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THE TECHNOLOGY OF INTERACTIVE COMPILATION

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Abstract

Digital technology now makes it possible to compile a nautical chart from digital source data, and to draft the chart automatically. This paper describes some of the hardware and software tools used in the Canadian Hydrographic Service that make this process possible. It also considers what has to be done to make these techniques more effective, how the technology is expected to evolve, and the impact of these changes on chart producing organizations.

1. INTRODUCTION

In Canada, 1984 roughly marks the period when digital technology started evolving faster than it was possible to make use of it. Up to this time the cost, functionality, availability, and stability of the hardware and software were such that the Canadian Hydrographic Service could reasonably evaluate, plan, test and implement new technology and obtain a satisfactory return on the investment. Today equipment is hardly broken in, and software barely debugged before something better is announced that seems to make the latest installation obsolete in some fashion. Furthermore, up until this period the technology was limited and the main application, in Canada, had been for computer-assisted drafting; computer-assisted compilation had been limited to a few experimental projects.

Today there exists an ever changing plethora of powerful, high quality graphics workstations which are a fraction of the cost of just a few years ago. Furthermore, much of the specialized software needed for chart compilation is now commercially available. New capabilities are also being added regularly. Our organizational ability to absorb these new capabilities and to implement and use them optimaly is also being stressed. Similarly, our ability to train production staff and to keep them current with the technology is a major challenge. Currently the Canadian Hydrographic Service (CHS) has approximately 23 cartographic work-

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stations installed across Canada, and the falling cost of this equipment means that the dream of having a workstation on every cartographer's table may soon be here.

Paper products will be around for a long time, so how are we going to deal with the electronic chart and with the ever increasing volumes of survey data being produced by new survey technologies? Should we develop (paper) products more amenable to automation so that newer and better information can get out to our users faster and be easier to maintain? There are many new possibilities but unless we can alter our mental fixation with the traditional paper chart, which was an excellent product for its time, our clients may be denied new products that would improve their activities.

This paper attempts to describe the technology that is now being used in the CHS for the compilation of nautical charts. It deals mainly with the traditional paper chart, but also considers the electronic chart and the trend to use existing charts as the basis of the Electronic Chart Data Base (ECDB). It also questions whether our basic approach to nautical charting is entirely appropriate for this new era.

It took many decades to develop standards for the paper chart. These standards are being used as a foundation for the electronic chart, but new standards for the digital products are also being developed. Descriptions of some of these activities are included since they should be considered in the acquisition of an interactive compilation system. The paper concludes with some biased predictions for the future.

2. WHAT IS INTERACTIVE COMPILATION?

Just as digital technology and its application to charting are evolving, the terminology used in these processes is also evolving. New terms are being coined, which are not well defined, nor used in a consistent or even a sensible fashion (e.g. automated cartography). The term 'interactive compilation' is also not well defined. It is being applied, in a narrow sense, only to those sessions where a cartographer works interactively with a graphics editor, and also in a broad conceptual use of 'interactivity' to describe the overall process of producing charts from digital source data with computer systems. In this paper the broad definition is used and therefore includes the use of graphic editors and all related on-line or batch software. In the past, this author has tended to use the term in a narrower sense to describe only the interactive graphic sessions and to call the overall process 'computer-assisted compilation'.

The top of Figure 1 shows a highly simplified flow diagram of interactive compilation as it is now evolving. Below the blocks are the software components or processes that are a focus of this paper and are discussed in Section 4.1. Although the CHS is endeavouring to establish Data Base Management Systems (DBMS) for the hydrographic source data as well as for the other expert data bases that are required, these systems are in an early state of development. Currently the cartographer must obtain and combine the available digital source

