performance envelopes of the AD radar and missile systems, which defines the boundaries of AD protection around the defended localities:

- The radar coverage calculated by VIEWFINDER.
- The coverage of the four SAM 7 sites.

By comparing the two pictures, the optimum route to weapon release, the time at which AD suppression activity should commence, and the escape route post attack can be determined.

CONCLUSION

This paper describes the use of a software package that is independent of host machine and graphics device.

It uses basic map data that can and will be used in the printing process of maps, such that the data used for interpretation, planning and decision processing is the same as printed on the conventional paper map.

The system then provides the user with an interactive planning, and simulation aid for many types of military and civil situations.

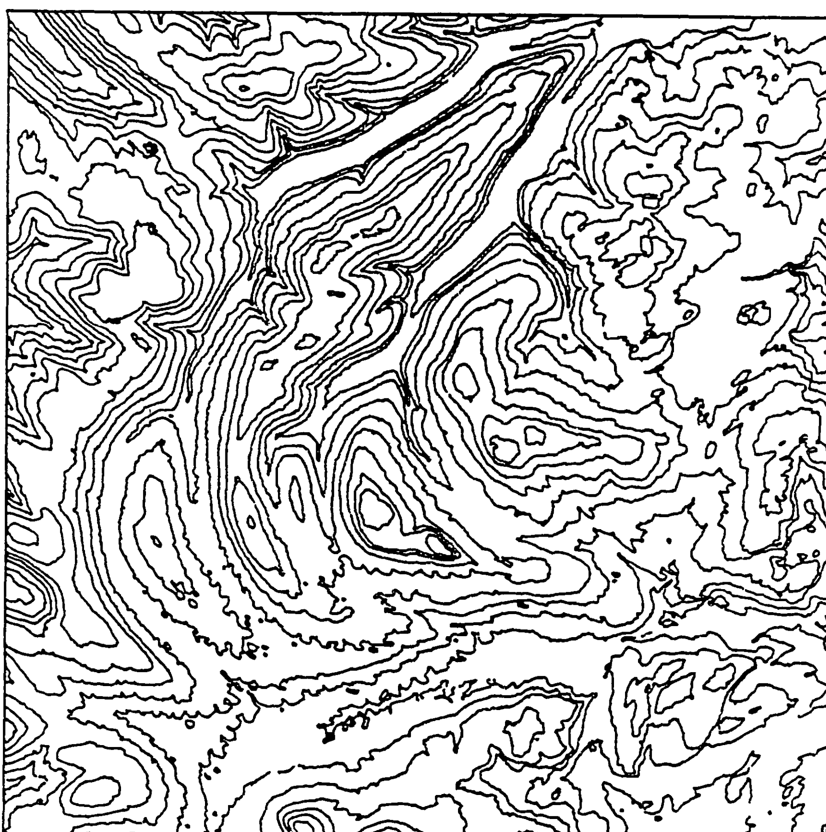

Fig I 50mt Input Contours of 20 kmsquare Area of Yorkshire

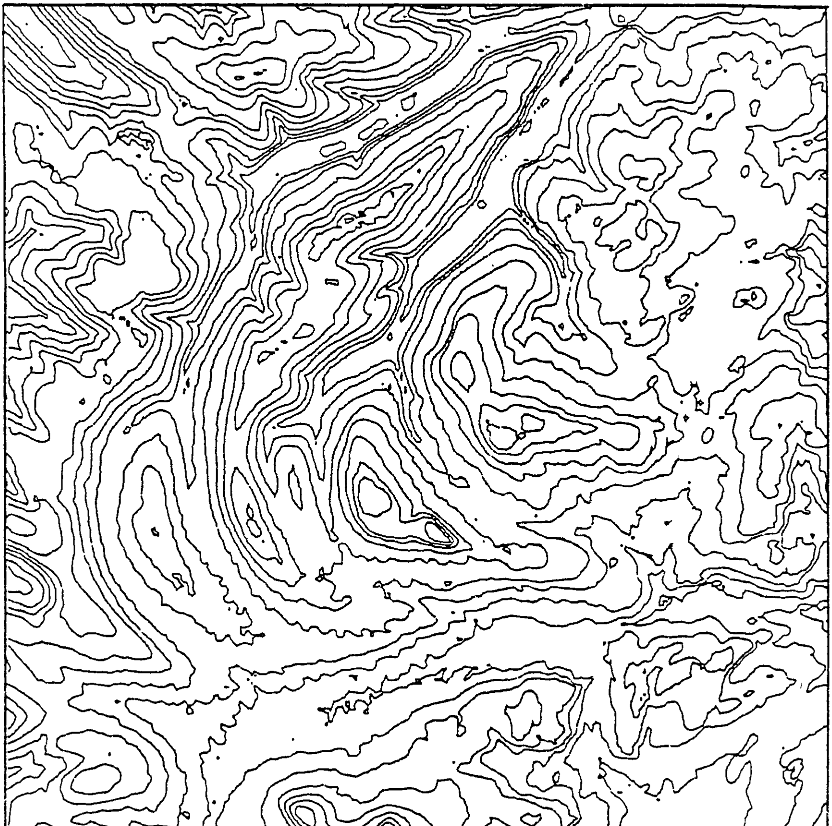

Fig II 50mt Recomputer Contours of 20km square Area of Yorkshire

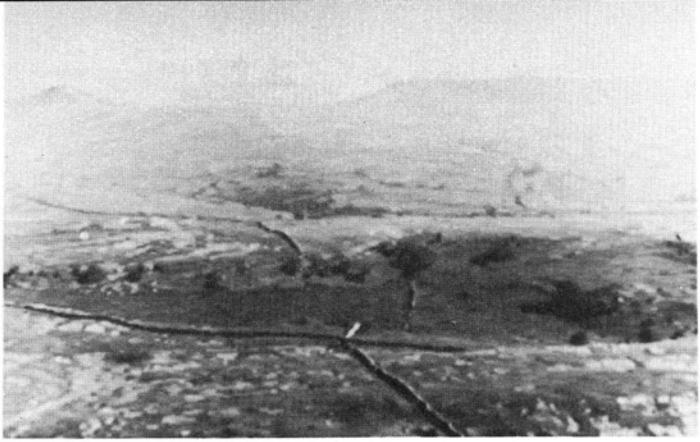

Fig IIIa) Real scene looking N East over area of interest

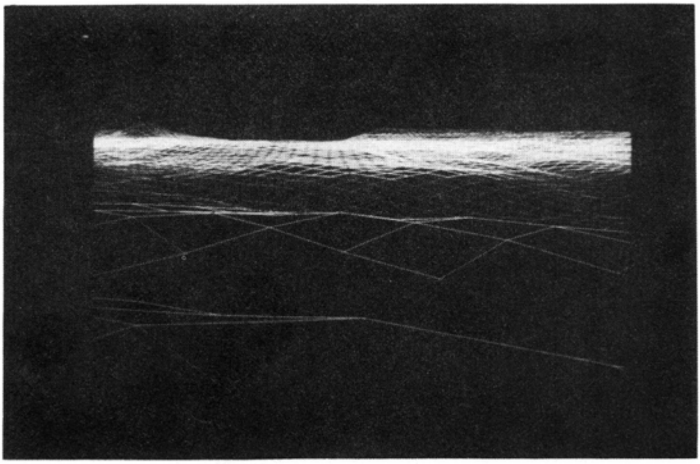

Fig III b) Computer generated scene equivalent to IIIa

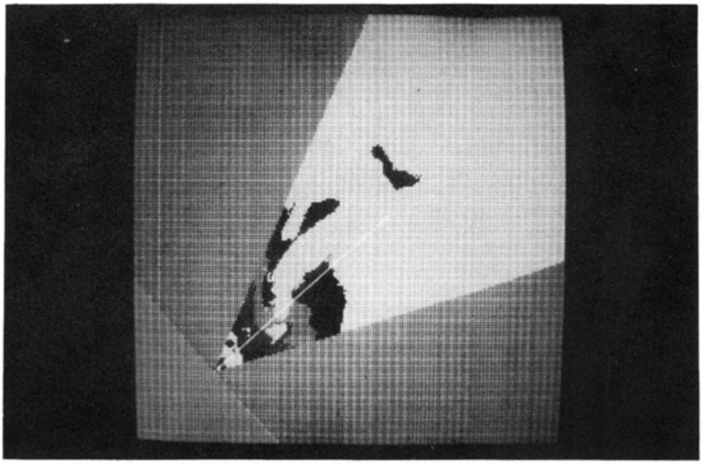

Fig IV Intervisibility matrix showing visible and invisible nodes for Fig IIIa

A DECISION-MAKING TOOL FOR LAND EVALUATION IN THE DEVELOPING COUNTRIES

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ABSTRACT

In many areas of the World a rapidly increasing growth in population is putting severe pressure on the Earth's resources. It is, therefore, important that land management practices are carefully regulated. This fact is gradually being recognized by governments in developed and Third World countries alike, and more money is now being channelled into programmes which attempt to offer long-term solutions to this problem. One such programme is the Land Evaluation System which has been developed by the Norwegian Computing Center for the Soil Survey Unit of Zambia. Developed on an IBM/AT personal computer, the system requires two main sources of input data. First, the spatial data is digitized from existing soil and agro-ecological maps. Second, the potential for any given crop to grow in any given area on any given soil is recorded for a number of 'climatological potentials' and 'soil constraints'. Processing of this data allows the user to answer questions such as "How suitable is a certain area for a particular crop?" or "What is the best crop to grow in a certain area?". Output from the system comes in the form of maps either produced on an A3, 6-pen plotter or on a colour screen. Tabulated summaries can be produced on a printer.

INTRODUCTION

In those areas of the World where a rapidly increasing growth in population is putting severe pressure on the Earth's resources, the importance of careful land management practices cannot be under-estimated. This problem has been confounded in recent years by the occurrence of devastating natural disasters in just those areas where the margin between success and failure of a harvest is already very small. Governments in both developed and less developed countries have been aware of this problem for a number of years, and numerous aid schemes have been initiated to help the populations of the most badly affected areas. Within many of these schemes computer technology has played a significant role. However, it is only fairly recently that the costs of computer systems, which could help in offering long-term solutions, have reached a sufficiently low level for the less developed countries to be able to afford them. Considerable effort is now being made to develop systems which provide at least a first step in the process which could alleviate some of the severe human, physical and economic problems afflicting many countries in the World. One such programme is the Land Evaluation System which has been developed by the Norwegian Computing Center for the Soil Survey Unit of Zambia and has been funded by the Norwegian Agency for International Development (NORAD).

OVERALL SYSTEM DESIGN

Design Considerations

Land evaluation involves the integration of a number of factors: including soil properties such as nutrient availability, rooting conditions and salinity; the ways in which soils react to various farming methods; climatic variables such as rainfall, temperature, humidity, wind and amount of sunshine; topography, such as elevation, slope steepness and aspect; geology and geomorphology; and economic and technical considerations. A land evaluation system uses these factors to determine the suitability for growing certain crops in particular areas using a given set of inputs, such as the amount of fertilizer used, the availability of mechanized labour, and the use of irrigation and drainage. However, there may be a number of over-riding human factors which could influence the 'suitability' of a crop. These factors may include traditional farming practices, eating habits, religious beliefs, or societal structure. However, because of the difficulties involved in trying to measure such variables, it is usually necessary to base the design of a land evaluation system on mainly physical characteristics. This approach, of course, yields satisfactory results for determining the physical suitability for crops, but it is important that these results are interpreted in the wider human context.

Information required for a land evaluation system can come from maps, such as soil, geological and topographic maps. Climatic data may be obtained from maps or from tabulated sources. In addition, it is necessary to have a set of rules which define how this derived data should be combined in order to give the suitability for growing any crop on any soil in any location. These rules are usually collated by national agricultural or soil organisations or by international organisations, such as FAO. Clearly, the rules tend to get very complicated and numerous when all the possible combinations of soil, crop, climate, topography, geology and geomorphology are considered for any one country. In order to calculate the suitability for a particular crop to grow in a particular area, all the evaluation rules have to be resolved for the physical characteristics for the area concerned. The final suitability rating for growing a given crop in a particular area is usually defined by the suitability of the physical characteristic which poses the most severe constraint on the growth of the crop. For example, if rainfall was the most severe constraint on the growth of paddy rice in a given area, then the suitability for growing paddy rice in that area would be equal to the suitability rating for rainfall.

Output of the results from an evaluation may be in the form of maps, graphs or tables. By defining suitability as a number of classes ranging from 'very suitable' to 'not suitable', maps can be used to show the suitability of growing a particular crop over a whole country or over a region. Graphs can be used to show which characteristics pose the most severe constraints on the growth of a particular crop. Tables can be used to show summaries or derivations of evaluation results. However, the type of output which is appropriate for any given user may have to be considered carefully. For example, it may be necessary to take into account the fact that farmers may be illiterate or that their map-reading abilities may be very poor or that a numerical suitability rating may mean very little when a farmer measures the success of a crop on the its ability for feeding his family. On the other hand, for agricultural planning purposes, a map showing the suitability for growing a particular crop in a country may be a much easier tool for decision-making than long lists of tabulated results.

System Description

The Land Evaluation System developed at the Norwegian Computing Center (figure 1) incorporates data relating to many of the physical properties of soils, the effects of soil erosion, soil workability, and several climatic variables. A soil map and an agro-ecological map are used as the two major sources of input of spatial data. The former map shows the distribution of soils, and the latter shows agro-ecological zones in which each zone is defined as having homogeneous climatic properties across its area. By overlaying these two maps, one obtains a set of polygons, or geo-units, and to each geo-unit an agro-ecological zone number and a soil type can be assigned in order to identify the climatic and soil characteristics which are to be used in the evaluation process.

The evaluation rules used in this system contain information on the suitability for any crop to grow in any given agro-ecological zone on any given soil for a number of 'climatic potentials' and 'soil constraints'. The 'climatic potentials' are defined as a number of climatic variables relating to: radiation, temperature, humidity, and precipitation. The 'soil constraints' are defined as soil variables relating to: oxygen availability, nutrient availability, the possibility of deficiencies of important minerals, salinity, alkalinity, erosion hazard, soil degradation hazard, and soil workability. Suitability is defined in one of five classes from 1 to 5, and these indicate a range from 'highly suitable' to 'not suitable' for growing a particular crop.

When data from the maps and the evaluation rules are combined, it is possible to produce maps showing the suitability for a given crop to grow in all the areas (geo-units) in a region or to produce maps showing which crop grows best in all the areas in a region. Results can also be produced in tabulated form.

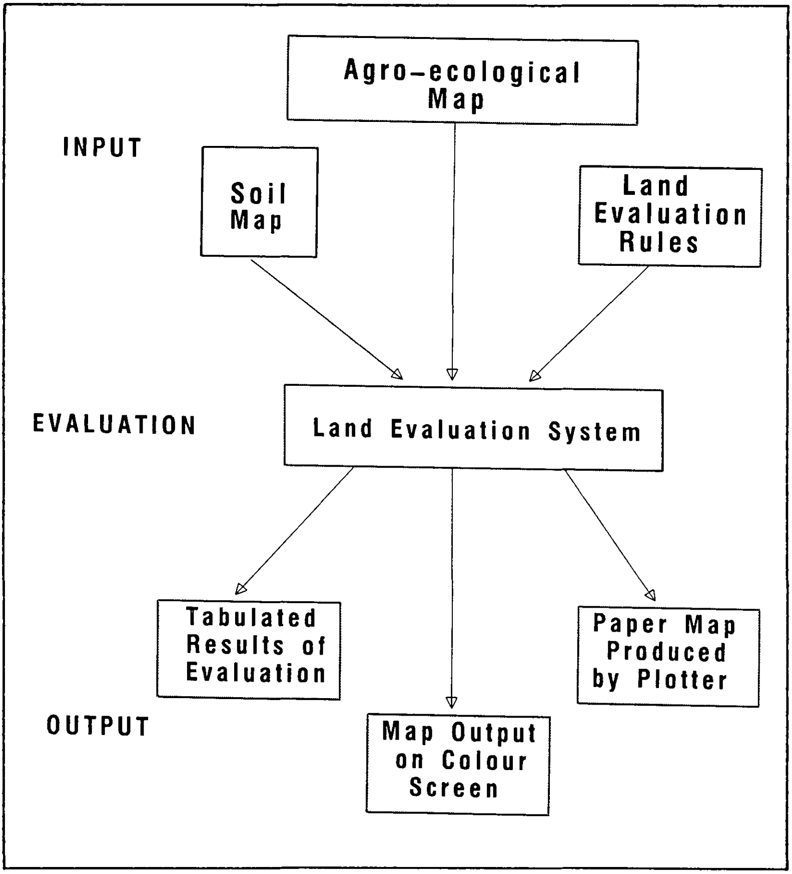

Figure 1. General Structure of the Land Evaluation System

IMPLEMENTATION

Introduction

The system is implemented on an IBM PC/AT with a 20 Megabytes fixed disk and operating under MS-DOS version 3.1. The peripheral devices attached to the PC/AT are as follows: monochrome monitor, colour monitor, printer, Hewlett Packard A3 6-pen plotter and Calcomp 15" digitising tablet. A special variant of PASCAL, Turbo PASCAL, was chosen as the main programming lauguage.

The three parts of the system shown in figure 1 have been programmed in eight major modules :

1. INIT - initialization module
2. READEVAL - data entry module
3. GEODIGIT - digitizing module
4. UPDATE - update module
5. MANEVAL - manual evaluation module
6. GEOEVAL - geo-evaluation module
7. DISPLAY - module for displaying previously generated maps
8. HARDPLOT - plotting module.

Input

Input to the system is carried out in four stages:
1. initializing the system (INIT) ;
2. entering the land evaluation rules (READEVAL);
3. digitizing the overlay of the agro-ecological map and the soil map (GEODIGIT);
4. updating the existing data (UPDATE).

The initialization is carried out by module INIT. The data needed to set up the system are entered here. These include the names and codes of all agro-ecological zones, soils, crops, 'climatic potentials' and 'soil constraints' which are to be used by the system. The dialogue between the user and the system is in tabulated form using the screen-oriented facility provided by Turbo PASCAL. Output of this module is a number of sequential files, each one containing the data relating to one of the items mentioned above.

After the initialization, the land evaluation rules are entered by invoking module READEVAL. At a scale of 1:2.5 million Zambia consists of 60 agro-ecological zones, and at this scale the rules use 11 major soils, 13 crops, 11 'climatic potentials' and 24 'soil constraints'. Obviously, if the suitabilities for every combination of zone/soil/crop have to be included in the system, then the number of items to be entered is very large. To avoid this problem all possible combinations are assumed to belong to suitability class 1 for every 'climatic potential' and 'soil constraint', and only combinations which have suitability classes other than 1 are entered specifically. The READEVAL module creates two files for each agro-ecological zone: one contains all the data relating to the 'climatic potentials' for a zone, and the other contains the 'soil constraint' data.

Digitizing of the overlay of the soil map and agro-ecological map is carried out by module GEODIGIT. During the digitizing process, each geo-unit is assigned an agro-ecological zone number and a soil identifier so that there is a direct correspondence between the spatial data and the evaluation rules. The outcome from this module is a set of binary geodata files which are used by the plotting routines later on.

Occasionally, new agro-ecological zones, new crops or new soils may be introduced to the system, thus the data files have to be updated. This can be done by invoking the UPDATE module. Since the updating process is very similar to the data input in the READEVAL module, many of the procedures used in the READEVAL module are also used in this module. The update operation is limited to introducing new zones, new soils or new crops to the system.

Evaluation

There are two modules which are used to compute evaluations: MANEVAL, the manual evaluation module, and GEOEVAL, the geo-evaluation module. The evaluation modules are able to compute two basic types of evaluation: firstly, "How suitable is a certain area for a particular crop?", and secondly, "What is the best crop to grow in a certain area?". The evaluation is computed by using either all 'climatic potentials' and 'soil constraints', or only some of them. As was mentioned earlier, the evaluation is based on a "worst case" principle: for a specified crop in a given region growing on a given soil, every potential and constraint has a certain suitability, and the lowest suitability class is taken to be the final result. The result of an evaluation is displayed in text form on the monochrome monitor (figure 2), and it can also be output on the printer.

GEOEVAL performs a similar function to the MANEVAL module except that the evaluation is made for all areas in a given region and the results are displayed in the form of a map on the colour monitor. A total of 15 suitability classes can be produced by the evaluation, but to present all of them at the same time on the same map would be difficult. Therefore the results are grouped into 5 categories: the first class is used for areas where the limitations on growing a crop are negligible, and the fifth class is used for areas where the limitations for growing a certain crop are very severe. Each class is represented by a different shading on the map displayed on the colour monitor. When the evaluation involves determining which is the best crop to grow, a different shading is assigned to each crop. Like the MANEVAL module, the tabulated results are also displayed on the monochrome monitor, or can be printed out. A file containing plotting instructions is generated and saved so that the map can be produced again at a later stage without having to re-compute the evaluation.

```
Result from Evaluation:
Zone : 3-e
Soil : Podzol
Crop : Wheat

Potentials :
Radiation, sunshine
Occurrence of frost
Occurrence of relatively low air humidity

Constraints :
Inherent nutrient availability
Rooting conditions

The result of the evaluation is :
Potential Class : 2
Constraint Class : 3
Suitability Class : 3
```

Figure 2. Text Output from the Land Evaluation System

Output

The last stage is to present the results of the evaluation, and in order to do this two modules are available: DISPLAY which draws a map on the colour monitor and HARDPLOT which makes a hard copy of the map on the plotter.

Module DISPLAY uses the file generated by the module GEOEVAL to draw a map showing the evaluation results. This module can also be used to check that the digitizing done in module GEODIGIT is correct. In the module HARDPLOT, plotting instructions are entered into a batch file, and the hard copy map is produced by executing the plotting instructions one at a time. The user may define the colours and types of shading of the hard-copy map. In addition text and a map legend can be defined and positioned by the user. An example of the map output is shown in figure 3.

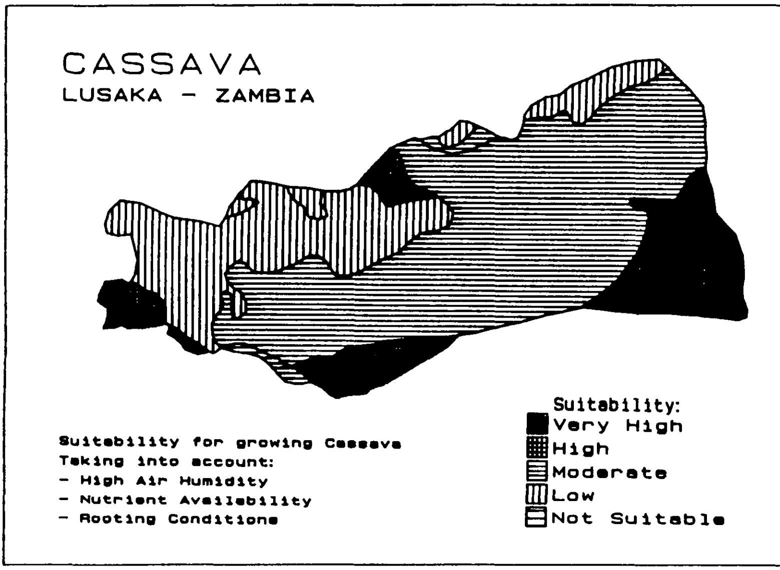

Figure 3. Hard-copy Output from the Land Evaluation System

A TOOL FOR PLANNING?

The intention behind the Land Evaluation System is to provide a tool for agricultural planning in the Third World. Such a system allows soil scientists to analyse the data they have collected. This task is cumbersome and time-consuming, as the methods employed are quite intricate. Precious time is saved by using computer assisted techniques. The professionals may allocate more effort to the enlargement of their data base, as well as spending time on refining the evaluation methods. Thus, the computer-based Land Evaluation System is a necessary tool in order to process data, and make soil information more rapidly available for planning purposes.

The value of such a system is, however, restricted by the data and knowledge represented by the software. As a tool for planning, the system must be applied to problems on the same level of generalisation as is provided by the background information. If the system is loaded with soil observations from a map with a scale 1:2.5 million, proper answers can only be given for questions aimed at that same level of detail. Advice given to the individual farmer or peasant concerning what crop to grow may then prove to be incorrect, as local conditions may vary rapidly over short distances. The crops found to be suitable in large regions, however, will provide central planners with basic information which can be used to allocate the right kind of resources and technical support to that area.

If, on the other hand, the Land Evaluation System is be used for planning on the micro-level in order to help the individual farmer on his piece of land, then the data used in the evaluation must apply to this level. The information about soils as well as agro-ecological conditions in the area under consideration must be sufficiently detailed in order to generate adequate advice.

Another aspect of this problem is to decide what is adequate information. The method of evaluation used in the system is based on a FAO scheme which has been adapted for Zambia by the Soil Survey Unit. Here, soil properties and ecological conditions are taken into account. Social and economic considerations may, however, be just as important in order to make a final decision in agricultural planning. It is not likely that a system like the Land Evaluation System will be able to cover all aspects of the decision-making process. Soils, local climate and other ecological factors may change more rapidly over space than can be taken into account by the data structure. Other factors, not even thought of in the general model, may be critical in a certain area. For example, a lack of transport facilities may prevent authorities from bringing in the neccessary technical support for growing new crops. Also, the same shortage would be an obstacle to growing cash-crops in remote areas, irrespective of the physical suitability of the land.

In Zambia, as well as other places, local knowledge must be applied to the information generated through the computer software, in order to maximize the decisions that are made. Thus, further research into Geographic Information Systems for planning purposes should take into account two aspects of integration of local knowledge: firstly, to formalize and integrate social and human factors in the evaluation rules; and secondly, to find out where the computer should halt processing, and let man enter informal knowledge and make decisions dependent on the local situation. It should be stressed that a system like the Land Evaluation System is an important tool which can be used to aid agricultural planning, but, at the end of the day, it is man's responsibility to ensure that the correct decisions are made.

CONCLUSIONS

The current version of the Land Evaluation System, clearly, is tailored to the Zambia situation. However, if the same FAO evaluation system is used, then new rules, which fit the conditions in other developing countries, can be added to the system. The comparatively low cost of the equipment could allow the system to be located in many field locations within one country, thus making the facilities available in just those areas which require them most.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of Stein Bie of the Norwegian Computing Center, the staff of the Soil Survey Unit, Mount Makulu, Zambia, and the Norwegian Agency for International Development (NORAD).

