THE CAPTURE OF SURVEY DATA

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ABSTRACT

Survey data of Great Britain has been digitally captured from graphics on cartographic digitising tables since 1972, but despite work now also going out to contract, less than 15% of the archive has been collected and the estimated completion date of 2015 is criticised by map users. The paper describes the build-up of production and efforts to achieve acceleration of the programme by automation. Steps to incorporate data captured on photogrammetric stereoplotters or field 'total' stations are covered, as is the development of a workstation to enable revision data to be captured in the field section office. Significant changes are in hand.

THE ADOPTION OF DIGITAL MAPPING

Initial Installation of Equipment

For the purposes of Digital Mapping the term data capture must imply topographic detail in digital form and ignore observations recorded for control purposes. The first Ordnance Survey equipment capable of digitally recording topography was set up in the then Air Survey Branch, now Photogrammetric Services Division, in 1969 and consisted of a set of shaft encoders for a Wild A8 Stereoplotter, a D-MAC digitising table and a Calcomp 24 drum plotter (Sowton 1971).

Consideration of Tasks

The original concept had been to capture detail in the photogrammetric stereoplotter and use the D-MAC for supplying additional features and corrections before making a plot ready to send out for field checking, the objective being to save penning time rather than to collect digits or to make a cartographic product. It is worth considering the tasks facing OS in 1970 to appreciate why investigations then took a cartographic turn. The 1:1250 resurvey of urban areas, amounting to nearly 50 000 sheets, was complete except that then, as now, there was a steady trickle of new areas being either extensions to existing blocks or small towns whose development was sufficient to justify this scale of mapping. About 400 sheets (100 km^2) per year were then being upgraded, perhaps half of them photogrammetrically. The overhaul of the old County Series 1:2500 was in full spate; the objective was to complete by 1980 the 170 000 or so sheets and a peak production in excess of 10 000 sheets per year was achieved at that time. This was a combined field/photogrammetric graphical revision process using rectified enlargements of the photograph but no stereoplotters. The major photogrammetric effort divided some 30 assorted stereoplotters more or less equally between the 1:10 000 resurvey and the supply of contours to the 1:10 000 derived series.

Emphasis on Cartographic Digitising

In view of the situation in which an overwhelming majority of the basic scales mapping was either already available as a published map or would arrive, after graphical survey processes, for production it is hardly surprising that early experimentation very soon concentrated on digitising from graphics (Irwin 1970). The phrase Digital Map was used, if at all, to describe a plot produced from digital data; the idea of the digital version itself being a useful commodity had not arisen and the processes were geared towards the use of automated drafting machines which ought to be more economical than draughtsmen. In this context there was an experiment in 1971 to capture contours digitally and plot them automatically to save penning time but this was not economical. With hindsight one can regret the decision not to capture and preserve digital contours but since at that time the sole objective was to produce printed maps, digits were not the best means to that end. Apart from this the decision to concentrate on cartographic digitising was both logical and inevitable.

Original Production System

Experiments with this equipment led to a system easily recognisable as the forerunner of today's digital specification. The data is captured as a series of features, which may be lines, points or text, defined by feature serial numbers, feature codes, and as many co-ordinate pairs as are necessary. It is digital cartography being oriented towards the production of a plot of publication quality rather than use in digital form (Gardiner-Hill 1972). To produce the required accuracy and quality it was necessary to introduce more sophisticated equipment but the principles and the basic software had been developed. Regarded simply as a process for producing printed large scale maps more or less indistinguishable from the conventional versions, the economy was at best doubtful, and in the event the digital route proved to be more expensive; however there were real hopes that revision of the digital version would be simpler and that economies would arise in the production of derived maps. The decision to start production, in 1972, of the so-called Digital Map was therefore a bold one based on hopes of future economic benefit; those benefits have not been realised so it is the subsequent demand for the real digital map, topographic detail in digital form, which makes that early decision an enlightened one. Without doubt had the OS sheltered behind a decade of indecision the digital map would now be very very different from the version started in 1972 and effectively still in production in 1986.

