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State of the art in high accuracy high detail DTMs derived from ALS

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High-resolution Digital Terrain Models (DTMs) representing the bare Earth are a fundamental input for various applications in geomorphology. Airborne laser scanning (ALS) is established as a standard tool for deriving DTMs over large areas with unprecedented accuracy. Due to advances in sensor technology and in processing algorithms in the recent years the obtainable accuracy is still increasing. Accuracy is understood as the deviation from the elevation at one specified point to its true value. These advances may lead to a more efficient data acquisition, if reduced accuracy is targeted, but also allow data acquisition schemes with more detail becoming visible, i.e. small features of the relief. For the latter a high internal precision, i.e. repeatability, is necessary. The essential advances in the technologies are improvements in ranging through the introduction of full-waveform (FWF) laser scanning and rigorous models of strip adjustment.

In FWF laser scanning the time-dependent strength of the backscattered signal is recorded. This is opposed to the analogue processing of the incoming energy and storage of one arrival time of discrete-return systems. In a simple one-echo situation, the arrival time corresponds to the maximum of the waveform. By applying a decomposition of the full waveform into single echoes, which are transformed copies of the emitted signal, it is possible to retrieve more echoes per shot.
Additionally, if echoes of individual scatterers are overlapping, FWF sensors might be able to separate them, whereas discrete return systems might rather only be able to derive one collective arrival time. Finally, the overlay of two echoes does not have the maxima at the same positions as the individual echoes. Additionally, the pulse repetition rate of laser scanners has increased, which allows higher point densities and therefore higher richness of detail.

These advances in data acquisition increase the precision within one ALS strip. Deficiencies in the calibration of the multi-sensor system ALS, consisting of laser range finder, scanner, inertial measurement unit (IMU), and global navigation satellite system (GNSS), lead to a decrease in overall accuracy, which becomes apparent in discrepancies between overlapping strips. Especially small features of the relief are distorted by these discrepancies and therefore appear blurred or undiscernible from the noise. Strip adjustment algorithms are targeted at removing these discrepancies by improving the calibration of the single components of the measurement system, and estimating the relative orientation (offset and angular attitude) between the components.

These improvements in precision allow filtering algorithms, i.e. the classification of the acquired points into ground points and off-terrain points, to perform better in the separation of random measurement noise, small terrain features, and off terrain points. The first one shall be reduced by suitable averaging, the second are to be maintained, and the third to be removed. Filtering is also improved by considering the shape of the recorded echoes. Near ground vegetation often leads to an increase in echo width, which is an indicator for a reflection from objects above the terrain.

These advances in sensor technology and processing methodology lead to improved DTMs with respect to accuracy, precision, and terrain detail. Therefore, geomorphological features and processes can be identified more reliably. The improvement of “raw” point clouds and DTMs also enables advances in automatic lineament extraction and data reduction.

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