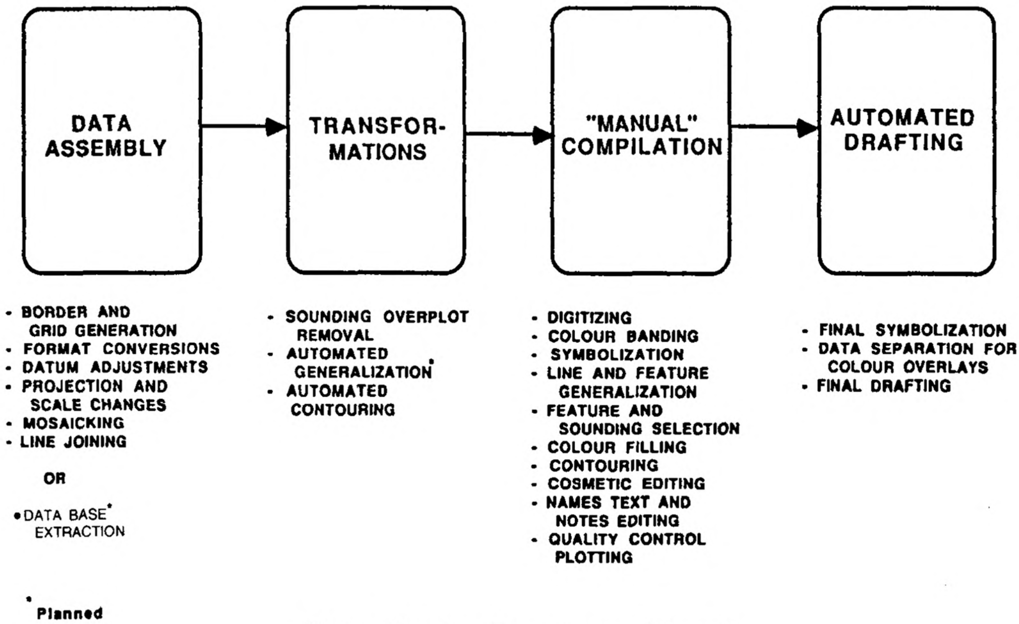

FIG. 1.— Overview of interactive compilation tools.

material through a batch computer process. This may be a very time consuming task if there are different data sets covering the same area, and it may require the cartographer to validate the data prior to using it. It is planned to establish a data base that contains up-to-date validated data from which the cartographer need only extract the data for the area of interest. Interactive compilation will then become the process of transforming the probable large volume of source data into another form of information that can be readily understood and applied by the user. Interactive compilation thus includes data reduction, interpretation, generalization (of various kinds), smoothing of line data, cosmetic editing, labelling, etc. Today some of these processes have been automated to a limited extent but there is an enormous potential for much further automation. At some time in the future we can assume that 'interactive' compilation will be replaced by 'computer' compilation.

3. HARDWARE

The earlier versions of the cartographic systems developed in the CHS have been replaced with standard hardware components and commercially available software (CARIS) that evolved from the earlier systems. In Ottawa, a local area network ties the five cartographic workstations together for data exchange, and to other facilities for plotting, backups, and to a link to an external network for communication with other regional offices.

3.1 THE CARTOGRAPHIC WORKSTATION

Usually the workstation consists of a colour graphic terminal, a networked mini/micro computer with a hard disk and a digitizing table or accurate pointer as it is often called, and a variety of software modules that makes this hardware useful. The bottom of Figure 1 lists the software modules that are available on the 'CARIS' workstations used in the CHS. They are described in more detail in Section 4.1.

3.1.1 Graphic Terminals

Next to the computer, the most important component. Virtually all the cartographer's requirements can be met with standard, affordable systems, with one exception, and that is the option of a large (e.g. A0 or chart-sized), flat, high quality screen. Preferred specifications for the terminal are:

Resolution: 1280 by 1024
Size: 19 inches (Larger size when available at reasonable cost)
Internal Vector Display Memory: 2 Megabytes minimum
Communication Link (to host micro): 38 Kbaud minimum, DMA link preferred.

3.1.2 Input Devices

Since all the source data will, generally, not be available in a digital form, some of the data will have to be digitized. If the only use of this data will be the construction of a chart, it is not usually cost effective to digitize all the source data and only a selection will be digitized. If all the data is in a digital format, the table may serve as an 'accurate pointer' relating a position on a hard copy graphic to the digital file. However, when working with complete digital data sets, the need for a digitizing table is reduced and not all workstations would require them.

• **Digitizing Table:** If done at chart scale, an accurate table and good digitizing techniques are essential. Preferred specifications are:

Absolute accuracy:	± 0.003 inches
Resolution:	± 0.001 inches
Repeatability:	± 0.001 inches.

To obtain accurate digitized data, special care must be taken with the registration and environmental conditioning of the hard copy document. For digitizing source data, that may already have a sizeable inherent error or may be used at a reduced scale, these tolerances can be increased substantially.

