A MINICOMPUTER GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

A minicomputer geographic information system is under development at the University of Saskatchewan, complementing their work on automated cartography which is now nearing completion. Attribute data for locations, routes and areas can be retrieved by querying the appropriate map image on a location basis. The close relationship between the visual image and the user is of great importance and the combination avoids the use of large computers in almost every geographic problem. It is felt that this system will provide the actual decision maker with the personal tool he so badly needs; the request methods are simple and the presentation of data as well as results of calculations are equally understandable without training. To this location specific retrieval system, can be added computer modelling techniques to aid the man's own mental processes.

RESUMÉ

A l'université du Saskatchewan on a presque complété l'étude de la cartographie automatique et l'on continue à développer un systême de récupération de données geographiques par mini-ordinateur. On peut récupérer les données attribuées aux positions, aux routes ou à la région en demandant l'image de la carte de la région appropriée. La relation étroite entre l'image visuelle et l'utilisateur a une grande importance et, avec cette combinaison, on n'a pas besoin de gros ordinateurs pour la plupart des problêmes géographiques. On croit que ce systême donnera à la personne qui prend les décisions l'outil dont il a tellement besoin. Les méthodes de demande sont simples et la représentation de données et les resultats des calculs sont compréhensibles sans instruction spéciale. On peut ajouter à ce systeme de récupération de données par attribution aux positions certaines techniques de simulation par ordinateur pour faciliter les processus mentaux chez l'Homme.

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Papers given by this group at previous NRC symposia in 1969 and 1971 will have indicated to you an interest and some expertise in the handling of cartographic data. This work started in Canada in 1967 with the development of an automatic drafting system and a method of manual, but on-line, digitization which appreciably aided the cartographers in their accurate and tedious task. A more highly automated system of digitization is expected to be operational in the not too distant future; this development proved to be essential because of the very high cost of manual - even computer aided manual - digitization. Perhaps we can report on this work at the next symposium.

We are here concerned mainly with the advantages of close liaison between man and machine. In cartography of a modern type this occurs at two stages; the first is when new survey or digitized data is being entered into a databank, the second is when a map is to be drawn from stored data. Both of these require the handling of large amounts of data coupled with subjective decision processes; together the two stages are called 'computer aided map compilation'. We believe that we have now brought this work to a very high level of computer and cartographic sophistication. Future work will involve only minor additions, improvement in data handling speeds in certain cases, possible re-programming for other minicomputers, and development and testing of display devices. Of particular interest would be a storage display with colour.

The present system includes programs which will convert digitised or other coordinate input to a suitable composite system usually longitude-latitude or UTM. There is a flexible method of selection of feature data and of working area which includes a fast windowing facility. Normally this windowing consists of magnification, in which lines widen and symbols enlarge as the image is magnified. Full name and symbology for locations and lines are available. Any line, symbol, or name data can also be deleted, added or modified. Most of the displays are created under default options unless the user decides to request otherwise; operation is fast, simple and accurate. Descriptive documentation is available and arrangements can be made for interested parties to use the programs.

Geographers became acquainted with the process, and suggested the possibilities of its use in a geographic information system where the map became the reference frame, and background, for the display of attribute data, and for the results of calculations on that data. The problem sounded interesting and about twelve months ago we started seriously to provide such a system.

A number of changes in the cartographic system were necessary. Instead of the data magnification required for cartographic detail viewing and manipulation, a binary scale change was necessary. This proved to be only a matter of removing the magnification default option, so that the lines did not widen and the symbols did not enlarge automatically. Various simpler methods of work area selection were tried out and were later found to be most useful in cartographic work. Files of attribute data had to be added in such a manner as to give compact storage and fast access. All of these changes have already been implemented; the next aspects to tackle are the addition of computational routines for the attribute data and to add a facility for on-line attachment to remote input devices and to other geographic information systems.

It has been necessary to add many routines to the main cartographic monitor system, in order to interconnect cartographic and new attribute data. For example, when pointing to a location on the screen the cartographic programs will calculate the relevant longitude-latitude coordinate, and then make a search of attribute data against those coordinates. Problems with route and area retrieval are much more complex. In other cases a conditional search of the attribute data can yield a location coordinate which is then passed, in the other direction, to the cartographic system to produce a map display centred on that point. It will thus be seen that there are two monitor systems, an attribute and a cartographic one interconnected by a third, a communication monitor system.

