MAP GENERALIZATION TO OBTAIN THE TOPOGRAPHIC MAP OF CATALONIA 1:10.000

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The Institut Cartographic of Catalonia has been working since 1998 in the design of the workflow to produce the Topographic Map of Catalonia at scale 1:10.000 from the Topographic Database at 1:5.000 using generalization tools. The new series has 1.070 sheets covering the country of Catalonia, approximately 32.000 square kilometers. The design of the map is completed, the first version of the software and the equipment are ready and production is about to start. The paper provides details about the production of the map, the motivation for the new product, its design, the generalization process and the distribution of the printed sheets.

We will emphasize different aspects of the generalization workflow: the characteristics of the original database, the automatic processes used and the tools developed ad-hoc to optimize manual generalization and cartographic editing.

Finally, we will show some results on productivity and we will give the conclusions.

THE ORIGINAL DATA: THE TOPOGRAPHIC DATABASE OF CATALONIA 1:5.000

The Topographic Database of Catalonia at scale 1:5.000 started in 1985 and lasted for 10 years. The information was compiled using computer assisted analog and analytical photogrammetric stereoplotters and stored as 3D "spaghetti" vectors. The series was not designed to create a geographical database for GIS purposes. It was just a digital map compiled using existing CAD-CAM systems.

Contour lines were computed each 5 meters from profiles and breaklines. In addition, a

15x15m digital terrain model (DTM) was interpolated and stored in an own designed continuous database. The DTM has been used extensively for digital orthophoto generation since 1987 and in the generation of shaded relief for maps at smaller scales.

Figure 1.- Map plotted from the first version of the Topographic Database of Catalonia at scale 1:5.000.

Short before the end of the first version we started the design of the second one with changes and enhancements in the data model. The new version should provide the underlying data model for GIS applications and make it easier the use of automatic generalization and symbolization tools. The limitations of a too simple data model became clear after the unsuccessful experience trying to use automatic tools for generalizing from the old 1:5.000 to 1:25.000. This was reported several times in 1993. In the second version, the model includes polygons, centerlines of roads and footpaths, blocks in urban areas that help defining the street network, a better classification of toponymy, etc.

The departure of the new design from the old one made it necessary to set up a preparation step in which the old data were processed to match the new data model as automatically as possible. This includes the creation of polygons, generalization operations such as automatic generation of centerlines from both margins of roads and footpaths, better classification of toponymy, etc. In addition, the data model provides enough information to create the Digital Terrain Model for contours and shaded relief generation, and the Digital Surface Model (DSM) for true orthophoto rectification.

We also use generalization when we import digital data from existing topographic projects at larger scales, specially 1:500 to 1:2.000. Buildings are simplified before superimposing them for updating on digital photogrammetric systems and contours are selected and used for the DTM.

Figure 2.- Left image shows an orthophoto rectified using a DTM, right image shows the same orthophoto rectified using DSM.

From the database, the map on paper is obtained by applying automatic selection and symbolization of features during the plotting process. Different linear patterns, line widths and colors are applied depending on the priorities between lines, texts and polygons of the database. This process is done on demand on site at ICC shops using ink-jet Hewlett-Packard plotters.

