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Cartographic Generalization in the Automated Generation of Multiscale Cartographic Representations of Rock Formations

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Abstract:

The representation of rock formations in topographic maps remains a challenging task in cartography due to their specific morphological characteristics. Traditional cartographic approaches, particularly hachure-based representations, allow these features to be depicted in a visually expressive and informative way; however, their manual production is highly demanding in terms of both time and expertise. Despite partial advances, the automation of cartographic representations of rock formations therefore remains an open and not yet fully resolved problem, closely linked to the issue of cartographic generalization and, more broadly, to the generation of multiscale representations.

Building on previously proposed workflow for the automated creation of rock formation representations in the so-called “ladder style” technique (Kyncl and Lysák 2024), which is designed for a specific target scale, this paper addresses the challenges associated with extending this approach to a multiscale context. It focuses on the role of cartographic generalization in enabling consistent representations across multiple scales. Generalization is considered a key component of the entire process, as it fundamentally determines the ability to produce consistent representations across multiple scales. The contribution does not primarily focus on the generation process itself, but rather on the role of generalization within it and on the identification of possible approaches to its implementation. The proposed framework is primarily designed for rock formations within the Czech State map series, but with appropriate modifications and input data, it is transferable to other geographic contexts.

The proposed approach is implemented as a unified workflow. Starting from a digital elevation model and rock polygons, key structural features – particularly terrain skeleton lines – are derived and subsequently used as input for automated hachure-based representation. The entire process is parameterized, allowing the level of generalization to be controlled according to the target scale and desired level of detail.

Within the proposed framework, generalization is conceptualized as a multi-level process that operates across different stages of data processing and takes different forms. These levels interact with each other, and their combination critically determines the resulting cartographic representation. Two main levels of generalization can be distinguished: (i) generalization of input topographic information and (ii) generalization of the cartographic representation itself.

The generalization of input topographic information enters the process at its initial stage and can be further divided into three main components: (a) generalization of the input DEM – this step reduces unnecessary detail in the raster elevation model while preserving morphologically significant features (terrain skeleton lines). To preserve these key structural elements, an edge-preserving filtering approach based on Line Integral Convolution (LIC) is applied (Geisthövel and Hurni 2018). The method is parameterized, enabling its settings to be systematically adapted to the target map scale, with increasing generalization achieved through scale-dependent adjustment of LIC parameters. (b) Generalization embedded in feature extraction methods – this component is based on the parameterization of methods used to derive vector features from the DEM, particularly terrain skeleton lines. These features form a crucial input for subsequent cartographic representation processing, and their level of detail directly affects the final output. Generalization is not performed as a separate operation but is inherently embedded in the feature extraction process. By adjusting method parameters, it is possible to control the number, length, segmentation, and geometric complexity of detected features. (c) Generalization of vector data derived from the DEM – this stage involves direct modification of derived linear and areal features, such as terrain edges and rock polygons, using standard cartographic generalization operators (e.g., line simplification), resulting in further scale-dependent reduction of detail.

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The generalization of the cartographic representation takes place in the final stages of the process. In the context of "ladder style" hachure representation this primarily involves adjusting the geometry and parameters of individual hachures, including their density, length, orientation, and spatial relationships (Figure 1). The level of detail is influenced both by the properties of the input data and by the parameter settings of the hachure generation process. Generalization is thus reflected not only in the reduction of elements, but also in modifications of their graphical characteristics, directly affecting map readability and visual interpretation of the terrain.

Figure 1. Illustration of generalization of cartographic representations.

The proposed approach demonstrates that cartographic generalization in automated mapping cannot be treated as a single isolated step, but rather as a complex process distributed across the entire workflow. The interaction between different levels of generalization is essential for achieving visually coherent and cartographically appropriate representations at multiple scales. The paper thus provides both a methodological framework for a specific class of topographic features and a more general conceptual perspective on multi-level generalization in multiscale cartographic representation.

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