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Neural-Based Cartographic Relief Shading for Alberta

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Abstract:

Relief shading remains one of the most effective techniques for communicating terrain structure, but its success depends on more than the physical simulation of illumination. In the Swiss cartographic tradition (Imhoh, 1982; Hurni et al., 2025), shaded relief was developed as a designed interpretation of landform structure in which tonal balance, selective emphasis, terrain hierarchy, and readability were prioritized alongside realism. Although analytical hillshading (Burrough and McDonnell, 1998) later made terrain depiction faster and more reproducible in GIS-based workflows, it often fell short of the clarity and expressive quality achieved by expert manual shading. Recent neural approaches (Jenny et al., 2021) offer a promising alternative by learning cartographic design characteristics from high-quality examples and making them usable in practical software environments such as Eduard (2025).

The scope of this study is to better understand and evaluate neural-based cartographic relief shading through a geographically grounded investigation centered on Alberta, Canada. More specifically, it develops an integrated framework that links the historical foundations of shaded relief, the perceptual effects of illumination direction, and the practical evaluation of neural rendering across diverse terrain types and map scales. The study places AI-based hillshading within the longer development of relief representation and presents contemporary neural methods as a continuation of both Swiss manual shading traditions and later analytical terrain-visualization techniques. From this perspective, neural-based relief shading should be assessed not only in terms of technical realism, but also through cartographic criteria such as terrain legibility, visual hierarchy, naturalness, and scale-appropriate depiction.

A central component of the study examines illumination direction as a perceptual design problem in Banff National Park within the broader Alberta Rocky Mountain context. Conventional Euro-American hillshading has long favoured upper-left or northwestern illumination (Biland and Coltekin, 2017), based on assumptions about how readers interpret lighted landforms. However, research in vision science (Morgenstern et al., 2011) suggests that this prior is more flexible than traditionally assumed and that terrain perception is also shaped by cues such as shadows, hydrography, vegetation texture, snow patterns, and atmospheric perspective. Because Banff's ridges and valleys are strongly aligned, northwest illumination may reduce contrast where light runs too parallel to dominant terrain grain. Southern-sector illumination may instead provide stronger cross-slope tonal variation and a more naturalistic appearance for a Northern Hemisphere alpine landscape. The analysis therefore reframes the problem from choosing a conventionally correct azimuth to identifying illumination strategies that best support terrain readability while preserving a convincing visual appearance for nonexpert map users.

The study further evaluates Eduard-based neural hillshading across Alberta's diverse physiographic regions, including alpine mountains, foothills, lower mountains, incised plains and badlands, broad agricultural plains, and subdued northern lowlands. Alberta provides an effective testbed for improving understanding of how neural-based cartographic relief shading performs under contrasting terrain conditions within a single regional framework. Eduard functions not only as a software tool, but as an application environment for neural-based cartographic relief shading, enabling controlled experimentation with terrain-type settings, generalization, aerial perspective, and related rendering parameters. Using six standardized 50km × 50km sites prepared from native 10m and resampled 100m DEMs, the study compares terrain legibility, naturalness, and scale appropriateness at 1:50,000, 1:250,000, and 1:500,000.

Overall, the study explores the future of relief shading and questions whether it should be hybrid rather than exclusively analytical or exclusively AI-driven. Swiss relief shading provides the conceptual foundation, perceptual testing clarifies how illumination influences terrain interpretation, and neural methods operationalized through Eduard make it possible to translate these insights into reproducible workflows for professional cartography. The contribution is a terrain-sensitive framework for better understanding, evaluating, and applying neural-based cartographic relief shading in Alberta in ways that are historically informed, perceptually aware, and practically relevant to modern map production.

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