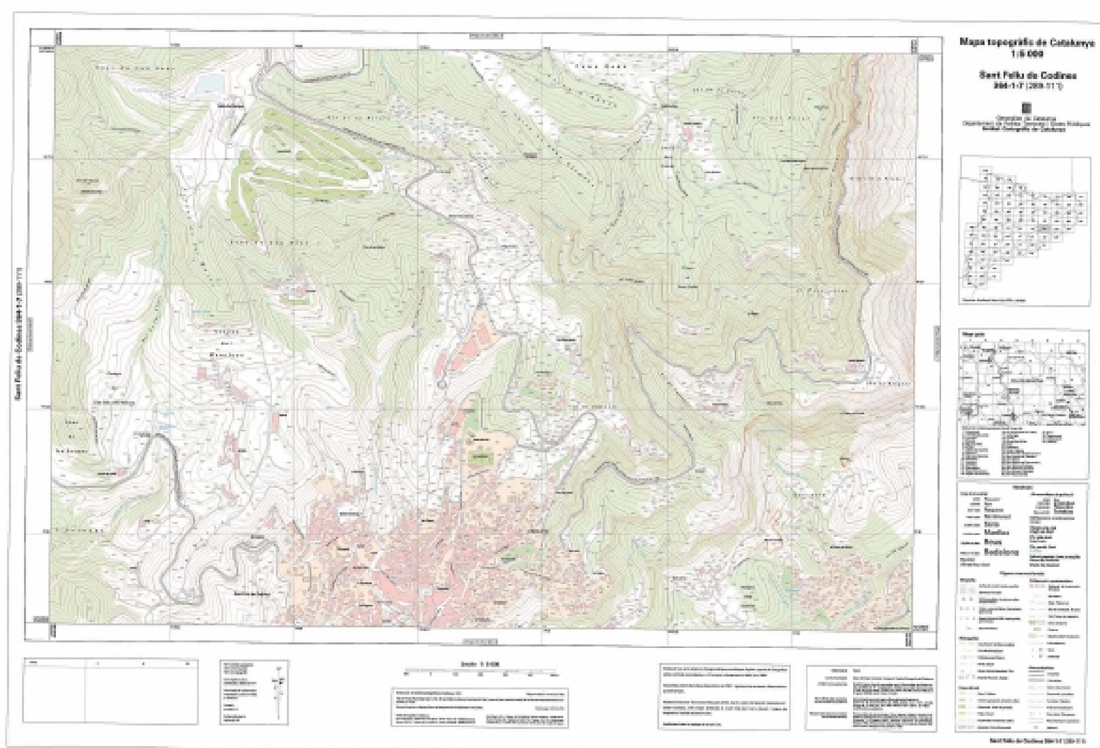


Figure 3.- Printed map of the new version of the Topographic Database of Catalonia at scale 1:5.000.

THE GENERALIZED MAP: THE TOPOGRAPHIC MAP OF CATALONIA 1:10.000

After analyzing the demand of the Topographic Map of Catalonia at scale 1:5.000, we saw that an intermediate scale between the 1:5.000 and the 1:25.000 would satisfy the requirements of users wanting to cover areas with less sheets. Two aspects were considered in deciding for the 1:10.000, namely the availability of data and the low cost if generalization could be used. The Topographic Database 1:5.000 provides the data and the factor between the input and the output scales is low enough to avoid large costs in the overall generalization process.

