PHOTOGRAMMETRIC NEWS: Doctoral Dissertation

Mr. Daniel Schraik defended his doctoral dissertation on the 11th of November 2022 at the Aalto University School of Engineering, Finland. Professor Kim Calders, Ghent University, Belgium, appeared as opponent. The Supervisor was Professor Miina Rautiainen, Aalto University, School of Engineering, Finland. The title of the thesis was “Clumping in Forest Radiation Regime Models”.

Abstract of the thesis

Forest structure is realized in a variety of ways in forest radiation regime models. Depending on model complexity, canopy structure can be quantified by simple parameters such as leaf area index, describing the density of canopies, and an associated clumping index, quantifying the degree of deviation of the spatial distribution of leaves from a uniform distribution, or by realistic three-dimensional models of tree crowns in ray tracing models, for example. Complex models, while being more realistic, are generally difficult to apply to large scale and high temporal frequency observations, as is common in passive optical remote sensing. To this end, simpler forest radiation regime models are useful, and complex models provide valuable insights for calibrating, improving, or training simpler models. The aim of this dissertation is to use a high degree of spatial complexity to analyze how simpler parameters of forest structure behave in different types of forests.

In simpler models, forest structure is described through the leaf area index and clumping index. These two variables are capable of quantifying forest structure, however, the clumping index is typically difficult to measure. In the so-called spectral invariants theory, forest structure is summarized by a single parameter, the photon recollision probability, i.e. the probability that a photon, upon being scattered by a canopy element, will again interact with the canopy. Closely associated to this parameter is the silhouette to total area ratio (STAR), i.e. the ratio between the projected area of a body and its total surface area. STAR has commonly been used in shoot clumping correction and been studied in simulated tree crowns.

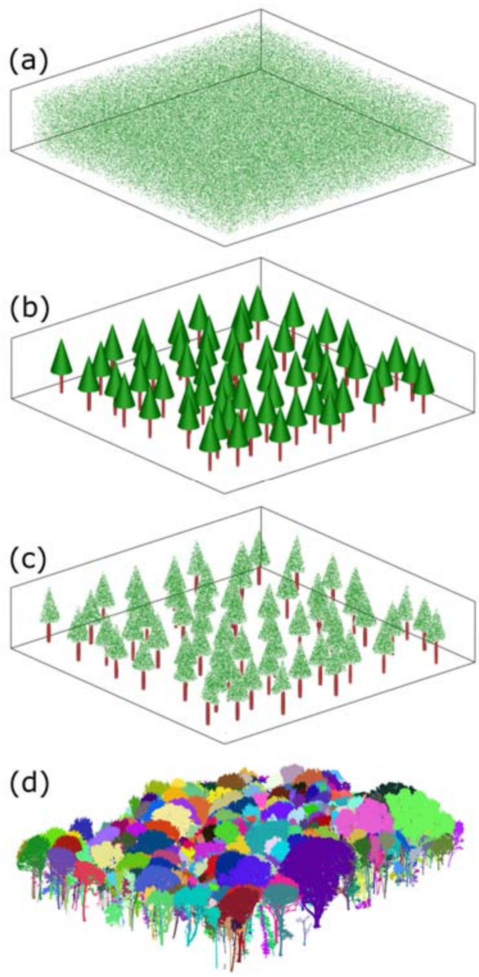
In this dissertation I developed a method to measure STAR using terrestrial laser scanning (TLS) point clouds, and expanded its application to forest stands. I used this method to assess the capability of TLS to analyze forest structure in general, and clumping in particular. To this end, I validated the STAR measurement method using individual tree crowns and destructive reference measurements, and measured STAR at the stand level in 38 forest stands to explore the range of both STAR and clumping index that can be found in different boreal, hemiboreal, and temperate forests. Since STAR is a driver of the forest radiation regime, I explored the relationship between stand STAR and forest reflectance. Forest reflectance was closely related to STAR in spectral regions that are known to be sensitive to forest structure, i.e., especially the red portion of the visible spectrum. In addition, I inverted the forest reflectance model PARAS and showed that realistic prior distributions are required to obtain unbiased LAI estimates.