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TRANSFER OF HIGH TECHNOLOGY TO DEVELOPING COUNTRIES

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SUMMARY: This paper reviews, on the basis of objectives and constraints, the characteristic problems encountered when transferring the technology associated with computerised Geographic Information Systems to developing countries.

1.0 INTRODUCTION.

High-technology is an umbrella term for that branch of advanced technology which utilizes electronics. At ITC we are particularly concerned with developing countries, and this is realised through our education, consultancy, and research programmes directed towards the resource problems of such countries. For whatever reason, these countries have chosen to move away from traditional practices; these traditional practices may refer to particular agricultural, settlement, or labour patterns. Having been asked to address the problem of high-technology transfer to developing countries, we can do so only within the context of implementing Geographic Information Systems (GIS's) in those countries which have had, hitherto, little or no experience of computer technology.

There is evidence of large investments having been made, GIS's having been acquired, and at least partially installed in many developing countries, e.g. Brazil, Colombia, Egypt, Indonesia, India, Iran, Malaysia, Mexico, Saudi Arabia, Senegal, Singapore, United Arab Emirates. There is much less evidence that the systems are functioning satisfactorily and almost none that they are contributing to national development; although this is not only a problem in developing countries. We shall try to identify those characteristics of such countries which affect high-technology transfer.

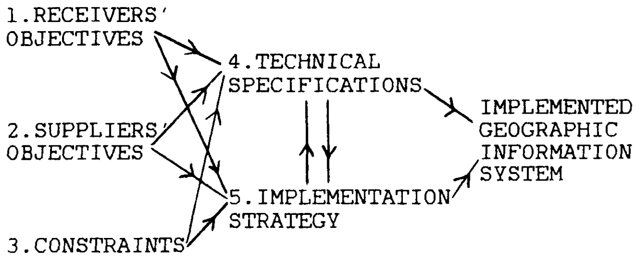
With technology transfer there are supplying organizations and a receiving organization. All parties are guided by different sets of objectives. For the supplier these are: commercial; ideological; or, political; and for the receiver: product related; educational; or, political. Thus, as in any transaction, problems will arise as supplier and receiver attempt to balance their differing objectives.

When a receiver of technology attempts to realise the objectives, certain constraints will operate which will make this task more difficult. These constraints relate to: finance; manpower; environment; location; motivation; institutional practices; and, politics.

Some developing countries are extremely poor, but, although the technology transfer may alleviate this poverty, an initial and continuing investment is required. Some other developing countries may not be poor, but their cultures (aspects of which the transferred technology will change) are not those of the supplying country, nor, more particularly, of the countries in which the technology evolved. Thus even the non-financial constraints listed above may be very difficult to overcome.

A GIS consists of hardware, software, and manpower. Such a system will have particular technical specifications. The system will be implemented in phases over a period, or in one go. The system will be implemented by the supplier for the receiver, or through the mechanism of consultants (acting for either the supplier or the receiver), or both, with the receiver being an existing mapping organisation, government organisation, or a new specially created one with a remit in the field of GIS. The technical specifications for the system, its implementation period, and the mechanism for its implementation are all functions of: the receivers' objectives; the suppliers' objectives; and, the constraints within the receiving country. This is shown diagramatically in Figure 1. It is the purpose of this paper to address the problem of high technology transfer to developing countries, and Figure 1 will be used as a framework. We will consider each of the numbered (1-5) divisions in turn, highlight those items found in each which are, in our opinion, likely to generate problems in developing countries,and present some solutions.

Figure 1. THE FACTORS AFFECTING THE NATURE OF THE IMPLEMENTED SYSTEM



2.0 RECEIVERS' OBJECTIVES.

Lack of up-to-date human and physical environment data is a problem in developing countries. Present capabilities with respect to data collection and their use are inadequate. There is a lack of resources and trained manpower which results in a failure to meet requirements and the advocacy of computer assisted methods, which are thought (and therefore required) to reduce manpower needs.

Explosive population growth and a corresponding increase in food demand force governments to invest in vital development projects, and the tools (including planning and mapping tools) used must therefore be reliable and timely.

Critical assessment by developing countries of the environmental and social impact of technology is now quite customary, and the use of advanced data collection methods may only be advocated if they do not cause environmental and social problems.

Finally advanced information systems are often implemented because it is thought that their existence improves national or political prestige.

3.0 SUPPLIERS' OBJECTIVES.

Technology transfer is often the joint venture of several supplying organizations, which may include governments, manufacturers, educational institutions, and mapping organizations. Each of these may be guided by different sets of objectives.

One of the obvious objectives of technology transfer is immediate profit. In addition manufacturers may be interested in creating new markets. Developing countries represent an unexploited market for computer technology. Manufacturers, and other organisations such as those involved in consultancy, are eager to learn about developing countries, and accept early losses to that end. Such entrepreneurial activity may benefit developing countries in the first instance, but if it becomes combined with equipment testing, or later extreme profit taking then it becomes less beneficial.

There may be an ideological element in technology transfer, and one aim is to eliminate inequalities among nations; this may best be achieved by efficiently managing a developing country's resources. Another ideological aim is to provide help to the very poorest in a nation, often within the context of land reform. In both cases GIS may have a part to play. Less ideologically, a supplying government may wish to eliminate that poverty in one country which is seen as a threat to its own security. Technology transfer may be perceived as a means to this end. A further aim of a supplying governement may be to create work for its own under-utilized work force by funding development projects restricted to its own manufactures or requiring its own expertise (or both).

4.0 CONSTRAINTS.

We are considering seven groups of constraints.

4.1 FINANCIAL CONSTRAINTS.

Some developing countries are poor and lack resources, others are richer but dependent on a few commodities. These characteristics create economies which are prone to inflation and where money flow is unpredictable. For a poorer country dependent on aid for technology transfer a single (large or small) grant may be received for acquisition of a GIS, or several (large or small) grants may be received but be unpredictably spaced. For a country producing a valuable commodity a fall in its price may lenghten the period over which the financial investment (whether large or small) can take place, or result in the complete cessation of further investment. When planning the installation of a GIS system an attempt must be made to predict the type of money flow, and the technical specifications and implementation strategy developed accordingly.

4.2 MANPOWER CONSTRAINTS.

Skills can be described as professional, technological, or operational. In the past skills were acquired through on-the-job training after a general secondary or tertiary education, and this approach may continue to work, even in high-technology industries, as computer awareness becomes part of the general educational package. However this model does not exist in developing countries. Computer awareness is not general. There may be a relatively large pool of academically trained personnel with professional potential, but who have had little opportunity to develop computer skills. Apart from those with an academic training there may be an extremely small pool of educated personnel. There will certainly not be a high-technology industry where on-the-job training can be acquired. Any organisation hoping to implement a computer assisted mapping system in a developing country will have to give far more consideration to manpower training than is expected in developed countries, and of course more finance.

On-the-job training has to be replaced by training courses. If the acquisition of a system has already been planned such courses have to be efficient, and must be directed to the manpower needs of the system. Professional training has always been associated with university-level institutions, and may be undergraduate (3-6 years) or postgraduate (1-4 years). But for this training to be efficient it will have to prepare its students to step immediately into decision making positions, which can only happen if students have had exposure to a very wide range of systems or the specific system they will be using, and exposure to a very wide range of mapping problems or the specific problems they will be facing. The 'very wide range' solution should be searched for, but may not be found. The 'specific' solution is found in well designed student projects carried out at institutions with the right equipment; such projects may be part of a post-graduate course. Post-graduate courses may be the best way to train professionals from developing countries, but very careful attention must be paid to selecting the course. Suitable candidates for these courses can be selected from the pool of young academics in the developing country; such people need technological and decision making capabilities and their university transcripts or references should indicate this. Their diplomas may not.

In developed countries technologist level education is associated with colleges of technology. Developing countries may be poorly supplied with such colleges. In developed countries these colleges are unlikely to provide a technologist from a developing country with relevant project experience. However the education of these people is extremely important as they will provide, for example, the system managers. They will have to be familiar with many technical aspects of their system.

Manufacturers also provide training courses. To be useful to future technologists from developing countries such courses may have to cope with a low education level on entry. Evaluation and feed-back are extremely important. Such courses are expensive. Identifying suitable staff for technologist posts may be difficult, and may require special testing procedures or very rigourous interviewing. At the moment there is little contact between the conventional education establishments and manufacturers over the training of GIS personnel. Consideration could be given to more cooperation between the education establishments and the manufacturers in the design and supervision of projects for personnel from developing countries.

In developed countries operator level training is on the equipment staff will use, and is carried out by their eventual supervisors, or training staff working in close collaboration with the supervisors. When a system has still to be installed such training has to be replaced by courses. A course must be at an organisation using similar equipment for similar projects, and with training experience. Such an organisation may be a mapping organisation in a developed country or a suitably equipped educational institute. Such courses are unlikely to exist as standard offerings in any organisation, and will be expensive. Because of the numbers, the training of operators will be the most expensive training element for any organisation in a developing country if it is decided that a pool of trained operators have to be ready as soon as a system is installed.

4.3 ENVIRONMENTAL CONSTRAINTS.

Generally manufacturers indicate some limits related to temperature and humidity beyond which their equipment is not guaranteed to function. The natural environment in many developing countries does not fall within these limits, thus if users are going to adhere to their guarantee conditions, air conditioning will have to be used. This is an expense additional to the actual system. It may be in the manufacturer's interest to ascertain whether the environmental limits are too strict.

Wildlife in the form of ants and rats may present problems which have implications not found in developed countries.

Many developing countries do not suffer from the extremes of cold found in developed countries, and their building construction is lighter. Without additional investment in construction, workspaces may be prone to roof leakage and vibration.

Dust is a characteristic of developing countries, and uncontrolled can affect the surfaces of storage media.

Finally, variable electrical power supply can be damaging to computer systems, and this is a common problem in developing countries. Extra investment may be required.

4.4 LOCATIONAL CONSTRAINTS.

Developing countries are often located far from equipment manufacturers. Long distances present a risk to manufacturers, and only those with good capital reserves can afford to be interested in such markets. This leads to a lack of competition, and prices higher than those found in developed countries. The prices for computer assisted mapping equipment are also extremely high relative to local prices for other goods. These high equipment prices compared to locally low labour costs create an unfavourable cost-benefit situation for high technology and make such purchases unattractive. So the number of sales remains low, further discouraging competition in the market-place and thus continuing the cycle. In consequence initial investment costs are high, stay high, and cannot easily be met. Elimination of this problem is difficult. Funds are often short and loans (or at least their repayment) may further widen the economic gap between industrialised and developing countries, and this gap created problems in the first place. Grants are only a temporary remedy because they occur infrequently, may not include follow up, and in times of economic depression in donor countries, may cease altogether.

Even when equipment has been successfully installed the location of developing countries causes difficulties in equipment maintenance. Because of distance repairmen's visits are expensive. Cases are known where users have had to wait a whole year for a repair, leaving the equipment idle the whole time. Manufacturers are encouraged to establish local representatives only if they can expect a financial benefit. Most hardware required for GIS is not yet commonplace in developing countries (in any application), so an attractive number of sales is not possible, and local representatives are not established.

However the reliability of computer equipment has been improving and this development is expected to continue. Central processing units, digitizers, plotters, printers, Winchester disks and drives, floppy disks and drives are all expected to give long service with minimal repair. Hard disks and drives, alphanumeric and graphic screens, magnetic tape units, and interfaces fail more often, but the repair may consist mainly of diagnosis and the replacement of the faulty part. Often difficulties occur when various equipment items are not under the responsibility of one manufacturer, or when interfacing between items from different manufacturers is new and insufficiently tested. But there is some hope for improvement. First of all insufficiently tested interfaces should not be incorporated into the acquired equipment. Manufacturers should be encouraged to standardize and improve diagnostic procedures so that users may easily complete them with little (e.g. only telephone) or no help from the manufacturer, and replace any faulty part themselves. An unfavourable aspect of th s procedure is that the user is obliged to keep a rather large stock of spare parts, making investment costs higher. A possible solution is the use of express delivery services from the manufacturers' stocks, but this increases costs too.

Special problems are created by software "bugs", which, although less serious than hardware problems, are much more difficult to repair, because the user is denied access to the source programs. The problem of software "bugs" is world-wide, but the isolated location of developing countries makes it more serious for them. It is difficult to imagine that manufacturers will change their protective attitude towards software, although new techniques have been developed which enable alterations directly to the executable versions of programs. The way to avoid the problem of "bugs" is to use only software which has been extensively tested in practice, but this will exclude the use of the newest programs.

Obviously the best solution for maintenance is to make the staff at the location in a developing country more self-sufficient, so that they can execute repairs on their own. This again stresses the central role of education, and of training in computer related skills.

For more efficient maintenance in developing countries it could be recommended that all computer using organizations situated close to each other combine their efforts. But it is questionable whether this will be possible in practice, because of the variety of equipment and organizational problems.

4.5 MOTIVATIONAL CONSTRAINTS.

Another obstacle which makes the transfer of technology difficult and which jeopardizes its application once it has been transferred, is the low motivation of employees in developing countries. Low salaries are the most serious reason for lack of motivation. The employees are forced to search for various sources of income and acquire several jobs. They cannot devote sufficient attention to any single one of them, and this has consequences when the application of new technology is involved. Very often even the simplest means of motivating staff are missing, such as promotion and achievement recognition. Finally the failure to meet objectives in any particular project causes cynicism, a feeling of purposelessness, and is thus demotivating.

It seems rather easy to recommend measures that will improve motivation among employees, but their successful execution requires major changes in the economic conditions and the social structure of developing countries. Increasing salaries only for the staff dealing with high technology will create a new technological elite. Motivated consultants are a temporary solution.

4.6 INSTITUTIONAL CONSTRAINTS.

Institutional practices in developing countries generate many constraints for technology transfer. Corrupton is the most serious of these. Although a worldwide problem, the extent of corruption in developing countries must make it a matter for concern. Through corrupt practices unqualified and incompetent, but often influential individuals may be drawn into the ranks of the civil service. Such executive officers surround themselves with relatives and friends, or other corrupt individuals, instead of surrounding themselves with qualified and efficient staff. Corrupt customs and bribery slow down the acquisition of equipment, make it additionally expensive and prevent normal selection procedures. The result is obviously the late delivery of expensive and often unsuitable equipment. In contrast to the private sector corruption in the public sector is often publicised, and this creates the false impression that it is only active in the public sector.

Another completely different problem is the drain of qualified personnel due to the very early retirement age permitted in many countries. In such a way qualified and experienced staff end their career just when they are in a position to be most useful.

Governments in developing countries often assume an increasing number of responsibilities in order to promote development. If the social structure is reasonably democratic this may create multi-level bureaucracies, which inevitably function slowly. To avoid this independent government groups directly responsible to a minister or even head of state may be created. Such groups (although perhaps suitable for experimental work) are prone to exploitation by empire builders, who will not easily cooperate with other groups in similar fields. Regardless of the structure in the civil service, organisations are established within the public sector which are not required to function as effectively as they might if exposed to all market forces and apart from the excessive bureaucracy and empire building already mentioned autocratic decision making and a lack of power delegation may go unchecked, reduce efficiency, and increase costs - thereby limiting the exploitation of high technology.

A final institutional characteristic is that there may be an excessive number of managerial staff with no technical function, but having a requirement to be involved in technological developments. Their involvement also increases financial and time expenditures.

4.7 POLITICAL CONSTRAINTS.

Some of the political conditions in developing countries constrain technology transfer. Political instability especially undermines long-term development in many countries. High technology transfer represents long-term development. The rejection of western culture in some countries generates resistence to technology. Incompatibility between the political system of a potential supplier and the receiver of technology prevents an otherwise advisable transaction. The abuse of power in dictatorial regimes may lead to the establishment of projects for completely selfish reasons and they are thus almost doomed to fail. High technology may be considered to have military or strategic significance. The transfer of such technology may be restricted to maintain an extant military power balance.

The above mentioned political and institutional constraints may be diminished by some administrative and educational measures, but their roots lie deep. The elimination of these "social" constraints is a formidable task and we will have to accept the development consequences for some time.

5.0 TECHNICAL SPECIFICATIONS.

The success of an implemented mapping system depends very much on good technical specifications. As shown in Figure 1 specifications are a function of suppliers' and receivers' objectives, and constraints. Careful and precise specifications for all four components of the system - space, hardware, software and manpower - are equally important.

As indicated in section 2.0, reliability is an extremely important technical specification in developing countries. This may take the form of guaranteed minimum downtime and an agreement to correct all software "bugs" found. To be an effective guarantee for hardware this will require fairly local service personnel. Good software can be serviced at a distance. Bad software can only be used by staff with considerable experience of that software and its "bugs". So called portable software may not be as portable as envisaged when non-standard peripherals are used, so portability guarantees are another aspect of reliability. GIS is a fast developing technology. New and more efficient solutions appear almost sooner than one is prepared to accept them. Because it is unlikely that an organisation in a developing country will buy a system in its entirety at one time, or because the vital nature of the problems of a developing country will always result in a demand for the best solutions, systems simply have to be flexible to permit the incorporation of future unpredicted technology.

Even a successfully implemented mapping systems may cause demotivation if it does not deliver results as stated in development policies. Individual systems may form a part of a much larger integrated GIS and therefore an individual system should be able to export and import information to and from other systems both physically and conceptually.

Specifications should also identify manpower requirements. Because sufficient qualified manpower is usually not found locally, the mechanism for training the available manpower has to be specified.

Once specifications have been established procedures for finding a suitable system commence. Compared to similar exercises in industrialised countries, an extremelly limited choice of hardware may be available for testing. The systems with good support inside the country are always preferable to otherwise superior systems with little support. This makes the selection procedure easier, but at the same time one may have to adapt the technical specifications to the available systems and make a number of compromises.

6.0 IMPLEMENTATION STRATEGY.

System implementation strategy provides guidelines for the distribution in time of components acquisition and implementation. The components are either physical or manpower.

Considering manpower resources, an organisation may import skilled staff, or train its own people. Training may be carried out externally, or in-house. Different training approaches were discussed in 4.2, but it is our experience that training at the operator level must be given immediately before skills are implemented, or they will be lost.

Considering physical resources, an organisation may choose to implement a system in its entirety, or in modules. Modularity can be achieved in several ways. For instance it may be achieved by purchasing a "starter-system" consisting of a single graphics/alphanumeric screen; digitizing, interactive editing, and plotting software; a digitizer; a plotter (at least A3 format); some magnetic storage; and a "super-micro" central processing unit (cpu). As more funds become available this system can be upgraded in several ways. For example one can purchase an additional cpu; more graphics screens, more digitizing capability, data manipulation software; more plotting capability. If there is an element of self-funding, products will have to be sold before additional modules can be purchased. Modularity will be achieved by initially concentrating on those aspects of a system which produce saleable products.

Only countries with a large supply of assured funds at the outset of the development will be able to adopt a non-modular approach and at the same time buy an advanced (operational with high quality output) system. However such countries may opt for a modular approach for educational or managerial reasons.

Whether or not an organisation adopts a modular implementation strategy, a decison will have to be made on whether to buy the system hardware and software from one supplier, essentially a "turn-key" system, or from several suppliers. With the purchase of a "turn-key" system one is dependent on one supplier and the responsibility for servicing is therefore completely clear. However if the market in a country turns out to be particularly small for that supplier he may renege on his responsibilities, with no other supplier willing to step in, thus rendering the whole system useless. A "turn-key" system is not tailored to actual needs and may also present the operator with redundant software, and encourage a "black-box" attitude towards the system, but a timely product is guaranteed. To build a system from a variety of hardware and software (including in-house software) will be a good educational experience, take an unpredictable number of (salaried?) manhours, and definitely create hardware and software servicing problems. If a development is highly product driven, then a "turn-key" system in conjunction with a good servicing contract is advisable. An organisation may not be entirely free to choose between these various options because of financial constraints, so, very few organisations in developing countries will be able to opt freely.

Components have to be implemented in the following order (Figure 2), although looping may occur with a modular implementation strategy.

Figure 2

SYSTEM IMPLEMENTATION

	PHYSICAL COMPONENTS	MANPOWER COMPONENTS
1		planning manpower
2	space preparation	
3		systems manpower
4	hardware acquisition	
5		software manpower
6	software acquisition	
7		operations manpower
8	materials acquisition	
9		distribution manpower

7.0 CONCLUSIONS.

Technology transfer is an important issue. Attempts to realise it must be continued despite difficulties, but one must proceed selectively and cautiously. The successful implementation of technology depends not only on good technical specifications, but also on the right social, political, and institutional environment. The existing type and capacity of educational institutions in developing countries are not adequate. Education abroad is therefore unavoidable, but usually special courses are required. At the same time local educational support has to be strengthened. Educational institutions in developing countries should be provided with computer facilities to enable hands-on practical training. Special attention should also be paid to on-the-job training. The training of technologists and operators which forms the basis for the implementation of a new technology has to be given a high priority. For the long-term planning required of a GIS reliable funding must be assured.

DIGITAL CADASTRAL INDEX MAPS
FOR A LAND INFORMATION SYSTEM
IN TRINIDAD AND TOBAGO

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ABSTRACT

The need for Land Information is much more critical to developing countries than to the developed. The former have to maximise the returns from resources already available in the country. This paper explains the LIS concept, the essential components, and major functions. The difference between a multipurpose cadastre and LIS is clarified. A parcel based LIS with a data base structure capable of growth is advocated for developing countries whose present land data sources are akin to those in Trinidad and Tobago. The digital form of the Cadastral Index Map is seen as the linking device between subsystems. Transformation techniques based on the least squares and colocation principles are given to refine the existing cadastral index diagrams in order to improve their metrication properties.

LAND INFORMATION SYSTEM CONCEPTS

The concept of Land Information system appears to have been vaguely described and misunderstood in the surveying community. Computerised land based data which were originally contained in files , registers, card indexes and maps is concieved to constitute a land information system or subsystem. This is incorrect and some clarification is appropriate.

A Land Information System (LIS) is defined by the Federation des Geometris (FIG) as follows:

> "A Land Information System is a tool for legal, administrative and economic decision-making and an aid for

planning and development which consists on the one hand of a data base containing spatially referenced land related data for a defined area and on the other hand of procedures and techniques for the systematic collection, updating, processing and distribution of data. The base of a land information system is a uniform spatial referencing system which also facilitates the linking of data within this system with other land related data." (Eichorn, '82).

It is evident from the definition that LIS is a facilitating system for generating decisions with the view to initiating, planning, developing and controlling the use of land based resources. Information is different from data and the distinction is important. Data are values not necessarily numerical, assigned to attributes of entities that are not used in the decision process. By contrast, information consists of classified and interpreted data required for decision-making. For example, market values of land parcels residing in land registry records constitute data. These figures when classified by geographical regions, over predetermined periods and vendor-vendee relationships, provide information, for decision on land valuation.

A system implies the existence of a number of subsystems. Geographical positioning, Legal cadastre, Fiscal cadastre, Utilities and Building cadastre, Topography, Land Use, Demography are examples of subsystems of a LIS. Each of the subsystem may be composed of further subsystems. A co-ordinated network of subsystems is characterised by its synergy, that is, all subsystems or elements are more effective in the system taken as a whole, than if they were functioning independently. In other words, decisions made on the basis of information from all relevant subsystems is likely to be better than those made from each taken separately. This, however, implies the existence of a defined policy, a procedure, a rule, or a set of guidelines for decision making, formulated, on the basis of ranking goals. Lack of such decision making guidelines will no doubt result in negating the purpose of an information system and reducing it to a data source.

The key word in the definition of a LIS that distinguishes it from a multipurpose cadastre is 'data base '. This term evolved with advances in computer data storage and became current in the late 1960's. It is used to refer to a collection of interrelated data stored to serve many applications. The basic components of a data base are:

(i) A data bank - which is a collection of data relating to a given subject.

(ii) A data base management system (DBMS) - a system enforced through a software to update, add and/or retrieve attribute values of identified data elements.

(iii) A data dictionary - which is a catalogue of all data elements giving their names and structures.

The distinguishing characteristics of a data base are:

(i) Logical data independence - which refers to the ability to change the overall structure of the data base without changing the application programs instituted to process information.

(ii) Physical data independence - this refers to the independence of the physical location of the data and the logical relationship betwen them or the application programs.

It is therefore evident that a computerised land data system does not necessarily constitute a data base, unless it contains the identified components and characteristics. Physical and logical data independence enables growth of data bases which property is not available in manual or non-data base subsystems. The latter permit increase in attribute data values but not new attributes or data elements.

The essential components of a LIS may therefore be summarised as:

(i) One or more Data Banks of attributes of land in a form that can be integrated or related to each other.

(ii) Data Base Management System.

(iii) A series of application programs prepared to process data on the basis of identified procedures and policy guidelines to provide information.

(iv) Procedures, and techniques for the systematic collection and validation of data as well as the updating of the data bank.

(v) Feedback mechanism to assess and improve application programs and data requirements.

INTEGRATION OF SUBSYSTEMS

The growth of computer technology and the demand for improved and efficient transaction processing in the industrialised nations have contributed greatly to computerised land data systems. This is evident from a study of operational systems in Austria, New South Wales, South Australia, Sweden and West Germany (FIG 82; Hamilton, '85). These were iniated to improve the processing of transactions at the land registry. The Land Registry in Britain has recently embarked ona similar venture (Sharman, '86). The Wyandotte County, local authority in USA operates a system directed towards improving its fiscal cadastre, and reports cost effectiveness resulting from efficiency in collection of land and building taxes (Rhodes, '85). Attempts are in progress to update most of the above systems which are land parcel oriented to LIS. On the other hand the Maritime Provinces and Alberta State both in Canada and Victoria State in Australia are progressing systematically towards the formulation of LIS, based on geographical positioning subsystems. The basic entity in the former group of data systems is the legal land parcel with the exception of Wyandotte County which uses rateable land parcel. The latter group however may have points, strings, polygons or even solid figure entities.