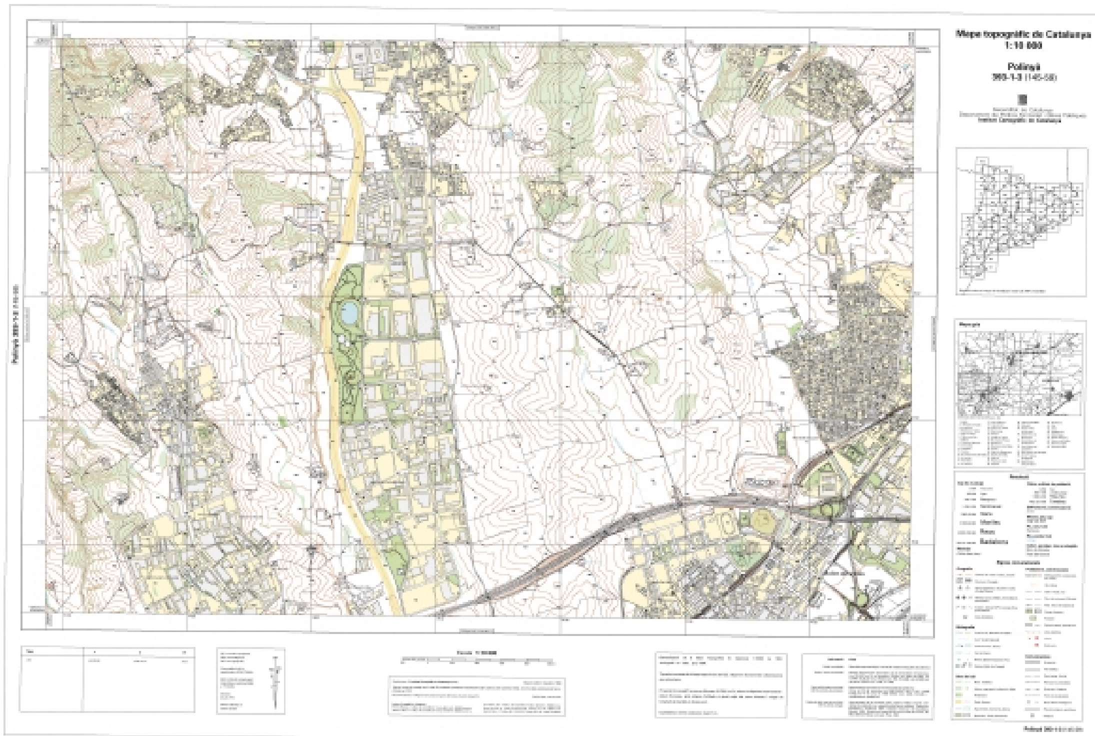


Figure 4.- Topographic Map of Catalonia at scale 1:10.000.

The final product is a map, not a database. The generation of a database at scale 1:10.000 is not justified because it would be too close to the original at scale 1:5.000.
The map doesn't contain more information than the original one. The digital map is 2D and the objects of the 1:5.000 used for creation of networks and other GIS structures such as centerlines or connections, are not maintained.

Moreover, and since the goal is to obtain a product metrically and aesthetically correct at reduced cost, some compromises were allowed if not visible on the output map. For example, the impossibility of generalizing by taking into account the topology forces to use duplicate lines as a substitute of shared boundaries. Since they are becoming generalized separately, it often ends up with two different lines as showed in the following figure:

Figure 4.- The top picture shows the result of generalizing of shared lines in polygon boundaries. Even though they are not coincident, the result is not visible at 1:10.000 scale, as it is showed in the bottom picture.

As we do for the plotted version of the Topographic Database 1:5.000, the 1:10.000 map on paper is plotted on demand at user's requests on our shops. During the plotting process, we apply automatic symbolization..

GENERALIZATION: THE WORKFLOW

One sheet of the Topographic Map of Catalonia at 1:10.000 is obtained by merging and generalizing four sheets of the Topographic Database at 1:5.000. The workflow of the process is as follows:

