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Experiences in modelling and representing the relief at the Institut Cartogràfic de Catalunya

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Zusammenfassung

Das Institut Cartogràfic de Catalunya (ICC) wurde 1982 gegründet. Zielsetzung war einerseits eine flächendeckende und vor allem kontinuierliche kartographische Abdeckung von Katalonien zu gewährleisten und andererseits moderne Technologien und Innovationen in der Kartographie zu forcieren. Seit der Gründung des Instituts wurde die Schaffung einer kartographischen Datenbank für die Produktion verfolgt. Dieser Beitrag zeigt die Genese und die Abdeckung von Digitalen Höhen- und Geländemodellen (DHM und DGM) von Katalonien am ICC. Dabei wird das gegenwärtige Datenmodell aus verschiedenen Richtungen betrachtet: Datenerfassung, Datenprüfung, Datenspeicherung, verwendete Software und ableitbare Produkte.

Summary

The Institut Cartogràfic de Catalunya (ICC) was founded in 1982, in order to achieve a consistent cartographic coverage over all the catalan territory, incorporating new technologies and working techniques. From the beginning the ICC has been working with the purpose of creating cartographic databases to use automatic systems in cartographic design and production. This article shows a historical perspective of the generation of digital elevation models (DEM) and digital terrain models (DTM) of Catalonia at the ICC. The present data model is described from several aspects: method of data capture, data verification processes, formats of data storage, software used and products obtained using it.

1 Introduction

The Institut Cartogràfic de Catalunya (ICC) was founded in 1982 after a law of the Parliament of Catalunya, in order to achieve a consistent cartographic action over all the catalan territory, incorporating new technologies and work techniques. From the beginning the ICC has been working with the purpose of creating cartographic databases to use automatic systems in the cartographic design and production.

2 DEM of Catalonia, historical perspective

The project Orthophotomap of Catalonia at 1:5.000 was planned as the first complete coverage of the country at that scale. Image rectification required a digital elevation model that was created using a system based on correlation of images using an analogical stereodevice, the Gestalt PhotoMapper IV. The output was a grid file that contained the elevation of one point every 3.5 meters. This sys-

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Fig. 1: Orthophoto rectified using a DTM in grid format

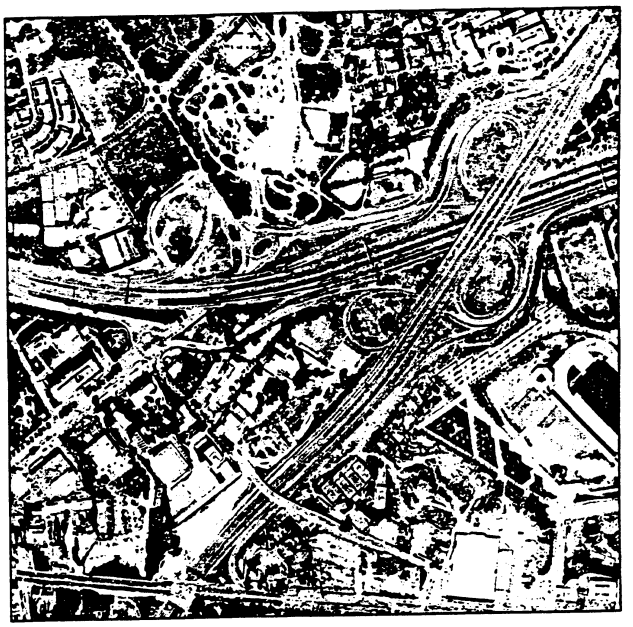

Fig. 2: Orthophoto rectified using a DEM of triangles

tem had some limitations, and to improve the productivity other systems had to be analized.