Updating, land parcel based systems to LIS involves the need to establish a linking mechanism which is capable of relating data in the various subsystems. This integration process is obviously facilitated by the spatial referencing of all data. If however, all the data is parcel based then some measure of integration is possible if they bear a one to one relationship with one or more land parcel. The limitation is essentially in respect of point and string data. The usefulness of such data is reduced through generalisation when associated with a polygon. Raster type or statistical data can however be used with little or no loss of precision. Further, statistical analysis or study of spatial variations of data, an essential requirement of information, is restricted or complex. Therefore the systems potential as an information source is constrained. The use of spatial reference of a single point in each land parcel helps to overcome these defects to a great extent. The assumption here is that all data can be attributed to the chosen points. Where parcels are large or constitute long corridors this assumption may not be valid and can result in distortion of information. Partitioning of such parcels is an adequate solution, but spatial referencing of parcel boundaries improves the system capability considerably.

A resource that is available in many developing countries. but seldom used effectively for spatial referencing, is the cadastral index diagram. They are used at present by land registries and national survey organisations as indexes to record ownership, plan reference, title or deed documents storage location etc. Such diagrams are generally on the scale of 12 ch to 1 inch (1:9504). Larger scales are used in urban areas. These diagrams have been maintained for over a century. They are compiled by reducing larger scale cadastral plans to the nominal scale and positioning them in the diagram by ensuring visual coincidence with boundaries already shown in the diagram, or through co-ordinates, derived from smaller scale topographical maps. The cadastral surveys though of sufficient precision are on independent coordinate systems and are seldom connected to the national reference frame. Therefore the orientation and positioning of the surveys in the cadastral index diagram is of questionable accuracy. It may therefore be appropriate as an initial step in the direction of formulating a LIS, to consider refining these diagrams, with the view to improving their metrication properties. This suggestion may also be viewed in the light of other land data sources.

Physical features of the landscape and thematic resource data are recorded in topographical maps which were generally on the scales of one mile to an inch (1:6360). The introduction of the metric scale and larger scale topographical maps rarely contributed to rationalisation of sheet boundaries to accord with index diagrams though they were redesigned on scale of 1:10,000. Data from index diagrams were seldom reconciled with topographical maps or vice-versa. Reasons for these may be sought, in the lack of co-ordination of the techniques and personnel, involved in mapping and cadastral surveys, of developing nations.

Demographic and other socio-economic data are on the basis of the smallest administrative unit of the country. Their correspondence with topographical map boundaries or index diagrams is rarely established. Local Government, Planning, Valuation, Utilities, and other land data source organisations adopt their own systems and methods to record data. Some use topo maps or cadastral diagrams as their base map but the methods employed to add data are so inaccurate that they require extensive validation.

Much of the lack of integration of land data may be attributed to the absence of sufficiently large scale base maps showing parcel boundaries. Cadastral index diagrams continue to function as reference diagrams only. The precision of individual surveys that constitute the diagram has increased over the years, sometimes disproportionate to the needs, but, the diagram as a whole has not acquired the status of a map. Simultaneously with the refining of cadastral index diagrams correspondence of details appearing in topographical maps requires to be established. Land data source organisations may then validate and transfer data to these base maps. Spatial referencing may thereafter be achieved by digitising these maps. The maps in themselves are valuable analogue data sources for decision making when contrasted with the present recording in files, registers and diagrams.

REFINING CADASTRAL INDEX DIAGRAMS

In Trinidad cadastral index diagrams (referred to as Ward Sheets), 140 in number are on the scale of 12 chains to an inch (1:9504). They are nominally on the Cassini projection. Urban areas are covered by 17 section sheets on the scales of either 1:1250 or 1:2500. The data on the index diagrams are being transfered photographically to 191, 1:10,000, UTM sheets. This implies a change of scale and orientation as a whole to visually match three or four plotted positions. Problems of sheet edge matching is solved by compromise and the art of the draughtsman. The ward sheets may be characterised as giant jig-saw puzzles of reduced legal survey plans The legal survey plans are generally on scales varying from 1:500 to 1:5000, the latter scale is for rural agricultural land.

Two approaches are suggested for improving the metrication property of cadastral index diagrams of Trinidad. They were carried out in a test area and the results are given, (Table 1).

The first approach uses the principle of a two dimensional conformal transformation. The transformation parameters are computed using the national coordinates of identifiable points on the index diagram. These are similar to ground control points used in photogrammetric mapping or control extension.

The transformation model takes the form:

$$\begin{bmatrix} e \\ n \end{bmatrix} = \begin{bmatrix} a & -b \\ b & a \end{bmatrix} \begin{bmatrix} E \\ N \end{bmatrix} + \begin{bmatrix} e \\ d \end{bmatrix} \qquad (1)$$

The quantities on the left of the equation refer to digitised coordinates of stations their national coordinates are (E,N). a, b, c and d are the transformation parameters, they are functions of the scale, orientation and origin of the digitiser frame. With sufficient control points a least square solution is possible. The transformation model is then inverted to determine the national coordinates of other points whose digitised coordinates are measured.

The assumptions in this approach are:

1. Distances and directions in the index diagram are based on the same standard or reference direction.

2. There is no scale variation over any one refined index diagram.

3. The nominal scale of the index diagram does not correspond to he scale of the refined diagram.

4. Factors arising from non-uniform shrinkage of the index diagram are controlled.

The first assumption is strictly valid in so far as the points are in respect of the same cadastral plan, where they are from different plans errors arising from non-standardisation of distance measurement may be ignored considering the scale of the diagram. Use of different reference directions cause the largest errors. However it must be stated that a measure of uniformity in reference direction is obtained on the diagrams by the need to ensure coincidence of boundaries of abutting surveys. Use of the grid north derived from applying a convergence correction to magnetic north is also helpful.

The second and third assumptions relate to the map projection and the inability of the method to model scale variations prevalent in an orthormorphic projection. This may be ignored considering the purpose for which the refining is attempted.

The residual errors obtained at the control points are measures of the extent of deviation from these assumptions. They may be used to review the fixation of relevant cadastral plans.

The second approach is an attempt to use the Colocation principle to model the errors inherent in the assumptions of the first method. The mathematical model takes the form

$$O = AX + S + n \quad \ldots\ldots\ldots\ldots \quad (2)$$

where O represents the observed digitised values, X the transformation parameters, A the national coordinates, S is called the 'signal' and n the 'noise'. (S + n) represents the residual in the least squares transformation. The 'problem of refining cadastral index diagrams is here reduced to one of determining X, the transformation parameters and the signal corresponding to any digitised value. The solution is dependent on determining the covariances between signals of control points and between observations and the signals.

The covariances were derived from residuals obtained at the control points when the least squares method was applied. Attempts to fit a continuous function for the covariances was unsuccessful and the derived discrete values were used.

The reader is referred to the report on the method of colocation (Moritz, '72)for a detail account of the principles and proofs.

The validity of both methods were checked by comparing computed national coordinates with known values. The difference is identified as the error and tabulated in the table along with the linear displacement of the points. It is seen that the mean linear displacement for the first method is 7.7m, and 5.5m for the second, while the least plottable error is 1m. The method of colocation, generally gives better results. The mean displacement may be identified as a measure of the accuracy of the refined index diagram.

The choice and distribution of the control points for the computation of the transformation parameters and the covariances requires further investigation. A suitable continuous covariance function is likely to improve the results further.

CONCLUSIONS

Information consists of classified and interpreted data for decision making. A collection of a variety of data, requires, a set of objectives and stated goals for processing and providing information. However, data collected from a number of sources may not be integrated unless they are linked and their correspondence is established. The cadastral index diagram used by most developing countries is seen as a useful resource to integrate land based data. The need to improve the metrication property of these diagrams is proposed, two approaches are suggested and demonstrated.

ACKNOWLEDGEMENTS

The author acknowledges with thanks the assistance given by Mr. Malcolm Robertson for furnishing the data relevant to the Ward Sheet, Mr. Maurice Elliot for digitising and Ms. Pauline Sifontes for preparing this paper.

TABLE I

TRANSFORMATION AND VALIDATION DATA
WARD SHEET NO. 13D/23A

TRANSFORMATION PARAMETERS		
PARAMETERS	LEAST SQUARES	COLOCATION
a	0.0098527	0.0100258
b	0.0000108	-0.0000218
c	-6553.520	-6618.893
d	-11757.260	-11783.519

CHECKS AT POINTS WHERE NATIONAL COORDINATES ARE KNOWN					
STATION NO.	DIGITISED COORDINATES CMS	ERROR EAST NORTH		DISPLACEMENT	
		LEAST SQUARES		COLOCATION	
D 13 - 303	32.05 18.84	02.9 -11.3	11.7	-06.3 00.0	6.3
D 13 - 304	34.51 18.50	07.1 -10.0	12.3	01.5 -08.3	8.4
B - 215	37.28 42.14	-04.2 -04.4	6.1	06.7 -02.2	7.1
B - 219	40.41 50.60	05.1 -05.5	7.5	02.1 -07.3	7.6
B 222	43.57 56.02	07.2 -03.1	7.8	-00.4 03.5	3.5
B 225	45.80 59.32	09.5 02.5	9.8	03.3 00.4	3.3
B 227	46.01 61.61	04.5 03.8	5.9	-02.8 -02.7	3.9
B 229	48.73 63.32	05.9 02.1	6.3	03.6 02.8	4.6
B 230	48.79 66.22	-00.2 -02.0	2.0	-04.5 00.1	4.5

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COMPUTER ASSISTED CARTOGRAPHY IN DEVELOPING NATIONS

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ABSTRACT

This paper examines the arguments for and against the introduction of computer-assisted cartography in a Third World context. The general arguments will be considered by using case studies from Nigeria, India and China. Computer-assisted cartography can be an even more appropriate form of technology in developing nations than in industrial societies but it must be seen within the context of a new approach to cartography. In this respect the technological aspects are only one, and perhaps not even the most important issue. Appropriate technology is defined as that most appropriate to the task. In some instances that is simple technology of a labour intensive type and in others it can be the highest technology which can be capital rather than labour intensive. If a new view of cartography and its role in the development process is taken then computer-assisted cartography has much to contribute.

COMPUTER ASSISTED CARTOGRAPHY IN DEVELOPING NATIONS*

Introduction

There is no doubt that computer-assisted cartography has a positive role to play in developing nations but for this to be effective there are problems which must be overcome. This paper will argue that in addition to the normal range of problems in technology transfer, computer-assisted cartography faces special problems not the least of which is the need for a radical reappraisal of the nature and role of cartography in the information era. A "New Cartography" (Taylor 1985) is emerging in post-industrial societies which demands adjustment in a variety of ways. Some have argued that sophisticated technological developments have little relevance to developing nations. It will be argued here that some aspects of modern cartography may be of even greater utility in developing nations than they are in the post-industrial societies of Europe and North America in which they are being developed. Appropriate technology is perhaps best defined as that most appropriate to the tasks at hand. This requires a thorough understanding of these tasks and of the socio-economic setting in which they are to be performed. Cartography for development is quite different from the development of cartography although in some instances there may be a close relationship between the two. The arguments will be developed by looking at three case studies from Nigeria, India and China which illustrate the complex issues involved.

Nigeria: False Start in Africa

Cartography in Nigeria lacks relevance to the developmental problems facing the nation. There is a heavy emphasis on the production of topographic maps but despite this emphasis 20% of the country still remains to be covered by any topographic may series (Duru 1985). Computer-assisted cartography is being introduced into Nigeria but in a way which is not likely to lead to significant improvement. Existing mapping agencies are described as being "...almost incapable of producing thermatic maps" (Adalemo et. al. 1985:228). New technologies are being introduced to substitute capital for labour and to replicate existing manual map production methods by automated means. There seems to be no sustained effort to question the relevance of existing cartographic products to the development process or to use the technology to develop new products. This is not to question the need for adequate base maps but in a situation where one of the main problems for socio-economic analysis is that the census has no accurate enumeration maps, new priorities are needed.

*This paper is an extensive revision and extension of some of the ideas on this topic contained in Taylor 1985.

There is an almost classic "catch 22" situation. The government is accused of being unaware of the importance of maps and failure to provide resources to improve the situation, but cartographers are producing inadequate, outdated topographic maps of limited relevance to the pressing and immediate problems of national development. In these circumstances why should the government put scarce capital resources into cartography? This problem is heightened by the fact that the equipment demands being made are usually for very expensive main-frame based systems of a turn-key type which make heavy demands on scarce foreign exchange.

The recommendation for the installation of such systems often comes from foreign experts and vendors for international companies. The latter are understandably interested in profit not development and are unlikely to take this latter element fully into account except in their sales rhetoric. Business practice in Nigeria leaves much to be desired. The system is fraught with corruption and unscrupulous and unethical behaviour. Foreign experts who understand the technology but not the development context in Nigeria are as much part of the problem as the solution and the frustrations of Nigerian specialists in the field with their activities is understandable (Duru 1985, Adeniyi 1985).

The internal situation in Nigeria compounds the difficulties (Wright 1985). Inefficiencies and lack of cooperation can reach levels bordering on the absurd. In 1984 Adeniyi reported that of 93 Nigerians trained abroad in remote sensing only 22 were in positions dealing with remote sensing and of these only five had equipment to work with (Adeniyi 1985). Nigerian cartographers report that "...it is easier for some Nigerians to study cartography in the Netherlands than at Kaduna Polytechnic" (Adalemo et. al. 1985:236).

To borrow René Dumont's phrase, cartography is off to a 'false start' in Nigeria and entirely new approaches are required. A first step towards an improved role for cartography in socio-economic development is a reappraisal of their role by cartographers themselves. There must be a move away from the traditional role of surveyor or draftsman towards that of an information manager. The driving force for a New Cartography in developing nations must be the provision, analysis, representation and transmission of timely spatial information central to the needs of a developing economy. Exciting new technologies exist to facilitate this task but these technologies are in themselves a necessary but not sufficient step towards a better solution.

India: Effective Technological Transfer

India has a long cartographic tradition and a good topographic mapping program. The current Surveyor General, Major-General Agarwal is well aware of the need for new initiatives for cartography (Agarwal 1984) although movements in this direction have been slow and still face many problems.

The Indo-French Compu-Graphics and Planning Project which began in 1979 (Chappuis and de Golbery 1984) is one of the more successful examples of the use of computer-assisted cartography in the development process.

The project is centred in the Planning Department of the Bureau of Economics and Statistics of the Government of the Indian state of Andhra Pradesh. It is designed to provide timely information to both planners and to the people affected by planning decisions.

The project uses microcomputers to process and map data and the output includes both graphic analysis and presentation and statistical analysis. A cheap microcomputer graphic laboratory was installed in 1980 and began functioning early in 1981 despite the difficult physical environment. As is the case in many developing countries, in addition to the problems of heat, humidity and dust, there are sudden surges in voltage and frequent power cuts. These can play havoc with sensitive computer equipment and as a result many mainframe computer installations are only to be found in major cities where a controlled environment can be more easily provided (Taylor and Obudho 1977). Even in these circumstances the machine is usually down as often as it is up. The expense involved in such mainframe installations is very large and ongoing running and maintenance costs are high.

The project uses a Hewlett Packard 9825 microcomputer with a 64K memory. Power problems are alleviated by the use of a power modulator with a battery backup. Other elements of the system include a Summagraphics digitizer, two four pen plotters and two graphic printers. None of these is expensive and the system has worked very well indeed.

The system links data banks of information on various geographical units at different scales such as districts or villages with statistical information which has not been organized on a spatial basis. The programs allow easy use by non-specialists and fast retrieval of information by means of a key-word library system.

Base maps are digitized in a variety of ways to allow output of points, zones, matrices, lines and combinations of these. Maps are output either on the plotter or on the graphic printer.

Data can be output either as straight lists or after various standard statistical manipulations. With maps, simple distributions can be shown or the data can be mapped after statistical manipulation.

It takes about three weeks for an individual with no computer experience to be in a position to fully utilize the system. The Indian participants working with the project are mainly villagers with educational levels ranging from two or three years of high school up to bachelors degrees and in some instances, people using the system are producing graphics the first day they are on the machine.

The main applications are at two scales. Andhra Pradesh is a state of over 60 million people and there is a need for state wide analysis of data of a variety of different variables by district, taluk, or other appropriate geographical unit.

The second scale is the regional one where a comprehensive village data base for one of the districts, Guntur, has been built. Guntur district has a population of around three million people in 730 villages and the data base includes almost 300 parameters. These data are up-dated seasonally whenever possible. A planning atlas of over a hundred thematic maps was produced in less than two months with output on plastic sheets at the same physical size as the standard administrative file (22 x 34 cm.). This allows the planner and administrators at the local level to carry the map along while visiting villages and to use them in situ.

The system is not without its problems and is, of course, only as good as the data which is fed into it. Data reliability and comparability also varies over both time and space. Much of the village data was collected by village officers, for example, and that position has now been abolished. Despite this, impressive results have been obtained and particularly noteworthy is that data for rural development have been made available at the micro-level in a timely, effective manner and by careful use of Bertin's Semiology of Graphics, good graphic illustrations have been produced. The information is both statistically and graphically accurate within the limitations of the accuracy of the raw data and has been produced in a form that people can both understand and use.

As a result the Government of the State of Andhra Pradesh has decided to strengthen the state laboratory and to put compu-graphics laboratories similar to that described here in each of the 22 rural districts. Each of these will be equipped with a microcomputer produced in India and data bases will be maintained for the village, hamlet and household level. A new system of agricultural data collection has been proposed to replace the village officers. Sample field and farmer surveys will be used together with aerial photographs plus satellite imagery analysed using the microcomputer. Adequate image processing systems for microcomputers now exist (ACSM/ASPRS 1986) and are being improved all the time. It remains to be seen if adequate data can be collected and updated utilizing these new methods in the Indian setting.

The project has also attracted interest from the Land Record Department in the state and the cadastral survey maps are now being put on the microcomputer in three stages beginning with village outlines and then farmers' plots. Finally these will be linked with crop information. It is hoped in this way that an 18 year backlog created by the inadequacy of existing cartographic methods can be cleared up.

Arguments for the use of microcomputer based cartography in developing nations have been made before (Taylor 1979; Prashker and Taylor 1983) and demonstrations made, but the example for India clearly demonstrates the potential in an operational fashion.

India has a long cartographic tradition and good base map coverage. There is, in fact, a large multi-coloured Atlas of Andhra Pradesh produced on the model of European regional atlases but this product of traditional cartography is of very little value to the development process. As Jacques Bertin comments, the data on which the atlas was compiled is seriously outdated and the atlas itself difficult to consult and use (Bertin 1984).

The contrast with the micro-based system is a startling one. Bertin argues that the system gives administrators the maps and matrices they need for planning purposes; the state of the last rice harvest, the last use of irrigation water, the real distance (non-linear) of each village to fertilizer depots, seed stores, milk collection centres, health services, etc. The micro system is powerful and reasonably cheap and will utilize computers produced by Indian industry. Indians involved in administration and planning at the grassroots scale can use the system to solve real problems and can interact with the system to produce analyses and new maps to their own specifications. The system as currently configured is a highly decentralized one but it can be considerably expanded while preserving the necessary homogeneity required to central planning and comparative purposes. A network in this case can be constructed from the "bottom up" rather than from the "top down" as is more often the case. Bertin argues that the cartographer's role is to define the smallest possible number and types of maps and diagrams with four objectives: to answer the pertinent questions posed by the decision makers; to take into account the human constraints of India; to take into account the physical constraints of "micro-graphique"; and to propose together with the computer programmer an electronic architecture adapted to modern graphics.

Although foreign experts have been involved, the key individuals lived and worked with the project for several years rather than flying in to give "expert advice" and then departing. Bureaucratic barriers in India were also reduced by carrying out the project at the grassroots level.

Graphic presentation of information has particular strengths in an environment where literacy levels are low. Chappuis and de Golbery provide concrete examples of how the presentation of information in map form has made information more comprehensible to Indian villagers in a way which has better facilitated explanations of planning problems and increased awareness of prevailing social and economic inequities.

China: Indigenous Technological Adaptation

Cartographic developments in China over the last several years have been impressive and are an integral part of the development process. The central goal of cartographic production in China is to aid in economic reconstruction. Given the role of the rural areas in China's economy it is perhaps not surprising that "...China pays special attention to agricultural mapping" (Hu and Liao 1984:2) and has produced a series of maps and atlases at the country level for agricultural regional planning. Special attention is paid to composite mapping and to analysing and presenting spatial interrelationships between different factors. The digitized data base of China's 2300 countries is a basic part of the Population Atlas of the People's Republic of China which "...will mainly be compiled by computer-assisted cartography." This same country data base has played an important role not only in population mapping but also in the compilation of an Atlas of Local Diseases. Remote sensing imagery is being used for thematic mapping especially of vegetation, soils, geology and environmental change.

Major attention in topographic mapping is being given to agricultural areas. It is interesting that large scale mapping at 1:10,000 and 1:5,000 was concentrated on intensive farming areas with over 750,000 square kilometres being mapped. This is in marked contrast to many other countries where priority is given to urban areas and no large scale maps of rural areas exist.

Cartographic education at all levels "has been restructured to meet the new demand of national reconstruction" (Hu and Liao 1984:4). To modernize Chinese cartography a major approach used has been to send postgraduate and visiting scholars abroad to update their expertise and then to use these scholars to develop new education and training programmes within China itself.

The contrast between the national situation in China and that in Nigeria is marked. In China cartography plays a central role in national socio-economic development and new cartographic ideas have been introduced by Chinese rather than by foreign experts. In Nigeria many cartographic projects have been carried out by external agencies and foreign consulting firms while in China the effort has been overwhelmingly indigenous. The decision on what is appropriate for China is being made by Chinese.

CONCLUSIONS

The evidence from the three case studies supports some general conclusions:

1) The challenge for cartography is the relevance of the discipline and its products to the development process. Where the contribution is clearly demonstrated to be of value (India, China) there is no lack of support or response from government. Where this is not so, support is unlikely to be provided (Nigeria), expecially in situations where resources are limited and foreign exchange is a scarce and valuable resource.

2) Computer-assisted cartography is likely to be most useful when introduced selectively by indigenous cartographers (China) who understand the complexities of the development context of their own nation. It is likely to be least successful when introduced by foreign experts and consulting firms and can be counter-productive in many instances (Nigeria). Cooperative projects are particularly successful where there is a high indigenous component and an ongoing commitment to development aims by the foreign participants (India).

3) There are some advantages to the adoption of the most modern concepts and techniques of cartography if these are appropriate to the tasks at hand and are feasible in the particular set of circumstances and constraints each developing nation faces. The development of cheap micro-computer technology increases the feasibility of such an approach. New data collection technologies such as remote sensing can provide information vital to survival in a timely and continuously updated fashion. When cloud cover limits the utility of remote sensing radar can be useful for crop yield forecasts (Paul 1986). New communications technologies can be used to disseminate information more efficiently than existing technologies. Modern cartography may be more appropriate for developing nations than "traditional" cartography especially where existing cartographic products are inaccurate, outdated or non-existent. New technologies may allow cartographers to 'leapfrog' over existing approaches in a way which will make their products of more direct utility to development problem solving. A judicious mix of new and existing techniques is required. If computer-assisted techniques are seen primarily as a replacement for labour in the production of existing cartographic products then there is little justification for their introduction.

4) The technology itself is not the central issue; it is the use made of that technology. A micro-based Geographic Information System can be just as inappropriate as its much more expensive mainframe predecessor as an interesting case study by Cowen for Curacao has shown (Cowen 1986).

5) If the role of computer-assisted cartography in developing nations is primarily "technology driven" it is unlikely to make a significant contribution. It must serve as a means to an end rather than as an end in itself. By coming relatively late to the field, developing nations may be able to avoid the many mistakes still being made in Europe and North America in this respect.

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DIGITAL MAPPING - THE CHESHIRE EXPERIENCE

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ABSTRACT

Cheshire County Planning Department has ten years practical experience with digital mapping. The approach adopted is problem-solving rather than research-based. Progress has been made a step at a time by involving partners with similar needs. At each stage lessons have been learnt, clients increased and the work consolidated both technically and politically. The standards achieved do not represent the highest state of the art but the paper shows what can be achieved within limited budgets by co-operation and by the right balance of organisational and technical issues. The paper outlines some of the more spectacular successes and highlights the problems encountered. It concludes by looking forward at the County's total mapping requirement and speculates on what will be achieved in the next ten years.

THE ORGANISATION

Cheshire County Council is a democratically elected Local Authority which is responsible for providing services for about 940,000 people. Cheshire is situated in North West England just to the south of Greater Manchester and Merseyside. It covers a geographical area of 900 square miles and has road network of 5000 kilometres. To operate its services the County Council employs some 39,000 staff in about 2,000 County-owned properties. The County's budget for 1986/87 is £519 million. By far the major share goes to providing Education (£316m) followed by Social Services (£56m), Highways and Transportation (£53m), Police (£46m) and Fire Services (£13m). By comparison the money spent on Planning and Environment Services is small (£3m). Cheshire is divided into eight District Councils who have different functions including housing, the control of development and environmental health.

Local Authorities are statutory bodies funded mainly by rates and taxes. They aim to provide their services to the community in the most efficient and effective manner. All this activity has an important geographical dimension. A vast and diverse amount of data relating to people, places and networks is gathered and stored in manual and computer systems at many locations around the County. Maps play a vital role in presenting and linking together this information.

THE INTRODUCTION OF DIGITAL MAPPING

Digital mapping was introduced into the County Councils' Planning Department in 1976 for two reasons. First, as a means to speed up cartographic services and second, to search large computerised data sets to extract spatially encoded information.

Cartographic Services.

The department had the task to supply District Councils, other County Council departments and the public with details, including mapped boundary definitions, of land parcels which were available for residential and industrial development. The Cartographic Services had difficulty in providing these maps with the parcel boundaries on time because of the large number of sites which required frequent updating. The problem was solved by digitising the boundaries and producing map overlays at the specified scales from a graph plotter. There was a bonus in that the areas of the land parcels were automatically computed.

Searching of Data Sets.

The department held large Ordnance Survey (OS) grid referenced data sets on several topics - planning applications, industrial premises, development sites, archaeology etc. Often these sets needed to be searched to extract information by 'areas of interest' (eg) a list of planning permissions for industrial use in the Green Belt in the last five years. This information could now be extracted by digitising the 'area of interest' and interrogating the file using point-in-polygon searching techniques.

