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## Presenting the GeForse approach to create synthetic LiDAR data from simulated forest stands to optimize forest inventories

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LiDAR-based forest inventories focusing on estimating and mapping structure-related forest inventory variables across large areas have reached operationality. In the commonly applied area-based approach, a set of field-measured inventory plots is combined with spatially co-located airborne laserscanning data to train empirical models that can then be used to predict the target metric over the entire area covered by LiDAR data.

The area-based approach was found to produce reliable estimates for structure-related forest inventory metrics such as wood volume and biomass across many forest types. However, the current workflows still leave space for improvement that may result in cost-reduction with respect to data acquisition or improved accuracies. This is particularly relevant as the area-based approach is increasingly used in operational forestry settings. To further optimize existing workflows, experiments are required that need large amounts of forest inventory data (e.g., to examine the effect of sample size or the field inventory design on the model performances) or multiple LiDAR acquisitions (e.g., to identify optimal/cost-efficient acquisition settings). The acquisition of these types of data is cost-intensive and is hence often limited to small extents within scientific experiments.

Here, we present the “GeForse - Generating Synthetic Forest Remote Sensing Data” approach to create synthetic LiDAR datasets suitable for such optimization studies. GeForse combines a database of single-tree models consisting of point clouds extracted from real LiDAR data with the outputs of a spatially explicit, single tree-based forest growth simulator (in this case SILVA). For each simulated tree, we insert a real point-cloud tree with properties (species, crown diameter, height) matching the properties of the simulated tree. This results in a synthetic 3D forest with a realistic 3D-structure where the inventory metrics of each tree are known. This 3D forest then serves as input to the “Heidelberg LiDAR Operations Simulator” (HELIOS++, <https://github.com/3dgeo-heidelberg/helios>) and thereby enables the simulation of LiDAR acquisition flights with varying acquisition settings and flight trajectories. In combination with the “full inventory” of all trees in the simulated forest, this enables a wide variety of sensitivity analyses.

In this contribution, we give an overview of the complete GeForse approach from extracting the tree models, to generating the 3D forest and simulating LiDAR flights over the 3D forest using HELIOS++. Further, we present a brief case-study where this approach was applied to optimize certain aspects of area-based forest inventory approaches using LiDAR data from a forest area in central Europe. Finally, we provide an outlook on future application fields of the GeForse approach.