At the same time, the project of the Topographic Map of Catalonia at scale 1:5.000 was started. This digital vector data was designed to be stored in 3D, and digitized using analogical and analytical photogrammetric systems. The information was never structured to create a geographical database with GIS purposes, it was only "spaghetti" data. The idea was to collect scan lines and break lines on the terrain, during the compilation of the Topographic Map of Catalonia at 1:5.000, that allow to interpolate grid files to be used by the orthophoto rectification process, and also to interpolate contour lines which can be added to the topographic map. The grid file covered the terrain with one point every 15 m, that was the optimum density used by the automatic rectification process of orthophoto images at 1:5.000 developed by the ICC in 1988. Both products, grid and contour lines, had some limitations, derived from the method of capture and from the algorithms of interpolation. But in 1993 the first Digital Terrain Model (DTM) of Catalonia was finished.

In 1992 a project to publish the Topographic Map of Catalonia at scale 1:50.000 was initiated. It was decided to create a Digital Cartographic Database for GIS purposes and the same information was used, after some cartographic edition processes, to publish the maps. The data was digitized on screen using orthophoto images at 1:25.000 in B/W or color, with pixels of 1.8 meters on the ground. The method used for data capture only allows digitizing 2D information. The altimetric information was obtained applying generalization to the existing DTM. Contour lines were interpolated from the grid after applying some simplification and smoothing, and spot heights were selected interactively from the original vector data.

The main problem derived from the DTM, was the generation of shaded relief. It has to homogenize some details and correct some errors that were not detected during the contour interpolation or grid generation. It showed that digital shadow relief is more sensitive to DTM limitations than contour interpolation. The corrected DTM was also used in the generation of some altimetric data of maps at smaller scales, for example shaded relief at scales 1:250.000 and 1:500.000, orthophoto rectification at a scale 1:25.000 and 3D maps at scales 1:100.000 and 1:250.000.

In large scales the use of digital terrain models for orthophoto rectification presents some problems when there are differences between the terrain and the actual elevation, for example in buildings or bridges. For the second version of the Orthophotomap of Catalonia at 1:5.000, the rectification process was improved developing software that uses triangulation model of digital elevation model, instead of a grid model, to introduce elevations where the digital model of the terrain based on a grid is not acceptable.

3 DEM of Catalonia, present

In the update process of the MTC 1:5.000, some changes have been introduced in the data structure in order to obtain a database for GIS purposes, to obtain a Digital Terrain Model (DTM) for contour line interpolation and shaded relief generation and a Digital Elevation Model (DEM) for orthophoto rectification.

Features for the DTM generation include scan lines, break lines, spot heights, contour lines used to infer break lines during the generation of the triangulation model, and flat areas. All the planimetric features captured on the ground are used as break lines. Features for the DEM include DTM except in areas covered by buildings or bridges, where their elevation substitutes the terrain. Some processes are required to generate special data to avoid vertical triangles, that are not supported by most of the software available.

Data is verified during data capture and the global process includes different techniques to detect and correct errors. At this moment, only digital photogrammetric systems are used, where the superimposition of stereo image and vector data is a powerful tool to detect severe mistakes. Crossing tests between break lines or contour lines allow to queue and assign correct high value to the erroneous crossing points. Generation of contour lines allows to analize the result of the interpolation of these elements. Finally the generation of shaded relieves gives an idea of the quality of the grid and helps to detect small errors. All these verification processes can be repeated until the digitized data will become acceptable.

The ICC is using, for data capture, the digital photogrammetric system developed on CLIX by Intergraph, that includes hardware and software. Verification and generation of the model runs on Windows NT and uses Modular GIS Environment (MGE), MGE GIS Analyst (MGA), MGE Terrain Analyst (MTA), IRASC from Intergraph, MicroStation from Bentley and software developed at the ICC. Management and operation of the database runs on VMS using also ICC software. The data is stored as regular grid in ICC internal format, the spacing is 15 meters x 15 meters. The total size is 1.2 GB and it resides permanently on disk.

4 DEMs for external projects

Digital Elevation Models for external projects are obtained using several methods, depending on the available data, the scale and the product to be generated. For large scale orthophoto projects, the DEM is obtained by digitizing of photogrammetric data as contour lines, scan lines, break lines and spot heights. Usually many hours are required to complete the DEM. Correlation systems can not be used at these scales.