Initial Hardware and Software.

The department operated an AO digitiser which output to a card punch. The software was written in the department in Fortran for an IBM 370 mainframe. This machine was connected by line to a PDP 11/34 which serviced an AO graph plotter in our Highways department some 4 miles away. The Planning Department was off line. This primitive arrangement was to serve us for seven years but the two problems were solved. It was no toy.

DEVELOPMENT

Zonal Model.

It quickly became apparent that the 'ad hoc' manner of digitising 'areas of interest' was inefficient and where areas enjoyed a common boundary for part of their perimeter it could lead to errors whereby data could be found in both zones (or neither) because of boundary overlap problems. The concept of a zonal model was decided upon. Essentially zones would be formed from segments. Segments would only be digitised once and cut and joined to make larger or smaller segments to form other zones. Segments were stored as grid referenced points in a Line File or as elemental segment references in a Line Definition File. Similarly zones were stored on a Zone File or a Zonal Definition File. Each segment has a unique reference number consisting of a feature reference and a spatial reference. The spatial reference uses the 'Left/Right' rule whereby the zone to the left of the segment being digitised forms the first part of the spatial reference whilst the zone on the right forms the second part.

The ability to produce zones meant that thematic mapping could now be undertaken. For example, social statistics from the Population Census could be allocated to the 202 ward zones of Cheshire to produce a shaded ward map by each statistic.

System Development.

Fortunately the IBM mainframe resources were 'free' in the sense that the Planning department did not directly pay for them. However, no professional programming resources were provided by the County's central computing services and only off-peak time processing was allowed. The planning department produced the bulk of the software single handedly over five years at the same time as carrying out its routine tasks.

The data structure has not changed but the plotting and data base system has been improved extensively to increase performance and quality of output. It would seem to be a feature of this type of system that it needs to be continuously developed as data volumes grow and experience with users' requirements dictate the need for enhanced facilities. Perhaps this is inevitable if one considers geographic information systems to be a major extension of Information Technology. However, it does not accord with the Data Processing manager's modus operandi as he likes to finalise the development of systems before handing them over.

Management Considerations.

In a non-profit making organisation like a local authority there are no easily defined guidelines to apply when investing resources in a new activity like digital mapping. In addition, with users' requirements and information technology developing rapidly, it is virtually impossible to balance carefully the likely benefits against extra costs.

The approach we chose was to produce a regular stream of usable output in response to the increasing demands of users. The early history of digital mapping in Cheshire was one of pioneering development by a few people with a joint interest. Critical to the credibility of our service was the timescale of our response. We recognised that is not easy to maintain the enthusiasm and commitment of either managers or users if they have to wait long periods of time prior to obtaining results. Positively responding to our clients and the good-will that this generates has been politically important to the project's survival.

The range and nature of requests have been extensive. Organisations like the Ministry of Agriculture, the North West Water Authority, British Telecom, and County departments such as Architects, Emergency Planning, Fire, Highways, Police, Trading Standards, etc, have all experimented with the facility. Triumphs have been important to our progress, and three of our most prestiguous products have been

1981 Census of Population. The statistics were mapped for the 202 Census Wards of Cheshire resulting in a more easily digestible display of the data. This was a factor in increasing the range of users and analysis of the statistics over previous Censuses.

Areas of Family Stress. Sixteen parameters of family stress such as the number of free school meals, probation orders, youth unemployed etc, were collected for the wards of Cheshire. A map shaded by ward was plotted for each parameter and a summary map showing the ten most heavily stressed wards was produced. This improved our knowledge of the varying social conditions of communities throughout the County and was positively received by both politicians and Chief Officers.

Ecological Data Base. A voluntary organisation, the Cheshire Conservation Trust, surveyed the County area for sites of ecological value. They then approached us to provide a system for their display and up-dating. As a result they digitised some 10,000 sites classified into 20 categories. The maps plotted from this data base have been used in Public Inquiries and pie charts showing the total area of each classification drawn.

This last initiative is an example of another of our management principles - that of co-operation between organisations and departments. Fortunately, within the County Council there has been a high degree of co-operation between departments. The 'free' use of the central mainframe and the Highways equipment and software to plot maps has been paramount. Without it the project would have failed. In return, departments are encouraged to digitise their own data using our facilities. We have also exchanged information with external organisations such as the Water Authority, and the District Councils.

Finally, shortage of personnel with the necessary background and experience required to design and implement the digital mapping system meant that we had to train and develop our own staff. Initially it was not easy to gain their co-operation because the field was new to them and few of the operators had any real technical ability. Understandably they were nervous and the fact that the software was initially primitive and not fool proof did not help matters. By responding immediately to staff problems - technical or physiological - confidence was built up and standards and productivity rose. In short, technical leadership is vital when establishing new practises.

EXISTING SITUATION

The number of segments now on file is around 30,000 and the total number of zones is about 16,000. It continues to grow as users become aware of the facilities and start to put their own data on the system or set up grid reference data files to use with the system.

The whole exercise can be regarded as a development project to gain experience in a new field of information technology and make the County Council aware of the potential whilst at the same time solving problems and bearing some useful products. In this it has succeeded.

A feasibility study has been set in motion to identify the corporate uses of digital mapping and to establish the resources and skills required. This study was recommended by the District Auditor, the Government's watchdog on public sector efficiency, and has the backing of senior management.

Lessons learnt.
A number of simple lessons have been learnt and the most notable of them are as follows

Spatial Data Base. Our most important lesson was the realisation that digital mapping was merely a form of output. We had constructed a simple spatial data base whose data structure allowed us to build a zonal model and an elementary cartographic model. Other models especially a network type, would eventually be needed in the County Council.

Visual acceptance. Our early cartographic attempts were of a primitive standard and generally disliked by the user. Great strides were made subsequently in presenting a good and clean visual product as it was found that users could be more attracted to the blemishes on a map than the message it contained. Colour, various line formats and thickened lines have all helped to de-fuse this initial rejection.

Inconsistent data accuracies. It is necessary to understand the surveyed accuracies of the various topics in the data base to avoid spurious accuracy. Caution is required when producing maps where the plot scale is larger than survey scale. Similar problems occur when creating point-in-polygon searches on zones without making allowance for the survey accuracy of the zones especially at the boundaries. For example, it is not reasonable to search the Agricultural Land Classification data which has been digitised as 1:63360 scale and has a survey accuracy of ± 100 hectares, to see whether a proposed housing development of 20 units lies within a certain class of land. There is a temptation for this type of error to occur because of the ease with which the data bases can be accessed, combined and searched.

Updating. As the number of segments has grown and the frequency that a segment (or part of a segment) helps form a zone increases, then the problem of updating magnifies whenever a segment is changed. By breaking down a segment into two or three elemental line types this problem can be minimised. So whenever these elemental lines are updated, all the relevant segments and zones are automatically updated. Without this facility the data base would eventually become inconsistent.

Data capture. The whole operation of data capture is too slow at present. The cost of reorganising and inputing data from several differently structured paper files can be prohibitive. The use of automated techniques for capturing graphic data is a particularly important issue for us, especially as we currently have virtually no OS digital map data. The data volumes generated are considerable compared to traditional data sets.

Management Techniques. The ability to search, combine and 'layer' zones gives new opportunities to analyse and present spatially located data. Techniques such as 'sieve' analysis have been programmed together with simple searching routines. However, users have not grasped these tools and this lack of experimentation is disappointing. There is a great tendency to concentrate on graphics and to neglect the potential of the digital data base. A great deal of new education is required to increase user awareness. Even then it may be only the enthusiastic who have the motivation to pioneer.

Demand. The demand for our digital mapping service grows steadily as more managers appreciate its role in helping them make speedy decisions about property management, road maintenance programmes, service delivery, route planning, policy planning etc. However the market for our products is at an early stage of development and therefore likely to have a large element of latent demand because users are currently unaware of the possibilities offered by geographic information. The appetite for this information could be insatiable, so a balance needs to be struck between the need to know and the cost of finding out.

A DIGITAL FUTURE

Digital bases in Cheshire have reached a plateau. This plateau has been reached after a ten year ascent and we are now in a good position to realise the full corporate potential of digital systems. We can now see some things very clearly but there are a number of obstacles to overcome on the way ahead.

Geographic information underpins much of the work of the County Council; the analysed data providing a powerful mechanism for informed decision making. We therefore need to develop our spatial digital systems.

It is clear that our immediate technical requirement is to improve our current models - zonal and cartographic - by enhancing our local computing facilities. This can all be achieved for a modest cost and will be valuable in increasing our productivity. By reducing the learning threshold with user friendly software, it will also increase the interest and participation in digital activities by a wider range of users.

It is clear that high volumes of data in digital mapping technology gives rise to problems of cost of storage and speed of retrieval of data.

Finally, it is clear that improved speeds of data capture are a vital requirement for both ourselves and the Ordnance Survey. Our most difficult task will be to acquire the basic digital topographic coverage of the County. Ideally this should be provided by Ordance Survey in a data structure that will allow us to construct several models. The only realistic way this can be achieved over the next 5 years is through technological development. Raster technology is moving in the right direction, but there are still problems to overcome, and further work is required on pattern recognition.

One way forward is for us to join with our partners such as the Statutory Undertakers and the District Councils, and commission a project to digitise a limited number of topographic features fully structured at a lower standard of accuracy than OS. Alternatively we may resort to raster cover with limited vectoring. This would allow us to produce thematic maps on a topographic background and, most importantly, to produce models to allow us to tackle operational work such as police and fire fighting activities, emergency planning and road maintenance. It is these basic 'life or death' uses of digital data which may help to trigger the necessary financial investment at a time of severe financial restraint.

When we reach this point the summit will be in sight.

CONCLUSION

We must now launch our second initiative. This is to mount an ambitious development project on a corporate basis. This 'demonstrator' project will tackle operational type problems and increase the range of users, the areas and intensity of use. The project will need to find partners amongst the District Councils, the Statutory Undertakers, the Universities, the private sector, the software houses and the Ordnance Survey to fund, implement and demonstrate that the digital world has arrived at the work bench.

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Footnote: Any opinions expressed are those of the authors and not Cheshire County Council.

MARKETING DIGITAL MAP DATA

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ABSTRACT

Suppliers of topographic information will only stay in business if they meet the needs of their users. For centuries the map has been the obvious way in which to present the information, but with the advent of computers users are asking for it in other forms. Nevertheless, basic marketing concepts still apply and the paper will discuss them.

INTRODUCTION

Computers are now firmly established as part of the fabric of modern society; they support such diverse functions of everyday life as financial transactions, academic research, and controlling the temperature in a greenhouse. The public at large is increasingly exposed to new technology and, particularly amongst the business community, this demands the re-appraisal if not of corporate objectives, at least of the means by which they are achieved, and opens doors to exciting and challenging new opportunities.

Collectors and suppliers of topographic information are as involved with these developments as anyone, and there is no doubt that Information Technology will radically affect the services we can offer in the future. For centuries the printed map has been the medium by which the information has been presented, and we can be confident that it will retain such a role for years to come. But alternative forms are being demanded by those users who are introducing computer-based systems to their organisations. To survive, the supplier must identify the means of satisfying economically these emerging and developing requirements. This is the fundamental law of marketing as relevant in the world of digital mapping as of digital watches.

MARKETING

This need to be user-aware is described by John Frain in his "Introduction to Marketing":

"A business organisation should face outwards towards the wants and needs of users and not inwards towards what it likes doing or is experienced in doing." (1)

Philip Kotler in his study of marketing for non-profit organisations talks of "de-marketing or the cutting back of unneeded services" as being "just as important in a comprehensive marketing programme because the ultimate goal is improved efficiency". (2)

INFORMATION TECHNOLOGY

It is comforting to realise that sophisticated as they are, computer systems are unable to do some of the things we humans can achieve, frequently without conscious effort. For example, they are not good at making deductions and need much more data than we would find necessary. Their contribution to greater efficiency and better informed decision-making stems from their ability to store vast quantities of data in a compact form, to retrieve and manipulate it very quickly, to transfer it almost instantaneously over long distances, to display it in a variety of formats, and to do all of these with the minimum of manual intervention, tirelessly.

DIGITAL MAP DATA

There is a need to emphasise the title of this section and to make the point that it is more than 'Digital Mapping'. There are some producers who see digital technology merely as a means of automating map production rather than as the solution to some of the problems inherent in the map as a means of communication, and as the opportunity to provide new services. The first steps along the digital road were taken by conventional map producers and it is hardly surprising that 20 years ago none of us could have seen the full scope to be provided by technology for combining sets of information previously difficult to relate, and thus the role of the digitised map as a base for other spatially related data. That inability to foretell the effect of new technology was not due to a lack of awareness at the time and the accelerating rate of development in this field is going to make it no easier to get it right in the future. However, steps can be taken to minimize the effect of technological change.

This is a paper about marketing so instead of talking about the suppliers we should have started with the users. How are they being affected by digital technology? Most of them were at home with maps, had developed their own means of using them for their particular purpose and, when using series mapping, accepted it as a reasonably complete picture of their world which would need updating every now and then.

I am not aware of a single customer who had the foresight to demand his map in computer readable form before such products existed. In other words, the supplier created the market, but now that digital map data is available, it seems to many to be a product which fits naturally into the computer-based business environment they are building themselves.

The principal attraction to investing in new technology is the promise of greater efficiency, and implicit in this is the ability to create a system which suits the customer's very own requirements. In the market for topographic information, there are as many applications as there are feature codes - our customers are more varied than those in some other markets in which systems capable of providing ALL the answers really are feasible.

It is at this stage that the customer begins to develop ideas about altering the standard product to fit his particular system and requirements. Given the freedom to select less than the whole product, many customers will want to do this. Not surprisingly, they expect their constraint to be reflected in the price they pay although in the days of the standard map, they paid the asking price even when much of its content was of little interest to them.

In a world of one-offs, twins are king - at least in the eyes of the supplier who seeks multiple use for his product and who would rather identify the highest common factor in order to provide a standard product as a best mean fit for the generality of users. Few users have totally abandoned the map and it is difficult with our poor perception of the future to envisage a world of no graphics. However, increasingly to the collector of topographic data there are advantages in retaining it in the digital form in which it arrives - from the instrumental survey, the photogrammetric plotter, or remotely sensed data. It is the conversion for graphic use which reduces its accuracy, increases its bulk, and causes the loss of some of its flexibility. But, for the moment at least, digital map data must be capable of being manipulated and plotted to produce a conventional map.

With the flexibility provided by the tailor-made system, users are demanding a much more personal service than when they had to accept a standard package. They want to do more with their own data than to lay it over the topographic base, but each requires his own personal model of the world. Printed maps are by their nature always out of date and this is frequently a source of frustration and uncertainty. Now updates will be demanded by users to justify their investment, and possibly in a form which provides only the change; not a new map but an input of additions and deletions.

Finally, this spirit of individual freedom is calling for supporting software, advice and other forms of after-sales service. To all suppliers brought up as map-makers (apart perhaps from the Hydrographic Office for whom change and its supply is a way of life), this is a commitment difficult to accept. And yet it is reasonable for the customer to expect these types of support to be available, if not directly from the data producer, then from software houses, consultants and maintenance engineers. Before the advent of computers the customer could solve problems with ingenuity and practical common sense. The hi-tech solution frequently leaves no such remedy - it's all or nothing, and hiccoughs cannot be tolerated.

So the suppliers and users together are attempting to take account of future changes in technology and unforeseen uses of the data, but can the suppliers accommodate the changes deemed necessary, and still produce the data economically and quickly enough?

THE DEVELOPMENT OF NEW PRODUCTS

Everyone has an interest in the relationship between features on the ground at some scale or another, from the Land Registry concerned in property boundaries to the salesman planning his visits. For some of these interests the map serves very well, but for other more demanding enquiries, something more comprehensive in the data and the way it links together will be essential. Developments in other fields of technology are creating the potential for still more complex applications; for example, the increase in accuracy, and reduction in cost and size of position-fixing systems open the door to practical vehicle navigation systems which need to be related to topography if they are to be useful.

Other developments in both hardware and software are making it easier for users to create information systems. For these the topographic information needs to be collected and stored so as to allow it to be an entry point to the system. Ordnance Survey large scale digital data currently allows only a non-automatic combination of topographically and culturally linked information - a human eye is needed to infer the property 10 High Street (particularly if "8" and "12" appear on the map but "10" does not, and if the boundary is incomplete), and to cross reference it with lists containing its rateable value, the name of its occupier, or the telephone number, even though all of these sources may be computer-based.

In the areas discussed, there is much work being done to identify the form in which data will be required, and these studies need to be carried out by both parties; the suppliers providing the guidance on what is technically feasible, and the users analysing their current and future requirements. However, there are at least two guiding principles. There is the natural inclination of the convert to new technology to include everything from his current system without sufficient critical assessment of whether all aspects are appropriate to conversion and, even more importantly, whether some parts should not be changed before conversion because they are inefficient; there is no justification in automating what should be abandoned.

There is also the subject of tailoring which we have touched on already. Certainly for a national supplier it is frankly unrealistic to imagine that he can supply the perfect solution for every user. We have agreed that the digital data has to be collected, stored and supplied in a way that reflects as much of the topographic and cultural background as will be needed, rather than a single representation of that background which in its simplest form is a printed paper map. In the same way that the user of a general topographic map had to create a system for effectively applying the information it contained to his own needs, even more now he may have to change, reorganise or add to the data with which he is provided in order to make it compatible with his own system and applications. So, the aim of the supplier must be to create a system which concentrates upon collecting and storing the required data in a form which allows the individual to access it. The customer must be left to create his own information and link it to the digital map data in his own database.

THE EFFECT ON DATA TO BE COLLECTED

Potentially more data can be brought together and viewed simultaneously when in digital form, but that does not mean that any one agency has to increase the amount of information it collects. On the contrary, it is important to define separate tasks so as to avoid duplication.

How data is classified may very well be affected; it may become more important to identify a linear feature as a boundary between two particular properties than as a hedge. Perhaps both these attributes will need to be recorded.

We talked earlier about the limited ability of the computer to deduce. However, given enough information it can produce solutions akin to the human's deductions. For example, if every link making up the length of a road is tagged with its route number, then it is possible to undertake effective automatic route-finding.

For the user to access and to link data, entry points and tags need to be provided. Just as it is essential that many of the material things in our daily lives are standardised, so it will be necessary to create a standard way in which this tagging is done. It must be made possible to attach data to any entity, be it node, link or polygon.

STANDARDS

This is not the place to do more than emphasise the importance of standards. Indeed we have done so already in talking about the supplier trying to avoid the "one off" and the desirability of creating only one type of connection between the topographic information and the user's. Suppliers can impose standards, but the best ones are introduced by consent between them and their customers. When stall holders and shoppers agree, the manufacturers (in this case those who build the hardware and create the software) will follow. In this scenario everyone benefits by lower costs, greater consistency, reliability, and scope for transferring and accessing data. Without these latter capabilities and the scope they introduce for coordination and cost sharing, many potential customers may never enter the market.

MODELS & STRUCTURES

It is necessary to define these terms.

"A DATA MODEL is an abstraction of the real world which incorporates only those properties thought to be relevant to the applications at hand. It is independent of a computer system and its associated DATA STRUCTURES. A map is one example of an (analogue) data model." [3]

"A DATA STRUCTURE is the defined logical arrangement of data as used by a system for data management. It is a representation of a DATA MODEL in computer form. [4]

Experience to date with the Ordnance Survey large scale mapping archive illustrates a great range of user's requirements for digital map data; everything from a background map to structured data suitable for input to a Geographic Information System. Some find that the model currently provided is not ideal. It is either too complex, or it does not provide all the "sockets" required into which to plug their own data. I cannot believe this situation is unique and so it raises issues which will occur elsewhere.

There is a body of opinion which says "if you have not the resources to provide us with the model we really want, give us an interim solution which is cheap and quick to produce".

This could perhaps be justified if the interim is a step towards the final destination and providing that taking two steps will not add considerably to the effort involved in getting there with a single stride. The economics of alternative "two steps" are being investigated and there is little point in discussing the options in any detail. The most attractive because of its potential for reducing the tedium of data capture is to raster scan and provide a background map for those who require no more, with subsequent vectorisation and coding by interactive means to achieve an acceptable model for everyone else. Alternatives are a vectorised product containing a minimum of coding, to be followed by an enhanced version in due course, or the establishment of a linked database containing cartographic information by which to carry out the separate business of map making. All that is certain is that it is impossible to satisfy all of the users all of the time, but this is ground we have covered already.

SELLING

"The aim of marketing is to make selling superfluous" (2) The customer must be convinced that he not only needs the product, but that its price offers good value for money. Suppliers must provide evidence to the potential user and this, in all its forms, is expensive. They must produce proper documentation, participate in trials, run demonstrations, discuss applications, formulate standards, and generally act as consultants in the field. The "selling points" for using digital map data are discussed elsewhere in this paper, but there are others which help to explain to the potential customer its apparently high price. Development costs are enormous because of the level of sophistication demanded, and the variety of application that needs to be catered for. Maps represent one of the densest sources of information available so that a customer is getting a lot for his money, but it helps to explain why the processing of spatial data consumes a lot of computer effort.

The cost of data is seen by many potential users as the principal deterrent to entering the field. It is worth pointing out to them that the data is likely to have greater longevity than the hardware and software by which it is manipulated; the decision on whether or not to proceed should be based on a comparison of these costs with the perceived "added value" to the data by having it in its new form.

The customer must be persuaded to compare prices on the same basis; there is a tendency to underestimate internal costs through a failure to fully absorb all overheads - to count only the marginal costs involved in taking on additional work when considering alternatives to buying the service from outside. On the other side of the coin, it is important not to concentrate only on the initiation costs and to overlook those involved in continuing maintenance.

One of the many areas still to be developed in this field is an acceptable pricing policy for data. In the Ordnance Survey, prices reflect cost recovery targets set for it by Government, but there is still a large element of faith involved; current sales of digital data do not approach the level they will need to if the supply of data is to continue, and we have to believe that given more data in the right form - a critical mass - demand will increase dramatically. The proper level and method of charging for updates is even less clear because of uncertainty over the effect digital updates will have on revenue from conventional mapping, and whether traditional methods of charging copyright can persist when the protected data is being put to these more sophisticated uses. It is likely that technology will play a part in this field too because whatever system of charging is introduced, it has not only to be acknowledged as fair but be simple to administer; perhaps it will become technically possible to raise invoices automatically related to actual usage irrespective of how access to the data is achieved.

DISTRIBUTION

Fundamental to a service is the means by which it is provided. With the trend in retailing and access to information by remote means such as mail order, Ceefax, Oracle and Prestel, it is advantageous to its suppliers that digital data is already in an ideal form for transmission. In Great Britain digital networks are being established which will increase the speed and reliability of data transmission. Given such networks and the necessary common transfer standards a central data source becomes feasible, with the choice on form of access being determined by individual user needs; everything from 24 hours a day instantaneous on-line access for the emergency services, through overnight transfers for Local Government, to postal delivery of mail-ordered updates for small firms.

CONCLUSIONS

Digital mapping has several advantages over mapping produced conventionally, particularly because of the freedom it provides from sheet edges, and the facility to change scale and select features. In addition, a recent video produced by British Gas comments that "with digital mapping nothing wears out, nothing has to be redrawn". But customers want more than this and maps are increasingly becoming a by-product of a digitising process which can provide information about topographic data impossible to show in a purely graphic form; information about how and when it was surveyed, its accuracy, and whether it reflects planned or as-built change. But more important even than that, the information can be modelled in such a way that it allows the user to recreate the world in which he is interested in a more tangible form than a mere map ever can.

Customers want to get more from their data than they can at the moment, to be able to add to the system as their requirements and confidence develop, and to have the assurance that the investment is 'sensible'. Suppliers of systems and information alike must respond to this market by providing the maximum of flexibility for technical development and the emergence of new applications. At this stage there is probably no scope for practising what we defined as de-marketing on page 2 of this Paper. The future is too uncertain to allow us to cut back on any of our current conventional products and services: the two types of technology will continue to co-exist for some time.

Major users are already making the transition from the analysis of maps to the computer analysis of data. Without the concentrated efforts of suppliers this initiative will wither, an important market will fail to develop, and the efficiencies which it could provide for the benefit of the community will not be realised.

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CARTOGRAPHIC DIGITISING - TECHNICAL TRENDS AND ECONOMIC FACTORS

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ABSTRACT

Automatic digitising of map data has made substantial progress, with improved techniques for both raster and vector scanning. Further progress can be anticipated, but effective and economic mass digitising remains a bottleneck. The paper discusses a classification of the wide range of requirements for digital map data. The digitising complexity of these requirements, together with issues of accuracy and quality both of input documents and of required digital output dramatically affect the applicability and the economics of techniques for automatic digitising.

INTRODUCTION

The more senior British members of the audience may well recollect a very worthy BBC radio programme of years gone by called "The Brains Trust". One of the leading members of the Brains Trust was the late C E M Joad, who invariably prefaced his answer to each and every question by the famous words - "Well, it depends what you mean by.....". This response is particularly appropriate to the question "What will it cost to have these maps digitised?" This paper is an attempt to map out the various issues involved, against the background of rapidly changing technology, and to relate these to management and cost considerations. As such it has to be a taxonomy of both the requirements for digitising and the techniques available for digitising - a daunting task in a short paper, but one that can be undertaken in the context of Auto Carto London, where so much of the evolving technology and the motivating requirements can be studied both in the papers and the exhibition.

The problem with taxonomies of multidimensional phenomena is determining which is the key variable to use for the primary classification - how to skin this particular proliferating genus of cats. In this paper I will seek to order the phenomenon of the capture of cartographic information into computer systems by analysing primarily the range of requirements, using this classification as a framework for further considerations of technology and economics. This is, I believe, the most fruitful approach.

The data capture bottleneck is still with us, despite the advances in technology, although the problems, and the associated costs, are being significantly re-defined as the requirements are refined and better understood.

REQUIREMENTS FOR MAP DIGITISING

Maps as pictures

Rapid advances are currently underway in the enabling technology for handling and distributing maps as pictures, both in video form and in computerised systems giving scope for mixing map information with other information held in databases. One attraction of these applications is that the digitising requirement is particularly simple since basic raster data can be used. Digital cameras will suffice for low resolution requirements and the needs of the facsimile market are leading to the availability of cheap, medium resolution scanners.

