CARTOGRAPHY IN 1990

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The engineering lead-time for the design, construction and implementation of hardware and systems is long. It is thus possible to predict the methods that can be available five years hence with great certainty. With a little guesswork, an understanding of human weaknesses, and an appreciation of user demands, this five year period can be extended to ten with a somewhat reduced certainty. This paper is therefore concerned with logical prediction and not one of crystal-ball gazing.

The history of automated cartography to date has not been inspiring. Too much emphasis has been given to the obtaining of large machines and systems, and too little to thinking of true capabilities related to the real needs of cartography. Map throughput has been poor, quality often inadequate and real costs have been very much higher than expected or often admitted.

The question must be asked as to why so few maps of topographic quality have been produced by the millions of dollars worth of equipment that is sitting around. The main single cause, amongst others, is the lack of a useful amount of base map data in digital form. While some rather pedestrian progress has been made in digitizing from new aerial photography this, except for large scale work, is often useless without the accompanying data from existing map sheets. The tedious experiments in manual digitization of multiple topographic quality maps followed by even more tedious correction of all the errors generated by the machine and the operator, cannot be accepted for much longer.

It would appear that many users want standard map data in digital form so that they can make their own selections and calculations. In fact, many are not concerned if the data is exact to absolute truth; they are quite prepared to overlay their data to the map as a base. The need for data would seem to be countrywide and almost world-wide. The question for us to consider in 1979 is the likely costs to the user and how much it will cost the country. In fact the latter is probably more important, as few map users at present could do their jobs if they had to pay the real map costs.

We can take by way of example, the 1:24,000 Topographic Quadrangle of the United States. There are nearly 50,000 maps in that series, each with about ten to twelve colour separations. It is very important that we note that these separations are available, as otherwise we would probably not be able to propose an answer to the problem. At 1979 manual digitizing values, we would probably be considering costs per map between $5,000 and $10,000, or a total series cost between 250 and 500 million dollars. Maybe this is acceptable; I myself would doubt it. However, we must also look at throughput. If we take figures of 1, 10 or 100 hours per map we are considering 25, 250 or 2,500 man or equipment years. Even with multiple equipments, 2,500 equipment years seems completely unacceptable, and yet 100 hours per map including all separations could be on the low side! We must therefore come within the range of less than 10 hours per complete map if we can consider completion by 1990; in fact we must aim at 1 hour.

Fortunately the separations which have been made so carefully for colour printing are available, and almost completely meet the needs of an automatic analysis; only the culture sheet is a little more complex than is desirable. Quality control of the copies used is critical, but no more than for good printing.

If large amounts of high quality map data were available in digital form, it would completely alter the cartographers view of his working processes. The use of the data would accelerate, creating further demand and a rapid development of new methods and equipment. The provision of such data must, and will, have a very high priority, so that we can consider it to be appreciably complete by 1990. We will examine the likely methods to accomplish this later in this paper, but at this time, let us look at the effect on cartography and cartographers, based on this assumption.

The much greater ease of updating will mean that yearly updates will be regarded as normal. This will in turn mean that printing methods giving high quality and good economics for short runs, will be in demand. A much larger number of derived maps will be easily created for many special uses, which at present cannot be serviced by cartographers due to cost and time. It will be accepted that any new map compilation or special overlay will be digitized immediately as a matter of course. Once the main database is available, the cartographic user will want to make certain that his new production is included, mainly for his own use but also for easy access by others. Obviously, there will have to be developed a method of referencing such data for quality, reliability and so on. The allocation of such codes will be a difficult responsibility for the professional cartographer of the future. New photogrammetric compilations will also be digitized as a matter of course. Purely topographic data will probably be obtained almost entirely automatically, much more so than at present, but it will still be necessary to digitize the results of photo-interpretation. It is not expected that the human eye, and the mind of the interpreter, will be superceded in a meaningful manner by machines and vast parallel processors by 1990!

The outstanding change situation will be in user generated maps. Many of these will be virtual or ephemeral maps for interactive browsing and geographic information systems, but there will also be an increase in the compilation of special purpose maps. A few such users will have a good understanding of graphic communication and visual art, but in general this will be the province of the true cartographer who will be stimulated by user competition to a greater appreciation of his own abilities and art, and be aided by being able to try new ideas in presentation without the time and cost aspects of today. Cartographic art will make great advances and those who think that from an artistic point of view, automation is a poor substitute, will have to change their opinions.

