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Virtual Laser Scanning for the Analysis of Platform-Related Effects in Urban Tree Species Classification

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In the last decades, the established Airborne Laser Scanning (ALS) approach for urban tree species classification has been increasingly complemented by laser scanning datasets measured from further platforms such as Terrestrial Laser Scanning (TLS), Mobile Laser Scanning (MLS), and UAV-borne Laser Scanning (ULS). However, the characteristics of the different capturing platforms (e.g. point density, scan perspective, etc.) affect point cloud based feature extraction and object classification, which limits the universal usage of point cloud features.

The aim of this study is to quantify the effects on geometrical features with respect to different laser scanning platforms and measurement configurations. Geometrical features are LiDAR metrics related to the geometry of the trees (e.g. crown shape) calculated by using only the x,y,z attributes. A multi-purpose LiDAR simulation tool (HELIOS; http://uni-heidelberg.de/helios) is used to test scenarios in a simulated environment, which we call Virtual Laser Scanning (VLS). In this analysis, individual virtual 3D tree models are built based on real high point density MLS data of an urban city park in Budapest. VLS is carried out with the commonly used measurement configurations related to platforms of ALS, ULS, TLS, and MLS with in total 8 different simulation scenarios. Thereafter, the laser scanning features are analyzed with the calculation of Pearson's correlation coefficient and Combined Cluster Discrimination Analysis (CCDA). Two main most frequently published feature classes are tested: 1) subset-related features of individual trees (for example subdividing a tree object into vertically stacked slices of 10% of height in percentage and calculate pulse penetration ratio), and 2) aggregated features related to the entire tree object (for example mean height).

The correlation analysis of the subset features showed that the features of the upper 25% of tree parts correlate between the different platforms (mean r^2~0.88, pair-wise correlation) in contrast to the features of the lower 25% of tree parts (mean r^2~0.47). The low correlation between the subset related geometrical features can be explained by the poor representation of the stem with the airborne based laser scanning compared to TLS and MLS. The CCDA analysis shows a separation of subset features into two groups: airborne (ALS, ULS) and ground-based platforms (TLS, MLS). This separation can be explained by the effects provided by the different scanner perspectives and respective scanning geometries. The features on a tree object level indicate significantly lower influence from the applied platform.

Our results show that the frequently published subset-related features optimized for ALS data cannot be directly applied to ground-based LiDAR measurements. This indicates the demand for research on relevant and robust feature-sets that are applicable to datasets from more than one laser scanning platform. VLS allows identifying and quantifying a clear distinction in importance of features between the two perspectives, airborne and ground-based. Virtual laser scanning can evolve into a transparent and reproducible solution for the inter-comparison of laser scanning platforms and scan configurations with no costs, with pre-defined ground truth and for any point cloud classification task.