Certain cartographic publication tasks can be automated by computerised graphics arts techniques although costs are still high and the benefits have to be realised entirely within the cartographic publication activity, there being no potential to create map databases or derived products such as terrain models.

Map backgrounds

The major users of large scale mapping are utilities (gas, water, telecommunications etc) who require a map background as the spatial reference for their plant records. Traditionally this has been accomplished by drafting plant records as an overlay on a map background. Analogous requirements exist in command and control display applications with the extra complexity of a time variable.

In computerised systems, map backgrounds can be generated by projection displays or by use of raster map data on raster displays. Raster map data is easily and quickly captured, but data storage requirements are high. It is difficult to build-in structure or feature coding and interrogation on the display is by position only. Care is necessary to compensate for distortion if, for example, paper documents are scanned, and coordinate transformations are computationally heavy.

The speed and low cost of creating raster map backgrounds may lead to their use as an interim solution even though many of the benefits of map information management systems are precluded.

Map Data for Display and Simple Interrogation

Most existing computer systems use map data in a vector form and the dominant and rapidly escalating requirement for digital map data at large scales in countries such as the U.K. is for this form of data. The requirement, by comparison with the basic mapping available from the national mapping organisation can be characterised as follows:-

(i) area cover. It is a strong requirement that substantial areas be covered in short periods of time. The perceived benefits can only come from the computerisation of whole areas.

(ii) partial capture. Not all the detail on the base maps is required, a typical selection being building outlines, property numbers/names, road outlines, road names, walls and fences and "miscellaneous linework".

(iii) simple feature coding. The data needs to be classified into a small number of layers, typically 6-10.

(iv) planimetric accuracy. Data needs to be captured and held to an accuracy criterion of within a half line width at source. In practice there may be some relaxation of this to cut costs, but this is not encouraged (and should not be).

(v) appropriate presentation. Within the requirement for planimetric accuracy, cartographic presentation standards can be quite relaxed. There is no requirement in this application for the fine positioning of names, or niceties of alignments for cosmetic purposes, particularly if these result in significantly higher data capture costs.

(vi) economy of representation. It is important that data volumes are kept near a minimum, and consequently that features in the data are represented by the optimum number of coordinates. This is particularly so when the lifetime costs of holding, using and maintaining the data are considered.

This requirement as it is currently evolving has been spelt out in some detail because of its market importance and because in certain fundamental respects it is at variance with the next requirement to review.

Map Data to Support Cartographic Products

Map Production agencies can support certain products by using "maps as pictures" techniques. However many requirements necessitate the creation of databanks (collections of unstructured datasets) if not fully structured databases, but the additional requirements of cartographic presentation lead to a different set of characteristics:-

(i) slow, progressive area cover

(ii) full capture

(iii) complex feature coding

(iv) planimetric accuracy essential

(v) heavy emphasis on a cartographically acceptable presentation.

Some of the conflicts between these characteristics and the preceding requirements are obvious; others have very important repercussions on the applicability of automatic digitising and hence on cost. These will be expanded later.

Map Data in Structured Form

The more ambitious aims of Geographic Information Systems present a requirement for map data in structured form, and a clear consensus is emerging that a link and node structure is the master pattern. Production experience of creating (and, more importantly, of using and maintaining) large amounts of map data in this form is not yet available and any special repercussions on digitising are not yet clear, although it is clear that the requirement for structured data increases the need for automatic, or semi-automatic, digitising.

Map Data for Terrain Modelling

This important requirement is used as an exemplar of requirements for non-cartographic purposes. It poses some requirements on map data capture in a particularly stringent manner, namely:-

(i) the need to reconcile data across sheet boundaries (this is present in all requirements to create continous digital maps but is particularly acute in terrain modelling).

(ii) the need to use appropriate source material, augmented if necessary. For high quality terrain models, source augmentation is more costly than digitising, especially if sources are defective in any way. The mathematical exercise of modelling exposes source mapping to a very thorough self-consistency check.

This excursion into a particular non-cartographic requirement is an example of the fact that digitising often involves much more than the conversion of existing graphic sources into digital files.

TECHNOLOGY AND QUALITY ISSUES

Manual Digitising

Most digitising is still done on manual digitising tables, and the advent of cheap microcomputers has considerably enhanced this approach since quite sophisticated checking and formatting software is readily available. Attempts have been made to increase the throughput of manual digitisers by adding a form of local scanning, but any successes using this approach have not been widely reported.

Manual digitising involves low capital cost and has a very fundamental advantage if source documents are of poor quality or in need of human interpretation. Slow speed and the difficulty of maintaining accuracy of output remain as fundamental disadvantages. Software can provide checks on syntax but not on content (i.e. accuracy of coordinates or of coding). Attempts to perform volume digitising by "cottage industries," unless very carefully managed, result in significant quality control costs.

Automatic Scanning

Most automatic digitising systems are based on the use of raster scanners, with a subsequent raster-to-vector conversion stage (usually software, but increasingly implemented in hardware), followed by editing and tagging cycles until clean data is produced. Scanning and raster-to-vector conversion times are impressively quick and progress is being made on symbol and character recognition.

The quality of the source document has a key effect on the applicability of automatic scanning. Blemishes or noise can throw the most sophisticated algorithms and create clean-up problems for the edit phases. Unless source documents are of a very high quality effort therefore has to be expended to prepare the source document graphically before scanning or to clean up the scanned data prior to vectorisation. In some cases the latter process can be substantially achieved automatically. A further point to note about automatic scanning is that the whole source document is scanned and processed, even if only a selected amount of information is actually required. A related issue is that it is difficult to apply specialised algorithms to particular classes of features (since to do so such features have to be recognised first). This makes it difficult to achieve optimal representations of say building outlines on an urban plan, and in consequence it is generally found that data volumes from vectorised raster data are greater than is desirable, with resulting increased costs in using and maintaining the data.

Hardware for automatic scanning is simple and costs are rapidly falling, since developments are underwritten by a market much wider than cartography. Software and procedural improvements continue, including separation of data into simple layers by differing physical characteristics (line weight, line style, colour) and the separation of text from linework, with subsequent text recognition.

As with all automatic processes it is essential in evaluating the cost effectiveness of automatic digitising to assess and measure the "bottom of the line" cost of the whole process, including all phases required to produce clean, accepted data.

Interactive Scanning

The alternative approach to automatic scanning is interactive scanning, or as it has somewhat misleadingly been termed historically, line following. The hardware required for this is a programmable scanner that can access the source in arbitrary patterns, and a means for an operator to follow and supervise this process. One particular system using this approach is the Laser-Scan Lasertrak.

Interactive scanning allows selective data capture, both in the sense of capturing only data that is required and in the sense of selecting the algorithm to be applied to a particular type of feature. This results in optimal, or near-optimal, feature representation and consequently near optimal data volumes. Furthermore feature coding takes place in parallel with scanning, although this advantage is reduced if feature coding schemes are complex. Because the interactive operator can resolve difficulties as they occur, and because high scanning resolutions can be used in local areas, interactive scanning can be less susceptible to the effects of defects or noise in the source document than automatic scanning. For example it is quite possible to effectively digitise data from a U.K. Ordnance Survey SUSI (Supply of Unpublished Survey Information) document on the Lasertrak.

Interactive scanning has the disadvantage of involving the operator with high cost capital equipment and an adequate cost assessment can only be made on a case by case basis. Developments continue aimed primarily at exploiting the flexibility of this approach and at optimising the production of structured (link and node) data.

The Applicability of Automatic Digitising

The applicability of automatic digitising, either automatic scanning or interactive scanning, depends critically on three parameters of the task in hand:-

(i) the quality of the source documents. The physical quality of the graphics may not be adequate for scanning or the content may be incorrect or inadequate to sustain the task. One of the fundamentals of computerising anything is that famous maxim "Garbage In, Garbage Out". To defeat this is expensive and likely to remain so.

(ii) the complexity of the coding required. If feature classes can be physically distinguished, either as separate overlays or different line styles, then automatic processes can cope effectively. If the number of feature codes is small and the classification is simple and unambiguous, efficiency of data capture is not seriously impaired. If the feature coding scheme is complex and "judgemental" the costs of feature coding will outweigh those of data capture, particularly when the costs of checking and quality control are included, as they must be.

(iii)the quality specification for the output. Costs rocket if this specification contains, explicitly or by implication, a subjective criterion such as "cartographic acceptability". Digitising is analogous to tracing not to fair drawing, if drafting analogies may be used. Automatic digitising is simply quicker tracing. It may, at a cost, incorporate elements of the fair drawing process and it is very desirable in many cases that it should do so. However the cost effectiveness of doing so can only be established if these additional elements of the task can be defined and quantified and so expressed algorithmically and checked reasonably.

SUMMARY FOR MANAGEMENT

Insofar as progress in Auto Carto still depends, in part, on progress in the creation of digital map data, this paper has attempted to summarise key factors in the definition of this task, and hence in the applicability of emerging technology. Some of these issues result in a strong divergence between the requirements of major users of map data and the requirements of the map production agencies. This divergence has to be resolved if Auto Carto is to produce, in the words of that deceptively simple maxim, "the right product, at the right time, at the right price."

ASSESSING THE CONSUMPTION BENEFITS OF L.I.S. PROJECTS

BY C.H. WEIR AND R.B. SWETNAM

ABSTRACT

An understanding of the nature and extent of the benefits of L.I.S. projects is essential for making informed investment decisions about them. This paper examines the two major types of benefits generated by L.I.S. projects - production benefits and consumption benefits - and outlines a procedure for investigating consumption benefits.

ASSESSING THE CONSUMPTION BENEFITS OF L.I.S. PROJECTS

BY C.H. WEIR AND R.B. SWETNAM

One of the most difficult aspects of making investment decisions regarding land information system projects (L.I.S.) is assessing the benefits which are likely to result.[1] The benefits of L.I.S. projects are difficult to define and even harder to measure. Nevertheless, if we are to justify the considerable costs of these projects and make informed investment decisions about them, an assessment of benefits is essential. The purpose of this paper is to suggest one procedure for investigating and assessing the benefits associated with L.I.S. projects.

Before developing such a procedure, however, it is useful to first examine what is meant by the term "benefit" and to identify the types of benefits which can be expected from an L.I.S. project. In general terms, a benefit is any result of an action or project which is considered desirable, while a cost is a result that is undesirable. In economic terms, a benefit may be thought of as the desirable result of a project or action which improves the welfare of a community, organization or individual by increasing the opportunities to consume and/or produce goods and services. Similarly, a cost is a result of a project which reduces opportunities to consume and/or produce goods and services.

There are two major ways that an L.I.S. project may produce benefits. The first is by reducing the cost of producing land-related information. We shall refer to these as production benefits. By reducing the cost of producing land-related information, the L.I.S. project makes available for other uses resources which, in the absence of the L.I.S. project, would have been used in the production of land-related information.

The second way that an L.I.S. project may generate benefits is by increasing the consumption value of the land-related information. We shall refer to benefits generated in this way as consumption benefits. Consumption value is simply the value which consumers place on consuming a good or service. The amount that consumers are willing to pay for a product or service does not depend on the cost of producing it. Rather, it depends on the satisfaction or the utility that they receive from it.

A single L.I.S. project may generate both consumption and production benefits. Consider the example in which a government undertakes an L.I.S. project to computerize land registry which contains information on the ownership and valuation of land. Figure 1 represents situation before the L.I.S. project is undertaken. The demand curve d_1 shows the amount of this type of land-related information that consumers are willing to purchase at various prices. The curve is downward sloping indicating that as the price of the information decreases, the amount demanded increases. The supply curve at P_1 shows the price at which the government is willing to sell land-related information. For the purposes of this example, assume that there are no economies of scale and that the government is willing to sell land-related information at cost. Thus P_1 is also the cost curve for the government.

Let us now assume that as a result of the L.I.S. project, the cost of producing and maintaining land records is reduced due to increased effeciency resulting from computerization. This is represented in Figure 2 by the downward shift in the supply curve from P_1 to P_2. As a result of the L.I.S. project, there would be a saving on the production of the original volume of messages that was produced. This saving would be a production benefit and is shown by the area "abcd". This area represents the cost saving on the production of each message (P_1-P_2) multiplied by the original volume of messages (M_1).

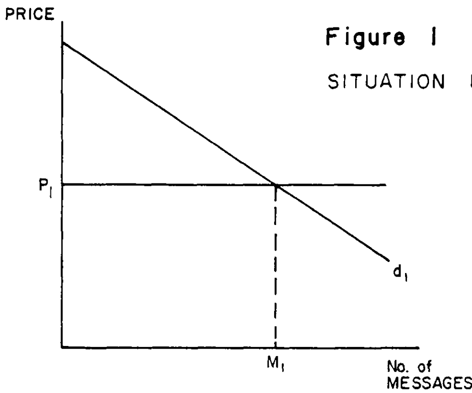

Figure 1

SITUATION BEFORE L.I.S. PROJECT

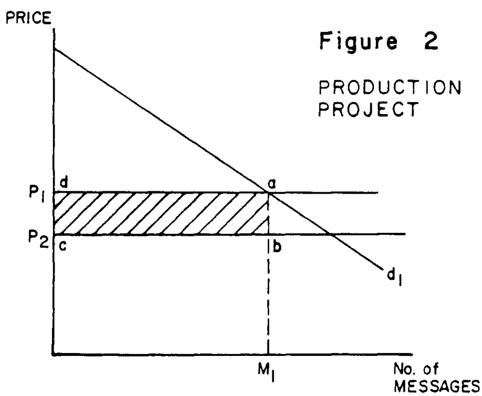

Figure 2

PRODUCTION BENEFITS OF L I S PROJECT

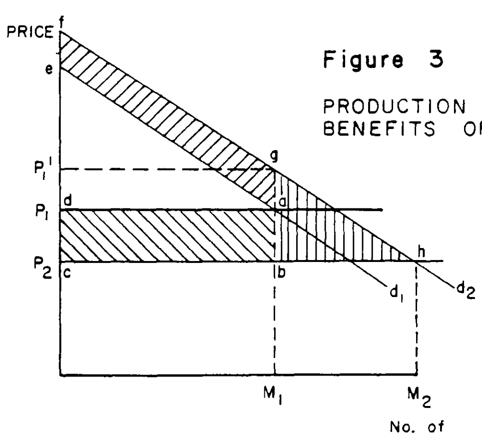

Figure 3

PRODUCTION & CONSUMPTION BENEFITS OF L.I.S. PROJECT

Let us say that as a result of the L.I.S. project, the information about land records that is produced by the new system is more accurate and current and that it can be combined directly with land-related information found in other data bases. Let us assume also that consumers are willing to pay more for land record information as a result of the improvements. This is reflected by an upward shift in the demand curve from d1 to d2. Figure 3 shows that consumers are now willing to pay an additional amount (P_1'-P_1) for each message that they receive. The additional amount that consumers are willing to pay for each each message (P_1'-P_2) multiplied by the original volume of messages (M_1) is a consumption benefit produced by L.I.S. project which is realized on the initial volume of messages. This is represented by area "aefg" in Figure 3.

Because the land record information costs less to produce and purchase and because each message is now more valuable than before the L.I.S. project was initiated, this means that the amount of information demanded and supplied will increase to M_2 messages (See Figure 3.) This is the amount at which the new demand curve d_2 and the new supply curve P_2 intersect. The cost of producing this additional information is represented by the area "bhM_2M_1". This is the new cost of production P_1 multiplied by the additional volume of messages M_1-M_2. The value to consumers of this additional volume of messages is represented by area gM_1M_2h which represents the total amount that they are willing to pay for this information. The triangle "gbh" represents the surplus to consumers or the consumption benefit realized from the additional volume of messages.

Determining the production benefits on the original volume of messages is a relatively straight-forward though by no means simple task. The analyst must first determine the period over which the benefits would be realized Next, the costs of implementing the project and operating the system are estimated over the relevant period. Future costs are discounted and expressed as present values. Next, the costs of producing the information over the relevant period in the absence of the project in the absence of the project are estimated and discounted to their present value. The difference between the total production costs under current conditions and those assuming that the project was undertaken is the value of the cost savings or production benefits that would be realized on the orignial volume of information as a result of the L.I.S. project.

To estimate the consumption benefits which would result from the L.I.S. project, the analyst must determine the additional amount that consumers are willing to pay for the land-related information as a result of the L.I.S. project. In normal markets, the amount that consumers are willing to pay for goods and services is reflected in market transactions. By observing market transactions we can tell how much consumers are willing to pay for various quantities of a good or service. For land-related information, however, there is a problem in that there are very few developed markets from which we can obtain information about consumers' willingness to pay. Those markets which do exist are highly distorted by monopoly and government subsidies.

Since it is impossible to determine from market transactions what consumers are willing to pay for land-related information, another means of determining the benefits which they derive from this information must be used. What we must do is to is to investigate how consumers would use the information resulting from the L.I.S. project and ask them about the nature and magnitude of the benefits that they would derive. While this seems very straight-forward in theory, in practice it is a very difficult task.

The reason for this is that it is extremely difficult to determine all the ways that consumers might use a land information system and the information that it provides. By nature, land information systems, especially the ones developed in recent years using data base technology, are open-ended. That is, they are designed to accomodate multiple applications which may or may not be known when the system is being developed. It is quite possible, for example, that a land information system that was developed to provide cadastral information may be expanded and used extensively for transportation planning.

Another reason that it is difficult to determine how many land information systems will be used is that L.I.S. technology are developing so rapidly that the uses and potential of this technology is unfamiliar to consumers. Although new applications for this technology are being constantly discovered, it will take years of experimentation by consumers before we will be able to say with any degree of confidence how these systems are likely to be used.

Because it is difficult to determine how consumers will use the land information systems that are being developed, it is even more difficult to determine the benefits that they will derive from these systems or the value that they derive from the information that is produced. As one observer has stated:

> "In practice, it is a formidable task to try to measure the value of information to ultimate users. It is difficult to identify all the types of decisions in which land information is used. It is even more difficult to establish the ways in which individual decision makers process the information. And, it is extremely difficult to specify how changes in the form of the informaton will alter the individual decisions made."[2]

Despite these difficulties, it is essential that we understand how a land information system will be used if we are to investigate the consumption benefits associated with the L.I.S. project.

In the remainder of this paper, we shall describe a procedure for investigating the consumption benefits of L.I.S. projects. This procedure is part of a larger procedure for undertaking cost-benefit analysis of land information systems that was developed by Stewart, Weir & Co. for the Government of Alberta, Canada which is currently in the process of developing a network of land information systems in the Province.

In order to determine the consumption benefits generated by the L.I.S. project, we must question potential consumers about their reaction to the changes in the output of land-related information that would occur as a result of the project. This in turn requires that the analyst have a clear understanding of what those changes would be and to communicate these changes to those whose reaction to the changes is being sought.

Often the changes to the outpout of land-related information are not obvious to either the developer of the land information system or to the analyst. Small changes which might be very important to the consumer may appear as trivial to the analyst or the system developer and not be communicated to consumers. If these changes are not communicated, however, it will be impossible to get a realistic assessment of the consumption benefits that would be generated.

In analyzing changes to the output of land-related information which would result from the L.I.S. project, it is useful to view land-related information as a product (the L.I.S. product) and the distribution of that information to consumers as a service (the L.I.S. service). As with any other product or service, the L.I.S. product and service have certain characteristics or features which determine their attractiveness to consumers.

To help identify the features of the L.I.S. product and service, the following checklist was developed. This checklist breaks the features into major categories and suggests a number of questions which should be asked for each category. The L.I.S. product, for example is divided into features which describe the content of the land-related information and those which describe the way in which that information is related to a position on earth (see Figure II). With respect to the content of the land-related information the following categories and types of questions were suggested:

FIGURE II

CHECKLIST

L.I.S. PRODUCT/SERVICE FEATURES

FEATURE CATEGORIES	CURRENT SITUATION	AFTER L.I.S. PROJECT
<u>L.I.S. PRODUCT</u> <u>Content</u> Subject Matter Accuracy Temporal Characteristics Compatibility - Graphics Format Report Format <u>Spatial Referencing</u> Mode Accuracy Resolution Areal Coverage		
<u>L.I.S. SERVICE</u> Mode of Access Output Devices Security and Privacy User Data Analysis Capability Response Time		

Subject Matter: How would the L.I.S. project change the subject matter or the content of the land-related information that is currently available? Would new types of information would be created?

Method of Data Collection: How would the L.I.S. project change the way in which the data was collected upon which the information is based? For example, if the information was statistical, what sort of survey methods were used? How would this be different from they way that the data is currently collected if it is now collected?

Graphics Content: To what extent would the L.I.S. project affect the graphical representation of land-related information? What forms or graphical output would be made available?

Report Format Characteristics: How would the L.I.S. project change the format in which standard reports were made available?

Accuracy: How accurate would the land-related information produced as a result of the project be? Is this more or less accurate than what is currently available for this type of information? Have standards of accuracy been established? Would the level of accuracy of the information be made known to the user? Would the level of accuracy be consistent or would it vary?

Temporal Characteristics: To what time periods would the land-related information refer? Would time series data be available? How often would the information be updated? How recent or up-to-date would the information be? How does this compare with the temporal characteristics of this type of land-related information if it is now being produced?

Compatability: With what other types of data bases could the L.I.S. product information resulting form the L.I.S. product be compared with? For example, if the information describes various characteristics of the population according to age and geographic location, to what extent are the age categories used compatable with age categories used in other information bases. What are the major types of cross-referencing with other data bases that would be possible as a result of the L.I.S. project?

By its very nature, land-related information is information that is referenced spatially. The L.I.S. product may also be described in terms of the features which describe the way that it is related to a position on the earth. With respect to the spatial-referencing characteristics or features of the L.I.S. product, the following types of questions are suggested in the checklist:

Mode of Spatial Referencing: How would the L.I.S. product be referenced spatially? (e.g. by survey co-ordinates, administrative boundaries etc.) How would this differ from the way that this type of information is currently referenced spatially if it is available?

Accuracy of Spatial Referencing: How accurate is the system by which L.I.S. product would be referenced spatially. How accurately is the L.I.S. product referenced within that system? How does this differ from current levels of spatial referencing accuracy for this type of land-related information.

Resolution: At what degree of resolution is the system by which the L.I.S. product would be referenced spatially? How would this differ from the current situation?

Areal Coverage: How broad an area of the earth would be covered by the L.I.S. product? How would this differ from what exists currently?

With respect to the features which describe the L.I.S. service, that is the way in which the L.I.S. product is made available to consumers, the following questions are suggested:

Mode of Access: Could the information be accessed by remote users? If so, how would the information be transmitted and received? Would there be a limited number of remote terminals in designated offices or could the information be accessed via modem over telephone lines, for example? What type of hardware or software would be required to access the system? How would this compare with the current situation?

Output Devices: How would the L.I.S. project affect the type of devices by which the L.I.S. product would be displayed? Would special printers or plotters be required to produce hard copy of the information? If so, what type would be required? Could the information be displayed in colour? What ranges of colour would be available?

Security and Privacy: What types of users would be able to access the information? What protection would there be against accidental or intentional disclosure to unauthorized persons or unauthorized modifications or destruction of data? What restrictions on access would be placed? How would this differ from the current situation?

User Data Analysis Capability: To what degree would those receiving the L.I.S. product be able to manipulate that information or perform functions such as distance and area calculations, statistical analysis, buffering, Boolean logic analysis, route selection, digital terrain analysis, site line analysis, and pattern recognition? How would this compare with their current ability to perform such functions?

Response Time: How long would the average response time be for receiving information from the system? How would this compare with current average response times for receiving this type of information?

Once the changes to the output of land-related information have been defined, the next step is to determine the potential users of the L.I.S. product and service. Most L.I.S. products will not involve the creation of entirely new land-related information but rather the modication of information presently available in some format. The first step in identifying potential users should be to contact the producers of this information and various experts in its use to determine who are the major current consumers. The various user groups should be identified and ranked according to their level of usage.

Next, the features of the L.I.S. product should be communicated to the producers and experts and they should be questionned about other possible user groups among the current users of this information. To help in this identification, it is useful to scan a standard industrial classification. A standard industrial classification is a systematic, comprehensive listing of all sectors in the economy, including the government. The Standard Industrial Classification of Canada, for example, divides the economy into 18 major economic divisions each of which is broken into major groups, groups and classes. By scanning the appropriate parts of this classification, it may be possible to identify potential user groups which otherwise might have been forgotten.

The next step is to identify the size and major characteristics of each current and potential user group. For this, various government and private sources may be consulted. In Canada, private sources such as Scott's Directories, Dun and Bradstreet, and Moodies provide extensive information about the numbers, names, and adddresses of companies according to their SIC code and location. In most cases, potential government users of the product will have to be identified by contacting the relevant department and agencies. Once the major consumer groups for the L.I.S. product and servie have been identified, the next step is to conduct interviews with a small, though representative, sample of consumers.

It is important to have personal discussions with the potential consumers in order to develop an understanding of the practical problems associated with the use of the L.I.S. product and service. Personal discussions also help to avoid naive assumptions about the benefits produced by the L.I.S. project. Through personal discussion with those who will be using the title information including the farmers and bankers, many of these factors can be identified. The findings of these discussions can help the analyst to avoid naive assumptions in the measurement and analysis of benefits at a later stage. They are also useful for showing what other actions must be taken in order to realize the expected benefits of the L.I.S. project.

Feedback from potential users of the L.I.S. product is obtained through the Focus Group interview. The Focus Group Interview is a technique used by marketing professionals for developing and testing new products. A typical interview involves a Focus Group leader and 6 to 8 participants who are all members of the user community. Typical sessions last between two and three hours. The leader's role in the interview is critical. He or she must carefully plan the meeting and determine the important issues and questions to be discussed. During the meeting, the leader must lead discussion without being too directive. The leader should do as little talking as possible and make sure that all participants contribute to the discussion. Finally, the leader must have a good understanding of the features of the L.I.S. product.

The number and format of the focus group interviews required depends upon the variety of potential users, the type of decision to be made and the budget available for the study. If it is felt that there are a few large users of the L.I.S. product, it is advisable to conduct one interview per industry where there are only members of the same industry present. If the major users come from a large number of different industries, then it may be necessary to have a mixture of several industries at each interview.

