AUTOMATIC CARTOGRAPHY

SPECIAL PROBLEMS OF HYDROGRAPHIC CHARTING

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This application of automatic cartography essentially involves chart drawing information stored in a digital data bank. In order to accomplish this in an efficient manner, detailed design has to be carried out on the databank itself, on methods of retrieval and incorporation of data, and on interactive display systems in order to utilize fully the experience and aesthetic ability of the human compiler.

More than any other part of cartography, hydrographic charting has always been orientated towards a digital presentation of data. This fact, together with the present tendency towards fully digitized surveys, makes hydrography an eminent example for the best implementation of automatic cartography. There has to be no complete change in philosophy, it is only a normal progression which opens up the way to better analysis and higher accuracy of data, faster access to the latest data and possibly moving towards the use of navigational data directly by machines such as automatic helmsmen. In a number of countries the present change to the metric system for charts makes this a particularly appropriate time to consider the new possibilities.

Hydrographic charting raises some special problems which do not exist to the same extent in other applications of automatic cartography. A navigational chart is a measurement tool as well as being a visual presentation of the area; the highest requirements of accuracy, quality and versatility must be met and thus it is essential that the equipment and operation be of the highest quality and reliability.

The system designed at the University of Saskatchewan for the Canadian Hydrographic Service has taken these factors into account in its engineering design [1]. It is believed that the concepts used in the design, and the methods adopted, are of special interest to those involved in this field of work. The most important concepts may be summarized as follows :

1. In order to obtain the essential accuracy and definiteness of data, a completely digital, centrally controlled system was designed. All operations were continuously checked by the monitoring and control computers, and the smallest defect reported to the operator. For the drawing work,

the most accurate, purely digital, drawing unit available, the Gerber Type 32, was chosen (figure 1).

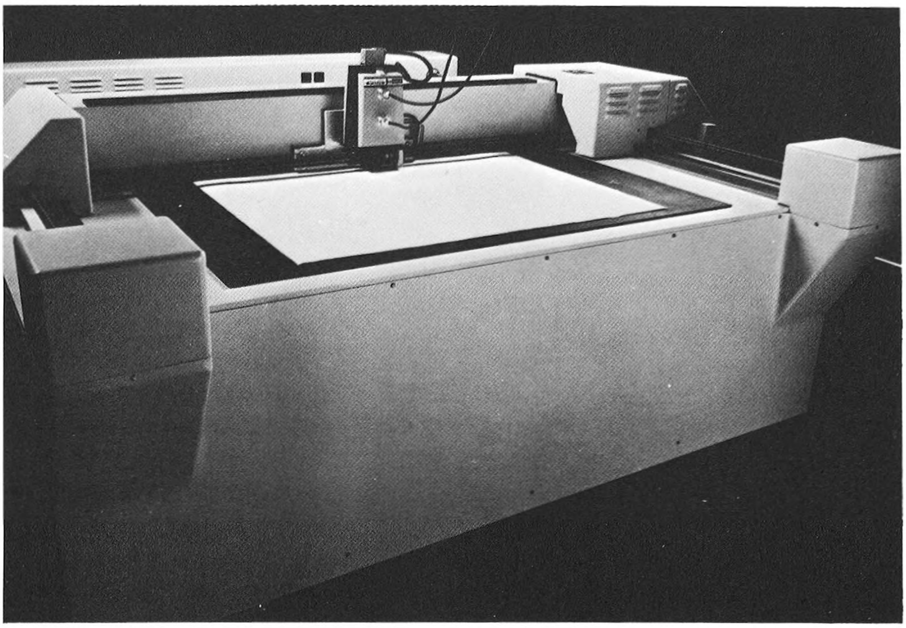

Fig. 1. — Gerber 32 drawing unit.

2. In order to provide the necessary powerful computational and database facilities, a large off-line computer was made available to the control computers, connection being made by the transfer of 800 bpi., 9-track IBM-compatible magnetic tape. It was decided that no fast individual requests would be made but that bulk data could be transferred at convenient intervals.

