CREATING AN INTERACTIVE GRAPHIC TOOL BASED ON A RELATIONAL DATA BASE MANAGEMENT SYSTEM

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Summary

The French Hydrographic Office has developed, for its own needs, very powerful computer tools to assist its cartographic work. This software, which is used at all stages of chart making, has been set up in two main phases, backed by ultra-modern computer technology affording maximum ease of use for the cartographer. The modular nature of the software that has been developed ensures that the tools are well adapted to future developments in computer equip- ment and makes it possible to adapt it, where necessary, to other cartographic work besides nautical charting.

I. ORIGIN OF COMPUTER TOOLS FOR CARTOGRAPHY

In France, the 'Service Hydrographique et Océanographique de la Marine' (SHOM) is responsible for the collection, processing and promulgation of maritime and nautical information with a view to providing various categories of users with the means of guaranteeing the safety of their shipping. In order to meet this objective, rapid and sure systems of manipulation of information must be set up — therefore computer techniques are necessary. As soon as sufficiently reliable and efficient computers appeared on the market at a reasonable price, SHOM endeavoured to integrate such equipment into its production chain for cartographic documents, beginning with the operations to which it was easiest to apply automation, i.e. data base collection and management. At that level, indeed, even though the volume of data may be considerable, the processing to be carried out is relatively simple, since among the most complex operations notably involved are:

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— for collection of data at sea and compilation of bathymetric plotting sheets: the choice of soundings along a profile (selection of soundings according to a criterion based only on the linear structure of the profile) and the elimination of superimposed soundings before drafting the fair sheet (surficial choice but one using an elementary criterion).

— for data base management: checking of compatibility between files containing information on various manipulated geographic objects (wrecks, landmarks, buoys and beacons, lights, coastline ...).

Cartographic operations themselves, as opposed to data collection, not only involve extremely large quantities of data of widely differing types, but the processing may be quite complex and difficult to express in the form of algorithms.

The complete charting process essentially consist of three phases :

1) Creation of the draft chart leading to the precise definition of the chart and any insets and drafting of the template.

2) Extraction of basic information (digital or otherwise) concerning the area considered, cartographic selection of information to be portrayed on the chart and determining of the placing of such information.

3) Fair drafting of the document resulting from the previous phase on various plates which will then be used directly in order to make the printing plates by means of a photographic process.

Phase 2 above is called   PREPARATION, while Phase 3 constitutes the EXECUTION (or final drawing) of the nautical chart.

It is easy to note that in this process the non-algorithmic processing centres around Phase 1 (except for the drafting) and Phase 2 (cartographic selection) and that, à priori, therefore, computerizing of the other phases is possible and relatively simple. About six years ago, SHOM therefore launched into the programming of software tools to assist the carrying out of these tasks.

II. THE FIRST GENERATION   OF CARTOGRAPHIC TOOLS

1. Object and computer environment

The object of the first generation of computer tools developed by SHOM was to place at the cartographer's disposal supporting software for carrying out the drafting of the chart template, extracting data and final drawing of the chart.

These tools, still in service, are put to work in a powerful computer with an interactive system making it possible to deal with about fifty users simultaneously and in good conditions. Digitizing tables, alpha-numeric terminals and various plotters, including a high-precision vector photoplotter (resolution of 10 microns, global accuracy of 0.1 mm in A0 format) make up the peripheral environment of this computer.

Apart from the computer's MULTICS operating system, the software tools developed are based on the TEXTO file management system for storing, updating and exploiting the basic data.

2. The computer-assisted cartographic process

The first-generation computer tools are essentially applied to the phases mentioned above, where they reduce manual intervention. They are, however, not without effect on the other phases of the cartographic process. The attached diagram (Annex A) describes the general organization of the process. The phases in which computer science is involved are shown in the right-hand part of the diagram; action by the cartographer for computer-assisted operations is detailed below:

a) Development of a TEMPLATE file

Following definition of the proposed chart, which is always carried out manually, input of the items of information defining the coverage of the chart itself and any insets is carried out on an alpha-numeric terminal. These items are: definition of the type of projection (Mercator, UTM or Lambert) and of the ellipsoid, the scale, the geographic coverage (the chart and insets must be rectangular), the origin of the insets and the border graduations. This results in a file giving the TEMPLATE of the chart, which is subsequently used for automatic extraction of useful information from the digital files existing at SHOM. The drafting of the template, fulfilling international (INT) standards, including lines and lettering, is effected on a photo-plotter (final document) or on a conventional pen plotter (proof document).

