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Tree architecture and forest canopy structure obtained from terrestrial LiDAR measurements

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The modelling of the water transfer in vegetation on a small scale is important when the interaction of single plants and the competition of species are in focus of interest. Explicit geometrical functional-structural models that simulate the water flow in the single plant components such as roots, stem, and branches have been developed recently. These models need an explicit geometrical model of the plant hydrology, more precisely the possible pathway of the xylem and phloem water flow. Roots, stem, and branches are represented by connected porous cylinder elements that are divided into the inner heartwood cylinders surrounded by xylem and phloem.

Terrestrial laser scanning (TLS) has been successfully applied to assess the structure of the aboveground vegetation in situ in the last years. Based on the technique of light detection and ranging (LiDAR) this method provides a set of three dimensional points that are located on the surface of objects such as vegetation. A further data processing of this three dimensional point cloud (typically consistent of some million points) enables to obtain structural properties like the spatial leaf distribution or large scale characteristics such as the stand height or plant density. Whereas the resolution and detection rate of the laser scanners have increased in the last years, there is still a need for a data handling especially in the field of ecology.

We present the results of a skeleton extraction algorithm that is able to obtain the position and size of branch and stem cylinder elements from a three-dimensional point cloud obtained by TLS field measurements. No manual data processing is necessary to apply the algorithm allowing the analysis of a high number of individual plants. The resulting hydraulic architecture determines the possible pathway of water through the stem and the branches. It can consist of several thousands of connected cylinders depending on the plants that are observed. Examples are given and discussed ranging from single tree architectures to tree stand architecture of almost 100 deciduous trees of 25 meter height. The handling of the effects of self-shadowing and data gaps and the limits of the algorithm is discussed as well as the requirements for the laser scanner hardware and data acquisition.

We show the use of the obtained tree and canopy architectures to simulate water uptake, water storage, and transpiration in combination with light absorption and leaf photosynthesis using a ray tracer model.