3. In order to allow for human communication with the system, Tektronix 611 storage displays [2] (figure 2) were fitted, working interactively using the 'Write Through' pointer mode. The display is particularly useful for cartographic work as its principle of operation allows a large amount of detail to be developed in the image without any flicker. The image can be viewed for minutes or hours without the necessity of refreshing from the computer.

4. In order to obtain the necessary line and symbol quality and versatility, the sophisticated light spot and symbol projector made by Barr and Stroud in Scotland was used with direct computer control of all parameters [3].

5. In order to give the greatest possible assistance to a digitizing operator, a completely on-line interactive digitizing operation was set up (figure 3).

6. For ease of maintenance, the complete engineering control was designed as a system, utilizing common modules and philosophies. In

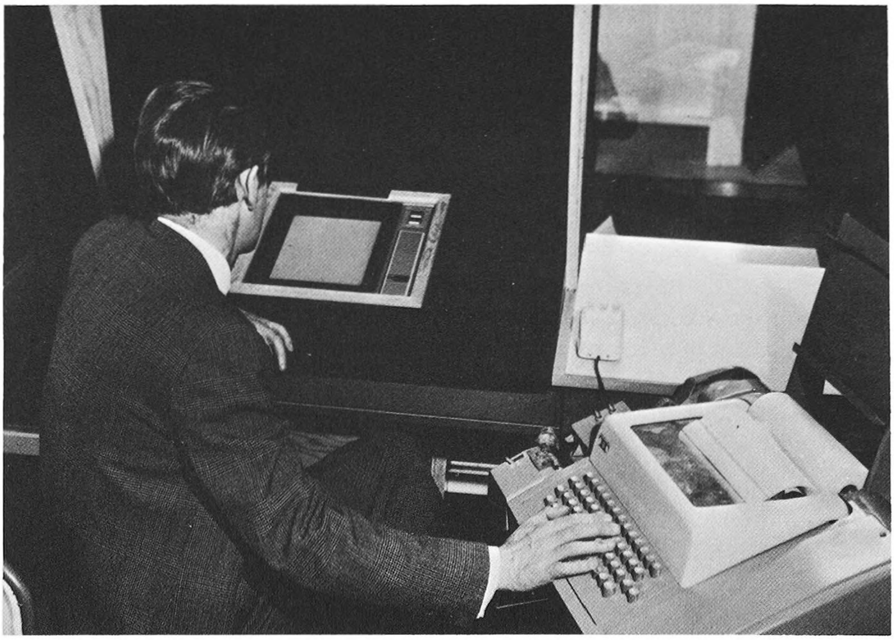

FIG. 2. — Tektronix 611 interactive display.

FIG. 3. — Pencil Follower interactive digitizer.

practice, PDP-8 control computers were used with all interfaces constructed of DEC modules.

One of the most important problems in hydrographic charting is associated with sounding data. There is no room for error in any handling of this data, so that all operations whether by man or machine, must be carefully checked. There would be little difficulty in storing this data and forming a databank if all new data were strictly additive to older data. Unfortunately data points are collected with different accuracies of position and depth, both within a single survey and certainly with different survey methods at different times. Sometimes new data appears to conflict and programmed decisions becomes very complicated. Frequently the resolution of conflicts involves factors beyond the knowledge of the computer and then the problem must be presented to the compiler or hydrographer for his arbitration. The best means of doing this is by visual display techniques and such units are an essential part of a well designed system. Moreover these displays must be interactive, allowing the compiler to erase, add or modify at will. The problem of tolerancing data to allow efficient computer databank incorporation is a serious one for hydrographers and needs to be taken into account in any data acquisition system.