While the format of the session may differ, each Focus Group Session should have three major parts. In the first part, the focus leader should question the participants about how they are currently receiving and using the relevant types of land-related information. Needs will be identified and the satisfaction with the current system should be explored.

The purpose of the second part of the meeting is to communicate the features of the product to the participants. The articulation of features which was done in the previous stage should help to Focus Group leader to structure his communications. Depending upon the degree to which the product concept has been developed and the nature of the product, it may be useful to group various features together and/or present a few features as options.

It is important that the presentation of the L.I.S. product and service be as clear and succinct as possible. In come cases, it may be very useful to demonstrate how the L.I.S. project would actually work using prototypes or mock-ups of the system. This makes it much easier for the potential user to comprehend the product and react to it. It also makes it much easier to identify required changes to the product at an earlier stage of development when such changes are much easier. For this reason, prototypes of the product should be demonstrated wherever possible.

The purpose of the third part of the focus group session is to get the participants' reaction to the product which is being proposed. Once the focus group leader is certain that the participants understand the concept, he will ask a series of questions in regard to the new system to determine from the participants:

- their reaction to the various features of the L.I.S. product;

- the factors that would affect their usage of the L.I.S. product;

- the probable extent of their use of the L.I.S. product;

- the savings or increased revenue that they feel they could realize in their current practices through use of the L.I.S. product.

At the end of these interviews, the findings should be tabulated. At this point, the analyst should have a general understanding of the major ways that the L.I.S. product and service would likely be used and the benefits associated with those uses.

Presentation

If the findings of the benefit study are to be useful in the desicion-making process, they must be clearly understandable to decision makers. If the findings are buried in a mass of extraneous detail, it is likely that the procedure will be of little use to decision makers. For this reason, the presentation of findings is extremely important.

At this stage a concise, well-organized and easily-referenced report should be prepared which communicates to the decision maker:

1. The nature of the L.I.S. product and service and how they will likely be used;

2. The magnitude, timing and distribution of the costs and benefits associated with the project;

3. A general indication of how the measurements of benefits were arrived at and a general indication of their reliability.

It should be stressed at this stage that in presenting the findings of cost-benefit analysis, the purpose is not merely to transmit the findings of analysis but to communicate them in such a way that will help decision makers to make their own evaluation of the project under consideration.

Conclusion

In this paper, we have suggested a procedure for investigating the benefits of L.I.S. projects. It is anticipated that the procedure will be tested as the Government of Alberta proceeds with the development of its network of land information systems. The measure of the success of the procedure will be the degree to which it helps government decision makers to make informed investment decisions about L.I.S. projects.

FOOTNOTES

1 An L.I.S. project is defined as any action which is undertaken in order to create or modify a land information system. A land information system is defined as: "a tool for legal, administrative and economc decision making and an aid for planning and development which consists on the one hand of a data base containing spatially referenced land-related data and on the other hand of procedures and techniques for the systematic collection, updating, processing and distribution of data. The base of a land information system is a uniform, referencing system for the data in the system, which also facilitates the linking of the data within the system with other land-related data".

The definition of the term land information system has been the subject of considerable discussion in recent years. (See for example A.C. Hamilton and J.D. McLaughlin ed., (1985) The Decision Maker and Land Information Systems, The Canadian Institute of Surveying). Distinctions have been made between land information systems, geographical information systems and spatial information systems. While these distinctions may be important for some purposes, we shall consider them to mean the same thing for the purposes of this paper.

2 Pamela Angus-Leppan, (1983), "Economic Costs and Benefits of Land Information" in Publication of the 17th Congress of the International Federation of Surveyors, Commissin 3: Land Information Systems, Sofia, Bulgaria, p. 309.2/14.

3 Stewart, Weir & Co., The D.G.S. Cost-Benefit Procedure: A Manual for Undertaking Cost-Benefit Analysis of Land Information Systems, Alberta Bureau of Surveying and Mapping, 1985.

LOCATIONAL MARKETING ANALYSIS : A NEED TO BE INFORMED FOR STRATEGIC DEVELOPMENT

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INTRODUCTION

There is no dispute that disaggregated market information is a prerequisite for a successful company; it is an increasingly important source of competitive edge. Companies must react rapidly and locally to both competitive threats and consumers' needs. However, in spite of this growing awareness, it is fair to say that the majority of companies need to enhance their ability to generate, process and interpret available market information.

From our experience with clients in both the public and private sectors, the mapping of information provides an excellent way to present results and aid decision-making. However, it is unneccesarily restrictive to view digital mapping with the conventional cartographic perspective of printed maps; the real opportunities for informed locational marketing analysis arise from using available technologies to manipulate digitally-based spatial information.

Rather than the usual concentrations on database management and map presentation in discussions about geographic information systems, attention in this paper is focused on an integral analytic framework involving the conversion of spatial data into actionable information through the application of appropriate statistical methods of classification and spatial modelling.

Two important practical issues also underlie the discussions, specifically:

- what type of information is required by marketing management;

- how can this information be produced at an acceptable cost and level of effort.

CONTENTS

For locational marketing analysis, we consider theoretical and practical aspects of spatial data collection, spatial data analysis and results presentation. The basic tenet is that in locational marketing analysis, the manipulation of digital spatial data and the output of maps is a tool to assist, rather than replace, decision-making.

In terms of spatial data collection, reference is made to the accuracy and availability of data and to the appropriateness of particular spatial units.

Potential effects of spatial scale on the results and therefore on any interpretations are noted.

In terms of spatial data analyses, experiences in applying a range of approaches, including mulitivariate statistical techniques, spatial analytic models and simulation methods are described. The basic aim of locational marketing analysis is to match demand and supply interrelationships over space. The problems arise because there is a varied demand for goods and services from different customer groups that can be supplied by competing branches.

For results presentation, by providing direct and clear messages, maps can help remove a reluctance to apply sophisticated analytic methods in marketing; they are usually much clearer than a hundred sheets of computer printout! Thus, mapping has direct implications for educating management about the potential benefits of locational marketing analysis. As maps improve the scope for application is evolving and growing. For instance, the power of using digital Ordnance Survey 1:1,250 maps demonstrates the enormous potential for flexible data integration in decision support systems for interactive analyses.

SPATIAL DATA COLLECTION

The essence of locational marketing analysis is the linkage of different geographic data sets. Computers permit the linkage of different data sets to produce new, actionable information - the product is greater than the sum of the individual data sets. The fundamental problem today arises from constraints on cross-referencing and aggregating data sets, because they are based on different spatial units.

For instance, in many marketing analyses, it is necessary to link socio-economic and demographic household data based on census Enumeration Districts with customer data by postal geography.

For marketing, especially direct marketing, the postal geography system is accepted and in widespread use. Thus, a cogent argument can be made for postcodes (containing an average of fifteen addresses) to provide the base for other data. However, postcodes do not represent a comprehensive geographic reference system; postcodes are a geographic reference, but their usefulness and flexibility is resticted because they lack a proper coordinate system.

In conclusion, for locational marketing analysis, some important data constraints exist, including:

. the lack of national coverage of (1:1250) map data in a digital form (and the current Ordnance Survey timescale to complete this task, beyond the turn of the century, is unacceptable);

. the general demise of official statistics and their coarse spatial disaggregation.

SPATIAL DATA ANALYSIS

The value of an analysis is decided by whether it aids correct decision-making, not by its methodological criteria or sophistication. The success and relevance of locational marketing analyses are dependent on communication between technical analysts, who produce the results, and management, who use the results; failures to provide meaningful and actionable analyses are often more attributable to poor lines of communication than to any technical shortcomings per se. Mapping of results, therefore, can be especially helpful.

The demand-supply interface is the essence of much locational marketing analysis. It is appropriate to list some of the constituent elements common to many applications of locational market analysis:

. demand:

- sampling frames and designs;
- catchment area definitions;
- catchment area demographics;
- catchment area expenditure estimates;
- ranking local markets' potential;

. supply:

  - number and size of branches in a network;
  - competitive position;
  - local marketing;
  - product range/merchandise mix;

. demand-supply interface:
  - key performance indicators;
  - sales and market forecasting;
  - investment appraisal.

Three types of analytic approach are employed regularly:

. multivariate statistical techniques;

. spatial analytic models;

. simulation methods.

Multivariate statistical techniques are used to describe market segments and identify potential customers. In future, as address-based customer data become more readily available, attention will be given to the development of bespoke geodemographic discriminators, derived explicitly from the important socio-economic and demographic household characteristics of the specific problems of interest. There is no such thing as a single classification either for a particular data set or for all problems.

For management, spatial analytic models that optimise specified objectives against constraints are increasingly being applied in studies of branch location, sales territory delimitation and distribution management. While many of the methods have a relatively long history in Operational Research, their use will be facilitated for locational marketing analysis by suitable decision support system developments to permit interactive computing. Attention should not be restricted to the optimum results; insights into trade-offs and conflicts between alternative aims and the implications of selecting "sub-optimal" solutions are especially useful for management. What is the efficency of our existing network?

In a similar applied spirit, assuming model calibration has been completed correctly, "what if" simulations provide management with a comprehension of the implications of alternative actions. For instance, what will be the "cannibalisation" effects on existing branches of new developments?

In conclusion about analytical methods, it is helpful to use dichotomies as a way of seeing future trends:

. objective, rather than subjective, methods;

- causal, rather than extrapolative, models;

- bespoke, rather than general-purpose, approaches.

Such predictions are seen as conditional, rather than unconditional, because there is an economic imperative forcing change; without appropriate information, no manager can be expected to fulfill his function in a business environment of changing competitive positions, rapidly evolving technologial developments and modified regulatory situations.

RESULTS PRESENTATION

It has been argued already that often results presented in the form of a map can be more useful, and, in the remaining sections, this theme is developed for the future.

For completeness, it is emphasised that results are also presented in other forms, including:

- names and addresses for direct targeting by post;

- street listings for leaflet distributions.

FUTURE ISSUES

From recent experiences, it is clear that the handling of spatial data not only generates useful and relevant information for management, but also is creating new, more sophisticated demands from existing users. Unfortunately, today, some of these requirements cannot be satisfied effectively. The issues raised are of a practical and developmental rather than research, orientation. The value of existing technology is proven. However, developmental coordination is a basic requisite because of the multidisciplinary and scattered independent interests in handling geographic data.

The future of digital mapping will see a shift in the driving force from the map producers, cartographers, to the users, including marketing management. Moreover, while maps will continue to be used to provide an inventory of spatially distributed phenomena of interest, the spatial data analyses and results presentation will be more application-orientated.

Effective use of maps in decision-making depends on discarding irrelevant data and showing only what matters. The cartographer's conventional view and his long experience of high quality printing are of little relevance. The move towards geographic information systems will permit the selection of just those features relevant to a particular problem. In fact this is a difficult decision dependent on trial and error so the ability to produce simple maps very rapidly will be of increasing importance.

As technology in this area improves, it becomes possible to use maps interactively. Many of the problems discussed earlier are so inherently geographic that decision-making and "what if" analyses may as well take place in front of a map which constantly changes to reflect the choices made so far. We know this can be done; we are still learning how to do it cheaply and how to trade off better decision-making against time.

If hard copies are only printed as required, then output maps on a dot matrix printer have cost attractions for users, such as leaflet distributors, who do not require very high quality output for their daily work.

Finally, to the extent that maps provide locational referenced information, marketing management is often not interested in spatial patterns per se. For instance, having defined neighbourhood types for direct targeting by say a leaflet drop, it is not sufficient to know their configuration. With computer storage of data in a digital form (and possibly the development of "Knowledge Based Systems"), answers to the following practical questions can be derived directly:

. how many distributors are required to complete the coverage in three days before the campaign?

. what are their optimum routes?

. what is the best allocation of distributors to distribution routes to minimise the overall travel time of distributors from their home?

For management, limitations of data on printed maps is often their static nature - out-of-date. The opportunities to up-date information and also to add information, using perhaps company-specific data, are likely to be more easily satisfied by databases maintained in digital form.

However, to suggest the demise of printed maps would be wrong. Indeed, as the applications develop, maps use, particularly customised ones showing only the relevant information, is likely to expand. A map has the inherent advantages of portability and practicability (as compared with even so-called "portable" computers!)

CONCLUDING COMMENTS

Management are becoming aware increasingly of both the practical relevance and usefulness of locational marketing analysis and the associated power of mapping to present information. Criticisms of existing approaches arise because too much emphasis is placed on the mere presentation of raw data. A systematic analysis of the demand/supply interactions over space can transform this raw data into actionable information. Indeed, future data collection by itself, without explicitly considering relationships between consumers' behaviour, branch location and competitive position, does not provide the required firm foundation for future decision-making; information overload is a real danger to efficient and effective marketing.

AEGIS - A PRACTICAL EXERCISE IN DATA MANAGEMENT

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CACI Market Analysis has for a number of years been faced with spatial data management problems for which no commercially available system has been found to provide a satisfactory solution. The company has now designed and partly implemented support for a powerful and flexible data model to satisfy the following criteria:

1) Ability to perform editing, digitising, analysis, manipulation and mapping functions directly upon a single data structure. A prime requirement was to eliminate any need for continual data conversion between different storage formats.

2) Compatibility with existing CACI software.

3) Subroutine library support for basic operations.

4) Sufficient flexibility to cope with any cartographic information we could envisage handling in the medium term future.

This paper describes the software implementation aspects of the model, its applications, and an outline of envisaged future developments.

Introduction

CACI Market Analysis was the first commercial organisation to become an agency for resupply of census statistics in 1977, and has been a pioneer in the use of spatially referenced data for market analysis and planning. Since that time the volume and range of applications have undergone a process of continual and rapid expansion. The company now provides consultancy, analysis and data services to clients in both the private and public sectors.

Mapping as a means of presentation of data and results has always been a requirement. During the last few years, however, the need for sophisticated mapping and GIS capabilities in our application areas has grown steadily. After a review of the available software in this area CACI has decided that the most effective course of action is to independently develop new software. This paper describes the approach adopted to the management of structured vector cartographic data.

It should be stated at the outset that our requirement is for usable software rather than ideas or academic theories. The primary concern is to put ideas to work rather than to unearth their origins.

Our review of commercially available software began towards the end of 1984. CACI uses a range of software for GIS-related purposes, in particular a digitising package has already been developed in-house. GIMMS has been used for some mapping purposes, and a friendly CACI mapping package is used for maps not requiring the flexibility of GIMMS. This package has undergone gradual enhancement, and is expected soon to be used for all mapping purposes within CACI Market Analysis.

The criteria used in our search for GIS capabilities are described in the abstract. Of these, the requirement for a single vector data structure was considered paramount - the requirement to convert boundaries to and from GIMMS format has caused many problems, and these problems will inevitably multiply as spatial data becomes more abundant and more complex. Criteria (2) and (3) are to some extent equivalent, in the sense that any package satisfying criterion 3, is likely to be compatible with our existing range of data management and analysis software. Not to require criterion (4) would be short-sighted.

Design of a suitable data model and subroutine library was started in summer 1985 with the help of Phillip Wade of Hull University (funding from a SERC-CASE studentship), and was completed by the authors and Duncan Campbell of CACI towards the end of 1985. At the time of writing implementation is in progress and is expected to be complete before this paper is presented.

The Software Philosophy

Much interest in this field at present revolves around the implementation of cartographic data management within a relational (or other) database management system. We have taken a different approach in this exercise. The objectives have been to develop a data model, to identify the necessary fundamental operations on the data model, and to develop a subroutine library (named AEGIS) to support these operations. The result is a software tool which provides low-level cartographic data handling support for any application program, particulary for digitising (and editing), mapping and analysis applications.

This approach was chosen primarily because it provides support for all operations which will be required on the data, whereas a DBMS implementation is unlikely to do so in an effective manner.

We see further advantages as follows. There are great benefits in speed of operation since file structures and access modes are designed specifically, and since much redundant housekeeping which a DBMS would perform, is discarded. In addition the application programmer's job is made much easier by having access to subroutines which do just the operations required, rather than a much more general set of access subroutines which are typically supplied with a DBMS package.

We do lose out by not having immediately accessable all the facilities a DBMS provides. To some extent we can offset this loss since we have code-level access to CATALIST, a CACI data management and report generation package, which we will be able to incorporate as an application package using the AEGIS subroutine library. Some facilities - such as simultaneous write access to a coverage by more than one user - we will just have to do without.

The Data Model

Basic Entities

There are four basic entity types

1) Points
2) Line Segments
3) Primitive Region
4) Compound Objects

In geometrical terms, Line Segments start and end at points, and may have any number (zero or larger) of intermediate co-ordinates. Note that the intermediate co-ordinates are not point entities. The term 'point' will henceforth always mean a point entity, and is distinct from an 'intermediate co-ordinate'. Primitive Regions are contiguous uncut, bounded regions. Unlike the other entity types, primitive regions cannot be added or deleted by editing operations. They are created only by a polygon build process. Compound objects are, in general, lists of entities of any of the four types.

This framework, although developed independently of the Ordnance Survey small scale proposals, is similar to the structure described by Haywood (1986).

Attributes.

The treatment of attributes is of central importance.

Any entity may, and usually will, have a list of attributes attached to it. All attributes have the same structure - there is a numeric attribute type, which in the present implementation must be in the range 0 to 16383, followed by further information, which may be of any length and of any format.

Attributes are used for two purposes.

1) To record information about the object it belongs to - for example that a point represents a railway station, that the railway station is called St Margaret's, or that a line segment represents a section of railway line.

2) To record geometrical and other relationships between objects for example that St Margaret's railway station is one of the end points of the above mentioned line segment. Typically such attributes will identify other entities by their internal reference number.

It is important to note that the attribute list is the only means of holding information about an entity, other than the basic information which is held for all entities of a particular type.

In implementation terms, all attribute types exactly divisible by ten (ie numbers ...0) are reserved by the system and have specific preallocated meanings. Some of these may not be manually added or deleted by the user. For example point attribute type 0 is used to record the fact that the point is a node of a line segment - it is added or removed only by the ADD_SEGMENT and DELETE_SEGMENT subroutines.

All other attribute types are user definable, and may be used for whatever purposes, and have whatever meanings, the user wants.

Housekeeping and General Support

In addition to the basic operations described in the following sections, a number of general housekeeping functions are undertaken automatically. In summary the AEGIS subroutine library provides the following support:

a) Database consistency is ensured, except in the case of a machine crash (in which case all data is recoverable).

b) Two separate point features cannot have the same location.

c) There is unlimited feature-sharing using attribute lists.

d) There are automatic checks for knots as segments are added.

e) Null segments cannot be added (if a segment has start and end node the same, it must have at least two intermediate co-ordinates).

f) Update histories are automatically recorded.

g) Application programs are independent of physical file structure.

h) Douglas-Peucker line generalisation is supported.

i) A comprehensive set of basic operations on spatial data is easily accessable to the application programmer.

Points, and Operations Upon Them

The basic information held for each point is as follows:

Unique internal reference number
Location specified by two floating point numbers
The degree of the point (ie. the number of segments for which it is a node).

The basic operations supported are ADD, FIND (ie. locational search), READ, READ_SEQUENTIAL, ADD_ATTRIBUTE, READ_ATTRIBUTE, DELETE_ATTRIBUTE.

Within these operations there is automatic support for one particularly important consistency check - namely that it is impossible for the user to cause two point entities with the same location as each other to be entered into the coverage.

There is no operation to delete a point. This is because a point is considered meaningless unless it has at least one attribute. A point without attributes is termed a 'ghost point' and is effectively deleted: read operations will not read such a point, but it can be activated by addition of an attribute immediately after its creation, or less commonly at a later time if its reference number is known. This approach avoids the problem of coping with delete-protection for points which are nodes.

Line Segments, and Operations Upon Them

The basic information held for a line segment is as follows:

- Unique internal reference number
- Start and end nodes (which are references to point entities)
- Length
- Area (cf Wade (1986))
- Envelope
- Date and Time created
- Date and Time deleted (if it has been deleted)
- XY location and a generalisation code, for every intermediate co-ordinate.

The basic operations supported are ADD, READ, READ_SEQUENTIAL, DELETE, ADD_ATTRIBUTE, READ_ATTRIBUTE, DELETE_ATTRIBUTE, JOIN, SPLIT.

The ADD operation automatically adds type 0 attributes to the point entities which are the start and end nodes. These provide pointers from the nodes to the segment. DELETE_SEGMENT will remove these attributes.

Unlike points, line segments may be deleted. This is because a line segment without attributes is more meaningful than a point without attributes. One may wish to create a coverage containing only local authority boundaries, for instance, without bothering to add any attributes because the meaning of all line segments in this coverage is already known. To do the same with a point coverage is less satisfactory since there may have to be other points (such a digitiser reference points) in the same coverage. In addition, the problem with delete-protection does not arise, because primitive regions are invalidated whenever any segment is added or removed from a coverage.

The DELETE operation does not remove the basic information for a segment. The segment is marked as deleted, and the date and time of deletion recorded. This allows the segment/node structure of a database as it was at any specified past time to be recovered, provided no subsequent garbage collection has taken place.

The ADD_SEGMENT operation automatically adds generalisation codes, calculated using the Douglas-Peucker algorithm, to all intermediate co-ordinates, and READ operation can filter intermediate co-ordinates using these codes. The user can, alternatively supply generalisation codes, or even use this facility to store height information for each intermediate co-ordinate.

Primitive Regions, and Operations Upon Them

These are a little more complicated. The reader is referred to Visvalingam (1986) and Wade (1986) for background and definitions.

The basic objects held are actually boundaries, but attributes are used to form a structure in which primitive regions are (almost) as easily accessable.

For each boundary, the following basic information is held:

- Unique internal reference number
- Type (either enclosing boundary, or hole, or null boundary)
- Area
- Perimeter length
- Envelope
- Inside (described further below)

The basic operation are BUILD, READ, READ_SEQUENTIAL, READ_ATTRIBUTE, READ_POLYGON_SEGMENTS

The BUILD operation is in two stages. The first stage builds boundaries, and identifies each boundary as either an enclosing boundary, or a hole. Each boundary comprises a list of segments, and these are held as attributes. Each such attribute contains the internal reference number of a line segment. This stage also adds an attribute to each line segment, containing the back pointers - ie. the internal reference numbers of the boundaries on the left and right of the segment.

The second stage forms primitive regions by allocating each hole to an enclosing boundary. The reference number of the enclosing boundary is entered into the INSIDE field of the hole, and an attribute containing the reference number of the hole is added to the enclosing boundary. To make everything tidy, there is a 'global enclosing boundary' with reference number zero, which has no segments, but has attached to it all the outermost holes of the structure.

Once this has been done, it is possible to access primitive regions by ignoring records corresponding to holes, and remembering when accessing segments for an enclosing boundary to also access segments for holes inside that boundary.

The third stage of Wade's boundary building algorithm has not yet been implemented because of lack of a good reason for doing so, but the data structure allows for it - each enclosing boundary (except the global enclosing boundary) would be marked INSIDE a hole, and each such allocation would cause an attribute to be added to the hole, giving the reference number of the enclosing boundary.

Compound Objects, and Operations Upon Them

Compound objects are lists of entities held as attribute lists. To a great extent, therefore, a compound object is nothing more than its attribute list. There is a little basic information held, however:

- Internal reference number
- Keys - four integers each in the range -32768 to 32767
- Name
- Envelope

The basic operations supported are ADD, READ, READ_SEQUENTIAL, READ_KEYED, DELETE, ADD_ATTRIBUTE, READ_ATTRIBUTE, DELETE_ATTRIBUTE, ADD_ENTITY_TO_COMPOUND_OBJECT, REMOVE_ENTITY_FROM_COMPOUND_OBJECT.

The ADD_ENTITY_TO_COMPOUND_OBJECT operation adds an entity of any type to the components of a specified compound object. It is just a double ADD_ATTRIBUTE function - one attribute added to the component list of the specified compound object indicating which object has been added, and one to the added entity indicating which compound object it is now a component of.

The most frequently used means of attaching a primitive region to a compound object is via an area seed. The general method is that area seeds are components of compound objects, and an area allocation procedure finds, for each seed, which primitive region it lies within. The primitive region is then attached to the compound object.

The reason for the keys is to provide a permanent unique identifier for each compound object which may be specified by the user, for instance, to specify a county, district, ward or enumeration district using standard OPCS area keys. This method can be used to represent hierarchical relationships between compound objects.

If permanent area objects, say counties, are to be stored they will be stored as compound objects. For example, the 'Islands Region' of Scotland would be a compound object (keys 65,0,0,0 if following OPCS codes) which would have many primitive regions attached to it.

Summary

We currently have an interactive digitising package acting directly upon these data structures via the AEGIS subroutines, together with a rather basic mapping capability. It is expected that all spatial data used by CACI Market Analysis will be held in this form, and accessed only via the AEGIS library, before the end of 1986.

We intend that a far more powerful mapping capability will be developed shortly, together with data dictionary and query language facilities.

No final decision has yet been made on whether the software will be made commercially available. The authors would be interested in hearing from any parties who feel that they could either contribute to the ongoing development programme, or benefit from it.

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DESIGN OF THE CAPITAL AREA DEVELOPMENT INFORMATION SYSTEM (CADIS) BAGHDAD, IRAQ

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ABSTRACT

Environmental Systems Research Institute (ESRI) of Redlands, California, U.S.A., under contract to PASCO International, and under the direction of the Japanese Consortium of Consulting Firms, has been participating in the Baghdad 2001 Project which will produce a long-term development plan for the City of Baghdad and its regional environs. ESRI's work has been the development for Amanat Al Assima (AAA) of a conceptual design and implementation plan for an automated geographic information system (GIS). ESRI's work included assessment of GIS user needs, evaluation of existing data, designing a new data base, designing an information system and developing an implementation plan. Based on these efforts a new data base (including the cartographic layers and related tabular items) and 22 "applications modules" (each a set of software procedures which use, manage and update a commonly stored data set) were designed to satisfy the information needs of all the user groups. This new system, the Capital Area Development Information System (CADIS), is now under development.

INTRODUCTION

In the past decade the City of Baghdad has experienced an exponential growth in its population; currently this growth rate exceeds five percent per year. It is anticipated that the population of Baghdad will reach 7.65 million by the year 2000-- nearly double the present population.

