AUTOMATED SMALL-SCALE RELIEF SHADING: A NEW METHOD AND SOFTWARE APPLICATION

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ABSTRACT:
Shaded relief derived from high-resolution terrain models often contains distracting terrain details that need to be removed for medium and small scale mapping. This paper introduces Terrain Sculptor, a software application that prepares generalized terrain models for relief shading. The application uses a generalization methodology based on a succession of raster operations. Terrain Sculptor offers a graphical user interface to adjust the algorithm to various scales and terrain resolutions. The freeware application is available at http://www.terraincartography.com/terrainsculptor/.

Keywords: *Relief shading, Terrain Sculptor, graphic user interface.*

1. INTRODUCTION

Automatic relief shading is nowadays commonly used for relief mapping. Yet, many cartographers consider manually produced shaded relief to be superior. A discrepancy in quality between automatic and manual shading is especially visible at small scales. Small-scale shaded relief derived automatically from high-resolution digital elevation models shows many disturbing terrain details and often fails to emphasize important landscape features. Standard GIS software generally does not provide appropriate generalization tools for both removing unnecessary details and for preserving main landforms. When standard raster filter operations are applied to digital terrain data, important ridges and valley edges are blurred, and their characteristic shape is not portrayed successfully in shaded relief.

This paper presents a new method for the generalization of digital elevation models specifically designed to process digital elevation data that afterwards can be used to calculate generalized relief shading. The method was developed by *Leonowicz et al.* (*2010*) and implemented in the freeware software application Terrain Sculptor.

2. GENERALIZATION METHOD

The generalization method consists of a succession of raster operations performed on digital elevation data. The general idea is to divide the terrain into mountainous and lowland areas, and to separately generalize these morphologically different areas—in different ways—and afterwards re-combine them into one elevation model. This idea follows a principle formulated by *Imhof (1982)* for manual relief shading, who recommends accentuating ridge lines in high mountain areas and river valleys on flat plains. The digital method uses the following operations, which are illustrated in **Fig. 1**:

1. Digital elevation data (**Fig. 1A**) are filtered with a low-pass filter to produce a smoothed elevation model (**Fig. 1B**). This model serves as a base surface onto which relevant details are added using the following processing steps.

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2. Terrain features (ridges and valleys) are detected by curvature coefficients: maximum and plan curvature are used to identify ridge lines, and minimum curvature is used to identify valleys (see *Wilson and Gallant, 2000* for details on curvature computation). For detecting large terrain features and removing small details, elevation data are smoothed, using a mean filter, before calculating the coefficients.

3. Two additional elevation models are created by vertically exaggerating and deepening the smoothed elevation model (models not represented in **Fig. 1**).

4. Two grids with weighting factors are created from curvature coefficients (**Fig. 1C** and **D**), and used to combine the exaggerated model and the deepened model of step 3 with the smoothed model generated in step 1. In areas with extreme curvature values, either the exaggerated model or the deepened model of step 3 is used, whereas the smoothed model of step 1 is used in areas with low curvature values. As a result of these combinations two elevation models are created: a mountain model (**Fig. 1E**) and a lowland model (**Fig. 1F**).

5. Smoothed slope values (Figure 1G) are used to re-combine the mountain model with the lowland model. The mountain grid is used in the areas with high slope values (white in **Fig. 1G**) and the lowland grid in areas with low slope values (black in **Fig. 1G**).

6. A shaded relief image is calculated from the model generated in step 5 (**Fig. 1H**).
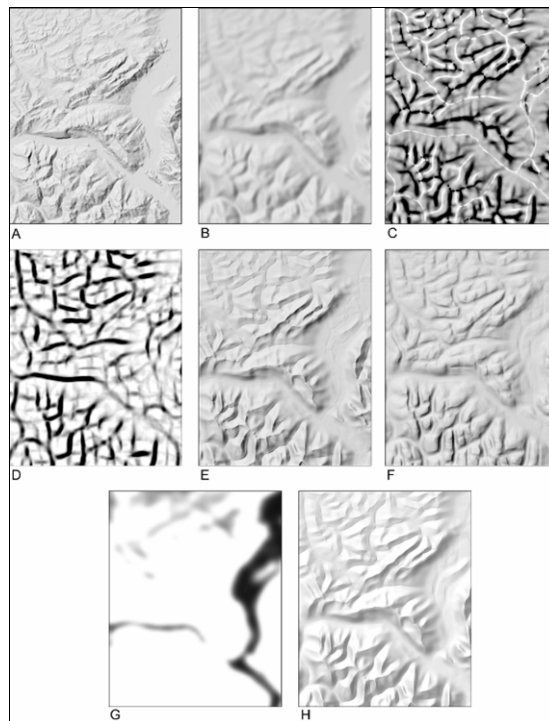

Fig. 1 Intermediate steps of the generalization method. A: ungeneralized terrain model. B: smoothed terrain model. C: weights for exaggerating ridges. D: weights for deepening valleys. E: mountain model with exaggerated ridges. F: lowland model with deepened valleys. G: weights for combing models E and F. H: final shaded terrain model

3. IMPLEMENTATION: TERRAIN SCULPTOR

Terrain Sculptor is a cross-platform Java application implementing the generalization procedure described above. The application is intended as a production tool for creating generalized shaded reliefs at small and medium scales. *Terrain Sculptor* reads and generalizes digital elevation models, which can then be visualized with any shading algorithm in other GIS or mapping software. *Terrain Sculptor* can also calculate shaded relief using a standard diffuse shading algorithm, and export it as a raster image file.

