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.

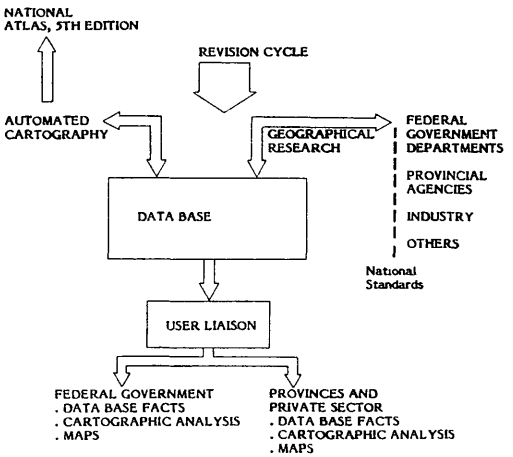

Fig. 1 National Atlas Information System

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.

REFERENCES

McGuire, F. et al. (1986) "National Atlas Information System, a GIS approach", submitted for publication in the Proceedings of the Canadian Cartographic Association conference, Vancouver, 3p.

Muller, J.-C., (1984) "Canada's Elastic Space: A Portrayal of Route and Cost Distances", Canadian Geogapher, Vol. XXVIII,No. 1. pp. 37-42.

Ratajski, L. (1973) "Discourse on Cartographic Generalization", in Polish with English summary, Polish Cartographical Review, 1973, Vol. 3, No. 2, pp 49-55 and No. 3, pp. 103-110.

Siekierska, E. (1983) "Towards an Electronic Atlas", Proceedings of AutoCarto VI conference, Vol. 2, pp. 464-474.