This rapid growth is placing a tremendous burden on agencies involved in the planning and implementation of municipal infrastructure and community services. To meet the challenge of spiraling growth as well as to be able to conduct day-to-day management activities, planners and managers need comprehensive and up-to-date information about the City, its operations, and its population; and they need tools to effectively store, use and manage this information.

The Amanat Al Assima-- the "Keeper of the City"-- is the central government agency responsible for municipal functions within the City of Baghdad. To facilitate the management of growth to the year 2001 and beyond the Amanat Al Assima (AAA) has undertaken the development of a comprehensive masterplan for Baghdad. This development is being carried out at three levels: a study for the Regional Framework, the Structure Plan of Greater Baghdad, and the Comprehensive Development Plan of the City of Baghdad.

In scope and content this study, called the "Integrated Capital Development Project: BAGHDAD 2001", is one of the most comprehensive and intensive studies of this type ever attempted.

One element of the Integrated Capital Development Program (ICDP) is the development of a Capital Area Development Information System (CADIS), a computerized geographic information system to support current metropolitan planning efforts and, ultimately, municipal operations of the various agencies within AAA.

This paper reports the results of a several month effort to:

-- define the data and applications needs of the various departments within AAA and the ICDP planning team;
--to develop specifications for hardware and software for a Geographic Information System (GIS);
--to design a conceptal structure for an AAA geographic data base, and, finally;
--to develop an implementation plan to guide the development of CADIS.

STUDY METHODS

This study effort involved the application of a comprehensive method for the design, development and implementation planning of a municipal Geographic Information System (GIS).

The method involved a five-step, rational process of defining how geographic information is used by AAA and then a translation of this knowledge into detailed specifications and an implementation plan for CADIS.

The five steps were:

1. Conduct User Needs Assessment
2. Evaluate Existing Data
3. Define CADIS Conceptual System Design
4. Develop System Component Specifications
5. Develop Implementation Plan

USER NEEDS ASSESSMENT

The design of CADIS was based on first gaining an understanding of how municipal operations and planning are carried out in Baghdad at present, and, secondly, translating these needs to specifications for the basic components of a GIS system and alternatives for how it might function. To understand the current systems, the CADIS design team spent three weeks in February, 1985, in Baghdad conducting interviews with various agencies within Amanat Al Assima and several other ministries involved either directly or indirectly in municipal operations.

The report on each interview was divided into four sections:

--A brief description of the basic organization and responsibilities of the agency.
--A description of the general tasks carried out by the agency and systems (i.e., procedures and/or equipment) used to carry out these tasks.
--An inventory and descriptions of geographic data used and/or generated by the organizations.
--A short narrative of general observations and GIS potential within the agency, whether stated directly by the interviewees or perceived by the design team.

As a result of the study various geographic data management procedures, issues, data and analysis needs were identified.

These may be summarized in three subsections:

1. Generic Municipal Functions in Baghdad.
2. Generic Data Management Procedures.
3. Generic GIS Applications.

Needs Assessment Summary

Generic Municipal Functions in Baghdad. Municipal functions, or tasks, and the types of data which support them, comprise the vital element which ties together the various AAA departments and other ministries involved in operations and planning in Baghdad. An examination of these tasks, together with the manual and automated data bases which are used in supporting these functions, provided the fundamental framework upon which a conceptual model of geographic data entities and their relationships in Baghdad was developed.

Municipal agencies in Baghdad carry out over 100 basic tasks. These were consolidated into a series of 34 generic municipal functions as a result of information from the interviews and experience in developing similar lists for cities in other parts of the world. These generic municipal functions are shown in TABLE 1.

Generic Data Management Procedures. The 100+ basic tasks identified required the use of geographic data management procedures (e.g., storage, manipulation, analysis, retrieval and display). Analyzing the data management procedures needed by each agency was useful in identifying and managing the software and system requirements used for developing software and hardware specifications.

Generic GIS Applications. The analysis of GIS activities and needs of the various organizations revealed several areas of common interest and some areas unique to individual entities.

Among the areas of common interest were:

--A centralized base map generation and maintenance function.
--Automated update of files from operational transactions.
--Access to a comprehensive data base of parcel related data.
--A commonly used universal parcel identification system.
--Access to a data base of information concerning land development activities throughout the City and Region.
--A capability to analyze community facility service areas, site efficiency and clustering of events.
--A capability to process map data on the basis of variable defined polygons (administrative units, census districts, fire response zones, etc.).
--The capability to produce shaded thematic and data value maps of numerous data sets.
--Direct and convenient access to computer facilities and data bases.
--Need for an integrated AAA resource library.

EVALUATION OF EXISTING DATA AND SYSTEMS

Table 1

Generic Municipal Functions

1. Acquire & Dispose of Property
2. Process & Issue Parcel-Related Permits
3. Perform Construction Inspections
4. Provide Legal Notification
5. Conduct Street Naming
6. Review Site Plans
7. Review Subdivisions
8. Create Street Addresses
9. Perform or Compile Event Reporting
10. Conduct Dispatching
11. Perform Vehicle Routing
12. Conduct Traffic Analysis
13. Conduct Facility Siting
14. Administer Area Districting
15. Administer Zoning By-Laws
16. Conduct Land Use Planning
17. Conduct Engineering Design
18. Conduct Drafting
19. Conduct Land Title Searches
20. Perform Tax/Fee Billing Collection
21. Create & Manage Mailing Lists
22. Allocate Human Resources
23. Perform Facilities Management
24. Perform Inventory Management
25. Perform Resource Management
26. Miscellaneous Maintenance
27. Perform Map Management
28. Conduct Drawing Management
29. Perform Data Base Management
30. Conduct Development Tracking
31. Desseminate Public and/or Government Information
32. Respond to Public & Government Inquiries
33. Conduct Surveys
34. Maintain Library

The spatial units and related tabular data sets which comprise the elements of geographic data used for planning and operational tasks in Baghdad were identified. This assessment was based upon task descriptions identified in the user needs survey and upon on-site evaluation of map and tabular data.

A central component of CADIS is the data base of spatial and tabular information. This includes maps of spatial information and tabular data tied to the spatial information by means of geocodes. (Common geocodes include land parcel address, enumeration district number, traffic analysis zone (TAZ), etc.). These maps and tabular data provide the basic framework for day-to-day operations of the City and long-term planning.

The evaluation of these data elements included specifications and characteristics of each element and the interrelationships which have bearing on how these could be physically and functionally integrated to form a conprehensive data base for Baghdad.

The specific characteristics of each data element which were identified including the following:

--Source Organization
--Data Entity
--Variables
--Data Form
--Conceptual Municipal Geographic Data Model Component
--Cartographic Primitive
--Geocode

CADIS CONCEPTUAL DESIGN

A conceptual design for functional and data components of CADIS has been prepared. The concepts were based on the work described above as well as experiences and approaches from other city governments with similar information needs in different parts of the world. The concepts presented were broader than just geographic information concepts. They dealt with many processes and kinds of data which are dependent on geographic relationships or geographic location.

Overview

The overall conceptual design of CADIS is organized to meet the varied requirements identified in the individual departments and related agencies. The wide range of necessary capabilities are organized into a series of conceptual system components or "application modules" which are integrated into the overall GIS. Each of these modules contains a set of software procedures which use, manage and update a commonly-stored database. The integrating concept of the system is that all application modules are built around a common data model containing all the geographically-related information. These 22 "application modules" are listed along one axis in TABLE 2. As evidenced by the information acquired in interviews and previous studies, the GIS concept for CADIS must address several basic classes of geographic information (maps and tabular data) shown on the other axis of TABLE 2.

Several basic principles were applied in developing the design of CADIS.

1. CADIS is structured around a common, integrated database which is available to all user organizations.

2. The database is to be developed in a logically consistent manner using modern principles of database management (e.g., minimum redundancy, transaction updated, user-oriented data definition, and a well-defined data model related to user requirements).

3. The CADIS database will be constructed according to an incremental phasing program and will be maintained through tranasaction updating as part of ongoing programs and operations. These transactions will be built into the operational procedures of each department.

4. The software for the application modules will be developed using an existing library of software tools from a DBMS designed especially for management of spatial data.

5. The CADIS software and database will be supported by a common and integrated hardware environment and a data communications system.

6. Management and implementation of CADIS will be by an interdepartmental committee with central coordination and technical support.

FIGURE 1 illustrates the CADIS conceptual system design. The design is composed of the 22 application modules using a set of geographic data management procedures or software tools, to access, manage and use common database components.

CONCEPTUAL DATABASE DESIGN

Table 2

Data Requirements Per Application Module

● High Dependence
○ Moderate Dependence

APPLICATION MODULE	Base Map (Horizontal/Vertical Control)	Environmental/Physical Overlays	Environmental/Physical Tabular Data	Engineering Map Overlays	Engineering Tabular Data	Street Network Map	Street Tabular Data	Administrative Boundary Overlays	Administrative Boundary Tabular Data	Cadastral Overlays	Parcel Address Tabular Data
	DATA MODEL COMPONENTS										
1. Baghdad Basemap System	●										
2. Land Subdivision System	○									○	●
3. Cadastral Mapping System	○									●	
4. Land Registration System	○									○	●
5. Roads Information System	○					○	●				
6. Transportation Analysis and Planning	○					●	●	○	○	○	
7. Building Permit System	○									○	●
8. Water Supply Management System	○			●	●	○					
9. Sewer Management System	○			●	●	○					
10. Administrative Mapping/Reporting	○							●	●	○	○
11. Property Management System	○									○	●
12. Land Use/Environmental Planning System	○	●	●								
13. Cultural Resources System	○	○	●							○	
14. Environmental Monitoring System	○	○	●								
15. Vehicle Routing System	○					●	●			○	
16. Facility Siting System	○	○	○	○	○	○	○	○	○	○	○
17. Development Tracking System	○			○	○	○	○	○	●	○	●
18. Land Appropriation System	○			○				○		○	●
19. Emergency Planning System	○					●	●	○	○	○	○
20. Emergency Response System	○					●	●				
21. Fire Inspection System	○									○	●
22. Contract Status Management/Reporting	○							●	●	○	○
23. Metropolitan Plan Review and Comment System	●	●	●	●	●	●	●	●	●	●	●

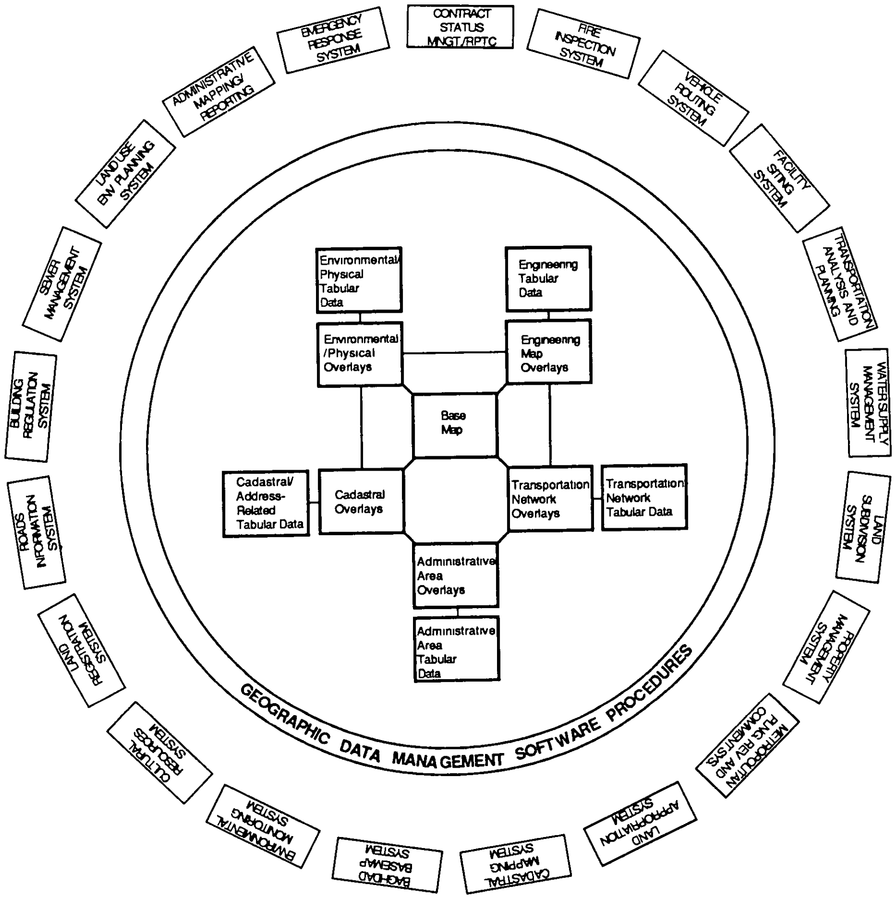

Figure 1

CADIS Conceptual System Design

Initial data evaluations revealed the existence of 15 potential spatial primitive "layers" associated with over 240 tabular data elements by means of a geocode or other geographic identifier. Further evaluation based on analysis of data requirements for carrying out the 22 applications modules revealed that this list could effectively be consolidated to six basic spatial layers corresponding to basic components of the Baghdad Municipal Data Model. These include:

--Base Map Layer
--Parcel Layer
--Environmental/Physical Overlays Layer
--Street Network Layer
--Administrative Boundary Layer
--Utility Map Layer.

SYSTEM SUPPORT

CADIS will require a support environment which consists of four basic components which will provide the infrastructure for the effective implementation and ongoing use of CADIS. These four basic components are:

--System Management
--Computer Hardware
--Computer Software
--Training.

CONCLUSION

The implementation of this design will require a six-year, three-phased effort. A plan for this implementation effort has been submitted to AAA.

GEOGRAPHIC INFORMATION SYSTEMS AND THE BBC'S DOMESDAY INTERACTIVE VIDEODISK

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ABSTRACT

The Domesday Project is an ambitious attempt by BBC Enterprises Ltd. to present a contemporary snapshot of the United Kingdom in the 1980s on interactive video disk. Two disks are being produced: the first, the local or community disk, consists essentially of information collected by the people of Britain. The second, the National disk, has (amongst other material) a selection of data from both government and quasi-government sources. In total, the disks will hold about 500 megabytes of digital data, some 50,000 photographs and around 20 million words of text. The paper introduces, briefly, the idea of interactive video, and the local disk. It then concentrates on methods of access to, and cartographic display of, data on the National disk. We concluding that it is a significant Geographical Information System which will form the ultimate widely-used database system for the forseeable future.

INTRODUCTION

1986 marks the 900th anniversary of William the Conqueror's survey of Britain, the results of which became known as the Domesday Book. To mark this event, BBC Enterprises Ltd. has undertaken a major project to combine the latest optical disk technology with data, text and photographs from a huge variety of sources; the resulting 'Domesday Disks' will present a contemporary snapshot of Britain in the 1980's.

This material is to be stored on two interactive PAL video disks: 'traditional' video disk technology allows for the storage on any one video disk of 108,000 images, or pictures. However, Philips Electronics Ltd., who are partners in the Domesday Project are developing a new disk player which can retrieve data stored in the sound track and, under control of a BBC Master Series microcomputer, can combine data and images and display them in an appropriate manner. The 320 megabytes of data which can be stored per side on any one video disk, in combination with 54,000 images, provide an enormous data resource for a wide range of uses by an equally wide range of users.

The two component disks of the Domesday system are very different in both origin and content. The first disk, the

Community disk, has been dubbed the 'People's database', and consists of information collected by schools, community groups and individuals (Atkins, 1985). Text and photographs describing small areas of Britain can be combined with Ordnance Survey maps at scales of between 1:625,000 and 1:10,000 to provide a unique representation of how people in the various parts of the United Kingdom, the Isle of Man and the Channel Isles see themselves in 1986.

Of particular interest is the second disk, the National disk, which offers probably the largest and most accessible geographical database for Britain which is available for interactive use. The system offers an automated map display system which is novel in that digitally generated maps can be displayed over specially prepared base-maps stored as video images. The GIS is also unusual in that it is simple enough to permit fast access to data and allow interactive mapping and some limited data analysis in real time by relatively unskilled users.

The Domesday system is distinctive for a number of reasons. It has cost about £2.5 million to assemble the necessary data, hardware and software; the disks contain contributions from about 1 million people, mainly on the local disk; it promises to become a prototype system that could well be repeated with different data sets (particularly commercial data) and for various other countries, and it is designed to be used by the general public. It was intended to be reasonably cheap to foster a mass market but it now seems that its prices will not favour home purchase; nevertheless, it is expected to sell sufficient copies over the next few years to constitute a base for future video disk developments.

Domesday, however, was never intended solely to be a conventional Geographical Information System. In the first instance, it contains much information of non-spatial interest, such as picture libraries, press clippings and other indicators of the life styles and attitudes of the British in the 1980s. It goes far beyond most GIS, however, in tying together spatially related data held in digital, picture and text form and permitting the user to move rapidly from one to the other searching on a number of keys. This has particular interest because the technology is not specific to the current project.

THE LOCAL DISK

The local or community disk is largely a conventional interactive video system which is novel in that the access path is map-based. In fact, a hierarchy of maps is stored which ranges from level 0 (the entire country) through level 1 (six divisions of the UK), level 2 (40 by 30 km rectanglar areas within level 1), level 3 (4 by 3 km rectangular areas within level 2), level 4 (0.8 by 0.6 km rectanglar areas within level 3) to, in some cases, a level 5 or more detailed plan of some object. The maps are stored as video-images and include a complete set of 1:50,000 scale OS sheets held as images, together with other maps at 1:625,000 and also some maps at 1:10,000 scale. The user can use a pointer to move up and down the map scale hierarchy and 'walk' across map sheets. Each map may have a set of photographs associated with it and text describing various aspects. Access is also possible by specifying a place name of interest (the 250,000 word Ordnance Survey gazetteer is stored) and by use of National Grid references. The principal use of the disk will be to acquire information about areas of Britain; the ability to link video images of maps with photographs with text make it a very powerful geographical tool. Moreover, digital operations can be performed on these video images - distance may be measured along cursor-defined routes amd areas measured within user-defined boundaries. In short it offers a means of obtaining pictorial images of what 'places are like'. It's use was recently demonstrated to the Prime Minister by 11 year old children who had only two hours practice on the machine. Hence it is so easy to use that we could envisage even Government ministers using it to obtain background information about places of interest to them (e.g. potential sites for nuclear waste dumps!). Of course, the method of collation of the information - schools and other organisations supplied their own pictures and descriptions - effectively provided an opportunity for communities to carefully 'launder' the Domesday image of their area! Finally, the local disk will probably also prove exceptionally useful as part of Computer Assisted Learning packages.

THE NATIONAL DISK

The National disk is more interesting in the GIS context in that it contains both 54,000 video images and some 320 mb of digital data stored in the sound track. It is estimated that about 100 megabytes are devoted to a large sample of cross-tabulated survey results based on data held by the Economic and Social Research Council Data Archive at Essex. Though some of this is referenced to areal units like counties or regions, it is regarded as 'non-spatial' data which can be reconstituted only in the form of tables and various plots and bar graphs. In addition, however, there are about 150 megabytes or so of mappable spatial data relating to one or more of 36 different sets of spatial units, a total of some 25,000 data sets, generated from the widest possible range of sources. These include data from the Agricultural and Population Censuses, employment and unemployment data, data on disease, and various environmental data sets. Owen et al (1986) and Rhind and Mounsey (1986) have described these data sets in some detail. Subject to the solution of copyright problems, there are then contributions from nearly all possible spatial data sets currently available in the UK. In practice, the principal limitations are not storage space but rather the availability of data. These data are accessed through a thesaurus of keywords, with geographical regions of interest being specified by either place names or grid references.

DESIGN CONSIDERATIONS FOR THE INTERACTIVE MAPPING SYSTEM

The data storage strategy

The interactive mapping system developed is one tailored to the micro-computer facilities used: a raster graphics system has been developed which can represent both grid square and non-grid square data. The basic principles are as follows. The grid square data are held in a raster form and are stored using appropriate compression techniques. In addition, however, the boundaries of 36 different sets of (non-square) geographical areas (see Appendix 1) have been rasterized and stored in a specially developed data structure. Each rasterised boundary data set is stored as a compressed grid-square data set and pointers link the vectors of data for each set of areas. This ensures that any one set of boundaries is stored only once, irrespective of the number of variables are available for these areas. The scale of compression achieved is substantial: a 1 km resolution raster boundary file dimished in size from 3276 to 82.7 kilobytes after compaction and a 1 km grid square data file dimished from the same starting point to 188.8 kilobytes. These are worst cases - coarser units permit the use of much less storage space.

Whilst data compression ensures minimal storage space and fast retrieval times, the limited processor power of the micro-processors used in the initial release of Domesday, and the design requirement that no more than 12 kilobytes of RAM could be considered available for data use in main memory, meant that no sophisticated data manipulations could be performed. Moreover, since the software was being designed at the same time as the video disk hardware, the elapsed time to retrieve data on the optical disk was unproven. Given this, it was logical to minimise all read activities, and especially those of a random access nature. This was one element of the design of the disk data structure; Openshaw <u>et al</u> (1986) describe how it was achieved via a doubly nested fixed block access method with an adaptive mix of several different compression techniques being employed. It also meant that it was worthwhile trading off optical disk space against the computational load placed on the processor. For example, a key problem with raster graphics is the size of raster cell; the critical value of this will vary according to the usual size of the map window to be displayed, the resolution of the display monitor, and the size of the areal units being shown. If the available processing power is inadequate always to work at the limits of the screen resolution or to re-aggregate the data dynamically whenever necessary, then the only possible solution is to store each areal unit for a range of different raster sizes. The Domesday system uses ten different raster sizes in the range 1,2,3 ... 10 km. It is then possible to select what is best for a given map simply by reading a different file instead of by re-calculation. Clearly, this solution is not as elegant as the use of quadtrees or KD-trees, but neither of these alternatives would work on the hardware available here because of the restrictions on memory and the necessity of minimising the number of reads; we suspect that, even if the hardware permitted their use, they would not be as fast as the methods used here.

The selection of areal units
A related design issue concerns the method of automatic selection of areal units (depending on the data sets, up to 36 possibilities exist), of raster size (10 alternatives), of map window dimensions (virtually any size in the range 30 km to 1200 km is possible) and speeds of drawing. The basic TV monitor display for a BBC microcomputer is memory-mapped and, when working in 5 colours, offers no more than 120 raster cells in the Y direction. Great Britain is about 1200 km in the north-south direction so this fixes the minimum raster size at 10 km for national level 5 colour mapping; if the region of interest is only 200 km in the north-south direction, it would now be possible to use 2,3,4 etc, to 10 km. raster cells. The 'map draw speeds' are a power function of raster size; a 2 km raster requires four times as many squares to be plotted as a 4 km raster; the number of optical disk reads is similarly affected although in a less direct fashion because of data compression. The selection decisions are thus ones of trading off raster size (and with it, map resolution), against the elapsed time needed to draw a map. In the longer term, it is clear that semi-intelligent / expert systems could make such decisions in an effective way. For the present, however, the Domesday system uses a simple function to compute the most appropriate areal unit (from those available for whatever variable is selected) and raster size, taking account of the maximum number of squares that can be drawn within a reasonable time and given an estimate of 16 as the minimum number of areas needed to generate (on average) an interesting map! It is a crude but very effective solution, and allows a degree of hardware independence. A faster processor or a higher resolution display monitor can both be dealt with by changing the initial parameters in the function or by adding additional code to allow the parameters to be evolved from experience.

Classifying the data
Finally, classing methods have provoked a large literature in the cartographic press (see for example Tobler (1973), Dobson (1973), and Evans (1977)). We evaded the issue by making available four automatic methods (based upon the use of quantiles, equal areas, nested means and signed chi squared values (see Evans, 1983)) and also allowing the user to specify his or her choice. Default class intervals

calculated by each of the four methods are stored for every data set; the user selects which method to use, and a binary split at run-time generates an appropriate set of intervals and hence colours. The user can change the classing method and re-define the classes over the selected mapping window. It is also possible to change the resolution of the display, either by selecting a different areal unit or a different raster size (within the limit set by the memory available). In general, the results are of a quality similar to the best coloured census atlases (e.g. the People in Britain atlas (CRU/OPCS/GRO(S), 1980)) except of course here the user can generate an infinite variety of maps to meet his own specification and can draw upon a much wider range of data than is shown in any one conventional atlas.

VIDEO UNDERLAYS

This ability to generate interactive digital maps with a high degree of automation of the map design is only part of what the Domesday system can offer. The video disk technology used in the system allows a digital map to be drawn in register on an analogue base map, assuming an appropriate one has been stored as one of the 54,000 pictures on the disk. Since no place names or other features are included in the digital map, this facility allows the user to identify more precisely places in the selected area of interest.

Some 500 analogue base maps are recorded on the disk; this particular number arises from the need to include an appropriate map for every individual area within each of the 36 sets of areal units. The system selects an appropriate map for a user who has defined a rectangle of interest by specifying grid references (c.f. by specific areal unit). However, because the potential number of such windows is infinite, the provision of an ideally centred analogue map cannot be guarenteed. In any case, however, the user is free to display his digital map without an underlying analogue image.

Experiments have indicataed that the 500 maps had to be at a number of different scales to cope with areal units ranging in size from a Central London postcode sector to the whole of Britain. They also had to be simple in design so as to enhance, rather than confuse, the overlaid digital map. To produce maps to such specifications then involved use of a substantial part of the Ordnance Survey 1:625,000 digital database to draw some 1500 original maps using ARC/INFO at Birkbeck College; Mounsey (1986) described details of this aspect of the Domesday project and the problems encounted and solved.

GEOGRAPHIC DATA MANIPULATION

The Domesday system has only a very limited ability to manipulate data due to speed limitations of the initial processor. It is possible to calculate correlations between two map patterns using Spearman's rank correlation and a Court map correlation index and, perhaps more interesting, to apply a logical AND operation to a displayed map. The latter allows multiple co-incidence patterns to be displayed. Simple spatial data retrieval is possible either by pointing at an area of the map and retrieving a value, or by ranking values shown on a map. More detailed radial searches would be possible but are not in the system at present. Likewise, there is the capability for calculating new variables from the existing data; for example, computing a ratio from two other specified variables. In fact, most variables are stored as ratios, since it is not sensible to map counts for areal units that differ in shape and size. To preserve flexibility, numerators are stored with each ratio so that future versions of the system would be able to re-generate denominators and thus offer arithmetic manipulation facilities.