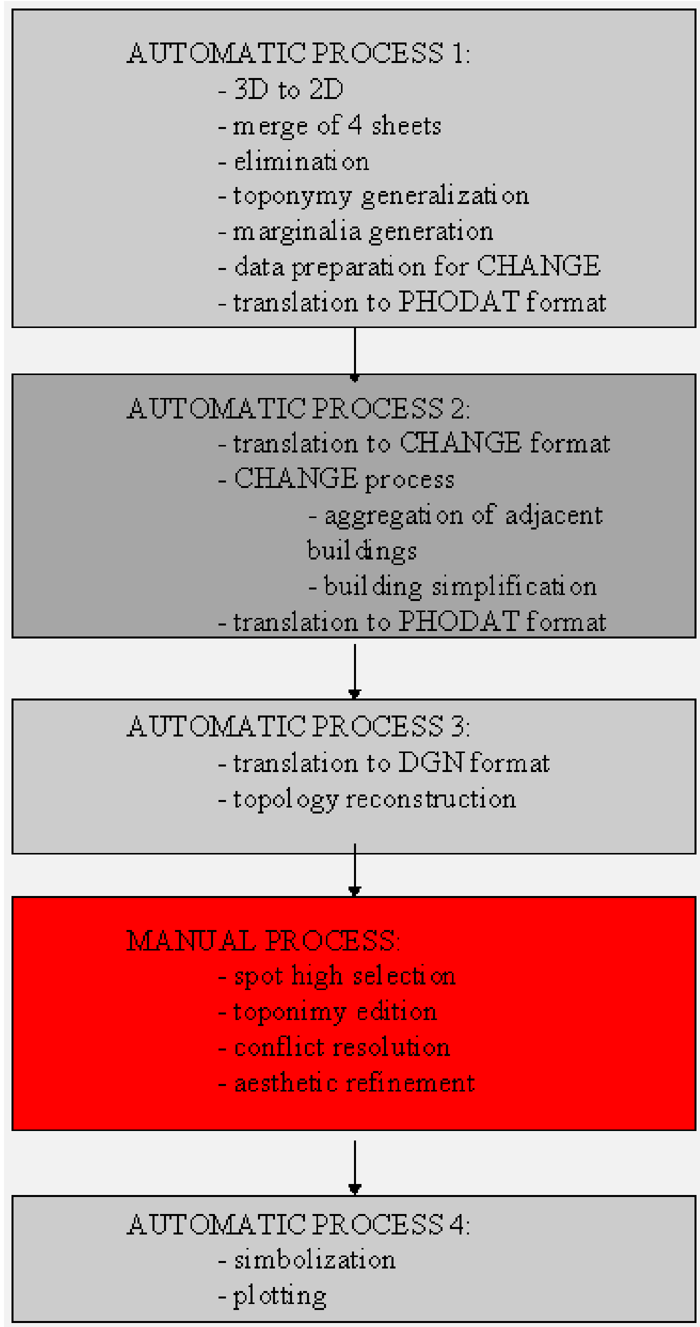


Figure 6.- Workflow. Automatic processes on Windows NT are represented in light gray, automatic processes on UNIX in dark gray and manual processes on Windows NT in red.

The small factor between the original and the generalized scale allows us to keep an important subset of the original data without generalization. Note that the interval of the contours are the same in both scales.

The generalization workflow includes automatic processes and interactive manual editing. Automatic processes are used for eliminating some objects (i.e. rustic parcels or connection segments), for the selection and modification of toponymy; for the scaling of symbols and texts (i.e. contour labels), for the aggregation of adjacent polygons between sheets, and for building simplification.

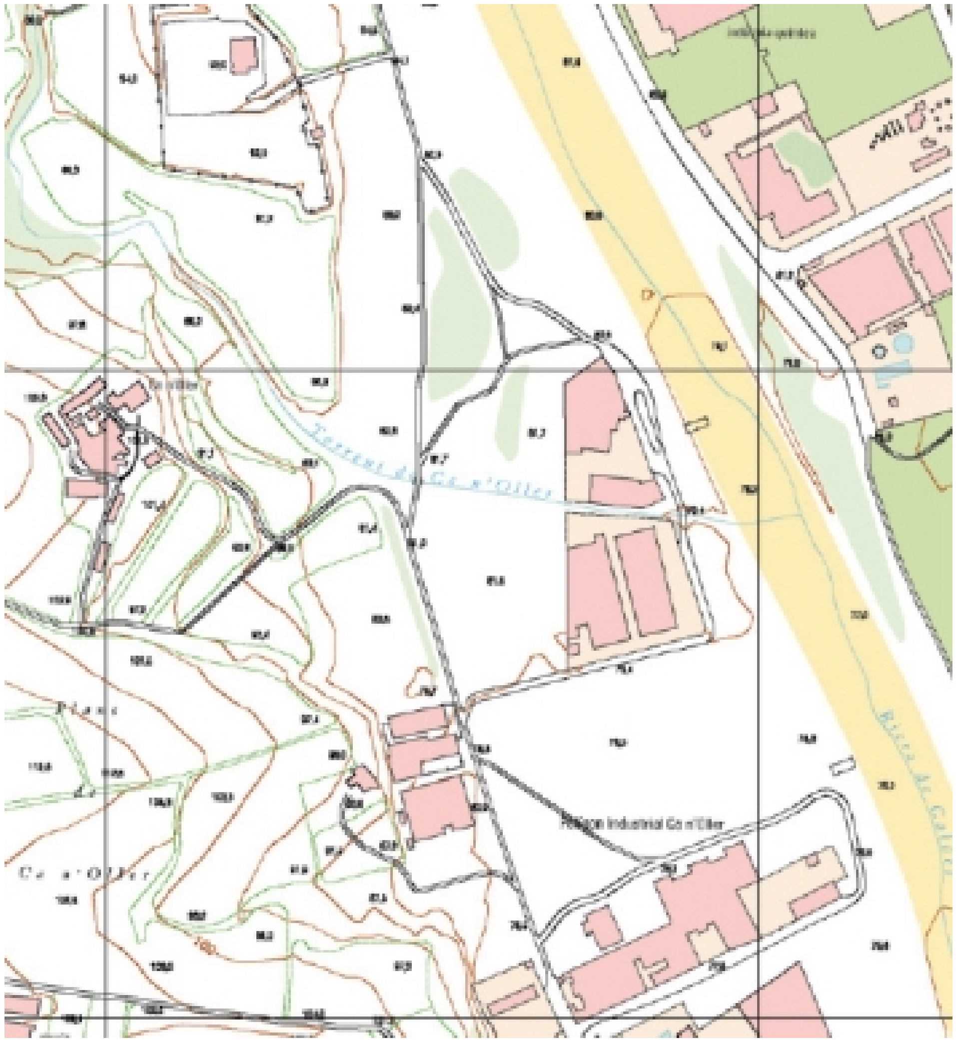
Very common generalization operators, such as linear simplification, has not been applied at all. This strategy reduces efforts in the interactive manual editing because we can not simplify roads and hydrography without manually adjusting the contours and other topographical objects. Note that the low factor between input and output scales allows to preserve the small details in the linear elements without decreasing the quality of the final product.