Terrain Sculptor processes elevation data according to the steps outlined in the previous section. The user is not required to understand the details and the various steps of the generalization method. The graphical interface instead aggregates various detail parameters and displays them as slider controls that are straightforward to understand. The application offers two interface modes: the basic mode consists of only two sliders to adjust the level of detail and the scale-dependent shading style. The interface elements of the advanced mode are shown on the left side of **Fig. 2** marked with numbers 1–5. They adjust the following parameters (numbers as in **Fig. 2**):

1. the number of filter passes used to smooth the original elevation model,
2. the size of ridges that are removed from the elevation model,
3. the vertical exaggeration of ridges,
4. the sharpness of ridges,
5. the slope threshold discerning between lowland areas and mountain areas.
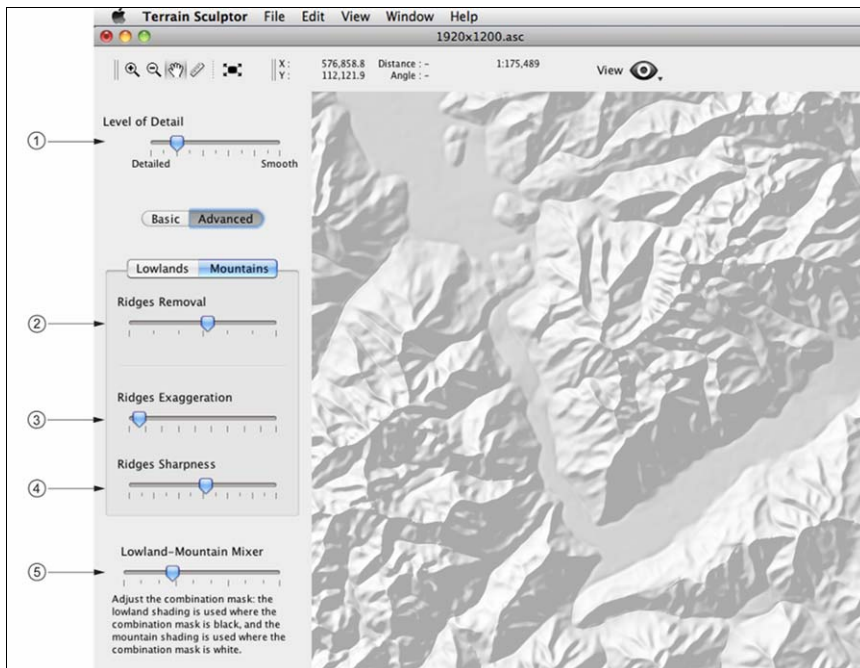
Fig. 2 Graphical user interface of Terrain Sculptor in "Advanced" mode
for adjusting generalization parameters

Three additional parameters can be adjusted in the lowlands panel (not visible on **Fig. 2**):

- the size of valleys that are removed from the elevation model,
- the amount of valley deepening, and
- the width of valley bottoms.

4. RESULTS

Fig. 3 and **4** show examples of shaded relief at medium and small scales generalized with *Terrain Sculptor* and compare them with manual and digital ungeneralized shading. Figure 3 shows medium scale terrain shadings at 1:1 000 000. Digital shading was calculated from SRTM data with a spatial resolution of 3 arc seconds (approximately 100 meters). **Fig. 4** shows shaded reliefs at 1:15 000 000 of the Carpathian Mountains. Digital shading on this figure was calculated from GTOPO30 data with a spatial resolution of 30 arc seconds (approximately 1 km).
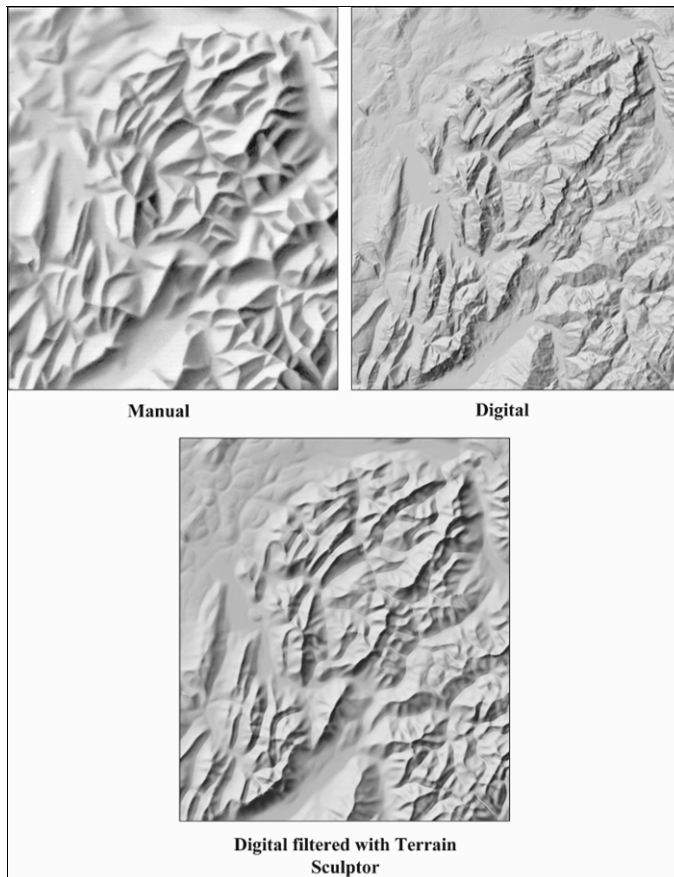
Fig. 3 Shaded relief at 1:1 000 000. Uper Left: Federal Office of Topography swisstopo DV033492.2
Upper-right: from raw SRTM data. Bottom: from SRTM data generalized with Terrain Sculptor

