Spot heights generalization: deriving the relief of the Topographic Database of Catalonia at 1:25,000 from the master database

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CONTENTS

- Introduction
- GENCOTES: UPV application for the generalization of spot heights
- Adaptation of GENCOTES to the ICC specifications
- Results
- Integration in the Topographic Database 1:25,000 workflow
- Further developments
- Conclusions
INTRODUCTION

- Since 1997, the ICC has been applying automatic generalization techniques, but never on the objects that characterize the relief.
- The available commercial software has not offered, until now, any tool specifically designed for the relief.
- From 2002, the UPV has developed an application, GENCOTES, to generalize spot heights.
- In 2006 UPV and ICC signed a collaboration agreement to adapt GENCOTES to the ICC requirements in order to be applied in the cartographic production workflows.
The ICC topographic data models represent the relief using contour lines and spot heights. Moreover the master database contains scan lines, break lines and contour lines to infer break lines.
The ICC topographic data model represent the relief using contour lines and spot heights. Moreover the master database contains break lines and contour lines to infer break lines.

The spot height generalization can be used in most of the workflows to derive large and medium scale databases and maps.

The ICC started the implementation of GENCOTES on the Topographic Database at 1:25,000 workflow:

- At that scale remains yet a significant number of spot heights.
- The cost of the manual generalization is quite high.
Application written in AVENUE, that works on ArcView 3.2

Two main steps to generalize spot heights:

- **Hierarchical classification:**
  to give a specific value to each spot height based on parametric criteria

- **Selection:**
  taking into account the previous hierarchical classification and a balanced spatial distribution
GENCOTES:
HIERACHICAL CLASSIFICATION

- Classification of the spot heights based on the user needs:
  - How are they useful to a user?
  - Where should they appear?

usually

- Areas close to roads
- Characteristic points of the terrain
- Referencing elements that help in orientation
- More density in elevated areas
The application considered three types of spot heights:

- **Special interest points**: significant points that must remain in the generalized data:
  - On the roads
  - Inhabited zones
  - Related with map names
- **Geomorphologic interesting points**: they identify characteristic terrain points:
  - Peaks
  - Passes
  - Depressions
- **Remainder points**
Points on influence area of:
  - Roads
  - Inhabited zones
  - Map names

Points inside these areas are weighted according to the priority (assigned by the cartographer) of the influence areas.

For each map name in the input data the program identifies if it is related with terrain, searches all the spot heights around it and selects the closest to the map name.
To find the geomorphologic interesting points, the application derives a triangulation model of the DTM from the original data to be generalized.

It analyzes the DTM to determine if the spot heights are:
- Peaks
- Passes
- Depressions

The classification and categorization is based on:
- Heights in a neighborhood
- Shape (only peaks):
  - Conic or asymmetrical
  - Open or closed
Height in a neighborhood (i.e. peaks):

- For each spot height, a fixed circular surrounding area is analyzed.
- If it has the maximum height in the area → peak of the area.
- The area is enlarged until a higher point is found.
- The peak category depends on the size of the its “peak area”.

![Diagram showing the analysis of spot heights and the categorization of peaks.](image)
Shape (only peaks):

- For each spot height, a non-circular neighborhood is analyzed.
- This neighborhood is defined by the lowest contour that includes only 1 peak (base contour line or BCL).
- The relationship between the BCL and the peak determines the shape:
  - Conic or asymmetrical
  - Open or closed
Only related with height value:

- Higher points have more importance than lower points
Once the points are classified, a weight to each point is assigned. How?

Combining:
- The value of the previous categorization
- An specific value assigned by the user to each category

This specific value allows modulate the result of the automatic generalization depending on the final product, for example emphasizing the geomorphologic points or minimizing the interest points.
Following this criteria, the first ICC priorities were:

1. Points interest:
   1.1 Crossroads
   1.2 Roads
   1.3 Map names
   1.4 Other areas

2. Peaks
3. Passes
4. Depressions
5. Rest of the points
GENCOTES:

SELECTION

- Takes into account:
  - Categorization of the spot heights
  - Density on the generalized data

- Density:
  - Division of the space
  - Rectangular areas with a similar number of points in the original data
ADAPTATION OF GENCOTES TO ICC SPECIFICATIONS

- After several proofs on selected test areas:
  - results were really promising, but
  - some modifications should be done to improve them

- The modifications were related to:
  - prepare input data to optimize the process
  - define new interest points
  - improve the classification
  - define new selection criteria
ADAPTATION OF GENCOTES TO ICC SPECIFICATIONS

ICC requirements in interest points - Roads

- One spot height every 1200 m on the catalogued roads
- Road intersections are preferred points
- In road intersections, main roads are preferred

- Input data was specially processed to:
  - Eliminate the nodes
  - Generate intersections as explicit classified points according to the importance of the road
Spot heights on the roads and on their intersections
ADAPTATION OF GENCOTES TO ICC SPECIFICATIONS