b) Automatic extraction of information

Starting with the TEMPLATE file, and SHOM's digital data files, one piece of software guarantees automatic extraction and alignment with cartographic standards of the information concerning the chart being prepared, theme by theme. This extraction is accompanied by automatic pre-selection which is based on the relative importance of the various types of information, as a factor of the scale of representation. Many themes, each covered by a file of basic data, are available and extraction produces a file extracted according to the theme chosen by the operator.

c) Cartographic selection of information

In addition to automatic extraction of digital data with automatic pre-selection, a manual cartographic selection operation is necessary so that only pertinent information is selected, whilst still maintaining a sufficient density on the chart as a whole. The process for putting these tools to work is a repetitive cycle, including work on an alpha-numeric terminal to effect the actual selection itself in accordance with the criteria of the operator (or to modify a selection already begun) followed by a proof drafting on a pen plotter. The process is interrupted by the cartographer when he considers that the result achieved is satisfactory. The digital files resulting from this selection, called PREPARATION files, are then archived.

Cartographic selection is finally followed by plotting all the PREPARATION files and the TEMPLATE file on the same film, which will serve as the cartographer's support for making the mock-up of the chart.

d) Digitization or correction of digital information

The end of the second stage of the cartographic process, elaboration of the mock-up, is done entirely manually, by the cartographer. During this stage, the film resulting from the computer-assisted cartographic selection is enriched with information from non-digital archives and may be modified to enable this to take place.

With a view to as far as possible limiting manual execution operations, the mock-up is digitized. This digitization affects all modifications by the cartographer of the information contained in the PREPARATION files during the previous phase of the process, as well as a number of items of information obtained from archives documents, the 'fairing' of which by hand is a particularly long and tedious task (letter in particular). A drafting for monitoring purposes is carried out and the operation is begun again until correspondence is attained between the drafting and the digitized part of the mock-up chart. The files thus obtained, called CHART files, are archived and integrated into SHOM's central data base.

The CHART files are finally plotted on the photoplotter to produce several films which will be used later, along with the documents resulting from the manual work, to make the printing plates.

3. Performances of the first-generation tools

The performance of SHOM's first-generation cartographic tools has already proved very worthwhile and they have resulted in an appreciable gain in productivity and quality in chart-making. Their many possibilities enable them to be used for the majority of types of charts produced by SHOM.

a) Portability and modularity

SHOM's computer tools for cartography have been developed permanently, bearing in mind their adaptability to new equipment: main or peripheral computers. This resulted in a set of software written in FORTRAN 77, perfectly standardized and therefore easily portable, which functions on common structure files that it enriches or modifies, progressively, throughout the cartographic process. The essential specific part linked to the particular peripherals used at SHOM is restricted to 'drivers' which manage the exchanges between internal files and the peripherals concerned in the input stage (digitizing tables) or in the plotting process (plotters).

These characteristics render the first-generation cartographic tools very largely independent of the hardware configuration once used and thus guarantee the lasting value of the considerable investment made by SHOM in producing and implementing this software.

b) Elaboration of the TEMPLATE file

The software for elaborating the TEMPLATE file enables work to be done on three projection systems: Mercator, UTM or Lambert. The ellipsoid can be chosen from among a list of about thirty elements or otherwise may be defined by the cartographer.

The number of insets in the chart is not limited and an order of priority is defined to cope with any possible superimposing. For the chart and each inset, the spacing of the meridians and parallels is proposed to the cartographer automatically, taking into account the scale of representation (these values to the nearest decimal point can, however, be modified).