For small scales, models obtained with correlation allow excellent results in orthophoto rectification, although some interactive edition is required to check the quality of the model and to introduce break lines or control points, specially in cliffs, plain water and areas of poor texture. The models generated by this method present serious limitations in contour interpolation. Correlation methods have been implemented in the past years, by many commercial vendors. ICC uses the software MATCH-T from Intergraph. The first version was tested in 1996 on CLIX platform. During 1997 several projects used the same platform and the productivity was really improved. During last year, Intergraph ported the digital photogrammetric system, with the same functionality that was available on CLIX, on Windows NT using powerful PC's and improving the software. The new product will reduce the process time of some projects in the ratio of 4 to 1.

Products at very small scale usually use digitized contour lines and spot heights to generate grid files for orthoimage rectification or shaded relief generation.

The use of the interferometry, that will be implemented at the ICC during this year, to obtain radar images will open a new possibility in the generation of DEMs for orthophoto projects.

5 Shaded relief

Digital shaded relieves in maps are generated introducing modulations of the background color using the DTM. There are different options depending on the map design. For example in the Topographic Map of Catalonia at 1:50.000, the land cover colors were modulated and also black shadows were added. The same design has been used in some hypsometric maps. The Topographic Map of Catalonia at 1:250.000 only has black shadows. In the Land Cover Map of Catalonia at 1:250.000 colors were modulated without introducing black shadows. In the Topographic Map at 1:25.000 Parc Nacional de Aigüestortes i Sant Maurici the shadows were generated by the components cyan, magenta and black.

The algorithm for shaded relief generation was developed at the ICC and uses the contrast as minimum and maximum percentage of color, the Z exaggeration and the light directions as parameters. There are plans to analyze the effects on the shaded relieves of data models generated from different data capture, because for example, different results are obtained using only contour lines or models that contain break lines. The process runs on VAX stations. Some resources will be devoted to port the existing software to Windows NT, to improve the user interface and to add more algorithms. In some cases Adobe Photoshop is used to improve the shadow relief obtained digitally. One example is the Avalanche Map at scale 1:25.000 of Val d'Aran North, a thematic map of snow avalanches in the Central Pyrénées.

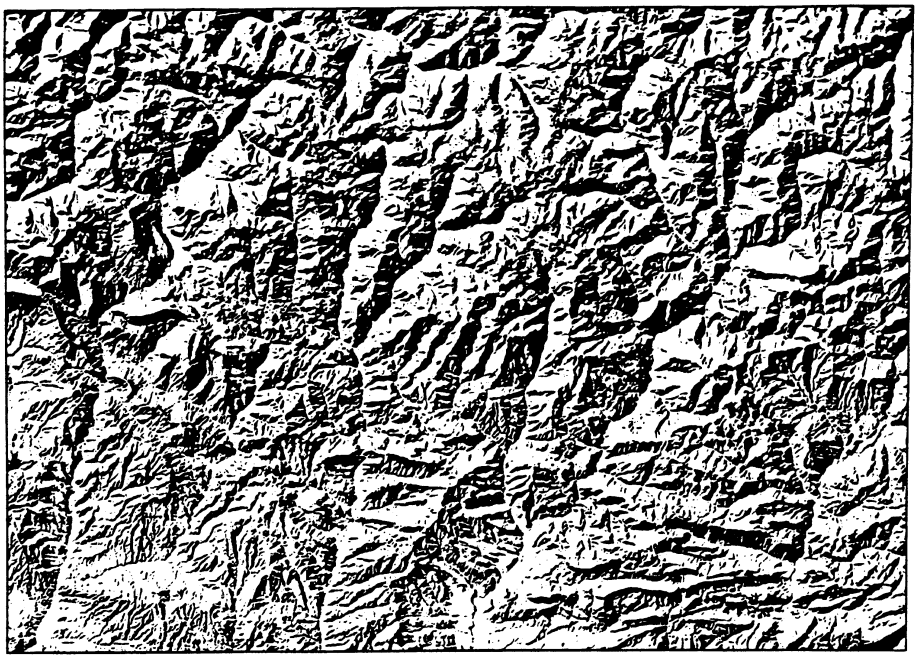

Fig. 3: Detail of shadow relief of the Topographic Map of Catalonia original scale 1:250.000

