DIGITAL MAPPING
AT THE ISTITUTO GEOGRAFICO MILITARE ITALIANO

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... difficile inlustrare ... esse,
multa novis verbis praesertim cum sit agendum
propter egestatem linguae et rerum novitatem.
(Lucretius, De Rerum Natura I, 137-139)

ABSTRACT

During the last five years the maximum effort was made at IGMI in order to design a national geographic information system. The principal characteristics of such a system, named SIG (SISTEMA INFORMATIVO GEOGRAFICO), may be summarized in terms of resolution and kind of information source: the resolution is the same of the 1:25000 national map, while the photogrammetric source was mainly analyzed and the direct digitization of the stereomodel was selected as acquisition method.
The report, after a description of the whole design of the a.m. SIG, carries out a detailed analysis of problems faced and solutions detected.
Finally it exhibits the first national map in digital form and the graphic and non-graphic performances of such product, that achieves the goal of a radical renovation in map making without revolution in map using.
Furthermore some comparisons are performed between the digital techniques and the conventional methods in terms of time consuming and cost-benefits ratio.

INTRODUCTION

During the last five years the maximum effort was made at IGMI in order to design a national geographic information system as well as to test the suitability of digital techniques in mapping process. Computer technology shows a completely new and different way for the cartographic discipline; in the same way of other deep technological changes we can observe these days, its introduction in a national organization with specific production goals meets many problems, strictly related with local situation. In our case, the first stage of such a téchnological change,well defined as the "stage of reluctance", lasted long, since the "wait and see attitude" is typical of public organizations. After that first stage we moved in a second phase: the use of computer-assisted methods to replicate existing products simulating previous methodologies, and here we are now. In our opinion, this is the most important phase in the development process: starting from an original situation where we could find old technology and old products, we intend to reach a future state with only new technology and new products, passing through an intermediate stage with new technology and "similar-to-old" products together with the new ones. For a production organization, a great problem is the operator conversion in a non traumatic way. We are convinced that the most suitable solution is the temporary simulation of "old" procedures: by this way people employed don't suffer any psycological trauma and gradually they become used to new procedures, new tools and new products, that, however, come afloat; this fact results in a useful reduction of the problems in the necessary reorganization of the complex cartographic process.

THE DESIGN OF THE NATIONAL GEOGRAPHIC INFORMATION SYSTEM

The main goal of the Geographic Information System (SIG) is to assure an efficient support to general land management.

The designed SIG consists of two different subsystems:

- the geodetic one (SIGEO), for geodetic and geophysical data management;
- the cartographic one (SICART), for topographic and cartographic data management.

The a.m. subsystems will be closely correlated in order to avoid redundancy and to assure completeness of information. The geodetic information system consists of a data base containing information relevant to about 20000 trigonometric points and 13000 benchmarks.

The structure of the data is reticular and the system is implemented on a DEC VAX 11/730 computer.

The cartographic information system, which has a hierarchical structure, is mainly based on data acquisition process from the follwing two sources:

- existing 1:25000 scale maps,
- aerial photos with field completion.

The former source is actually used, where separates exist, to digitize altimetric information (i.e. contours and spot heights) in order to build up a digital terrain model covering the national territory and to support ortophoto production. The digitization is performed for about four years by automatic scanning of the relevant overlays, subsequent vectorization and interactive height value attribution.

DIGITAL MAPPING SYSTEM: THE CONFIGURATION

A general photogrammetric data input system should include the following units:

- analog or analytical stereoplotters,
- interactive graphic workstations,
- central processing unit,
- software for data input, reduction, integration, interactive editing and cartographic data recording,
- mass memory unit for digitized data,
- plotter.

The system tested at the IGMI is constituted by:

- analog instrument GALILEO STEREOSIMPLEX G7,
- stereoplotter workstation INTERGRAPH DSP030 ("photogrammetric" workstation),
- interactive double screen colour graphic workstation INTERGRAPH DSP 042 ("cartographic" workstation),
- digitizing table INTERGRAPH TIS021,
- central processing unit INTERGRAPH DPS 052 (based on DEC VAX 11/730 computer), core memory 3 MB, system disk 84 MB, tape unit 1600 bpi, console,
- hard disk 300 MB,
- plotter KONGSBERG GT5000 off-line, with photohead.