As soon as the TEMPLATE file has been constituted, a drafting for monitoring purposes or the final drafting of the template of the chart can be carried out. This drafting respects INT standards and includes the lattice scales and graduations with all the associated texts for the chart and the insets, at the same time dealing with superimposing. An example of a drafting at reduced scale of the template of Chart 7205 is shown in Annex B (the coastline appears on the draft as well as the template).

c) Extraction of information

Selection of information is made automatically on the basic data files from data contained in the TEMPLATE file for the chart and any insets. The files of basic data each cover a specific theme and extraction is only made from one file at a time. The themes available are:

— wrecks (coasts of France)
— landmarks (coasts of France)
— buoyage and beaconage (coasts of France)
— List of Lights (coasts of France)
— coastline of France (exploitable for scales below 1/25 000)
— world-wide coastline (exploitable for scales below 1/1 000 000)
— submarine cables (coasts of France)
— topographic contours (mainland France)
— index of surveys (French surveys)
— GEBCO soundings (area of France's responsibility)
— radio-positioning lattices (world-wide coverage)
— framework of France charts (world-wide coverage)
— earth magnetism (world-wide coverage)

In addition to these files of basic data, automatic extraction can use in the first place the CHART files already drawn up for a neighbouring chart and the cartographer can in this way easily make use of work that has already been carried out.

d) Digitization or correction of digital information

This phase of digitization and correction of digital information, along with — above all — the drafting part which accompanies it, is particularly remarkable because of the wealth of options offered to the cartographer by the software tools. This diversity enables this software to process (i.e. digitize and plot) a very large

proportion of the charts produced by SHOM at present. The principal possibilities can be detailed as follows:

— processing of the sounding in accordance with French or INT standards (normal sounding or wreck).

— processing of individual cartographic features automatically generating the plotting of the appropriate symbol from the library, which includes all French symbols to INT standards.

— digitizing and plotting of the text with all typographic possibilities and inter-letter or inter-word justification. The text may be arranged along horizontal, vertical or oblique straight lines or along an arc or — finally — along a smoothed contour where longitudinal or transversal shifting is possible.

— processing of the contour with identification of eighty different types. Plotting makes it possible to generate, in particular, particularly realistic coral or rocky coastlines with the help of pseudo-random functions. The digitized contours can also be used for filling in areas with a view to automatic creation of colour screening masks (including those on coral or rocky coastlines).

4. The limitations of the first-generation tools

Despite the performances described above, SHOM's first-generation cartographic tools have certain limitations which have led to the creation of a second generation of software. The principal limitations are:

a) Generation of TEMPLATE file

Systems of projection other than Mercator, UTM or Lambert are used for SHOM's charts (polar-stereographic or conformal oblique, for example) and these cases are not dealt with by the cartographic software tools but their use remains very exceptional and this limitation does not amount to a real drawback in exploitation.

b) Extraction of information

SHOM's files of basic data have two essential drawbacks. The first is that they do not cover the whole of the information necessary for the production of a chart, and consequently efforts must be pursued to define and create new files covering areas that are now dealt with manually (soundings, toponymy, ...).

The second drawback is linked to the weakness of the tool used to generate the files: the TEXTO software. This tool allows only, with the greatest difficulty, the establishing of links between various files, whereas the nature of the information stored imposes a certain number of corresponding items (a lighthouse, for example — a unique geographic feature — is today handled partly in the LIGHTS file and partly in the LANDMARKS file and the link between the two is very tricky to effect). The modern data management tools which have appeared on the market over the last few years should, however, enable great improvements to be made here.

c) Cartographic selection of information

The cartographic selection of information is a repetitive process in which the cartographer makes a graphic plot of the digitized information extracted, then, in the light of this plot, modifies through an alpha-numeric terminal, and therefore 'blind', the contents of the extracted files. The great drawback in this method is the lack of interactivity in the process, the cartographer receiving the feedback from his decisions only after the plotting. This can thus lead, in complex cases, to several repeats being required, but, above all, imposes a minimum delay of one week between the automatic extraction and the obtaining of the validated PREPA-RATION files.

d) Digitization or correction of digital information

Like cartographic selection, digitization or correction of digital information is organized into a repetitive digitizing/input operation followed by plotting. These operations too are carried out 'blind', but the diversity of information to be processed and the great number of options offered by the software tools render the operation in this case extremely difficult while the lack of interactivity leads to delayed detection (after plotting) of the many input errors. The number of repeats carried out may then become relatively great and the time taken to complete the process is affected as a result.

III. SECOND-GENERATION TOOLS FOR CARTOGRAPHY

1. Object and computer environnement

The object of the second-generation computer tools for cartography is, naturally, to fill the gaps in the first-generation tools, more particularly emphasizing the 'execution' aspect of the work or the lack of interactivity of the hardware and software used, which until now has had a penalizing effect. This second generation of tools does not seek to replace the first set but to complement them. Both generations of software and hardware are therefore in use concurrently at SHOM.

