ABSTRACT

This dissertation addresses three challenges slowing the LiDAR-driven automation of manual forest inventory sampling. LiDAR solutions must improve field efficiency and be robust to noise and occlusions; they must be able to contribute to non-biometric assessments such as species identification; and they must offer insights useful for ecological research at the individual tree level. This dissertation examines the complete geospatial analysis pipeline, from data collection and georeferencing through to feature design and analysis, demonstrating that structural information captured from ground-based LiDAR, despite the undergrowth, occlusions, and site variability typical in natural forests, can meet these demands.

Single-scan terrestrial LiDAR (TLS) data, a minimum viable representative of high-density LiDAR modalities, forms the foundation of this study. The presented georeferencing workflow confirms the feasibility of precise TLS deployment in deciduous forest. The segmentation procedure presented in this dissertation separates each tree from the TLS data, then two complementary feature space designs extract structural features from each tree point cloud. The first, using distribution descriptors, highlights species-specific structural differences exclusively detectable in the understory, offering guidance for both terrestrial and aerial feature design. The second, using synthetic tree models with an explicit structure modeling framework developed in this dissertation, demonstrates that topology deformed by occlusions still contains useful indicators of structural variation and tree function.

These results show that single-scan TLS is field-deployable, capable of supporting species differentiation, and effective for extracting structural traits that reflect internal function and environmental constraints. Beyond TLS data, the methodologies developed for species detection and the application of dendritic modeling provide conceptual and technical frameworks adaptable to other LiDAR modalities, especially unmanned aerial LiDAR. Ultimately, this work advances automated forest sampling by demonstrating that even incomplete structural data can reveal forest function, species composition, and environmental conditions, bringing remote sensing closer to delivering the data needed to further support both forest and human flourishing.