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Extraction of geomorphological entities from unstructured point clouds – a three-dimensional level-set-based approach

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The use of 3D point clouds has become ubiquitous in studying geomorphology. The richness of the acquired data, together with the high availability of 3D sensing technologies, enables a fast and detailed characterisation of the terrain and the entities therein. However, the key for a comprehensive study of landforms relies on detecting geomorphological features in the data. These entities are of complex forms that do not conform to closed parametric shapes. Furthermore, they appear in varying dimensions and orientations, and they are often seamlessly embedded within the topography. The large volume of the data, uneven point distribution and occluded regions present even a greater challenge for autonomous extraction. Therefore, common approaches are still rooted in utilising standard GIS tools on rasterised scans, which are sensitive to noise and interpolation methods. Schemes that investigate morphological phenomena directly from the point cloud use heuristic and localised methods that target specific landforms and cannot be generalised. Lately, machine-learning-based approaches have been introduced for the task. However, these require large training datasets, which are often unavailable in natural environments.

This work introduces a new methodology to extract 3D geomorphological entities from unstructured point clouds. Based on the level-set model, our approach does not require training datasets or labelling, requires little prior information about existing objects, and wants minor adjustments between different types of scenes. By developing the level-set function within the point cloud realm, it requires no triangulated mesh or rasterisation. As a driving force, we utilise visual saliency to focus on pertinent regions. As the estimation is performed pointwise, the proposed model is completely point-based, driven by the geometric characteristics of the surface. The result is three-dimensional entities extracted by their original points, as they were scanned in the field. We demonstrate the flexibility of the proposed model on two fundamentally different datasets. In the first scene, we extract gullies and sinkholes in an alluvial fan and are scanned by an airborne laser scanner. The second features pockets, niches and rocks in a terrestrially scanned cave. We show that the proposed method enables the simultaneous detection of various geomorphological entities, regardless of the acquisition technique. This is facilitated without prior knowledge of the scene and with no specific landform in mind. The proposed study promotes flexibility of form and provides new ways to quantitatively describe the morphological phenomena and characterise their shape, opening new avenues for further investigation.