Without prior generalization digitally shaded relief (**Fig. 3** and **4**, uper-right) is not successful at portraying the main structures of a terrain: the many details and the static light direction result in an unstructured portrayal of the terrain. It appears as a disjointed collection of minor features and major landforms are difficult to detect. By contrast, the major landforms are immediately visible in the manual shading, because unnecessary details are removed and the light direction is locally adjusted to optimally illuminate landforms within the terrain trending in different directions.
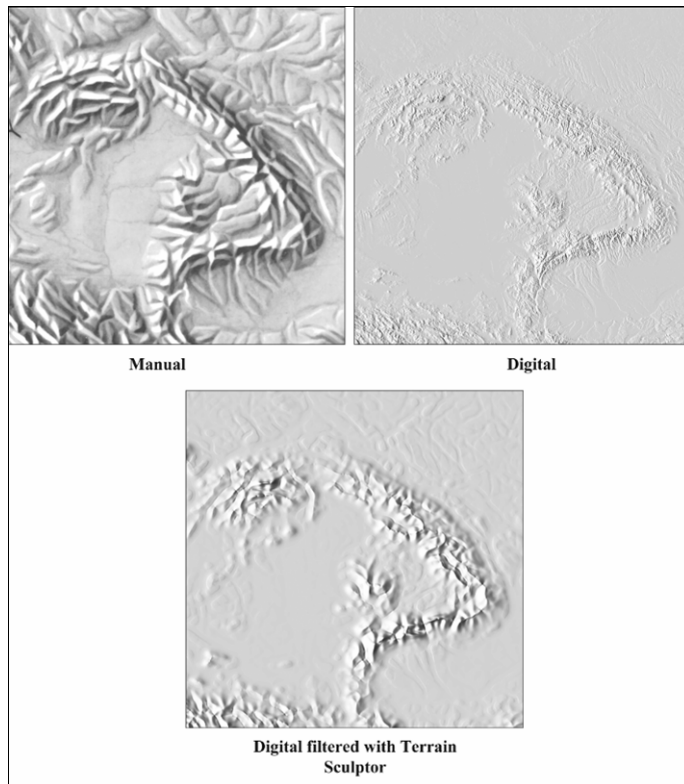
Fig. 4 Shaded relief at 1:15 000 000. Uper-left: Swiss World Atlas 2008. Uper-right: from raw GTOPO30 data. Bottom: from GTOPO30 data generalized with *Terrain Sculptor*.

Fig. 3 and **4** (bottom) show the same terrain generalized with *Terrain Sculptor*. A comparison with the shading derived from the original ungeneralized elevation data shows that *Terrain Sculptor* removes many of the unnecessary small terrain details, while the sharp structures of the main landforms are preserved. Ridges and valleys are clearly visible and unmarred by small terrain irregularities. Mountains are much more prominent and have a unified structure. The level of details achieved with *Terrain Sculptor* is similar to that of the manually-produced shaded relief at the same scale (**Fig. 3** and **4** uper-left). Differences are mainly due to local adjustments of the light direction, and the individual cartographer's manual shading style. Identical results can therefore not be expected.

5. CONCLUSIONS

Terrain Sculptor is a freely available software application for generalising digital terrain models, available at http://www.terraincartography.com/terrainsculptor/. The implemented generalisation method removes unnecessary and distracting terrain details, while accentuating main landscape features. The application can preprocess terrain models before standard shading is applied in GIS and raster mapping software, which often does not provide appropriate terrain generalisation algorithms. *Terrain Sculptor* will hopefully help geographers and cartographers generate improved terrain visualisations, especially at small and medium scales.

R E F E R E N C E S

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