CARTOGRAPHIC DIGITISING (MANUAL)

Initial Flowline

In order to implement the pilot production flowline in September 1972 it had been necessary to obtain equipment to a higher standard than for the initial experimentation. Six (later 8) Ferranti Freescan digitising tables each with its own magnetic tape deck were used for the manual digitisation, line by line, of the completed field document, or rather of a 5:3 enlarged negative of it. To control the effect of distortion in the field document, in the production of the enlarged negative, and in the digitising table itself, it is not adequate simply to record the corners for deriving the relationship between the map grid and the table co-ordinate system. A set-up procedure using four observations to each of 36 grid intersections was developed in OS based on a transformation developed for photogrammetric purposes (Harris et al, 1962). Each of the 25 squares so formed is transformed separately. Subsequently the 1:2500 maps were transformed on only 9 grid points but unsatisfactory results ensued and a full 36 point set-up was re-introduced. This seems an overcautious approach but has been shown to be necessary especially for 'blind' digitising where the operator has no feedback on whether a satisfactory set-up has been achieved. It is better to spend ½ hr at the start of each day than to reject 3 days work or more on digitising a full sheet which cannot be converted to National Grid. Digitising was checked from a four-colour ink on paper plot on the high speed Xynetics Plotter but all errors and omissions had to be corrected by returning the sheet to the digitising table. This sometimes needed to be cycled through four or more iterations. Finally the data was clean and put on a Ferranti Masterplotter with light spot projector to produce a fair drawing of linework, text and some symbols; the map was completed with the manual addition of ornamentation such as building stipple, trees, embankments and other symbols, and also parcel numbers and areas.

Expansion of Initial Digitisation

The further purchases of digitising tables in 1975 and thereafter were linked to a controlling mini-computer which was cheaper and more effective than each one having its own tape deck (Atkey et al 1975). At that time digitising only took place as part of the production of a new printed edition. The selection of sheets was somewhat random, it included some small blocks but no large contiguous areas. Map users naturally do not wish to transfer to costly and complex digital systems unless their area of responsibility is covered, or in the immediate programme. The expansion continued (Thompson 1978) and in 1979 block digitising was started; this meant larger areas being undertaken even though the majority of the sheets were only for incorporation in the cartographic databank and did not result in new printed editions (Fraser 1984). At the time of writing there are 54 digitising tables on productive work including 16 with the edit stations mentioned below.

Interactive Edit

An iterative cycle between the Xynetics Plotter and a blind digitising table is as uneconomic as it is frustrating, except when there are very few corrections required and this is preferable to reloading all the data for the sheet. The first Laserscan Interactive Edit Stations, (LITES) were installed in 1980 with a DEC VAX 11/780 mini-computer. There are now 12 of these stations and in early 1986 the software was converted to LITES 2 and prior to that in 1985 four ARC workstations (Applied Research, Cambridge) were purchased with a VAX 11/750. It is OS policy for the MSD to be returned to HQ after changes amounting to the equivalent of about 50 houses have been surveyed so that the microfilm negatives, held both at HQ and with agents, for the Supply of Information on Microfilm (SIM) can be renewed; if a digital version of the sheet exists then that also is updated. Various considerations such as the actual quantity and nature of the change, its complexity, or whether a digital specification change is also necessary dictate whether the sheet is redigitised, or the change is digitised at a cartographic table, or whether it goes straight to an edit station for an interactive update.

Progress and Status of Digitising

The House of Lords (1982) Select Committee recommended the allocation of more resources to the OS digital mapping programme, and although their recommendations cannot be met in full the current plan is to complete digitising the basic scale survey by 2015. This requires more resources than those described above and since 1984 blocks of digital data capture have been let out to contract on the basis of competitive tender. So far these contracts have all involved manual cartographic digitisating which has increased production to approaching 4000 sheets per year and a further increase is planned to meet the 2015 target. It is estimated that at the time of Auto Carto London in September 1986 there will be in excess of 30 000 sheets of large scale digital mapping in the OS cartographic databank. Most of the development work in digital mapping has considered software, data structure, specifications and formats for the transfer of data and this is reflected in the various references quoted above which give only minor attention to the data capture. More recently a programme of testing the accuracy of digitising tables was initiated (Rollin 1986) and this has fortunately shown that even over 15 years of usage all but one table (now transferred to Training Division) are still within specification. Routine periodic testing is now in hand. There has been disquiet over the set-up transformation used which was designed for relating analytical photogrammetric observations to the four fiducial marks on non-reseau photography. A consultancy with the Faculty of Mathematics, Southampton University, considered various algorithms on the data for a large number of MSD. The report (d'Inverno & Vickers 1985) indicated that for the large majority of MSD having only slight and/or regular deformation any one of several alternatives were satisfactory; however, because there are exceptions a changeover to a projective transformation has been recommended. This appears to have several advantages over the previous method: it is independent of the orientation of the MSD on the table, straight lines project as straight lines whence the grid line dividing two adjacent squares transforms to the same alignment in each transformation, and it has an inverse. The projective form will be successively introduced into the various packages where it is advantageous. Regrettably it remains necessary to apply 25 separate, square by square, transformations to allow for the small proportion of documents with irregular distortion.

