IRLTrees3D: A 3D Reconstruction Dataset of Trees

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Abstract

Measuring tree dimensions is fundamentally important to effective forestry and environmental monitoring, particularly in the estimation of investable carbon stock. Three-dimensional (3D) reconstruction, therefore, has become promising for enabling high-precision measurements and AI-driven applications in this domain, but remains challenging due to environmental uncertainty and the limitations of existing methods and datasets. This paper presents a novel, high-resolution dataset of 3D vegetation models comprising trees, logs, and plants captured from diverse locations across Ireland. The reconstruction pipeline with high-quality 2D views and 3D artifacts is provided to ensure methodological transparency and reproducibility for bridging multidimensional AI and computer vision tasks. To evaluate the geometric accuracy of the reconstructed models, we employed the diameter at breast height (DBH) as a validation metric. Our evaluation yielded a mean absolute error of 0.53 cm, with a standard deviation of 0.28cm, demonstrating the reliability of our cost-effective photogrammetry approach. The release of this dataset constitutes a significant contribution to the domain of 3D reconstruction of trees, providing a robust framework for future research in the field.

1. Introduction

In sustainability, living plants are fundamental to carbon management due to their ability to sequester and store carbon from the atmosphere. Above-ground biomass (AGB) is the total mass of trees above the soil surface, comprising stems, branches, and leaves. This metric serves as a direct proxy for the carbon stock within a given tree's woody and foliar tissues. The precise quantification of AGB is essential for various sustainable efforts such as global climate objectives, evaluating progress toward emissions reduction targets, guiding climate change policies and conservation efforts[1, 4, 17]. A standard methodology for AGB estimation involves measuring the DBH (defined as 1.3 m above ground) and the height of the tree. These measurements are then integrated into species-specific allometric equations to calculate the estimated AGB[2, 3, 5, 13]. Accurate estimation of above-ground biomass (AGB) is typically achieved through destructive sampling techniques, which entail the felling of trees. However, these field-based measurements are both labor-intensive and cost-prohibitive, rendering them impractical for large-scale application.

Consequently, Remote sensing (RS) emerged as a widely adopted approach for data collection in forestry due to its non-destructive nature. The continuous refinement of RS methods is driven by the demand for improved precision, cost-effectiveness, and temporal efficiency[8]. Among RS techniques, LiDAR (Light Detection and Ranging) provides highly accurate estimates of forest structure. However, the substantial cost of LiDAR platforms, including UAV (Unmanned Aerial Vehicle) and TLS (Terrestrial Laser Scanning)-based systems, constrains their broader use.

Photogrammetry involves the acquisition of reliable information on object and surface properties through the measurement and interpretation of photographs.[15]. This method is highly cost-effective due to its ability to leverage a wide range of readily available commercial off-the-shelf equipment capable of producing RGB imagery. However, publicly available benchmarking datasets for photogrammetry-based 3D tree reconstruction remain limited. Therefore, this study introduces a high-quality dataset designed to support AGB estimation and evaluates state-of-the-art tools and techniques, including the emerging 3D Gaussian Splatting (3DGS) representation[9]. To support a range of AI tasks in both two and three dimensions, we ensured that a top-down view was included for every tree captured in our dataset. For example, our 3D artifacts can be used to compute high-resolution volumes of trees, while top-view images can be used in computer vision tasks to estimate calculated volumes, enabling 2D-only AI workflows with commercial drones. We further assessed the geometric accuracy of the reconstructed models using diameter at breast height (DBH) as a reference metric. The evaluation resulted in a mean absolute error of 0.53 cm with a standard deviation of 0.28 cm, indicating reliability of our dataset.

2. Related Work

The landscape of 3D tree datasets is diverse; however, existing resources exhibit notable limitations. While several large-scale datasets are available, they predominantly fall into two categories: synthetic or LiDAR-based. Notable synthetic datasets, such as TreeNet3D, TreePointCloud, Smart-Tree, and TreePartNet, were generated through automated or procedural workflows [6, 10, 11, 16]. For instance, TreeNet3D comprises 13,000 models representing ten common species, but its synthetic nature limits the representation of the nuanced imperfections and structural complexity present in real-world trees. Similarly, Smart-Tree and TreePartNet rely on synthetic data for training, despite targeting applications in real-world scenarios.

Another prominent class of datasets, including NEWFOR, LeWoS, SYSSIFOSS, and FOR-instance, is derived from LiDAR [7, 12, 14, 18]. Although LiDAR provides highly accurate geometric information, these datasets are generally represented as point clouds, lacking the rich visual detail and surface textures captured by image-based photogrammetry. Moreover, they do not offer high-fidelity mesh or 3DGS representations.