The decision to develop these new tools was taken over three years ago and the hardware environment used is based on the technologies of that time, i.e. high-resolution colour graphic workstations. To provide for the future evolution of SHOM's overall computer science system, possible new network functions have been envisaged and the concern to be based as far as possible on the standards of the moment has led to the choice of machines functioning under the UNIX operating system. A large-format (A0) scanner linked to a laser-head plotter has also been supplied and integrated into the system of computer-assisted cartography.

2. Making the tools

a) Interactive cartographic workstations

The workstations equipped with ROYALE marine cartography interactive software are referred to at SHOM as 'postes cartographiques interactifs (PCI)', or

interactive cartographic workstations. The workstations serving as hardware support at SHOM are LOGO 6000 systems from the CELI. The ROYALE software was developed by the INNOVAL company, taking as a starting point the first-generation cartographic tools developed by SHOM. Many of the algorithms used by ROYALE previously existed in SHOM's software tools and so the various possibilities already referred to for digitizing or correction of digital information are to be found here too. The essential addition is the introduction of interactivity by very optimal management of the peripherals and the putting into effect of a graphic data base instead of the file-management system which was too cumbersome for applications with short answer-back time. Some supplementary possible functions have also been introduced into ROYALE, notably for contour manipulation.

b) Integration of the scanner and the laser head plotter

Since late 1985, SHOM has had at its disposal a system for processing graphic documents of large format: a SIEMENS CTX 330S. This system consists of a plotter (1000 dots per inch) and a set of computer equipment for storage and processing of digitized documents. Exchanges are possible with other computers using magnetic tapes. The value of this equipment for computer-assisted cartography operations is evident, as, on the one hand, it allows rapid and reliable digitization of complex documents and, on the other, it provides an organ for plotting on film of documents carrying surficial features (tint screening masks). Software has therefore been developed in SHOM's main computer for vectorisation of the documents digitized on the scanner (which then allows them to be processed by the cartographic tools and in particular the interactive cartographic workstations, which work only with vector-coded data) and to generate automatically tint screening masks (flat colour, constant-density screening or real half-tone screening for shading) based on contours contained in the CHART files.

3. Influence on the cartographic process

a) Aspects affected

The interactive cartographic workstations have been associated, in use, with digitizing tables to eliminate the digitizing/monitor plotting cycles in the process of computer-assisted cartography. As for the scanner, it is used to digitize complex documents consisting only of contours. The scribing done by hand can thus be digitized, then the files obtained displayed and, where necessary, worked over on the interactive cartographic workstations. Lastly, the laser-head plotter enables tint screening masks to be created automatically — though this option is little used to day because the manual procedure is not very constraining and is as quick as the automated procedure except as regards shading (blurring) (not required by INT standards).

On the diagram attached as Annex A, the area where intervention by second-generation cartographic tools is possible is surrounded by a dotted line. It covers cartographic selection of the information held in the files extracted and execution of the work. Interactivity, which had been lacking for digitizing tasks, has thus been introduced, notably in the execution stage where its absence was

more of a problem.

b) *Contribution made by second-generation tools*

In general, digitization being henceforth carried out at a workstation with a computer dedicated only to that task, the computer's time for responses to the operator's needs has been reduced by an appreciable amount. This is obvious in the overall digitizing time but, above all, it notably increases comfort in use of the tools. Using the scanner to digitize complex documents has also made it possible to relieve operators of this tedious task while at the same time improving the quality.

Using the interactive cartographic workstations for the phase of cartographic selection of information in the preparation stage is not envisaged in the immediate future, as the contribution by these new tools is greater in proportion with the complexity of the graphic result of action taken, which is not the case today as regards manipulated digital data. This viewpoint must certainly be reconsidered as soon as data base structures appear which support more complex information than that managed thus far.

For execution tasks, the second-generation tools allow the cartographer to view immediately the result of his action on the PREPARATION files through representation of the future chart on the screen of the interactive cartographic workstation. The possibility of also displaying, after analysis by the scanner, the result of the manual part of the execution process, again on the PCI screen, makes it possible to avoid interference among the various films and documents resulting from the execution process, the detection of which used only to be possible at a very late stage (during photographic operations). All these facilities for interactive monitoring finally lead to a great reduction in the number of repeat operations required and therefore to a very appreciable shortening of the time taken to produce a chart.