Once acceptance of the ideas suggested here, and the appreciation that they are good for cartography, is made, questions must also be asked by the cartographer of himself as to whether he is aiding or hindering this future. This is a serious matter as many procedures used today are certainly not being helpful. Most of these methods can be improved without much difficulty or change. For example, when polygons of land use or timber stands are drawn, they should use a different method of recording for the lines and the labels, methods that can easily be discriminated by machines. This may involve the use of scribing for the lines and ink for the labels, or even the simpler use of two different colour inks.

The major mapping agencies must appreciate that at this time they have a very serious responsibility in the design of cartographic data formats. Because of the bulk of data that they will produce, their formats will automatically have to become the standards. A faulty decision now can lead to endless and expensive problems later.

We now have to look at the advances that must be made in associated processes and equipment.

The first of these is concerned with data storage. Very fortunately we have exciting possibilities for cartography in the optical disk. It is amazing how often science seems to come up with the right answer to meet a need at the right time. The digital form of this disk is a further development from the presently available video disk for home television. The data is written by a laser beam causing minute eruptions on the surface of a metal disk. These eruptions can be copied by pressing in a similar manner to a phonograph disk, or can be read into a computer to recreate the information with a simple optical system. The advantages of this disk are firstly that it is archival and does not fade with time like magnetic tape, and secondly has truly enormous storage capability. Even allowing for a redundancy in recording of 10:1 to allow for minute surface blemishes, by the use of a well-compacted format as many as 1,000 TQ maps in full detail could probably be recorded on one disk. This would mean that 50 disks would handle the complete 1:24,000 TQ series!

While the recording of such disks is a very professional process and better left to the manufacturer's or a service bureau's clean room conditions, the playback units are simple and, at a cost a few thousand dollars, could be fitted to a small minicomputer, allowing a wonderful capability for the cartographic laboratory in 1990, either for browsing or the preparation of new hard copy.

Once the data is available and can be stored efficiently and economically, the usage will increase appreciably and some of the uses will require output plotting of the selected and possibly modified data. The precision X-Y plotters which have been the main stay of this type of work for many years give high quality but are extremely slow in operation when compared with estimated throughput. The more symbolized the lines, the slower the movement. There is no way that these large inertia devices could be made to work at the much higher speeds needed, while maintaining the high quality and providing great versatility in symbology for points, lines and areas. The only method that seems likely to meet the requirements is to use scanning units similar in some ways to those at present in operation in the Graphic Arts industry. There are at this time certainly large problems in the control of such scanners from cartographic input, but answers do seem in sight using a mixture of parallel processing interfaces and software. The most interesting scanners seem to be based on laser beam flat bed units. They will be discussed in more detail after the laser beam digitization scanners with which they have some aspects in common.

The last and perhaps most important subsystem is that concerned with display and edit. This is the way that cartographers communicate with their data. It must be efficient, fast in action and easy to use. The display and edit systems at present with us will be advanced in a number of aspects. Firstly each station will be self-standing in operation, requiring only intermittent connection to a central data base machine. This will make certain that a high operation speed is maintained on large sets of data and enable down-time to be essentially eliminated. Both of these aspects are creating problems, even in small scale production, at this time.

The cost of a station will be appreciably reduced by the use of small but powerful microprocessors and storage technology such as CCDs and magnetic bubbles replacing the disk drives, although the capabilities will be far superior to those of the present day. Colour will be standard and some units will be full map size. The display and edit software, aided by special hardware, will be extremely sophisticated but easy to use by the cartographer. The tendency will be for the machine to suggest where troubles have to be handled by the cartographer, making the change in the most suitable way itself, and only asking for approval. The machine will learn from the responses given to it and will improve in use. When it is best for the suggestions to come from the cartographer, then this also will be easy to do.

Automatic Digitization Methods

You will have noticed that the context of my prediction is based on the availability of high quality existing map data. We have said that in order to meet quality, cost and speed requirements, automatic means must be used for digitization and we are fortunate that we have available to us good input documents in the form of colour separations. As against the more heavily financed work in alphanumeric document copying, map separations are usually larger, but only require the same resolution (about 250 lines per inch) and are advantageous in that they have no grey scale and are available in negative transparencies.