• **Line Scanners:** Over the past decade the CHS has evaluated several line scanning systems. The scanned data pixels are converted to vector lines, and even though all the systems studied worked more or less adequately, this technology has never been extensively used for production. This is because the systems (or services) were costly, the outputs were not in standard formats, the small volume of documents, the relatively small amount of line data on each document, and soundings were not converted. These factors precluded the establishment of a cost effective operation in comparison to the manual techniques. The line scanning technology is continuing to evolve and may yet become a cost effective tool for nautical charting.

In the past, the only option was to convert the scanned data to vectors because of the large memory required to store the scanned images, but today large mass storage devices, such as the optical disk, make it feasible to create a data base of geocoded scanned images. Such a data base of all the graphic source documents could be very useful for chart construction since the raster images of the field survey documents could be used as a basis for constructing the vector chart. For example, vector contours could be developed on the CRT image of the raster scanned document, and soundings to be shown could be selected. Furthermore, as the soundings are selected they could be digitized, either by the machine and checked visually by the operator, or by reading the value from the screen and keying it in. Usually, only a very small percentage of the soundings on a hydrographic field sheet ever appear on the chart, so this could be a cost effective and practical method of dealing with, and managing, existing hard copy documents in an 'electronic' environment.

The mechanical tolerances for line scanning should be comparable to those for manual digitizing although, since operator errors can be reduced, some relaxation of those tolerances may be possible.

- **Character Recognition:** Although a fascinating approach to converting 20,000 field sheets of the CHS to a digital form, it has not yet been demonstrated that the conversion of the raster images of the depths to X, Y, and Z values is sufficiently reliable to be used for charting. Recent advances incorporating AI techniques offer some new promise and are being investigated.

3.1.3 Graphic Hardcopy Output Devices

The cartographer has a wide choice of devices to generate the hard copy documents still needed in the process of making a chart. Plotter usage falls roughly into five categories such as data verification, data review, documentation, checking, and generating final negatives. These requirements can be met by both vector and raster plotters. Plotters that generate hard copy images of the CRT (Cathode-Ray Tube) are limited in size and are usually used for documenting some decision or problem. Across Canada the CHS has plotters from more than six different manufacturers and generic hardware, independent software modules developed by the CHS have been important in helping the CHS to manage this variety of devices and to add new ones.

Vector Plotters

These plotters imitate the way in which lines are drawn by humans; the technology is quite mature but is gradually being replaced by raster technology.

- **Pen:** The lowest cost solution, yet offering a very flexible tool with usually up to 8 different pens and with roll feed paper for high volume operation. Useful for reviewing and verifying source data and for the initial checking of digitized documents. The lower accuracy and inability of drawing various line widths and of colour filling areas limit its use.

- **Scribing:** A medium cost tool, capable of good quality and accuracy; however, it requires constant attention by a skilled operator since the tool adjustments are critical. Not used in the CHS.

- **Optical:** An expensive tool that usually provides the best accuracy and quality and is used to produce the final plots for quality control checking, as well as the final negatives for the offset lithographic printing process. The plotting is automatic once the film has been placed on the table. Unfortunately, it has not been practical to use this device to fill areas and therefore a colour etch, contact print must be made for manual peeling of the colour areas. This limitation means that these plotters must be replaced by a raster plotter if the CHS is to achieve its goal of fully automated drafting.

Raster Plotters

This technology is going to play a more important role in nautical chart production over the next few decades, while attempts are made to get the electronic chart established. Powerful computers with large memories have made this technology practical and, although the plotters are still relatively expensive, they are growing in popularity and, hopefully, the larger demand will drive the price down.

- **Electrostatic Colour:** Available with resolution of 400 dots per inch, these devices have become very popular. Their colour capability is very useful for analyzing depth data using colour banding, and also for checking, since different colours can be used to plot each feature. They also have a potential for producing colour proofs and plotting complete charts, which has given rise to a concept of Print-On Demand (POD), to be discussed later. Current versions require a separate pass for each colour (4 passes), but new plotters with a single pass are now available. Low humidity may make it difficult to get uniform colouring from the electrostatic plotter, but perhaps other techniques (heat), now in use for smaller plotters (8.5 by 19 inches), may be extended to the larger format still needed for charts.

- **High Quality Laser:** Although the accuracy and quality of the electrostatic plotter are adequate for producing individual copies of charts, it is not, currently, good enough to produce the plates needed for volume printing of charts. For the latter application, a high quality, monochrome, laser plotter is needed. Unfortunately, the demand for these high quality, large format products is small and even though these plotters have been around for more than a decade, they have remained costly.

