THE APPLICATION OF INTEGRATED RASTER-VECTOR TECHNIQUES TO CARTOGRAPHIC AND PHOTOGRAMMETRIC DATA IN MAP REVISION PROCESS ORIENTED TO GIS IMPLEMENTATION

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Abstract

During last decade the efforts carried out at the IGMI in the field of GIS implementation were mainly oriented to the development of digital techniques for:
-photogrammetric data collection,their digital conversion and storage in vector form;
-cartographic data collection in raster form and raster to vector conversion.
The former aim being limited to the new surveying areas and the latter one to mapped areas, the problem of computer-assisted map revision is now under consideration. A suitable solution needs the contemporary use of photographic and cartographic data, that is photogrammetric survey and existing maps, after their conversion in digital form.
For this reason IGMI has designed a pilot study about raster and vector data integrated manipulation in order to evaluate the suitability of digital techniques in the revision process oriented to contemporary storage of geographic information in a data-base.
The report gives information about the experimental results of the study and its application to the national 1:25000 map series.

1. INTRODUCTION

Two great problems are to be faced nowadays by national mapping agencies in the developped countries. They are:(a) the revision of existing maps and (b) the transition from traditional cartography to data-base technology with the implementation of a Geographic Information System.
Solving the second problem by a digital remapping of the whole country starting from air photos is certainly a fascinating goal, but it needs an enormous amount of financial and technical resources.
In order not to neglect the existing graphic products it is therefore necessary to face at the same time the two problems with a realistic strategy. That is to say the revision process, whenever possible, should be organized in order to perform a step-by-step conversion of data from graphic to digital form.
The demand for revision is enormous, but photogrammetric methods have developped around new mapping rather than revision. In the next few years map revision by photogrammetry will be probably characterized by a wider application of existing technology rather than by fundamental changes in the technology itself.
It is hardly worthwhile to stress how much important and urgent the problem of map revision is; in general one can observe that the revision process plays a dominating role in the national agencies of the more developped countries.

It is certainly due to different reasons: let's remind that many countries have a complete coverage of their territory, that european maps, for instance, became and become more rapidly obsolete during these years of spectacular progress without wars and finally that just the cultural evolution makes us more intolerant to every thing looking obsolete, even if still useful.
Many changes certainly occurred in comparison with the time when, in the eighteenth century, the main maintenance problem showed by one of the first national base maps,the famous map of Cassinis at 1:86400 scale, was the restoration of the copper plates become old before the content,after many decades of use.
Nowadays a further reason is to be considered and added among those that make obsolete a map, though it may seem a paradox: the map itself, used to plan and modify the development of a country, causes its useful obsolescence.
Furthermore it is more difficult to define fixed rules for map revision than for map making, because many different factors have to be taken in account, both technical and economic.
The accuracy and the quality of the map to be updated and the preservation status of the originals are the most important technical factors, whereas the amount of changes is to be evaluated in order to choose the cheapest way between revising and remapping.
The lesson coming from a wide experience in conventional revision is the following: map series carried out during a long period of time with different methodologies and different materials cannot be treated with a predefined procedure without preliminary specific tests, at least from a geometric point of view.
Once we will have completed and filled our GIS, no more difference will remain between map revision and map making: then the old, still correct, data will be saved and the new ones will be added.

2. ITALIAN BASE MAP: ACTUAL SITUATION AND FUTURE GOALS

The italian topographic base map is constituted by the 1:25000 series, completed since many years and consisting of 3545 sheets. The projection used is the Gauss conformal one, with 6 degrees zone and a scale factor of 0.9996. The maps are delimited by images of meridian and parallel arcs referred to the national geodetic datum (Hayford spheroid oriented in Rome, 1940) whereas the European Datum 1950 grid is overprinted.They are mainly compiled with photogrammetric methods and printed in one of the following editions, depending on the age and the zone:

- one colour (black);
- three colours (black, bistre and blue);
- five colours (black, bistre, blue, green and red).

