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A multi-directional and multi-scale roughness filter to detect lineament segments on digital elevation models – analyzing spatial objects in R

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Automated lineament analysis on remotely sensed data requires two general process steps: The identification of neighboring pixels showing high contrast and the conversion of these domains into lines. The target output is the lineaments' position, extent and orientation. We developed a lineament extraction tool programmed in R using digital elevation models as input data to generate morphological lineaments defined as follows: A morphological lineament represents a zone of high relief roughness, whose length significantly exceeds the width. As relief roughness any deviation from a flat plane, defined by a roughness threshold, is considered.

In our novel approach a multi-directional and multi-scale roughness filter uses moving windows of different neighborhood sizes to identify threshold limited rough domains on digital elevation models. Surface roughness is calculated as the vertical elevation difference between the center cell and the different orientated straight lines connecting two edge cells of a neighborhood, divided by the horizontal distance of the edge cells. Thus multiple roughness values depending on the neighborhood sizes and orientations of the edge connecting lines are generated for each cell and their maximum and minimum values are extracted. Thereby negative signs of the roughness parameter represent concave relief structures as valleys, positive signs convex relief structures as ridges. A threshold defines domains of high relief roughness. These domains are thinned to a representative point pattern by a 3x3 neighborhood filter, highlighting maximum and minimum roughness peaks, and representing the center points of lineament segments. The orientation and extent of the lineament segments are calculated within the roughness domains, generating a straight line segment in the direction of least roughness differences.

We tested our algorithm on digital elevation models of multiple sources and scales and compared the results visually with shaded relief map of these digital elevation models. The lineament segments trace the relief structure to a great extent and the calculated roughness parameter represents the physical geometry of the digital elevation model. Modifying the threshold for the surface roughness value highlights different distinct relief structures. Also the neighborhood size at which lineament segments are detected correspond with the width of the surface structure and may be a useful additional parameter for further analysis. The discrimination of concave and convex relief structures perfectly matches with valleys and ridges of the surface.