The Journal of Open Source Software

PyTLiDAR: A Python Package for Tree QSM Modeling from Terrestrial LiDAR Data

John Hagood [1], **Fan Yang** [1], **Jeffery Cannon** [2], **and James Stroud** [3]¶

1 School of Computer Science, Georgia Institute of Technology, United States **2** Jones Center at Ichauway, United States **3** School of Biological Sciences, Georgia Institute of Technology, United States
¶ Corresponding author

DOI: 10.xxxxxx/draft

Software

- Review
- Repository
- Archive

Editor: Open Journals
Reviewers:

- @openjournals

Submitted: 01 January 1970
Published: unpublished

Summary

PyTLiDAR is an open-source Python software package that ports the MATLAB-based TreeQSM method (P. Raumonen et al., 2013) into Python, also providing an accessible, extensible, and GUI-driven alternative for researchers and practitioners in forestry, ecology, and 3D vegetation modeling. The software reconstructs Quantitative Structure Models (QSMs) of trees from Terrestrial LiDAR Scans (TLS) and provides interactive visualization tools for inspecting model quality and derived tree metrics.

Key features of PyTLiDAR include:

-A full reimplementation of TreeQSM's core logic in Python

-A user-friendly GUI built with PyQt6 for batch or single-file processing

-Automated and manual configuration of model generation parameters, including patch diameter ranges

-Support for interactive 3D visualization of tree models and parameter tuning

-Batch data processing

Statement of need

Terrestrial Laser Scanning typically utilizes LiDAR systems to collect millions of points on the surface of objects and preserves spatial information. For estimating above ground biomass (AGB), gap fraction, crown shape, and other ecological properties, accurate and efficient tree QSM reconstruction from TLS point cloud data is essential (Hackenberg et al., 2015).

TreeQSM has been widely used in forestry and ecology for modeling three-dimensional tree structures from TLS point clouds (Terryn et al., 2020). However, its reliance on MATLAB makes it less accessible for users without a commercial license or familiarity with the MATLAB environment. Furthermore, the lack of a graphical interface makes the tool less user-friendly and its parameter tuning less efficient.

PyTLiDAR addresses these issues by providing a native Python implementation of TreeQSM's core algorithms, wrapped in a streamlined graphical interface that allows researchers to visualize and evaluate their models. It promotes reproducible and exploratory research by offering transparent parameter control, open-source licensing, and seamless integration into Python-based analysis workflows. This work lowers the barrier for adoption of QSM modeling by removing the MATLAB dependency, enhancing accessibility for the broader open-source geospatial and ecological modeling community.

Method

TreeQSM models individual trees from terrestrial LiDAR scans by covering the input point cloud with small, connected surface patches. These patches form the building-bricks for reconstructing the tree's global shape. Based on neighbor-relation of the cover sets, the point cloud is segmented into individual branches, with parent-children relationships recorded. Then each segment is approximated as a collection of connected cylinders of varying radius, length, and orientation. This cylinder-based representation offers a simple yet effective regularization of the complex tree structure, supporting downstream analyses such as stem volume estimation or structural trait extraction (Pasi Raumonen et al., 2013) (Markku et al., 2015).

Software Description

PyTLiDAR implements the same method stated above in Python, and uses PyQt6 to create an intuitive interface for parameter configuration and data processing. Upon launching the application, users are presented with fields to input or generate values for key modeling parameters, including the minimum, and maximum patch diameters. The application supports both numeric entry and automatic generation of value ranges based on user-defined counts. Also, an intensity threshold can be set to filter the point cloud data, helping to remove noise and irrelevant data before modeling.

Users may choose between batch processing of an entire directory of point cloud files or processing a single file. The GUI also includes options for showing only the optimal model, based on selectable performance metrics such as 'all_mean_dis', and provides a dropdown menu to choose the preferred metric.

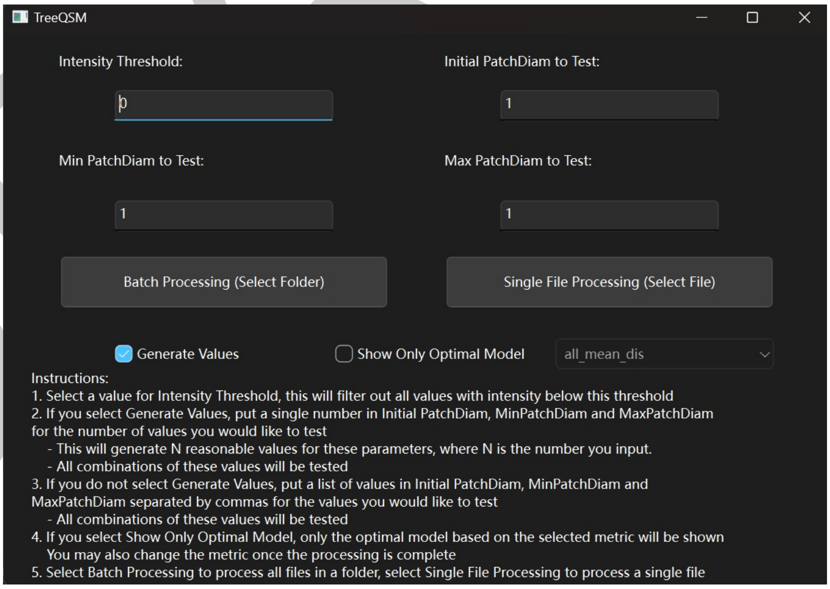

Figure 1: Software interface for user input and data selection.