Each map covers, on the average, almost 100 sqkms.
The greater problem to be faced is, of course, the inadequate status of revision. The average age of the series is almost of 30 years and just during these last 30 years Italy saw great changes in its landscape, derived from the socio-economic transformations occurred after the end of the second world war. Dramatic changes occurred in the relationships among population, territory, production system and communication system. More than fifteen millions of people changed residence:

from country to towns, from interior to the coast, from south to the centre and north and abroad, from small towns to metropolises. Such a rapid polarization gave a great contribution in accelerating the modifications of the territory. The base maps became obsolete in a few time and in many cases remapping is more convenient than updating.
Additional technical reasons suggest carrying out a new complete survey of one third of the country, at least; for the part not mapped with photogrammetric methods it is difficult and sometimes impossible to update existing maps. We experienced that unsurmountable obstacles arise when we use photogrammetric techniques to update old maps based on field surveying with plane table.
From this preliminary analysis we may assume that the success of a revision process basically proceeds from two factors:
- compatibility between the original surveying techniques and the new methods;
- amount of changes to carry out.
Because the latter factor is closely related to the age of the existing maps, we probably will decide an extension of new survey covering also areas mapped with photogrammetric techniques.
Untill recently, at IGMI mapmaking was largely a manual process. A lot of survey data were usually collected and compiled by hand. Converting this information into finished maps was considered as much an art as a science, requiring highly skilled technicians.
A full digital treatment would require digitizing all colour separates of the existing maps. Till a few years ago, with the available means, such digitizing was very time consuming, errorbound and considered uneconomical.
Revising digital maps is relatively easy, though data collection process remains traditional. It is particularly in the plotting that digital approach become interesting.
The interim procedure choosen and tested in detail consists in scanning the existing maps and keeping them in an unintelligent raster format. Since such raster data can easily be vectorised in a coarse way,we may transfer them into a vector-based system just as a skeletonized background,from wich one derives the geometry of cartographic features and detect the changes. In such a way one can update the map digitizing from stereopairs vector data relevant to new features.
The operations we have to perform in order to correctly update a topographic map are: (a) to detect and acquire new features; (b) to delete no more existing features; (c) to modify old features on the base of the gathered new ones.
In the designed procedure the first phase, that is stereodigitization, is carried out on a vector-based system and provides vector data, whereas the remaining phases are performed on a raster-based system.

3. OLD DATA ACQUISITION FROM CARTOGRAPHIC SOURCE

The system used to automatically digitize existing maps is constituted by a Scitex ELP Scanner connected with an interactive editing workstation,each device being based on a HP1000 processor.
The choosen test area is covered by a map at 1:25000 scale available in four fundamental colours relevant to (1) relief,

(2) hydrography, (3) vegetation, (4) culture and lettering.
The first phase of the procedure is therefore the scanning of the four overlays. As it is well known, the result of a scanning operation is a raster product without any organization of the acquired features, in the sense of their meaning.
Essentially, the only built-in data structure in raster images is the location of the pixels. Concepts as lines, polygons and areas are not explicitly defined. However, by help of the concept of connectedness some structures can be defined indirectly.
A major problem with raster representation is the large amount of data occupied by the image. A 0.5 by 0.5 m map with a pixel size of 50 microns (wich is hardly enough for cartographic purposes) will occupy 100 Mbytes.
Many methods have been developped for data compression. A very common one is the run-length-coding, implemented on our system, wich takes in account the fact that large areas of the map are usually uniform. By run-length-coding, each line in the image may be compressed, as each connected sequence of pixels of the same value is represented by the number of pixels in the sequence, together with the pixel value.
In our case each colour separate is obviously a one-colour line drawing, so it is enough to choose a suitable threshold separating the graphic information (black) from the background (transparent) in order to obtain a result directly organized in two channels (or screen colours).
Raster data resulting from scanning should follow two different ways and satisfy different requirements.
The first treatment is the vectorization; vector data will provide the geometric information we need for absolute orientation of the stereopairs, since the role of control points in revision process is played by cartographic features found in the new photos. Furthermore they have to allow the necessary visual comparison between the old situation and the new one during stereodigitizing.
For these purposes the result of scanning may be considered a provisional product, not oriented to any graphic output and partially oriented to the storage of digital vector information, limited to those ones of possible and easy organization, as we will see below.
So the characteristics of the raster data for this specific task should be: (a)low resolution and (b)feature separation as sophisticated as possible, paying attention to time-consuming and space-consuming aspects.
The selected resolution plays a very important role: too low resolution will miss important details, too high resolution may take too much space.
Secondly the raster data constitute the base to be modified before plotting the updated overlays. In this case, since the graphic output should have an adequate quality, the resolution should be high and data should be organized with reference to printing colours.
After a series of tests we found that optimal resolution for graphic purposes in order to have a finished result is 40 pixels/mm. Such a value is really too high for the treatment on the vector-based system, so we make a copy of each original file and lower the resolution to 20 P/mm; by this way the file size drastically decreases and so the vectorization time.

