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Automated Detection of Geomorphic Features in LiDAR Point Clouds of Various Spatial Density

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LiDAR, also referred to as laser scanning, has proved to be an important tool for topographic data acquisition. Terrestrial laser scanning allows for accurate (several millimeter) and high resolution (several centimeter) data acquisition at distances of up to some hundred meters. By contrast, airborne laser scanning allows for acquiring homogeneous data for large areas, albeit with lower accuracy (decimeter) and resolution (some ten points per square meter) compared to terrestrial laser scanning. Hence, terrestrial laser scanning is preferably used for precise data acquisition of limited areas such as landslides or steep structures, while airborne laser scanning is well suited for the acquisition of topographic data of huge areas or even country wide.

Laser scanners acquire more or less homogeneously distributed point clouds. These points represent natural objects like terrain and vegetation and artificial objects like buildings, streets or power lines. Typical products derived from such data are geometric models such as digital surface models representing all natural and artificial objects and digital terrain models representing the geomorphic topography only.

As the LiDAR technology evolves, the amount of data produced increases almost exponentially even in smaller projects. This means a considerable challenge for the end user of the data: the experimenter has to have enough knowledge, experience and computer capacity in order to manage the acquired dataset and to derive geomorphologically relevant information from the raw or intermediate data products. Additionally, all this information might need to be integrated with other data like orthophotos. In all theses cases, in general, interactive interpretation is necessary to determine geomorphic structures from such models to achieve effective data reduction. There is little support for the automatic determination of characteristic features and their statistical evaluation.

From the lessons learnt from automated extraction and modeling of buildings (Dorninger & Pfeifer, 2008) we expected that similar generalizations for geomorphic features can be achieved. Our aim is to recognize as many features as possible from the point cloud in the same processing loop, if they can be geometrically described with appropriate accuracy (e.g., as a plane). For this, we propose to apply a segmentation process allowing determining connected, planar structures within a surface represented by a point cloud. It is based on a robust determination of local tangential planes for all points acquired (Nothegger & Dorninger, 2009). It assumes that for points, belonging to a distinct planar structure, similar tangential planes can be determined. In passing, points acquired at continuous such as vegetation can be identified and eliminated. The plane parameters are used to define a four-dimensional feature space which is used to determine seed-clusters globally for the whole are of interest. Starting from these seeds, all points defining a connected, planar region are assigned to a segment. Due to the design of the algorithm, millions of input points can be processed with acceptable processing time on standard computer systems. This allows for processing geomorphically representative areas at once. For each segment, numerous parameter are derived which can be used for further exploitation. These are, for example, location, area, aspect, slope, and roughness.

To prove the applicability of our method for automated geomorphic terrain analysis, we used terrestrial and airborne laser scanning data, acquired at two locations. The data of the Doren landslide located in Vorarlberg,

Austria, was acquired by a terrestrial Riegl LS-321 laser scanner in 2008, by a terrestrial Riegl LMS-Z420i laser scanner in 2009, and additionally by three airborne LiDAR measurement campaigns, organized by the Landesvermessungsamt Vorarlberg, Feldkirch, in 2003, 2006, and 2007. The measurement distance of the terrestrial measurements was considerably varying considerably because of the various base points that were needed to cover the whole landslide. The resulting point spacing is approximately 20 cm. The achievable accuracy was about 10 cm. The airborne data was acquired with mean point densities of 2 points per square-meter. The accuracy of this dataset was about 15 cm. The second testing site is an area of the Leithagebirge in Burgenland, Austria. The data was acquired by an airborne Riegl LMS-Q560 laser scanner mounted on a helicopter. The mean point density was 6-8 points per square with an accuracy better than 10 cm.

We applied our processing chain on the datasets individually. First, they were transformed to local reference frames and fine adjustments of the individual scans respectively flight strips were applied. Subsequently, the local regression planes were determined for each point of the point clouds and planar features were extracted by means of the proposed approach. It turned out that even small displacements can be detected if the number of points used for the fit is enough to define a parallel but somewhat displaced plane. Smaller cracks and erosional incisions do not disturb the plane fitting, because mostly they are filtered out as outliers. A comparison of the different campaigns of the Doren site showed exciting matches of the detected geomorphic structures.

Although the geomorphic structure of the Leithagebirge differs from the Doren landslide, and the scales of the two studies were also different, reliable results were achieved in both cases. Additionally, the approach turned out to be highly robust against points which were not located on the terrain. Hence, no false positives were determined within the dense vegetation above the terrain, while it was possible to cover the investigated areas completely with reliable planes. In some cases, however, some structures in the tree crowns were also recognized, but these small patches could be very well sorted out from the geomorphically relevant results. Consequently, it could be verified that a topographic surface can be properly represented by a set of distinct planar structures. Therefore, the subsequent interpretation of those planes with respect to geomorphic characteristics is acceptable.

The additional in situ geological measurements verified some of our findings in the sense that similar primary directions could be found that were derived from the LiDAR data set and (Zámolyi et al., 2010, this volume).

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