Almost any aspect of the geographic system when taken on its own, is simple, easy to write, and to get working. However the overall monitor systems represent a formidable problem, not one to be undertaken lightly. It has sometimes been said that the complexity increases as the power of the number of routines to be interconnected. At the University of Saskatchewan an appreciable proportion of the work has been relative to these monitors.

An 8k PDP-8, associated with a million word disk and a Tektronix 611 storage display, has proved to be worthy of the task, both from a program writing, and user point of view; it is reliable and of low cost. In the operation of the program many of the facilities are maintained as 4k word 'swaps', retaining 4k within the system; in other cases it is necessary to exchange almost the whole of the 8k leaving only a few hundred words for control. Most of these 'swaps' occur under keyboard request control and the average time of 80 milliseconds is unimportant. Even within the swapping system data and routines are overlaid as the sequence of events requires. The total program length is of the order of 40k words in binary.

The format and structure of the data and system should now be examined. When data are transferred to the working disk or disks, a directory is set up in which are contained the descriptor of each line section, or set of symbols, name or attribute data, as well as its location on the disk. Within the data, the descriptor is repeated before each section or set. The data can be listed in any order; line sections many be alternated with symbols or names and thus no complex structuring is necessary. Using the directory system, very little time advantage could be gained by complex structuring. Data may also be accumulated on the disk from a number of sources; these may be from adjacent map areas, in order to examine overlaps, or from digitization and databank to check proper incorporation. In addition to this data, various symbol and alphanumeric matrix lists must be included, together with a gazetteer of the area.

Line data are recorded as increments in order to compact storage and to speed access. Each line is preceded and ended by an absolute coordinate. Any other data have an absolute coordinate followed by a label. The label length is constant within any set to aid search operations but varies from set to set.

When data sets are of considerable length they are sorted into order of longitude with a suborder of latitude. The system requires some other sets to be ordered alphabetically; an example of these is described later. Binary searches are employed, and an item from a long list can be retrieved in less than a half second.

Area data are recorded as the centre longitude-latitude, together with the longitude and latitude limits of an approximating rectangle (or possibly multiple rectangles). This is described more fully later.

When data from other geographic information systems are to be used, a special input routine is written to make the data conform with the standard within the display system. A similar routine changes the format back on output. While the writing of such a routine requires experience in bit manipulation, many such routines have already been written and have proved to be relatively simple. A range of absolute coordinate resolution and increment sizes can be handled on the standard routines.

Simple location specific attribute data are normally retrieved by pointing to a position on a displayed map of the area of interest. At the same time the type of attribute data is keyed in. The cartographic routines calculate the longitude latitude, pass that coordinate to the attribute data of the requested type, and, after a rapid search, the data appear as a list on a screen adjacent to the map display.

Route attribute data are stored against a location which is the end of the route (normally the mouth). Pointing to that route causes a cartographic search operation to be followed which will locate the appropriate end coordinate before searching the attribute data.

Area data are retrieved by pointing to a centre and to the horizontal and vertical limits of an approximating rectangle. The search is then somewhat more complex; location attribute data within the limits of that area are first searched. Following this, attribute area data are searched to find if any areas are located within or partly within the specified area. In the attribute sets, area data are stored by approximate rectangles parallel to longitude and latitude in a similar manner to the request method described above. While a good approximation might be obtained by only a single rectangle, often a number of rectangles must be used. It will be seen that attribute area data are thus only approximately specified as to limits but the speed of search is very high.

In addition to the area-approximating rectangle, the actual polygon boundary, if known, is stored in the cartographic file; both are displayed on the screen, usually in a non-store mode. It is then immediately obvious to the user if the approximating rectangle in that particular case is not sufficiently precise. He can rapidly make up for any deficiencies by requesting a subsidiary rectangle, or by erasing data which falls outside the actual polygon boundary. This approximating method works extremely well with a man-machine interactive process, but would be completely inadequate in a purely computerized process.