To illustrate the possibilities of second-generation cartographic tools, an extract from the plotting of all the CARTE files corresponding to Chart 7150 is shown at Annex C. These files have been obtained either by extraction from files of basic data, or by manual digitization, or else with the help of the scanner from documents resulting from the manual execution process.

4. Evolution of the tools

a) *Setting up a local network*

So long as the computer-assisted cartographic process took place only on the main computer (i.e. with the first generation of software tools) the problem of computer-to-computer transfers of data did not arise. Today, with the bringing into operation of the interactive cartographic workstations (PCIs), frequent exchanges between the main computer and the computers built into the PCIs are necessary. The system of data transfer used at present is based on RS 232 C liaison at 9 600 bauds; the resulting transfer time for all the files corres-ponding to a particular chart is, on average, from one to two hours, which is difficult to put up with. Moreover, the slow exchange rate precludes interactive access to the

main computer from the PCI and the operator is thus constrained to work only with extracted files. Installation at the beginning of 1990 of a local network: IEEE 802.3 should enable these transfer times to be reduced to an acceptable length and make possible interactive access to any data in the basic files from the PCIs.

b) Replacement of the data management system

The TEXTO software now used at SHOM allows for definition and management of data that are simple in structure and only allows with great difficulty (using specific-application software) links between items from different files. To remedy this problem, SHOM has acquired, early in 1990, the ORACLE relational data base management system (RDBMS). This product, in addition to greatly improved performances compared with TEXTO, makes it possible to create complex data structures (tree-like structures representing composite geographic objects) and links between various structures. Moreover, many tools facilitate monitoring for coherence of data and enable rapid creation of very user-friendly applications for maintenance or consultation of data bases. Lastly, ORACLE copes with the distribution of data among various linked machines in each network and allows each machine linked to the network to display all the data (subject to authorized access).

c) Adaptation of the software tools to the relational data base management system RDBMS

All of SHOM's software tools are based on files of a common structure defined and maintained with the help of TEXTO. These files are accessed directly via FORTRAN 77 software. Changing from TEXTO to ORACLE imposes a need to review the software relating to the data in order to adapt it to the new structures which are to be defined. Reading or updating data will no longer be done directly using FORTRAN, but using the standard request language SQL. This revision of software is not a minor affair, as it is not a case of simply changing the methods of accessing the data; the structures also will be modified in depth (appearance of tree-like structures) which will entail appreciable modification of the algorithms in use today in the tools for computer-assisted cartography.

d) Adapting the PCIs to the new environment

The ROYALE software used in the PCIs is already adapted to transmission of data by local network IEEE 802.3 through the UNIX system of operation of the workstations, which naturally support this type of network. The modifications to be applied to ROYALE to adapt it to SHOM's new computer environment must therefore be limited to integration of an SQL request generator coupled to the graphic system and to the internal data base. It will then be possible for the operator to indicate a geographic object (or group of objects) on the screen and to obtain via the local network all the information concerning that object contained in the central data base.

IV. CONCLUSION

1. Evolutivity of cartographic tools

As we have just seen, the cartographic tools developed by SHOM have been regularly adapted to the new possibilities offered by the hardware and software appearing on the market. It has been possible to obtain this result thanks to the care taken in development of these tools to guarantee good portability and to situate precisely and reduce as far as possible the parts linked to the structure of the hardware or software packages used by SHOM. For the future, therefore, this makes it possible to have available at all times tools that are perfectly adapted to the successive computer environments at SHOM, and this with a minimum of effort for adapting the specific software used; efforts could then be concentrated on the integration of possible new functions rendered accessible by the improving performance of the systems.

2. Defining another sphere of application

SHOM's cartographic tools are, of course, adapted to the problems of marine cartography. In closer analysis of their possible functions, however, it is noted that they enable automatic or assisted multi-criteria selection of territorial data to be made and elaboration of the graphic representation of such information on a synthesis document. A new definition of the data structures and the symbology therefore renders it possible to adapt SHOM's tools to processing another type of territorial data, and such adaptation is easily conceivable. Carrying it out, however, can prove to be a rather lengthy task, as it involves redefinition of the library of symbols and characters and adaptation of all the software to the new data structures. (This task should, however, be greatly facilitated when access can be made through the SQL to the RDBMS).

