Digital Cliff Drawing for Topographic Maps

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Abstract

In topographic mountain maps, cliff drawings are among those map elements which are most difficult to be produced. After a short overview of the most common cliff representations, new techniques are presented which allow to generate simplified ridge line and scree representations in an entirely digital and effective manner. Using examples, different applications of the program system are presented.

A brief overview of the historic development of cliff representation in Switzerland

When the first complete large scale surveys were carried out in the 19th century, also mountainous areas had to be mapped with an accuracy never needed before. Especially in the Alpine countries, techniques for a clearly designed but nevertheless precise terrain representation were developed. The most prominent examples are manual hill shading and cliff and scree drawing. However, as it is very often the case in cartography, graphic quality, clearness and geometrical precision are sometimes not fully compatible. Logically, different cartographic demands and applications also lead to a very broad variety of representations.

In the case of cliff drawing, mostly methods which were derived from slope shading hachures have been used. In Switzerland, already in the Dufour map (1838–1865) such hachures are overlayed by cliffs (see Figure 1). When changing to contour line maps, cliff drawing and topography could be consequently disentangled.

At the Federal Office of Topography (“Landestopographie”) at Wabern/Berne the technique of shadow cliff hachures has been developed further, especially after 1935 when the production of the new National Map Series began. Cliff areas are divided into morphologically compact units using structure lines. Structure or shape lines as well as the vertical or horizontal filling hachures are modulated according to an illumination model (see Figure 2).

As an example of this technique, figure 3 shows an extract of the map covering the “Panta” area in the Peruvian Andes [Spiess 1960]. The modulated shape lines and filling hachures have been scribed on coated glass plates. The rough, natural appearance has been created by the adequate handling of the grooving tool. More details concerning the cliff representation of the Swiss National Map Series can be found in [Spiess, 1970] and [Gilgen 1998].
Alternative cliff representations and recent experiments

Besides the cliff shadow hachures used by the Federal Office of Topography, a broad variety of alternative techniques exists. In Switzerland, intensive discussions about a new kind of cliff representation have been lead mainly in the Twenties and Thirties. Especially the proposal of W. Blumer, a former engineer at the Federal Office of Topography, must be mentioned. His method is very closely based on the original photogrammetric compilation and does not allow a geometrical exaggeration of cliff objects. Vertical cliffs are replaced by short, barely modulated hachures perpendicular to the contour lines. They are only interrupted by number lines. In less steep areas contour lines are not interrupted whenever possible. In some cases they are replaced by light, horizontal or vertical fill hachures. Figure 5 shows an extract of Blumer’s map of the Glärnisch massif compared to the Swiss National Map Series 1:25 000.

Figure 1: Extract from the Dufour map, sheet XVII “Vevey–Sion”, 1844. Slope shadow hachures combined with cliff hachures.

Figure 2: Modulation of shape lines (outlines) and filling hachures according to aspect. Source: Internal guidelines of the Federal Office of Topography [L+T, 1996].

Figure 3: Extract from the black plate of the map “Panta 1:25 000” by E. Spiess with cliff representation. Scribing on coated glass plates.

Figure 4: Extract from the Alpine Club Map “Steinernes Meer” by Leonhard Brandstätter.
Figure 5: Comparison of extracts from Walter Blumer’s map from 1937 (left) with the Swiss National Map Series 1:25 000, sheets 1153 and 1179 (right).

Figure 6: Map specimen series “Spitzhorn” produced by the Federal Office of Topography (1933). top left: Ridge line representation, top right: “classical” method with fill hachures and right: contour line representation with a light hill shading.

Later, the method of Blumer has been taken up again and modified by Leonhard Brandstätter. He also strives for an orthogonal and geometrically precise representation and for a combination of cliff drawing and contour lines. The plasticity of the bundled contour lines (“Scharungsplastik”) is mated with a ridge and edge line drawing which should help to pronounce the morphological and geological structures. The representation is...
supported by a locally matched hill shading. Figure 4 shows a cliff representation. [Brandstätter, 1996] gives an overview of the different cliff representation techniques used in the German and Austrian Alpine Club Maps.

Another method is the ridge line representation [Imhof, 1965]. Only dominant edges and structure lines are represented and modulated. Fill hachures are omitted. In 1933, the Federal Office of Topography compared the ridge line representation, the “classical” method with fill hachures and a contour line representation with a light hill shading in a series of map specimens (see Figure 6).

In the last years, mainly tests with combinations of orthophotos with conventional map elements have been undertaken. The experiments of [Aschenbrenner, 1993] with aerial images and overlaid ridgeline drawings must be mentioned. Figure 7 shows the main problems of the use of orthophotos in a high mountain environment. Steep shadow areas loose their information content (center bottom) and uninterrupted contour lines disturb the perception of the map image (upper left). However, in the original image, some line elements are depicted in colours.

### Digital cliff drawing

Unfortunately, most of the presented techniques are very time-consuming and costly to produce. For instance, the cliff drawing of an average mountain sheet of the Swiss National Map Series required about 2000 working hours and caused costs of about 250 000 Swiss Francs per sheet! It does not surprise that today, completely new designs of cliff plates can only be carried out in special cases, like for instance the National Geographic map of Mount Everest. Nevertheless, when carrying out new cartographic surveys and mappings, the question of how to represent rocky areas geometrically correct, well designed, inexpensive and computer-compatible is still relevant.