• **CRT Screen Copiers:** An option available with most colour graphic terminals provides a hard copy of the CRT image and is useful for documenting problems and the action taken to resolve them.

• **Desk Top Laser:** There is a growing availability of laser printing for word processing and desk-top publishing. These devices are also useful for the quick generation of small (8.5 by 11 inches) monochrome plots.

4. SOFTWARE

Finding the appropriate hardware for interactive compilation is no longer a major issue since many suitable choices are now available. Software for nautical chart production is still an issue since there are relatively few choices. Furthermore, the software packages are usually limited to specific hardware lines.

Even though new technology is being used in the production of today's charts, the design, content, and presentation of material on the charts has not been seriously affected by the introduction of this technology. The paper chart, and at the moment also the electronic chart, are made to the specifications painfully established over the past several decades and which are based upon manual graphic techniques that are optimized for the lithographic printing process. It will probably take 1 or 2 decades before new presentations, whether electronic or paper, will be created that may begin to make optimum use of the new technology.

4.1 INTERACTIVE COMPILATION

Interactive compilation is still evolving and at the moment consists of using powerful, customized, graphic editing software, supplemented with specialized software tools as listed in Figure 1. These tools are grouped under the four main tasks for:

1. Combining the source material into one file at a common scale and projection. This would also include the mathematically generated graphics such as borders, grids and lattices.
2. Automatically transforming the large volume of data into a more usable form. Generally, this covers well defined tasks that have not been too difficult to program.
3. Giving the cartographers the tools needed to use their skills and judgement to make the transformation of a certain level of source data into the final chart.

4. Providing the capabilities for generating check plots and final chart negatives.

The modules or software tools available for these major phases of chart construction are described in the next four sections. Phases 1, 2 and 4 cover the automation of the 'mechanical' processes that computers are good at, whereas Phase 3 involves the 'art' of chart construction, including things that are difficult or impossible to program, and require cartographic skill and judgement.

4.1.1 Data Assembly

- **Border Grid and Lattice Generation:** Generally a straightforward task but some of the more complex chart bases may require some editing.

- **Projection and Scale Changes:** Another standard task. In the CHS five projections are used, namely: Mercator, Universal Transverse Mercator (UTM), Polyconic, Lambert Conformal, Polar Stereographic.

- **Format Conversions:** Although not very serious at present, the problem of format conversion will grow as the CHS attempts to incorporate more data from external sources.

- **Mosaicking:** Combines several source documents, possibly at different scales, projections, and vertical datums into a single 'windowed' file.

- **Line Joining:** After combining several larger scale charts to create a base for another chart at a smaller scale, this program joins lines, at the initial chart boundaries, that have similar feature codes into continuous lines.

- **Median Lines and Territorial Limits:** Simple software aids that generate these boundaries.

4.1.2 Transformations

- **Sounding Overplot Removal:** As its name suggests, this software was developed to prevent the overplotting of soundings when hydrographic field sheet plots were drawn. The techniques have been extended and the software can be used by cartographers to further reduce the volume of depths that they need to examine.

- **Generalization:** Software is also being developed to aid the cartographer to reduce the density of line data after an area has been reduced in scale.

- **Contouring:** Accurate machine contouring has been available for a long time, but has not been used to any great extent for chart compilation in Canada. Developing the 'safe' contours used on a chart requires considerable judgement, a task which is still difficult to program.

4.1.3 Manual Compilation

Most of these tasks involve manual operations because the cartographer uses a mouse, joy-stick, cursor, or set of thumbwheels of an interactive graphics editor to add, select or modify the data set. There is also a growing list of on-line aids that can help the cartographer analyze the data and develop the chart presentation.

- **Digitizing:** Until recently, digitizing has been oriented towards the use of vector plotters for final plotting and lines were more or less randomly digitized and did not form closed polygons. Problems were encountered when this so-called spaghetti data was used to produce colour filled presentations for the electronic chart, or for output to an electrostatic plotter, since the lines did not form closed areas. Today the trend is to digitize data in a more structured fashion that supports colour filling. Fortunately, software has been developed that makes the new digitizing process quite effective and can also be used to convert the older spaghetti files to a structured form.

- **Concatenation:** Allows two or more files, at the same scale and projection, to be joined. Each file can be individually rotated or translated by the operator. Useful for incorporating non-geographic referenced information into a chart file.

