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From Point Clouds to Forest Complexity: Addressing Challenges of Structural Analysis of Forest Landscapes using Wall-To-Wall Airborne Laser Scanning Data

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Forests play a cruical role in global ecosystems, providing habitats for many species, having the potential for high biodiversity and offering substantial carbon storage. Characterizing and monitoring the structural properties of these ecosystems are essential for modeling various ecosystem services and designing management and conservation strategies.
Airborne Laser Scanning (ALS) allows us to acquire comprehensive 3D data due to its ability to penetrate the canopy and provide surface data as well as below-canopy information about vegetation structure. The emerging widespread accessibility of openly available wall-to-wall ALS datasets, in some cases even multi-temporal, increases the possibilities to thoroughly analyze forest structures. However, for large-scale applications, challenges arise from variations of data resolution and quality as a result of differences in sensors, point densities or acquisition dates or the sheer volume of data to process.
In this study, we present a unified, point-density-independent voxel-based approach to address these challenges of high-resolution wall-to-wall ALS data analysis in forest environments. Besides canopy height, we derive structural parameters like height quantiles, fractional cover, vertical complexity, understory height and number of vegetation layers to characterize the structural complexity of the forest landscape on different scales up to a level of detail of 1 m. These data are further combined and utilized for segmentation of structurally homogeneous forest areas.
The study site is the Vienna Woods Biosphere Reserve, located in the federal states of Lower Austria and Vienna (Austria), covering approximately 1056 km² of diverse forest landscape. This region encompasses diverse forest types (a.o. beech, oak-hornbeam, black pine), various topographical and geological conditions as well as different management types and levels of protection. To get full point cloud coverage of the area, it is necessary to combine point clouds from up to ten different scanning campaigns.
Initial test runs show promising results and demonstrate the possibilities of this approach to derive sound, area-wide structure metric and further characterize the forest based on structural varieties, provide easy-to-read maps for further deployment in operational use of stakeholders and show potential for structure-based segmentation of forested areas. These structure-based segments can serve as a base for habitat mapping, monitoring or management.