Consequently, there is a distinct gap in publicly available datasets for real-life, image-only 3D tree reconstructions that provide both detailed mesh and 3DGS representations. Datasets of this type are essential for training models that require a high degree of visual fidelity and for advancing research in photogrammetry and novel scene representation techniques.

3. Data Collection

Data collection was conducted in Ireland in 2025, selected for its extensive vegetation cover. The data collection was carefully planned to mitigate environmental uncertainty and took place during winter to reduce occlusion of branches and trunks by foliage and to mitigate wind-induced leaf movement, which adversely affects the photogrammetric reconstruction process. The thin, paper-like structure of leaves also presents challenges for accurate mesh generation, whereas the majority of carbon is stored in trunks and branches.

To ensure accessibility and reproducibility, images were captured using consumer-grade devices. Ground-level images were captured with a Google Pixel 6 Pro smartphone (12.5 MP, 3072 × 4080), while aerial images were obtained with a DJI Mini 3 Pro drone (48 MP, 8064 × 6048). Owing to the requirements of photogrammetry, target trees were preselected based on criteria such as being small, isolated, and providing sufficient clearance for drone flight. Additionally, groups of trees were also included in the dataset (Figure 1) to enhance its diversity and representation of more complex forest structures.

Figure 1. Example of a group of trees

Figure 2. Top-down view is captured for every tree

For each tree, aerial data acquisition was performed by flying the drone in at least two complete orbits around the middle and upper sections; larger trees required three or more orbits. Images were captured at high frequency to ensure sufficient overlap, complemented by a top-down sequence of photographs (Figure 2). Additional ground-level images were collected using a smartphone, with approximately two orbits at head to chest height to capture finer structural details. The distribution of camera poses for all images is visualized in COLMAP (Figure 3).

Figure 3. Overview of all the camera poses in COLMAP

Following image acquisition, the diameter at breast height (DBH), measured at approximately 1.3 m above ground, was recorded. In the case of codominant trees with multiple trunks (Figure 4), measurements were taken from the largest trunk. For logs, the diameter was measured directly. Additionally, surrounding reference objects were measured to provide scale calibration (Figure 5).

A major challenge during data collection was environmental uncertainty such as wind and lighting, which directly impacts the photogrammetry process. Even minor branch movements in smaller trees degraded reconstruction

Figure 4. Example of a tree with multi-trunk structure

Figure 5. Measurements for scale reference

quality. Dynamic background elements, such as moving vehicles or pedestrians, also introduced interference. To mitigate these issues, data acquisition was scheduled based on favorable weather forecasts to minimize wind, and efforts were made to capture images during stable lighting conditions, avoiding times of strong shadows or rapidly changing illumination. Background disturbances were reduced by selecting less crowded locations whenever possible.

4. 3D reconstruction process

We provide two types of 3D representations for each tree in the dataset: meshes and 3DGS. Initial experiments with open-source tools such as Meshroom and OpenSplat yielded limited success due to the complex structure of trees and hardware constraints. To ensure consistency and scalability, we employed Polycam's cloud service, which enabled the generation of both meshes and splats reliably. Post-processing was performed to remove extraneous elements such as humans and vehicles, both to ensure data quality and to address privacy concerns.

5. Measurement Process

To measure the DBH from the 3D reconstructions, we utilized Blender, a free and open-source software, as the measurement tools provided by Polycam were insufficient for this purpose. To scale the 3D mesh to real-world dimensions, reference objects were measured both physically and virtually. A scaling factor was derived by dividing the real-world measurement by the corresponding virtual measurement, and this factor was applied to the scale property of the 3D model. The accuracy of the scaling was verified by placing virtual objects with predefined dimensions (e.g., a cube) alongside the reference object for comparison (Figure 6).

Figure 6. An example of a road marking measurement being used for scale reference.

After scaling the models, several approaches were evaluated for measuring DBH in Blender. As the geometry produced through photogrammetry is irregular and unstructured (Figure 7), direct selection of edges around the trunk does not yield accurate results. To address this challenge, two techniques for estimating trunk circumference were tested using the MeasureIt add-on in Blender.

5.1. Shrinkwrap method

This method employs Blender's shrinkwrap modifier to fit a circular geometry around the trunk. A circle is first created and positioned around the target trunk, after which the modifier is applied. The resulting circle is then measured to obtain the trunk's circumference (Figure 8).

5.2. Boolean Operator method

This method applies Blender's Boolean modifier to extract the cross-sectional geometry of the trunk. A secondary 3D object (e.g., a cube or plane) is positioned to intersect the region of interest, and the Boolean operation with the "difference" setting is performed. This operation generates a cutout of the trunk's cross-section, from which the edges can be measured (Figure 9). The Bool Tool add-on facilitates this process by providing a shortcut for applying the Boolean modifier. Compared to the Shrinkwrap method, the Boolean approach yielded more consistent and accurate results, as it avoids irregularities introduced when the circle does not conform perfectly to the trunk surface.