Figure 7.- Top image shows original data at 1:5.000. The linear elements can be maintained without generalization as showed in the bottom image at 1:10.000.

As it is showed in the following figure, simplification is required on buildings because the original data is compiled so detailed that cannot be represented correctly at scale 1:10.000 without generalization.

Figure 8.- Top image, original data at 1:5.000 represented at 1:10.000, shows that buildings are too detailed. Simplification improves the representation as is showed in the bottom image at 1:10.000.

Some objects represented by two margins at 1:5.000 scale are collapsed to their centerline.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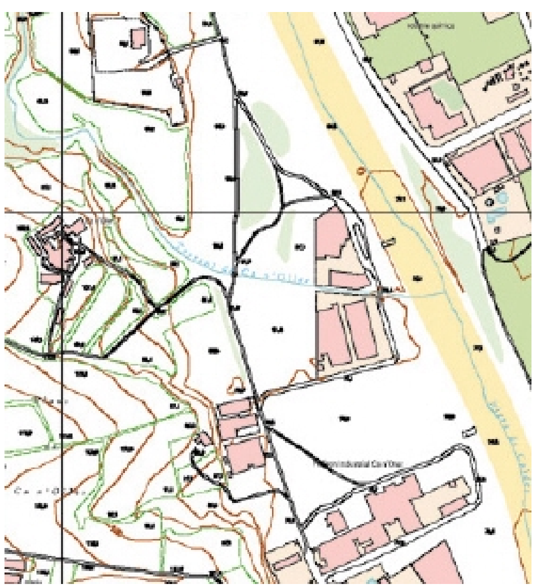


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Figure 9.- In the top image, original data at scale 1:5.000 shows a footpath represented by two margins. At scale 1:10.000 both margins generate conflicts, the bottom left image, that are solved collapsing them to their centerline, bottom right image.

The UNIX version of the software CHANGE developed by Prof. D. Grünreich et al. at the Institut of Cartography of the University of Hannover is used for building aggregation and simplification. Other software systems such as the Map Generalizer of Intergraph was tested but results were not satisfactory enough compared with the ones obtained using the last version of CHANGE delivered one year ago.

Figure 10.- Top image shows the original data at scale 1:5.000. Bottom image shows the result of applying building simplification using CHANGE.

Other operators for elimination, selection, collapse and scaling were developed by us on top of MicroStation. The programming languages are C and Visual C++ on Windows NT.

Toponymy is generalized also using own software that includes an automatic process for selection, scaling and changes in the typography. As shown in the following figure, the automatic result is not good enough and some interactive tools have been developed for final adjustments and modifications.