ICC requirements in interest points - Roads

- A new category of interest points has been added:
  - Intersections between not catalogued roads and paths
  - But, with less priority that other interest points, peaks, passes and depressions
  - This points were classified as a remainder points in the original version
ICC requirements in interest points – Map names

- In the original version, sometimes a selected point related to an orographic map name wasn’t coincident with the type of map name → the selected point must correspond to the geographical landform described by the map name (if the selected point is categorized as a peak, it cannot be related to a pass map name)

- Input data was specially processed to:
  - Export the map names classification according to the geographical landform (peak, pass or depression)
Spot heights on peaks or passes
ICC requirements in selection criteria

- It can not be selected a point with height, in meters, multiple of the contour line interval (10 meters in 1:25,000)

- Sometimes although the density of selected points was correct, the distribution was not homogeneous enough for the ICC requirements. To solve this problem, the space division was changed to a regular space division: rectangles of the same size which contains more or less the same number of points in the target data.
Finally, the ICC priorities are:

1. Points interest:
   1.1 Crossroads
   1.2 Roads
   1.3 Map names
   1.4 Other areas

2. Peaks
3. Passes
4. Depressions
5. Intersections between not catalogued roads and paths
6. Rest of the points
ICC requirements in classification

- In the original application the classification from the geomorphologic aspect was performed after the classification of interest points. In this way geomorphologic aspects was not applied to the interest points

- ICC suggested apply geomorphologic classification to all the spot heights. Moreover the original database can be enriched with this classification
ICC requirements in workflow optimization

- The original application required the cartographer interaction during the process. ICC suggested to interact only at the start point, that it means that the application can run in a batch mode.

- To control the process and the possible errors, the application stores for each point the problems detected during the execution:
  - Missing altimetric point for map name (peak, pass, etc)
  - Altimetric point eliminated by density problems
Four sheets (125 km²/sheet):

- Flat area
- Urbanized area
- Middle mountain area
- High mountain area

Comparison between automatic results and assisted manual results
RESULTS:
HIGH MOUNTAIN - COMPLETE SHEET

In red the original points, in green the automatic selection
RESULTS:
HIGH MOUNTAIN SHEET - DETAIL

In red the original points, in green the automatic selection
RESULTS:
HIGH MOUNTAIN SHEET - DETAIL

In red the original points. Automatic selection in green, manual in yellow
RESULTS:
HIGH MOUNTAIN SHEET - DETAIL

In red the original points. Automatic selection in green, manual in yellow
RESULTS:
AUTOMATIC vs MANUAL PROCESS

Manually generalized spot heights types proportion

GENCOTES automatically generalized spot heights types proportion

Flat area
Urbanized area
High mountain
Middle mountain
Automatic process:

- Most homogeneous distribution of the final points
- More selective than the manual process with the different type of points. Because in manual process is difficult to detect visually the significant points: contours help to detect peaks, but the detection of passes or depressions is not so easy

Manual process:

- The process takes into account more aspects. The specifications don’t contain all the contextual and aesthetical rules applied in manual process

RESULTS: AUTOMATIC vs MANUAL PROCESS
INTEGRATION IN THE BT-25M WORKFLOW

AUTOMATIC PROCESSES
- Feature Selection
- Merge of the 16 sheets from the 1:5K database
- Node generation
- Line simplification
- Building generalization:
  - Block aggregation
  - Inside each block:
    - Building simplification
    - Building aggregation
    - Building simplification
    - Z-coordinate assignment
- Centerline generation
- Map names generalization

ASSISTED INTERACTIVE PROCESSES
- Spot height selection
- Minimum length and area generalization
- Map names edition
- Conflict resolution
- Aesthetic refinement

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ASSISTED INTERACTIVE PROCESSES
- Minimum length and area generalization
- Map names edition
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- Aesthetic refinement
INTEGRATION IN THE BT-25M WORKFLOW

- More objective process
- Reduction of the cost (saved time around 3% of total cost):
  - Manual → around 9 hours/sheet
  - Automatic + manual revision → around 3 hours/sheet

Automatic result

After manual editing to solve conflicts
FURTHER DEVELOPMENTS

- Migration to ArcGis 9.2

- Integration in the MT-10M workflow:
  - Reduction of the cost (saved time around 40%):
    - Manual → around 10 hours/sheet
    - Automatic + manual revision → around 2 hours/sheet
CONCLUSIONS

- Automatic spot height generalization using GENCOTES is slightly different from the obtained using manual processes.

- The differences come from the difficulty to specify all the contextual and aesthetical rules.

- The results of the automatic process are good enough to be implemented in a real production environment: there is an effective time saving and an improvement in terms of homogeneity without an important loss of quality.

- These tools make more feasible the possibility to apply in the future fully automatic generalization through the web or mobile services.