- **Sounding selection:** Another simple task, but in the CHS a special sounding flag word is used (among many other things) to identify each sounding as either being selected, background, or suppressed. Each category of sounding can be viewed on the screen, by itself or in a colour coded combination. In use for over two years, this technique has been an effective aid for chart compilation. These flags can also be manipulated by the sounding overplot removal batch program.

- **Line Generalization and Smoothing:** Mimics the old manual techniques, but line editing commands, such as 'curve fit', allow the cartographer to draw new, smooth lines quickly.

- **Colour Banding:** A simple yet very effective function that helps the cartographer to analyze the depth data and to develop the depth contours manually. Colour banding can also be applied to feature codes, source identification codes, and other attributes of the data. Colour banding can be done on the CRT screen or on the pen or electrostatic plotters. A valuable function and it is important that it be available in a graphic editor used for chart compilation.

- **Contouring:** The development of contours is greatly facilitated with colour banding. This is a manual line drawing function with the graphic editor. Although contours can also be generated automatically and then edited by the operator, up to now this approach has not found much acceptance in the CHS. However, there are plans to integrate a contouring program into the system, this will be a useful tool that will complement the colour banding technique. Some skill and fine tuning will be needed to integrate these tools into an effective process.

• **Names Editing:** A link to the CHS names gazetteer has been established, but judgement is required for the final positioning and sizing of the names, which is done with the interactive editor.

• **Navigation Aids:** A link to aids data bases is being established but final positioning of some aids (e.g. buoys) may also be done manually.

• **Text and Notes:** Currently this information, in French and English, is keyed into each chart file. Much of this information is repetitive and potential errors and labour can be reduced when the CHS implements a link to the data base where this information is retained.

• **Cosmetic Editing:** Touch-ups to ensure that the final product meets cartographic standards.

• **Symbolization:** In the current system, the cartographer works with an unsymbolized file and views line data on the screen in an unsymbolized form. Thus roads, rocky ledges, etc., are not shown in their true representation. Alternatively, point data is symbolized, and all symbols and soundings are normally displayed as they would appear on the chart. This difference occurs because it still takes too long to symbolize all the line information before drawing it on the screen and, furthermore, editing symbolized line data creates some difficulties. However, the cartographer has the option of symbolizing small sections of the chart, specified by the operator, and thus has a fully symbolized presentation on the screen for checking, before plotting. The cartographer also has an option of having soundings set at the size that they would appear on a chart and then enlarged on a zoom operation, or of having the size of the sounding remain set at a fixed size on the screen so that a zoom operation can be used to examine source information that includes many closely spaced soundings. Some of the restrictions of dynamic symbolization will disappear as new, much more powerful, workstations are introduced. The option of having both the stored form of a line and its symbolized form displayed at the same time, in different colours, should be added to the editor.

• **Colour filling:** The process of building and identifying the closed polygons that are to be colour filled for the raster plotters or electronic chart.

4.1.4 Automated Drafting

• **Quality Control Plotting:** Pen plotters are used for most tasks, but the optical plots are used for final checking.

• **Final Symbolization:** The first step in the automated drafting phase. Any information already symbolized is not affected by this program.

• **Line Cutting:** Cuts line features where they intersect with certain other features, for example a grid line would be cut if it intersects a sounding.

• **Data Separation:** Several negatives are needed for chart printing and, just before the final drafting step, the chart data is separated according to its colour on the chart. This separation is determined from the feature code of the data items.

• **Colour Proofing:** Still experimental, but an attempt to employ the electrostatic plotter for generating colour proofs.

It can be seen that the cartographer has a collection of tools, some of which are still evolving, that can be used for the construction of a chart. The immediate challenge is to integrate these tools into an effective overall process, supported with the appropriate policies, standards, controls, training, and technical support. It is clear that the artistic skills and judgement used by the cartographer in the past are still needed.

The hydrographic surveyor also needs interactive tools to cope with the large volumes of data now being collected by modern surveys, and it has been gratifying to see the growing adoption of some of the tools mentioned above by the hydrographer. The use of a common system by the surveyor and the chart compiler will aid in bridging the large gap that has developed between hydrography and cartography during the past century.

4.2 HYDROGRAPHIC INFORMATION SYSTEM

Interactive compilation is one part of an overall information system that is envisioned for the Canadian Hydrographic Service. Many facets of this organization have been automated to some extent, but these have tended to be done in isolation and it has become a major goal of the CHS to join these islands of automation into an integrated information system. Each major area of speciality would still have its data base managed by its own experts, but these data bases would be networked regionally and nationally in a fashion that, it is hoped, would unify the CHS offices across Canada.