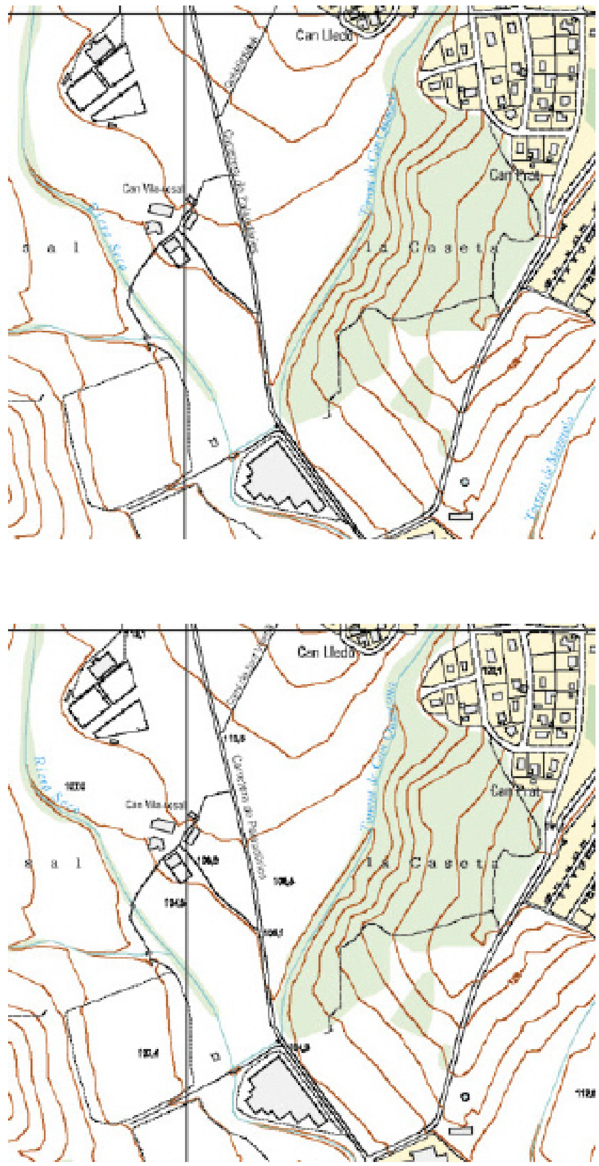


Figure 11.- Top image shows the data generalized automatically at scale 1:10.000. Manual editing is required as is showed in the bottom image.

In addition to the automatic processes, manual tools for interactive generalization were also developed. For example, it has proven impossible for us to automatically typify correctly the spot heights. Therefore, manual selection must be done by first looking globally at the areas and then pick-up the most significant one. This very lengthy task has been simplified by providing the cartographers with a tool that let them select the spot heights one by one and then scales automatically the symbol and the text. The tool enforces legibility by checking the minimum distance between the spot height symbol and the label.

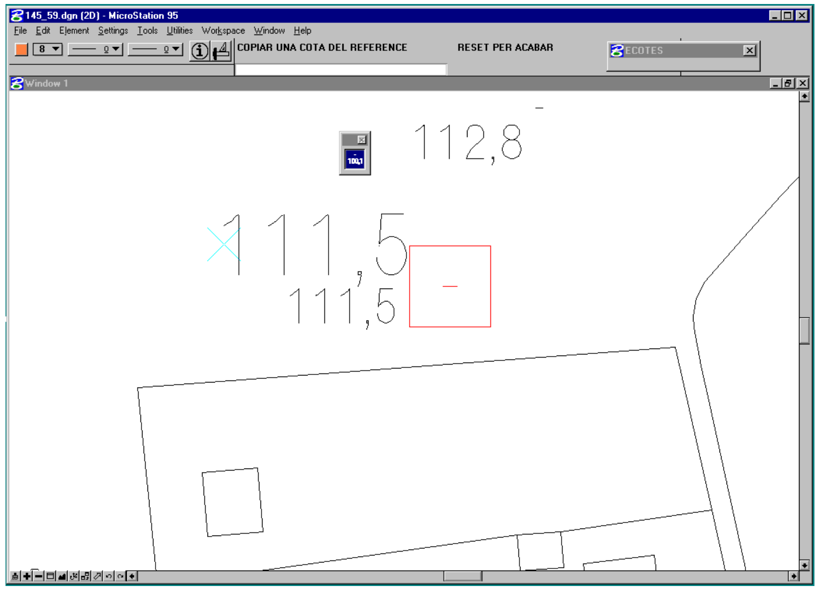


Figure 12.- Interactive tool for scaling and helping the cartographer in spot height manual generalization.

