International Cartographic Association
Association Cartographique Internationale

Selective Terrain Smoothing

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Keywords: curvature, shaded relief, DEM, generalization

Abstract:

A typical approach to generalizing terrain—smoothing with a low-pass filter—often softens or removes detail useful for terrain recognition, notably ridgelines and peaks. This disadvantage can be mitigated with selective and partial smoothing. Second derivative properties of the surface are a useful proxy to identifying areas where we may want to smooth less. This project explores the use of second-derivative properties of the surface to selectively smooth the terrain. Areas where the second derivative is high—where slope changes rapidly—remain unsmoothed, while other areas (flat terrains, even if the terrain has significant but consistent slope) are smoothed more strongly. Results show crisp detail to differentiating features (the peaks of mountains and skeletal ridgelines; deep valleys) while effectively removing detail elsewhere.

Of the second-derivative properties available, we use the Laplacian as the simplest and easiest to calculate for arbitrary terrains. It also has advantages over profile or plan curvature in terms of analysis. The Laplacian shows the rate of change of the gradient—the vector function encapsulates both of the GIS-centric measures of slope and aspect. Thinking of terrains in terms of their orientation simplifies much of the workflow. We prefer the Laplacian with its specific ties to vector gradient because it can easily identify in a single value those areas where slope intensity changes, as well as areas where slope direction (aspect) changes.

An "alpha-masking" technique is used to selectively apply smoothing based on the Laplacian. This is a weighted sum technique to combine the generalized and sharp DEMs. The per-pixel alpha value, which we derive from the Laplacian weights the contribution of each of these inputs to the final result. Figure 1shows the distribution of alpha for the Churfirsten, Switzerland study area. Alpha values are strongly negative (purple) for ridgeline, and strongly positive (green) for drainages or narrow valleys where we want the sharp DEM to contribute more to the output. With this scheme, alpha values near zero (symbolized as white) will favour the smoothed DEM.

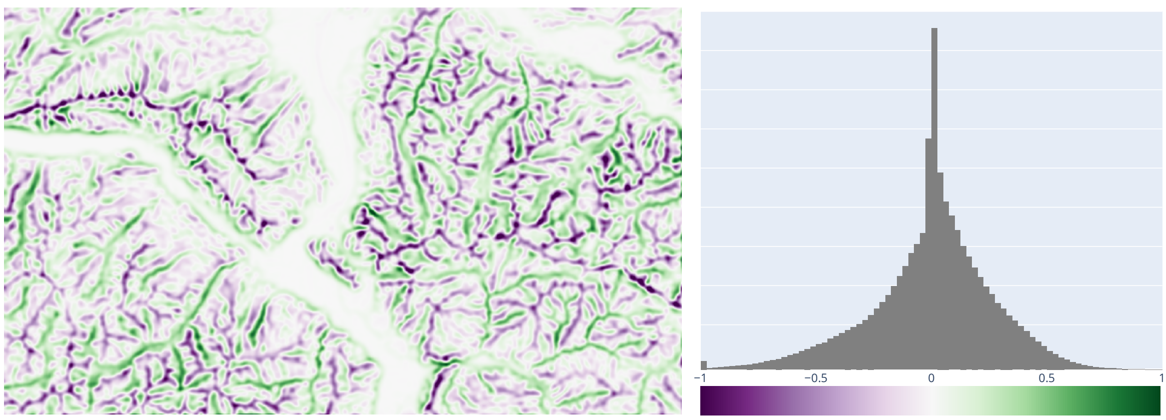

Figure 1. Alpha values derived from Laplacian.

A Laplacian-derived alpha value is used to combine two versions of the DEM, shown in Figure 2, below. The original, sharper DEM is combined with a generalized DEM created with a Gaussian blur of moderate strength. The rightmost panel in Figure 2 shows how these two versions of the DEM are combined using the alpha values in Figure 1. Where the alpha value encodes as a darker colour (either purple or green), the sharpened DEM dominates; white areas contribute more of the generalized DEM to the result.

Abstracts of the International Cartographic Association, 6, 259, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa.
https://doi.org/10.5194/ica-abs-6-259-2023

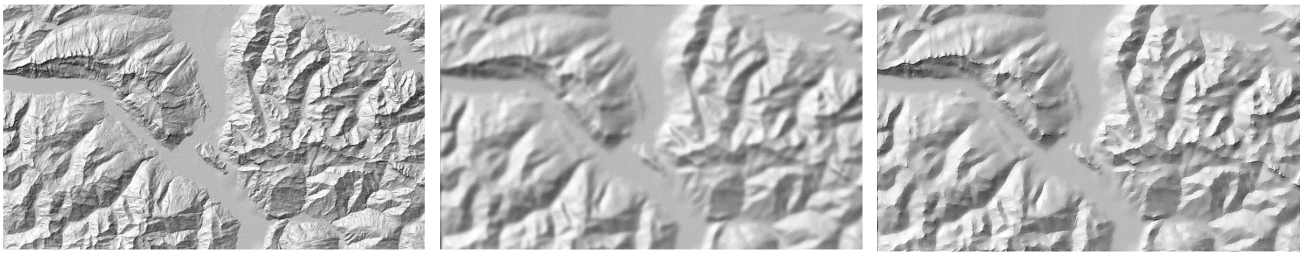

Figure 2. Shaded relief of the original DEM (left) generalized DEM (center) and blended DEM (right).

Alpha masking is not tied to the method for generalization, nor is it tied to generalizations at all. Any filtered (sharpened, generalized, de-noised, etc) versions of the DEM can be combined. Alpha values derived from a second derivative may have other uses, such as applying a non-uniform vertical exaggeration. A higher vertical exaggeration will increase the contrast in a shaded relief display; doing so in areas of high curvature can help to bring attention to these areas.

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https://doi.org/10.5194/ica-abs-6-259-2023