Many standards are needed if these systems are to be able to communicate with each other. As an initial step, the CHS is trying to standardize the computer hardware, the high level 4th generation languages used to develop the systems, the DBMS packages used to manage the information, the data formats for collecting, storing and exchanging surveying and chart data, as well as attempting to develop common data definitions across the Service.

5. PRODUCTS

5.1 PAPER CHARTS

Many hydrographic agencies now use some form of automated drafting in the process of producing the paper chart, but it is apparent that there is still a lot of manual effort involved in producing the final colour overlays used to print the charts. Fully automated drafting is feasible and the CHS plans to introduce this process as soon as it can supplement its current high quality vector plotters with a high quality raster plotter. Eventually final drafting is expected to be done on-line from an unsymbolized chart file.

The digital chart files now used to drive the automated drafting process form a Digital Chart (file) Data Base and it is now economically feasible to store these files on-line. The CHS also plans to develop a mechanism for updating the chart data base through integration with another system being developed for Notices to Mariners.

5.2 PRINT-ON-DEMAND CHARTS (POD)

If the digital chart files are routinely updated, then with the colour raster plotters now available it becomes feasible to print up-to-date charts directly from the digital chart data base (VACHON, 1989). Furthermore, with a low cost, high bandwidth network, these digital files could be sent to remote sites from either a centralized data base or a distributed data base. Initial investigations have indicated that POD could compete with current procedures, that include slow, costly, hand correction of each copy of a chart plus significant costs for storage and distribution of those paper products. Further research is required, but the raster colour plotters may thus provide a way in which to complement the electronic chart data bases that must be established. The raster plots could also be used for backing up the electronic system. Some customization of coverage, scale, and content is also feasible, and could reduce the volume of data that must be plotted. Enabling each user (safely) to tailor the paper presentation to his own needs could be a very useful option.

5.3 ELECTRONIC CHARTS (EC)

Current efforts appear to be 'forcing' a variation of the paper chart product onto the cathode ray tube of an EC System. Many years of effort have been devoted to obtaining international standardization of the paper chart and it is natural to try to use similar standards on the electronic media. This approach also makes it easier to get approval for EC use from international regulatory bodies, and furthermore it makes it easier for charting agencies to create and maintain the EC data bases since they can be based upon the paper chart data bases. A lot of new resources to produce an entirely different product would not be required. Unfortunately, this approach may retard the complete development of EC. The electronic media coupled with the powerful computer systems now available provide a basis for many innovative solutions, and there is an enormous potential, but it will take many years to explore, understand and then apply the results to marine navigation. Further, the new breed of master cartographer that is needed to design the EC is just beginning to be trained and, therefore, the specification of the EC must not be frozen too soon.

Until entirely new ways of presenting the information are developed, interactive compilation systems, such as those described in this paper, will be used to develop the electronic chart data bases from the paper chart products. Many of the hardware and software components used for interactive compilation are also used internally in an electronic chart system. This fact enabled the CHS to develop a very useful Electronic Chart Testbed (EATON, 1986), to test various EC concepts and also to demonstrate the value of the electronic chart. In this project, the CARIS Mapping System was modified to form an EC Testbed and the compatibility between the system that generated the information and the system that used the information made it much easier to implement, optimize and use.

5.4 UNIFYING THE PAPER AND ELECTRONIC WORLDS

For the Canadian Electronic Chart Testbed, minor modifications were made to the digital (paper) chart files in order to use them on the test bed. This included: reducing topological and cultural data to a minimum, flagging those features that formed the 'minimum data set' that is to be on the screen at all times, and restructuring some of the data to form closed polygons that could be colour filled. Eliminating information from the chart requires judgement, but the flagging and reorganization of the data can be done automatically. Also if data is digitized in a structured manner, then the colour filling process can also be automated. Overall, it thus appears that a great deal of labour is not required to generate the electronic chart version of a chart from the digital file used to produce the paper chart. In this work a common format (NTX) was used. The importance of such a common format was further demonstrated in the CHS' use of the testbed in the North Sea trials held in October 1988. For these tests, the CHS digitized data from North Sea charts rather than attempt to convert digital data that was being provided. Although improved accuracy and better reliability might have been obtained by using verified data set from the agency that made the paper chart, this data was not used because:

1. A stable, well defined, and documented exchange format (including the digitizing rules and feature coding) was not being used.
2. Structural data, supporting colour fill, was not being provided and some editing and reprocessing would probably be needed.
3. It was less costly to digitize data from the chart than to write and test new conversion software. Furthermore, by digitizing from the chart, the cartographer had more control over what to include and how to present the data.