I have shown that TLS may accurately measure stand level STAR, thus allowing to quantify forest structure and clumping in forest radiation regime models. This new method can help to improve forest structure quantification in forest radiation regime models as well as in the measurement of leaf area index in general, and thus contribute to remote sensing applications of forests.

Keywords: remote sensing, forest structure, clumping, spectral invariants, forest reflectance modeling, silhouette to total area ratio

Video summary of the dissertation: https://youtu.be/BuYGGq_A8K0

Highlighted figures from the thesis



Different conceptualizations of forest canopies, from simple turbid media (a), via geometric-optical (b) and hybrid models (c) to full 3D models of forests. The dissertation aimed to bridge the gap between these different simplifications.

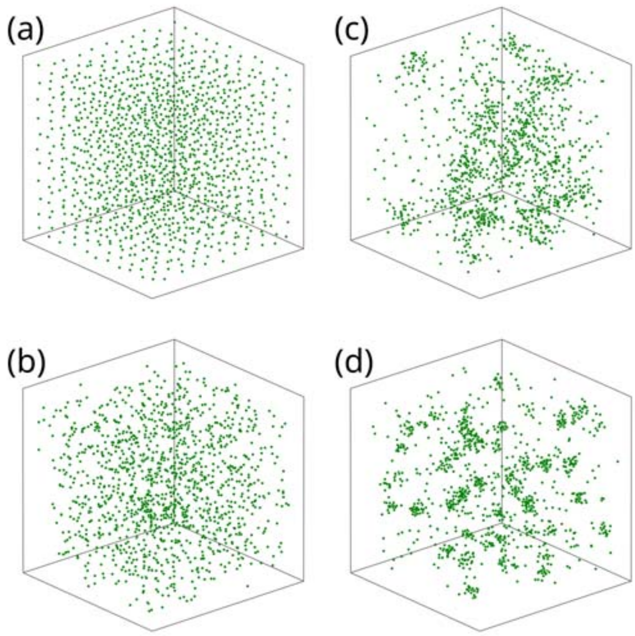
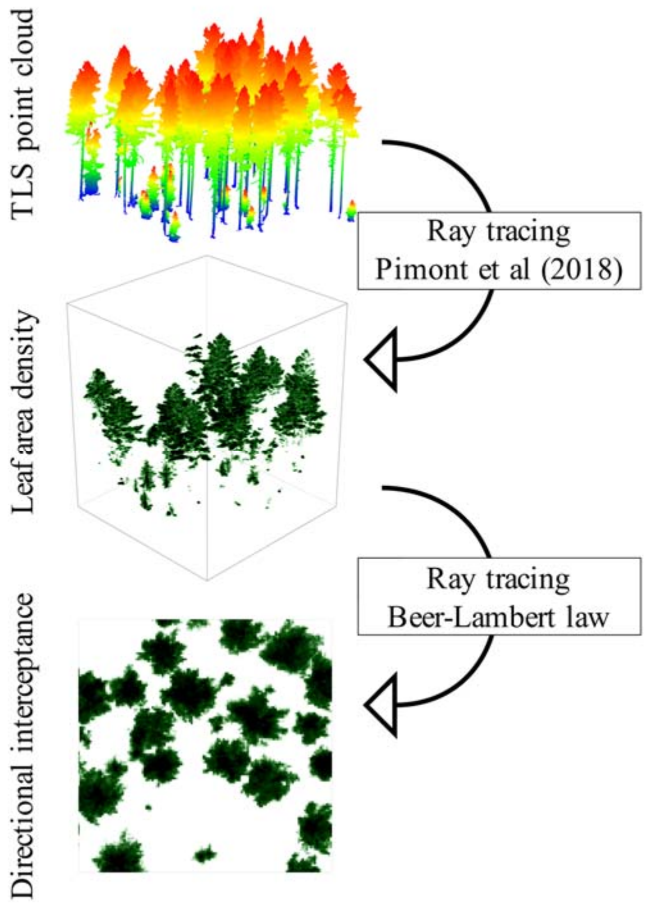


Illustration of different degrees of clumping in random 3D points. This effect is central to bridging the gap between turbid media and 3D reconstructed forests.



Processing workflow used to extract volumetric information about leaf area density from terrestrial lidar point clouds. To quantify clumping in terms used for turbid medium models, a conversion to 2D images used.