Another hard task is to modify the placement of the toponymy. Some tools developed here also are very useful for the cartographers in the interactive manual editing.

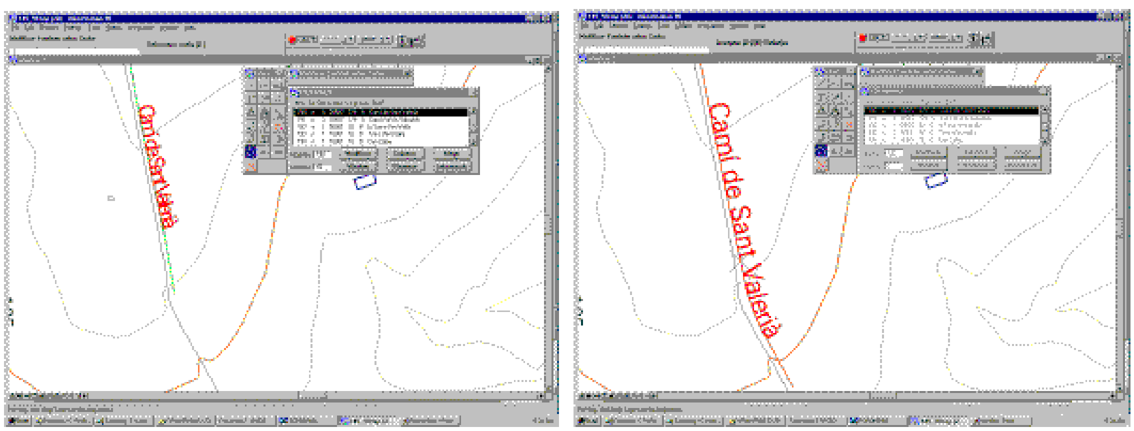
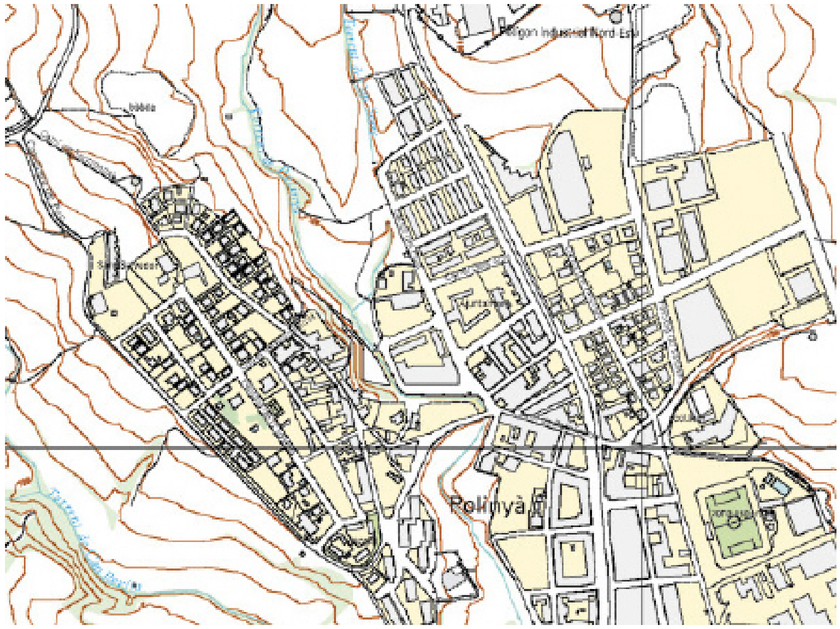


Figure 13.- Left image shows the result of automatic toponymy generalization. Right image shows the result after manual editing.

The main problem in this case is to displace texts to avoid overlaps with topographic data.



