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Extraction of Forest Roads from Full-waveform Airborne Laser Scanning Data

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The knowledge about the position of forest roads is important for the management and protection of forests. Most often this information is not available on a digital form so that it can be integrated into a GIS to use it e.g. for routing applications or to plan harvesting activities. Furthermore, the available information about forest roads is often not up-to-date. The extraction of forest roads from remote sensing data i.e. aerial photographs is often limited due to the visibility of the terrain within a forest. The increasing availability of airborne laser scanning (ALS) data has changed this situation during the last years. As an active measurement system ALS provide geometric information from the forest floor as well as the forest canopy. Additionally, the new generation of ALS sensors, the so-called full-waveform sensors provide in addition to the geometric information (i.e. 3D position, echo width) radiometric information (i.e. backscatter cross section) about the backscattering objects, which are excellent data sources to describe the terrain surface within a forest. Thus the aim of this study is to develop a semi-automatic method to extract the position of forest roads from full-waveform ALS data.

Based on the 3D point cloud different raster layers were derived such as the digital terrain model (DTM), the slope, the backscatter cross section, different roughness parameters (i.e. echo width, standard deviation of plane fitting residuals of terrain points), the vertical component of the surface normals and the normalized digital surface model (nDSM), which represents the object height above the natural ground. The developed workflow classifies each input raster separately into the classes roads and non-roads. Morphological operations were applied on the classified raster datasets to smooth the outline of the extracted roads and to remove any small gaps in the detected roads. Several raster outputs were combined and used further for additional GIS analysis and morphological processing. For example connected component analysis has been applied to derive shape information (e.g. component length and width) that is used to improve the classification. Furthermore, endpoints of individual road segments were connected if defined geometric requiremnts (e.g. slope) are fullfilled. The developed work flow was implemented into the software OPALS and MATLAB and was applied for a test site in Austria. The achieved output shows the high potential of full-waveform ALS data for forest road detection and demonstrate the benefit of the additional information from full-waveform ALS data. The detected axis of the forest roads have a completness of >95% and a correctness of >93% could be achieved using a fully automatic workflow without any auxiliary data sources.

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