DATA CAPTURE AND INTERACTIVE PROCESSING

The working procedure may be regarded as the combination of three separate phases, the first of them being the stereodigitization. The gathered elements are assigned to different levels and encoded according to the selected graphical representation (colour, line thickness, style) and the selected method for data input (point by point, automatic filtering of significant points, areas).
The levels used to separate different classes of features may be regarded as sophisticated versions of the overlays (hydrography, relief, culture,etc.)utilized in traditional procedures for colour separation.
The levels are used in three different ways: for data in-

put only, for data processing only, or, in some cases,for both of them.
The levels of the first type, used only for data acquisition, contain features as digitized at the stereoplotter and differentiated by graphical user-selected characteristics; interactive processing is required only to correct blunders.
The levels of the second type, used for data processing, are copies of the corresponding input levels; therefore interactive and automatic processing may be carried out on these copies. Such a duplication is justified by the need neither to lose nor to alter the acquired data, geometrically correct. Unfortunately this may occur under the conventional stereocompilation at 1:25000 scale. Here is an evident advantage of digital techniques: topographic position is collected without considering any subsequent map representation; mapping purposes influence only the content, i.e., in other words, the decision to acquire or not a feature.
The levels of the third type, containing both input and processed data, are used when it is not considered worthwhile storing the "rough" digital data, or when the cartographer intends to carry out some particular operations like directly patterning of linear features in order to symbolize the acquired data.
Once the model has been digitized, no further operation is performed at the stereoplotting workstation; all subsequent operations are carried out using another device, the "cartographic" workstation, more adapted to map editing and finishing. Between these two stages, field work should be organized in order to check and complete the map.
An important change in work organization is the choice of the stereomodel as unit of work, instead of the map sheet. In such a way we avoid to insert additional fictitious breaks in feature continuity and we decrease edge matching problems. Furthermore the generation of one file per model results in a practicable size of the file itself; in our case we experienced that a file of about 2 MB is needed to store a digitized stereomodel with approximate photo scale 1:33000, i.e. covering about 35 km^2.
One of the problems to be solved was to decide whether a feature present on the stereomodel, i.e. a 3-D model, is to be acquired with its three dimensions, or, according

to conventional procedures, its planimetric projection only is to be digitized. Such a separation between altime-tric and planimetric data seems really fictitious, since our aim is to convert the data from analog to digital form without losing information: when we convert a 3-D analog model into a 2-D digital model, this will however result in a loss of information. Thus, from a theoretical point of view, each feature should be digitized in 3-D, but some practical reasons convinced us to choice the way of sepa-ration between altimetric and planimetric data: at least with the hardware and the basic software we have tested, many difficulties arise during the interactive phases (e.g. error correction, data integration, feature displa-cement, etc.) at the "cartographic" workstation, if we ha-ve to process a 3-D file. Moreover, since different featu-res are acquired in different ways by the operator, a higher altimetric accuracy is achieved, for example, in a building digitized by its corners (static digitizing) than in the axis of a road digitized in a "stream mode" (dynamic digitizing); under this consideration it could be not really correct to merge unequally accurate data, without paying attention to this fact. Last but not least, considering separately altimetric data relates to the wi-de range of applications of digital terrain models, inde-pendently from other topographic information.

Once decided to acquire planimetric and altimetric data separately, we had to decide how to collect the altimetric ones; in the conventional procedure we acquire contours with 25 metres interval and additional spot heights with a medium density of about 4 points per Km^2.

From a general point of view, altimetric data may be col-lected as profiles, contour lines, random points and grids; profiles and contours are captured dynamically, consequen-tly there is a loss of accuracy compared to static point measurement.

"Progressive" and "composite" sampling became recently operational, but, of course, an analytical plotter is ne-eded, wich provides the capability of a closed loop sy-stem. Thus the choice of the method depends also on the available equipments. The development trends of hardware and software show that in a short time composite sampling with image correlator device is becoming one of the most suitable way for DTMs collection.