The attribute retrieval process could follow a different route. A conditional search of the attribute data might be requested, for example, a settlement with three hospitals and two schools. When the appropriate location is found the coordinates are handed to the cartographic system and a map or maps displayed on the screen about the centre found. Obviously the process becomes more complex when route or area data are being requested.

When many attribute lists can be found for a single request, it is normal to first display a list of titles and then request one of those for full display. This process is followed when finding bibliography data. The first search uses a longitude-latitude search and finds titles; the second finds data from an aplhabetic list under titles; a simple change would allow authors to be used instead of titles, if this were preferable.

In order to compact storage of attribute data and facilitiate conditional searches, all possible data are coded. Certain items such as 'author's name' and 'title' must be retained in alphanumeric form, but keywords for example can be coded.

This coding process on input would have to be associated with a decoding process prior to display, and with a similar encoding operation for updating, which will be described later. While there is no difficulty in writing such encoding and decoding routines when the system is being set up, each type of data requires a variation and it would be convenient if the user could form his own sets as necessary. Thus, considerable effort has been put into writing a 'high level language' for this purpose. From analysis of likely attribute data it appears that there are only about twenty 'types'. Examples might be the date, retention in alphanumeric form, a number which can be binary coded, or one of a predetermined list (e.g. key words or airport navigational aids). The user states his requirement for each line or part of line of input data from a simple use of code words, each calling a specific set of encoding and decoding routines automatically.

Updating of data is of vital importance. Data which have not been reported but are known by the user to have changed, can damage the credibility of the whole system. A number of different methods have been tried; the first is by pointing to a line of data and keying in the changes which are then displayed at the right hand side of the line. Upon pressing a confirming key, these data are entered into the databank proper. A second method is to create a series of numbers alongside each line or each item on the display; these numbers only appear when updating is to be done in order to avoid screen clutter. The user then keys in the number, followed by the desired new data. Arrangements are also being made for automatic updating particularly of rapidly varying data such as fuel stocks at an airfield. In this case the operation will pause prior to confirmation and will report the addition to the operator on the teleprinter. At some convenient time later the user will confirm the change.

In some cases databank updating is only confirmed with great circumspection; it may be necessary to pass the information through several supervision stages before acceptance. This can be allowed for. The user may also add lists to a set or add items to a list, but in the latter case all lists in that set must be extended.

One of the most interesting aspects of the program is the system of tagging which is used. In many cases data are not changed but merely tagged as 'rejected' and a new set or item created. Cartographic data are also tagged to say if they occur within the screen area following a request; this is extremely useful if a mistake is made in requesting the next image, because the last one can be immediately regained without a full, and possibly time consuming, databank search. Tags also occur in each item of attribute data. One of these indicates if the normally expected length of data has been exceeded; if so a continuation item is automatically created. This appears to be a very efficient combination of compaction of storage and speed of retrieval, so important in man-machine systems. An expected normal length of data is used to create fixed length items. Sometimes the length allowed is excessive but the constant length more than makes up for this in facilitating search. If the length proves to be inadequate then an extension item of the same standard length is added into the list. Another tag designates if data is unknown (which, of course, is different from 'none'). Another (not yet in operation) is a confidentiality tag. Only the use of a special code word would release such data to the user. It is perhaps useful to note that the self-contained nature of the system makes it inherently convenient for security information. A very useful tag on attribute data indicates that a comment is attached; this is usually used for transient data such as the warning that a particular facility will be out of action over a certain period of time. Normally comments are in plain language.

The size of the databank in absolute coordinates is of interest. It is essentially a binary count of resolution elements up to sixteen million. If the whole world were to be accommodated in longitude-latitude or similarly for UTM, the limiting ground resolution would be about 20 feet, but finer resolution could be obtained by restricting the total area or using a system of switching to a minibank. Of course line data at this resolution would occupy excessive storage and be of limited use. Thus in the descriptor for a line, a binary increment multiplier is included, indicating the size of the increment following, to the nearest binary multiple of the databank resolution element. The multipliers can be different in longitude and latitude.