Before vectorization it is necessary to process the four files in order to achieve a more detailed separation within the digital overlays; such a separation will make easier the identification of the vectorized data, otherwise lines with different graphic attributes (e.g.thickness, style) would become similar and their different meaning would be lost.
A compromise we found in order not to lose the meaning of different features avoiding time-consuming interactive work, consists in the following automatic separation starting from the four fundamental scanned overlays:

i) <u>relief file</u>

The overlay to be scanned contains four different classes of features, i.e. (a)main contour lines,(b)intermediate contour lines, (c) auxiliary contour lines if they exist,(d)hachures.
By testing the area sizes of each scanned line, it is easy to separate the auxiliary contour lines (dashed lines) and the hachures (small areas) from the other lines, that is to sort out them in different channels (or screen colours).
To separate main contour lines from the intermediate ones we may take advantage of the different thickness; with a series of "frame" function application, the thinnest lines are put in a different channel (or screen colour), while the axis of the thickest ones (i.e. the main lines), remains in the original channel.
At this point, after having so sorted out the relief data, one performs three different vectorizations providing three different vector files.

ii)<u>hydrography file</u>

The overlay to be scanned contains (a) point- and (b) linear-features. In a similar way as that one aforementioned for relief features, one may take advantage of the fact that the drainage network is generally constituted by open lines, whereas point features (i.e. symbols) are short closed lines; so with a final brief interactive phase, just oriented to check the correctness of the automatic classification, one produces two different files to be vectorized, the former one containing only the drainage and the latter one containing only symbols.

iii)<u>vegetation file</u>

The overlay to be scanned contains (a) limits of cultivated areas, (b) woodland limits and (c) symbols relevant to different kinds of vegetation; also in this case one takes advantage of the different graphic presentation of each class of features and prepares three different files for the subsequent vectorization process.

iv)<u>culture file</u>

This file needs a particular treatment before vectorization, since it contains area features in full colour, i.e. houses, wich cannot be directly vectorized in a correct way. It is necessary to extract the edges in order to substitute areas with their perimeter.
The goal is easily achieved by using recurrently the aforementioned "frame" function that allows at the same time the edge extraction for the houses and the separation among houses, roads and lettering. A final check is needed in order to remove some large mames from the channel assigned to house borders and to recover smallest houses.
So by a mixed interactive-batch procedure one obtains three files containing (a) houses, (b) lettering and (c) all

remaining cultural features and may carry on with the vectorization.

4. VECTORIZATION PROCESS OF ACQUIRED RASTER DATA

The vectorization process consists of two main steps: (1)extracting lines structures from raster data, and (2) representing them in a vector form. The line structures may derive from lines drawn on the original map, or from edges between different areas on the map. To extract the former kind of lines, a line thinning or skeletonization process is necessary. To extract the latter kind of lines, an edge extraction pre-process, as mentioned for culture file, is needed.

The purpose of the skeletonization process is to produce the one pixel wide mid-line. The skeleton should preserve the topology of the structure, even if it is sometimes vulnerable to small discontinuities and may create confuse intersections between lines.

To extract vectors from the skeletonized raster lines, the lines must be followed in a certain order, and the x,y-coordinates recorded.

Data reduction should also take place: only significative points are recorded, whereas those ones along straight lines are skipped, and the density may be changed using different parameters.

The vectorization process produces some noise like the appearance of small unwanted lines or polygons, deriving from the scanning process. Both small lines and small polygons should be removed by individuating the correct size threshold and performing a parameter-driven remotion, if one wants to obtain a finished product. In our case the use we make of such a product allows to accept the noise, provided that it does'nt prevent the interpretability of the features.

Once the raster files have been vectorized, they should be converted in a suitable exchange format in such a way to be transferred on the vector-based system. In our case the exchange format that allows data transfer is the well-known SIF (Standard Interchange Format), that ensures an acceptable compatibility for two-dimension vector data between our systems.

Vector data relevant to each raster file generated from the separation are then merged in an unique file, assigning each class of information to a different level, with different graphic attributes in terms of colour, thickness and style, that is, to some extent, codifying the differentiated feature families.By this way the operator receives on the stereoworkstation the image of the old map and may begin the updating procedure.

5. NEW DATA ACQUISITION FROM PHOTOGRAMMETRIC SOURCE

The system used as photogrammetric data input system is constituted by a set of analog instruments Galileo Stereosimplex G7, interfaced with Intergraph stereo workstations and connected with Intergraph double screen workstations.

The first phase of the procedure is the absolute orientation of the stereomodel. In the case of revision, regular control points are neither available nor necessary, because the role of control points is played by suitable features identified on the photos together with its corresponding representation on the old map. So the operator has to search for suitable control points on the vectorized image he sees on the screen as result of the phase above treated.