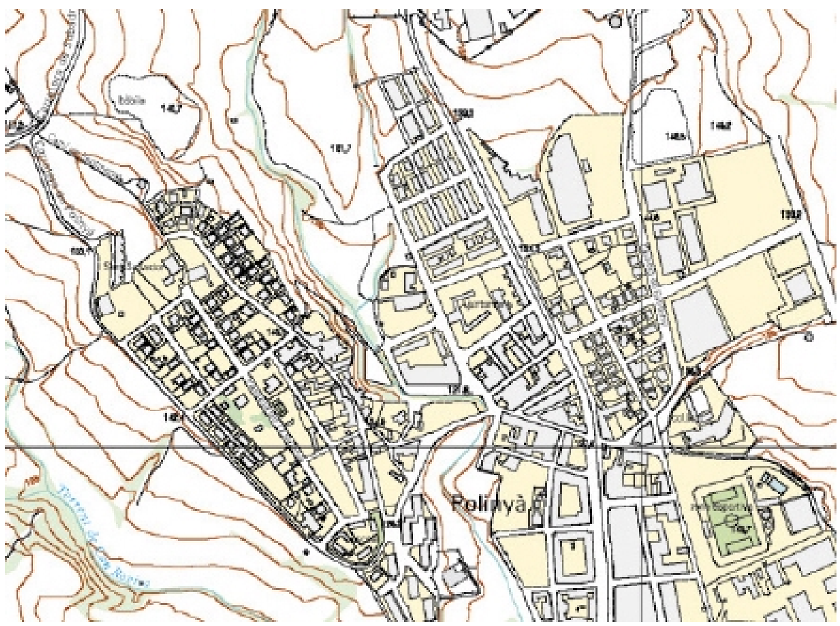


Figure 13.- Top image shows the result of automatic generalization. Bottom image shows the result after manual editing for solving conflicts between texts and topographic data.

SYMBOLIZATION OF THE MAP

The symbolization process is automatic and it is applied during the plotting process. It includes the patterning of linear elements, changing the line widths and fill polygons with color, and takes into account the overlay priorities between objects in the map. The size of the symbols, in most elements, is the same as in the original map at scale 1:5.000. Only for the representation of elements always close to others -and therefore prone to overlap- was decreased. This is the case for leveled grounds and embankments. Toponymy and texts are smaller than in the original map at scale 1:5.000.

The design of the marginalia is similar to the original at 1:5.000. This was decided to preserve the look of all map series at scales 1:5.000 and 1:10.000 including orthophoto. The marginalia is generated automatically by extracting information from related databases: map sheet coordinates, administrative boundaries, geodetic information, etc.

All our map series at these scales are plotted on demand using ink-jet Hewlett-Packard plotters.

RESULTS AND PRODUCTIVITY

So far, only few map sheets have been produced using this workflow. Timings are as follows:

PROCESS	TIME
Automatic process 1	2 '
Automatic process 2	1 '
Automatic process 3	1 '
Automatic process 4	3 '
Total automatic	7 '
Manual spot height selection	7 h
Manual toponymy edition	5 h
Manual conflict resolution	4 h
Manual aestetic refinement	4 h
Total manual	20 h
Data management	1 h 30 '
Total	**21 h 37 '**

After analyzing the results we decided that the project was feasible in terms of the quality of the printed map and the resources spent to obtain it.

At the time of this writing, the first version of the software is completed, the equipment is ready and training has started. We foresee to be in full production in a couple of months.

Comments of the cartographers will provide the necessary feedback to proceed with further improvements in the software and in the general workflow of the project.

CONCLUSIONS

The availability of automatic generalization tools has allowed to realize our goal, namely the generation of the Topographic Map of Catalonia at scale 1:10.000 as a product metrically and aesthetically correct at reduced cost. Without these tools the project would be unfeasible.

Even with a small scale factor between input and output scales, most of time and costs is spent in manual generalization. True interactive and user-friendly tools are required to help cartographers in the manual editing.

The use of two different platforms to process data, UNIX for CHANGE and Windows NT for other processes and manual editing, complicates the workflow and the management of the resources.

So important as the generalization software itself is the model of the data to be generalized. If the input data model is not appropriate, the cost of preparing and pre-processing the data is several times larger than the cost of the generalization process.

Since last years we have not observed qualitative improvements in the commercial generalization software used at the ICC. Aspects as topology or toponymy are still open problems.

Finally, it is necessary to think about how to update a generalized map. There seems to be three possibilities: to generalize again the updated input database, to update the existing generalized map directly, or to try to combine both options. Which is the best one?

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