These experiences have demonstrated the feasibility of using the digital data base established for the paper chart to produce the '1st' generation of Electronic Chart Data Bases (ECDB). It is felt that this solution might last for a few decades, until new and possibly automatically generated products are developed, proven and accepted.

6. PRODUCT UPDATING

In the CHS, interactive compilation is being implemented for the construction of paper charts. Fortunately, these tools are also suitable for producing the Electronic Chart Data Base (ECDB) and, as the demand for digital products grows, the CHS should also be able to provide them. Meanwhile, the CHS intends to increase the use of automation in its Notices to Mariners Section. This will include using the digital chart files to generate patches, and to endeavour to keep the bulk of the Canadian charts up-to-date. When such a system can be implemented effectively, then the foundation for supporting both the paper chart and its electronic version will be established.

A recent report (IHO, 1988) on updating the electronic chart provides a thorough description of some proposed models for global chart updating. The technical obstacles in implementing electronic charts and electronic systems to keep them up to date are disappearing. The main problems now stem from a lack of acceptable international standards, the need to develop new policies and practices and to create the new infrastructures both nationally and internationally to support the EC.

7. INTERNATIONAL STANDARDS

In self-contained or closed systems, users can establish their own conventions, and standards may not be needed. When a hydrographic agency purchases a Geographic Information System (GIS) which, as has been discussed, is an integrated set of hardware and software tools (plus the skills and data needed to make the systems useful), then that agency must develop its own conventions for digitizing, storing, and classifying its data, for symbolizing the data, and for drafting it. This can be a lot of work unless it follows the lead of some other agency which has already put a system into place. A problem with the latter is that the two systems will probably diverge as each agency solves its own problems in its own way. Since there are, at present, no established international standards for digital charting, each agency must devote considerable resources to implementing and maintaining its own system.

Work now in progress that may alleviate these problems is being done by two committees that have been established under the International Hydrographic Organization (IHO) to develop standards for electronic charting. These are:

1. Committee On the Electronic Chart (COE) covering:
   - *i)* Digitizing or data collection rules
   - *ii)* Chart design including feature representations
   - *iii)* Chart up-dating
2. Committee for Digital Data Exchange (CEDD) covering:
   - *i)* Feature coding
   - *ii)* Geographic referencing
   - *iii)* Data structures
   - *iv)* Data encapsulation for:
     1) Hard media
     2) Telecommunications.

These standards are intended for the design of the electronic chart presentation and for the delivery and updating of the data bases for the electronic chart, and although they may appear to be independent of interactive chart compilation, accepted standards might be useful in building future chart compilation systems.

8. CONCLUSIONS

For nautical charting agencies, the transition to the digital computer world for collecting data, managing it, and making navigational products is clearly gaining momentum. The interactive compilation tools described in this paper have evolved from the tools developed for chart drafting and now provide a solid foundation for this transition. These tools will continue to evolve, and new ones will be added. For traditional paper chart construction, sounding selection software will be improved, and will be supplemented with better automatic contouring tools. Furthermore, as more powerful workstations appear, it will become possible to integrate the tools in more effective and friendlier fashions.

The basic concepts underlying the collection, processing of the hydrographic data and its use for navigation has not changed very much, but the growing volumes of data being collected by modern equipment will surely alter the way to store, process and present information to the navigator. For example, the high density of the sounding data gathered in sweep and swath surveys would be more effectively used if the portrayal of the bottom was by a depth associated with an area rather than by more and more discrete co-ordinates. The size of each area element would be determined by the type of survey and accuracy of positioning used in the survey. This approach might eliminate the need to add accuracy factors to each sounding since those factors would be inherently determined by the size of the area element. Also, generalization of these elements into larger areas may be easier than trying to mimic the current sounding selection practices. Bathymetric contours are the boundaries between certain cells and, since these searches could be done very quickly, it could provide a practical method of performing real time contouring for electronic chart systems that incorporate tidal adjustments.

It also appears clear that until there is a much greater demand for digitally based products, the implementation and use of this technology will continue to move rather slowly.

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