CARTOGRAPHIC DIGITISING (AUTOMATED)

Line Following

Early in the digital programme it seemed that the high contrast of a cartographic master ought to make it possible for some form of photo-electric cell device to follow the linework, either on a positive or a negative and collect cartographic data automatically. No likely prospect appeared until the Laserscan Fastrak which used a laser and tilting mirrors and worked either as a line follower on a reduced fiche of the document or as a high speed plotter also to a fiche. The Fastrak was installed in 1980, with assorted peripherals, and used in Research & Development for various trials. Basically the problem of line following is that the instrument requires operator guidance when completing one feature to start the next, or when it encounters a junction. OS large scale plans contain innumerable junctions and short lines which demand full-time operator attention and slow down the work. As the result is still devoid of feature coding and text much remains to be done at edit stage and the result is not economical. Fastrak might have been suitable on such features as contours and water detail had the resources been available to include them in the OS programme. This, however, was not the case and Fastrak was sold in 1985.

Raster Scanning : Concept

The other option for automatically collecting digital data from a cartographic original is to scan it to produce a raster matrix of black or white pixels, a simpler process than that used for photographic or remote sensing imagery where each pixel is to be coded in up to 256 shades of grey, and even more so than colour systems. Nevertheless the system poses very considerable problems as well as offering some solutions. The data in raster form occupies significantly more storage space than vectorised data, and thus more transfer time also. Compression by quad-trees or run length encoding greatly reduces the difference but it remains significant. It shares with automatically line-followed data the absence of feature codes whilst text and symbols are captured but, like the linework, only in raster form. The manufacturers of the scanning equipment are putting considerable research effort into developing software to convert the raster data into a structure suited for digital mapping applications. It has the benefit that vectorisation leads naturally to a link and node structure (de Simone 1985) and when much improved symbol, text and feature recognition algorithms are developed they must surely provide the future for data capture.

Raster Scanning : Progress

Scanning equipment is available which will either scan the document in a series of parallel lines to build up a matrix of pixellated data, whilst others work more like a television camera or photo to a videcon screen. The latter are significantly faster (say a few seconds compared with a few minutes) but are naturally coarser and almost certainly less accurate. There are several systems on the market which have differences in form and concept but also much in common in that they correlate adjacent dark pixels to form lines (vectors) they can recognise broken lines (pecks) as continuous features and can detect that a cluster of very short lines probably forms either a symbol or a text character, but go no further. From this data it is possible to produce a plot that, at first glance, looks rather like the original, but a photo-copier does this. Potential digital map users purchase this data, produced with OS permission, to use as a digital backdrop for their own digital data, but it is not a digital map and does not claim to be. A recent consultancy with SysScan has led to the conclusion that a typical MSD is not a satisfactory original for scanning. A suggested way forward is to scan either the standing negative or a stable film positive from it, and then use interactive processes to edit and code the scanned and vectorised detail. Text and symbols would be identified and replaced interactively. New detail and demolitions since the last edition would also be edited interactively. This remains to be tested but some of the problems have been highlighted. The OS archive of topographic detail exists on about 215 000 MSD held in Section offices containing varying quantities of surveyed change. Some take up to 40 years to reach new edition criteria, by which time they are faded, often dirty and sometimes distorted. A sheet near this point is obviously unsuitable for scanning and would need so much editing that a complete manual digitising is cheaper. A sheet with practically no change is an equally obvious candidate for scanning, without test data we have no idea where the changeover may occur so cannot assess the likely impact of scanning. Two snags are created by building stipple on OS maps. A minor problem arises where dots can merge with outlines to create spurious nodes; a modification to the building squaring routine should cure this. The other concerns accuracy, not of the scanning equipment but of the document it scans. It has been stated above that all 36 grid intersections must be used for square by square transformation; but if the resolution of the scanner is set to eliminate stipple it tends also to eliminate the rouletted grid. Distortion of the document should be less of a problem if the scanning of MSD is excluded, but it is not impossible for a standing negative to distort. Clearly at the time of writing many problems remain before this technique can be introduced. However, nearly 185 000 basic scales maps remain to be digitised; the year 2015 is a long way off and many users say this completion date is inadequate. Current progress, even with contract digitising which needs considerable checking and quality control, will barely achieve even that. Automation has to be the answer and at present raster scanning is the only really promising solution in sight.