6 Problems in terrain representation from DTM

The problems in terrain representation from digital models are mainly related to two aspects: the limitations in the quality of the results and the difficulties in data management.

Some examples of the results generated using contour lines interpolation show the need to improve the algorithms to obtain better products of the existing databases. Some analysis have to be done to optimize the photogrammetric data capture, and minimize the impact of data distribution in the contour interpolation.

At the ICC, after the publication of some products that contain contour lines generated by using automatic interpolation from the DTM, for example the Topographic Map at scale 1:25.000 Parc Nacional d'Aigüestortes i Sant Maurici, internal discussion about the quality of the results ask for better interpolation software. For the moment, for some projects, such as the next topographic map at a scale 1:25.000, contour lines are being digitized during photogrammetric data capture instead of using interpolation.

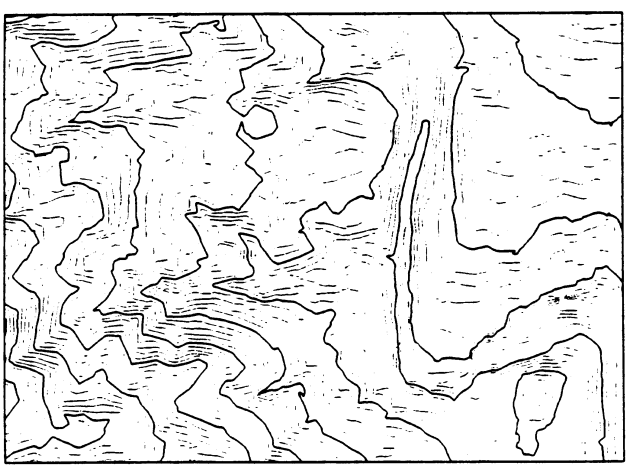

Fig. 4: Main problems of contour interpolation algorithms are manifested in flat or high sloped areas

The original DTM was collected at 1:5.000. At this moment there are no intelligent tools for DTM generalization, to obtain representations at small scales, for example 1:50.000 or 1:250.000. Only simple tools on the grid data, such as sampling or smoothing, are used. The generalization parameters are conservative to avoid the elimination of main characteristics of the terrain together with the details. Some experiences on the generalization of original photogrammetric vector data has been realized to obtain simplified models. The process includes line simplification algorithms applied on the break lines, elimination of irrelevant points, in scan lines and spot heights, based in elevation analysis, and the generation of a hybrid model of data. The results never have been implemented in production areas because of the hybrid model.

In shadow relief algorithm, the interaction between different parameters makes it difficult to predict results and many proofs are required to obtain good results. In most cases proofs are the result of plotting shaded relief together with the rest of map information.

Better data management will allow to introduce the use of triangulation models or hybrid data models, that include grid model and break lines, to obtain

terrain representations. These models are better adapted to the terrain than interpolated regular grids.

7 Cliff drawing

For the generation of cliff drawing, after some experiences, the use of digital techniques has been considered insufficient, and at this moment they are produced manually. In the published sheets of the mountain maps Randonnées Pyrénéennes at 1:50.000, the cliffs were generated in vector data using a combination of area patterns based on points at different sizes, linear patterns and some interactive edition to introduce some irregular aspect. The software used was MicroStation from Bentley.