CONCLUSIONS

The Domesday system provides a large geographical data base, together with a customised information retrieval and interactive mapping system. For those interested in the geography of Britain, it will probably constitute the ultimate mapping system for the foreseeable future, replacing the need for the traditional 'atlas' type for all applications other than those needing hard copy. Furthermore, subsequent developments of the software will almost certainly provide greater manipulative and analytical functions and allow the system to migrate into a full blown optical disk-based geographical information display and analysis system.

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APPENDIX 1: AREAL UNITS FOR WHICH DATA IS AVAILABLE ON THE DOMESDAY NATIONAL DISK

N.B. Not all variables are available for every areal unit

1 km grid-squares
2 km grid-squares
3 km grid-sqaures
4 km grid-squares
5 km grid-squares
6 km grid-squares
7 km grid-squares
8 km grid-squares
9 km grid-squares
10 km grid-squares

National Aggregates
Countries
Standard Regions
Counties
Districts
CURDS Local Labour Market Areas
CURDS Functional Cities
EEC Level 2 Regions
Parliamentary Constituencies
Local Education Authorities
Regional Health Authorities
Travel-to-work Areas
ITV Regions 'best fit'
ITE Natural Regions
Amalamated Employment Office Areas
European Assembly Areas
Police Authority Areas
ITV Non-overlapping 1
ITV Non-overlapping 2
ITV Non-overlapping 3
District Health Authority Areas
1981 Census Wards
GPO Postcode Sectors
GPO Postcode Areas
GPO Postcode Districts
CIPFA Library Areas

Abstract for Auto Carto London

Title Bench Marking and Acceptance Testing: Towards Standard Approaches

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Bench Marking and Acceptance Testing : Towards Standard Approaches.

A Benchmark test is a most important step for the client who, having no other information, must know how closely a system meets required specifications. A useful Benchmark test is costly

It is fairly unusual for a client to pay for a Benchmark, but clearly "free" benchmarking is in the end paid for by (other?) customers through initial and recurring charges

Each Benchmark test will check some functions which may be of interest to several users, and some specific functions representing the unique interests of the potential customer The results of Benchmark tests normally remain confidential, known only to the selling organisation and the potential customer, and perhaps to third parties acting as agents for the selling or the customer organisation But could the results of Benchmarks be made more widely available, thereby saving costs, without damaging the reputations of selling organisations still, for example, developing particular functions?

Benchmark tests are usually designed to ascertain whether, and how effectively, planned specifications are, or could be, met by a system As a result of these tests, specifications may be modified and a purchasing decision made. Some specifications, such as digitizer resolution, are stated by most selling organisations, but more useful quality parameters are not.
Industry wide procedures for determining quality parameters and the inclusion of such statistics in the commercial literature might be cost effective. Clear descriptions of software capabilities successfully achieved might permit the benchmark test to be reduced to those requirements of a buying organisation which are trully unique.

As the original specifications control the Benchmark testing, so the Benchmark testing, through the media of modified specifications, controls Acceptance testing. Acceptance testing ensures that the actual delivered system meets all modified specifications - both hardware and software. Acceptance testing may take place in several stages in a one week to six month period granted by the manufacturers, during which final payment for the system may not need to be completed. Because there is some time pressure on this testing, efficient procedures have to be developed.

Proposals for a range of suitable Benchmark and Acceptance tests are given.

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Abstract for Auto Carto London

Title GEOGRAPHICAL DATABASES FOR PLANNING PURPOSES

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Geographical data processing started early in Sweden. Already 1955 professor Hagerstrand at the University of Lund published a work in the Swedish Geographical Yearbook: "Data processing machines and aerial photography - a project of combination". That must be the first work in the field of Geographic Information Systems, however, the concept information system was not known at that time.

In the bootstraps of Hägerstrand and with the further development of the computers several administrative systems were computerized. As usual, the tax systems were the first ones, with a population register and a property register as the basic databases. Later on, the Central Board for Real Estate Data was established as a governmental agency with the task to implement a Land Information System for registration of real properties, land titles, mortgages and so on.

National Land Survey (NLS) is the official mapping agency of Sweden. Even if digital technique was used rather early, it is first in recent years the new technique has been used in regular production. Today, the digital technique is fully implemented and a mapping system, AutoKa, has been developed Along with the map production also databases are produced. These databases have a status similar to the official maps.

The objective of this paper is to present how the administrative registers and the databases created in the digital mapping are going to be used in physical planning at the regional level. First a pilot project in Skåne (the southmost province of Sweden) is described. In order to carry out the project the software of NLS was extended with a cabability to handle graphical and non-graphical data simultaneously.

After evaluation of the project three Land Information Centres (LINFO-centres) have been established in three different counties for a test period of three years. The LINFO-centres have to be organized, financed and managed by regional bodies. The support from NLS consists of basic land information education and software. Several projects have been designed. Some projects are concerned with the support of information, which is a new obligation of the planning unit at the county administration in the new laws on physical planning, building and conservation of natural resources.

The test period also has to show how the LINFO-centres will be organized and managed on a long term.

Abstract for Auto Carto London

Title A Design Framework for Water Resources Decision Support Systems

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Water resources decision support systems (DSS) can be organized in many ways depending upon institutional objectives and the nature of decisions that a system is designed to support. In this paper we outline a framework for aiding designers of water resources DSS through the use of the ROMC strategy advocated by Sprague and Carlson (1982): Representations, Operations, Memory Aids, and Control Mechanisms. These aspects of a water resources DSS should be clearly specified in order to ensure the successful development and operation of a water resources DSS.

Representations in a water resources DSS take the form of cartographic and non-cartographic displays, tabular listings, and computer formatted reports. At the DSS design stage, important choices must be made about methods of spatial referencing, and the degree of spatial precision chosen for storing cartographic representations. Thematic precision (e.g. number of categories) also plays a role in both cartographic and non-cartographic representations.

The specification of the number and types of operations in a water resources DSS is controlled by a need for information upon which to base decisions, a need to select from alternative problem solving strategies, and a need to design effective representations. From a cartographic standpoint, an important operation allows simplification (Douglas and Peucker, 1973) or enhancement (Dutton, 1981; Armstrong and Hopkins, 1983) of stream traces for producing maps at various scales. Examples of other, non-cartographic operations needed frequently in a water resources context are: production of summary statistics for streams or basins, and the application of logical decision rules to determine suitabilities from combinations of variables.

Memory Aids often take the form of a detailed database design and implementation strategy. An important component of a database is the adoption of a logical model to support representations and operations. Logical models vary in the types of relationships they support and in methods for producing efficient linkages among database elements. Miller (1984) has provided a structure for water resources applications based upon the relational model; Hopkins and Armstrong (1985) provide an example using a network design.

Control Mechanisms provide the means for performing operations, using representations, and manipulating memory aids. A number of control mechanisms are available, ranging from low level programming commands, to menu or icon driven displays, to natural language interfaces. The provision of documentation is also a vital aspect of control.

Abstract for Auto Carto London

Title: Graphic Stereo Raster Injected Verification Subsystem for Photogrammetric Acquisition

Author(s): R. Beerenwinkel, J.-D. Bonjour, R.D. Hersch, O. Kölbl

Affiliation: Swiss Federal Institute of Technology - Lausanne

The last two years, the practice has shown the importance of graphical injection systems for photogrammetric acquisition on stereo plotters (e.g. Zeiss-Videomap system and Intergraph system for Kern or Zeiss plotters). Such systems seem to be particularly necessary for cartographic updating - to confront photos with digital maps - and for controling precision and completeness of the map.

The Laboratories of Photogrammetry and Microinformatics of the Swiss Federal Institute of Technology of Lausanne have developed, in collaboration with the industry, such a graphical verification system. The main innovations of this system, in comparison with the above cited existant systems, are full editing facilities, the possibility to include the height information, and a rather low price. Furthermore, the system can be used as a peripheral for analytical <u>or</u> analog stereo plotters. These innovations are due to the development of a powerful display architecture with build-in dedicated panning functionality.

This paper will describe the characteristics of the hardware and the possibilities provided by the software. The system is based on a Motorola microprocessor and NEC graphical controller chips. It allows the operator to move in real-time (panning) in a virtual working space of 32'000 x 32'000 pixels, with a vertical and horizontal resolution of 1 pixel.

Abstract for Auto Carto London

Title Current state of development of a geographic information system based on linear quadtrees.

Author(s) James Hogg & Mark Gahegan

Affiliation School of Geography University of Leeds

Over the past two decades, scientists have developed geographic information systems to handle information about spatial structures and processes associated with man, his organisations and the physical environment. Most of these have been designed to perform specific and often a somewhat limited range of operations on one type of data for a particular set of applications. For example, geographic information systems for digital mapping rely mainly on vector representation for point, line and polygon mapping. While these are efficient for cartographic applications, they exhibit severe shortcomings in meeting acceptible levels of performance for geographic applications such as those involving search in large regional geographic information systems.

Over the past five years, the development of a variety of hierarchical data structures based on quadtrees has stimulated a review of traditional objectives and methods in designing geographic information systems. The potential advantage of using quadtrees lies in the efficiency with which many types of queries can be handled. Geographic information systems based on quadtrees overcome several major shortcomings that exist with traditional methods of storing spatial data, remove major barriers to geographical research and expand the horizons of geographers and other field scientists for participation in the analysis of large sets of images from archival maps, remote sensors and other sources.

In this paper, we describe the current state of development of a geographic information system using hierarchical data structures based on linear quadtrees. We outline briefly the philosophy that we adopted in developing the system. Then we explain the theory of the linear quadtree and its implementation in a suite of computer programs written in the C programming language on a VAX 11/750 computer running Berkeley UNIX 4.2. We describe the functions that we have implemented including quadtree encoding, set operations, determining properties of regions, neighbour finding, traversing an image, generation of statistics and output of maps. We illustrate how the geographic information system can be used with images from a variety of different sources to perform spatial analysis for applications in different fields of geographic research and comment on its performance, scope and limitations with particular reference to its potential use in Great Britain for regional planning and resource evaluation.

Abstract for Auto Carto London

Title: GIMMS Release 5, an overview of the facilities and design issues

Author(s): T.C.Waugh

Affiliation: Department of Geography, University of Edinburgh

This paper looks at some of the new facilities in GIMMS Release 5.0 and investigates the design thinking behind it.

The GIMMS system is a mature mapping system which has gone through four major releases since its inception in 1970.

The development cycle has continued and the opportunity was taken in generating the next release, 5.0, to radically change many parts of the system, bringing it more into line with modern computing practice while attempting to keep upward compatibility with previous releases.

In particular, the user interface has been greatly enhanced to include menu and conversational modes as well the previous command modes. Unlike many other systems, any user can define the characteristics of their terminal, and are not dependent on the supplier supporting their particular type of terminal for menu operation. As well as the GIMMS predefined commands, the system has also been enhanced to include sophisticated macro facilities, to allow the user to set up their own commands or menus, which can access many of the facilities of the system by defining a few parameters.

Mnay new facilities have been added, the most important of which is probably the capability to produce contour maps. The system can deal with very large grid structures for contouring, depending on the machine, and there is a straight trade-off between size of data set and speed.

The system has also been made much less machine specific, thereby making it easier for users, when they move to a new machine, to use GIMMS without learning new procedures.

Abstract for Auto Carto London

Title Database Management Handler for Wild SYSTEM 9

Author(s) George Moon / John Tulip / John Collins

Affiliation Wild Leitz Canada, R & D Division, Willowdale, Ontario, Canada

A new generation mapping and information system from Wild Heerbrugg uses a modified relational database management system for data manipulation. Modifications were made to circumvent the usual criticisms of the relational approach; too slow for spatial data manipulation. Two important modifications are the addition of a variable length text field and the addition of an undifferentiated variable length field. These modifications will be discussed in this paper. Examples from the database will be given to illustrate the results of the modifications.

The data structures for the spatial part of the database will also be examined with emphasis on the reasoning for the structures. Of special interest is the spatial request handler which manages the spatial data within the DBMS. The capabilities of the spatial request handler will be discussed with illustrations.

It is concluded in the paper that the spatial request handler by manipulating complex, simple and triangular feature classes is an effective means of handling spatial data.

Abstract for Auto Carto London

Title Integration of different mapping technologies

Author(s) Jan Ulc

Affiliation Intergraph Europe Inc.

This paper gives an overview of the design philosophy of Intergraph interactive systems for digital mapping, and reports on company's latest developments in the area of data acquisition and integration.

Hardware foundations include a range of standard processors and peripherals, as well as Intergraph-developed special processors to enhance system performance (incl. an array processor for raster image display and processing) and a range of graphic terminals. Of particular interest is the stand-alone UNIX and IBM-compatible engineering and surveying workstation Interpro32, which can also function as an Intergraph graphic terminal over Ethernet.
Open System Architecture and object-oriented system concepts are being utilized in developing next generation mapping and GIS software.

In the area of data acquisition: a) scanners are gaining acceptance, although not all types of maps are suitable for scanning. The "scanability", automatic feature detection and editing of different types of data will be discussed using practical examples.
b) The on-going integration of photogrammetry and interactive graphics resulted in development of first fully integrated photogrammetric workstation Intermap Analytic. INA includes dynamic colour superimposition, interactive graphics and user control in the stereoplotter's field of view. A summary of design objectives, technical characteristics and application software for INA will be presented.
c) Raster imagery, either remotely sensed multi-spectral digital image or scanned aerial photographs and other hard copy documents, can now be fully integrated with line-based mapping database. Intergraph's image processing software utilizes standard Intergraph colour terminals and include a range of display, spectral and spatial manipulations.

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Abstract for Auto Carto London

Title Object-oriented mapping and geographic information system

Author(s) Miguel Suarez

Affiliation ... Intergraph Europe Inc.

Object-oriented System and Open System Architecture are new concepts that are being employed by Intergraph to develop database and software foundations for next generation graphic systems.

Under this concept, the information is represented as a set of objects consisting of their own data definition, and a set of operations (methods) for manipulating the data, for carrying out tasks relative to an object, and, most importantly, for communicating with other objects.
Methods are invoked by messages, issued and controlled by an 'object manager'.
Open System Architecture makes code reusable in other programs, and transportable onto other computer environments.

Due to its inherent concept of distance, locality and proximity, the object-oriented system seems particulary suited for implementing new type cartographic and topological GIS databases. New approaches are being investigated to ensure satisfactory performance of interactive edit operations on highly structured databases.

The system further lends itself for integration and display of different data types, such as grid, raster and DTM, for extensive query possibilities, and for expert system possibilities. Progress in developing an object-oriented mapping and GIS system for a stand-alone UNIX environment will be reported, and a prototype demonstrated at the exhibition.

Abstract for Auto Carto London

Title: The Zeiss/Oberkochen PLANICOMP Family for Digital Mapping

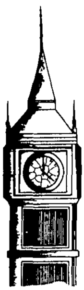
Author(s): J. Saile

Affiliation: Zeiss/Oberkochen

The range of PLANIMAP analytical plotters amde by Carl Zeiss/Oberkochen covers the entire field of photogrammetric plotting. While one fo the principal applications during the seventies was triangulation measurement, the last few years have also seen the emergence of these instruments in the field of mapping. Two of the reasons for this have been the favourable price/performance ratio and the use of digital mapping.

Digital mapping makes higher demands on the operator who must not only be familiar with the guiding of the floating marks but also with a multitude of commands for the measurement and classification of the objects involved. The efficient handling of the input data and the effective control of their influences are essential for the success of the work performed.

With PLANIMAP, VIDEOMAP and PLANICOMP, Carl Zeiss/ Oberkochen offers a complete system for digital mapping. This paper describes the latest new developments in the PLANICOMP family.



Abstract for Auto Carto London

Title .. ...Extensions in the Zeiss/Oberkochen PLANIMAP System ..

Author(s) ....K. Menke...... . . . .

Affiliation ....

The PLANIMAP software system from Carl Zeiss/Oberkochen is used for data acquisition, processing and output with photogrammetric and cartographic instruments. It has been repeatedly extended since 1983.

For direct mapping applications, in particular, the PLANIMAP has provided the user with an exemplary method for some time now. A large number of maps has been produced by the digital method for the first time. The PLANIMAP now offers various new features, permitting rapid and convenient map revision. This is backed up by a further improvement in operator comfort, an extended data structure and by intelligent high-resolution colour screens.

This paper describes the major innovations in the PLANIMAP.

Abstract for Auto Carto London

Title The Design of Future Archiving Systems to Support Advanced Remote Sensing Programmes

Author(s) D.R. Sloggett, A. Hull

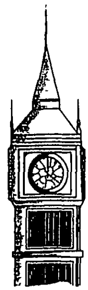
Affiliation Environmental and Space Systems Group, Software Sciences Ltd.

Future generation remote sensing programmes will provide order of magnitude of more data than current day systems due to the requirements for all weather operation coverage. This will generate larger quantities of data that will require archiving and management.

Collocated, with the raw data obtained from the satellite, ground truth data, calibration data and other sources of tabular information, required for product generation, will be stored within the archive. Single access mechanisms for this data and many other data types that will be stored within such a data centre archive will be essential and the paper discusses that in the context of the UK ERS Data Centre.

The paper features the design of the ERS-1 Data Centre as it has specific archiving problems with a total data rate of 100 Gbytes/day arriving in the course of the mission of the satellite. New technologies for archiving feature in the design and the issues of growth and interfacing with other data centres archived are also addressed.

The paper concludes with estimates of the size of ground data centres archives for many missions that are planned over the next decade and highlights the very real issues of costs of maintaining the data in readily accessible and in a format suitable for processing. The paper also addresses the issue of maintaining an archive of all products as they are generated or archiving of all raw data and generation of products on-demand.



Abstract for Auto Carto London

Title "Investigation of Alternative Algorithmus for the Transformation of Digital Cartographic Data"

Author(s) Ernst Jäger

Affiliation Institute of Cartography of Hanover University (FRG)

In digital thematic cartography the change of map grids is of great importance. The primary aim is to carry-over the contents of a certain map into another one -with different projection in both maps. By doing this one aspect gets more and more significant : to keep ready cartographic data digitized once for any map projection. This is possible by the successive establishment of a standardized data base (e.g. CORINE-Coordinated Information System of European Environment). In small-scaled map regions (< 1 : 500 000) the geographic-coordinate-system is the only practicable reference system of a data base.

The transformation of x, y-map coordinates into geographic coordinates φ and λ principally occurs on two alternative ways:

- inverted close projection equations and
- interpolation methods (e.g. power series).

In the Institute of Cartography of Hanover University (FRG) for both methods computer-programs are developed and tested. The accuracy of the results is discussed and compared with results published by other authors. The paper compares advantages and disadvantages of the methods and mentions guiding rules for the selection of the most efficient method under certain conditions.

Abstract for Auto Carto London

Title Generation of D.T.M. for Flat Areas by Least Squares Techniques on a Mini-Computer

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Affiliation Survey of India, Chandigarh (India)

A close description of earth's relief is needed for several purposes by administrators, planners and resource scientists. Such a requirement cannot be met in normal working, except by way of supplementation through various means. Digital Terrain Model (D.T.M.) defined as a registration of array of spatial coordinates is one such means. Expression of the terrain in D.T.M. is final, does not depend upon scale and can be regulated at will, provided source material is available. Basic problem of all D.T.M. is its density vs the sophistication of the mathematical model

$$Z = f(X,Y)$$

approximating the earth's surface.

D.T.M. was generated by linear least squares interpolation for flat areas of Punjab and Baryana States in India by adopting $Z = a_0 + a_1 X + a_2 Y$. It was based on 4,9, 25 control points for blocks of 25, 50, 100 sq. km. areas and grid nodes test checked on a large sample of known spirit level heights. A FORTRAN IV computer programme written for the purpose was used on the mini-computer Spectrum 7 of D.C.M. for these investigations. $\sigma_o^2 H$ on check points in each case was obtained. Heights generated were plotted on large scale maps with 2/5m V.I. and agreed very well. Further accuracies in heights could be obtained for large flat areas by use of second degree polynomials.

Abstract for Auto Carto London

Title Automatic Raised Relief Maps

Author(s) M. Claude Pilkiewicz

Affiliation Institut Geographique National (France)

A new type of output for the elevation
data base of the French Institut Geographique National:
raised relief maps.

Introduction

The Institut Geographique National having set France's Altimetry in a data base, the next step was to automatize one of its traditional activities: the production of relief maps. Two studies have been successively undertaken, on hardware and on software.

Hardware

The aim of the first part of this study was to examine the necessary instruments. It led to the purchase of a Rambaudi numerical controlled milling machine, to the manufacturing of a controller for the concatenation of data transfered and milling sequences and to establishment of a connection with the computer managing the data base. Simultaneously, materials were tested in order to find a bearer allowing milling as well as manual retouching.

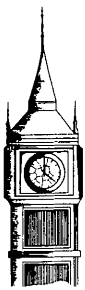
Software

The software is based upon the normalisation of raster files made at the IGN. It is thus possible to treat digital elevation models as well as thematic maps or any file from other sources. Completely modular, the chain of programmes can be divided into three parts:

- preparation programmes, such as introduction of tasks, reversing of relief, placing of houses, cutting out.
- control programmes, such as hill shading and visualisation on a graphic screen.
- the control programme of the milling machine. The aim of this last one is:
  - to make all the controls (size, security....)
  - to modify the milling parameters (drills, steps....)
  - to transfer orders to the controller and to the milling machine. It improves the necessary time by using drills of different size for sketching and touching up.

Conclusion

The last tests were being made as this summary was written. The first orders should be started in early 1986 and the results could be submitted in September 1986.



Abstract for Auto Carto London

Title Design Aspects of a Digital Mapping and Anaylsis System

Author(s) Reino Ruotsalainen

Affiliation Finnmap Oy

The paper will include different aspects when designing an economic system, which is intended to be used especially by urban planners for setting up a digital data base and to manipulate the data for planning purposes.

First, the objective and general principles of the system are specified. The hardware requirements are shortly reported.

Secondly, the software aspects are presented including:

- digitizing software and other input possibilities
- interactive graphic editing software
- plotting software
- attribute data base management and thematic analysis
- utilities software

Finally the experiences with the development of so called MASMAP-system (Mapping and Anaylsis with Small Format Aerial Photography) are presented. MASMAP-software has been developed by the Finnish company Finnmap and it is based on the above aspects and the specification of ITC (The International Institute for Aerospace Survey and Earth Sciences).

Abstract for Auto Carto London

Title The problems of implementing Computer Aided Cartography in Tertiary College Courses.

Author(s) R. Beard

Affiliation Luton College of Higher Education

A number of courses exist in the United Kingdom for the education and training of Higher Level Cartographic Technicians. With any vocational course the first problem is to establish the needs of the employer and employee. Always a difficult task, this is made even harder by the inexperience of most employers and the rapidly changing technology. Needs may range from purely operational skills, through editing and design skills to system development and innovation.

To satisfy these needs there are, in practice, a number of aims to be achieved. Firstly a familiarity with the operation of specific hardware and software; secondly an understanding of the underlying principles of computer graphics; and thirdly the application of the first two to cartography.

To achieve these aims colleges are faced with the problems of finding the resources to finance the hardware and software; to provide the expert support that is necessary to install, maintain and develop these; to maintain teaching staff expertise in such a rapidly developing field and to find the necessary teaching time.

There are a number of levels of compromise which can be adopted by a college, for example, the use of personal computers for the teaching of principles and the use of sample packages on college based systems for specific applications.

Of paramount importance is the need to maintain flexibility to accommodate changing demands of industry and technology.

Abstract for Auto Carto London

Title Teaching design aspects of computer Cartography

Author(s) ... D.W. Vicars, ...

Affiliation . . .Oxford Polytechnic. ..   . .

Few computer maps have been produced to production cartographic standards at economic costs or time scales The full introduction of computer based map production as an integral part of a sucessful degree in course in Cartography faces similar obstacles The students have to learn and apply Cartographic design principles, they cannot be impeded or compromised by the use of the computer

Thie paper examines the relavence of the standard aspects oif the computer mapping syllabus to the computer literate carographer and to the programmer who is also a computer programmer from the viewpoint of intetgration into the Cartography degree syllabus both as a digital cartography stream, where appropriate CAD methods are learnt and practised, and for expansion of major areas of subject areas such as surveying, photogrammetry, map projection, terrain analysis and map design This lays a basis for both the group project and dissertation to be computer based

The software used is a combined raster and digital database with input via a DTM (itself obtained from surveyed measurments) or direct from a digitiser, combined with the GIMMS thematic mapping package This exemplifies the bulk of the taught computer cartography material very effectivly.

The Oxford Polytechnic Modular Course allows students to combine a large range of subjects The paper explores the possibilities for those students who choose Computer Science and in particular information systems and software engineering.

Abstract for Auto Carto London

CONTOUR-TO-GRID METHODS FOR THE ARAC SYSTEM

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ABSTRACT

Lawrence Livermore National Laboratory has been concerned with the accidental release of radioactive material into the atmosphere for the past fifteen years. This concern is apparent from their development of the Atmospheric Release Advisory Capability (ARAC), an operation for estimating the concentration of foreign material in both space and time. Such estimates involve the execution of a suite of sophisicated computer simulation programs which use terrain, geographical, meteorlogical and source concentrations as input. Under optimal conditions, the required data would be readily available. However this rarely happens in actual emergency situations since the data may only be available from secondary sources. For example, digital terrain data for locations outside the continental United States are often nonexistent.

By combining a digitizing system developed by ARAC personnel with a contour-to-grid program developed for ETL by the ZYCOR Corp., ARAC has developed a capability which allows operators to develop digital gridded elevation data from contour maps in an automated fashion. When combined with extensive graphics and editing capabilities currently available, ARAC will have a method for obtaining accurate gridded terrain data for any location for which a contour map exists within a reasonably short time period. The contour-to-grid program is compatable with the programs that currently handle terrain data in the ARAC system. It also has a menu-driven human interface and includes an edit capability. The program allows the selection of either of two numerical techniques for performing grid adjustments. The contour-to-grid system will become an alternate method of obtaining terrain data which is of critical importance to the ARAC project.

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory, Livermore, CA under contract No. W-7405-Eng-48.

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ISBN 0-854 06-312-9