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Separating Landform from Noise in High-Resolution Digital Elevation Models through Scale-Adaptive Window-Based Regression

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Abstract : High-resolution elevation data are becoming increasingly available, but typical approaches for computing topographic features, like slope and curvature, still assume small sliding windows, for example, of size 3x3. That means that the digital elevation model (DEM) has to be resampled to the scale of the landform features that are of interest. Any higher resolution is lost in this resampling. When the topographic features are computed through regression that is performed at the resolution of the original data, the accuracy can be much higher, and the reported result can be adjusted to the length scale that is relevant locally. Slope and variance are calculated for overlapping windows, meaning that one regression result is computed per raster point. The number of window centers per area is the same for the output as for the original DEM. Slope and variance are computed by performing regression on the points in the surrounding window. Such an approach is computationally feasible because of the additive nature of regression parameters and variance. Any doubling of window size in each direction only takes a single pass over the data, corresponding to a logarithmic scaling of the resulting algorithm as a function of the window size. Slope and variance are stored for each aggregation step, allowing the reported slope to be selected to minimize variance. The approach thereby adjusts the effective window size to the landform features that are characteristic to the area within the DEM. Starting with a window size of 2x2, each iteration aggregates 2x2 non-overlapping windows from the previous iteration. Regression results are stored for each iteration, and the slope at minimal variance is reported in the final result. As such, the reported slope is adjusted to the length scale that is characteristic of the landform locally. The length scale itself and the variance at that length scale are also visualized to aid in interpreting the results for slope. The relevant length scale is taken to be half of the window size of the window over which the minimum variance was achieved. The resulting process was evaluated for 1-meter DEM data and for artificial data that was constructed to have defined length scales and added noise. A comparison with ESRI ArcMap was performed and showed the potential of the proposed algorithm. The resolution of the resulting output is much higher and the slope and aspect much less affected by noise. Additionally, the algorithm adjusts to the scale of interest within the region of the image. These benefits are gained without additional computational cost in comparison with resampling the DEM and computing the slope over 3x3 images in ESRI ArcMap for each resolution. In summary, the proposed approach extracts slope and aspect of DEMs at the lengths scales that are characteristic locally. The result is of higher resolution and less affected by noise than existing techniques.

Keywords : high resolution digital elevation models, multi-scale analysis, slope calculation, window-based regression
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