6. Results and Discussions

3DGS produces high-resolution, visually detailed renders of trees under optimal data collection conditions, outper-

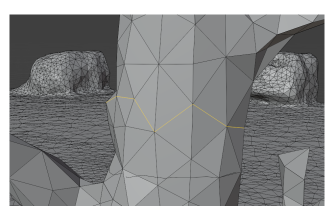

Figure 7. Wire view of a tree obtained through photogrammetry

Figure 8. Mesh (top) vs 3DGS (bottom)

Figure 9. Measurement with boolean operator method

forming traditional mesh representations. Figure 10 compares a photogrammetry-derived mesh (top) with a 3DGS render (bottom). However, due to its underlying point cloud structure, 3DGS currently has limited support for accurate geometric measurements. Scaling these splat models is challenging, as the mesh texture is required for reference. Additionally, Blender lacks native support for 3DGS; while an add-on provided by Kiri Engine enables basic interaction, it remains in early development and is not fully optimized. Consequently, only the mesh representations were used for measurement and included in the results.

Figure 10. Mesh (top) vs 3DGS (bottom)

To assess the geometric accuracy of the reconstructed meshes, the mean absolute error (MAE) and standard deviation (SD) were employed as evaluation metrics. The calculations were performed using the following formulas, where n be the number of measurements. R_i the i-th real-world measurement, and V_i the i-th virtual measurement.

Figure 11. Example of an unusable mesh.

1. Absolute error for each measurement:

$$E_i = |R_i - V_i|$$

2. Mean Absolute Error (MAE):

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n} E_i$$

3. Standard Deviation (SD) of the absolute errors:

$$\text{SD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} \left(E_i - \text{MAE}\right)^2}$$

We obtained a mean absolute error (MAE) of 0.5cm and a standard deviation (SD) of 0.28cm. Trees with poorly reconstructed meshes that hindered measurement, as well as measurements exhibiting unusually large errors, were excluded from the analysis. A total of 45 trees were included in the reported results. The dataset can be accessed at: https://IRLTrees3D.reliable-ai.org

While some meshes accurately capture DBH, portions of the branches and crown are generally partially reconstructed or missing, which can hinder accurate AGB estimation from the full 3D model. Additionally, certain meshes were unusable due to poor reconstruction quality and were therefore excluded from the analysis (e.g., Figure 11). Larger trees generally yield higher-quality meshes, as illustrated in Figure 12, likely due to their thicker branches, which are less affected by movement caused by wind.

Fundamentally, 3DGS relies on conventional photogrammetry processes, such as Structure-from-Motion (SfM); consequently, factors that impact SfM also affect the quality of 3DGS reconstructions. These factors include wind and complex tree structures, as illustrated in Figure 13.

This dataset serves as a benchmark for the quality of real-life trees reconstructed using our photogrammetry workflow and techniques. It includes diverse examples, varying in size, species, and structural complexity, captured under a range of environmental conditions, including different lighting and weather. For future model training, we advise

Figure 12. Multiple group of large tree mesh result.

Figure 13. Ground truth (left) vs Polycam's 3DGS render (right)

researchers to augment this dataset with additional publicly available data to enhance the generalizability of their models.

7. Limitations and Future Work

The results indicate that photogrammetry provides a reasonable estimate of DBH and can yield high-quality 3D reconstructions under optimal conditions. However, the average error is generally higher compared to more advanced LiDAR-based techniques. The workflow is also susceptible to human error during model scaling, as reconstructed models are manually scaled to match reference objects or measurements. To reduce human-induced scaling errors, automated scaling techniques—such as coded targets including CCTags (Meshroom) or AprilTags with known inter-target distances—should be employed.

Advanced and cost-intensive solutions can also be employed to enhance reconstruction accuracy in photogrammetry in future work. These include utilizing GNSS (Global Navigation Satellite System) base stations in combination with GCPs (Ground Control Points) which enhances spatial accuracy by providing precise georeferencing. High-end UAVs equipped with RTK (Real-Time Kinematics) or PPK (Post-Processing Kinematics) capabilities can also improve precision.

8. Conclusion

In this paper, we investigate the potential of photogrammetry for 3D tree reconstruction aimed at measuring tree dimensions, employing current state-of-the-art tools and services. We release a comprehensive dataset of reconstructed vegetation models in both 2D views, mesh and 3DGS formats, accompanied by their geometric accuracy evaluated using DBH measurements. Additionally, we provide a detailed documentation of our workflow, including all tools and techniques utilized to achieve these results.

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