At present, from an operational point of view, the aim to completely describe topographic terrain and to represent graphically the altimetry at 1:25000 scale may be better achieved by digitized contours and random points. A regular DTM may be built up in a batch phase, since many interpolation programs are available. Therefore our choice was to collect contours directly at the analog stereoinstrument, except for in flat or near-flat terrain, where data capture by grids seems a more suitable way. It is to be stressed that such a choice relates to the present availability of operational analog equipments as well as to national altimetric characteristics.

BATCH PROCESSING

In order to minimize the interactive procedure, to improve the performances of the system and to test the feasibility of extracting useful non graphic information from the acquired data, a software package has been written. Such a software may be divided in two fundamental classes: the former applies to the interactive work minimization and is constituted by the so-called "user-commands", i.e. short programs for automating repetitious sequences of interactive operations.

The latter classe of programs shows more general characteristics and constitutes a set of batch procedure.The most significant are the following :

Program EST: program for extracting graphic elements according to user-defined criteria from one or more files generated during the digitizing phase. In order to fulfil different requirements the criteria may be logical (i.e. related to the level where a feature lies), geometric (i.e. related to the range in which the search is to be carried out), graphic (i.e. related to the colour, line-thickness, style, etc.) or conventional (i.e. related to mnemonic codes which refer to the standard graphic classification adopted by IGMI). It is possible to define many criteria simultaneously and, in such a way, one can obtain a customized graphic file, fitted to his own requirements.

Program STAT: program for analyzing a graphic file generated during the digitizing phase; it performs statistical evaluations. The output data are referred to the same mnemonic codes defined as search-criteria in the program EST and related to IGMI standards. These codes identify the different classes of features as they are differentiated during the acquisition phase, and the program computes the occurences of each symbol present in the file as well as the length of linear features and the area of closed polygons. This program, together with the program EST, allows to carry out selective statistical performances in order to check the rate of production for each workstation as well as to plan the final plotting procedure. Therefore it is possible to extract non-graphic information useful for a wide range of thematic applications and to interrogate the graphic data base. Statistical analysis of features occurrences constitutes an objective approach to the problem of feature selection for generalization purposes; it allows a balanced omission of different features in order not to alter the main characteristics of the mapped area.

Program CASE 25: program for the generalization of the outlines of buildings. It analyzes the following parameters of each digitized building:

a) number of sides: if it is less than four, the situation is pointed out (it's the case of a triangular house, but it could be the case of a quadrilateral one where a side was wrongly omitted during digitization),
b) lenght of the longest side: if this value is less than a predefined threshold, the program computes the area; if it's greater than a predefined value, the building is not be altered, otherwise it is turned into a rectangular shape with its longest side oriented like the longest one of the digitized building; its area will be proportionally increased in order to fulfil the requirements of graphical representation.
   Furthermore buildings with a side shorter than 10 metres are pointed out using different colours, in order to submit the problem of their graphic representation to the cartographer.

Program SFOLT: program for processing hydrographic data previously digitized for 1:25000 scale map; it extracts and selects the elements of the hydrographic network to be represented on the 1:50000 scale map. The final output consists of a displayable file where final branches of the network no longer than a given threshold are omitted.

The other final branches are displayed in a different user-defined colour and assigned to a different user-defined level in order to submit a proposal for selection to the cartographer.

GRAPHIC PRODUCTS

Using the hardware, software and procedure above described, a complete 1:25000 map sheet has been compiled and printed in five colours. Fig. 2 shows a small segment of the map*, whereas fig. 1 shows the conventional product as it is produced at the analog stereoinstrument. Before making some comparisons it will be useful to analyze briefly the final steps of the procedure: after the finishing phase at the cartographic workstation, separates are produced by the photoplotter; they are the automatic translation into a graphic form of the data collected and processed.

EVALUATION AND CONCLUSION

Looking at figures 1 and 2 the first impression we have is concerned with the higher graphic quality achieved with digital techniques: even if any other advantage wasn't found, we realize that stereodigitizing generates better graphic products than stereoplotting, since the former method gives us a finished drawing, whereas the latter produces only a draft.

Anyway, apart from the obvious aspect of eliminating all manual drawing, the most important fact is that digital techniques, incorporating a suitable encoding system, make it possible to achieve a large flexibility in feature distribution during the data input process and in feature aggregation when one wants to transform data from the latent representation (magnetic support) to the graphical one.