Over the past few years I have closely examined most possibilities in automatic line following and scanning, and have come to the conclusion that scanning is by far the most effective. Physically the easiest method appears to be to scan the separation sheet line by line with a laser beam, noting when light is transmitted through the transparent lines of a negative. The mechanism is simple and can be made to the necessary precision without high cost. The scan method could equally be used to feed optical character recognition routines to analyse symbols, but other methods generally seem more efficient at this time because of the relatively small number of such symbols. The main work is therefore concerned with lines. The data produced by the scanner will have a number of picture elements (pixels) across the width of a line and these must be reduced to single pixel width data lines for any subsequent operations. There are a number of methods available at this time, which cover a wide spectrum of efficiencies. Only the fastest ones need be considered for future production in order to meet the cost and time constraints. However, the important aspect is that it is now fully known that it can be done to an acceptable efficiency and the design of production systems is advancing rapidly. There has been some argument about the line resolution required, but this seems to have been caused by a mix-up in thinking about the needs for digitization and for scan output plotting. More will be said about this later. I personally believe that 250 lines per inch is as good as the original drafting as far as precision is concerned. It should be noted that changing to only 500 lines per inch would quadruple the data and processing times and move beyond the critical knee of the cost curve. For the same reason the detection of line weight is not advisable as this would require a much finer scan resolution. Line weight can more effectively be noted by a mixture of interactive edit and automatic labelling aids.

At the present time most cartographers want their line data in vector line form. It is a relatively simple matter to create the vectors by software automatic line following, once the single pixel width data line has been produced. The vectorization would normally be followed by data compaction and de-symbolization to produce the cartographic database ready for general use.

Automatic Output Scan Output Plotting

An output scan plotter at first glance appears to be very similar to a scan digitization unit. However, there is a difference as well as the obvious physical one of replacing the negative separation and light detector by a sheet of film and a light beam chopper. The important difference is in fact that for good line and symbol appearance, 2,000 lines per inch must be used with a smaller beam size. The precision of the data does not have to be and, in fact, cannot be improved beyond the original 250 lines per inch of the digitization and database, but logical smoothing interpolation must be used to produce smooth lines and sharp corners. The 8:1 increase in data rates overloads a minicomputer controller if efficiency is to be maintained. Present developments are mainly concerned with associating the controller with a multiple parallel microprocessor interface for smoothing and interpolation and also for the necessary addition of side pixels to generate different line weights.

These devices, when development is completed, will have great flexibility for symbology of locations, lines and areas and be able to produce a sheet ready for final printing in a time of minutes rather than hours. Some difficulties remain but that only leads to excitement in development.

Scenario in 1990

You are in a County or State cartographic agency and you receive a request for a specific type of detail map to be created to deal with a particular environmental problem. You will have a stock of optical disks carrying all relevant TQs and attribute data in digital form for the area of interest. These are sent to you automatically each year by the Central Mapping Agency (CMA).

After viewing the data you find that some updates are probably available. A telephone call to CMA verifies this, and an immediate transmission of the updates is made to you by CMA over the data-carrying optical fibre links.

You now start a detailed browsing operation on your large screen colour display, using colour to distinguish between different features and overlays. When the available information has been noted you transfer the data to your editing screens for processes such as selection, local corrections, enhancement of important features, generalization and symbolization, until the data is felt to be in a useable state. This editing process may be lengthy or short depending upon the use and on the cartographer. The cartographer may wish to test out many different styles of presentation until he is satisfied, his large colour display giving him a clear idea of the final view.

The data, now in map presentation form, can be easily understood by the general public. However, it may never be presented on paper, but only retained in electronic form for public browsing at the local library, or for use on public interactive television discussions. If paper copies are required, it is likely that there would be methods different from those at present, mainly because of the short printing runs needed. Possibly colour electrostatic printers would be used. If colour separations are still needed, these will be made either on an in-house output scanner or at the nearest cartographic service bureau.

As this preparation of the official 'map' is proceeding, the locally concerned environmental group will be doing their initial work by a different procedure. It will also obtain information, but probably in less detail, from CMA, but it will do this at the local library on the public large screen colour information unit.

Attached colour copying machines will produce hard copy on request.

The Department of Environment and the engineering companies involved will also be preparing their own data and compiling maps to most easily present their data to the public. Data that is available in a timely manner is so much more valuable, that, after a suitable tagging as to reliability or inferential character, it is automatically digitized and sent to the CMA for access by the local cartographic establishments and by the public library system. As the data is improved and updated, these are also automatically fed into the system, again care being taken that the level of reliability is thoroughly appreciated by any user. Until the data reaches a level suitable for general use, it will probably be retained in transient memory rather than be transferred to optical disks.

In 1990 timely data will be available to all on fast and economic access. Some users will require it to be at high and some at low precision and detail. It will be in a common generally used format. New techniques and public need will force this situation and create a much more stimulating and fulfilling environment for cartographers than ever before.