### b) Installation in other environments

The evolution of the tools which guarantee easy transfer to SHOM's successive generations of computer equipment also permits, of course, installation of the software in any other environment. Certain peripherals are, however, essential for implementing cartographic tools such as alpha-numeric terminals, digitizing tables and plotters (including the photoplotter) to enable processing of the maximum format of the documents to be elaborated; an RDBMS using SQL language is also necessary (preferably ORACLE). The other equipment (local network, workstations) is highly desirable in order to be able to achieve maximum performance by the tools developed.
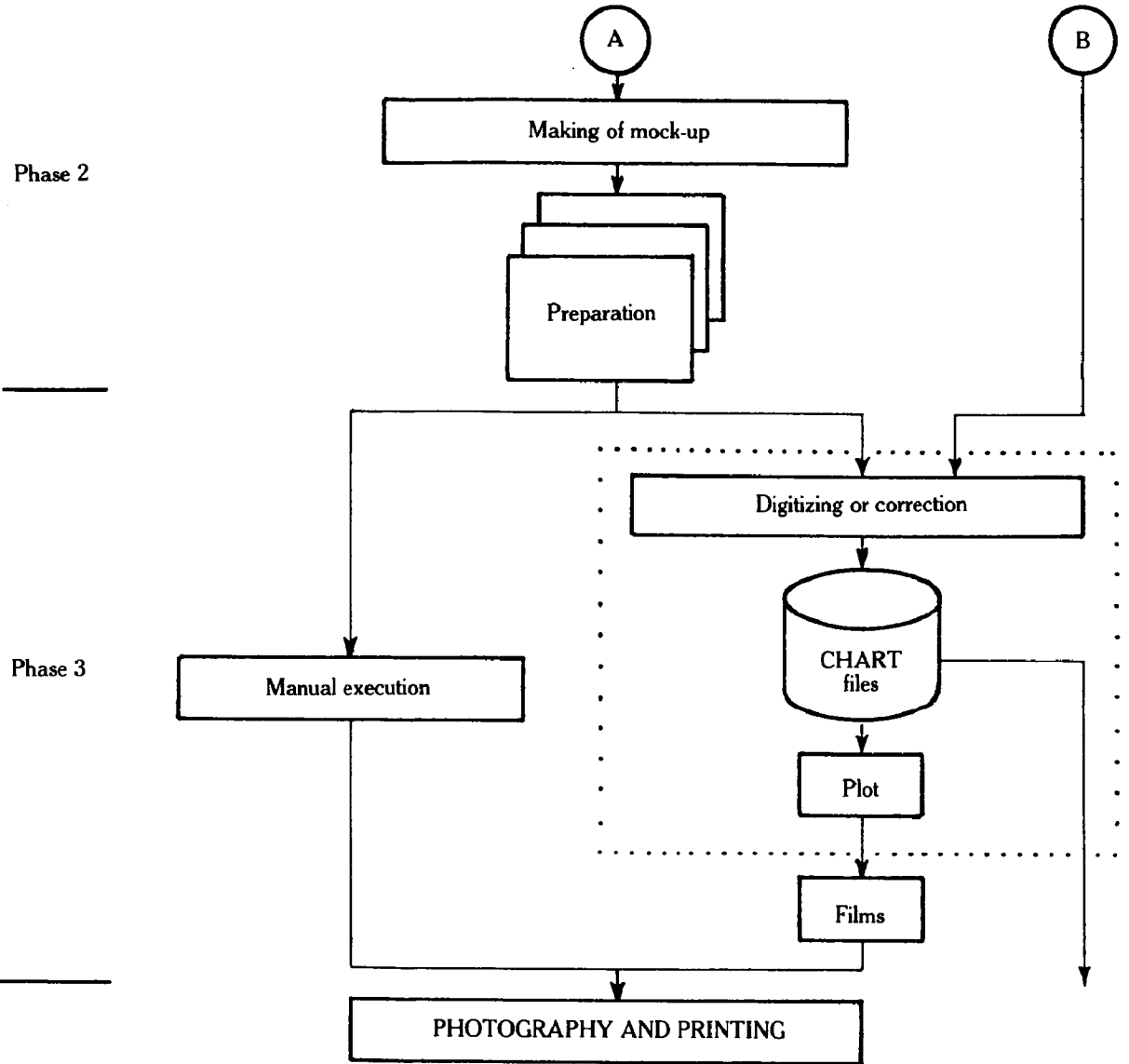
Bibliography

