1. Title of the Dissertation and the PhD Candidate

PhD defence date: February 26, 2018, 10:00 o'clock

PhD title: "Description of Natural Surfaces by Laser Scanning"

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3. Abstract

Laser scanning (also LiDAR – light detection and ranging) provides accurate and high-resolution geometric and radiometric measurements of natural surfaces at different spatial scales, which is relevant for many environmental and physical models. However, high-resolution laser scanning data are often not fully explored or are not used at all for surface description in such models. The aim of this research is to revisit current methods and to introduce new methods for the description of natural surfaces by exploring the full potential of novel high-resolution laser scanning data. The work comprises (a) natural surfaces such as soil, gravel, and vegetation; (b) a range of different laser scanning techniques, such as TLS (terrestrial laser scanning), ULS (unmanned aerial vehicle laser scanning), ALS (airborne laser scanning); and (c) ranging methods such as time-of-flight ranging, phase-shift ranging, and active and passive triangulation. The work is focused on three land-surface parametrisations such as surface roughness, a 3D model of a conifer shoot, and canopy transmittance, which are selected as representatives of geometric-stochastic, geometric-deterministic, and geometric-radiometric surface descriptions, respectively. As those parameterisations have also been the subject of several research projects, particular objectives are set and analysed in six separate studies. The research contributed by introducing new methods and by improving current methods for those parameterisations from contemporary high-resolution laser scanning data. Surface roughness is mainly analysed in the frequency domain by means of the roughness spectrum. A new method is introduced that optimizes the interpolation parameters so that a DTM (digital terrain model), derived from a laser scanning point cloud, has a unique stochastic property (the fractal dimension is maximized at high frequencies), which is important for an unbiased surface roughness assessment. Furthermore, multi-scale laser scanning point clouds are analysed to determine spatial scales over which corresponding roughness spectra can be used interchangeably. The 3D modelling of a conifer shoot is (to the author’s best knowledge) modelled based on point clouds up to individual needles for the first time. The modelling is based on a semiautomatic method developed here for micro-scale triangulating laser scanning data. Then, a new method is introduced to estimate canopy transmittance from small-footprint ALS waveform data, where assumptions on vegetation-ground scattering properties are not required. To enable upscaling of the canopy transmittance information to the space-borne LiDAR footprint scale, a waveform stacking method is developed in an additional study. The stacking method and the simulated space-borne LiDAR waveforms are then used, alongside with field measurements of forest inventory, to estimate aboveground biomass. The information and methods about surface roughness, 3D shoot geometry, and canopy transmittance that are derived here provide a basis for a better understanding and description of natural surfaces in environmental and physical models.