Although some difficulties may arise in point identification due to the monochromatic screen that is connected with the stereoinstrument, the absolute orientation always gave results within the tolerance stated in conventional revision procedures.

Planimetric coordinates of control points are directly derived from vector file after an affine transformation from scanner coordinate system to ground coordinates. Such a transformation makes use of the corners of the sheet and of the trig-points, well identifiable on the image of the map and obviously known in ground coordinates; so it allows to minimize the effects of dimensional changes of the scanned overlay.

Altimetric coordinates are derived from spot heights easily readable on the image. Both planimetric and altimetric coordinates are stored in a ground control point file to be used for the subsequent analytical absolute orientation.

Just as in conventional procedure, the most difficult operation is change detection, but it seems relatively easier and less tiring, because the operator may get at about the same scale both the old map on the screen and the stereoimage in the eyepieces. No doubt difficulties would drastically decrease using a colour display instead of a b.w. one, taking advantage of the different colours of each class of features; this is only an economical, not technical problem.

Furthermore additional advantages may be taken using devices that allow the injection of the display in to the eyepieces, but such a performance seems more suitable forlarger scales, in wich feature displacement and symbolyzation is not so intense as it is in our case.

By stereodigitization the gathered elements are assigned to different levels and encoded according to the selected graphical representation (colour, line thickness, style) and to the method adopted to gather topographic features (point by point, automatic filtering of significant points, and so on).

The levels used to separate different classes of features may be considered sophisticated versions of the overlays (hydrography, relief, culture, etc.) compiled in traditional procedures for colour separation.

Three primary classes of levels exist in the general organization of the file built up with the aforesaid procedure; they are:(a)levels containing old features,namely one level for each raster file generated during the separation process; (b) levels containing new features; (c) a special level in wich the operator puts no more existing features removing them from the levels relevant to the old map.

Once the model has been digitized, no further operation is performed at the stereoplotting workstation. All subsequent operations are carried out at the editing workstation, more suitable to map editing and finishing.

At this point two different operations are carried out: firstly,cartographic editing takes place, affecting only new stereodigitized data; it involves intersections cleaning, features generalization and displacement, lettering

positioning.
Secondly, a file is prepared to be sent back to raster-based system for the final stage of the procedure. Among the information resident on the vector-based system, only those ones relevant to new data are to be sent back, together with the level containing features to be deleted. All remaining data, namely the major part, already are lying in the raster system, as they have been generated by scanning; moreover they are organized in the most suitable form for graphic purposes, that is high resolution and colour separation.
Therefore the "updating" file is converted in SIF and sent to Scitex system for rasterization and plotting.

6. RASTERIZATION PROCESS OF THE ACQUIRED VECTOR DATA

Vector-to-raster conversion isn't a hard task as much as the reverse process is. Basically it consists of two steps: the former one is the generation of the raster skeleton (one pixel wide) from the vector lines. The latter one is the reconstruction of the lines with the thickness required in output; it is exactly the reverse procedure of the thinning operation performed before vectorization during raster-to-vector conversion.
In order to carry out this second step a font library should be implemented to associate correct style, thickness and colour to each codified line coming from vector system.
The resolution selected for the rasterization process is the same as for the scanning phase, that is 40 Pixels/mm; setting such a high value makes the process very time-consuming if the amount of detected changes is high, but it is a batch procedure and doesn't involve the assistence of the operator.
The result of the rasterization procedure consists of 5 raster files, of wich 4 correspond to the colour separates, wereas the last one contains features to be deleted on the old map.

7. EDITING AND PLOTTING OF THE UPDATED MAP

For the final stage the operator receives two raster files for each printing colour, namely the old file and the "updating" one. Every file has the same coordinate range and the same resolution, so one simply has to "execute the placement" of each file on the correspondent one and to merge all pairs in an unique file, sorting out the four digital overlays in different channels.
Finally the file containing features to be deleted is "placed" on the previous one and a frame-by-frame inspection is carried on in order to:
-delete old features no more found during photogrammetric revision;
-modify and adapt old features to the new ones.
Such a phase is interactive, so it is time-consuming in itself. However, considering that the operator may take advantage of many utilities, like colour protection and display zooming, the work goes on speedly enough and without errors. Though the time involved depends on the amount of changes to be made, no doubt the conventional procedure needs much more time and skill than the digital approach.
Once accomplished the interactive editing, one carries out the plotting of colour separates without any kind of problem or difficulties. The result is a set of films, because the device

used is a laser-based photoplotter, and the graphic quality may be defined very satisfactory (fig.1).