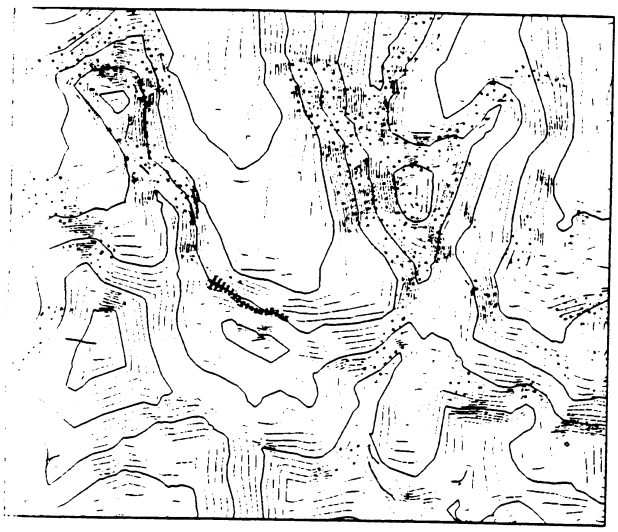

Fig. 5: Example of digital cliff drawing. Mountain Map original scale 1:50.000 for Randonés Pyrénées

For the Topographic Map at scale 1:25.000 Parc Nacional d'Aigüestortes i Sant Maurici, the cliffs were drawn by hand on film, in the areas limited by polygons specially defined during the land cover photointerpretation. The drawer used six different patterns depending on the type of rocks. The information was scanned, to preserve the original draws, and used during the layout of the map.

8 Conclusions

Existing DEM and DTM have to be continuously updated. New technologies allow to improve the quality of the data and obtain better derived products. More powerful tools for management of triangular models will allow to obtain better representations of the terrain. Improvements in existing processes will allow to optimize the use of existing data. At the moment, some resources are being devoted to improve shadow relief generation, introducing more algorithms and better interfaces in order to study DTM generalization, and analyzing contour interpolation algorithms.

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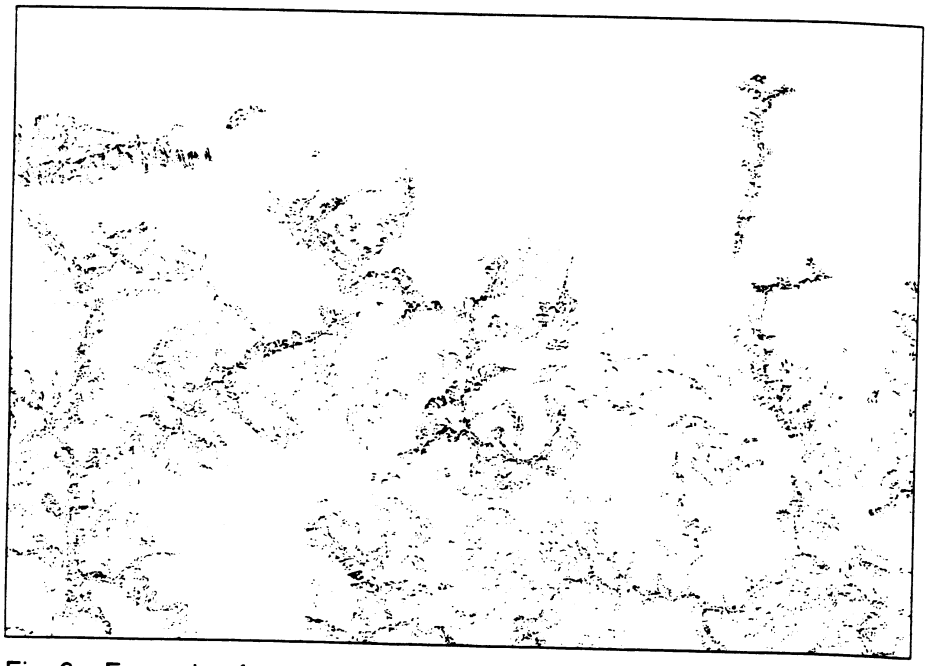

Fig. 6: Example of manual cliff drawing. Topographic Map original scale 1:25.000 Parc Nacional d'Aigüestortes i Sant Maurici

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