In a mapping project of the Institute of Cartography at ETH Zurich, about 1100 cliff objects on a volcanic peninsula in Greece had to be mapped in short time. In a pilot project, a program which allows the semi-automatic generation of cliff drawings has been developed for the first time. The ridge line representation which displays only the major contours, ridges and drains has been chosen in order to avoid the placement of complex hachures. The upper and lower edges of a cliff are digitized manually from field sketches. A catalog of design rules can be found in [L+T, 1996]:

- The representation is reduced to vertical ridges and drain lines (“form” lines) and upper and lower edge lines. There are no fill hachures.
- The line hachures should have a rough appearance.
- Aggregation of objects and high light/shadow contrasts are necessary.
- Light and shadow sides should be easily distinguishable by their overall brightness (line weights!).
- On the shadow side, upper edges are thicker than lower edges (cuneiform).
- On the light side, upper edges are thinner than lower edges.
- On the shadow side, vertical form lines are thicker on the upper side; on the light side they are thicker on the lower side.
- The angle of light is assumed from Northwest.
- On the shadow side and with Southwest to Southeast aspects, edge lines are thicker on the left side; with Northeast to Southeast aspects, they are thicker on the right side. With pure Southeast aspects, the lines are thicker on both sides and thinner in the centre.
- On the light side and with Northwest to Southwest aspects, edge lines are thicker on the left side; with Southwest to Northeast aspects, they are thicker on the right side. With pure Northwest aspects, the lines are thinner on both sides and thicker in the centre.
- Due to erosive effects, very often concave and convex shapes of the cliffs can be found.

Digitised upper and lower edges of the cliff objects with an identical number of vertices serve as input data. This leads to a box shaped ridge line image containing those edges and the vertical form lines. Therefore, the
method is best used for long cliff bands. All edge and form hachures are cuneiform and modulated according to an illumination model e.g. their line thickness is varied by aspect (see Figure 8). The rough appearance is simulated by a local variation of the line widths and the line positions using a random function. The program allows to fine-tune the line widths according to their position and aspect with about 250 parameters. Also concave and convex shapes between the vertices can be simulated with different degrees of cavity (see Figure 9). Manual corrections can easily be applied in an image manipulation program after rasterising the vector output of the cliff drawing software. Figure 10 shows the major production steps. For a detailed technical description, see [Hurni, 1995].

**Representation of scree**

Basically, one can distinguish between two main approaches for the morphological correct representation of scree: Area based approaches and line based approaches.

In the area-based approach [Spiess/Hutzler, 1993; Hurni, 1995], first a regular grid with a user defined resolution is initialised. The algorithm adds deviation in both x- and y-axis within a specified tolerance. Furthermore it varies in both block size and shape. Additional input parameters are the minimum distance to the edges of the input polygon, a minimum decartelisation distance between two colliding points and percentage values of each block shape on the overall of different block shapes. Besides, the user can influence the initial grid: Perpendicular, horizontal or diagonal arrangement.

If the goal is to represent scree flows with respect to gravitation or discrete thin scree flows (e.g. in deep ditches), the area based approach might not be satisfying. The line based approach [Hurni/Neumann, 1998] pays attention to these demands but is a bit more time-consuming. It starts with the vertices of a manually digitised line (trajectories). The algorithm first densifies the vertices along the line and then adds random values in both directions, along and perpendicular to the input line, resulting in rather natural block positions along the trajectory. Additionally it randomises block shape and size. Finally it increases block size continuously from top to bottom.

Both approaches have been implemented in perl in cooperation with Arc/Info and Corel Draw and will likely be implemented in Macromedia Freehand until the ICA conference takes place. The blocks are dropped as font symbols.
Examples

Up to now, the program has been applied in three large mapping projects: The digitisation of the 1100 cliff objects at the scale of 1:25 000 and the design of area based scree representation could be carried out in about 40 working hours (see Figure 13). In a large mapping project on the Arabic peninsula, dangerous canyon cliffs have been designed at the scale of 1:50 000 based on orthophotos. In a test map 1:25 000 of the Silvretta massif in the Austrian alps, the method was successfully used to visualise large cliff walls for the first time as well as a line based scree representation (see Figure 14).

Conclusion and further developments

The successful application of the described procedures proved their good performance and the necessity of easily producable cliff and scree representations. Nevertheless, control of the full process by an experienced operator is still necessary and desired. However, some craft related difficulties like e.g. the modulation of the hachures can be eliminated.

The original version of the cliff program worked only in batch mode on an Intergraph UNIX system. Thus, the cliff objects had to be digitised in groups before the program could be executed. In the last months, an interactive version has been developed. It serves as an extension to Macromedia Freehand (“Xtra” plugin) and allows fully interactive design and control of every single cliff object. Figure 15 shows the interface of the Freehand plugin, which allows to set parameters like light/shadow side, size of objects, cavity, overall line weights, and weights of the five line sections which make up a hachure. For further information about the plugin, please contact the authors.

Figure 10: Production steps for digital cliff drawing. From top to bottom: Digitisation of upper and lower edges, raw output of program, manual retouching, comparison with manual drawing after [Imhof, 1965].

Figure 11: Area based approach for automated scree representation. Initial grid, randomizing position, form and size.
**Figure 12**: Line based approach for semi-automated scree representation. Variation of block distance, excursion to the digitised axis, variation of block shape and increase of block size towards the lower end.

**Figure 13 (top)**: Extract from the Topographic Map 1:25 000 of Methana Peninsula in Greece with digital cliff drawing and scree representation according to the area based approach.

**Figure 14 (bottom)**: Extract from a test map 1:25 000 of the Silvretta massif with digital drawings large cliff walls and a line based scree representation.

Of course, the methods can only be applied in a limited range of cases. Further research should cover the implementation of a pallet of basic morphological structures and modules which could be assembled in order to create complex cliff walls and representations. However, our work proved the feasibility of the algorithms for the design of difficult cartographic representations, with well chosen simplifications and controlled by an experienced cartographer.
Figure 15: Interface of the Freehand plugin.

References


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