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Examination of cartographic generalization in multi-scale using digital elevation models

Theses of Doctoral Dissertation

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Introduction

The representation of terrain in maps was always labour-intensive and time-consuming; besides, the result is strongly influenced by the map-maker's geographic knowledge. Although most maps contain topographic information, the creating of digital elevation databases is rather limited: the surveys are made in detail, and the topography of small scale maps is derived from these databases. The recent manners of relief representation in maps are as follows: contour and bathymetric lines, hypsometry and bathymetry, spot heights, and hill shading.

My objectives of research were:

– The examination of topographic databases by focusing on open-accessed global or semi-global models and the Hungarian digital elevation models (DEM).
– Determining the relationship between the map scale and the resolution of the DEM, in which the DEM can be applied without any generalization.
– Examination of the suitability of DEM-s for cartographic purposes or what kind of preprocessing is needed before using them for relief maps.
– Collecting and analyzing the simplification and smoothing algorithms on isolines generated from DEMs, and giving

recommendation for the optimal automated generalization process.
- Creating an evaluation sheet to to show the results of generalization.
- Creating an automated manner for selection of contour and bathymetric lines in consideration of the topography of an area.
- Setting up a summary to support the education programmes because the topic of automated generalization has been missing from the Hungarian higher education.

Antecedents

Although the literature about the theory of traditional generalization is copious, much less attention is paid the execution of the process. As the Hungarian cartographers did not focus on the automation of generalization, the latest research paper is more than 15 years old. In contrast, this topic is very popular in the western European countries, in the USA and China. Currently, there are a lot of studies, and conference papers, several books and modules written on geoinformatics software for automated generalization. However, they were not developed for the purpose of terrain generalization.

Mátyás Márton introduced the concept of horizontal and vertical generalization (MÁRTON 2012). I followed this viewpoint in my research; besides, I tried to keep the most characteristic elements of the terrain, and save the geomorphologic forms in the maps.

Methods

Examination of DEM

I compared the DEMs with topographic or atlas maps to determine the resolution of the DEMs, and to check the formula for optimal scale-range. Most of the model, which are open accessible from the Internet, are surface models, which means the point cloud of the model also contains the objects laying on Earth's surface (such as vegetation, building). If the map-maker does not eliminate them from the model, they will be seen in the map. To detect and delete them, I used a free land cover data source (Corine).

In my research, I always pursued the usage of open source software and open data, and took my scripts open accessible. The wide accessibility guaranteed that the others could apply and develop further the program or data. I also tested and coded older algorithms e.g. image filtering methods (ELEK 2004), to compare them to the current ones or the methods developed by me.

Horizontal generalization

The generalization of contour lines can be executed by line simplification and smoothing algorithms. I collected the program codes or the detailed description of procedures. If I could not find the program, I have written it. I made visual and mathematical comparison among the results.

Vertical generalization

In large and medium scale maps, the interval of contour and bathymetric lines are constant. Earlier, the selection of each isoline in small scale was a much more subjective process, but recently it can be objectivized with mathematical rules. The hypsographic curve can help to select the appropriate elevations.

The above mentioned codes were written in Python. For reading and writing spatial data, I used the GDAL/OGR module. For displaying geodata, I applied the QGIS, Global Mapper or ArcGIS.

Automatic generalization in education

I compiled an outline based on Hungarian and English language literature for the education of automatic generalization. I examined and collected the available generalization modules in geoinformatics software at present (for example: QGIS, ArcGIS, FME, MapShaper.org, and database handling software).

Results

1. I collected the most popular open accessed, global or semi-global DEMs, and I examined their adequacy for relief representation in maps with various cartographic methods that can be found in geoinformatics software. I defined the term of optimal scale range, in which the details of geomorphologic features or the DEM are appropriate for the selected map scale. I combined DEMs with different resolution for the mainland and the oceans with simple geoinformatics operations. I achieved the right representation of continental depressions in DEMs. I corrected the distortion effect of vegetation in DEMs: I extracted the forests on lowlands, and the reedy areas from the lake surfaces, thereby the accuracy of DEMs was improved.

2. I presented the challenges of DEM's generalization. A DEM can be simplified by digital image filtering manners. I analyzed the inconsistencies caused by the filters, and tested the cartographic terrain representation methods on them. I modified the image filtering algorithm, then I added the lake's polygons and the river's polylines to reduce the mistake. I called it coordinated generalization.

3. The contour and bathymetric lines also can be generalized by line simplification and smoothing algorithms. I collected and reclassified the currently used line simplification and smoothing procedures. I tested and evaluated them following my criteria. I also examined the quality of the result generalized by various algorithms in large, medium and small scale maps. I made several sample maps about the continental as well as the maritime areas. I compared the results of line generalization and modified image filtering, and I gave suggestions to their usage. I studied, how the characteristics of isolines can be preserved the best in small scale. Furthermore, I reviewed the attempts of automatic generalization for supplementary contour drawings. At last, I summarized the mistakes committed by the inexperienced map-makers.

4. I elaborated a method that considers the elevation's distribution of an area in vertical generalization. Although I collected the contour intervals from national topographic maps, I focused my research on small scale maps. I divided the Earth's surface into further elevation layers to calculate the area of each layer, and I verified the previous results of Mátyás Márton by using DEMs and digital calculation methods. These layers formed the basis of my further research: I defined for any area which contour or bathymetric lines have to be displayed for best visualization. Besides, I summarized the generalization of a spot height database.

5. I elaborated an outline for the education of generalization, and I presented the current modules and software in generalization. I collected the most important English language and the Hungarian literature for introductory and master level courses. I tested the open source and the business software that contain generalization modules.

Finally, I compiled an outline for the education of automation in generalization.

Conclusions

The cartographic generalization is a subjective process, which cannot be completely automatize. The map editor has to undertand the potentials of automation in theory as well as in practice. The automation can help to save time and labour while map making, but it is necessary to check and correct the errors manually. The number of mistakes or inaccuracies caused by algorithms depends on the chosen procedure, the degree of generalization, the differences between the original and the target scale, and the quality of input data.

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