PHOTOGRAMMETRIC CAPTURE

A Resurgence of Interest

It has been explained that in 1970 there was no case to pursue digital capture of photogrammetric data and the contour test was too early, being judged wholly as a means to a graphical end rather than digital capture. The OS programme was to complete the Basic Scale Survey by 1980. With the overhaul and the 1:10 000 resurvey complete the ongoing tasks for Air Survey Branch appeared to be to complete the derived contouring and plot 200-300 sheets per year of upgraded 1:1250. As a result of reviews of tasks, of the needs of map users, and of OS revision policies there has been a revival (Newby & Walker 1986) of interest in photogrammetry and digital equipment has been purchased. The 1:1250 task remains as forecast; some minor towns qualify for mapping at this scale and some areas are being extended. The overhaul was a pragmatic solution proposed by the Davison Committee to recast the County Series maps to National Grid (OS 1972) and revise them. A root-mean-square vector error of 2.5 metres has been quoted but criticism has been made that this is not adequate for built up areas in small towns and also that there are areas which fail to meet this figure. There is a case for extensive remedial work and a study of this is in hand; an adjustment to a large number of co-ordinated detail points would be possible but a photogrammetric replot seems likely to be both cheaper and better. Also it has been found too expensive to keep rural areas of slow change under continuous revision; so there is now a periodic approach of waiting until such an area has accumulated a degree of change, then reflying and revising photogrammetrically. These two exercises overlap and must be taken together in framing the photogrammetric programme.

Digital Hardware/Software Installation

In 1982 the renamed Photogrammetric Services Division obtained from Kern a DSR-1 analytical plotter, four PDP 11/23 minis with Maps 200 software, four GP1 tables and digitisers fitted to three existing OS stereoplotters, Wild A10 and A8 and a Kern PG2. Subsequently three of the PDP have been upgraded to 11/73, one enables PAT-B or PAT-M43 to run on the DSR-1, one allows a second A10 to join the first and one now has Maps 300 software. A DSR-11 with another PDP 11/73 has been installed. Aerial triangulation is now running and high quality plots can be produced to send for field completion which saves the operator having to pen the plotted detail (Farrow 1985).

Transfer to Databank

It is now possible to address the transfer problem. Because the output from photogrammetry is only a tiny proportion of the digital capture task, and because software problems had to be resolved first, this has had to take low priority. First a decision has to be made about how much feature coding should be noted by the photogrammetric operator, and at least two different levels will be tried. Graphic field completion follows and it is then necessary to digitise and code this; it looks sensible to combine this operation with merging the new data to the photogrammetric data and adding the rest of the feature coding to the latter. The experimental sheets will be used to test alternative merge and edit operations, once in the normal cartographic flowline and again using the Digital Field Update System (DFUS). In the case of the cartographic route we must also decide, probably on the basis of how much there is to do, whether the whole edit should take place on a relatively expensive interactive edit station or whether to digitise the field completion on a blind digitiser and merge and afterwards edit. The software is already tested for transferring data from one format to another as required, and the original PASCAL listing of Maps 200 has been obtained from Kern and some modifications to tailor it to OS exacting requirements are in hand. It is anticipated with confidence that the photogrammetric data can be brought up to full OS specification and databanked. What has to be decided is which of several routes is best, and whether it is more economical than the present system. Logically it has to be better not to redigitise work that is already available in digital form and avoid the likely accuracy deterioration in going from digits to a plot and then back to digits.

INSTRUMENTAL FIELD SURVEY

Field Data Capture

Tacheometric Surveys have supported 1:1250 survey and revision since the mid-1950s, originally with Kern DKRTs. A wide range of theodolite mounted infra-red EDM instruments, Wild, Aga and Kern, followed and are now giving way to Wild and Kern Total Stations. Between 70 and 80 instruments are in use and by the end of 1986 it is hoped that all will be fully self-recording. This technique provides the framework on which field completion takes place, supplying 30-35% of the detail, twice as much as used to be supplied optically. In general these instruments are used to survey small areas of new development, say 2-3 hectares, within an existing 1:1250 area, which is either too small to justify aerial photography, or needed in a hurry, but too much to survey without instrumental control. The instrumental detail is sent to HQ where it is computed and plotted onto the MSD using the Kongsberg plotter on which up to six sheets can be mounted at one time.

Transfer to Databank

The problems of transferring Instrumental Detail Survey (IDS) data to the cartographic databank are very similar to the photogrammetric ones; they are being addressed by separate R&D teams but united under the author. The only coding currently added during field survey defines line type and connectivity and a previous trial has indicated that there is a significant extra cost when the coding is increased. However, if IDS revision falls in an area which is already digital it is again logical that the coding of this detail should be combined in some way with digitising and editing the field completion detail and text. If the field section concerned has a DFUS workstation it would seem logical to use it for this task, but for a number of years yet this is unlikely to be the case and the study into the incorporation of IDS data must consider all feasible options. Some of the software being developed for this project is also being used for the photogrammetric study and vice versa. Once again this has not been of high priority because of the comparatively small quantity of data involved, but in this case the likely deterioration in accuracy is more telling because the IDS data is more accurate. An investigation is also in hand into methods of preserving data of higher than average accuracy and of identifying it as such in store.