The software allows to vary the number of overlays on which the topographic features are to be distributed or aggregated. In theory it is possible to produce a separate for each encoded feature, or alternatively, a single sheet may contain all features. Thus, the fundamental reason behind the physical separation of the information on different overlays is altered. In the past, the separation was carried out for production requirements - one overlay per colour -; by employing digital techniques, the need of differentiating among the various elements is no longer tied to the requirements of the map producer, instead it can be better fitted to those of the user. The advantages of such a procedure will be felt by the majority of users, who consider the 1:25000 map as a base on which they superimpose specific topics. The user may order a customized map containing only the information he's directly interested to, without other details.

* Due to colour reproduction difficulties the figure shows a monochromatic copy of the different overlays at the original scale 1:25000.

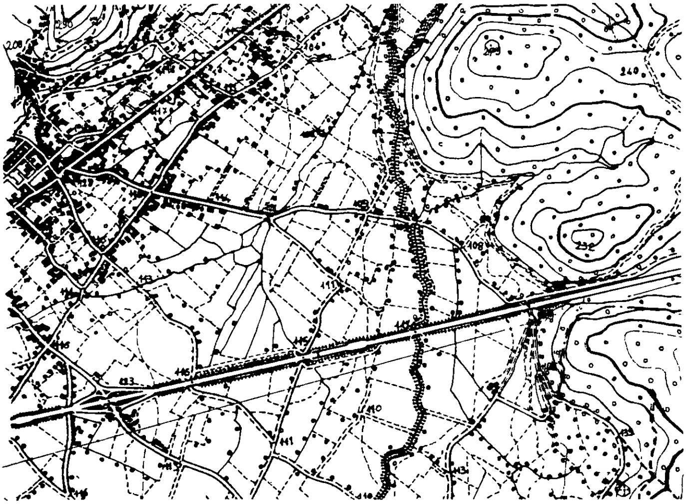

Fig. 1

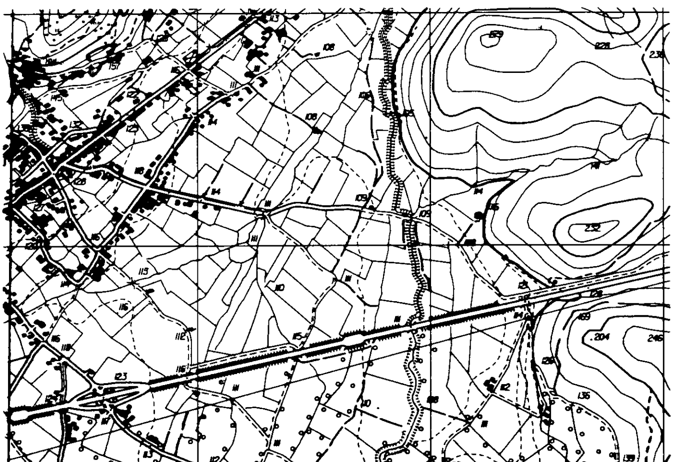

Fig. 2

In terms of time-consuming we experienced that no more time is needed with digital techniques than the time required by the conventional ones; a significant difference exists between the performances of the two methods: conventional techniques give us a single-end product whereas the new techniques give different subproducts among which there is a graphic one of higher quality than similar manual drawing.
Moreover digital techniques allow the construction of a topographic data base, and therefore the production of digital and graphic outputs more sophisticated with respect to traditional methods.
From the accuracy point of view it is to be stressed that digital techniques satisfy the standards at least as well, if not better, than traditional methods; furthermore with traditional methods for 1:25000 map compilation,only the cartographic position of the features is saved, while digital techniques allow us to save also the topographic position, i.e. the correct one. Such a peculiarity will result in a strong advantage during the future updating phases, when each feature can play the role of control point in the new stereopairs.
Finally, let us consider that an integral self-controlled information system, based on satellites automatically transmitting information interpreted in real time is undoubtedly our dream. However we must also remember that the first automaton that the man invented was a trap and the last one could be an ill-designed trap. The growing diffusion of digital products offers a more consistent basis for decision in every human activity. On the other hand this role of decision-support in engineering as well as in politics results in a dramatic decrease of individual freedom. For this reason the development of digital techniques must be carried out together with the development of ethical values in order to guarantee that information is used in the correct way.

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