SOUQIÈRE P. and J. FICHANT: Computer-assisted cartography: a provisional but promising solution. *International Hydrographic Review, Vol. LXVI(2), July 1989.*

Annex A

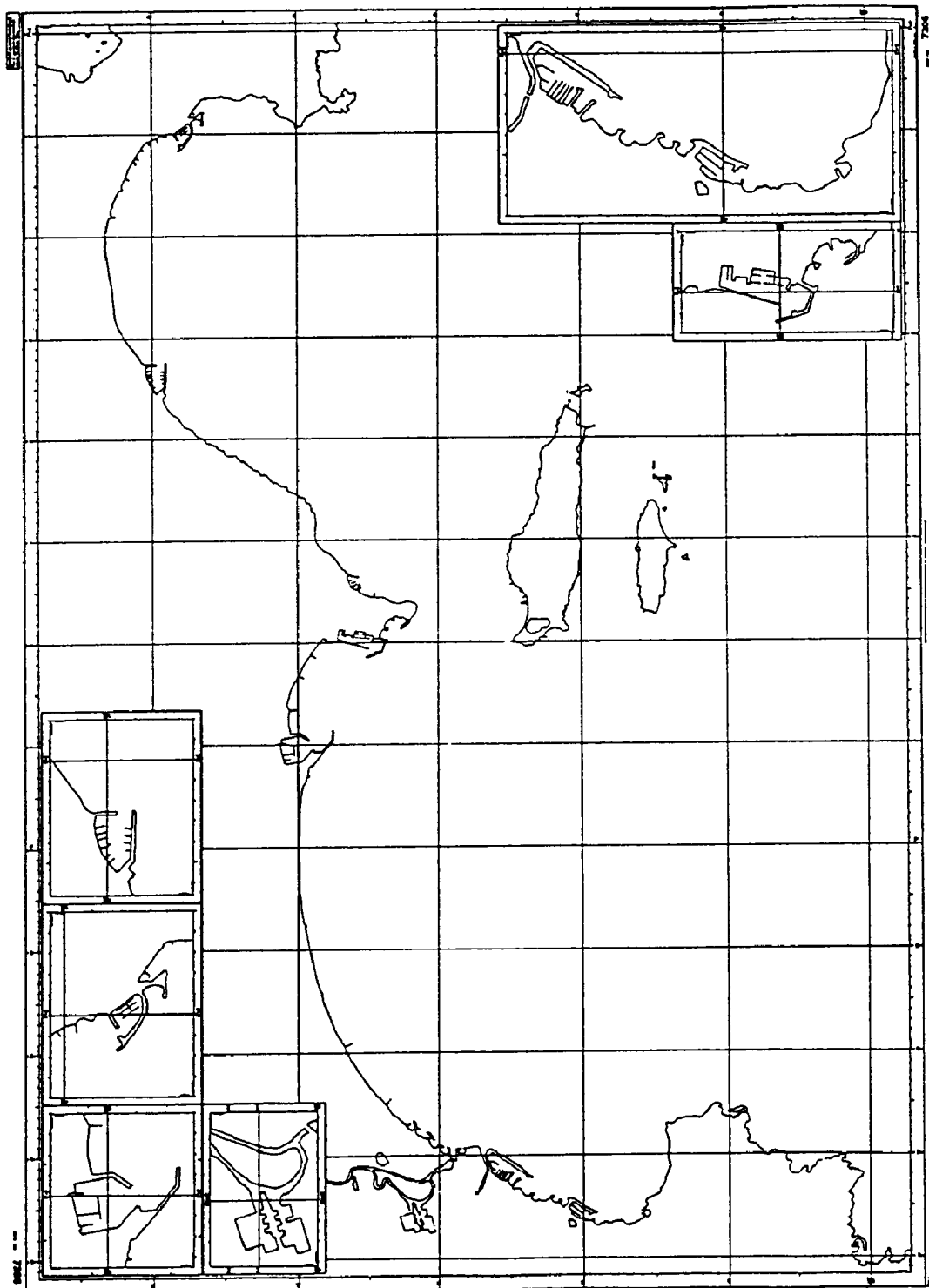**Process of computer-assisted cartography**