When working with large area databanks the user may find it difficult to remember the desired centre in longitude latitude values. It is frequently easier for him to key in the name of a settlement or town to be taken as centre. This operation assumes that the gazetteer of the area is available on the disk. An alternative method is to call up a small scale map, perhaps of the whole of Canada, and point to the desired central point. He also specifies 'normal' scale, although increase and decrease of scale in binary levels is available at will.

A one million word disk can hold an appreciable amount of data, possibly several million coordinate pairs, or 100,000 attribute lists. The worst situation is when appreciable alphanumeric information is included, as each character then occupies a half word. For example, less than 2000 full bibliography items including abstracts could be included on one disk. Disk cassettes themselves are rapidly interchangeable and are of low cost (about $100). Running disk units can also be added at a cost of about $5,000 per disk drive.

Cartographic data are normally entered into the system in machine coordinates with associated longitude latitude reference locations. Programs are available to convert this data to longitude latitude in the databank form as used in this system. Attribute data are usually punched onto cards and then transferred to tape before conversion to the coded form described above. It is useful to display the map data in a familiar projection as otherwise the longitude and latitude lines would present a boxlike square shape on the screen. Display can at present be in Mercator and work is commencing on a Lambert Conformal conversion process.

Many discussions are being held to decide which are the most useful computational subroutines to add to the system. Many of these are of a relatively simple statistical nature. Arrangements are being made to allow the user to add his own Fortran routines at any time, but this still requires much planning and thought.

The system is new and is not yet in operational use. Demonstrations for areas in N. Saskatchewan, the Northwest Territories and Yukon have shown that it is impressive in performance while being self contained and of low cost. The advent of the large low cost disks enabled the 8k core PDP8 to work like a major unit and it is extremely efficient in datahandling, as bit manipulation can be used. Work is at present concerned with finding the limits of this system, and at what stage it would be necessary to attach it on-line to a larger computational facility. It appears that the attachment of man as a peripheral device has removed many of the limits. It is a major concept of the design that it must be easy to use without going through a professional operator, for the full impact of the actual user's mind to be felt. We believe that we have gone a long way towards implementing this concept.

At present in other geographic information systems, much computational work is concerned with overlaying and modelling. Overlaying, in the present breed of digital computers, is tedious and costly, even with the simplest polygon structures. If the polygon overlays are presented on the display each with a different symbology the overlaying states are obvious to the man. He merely has to define the overlay limits by pointing to them and these are then reported to the computer. The man's brain as a parallel computer is much more effective than a large serial machine. This method appears to meet the majority of cases in which overlays of areas relative to a location or small area, are being examined. On the other hand if the total overlay area for a province had to be calculated, such an operation might become too tedious for the user and he would prefer to pay the high cost of computer overlaying.

Modelling has created great interest amongst geographers of a computational bent. In general they are finding it difficult to communicate the results of their work to the actual real world user. This is essentially a problem of communication and we believe that confidence of the user can only be obtained by allowing him to see the information presented to the computer model and allow him to 'eyeball' it in himself. The user has learnt to do this over many years and is relatively good at it. Such an interactive display of information as we have described here should improve his ability. If at the same time the computer model can give its view of the result, possibly presented on the same display image, then I am certain communication will be good and the user will understand and appreciate the model and the modeller: the modeller will then be more able to draw from the user the parameters of choice he so badly needs to quantify the data.

Finally it should be said that maps have been the communication link for geographic information to decision makers for many years. Unfortunately the cartographer in preparing these has had to be selective to avoid clutter and has had to generalize detail in a way which cannot be recalled. The new method described here uses the same process but any selectivity or generalization is entirely within the control of the user; data will always be recorded in the greatest detail.

I would like to express my appreciation of all members of the team involved during many years in this development. The present members are: R. Bolton, R. MacMillan, A. Schiller, W. Stehwein, W.T. Wilkie.

References:

Computer Aided Map Compilation, A.R. Boyle and D. Boone, Computer Aided Design Conference, IEE Southampton, UK, April 72.

Environment Information Systems, R.F. Tomlinson, Ed., UNESCO, IGU Conference, Ottawa, October 70.

Geographical Data Handling, R.F. Tomlinson, Ed., IGU Conference, Ottawa, August 72.