The addition of presently available sounding data to the databank raises even more difficulty than does new survey data. Existing data is usually only available in drawn form on navigational charts and survey sheets. Manual digitization is tedious and prone to error. Fortunately the sounding values on navigational charts have been most carefully drawn or scribed and are amenable to automatic reading by a character recognition system of relatively simple design. Survey sheets create greater difficulties for automatic reading, not only because the numerics have been drawn freehand but also because of the contiguity of the soundings. It is believed that a system which has been developed at the University of Saskatchewan [4] will be able to handle 100% of soundings on navigational charts and possibly 50% on survey sheets. The latter is still a useful accomplishment as the reader outputs a 'not recognized' signal if it is uncertain for any reason, and this position can later be examined by the operator. Experimental assessment is proceeding.

The system consists of a vidicon camera mounted on a precision X-Y mechanism (figure 4) and both are directly connected to the PDP-8 control computer. An overlay sheet containing the soundings is taken, and all information except soundings is 'duffed out'. The X-Y mechanism then commences a mechanically operated strip scan until the vidicon detects any mark. Operation then changes into the recognition mode and the computer analyses the area viewed.

The digitization of line data on hydrographic charts is not as onerous as in other aspects of cartography. Coastline is the most important and semi-manual digitization is highly efficient for this type of line, providing it is done in a fully interactive mode, with the computer checking the output continuously. If any data is thought to be unsatisfactory for any reason it can immediately request the operator to 'backtrack'. Psychologically this enables the operator to work more closely and carefully on his work because he can have complete confidence that his efforts are not being wasted. There is a small amount of work to be done in digitizing topographic contours adjacent to the coastline. Water contours are rarely digitized as they have doubtful validity in a databank and it is generally accepted that better results can be obtained by fresh calculations from

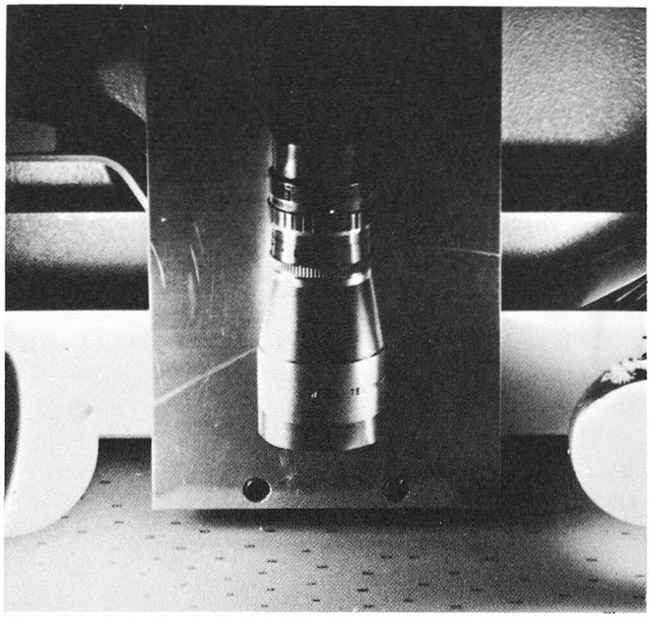

Fig. 4. — Character recognition system.

original sounding data for a specific presentation. Experiments at the University of Saskatchewan [5] on the use of Automatic Line Followers as an auxiliary to a semi-manual digitizer are proceeding but while this could be a process to take much of the tedium out of line digitization, nevertheless it often raises more problems than it cures. It should only be embarked upon if there is a large amount of line digitization to be done.

Having looked at the special problems of the formation of a hydrographic databank the comparable aspects of retrieval must be examined. These can be roughly divided into calculation, selection and symbolization.

Within 'calculation' are included programs such as scale and projection change, as well as calculations of water contours, graduated borders, grids and lattices. In general these calculations have to be made to a very high precision, but, except for the calculation of water contours, do not involve much difficulty in the formation of rules.

Within 'selection' are found the specification of area and of appropriate topographic contours for the required scale. A problem which is more difficult to define occurs in the selection of the soundings to appear on the chart and their visual correlation with the water contour calculations mentioned above.

Within 'symbolization' are multiple, usually small, subroutines to deal with navigational aids, complex image symbols and line symbolization such as is used for water contours. The symbolization of area, for example of sand or gravel, poses some interesting challenges to the programmer.