After data selection, the software opens a new interface allows for data processing and visualization. Once the QSM reconstruction process is complete, PyTLiDAR provides interactive 3D visualization of the generated QSM using plotly. Users can inspect the structural fidelity of the reconstructed model, including trunk and branch geometry, and compare different parameter configurations for best fit. This combination of visual feedback and customizable processing offers an efficient path toward accurate and transparent tree structure analysis.

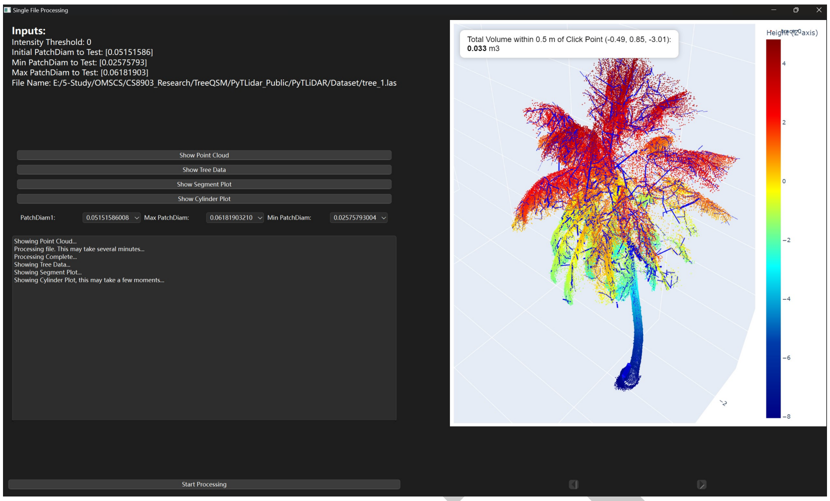

Figure 2: Software interface for processing and interactive visualization.

Users can also review the relavant morphological data of the QSM, including stem diameters, branch volume, surface area, and length with regard to diameter or order from stem.

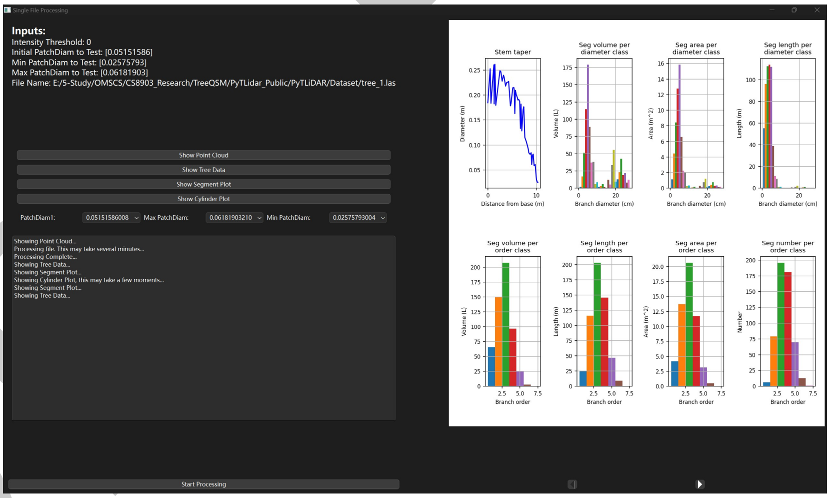

Figure 3: Software interface for user input and data selection.

Acknowledgements

We acknowledge contributions from XXX, XXX, and Amir Hossein Alikhah Mishamandani during the development of the package. This work is enabled in part by funding from XXXXX.

References

Hackenberg, J., Spiecker, H., Calders, K., Disney, M., & Raumonen, P. (2015). SimpleTree —an efficient open source tool to build tree models from TLS clouds. *Forests*, *6*(11), 4245–4294. https://doi.org/10.3390/f6114245

Markku, Å., Raumonen, P., Kaasalainen, M., & Casella, E. (2015). Analysis of geometric primitives in quantitative structure models of tree stems. *Remote Sensing*, *7*(4), 4581–4603. https://doi.org/10.3390/rs70404581

Raumonen, P., Åkerblom, M., Kaasalainen, M., & others. (2013). *TreeQSM: Quantitative structure models of trees from terrestrial laser scanning point clouds*. https://github.com/InverseTampere/TreeQSM.

Raumonen, Pasi, Kaasalainen, M., Åkerblom, M., Kaasalainen, S., Kaartinen, H., Vastaranta, M., Holopainen, M., Disney, M., & Lewis, P. (2013). Fast automatic precision tree models from terrestrial laser scanner data. *Remote Sensing*, *5*(2), 491–520. https://doi.org/10.3390/rs5020491

Terryn, L., Calders, K., Disney, M., Origo, N., Malhi, Y., Newnham, G., Raumonen, P., Åkerblom, M., & Verbeeck, H. (2020). Tree species classification using structural features derived from terrestrial laser scanning. *ISPRS Journal of Photogrammetry and Remote Sensing*, *168*, 170–181. https://doi.org/https://doi.org/10.1016/j.isprsjprs.2020.08.009