DIGITAL FIELD UPDATE SYSTEM

Development of the System

The map user who wants an up-to-date graphical map of an area subject to continuous revision may obtain a SUSI (Sale of Unpublished Survey Information) copy of the MSD as required. Some users of OS digital data do this and digitise the change themselves, but clearly it would be more efficient if OS could provide digital SUSI. In 1982 development of a Digital Field Update System (DFUS) to which reference has already been made in this paper, was started. As no suitable workstation was then available an experimental package was developed in-house to use an Altek 22 x 22 inch Datatab, smaller than those used in the cartographic area, and an ICL PERQ 2-megabyte mini-computer with portrait VDU as an edit station. The system needed a plotter to check the work done but it was also specified that it should be capable of plotting in ink onto the MSD to save time inking up new work which could be digitised from the surveyors pencil plot, and to produce an improved quality of linework. This imposed the constraint that the plotter had to have the facility to work as a co-ordinatograph, with a microscope, and relay the position of the grid set-up points. This restricted the choice and only the Glaser 1603S was found to satisfy both this and the high accuracy standard within the price budget. Inevitably there is a snag, in this case it is slow. A software package in PASCAL permitted set up and all the normal digitising and editing routines to proceed to a revised map to full specification. It can also then receive set-up data for the same MSD when it is transferred to the plotter, plot just the update on the back of the MSD in sympathy with existing work, and finally produce a tape of the revised sheet (Mayes 1984). As an interim measure each sheet is stored on one cassette tape, input and output through a Cristie reader; as a precaution the last three generations are retained.

System Testing

From November 1983 to August 1984 a field trial was conducted in the Birmingham office to test the feasibility of digitising change in the section office and of digitising direct from the pencil plot without erasing construction lines; to try out surveyors digitising their own work or cartographers, accustomed to digitising, interpreting surveyors work unpenned. The experimental work was sufficiently encouraging (Duckett 1985) to make it worth embarking, simultaneously, on two further stages. A production trial was run to provide operational data, under production conditions, with the digital updates going into the flowline and being supplied to a customer. At the same time a production version of the software in FORTRAN is being written, due for implementation in October 1986. There were problems with the PERQs and the Plotters during the trial but these were solved and it can be claimed that DFUS works well and will be expanded. The result is a workstation (Coote 1986) with in-house software, which can be altered on demand, not at the whim of the supplier, and which may have applications elsewhere in the Department.

Future of the System

It is hoped to expand the DFUS by about 10 workstations per year; one workstation seems about right to cope with the updates of a typical three surveyor section. Storage of the data for a section on thousands of Cristie cassettes is obviously unsatisfactory. With a communications link from HQ and a Winchester Disc to store those units required during the next few weeks it would only be necessary to have transfers periodically. Alternatively to continue the idea of a distributed database the whole area could be stored, with updates, on an optical disc which would last 5-10 years before being full, with security copies being transferred to HQ from time to time. Both these alternatives need a trial in production conditions. It is already seen that DFUS workstations may have a very important part to play in the editing and coding of photogrammetric or IDS data whilst digitising the field completion as an update. In the fore-seeable future it is a possibility that the MSD itself could disappear, the archive then being digital. A plot would be made of an area needing update, and when the update had been completed and digitised the plot would be discarded. No special facilities on the plotter would be needed, but it would have to be very fast as well as accurate, not only for the surveyors plot but for the customer who still wants his SUSI as a graphic.

CONCLUSION

The digital capture of the Basic Scale Topographic Archive of Great Britain commenced in 1972, at a rather low key, digitising from graphics on cartographic digitising tables. This has been greatly expanded, both in-house and by contract, but is still the standard procedure. However, 1986 is seen as a year of real importance towards extending the data capture process. It is confidently foreseen that data captured on photogrammetric plotters or during instrumental field surveys can, and presumably will, be assimilated into the databank and that DFUS will expand to make a significant contribution. However a great deal of data remains to be captured and because most of it already exists in graphical form a significant acceleration probably depends on automation of capture from graphics. This must be pursued energetically.

Meanwhile a major study into the adoption of a relational, structured database is well underway. It may materially alter the specification of digital data and thus alter the data capture techniques. One constraint, naturally, is that it must be possible to convert existing data to whatever new system is adopted. Therefore there is no need to place an embargo on collecting data for the current databank whilst awaiting the outcome.

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