Phase 1

Phase 2
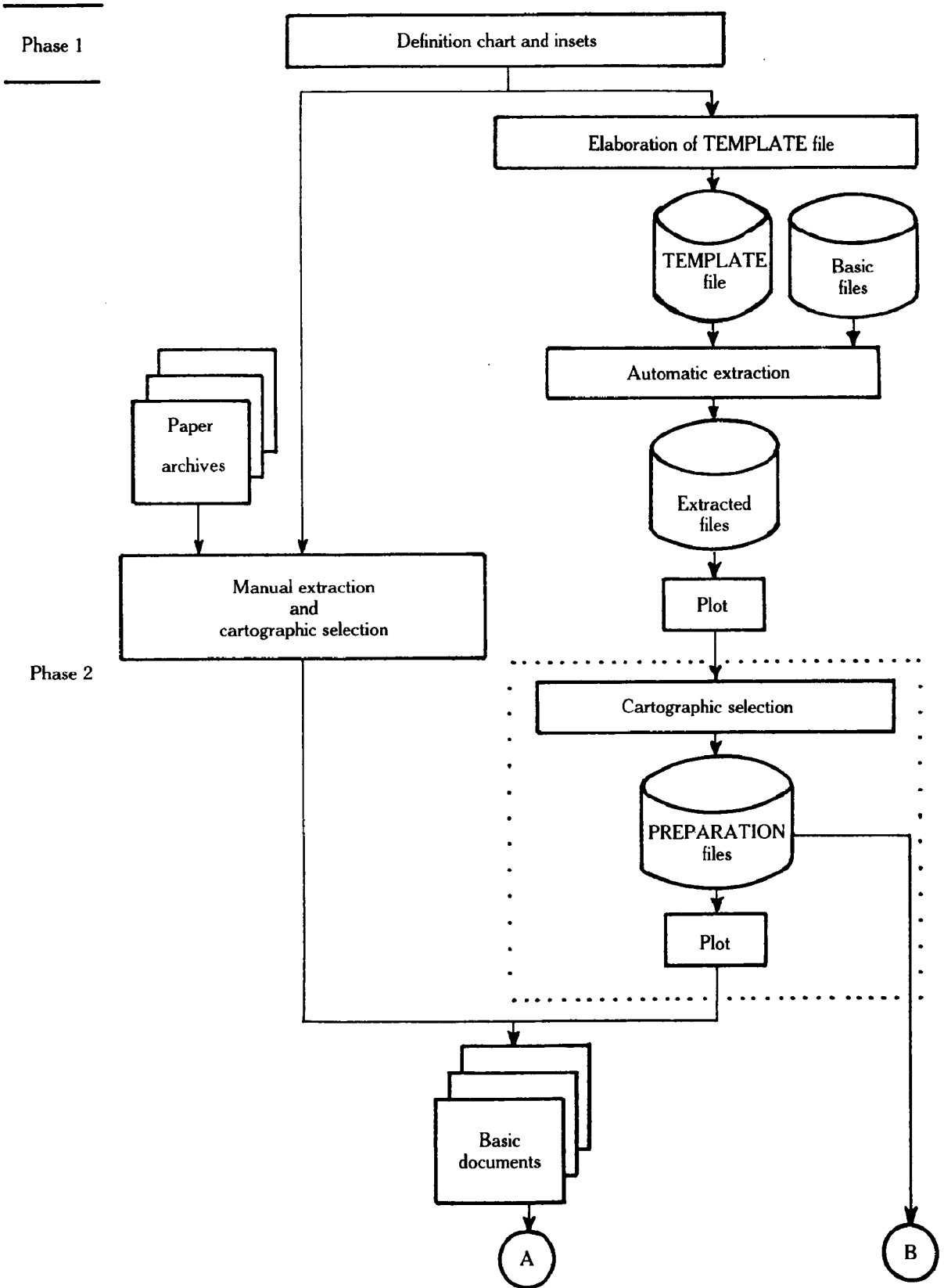
The above diagram represents the normal chain of tasks in the chart-making process. Monitoring takes place, however, at each stage and can lead to the process being re-started from a step further back in case of any anomaly. To avoid burdening the diagram, arrows showing such repeat actions have not been drawn.

The parts inside the dotted lines are operations in which second-generation computer tools in use with interactive cartographic workstations can intervene.

Annex B

TEMPLATE and coastline of chart 7205

Annex C

Extract from   chart 7150