

Protik Bose Pranto¹, Isaac Buo², and Ariane Middel^{1,2}.

A Scalable LiDAR-Based Framework for Automated Tree Inventory and Management

Trees provide essential ecosystem services, such as carbon sequestration, temperature regulation, and wildlife habitat. However, most cities lack a detailed, up-to-date, parcel-scale tree inventory, limiting the ability to quantify canopy-distribution, identify canopy gaps and inequities, and plan cost-effective planting and maintenance under water and budget constraints. Challenges such as private land ownership and labor-intensive manual surveys further limit routine monitoring, underscoring the need for an automated, scalable approach to tree inventory and management. This study presents an automated LiDAR-based framework for developing a tree inventory applicable to any region with access to airborne LiDAR and imagery. We extract vegetation and buildings by integrating NDVI, elevation data, and building footprints, and then delineate individual trees using 3D clustering (HDBSCAN). Since closely clustered crowns and multi-stem trees may be merged into a single canopy and are challenging to distinguish, each tree object is categorized by height variation and number of detected tree stems (detected from Agglomerative Clustering) into four structural types: single, multiple with the same height, multiple with moderate variation, and structurally diverse. For single trees, we estimate height, canopy width, crown shape, and transmissivity. Finally, we train ML models using ground-truth data to classify trees as mesic or xeric, to capture differences in irrigation and landscape regimes across neighborhoods and land use types. This classification enables assessment of how planting and irrigation decisions affect tree longevity, cooling performance, and long-term water and maintenance costs in arid environments. A current implementation in Tempe detected 269,970 trees. A manual assessment of 100 randomly selected trees across different urban zones yielded accuracies of 72%, 93%, 77%, and 96% for the four structural categories, respectively. Expected outcomes include a geospatial tree inventory, tree density maps, data-driven recommendations for urban planting and management, and a transferable workflow for time-series monitoring of canopy change.

¹School of Computing and Augmented Intelligence, Arizona State University, Tempe, AZ 85281; and ²The GAME School, Arizona State University, Tempe, AZ 85281

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