Generalization could perhaps be included in any of the above groups. It is difficult to define and difficult to program. Generalization of coastline alone covers a large area of discussion but it does appear that certain rules are now emerging. It is necessary to separate out the terms of line cleaning, line smoothing and line generalization. All of these have their place in the University of Saskatchewan system. The first removes cartographically useless line data from the databank, the second forms the digital or quantized data into an acceptable cartographic line, and the third goes as far as it can to follow specific, cartographically determined rules of generalization. The first two are effectively engineering operations and the latter a cartographic one.

Some aspects of line generalization which may be valuable are based on the maximum number of distinct features of irregularities which can usefully be represented in a certain length of line before they degenerate into visual noise [6]. An important concept in the present system is the addition of a 'saliency' or importance value within the descriptor which occurs at intervals along its length, aiding the computer in its attempt to make appropriate decisions. It is almost certain that the results of such work must be examined visually by a compiler, and this is another essential use of an interactive display system in addition to its use for the routine checking of the calculated symbolic forms.

Generalization can become extremely sophisticated when attempts are made to do such variations as moving islands away from coastlines to indicate a deep navigational channel between them, or retaining the size of important islands in a group when reducing scale. It is probably better for the present to leave such problems entirely to compiler modification on interactive displays prior to drawing.

A method of line smoothing to produce good visual lines from discrete quantized point data has been developed which appears particularly suited to the complex shapes of coastline with its wide range of radii of curvature. The quantized line in the databank follows the normal method of recording the nearest crossing point on a 0.004″ matrix, to the original line. The recording accuracy could therefore be to ± 0.002″, other human and machine aspects being neglected, and this is better than can be obtained from a manual draftsman. These values are relative to the original sheet being digitized and undergo some manipulation in form in the databank. However, no data should be less precise than this value when a chart is to be drawn and it is taken as the actual value in the present discussion.

A visually acceptable line could not be obtained by merely joining these points. It is necessary to follow a path which moves between these specified points and never more than ± 0.002″ from one of them. Various methods have been attempted including circular and parabolic interpolation, but these methods have problems when abrupt changes occur in a detailed coastline. At the University of Saskatchewan it has been found that a process which has been termed 'forward look linear' interpolation is advantageous both in results and in simplicity of computer operation. In this method, the coastline is built up from a series of short lines (approximately 0.004″) but between the gradients of each there is only a small angle. This is obtained by aiming the drawn line at a specified matrix point four points ahead of the present position, but only allowing it to proceed one quarter of the way before reaiming one point further ahead.

For topographic and water contours having a larger minimum radius of curvature, a longer 'look ahead' is taken.

Whilst the manipulative programs for hydrographic data may be more accurate and complex than in other fields, the actual bulk of the databank is small. Hydrography tends to suffer from a shortage of data due to the high cost of acquisition as against a photogrammetric input. Magnetic tape storage using a reasonably compact format seems well suited. It also seems acceptable to store data in latitude and longitude positions, and lines as a series of increments of latitude and longitude from a starting co-ordinate. An increment scale factor is used periodically to change the size to agree more closely with the precision of the source. There is also need for a complex organization of descriptors, as data not fully described is useless.

There is no need for hydrographic databanks in different countries to follow exactly the same pattern. International co-operation is essential to allow interchange of tapes, but translation programs are relatively easy to write. Obviously any country would strive to use efficient formats, but this sometimes depends on the computer system available. In this case it is even more important that all data should be properly described, including tolerance or reliability and saliency or importance, as reference cannot be made back to the original source.

The Canadian Hydrographic Service has set up working study groups to examine the detailed rules of hydrographic charting. The output from these groups has been invaluable in allowing proper system analysis to be done. A particular feature of the Canadian project has been the very close and friendly relationship between hydrographers, cartographers, system analysts and engineers.

The advantages of automatic cartography are very real and in the near future it should be possible to handle hydrographic data and produce navigational charts of high quality.

ACKNOWLEDGEMENTS

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