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Segmentation-based determination of terrain points from full-waveform airborne laser scanning data

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Airborne laser scanning (ALS), also referred to as airborne LiDAR (light detection and ranging), is a widely-used method for the 3D sampling of the earth's surface. The resulting point cloud is often used to derive digital terrain models (DTM). As a preliminary step for this purpose, the point cloud has to be classified into the points belonging to terrain and those that do not. This process, which is also referred to as filtering, can be carried out even in vegetated areas, provided the fact ground echoes are present and can reliably be recognized. Especially the classification of dense lower vegetation poses problems for standard filtering algorithms. Points within these vegetation structures might be included in the terrain point cloud, causing the resulting DTM surface to run above the actual terrain and therefore being incorrect.

The latest generation of ALS systems, the so-called full-waveform (FWF) scanners, provide 3D point clouds with extended information, which can support the process for terrain point classification. In contrast to conventional ALS hardware, which is able to detect one or more consecutive discrete echoes, FWF digitizers are capable of detecting and storing the whole emitted and backscattered signal, the so-called waveform. In order to obtain the single echoes, i.e. 3D points representing the backscattering surface, the recorded waveform has to be reconstructed and a decomposition algorithm has to be applied. During this echo detection process, not only the range from the scanner to the illuminated target, but also additional parameters can be derived. Apart from the amplitude, which is as well available in discrete ALS systems, the width of the backscattered echo, also referred to as echo width, is obtained. In this way, besides the acquisition of the geometry in terms of height measurements, the point cloud produced with FWF technology provides additional knowledge about the scanned surface that can be exploited for digital terrain model (DTM) generation. While the amplitude, as a measure of the backscattered intensity, holds information about the reflectivity of the surface, the echo width is influenced by height variations of small scatterers within the footprint area of the laser beam. In terms of ALS, overgrown areas were found to show lower amplitudes than open terrain, due to loss of backscattered energy because of the penetration of the foliage. On the other hand, vegetation is considered to feature large variations in height within the footprint area and therefore feature larger echo widths.

Hence, these two observables have potential to be used within the process of DTM derivation, eliminating echoes from vegetated areas and produce a more reliable terrain point cloud. A seeded region growing segmentation algorithm can be employed to gather points with similar FWF attributes. Further segmentation constraints can be the application of maximum height intervals, to prevent probable terrain segments from growing into vegetation. By signature analysis from training areas, thresholds for the extraction of the segments representing terrain can be provided. In addition, we assume that an acceleration in computation with conventional filtering algorithms can be achieved due to the reduced set of input points.