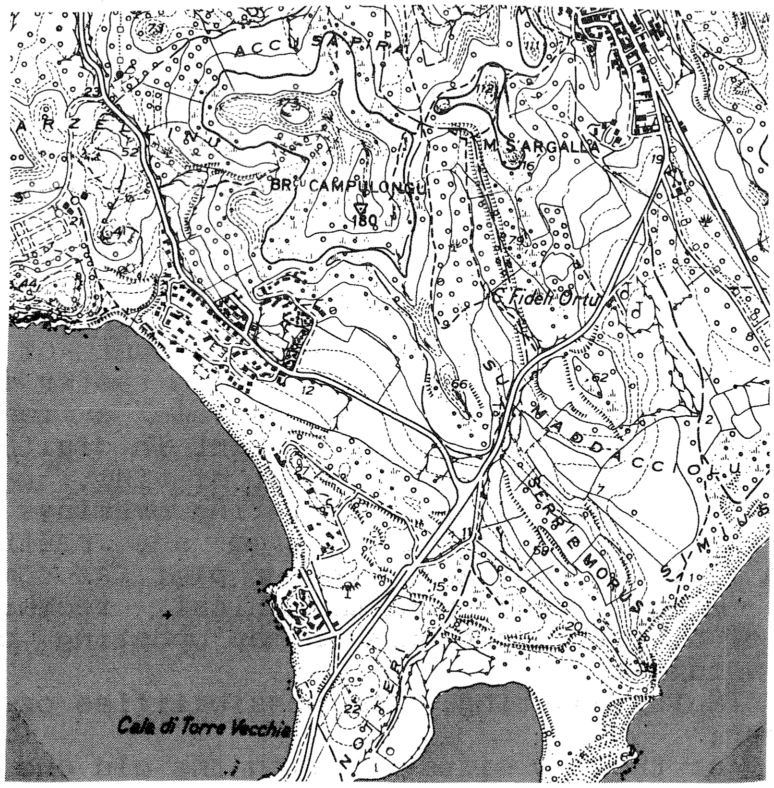

fig. 1

8. CONCLUSION

The main purpose of the described experimental procedure was to investigate wether the updating process may be improved by digital techniques.

We assumed that:

- a lot of digitization work is being carried out by several organization in order to exploit cartographic source as the main source for the implementation of a topographic basis of a Geographic Information System;
- manual digitization is out of the question due to its time-consuming and mainly to the amount of involved errors.

Within the framework of the previous assumptions we may differentiate two main classes of cartographic features, that are (a) morphological and hydrographic information on one hand, and (b) cultural and vegetation information on the other hand.

The former class has a cycle of obsolescence much longer than the latter one; moreover structuring and organizing those information in a digital data base is more easy than it is for the second kind.

On the other hand it has long been known the potential of digital terrain models and of hydrological models in contributing to the solution of a wide spectrum of problems. In Italy the IGMI has now completed the digitization of contour lines from 1:25000 scale topographic maps and foresees to complete, at the end of 1989, the digitization of the drainage

lines from the same map series, by using electronic raster scanner technology.
Such a work is performed independently from cartographic applications, so using the result of scanning in updating procedure may be considered practically expenseless.
Actually, the second kind of information needs a sophisticated treatment if one wants to put it in a Geographic Information System. In other words a lot of work would have to be invested into post-digitization process (mostly for coding the different types of object classes and for desymbolization) and into structuring the data. However, waiting for further investigations in this field and mainly for further technology developments in the field of automatic pattern recognition, we assumed that the first step in exploiting the cartographic source, that constitutes an enormous amount of available information, will remain the digitization in raster mode, under the consideration that raster mode allows a faster full-automatic conversion of the old map content in digital form.
Furthermore, from an operational point of view, raster mode allows a faster plotting of the printing overlays than the vector mode and doesn't suffer from any restriction in symbolization as it is typical of vector plot. As compared with conventional manual and photomechanical techniques the application of digital techniques in map updating offers the following advantages:

- in case of faulty updating, the possibilities of correction is fully better;
- the matching of the new situation with the old one is easier and can be performed in less time;
- the distinction among old data, new data and deleted data is more refined;
- the distortion of the original overlays, so common and dangerous, may be almost totally corrected.

In conclusion the concept that a wider application of the existing technology may play an important role in the necessary revision process of the existing maps has been largely confirmed by this experience, as well as the fact that a convergence may be found between the efforts to convert geographic information from analog to digital form and the time-consuming task of updating analog information: that is we called computer-assisted map revision oriented to GIS implementation.

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