**Measuring and Preserving the Texas A&M Century Tree using Mobile LiDAR**

*Technical Report*

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Abstract

As a symbol of Texas A&M University, the Century Tree is one of the most recognizable landmarks in College Station, Texas. This massive Live Oak (*Quercus virginiana*) has been growing at the university since the late 1800's, and supports numerous traditions and scholarships important to the campus community. As part of a new monitoring and preservation effort, we employed the use of mobile LiDAR as a non-invasive approach for estimating physical parameters of the tree and creating a 3D digital rendering. Our study suggests that LiDAR-derived measurements are more precise than traditional field-based methods for estimating tree height and diameter at breast height in an urban setting. These measurements can be utilized alongside species-specific allometric equations to estimate values previously calculated by collecting samples which may damage the tree. This study also contributes to the ability of LiDAR point clouds to be used as a tool for cultural preservation alongside historical recordkeeping.

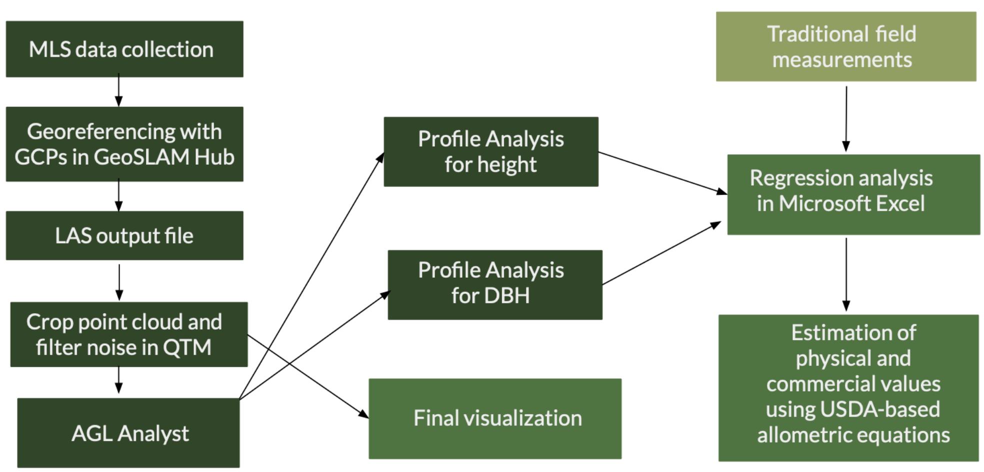



Figure 1. Graphical abstract of project methodology.

## 1. Introduction

### *1.1 Literature Review*

LiDAR-based remote sensing has become a popular approach for forest monitoring due to its ability to gather large amounts of 3D data and its relatively low financial cost (Wu et al., 2018). LiDAR sensors also allow for higher coverage of large areas and potentially less logistic difficulties than traditional survey methods. Ongoing advancements in the field have allowed us access to real-time 3D forest structures and created innovative methods for quantifying and monitoring ecosystem functions (Calders et al., 2020). Mobile LiDAR scans (MLS) are particularly effective for forestry applications due to their low weight and power requirements, and their high maneuverability (Raj et al., 2020). There are numerous mobile LiDAR sensor models available on the market for civilian use, providing a unique opportunity for extensive data collection. Some potential applications of MLS for forestry include measurements of tree height, crown size, diameter at breast height (dbh), or tree identification.

The use of LiDAR for purposes outside of forestry have increased in recent years as well. One application of this is for the preservation of culture and built heritage. Through the collaboration of multiple technologies such as 3D printing, machine learning, material analysis, and LiDAR, there is potential to explore real-time monitoring and digitization of our cultures (Li et al., 2023). This contribution to preservation allows us to safeguard our cultural identities from tragedy or environmental disasters. Ongoing efforts by organizations such as the United Nations Educational, Scientific, and Cultural Organization (UNESCO) have already proven successful in preserving damaged sites (“Cutting Edge”, 2023). Given the potential for such preservation, the use of LiDAR to preserve iconic living organisms appears obvious.

*1.2 Background*

Texas A&M University is a public land grant institution that was established by the Morrill Act in 1871 (“History of the University”). As a longstanding symbol of the state, Texas A&M has numerous traditions and a rich cultural heritage. One such tradition involves the beloved Century Tree, a massive Live Oak (*Quercus virginiana*) planted during the early days of the university. Although the exact planting date is debated, it is thought to have been planted in 1881. Those associated with Texas A&M believe that the Century Tree is a symbol of love, serving as a site for marriage proposals and wedding ceremonies for decades. There is a common belief that if a marriage proposal takes place beneath the Century Tree, the union will last forever. The Century Tree is so revered by its community that the sale of seedlings grown from its acorns is large enough to support thousands of dollars for student scholarship opportunities since 2010.

As a prominent symbol of Texas A&M, there is a need to preserve and digitize the Century Tree for future generations. Although the tree has persisted for over 100 years, it is not invincible to environmental hazards. We suggest the use of mobile LiDAR to create a digital rendering which can be kept alongside all other historical records of the Century Tree. The use of mobile LiDAR also provides a non-invasive opportunity to collect monitoring data on this iconic tree. LiDAR-derived measurements coupled with species-specific allometric equations allows us to estimate physical parameters and carbon storage without needing to collect any biomass from the tree. Since the Century Tree continues to grow every year, these equations can be continuously updated with new LiDAR-based measurements as needed.

*1.3 Objectives*

It is our goal to use mobile LiDAR for the creation of a 3D model. This model will be used to collect our measurements and create a digital preservation of the Century Tree. Our specific objectives are to:

1. Evaluate which physical parameters, such as DBH or height, can be better measured with a laser than traditional methods.
2. Estimate commercial values for the Century Tree based on MLS-based measurements.
3. Investigate the cultural impact of digital visualizations.

## 2. Methods

### *2.1 Study Site and Data Acquisition*

In March 2023, we began data collection on the Century Tree (Lat 30.615947, Long -96.341405) at Texas A&M University Main Campus in College Station, Texas (Fig.2). The surrounding area is dominated by urban cover, with additional Live Oak trees planted nearby. College Station sits at an average of 87 meters above sea level, with the minimum elevation being 55 meters and the maximum being 119 meters ("College Station"). The site lies within USDA Hardiness Zone 8b, and is part of the Post Oak Savannah ecoregion of Texas.

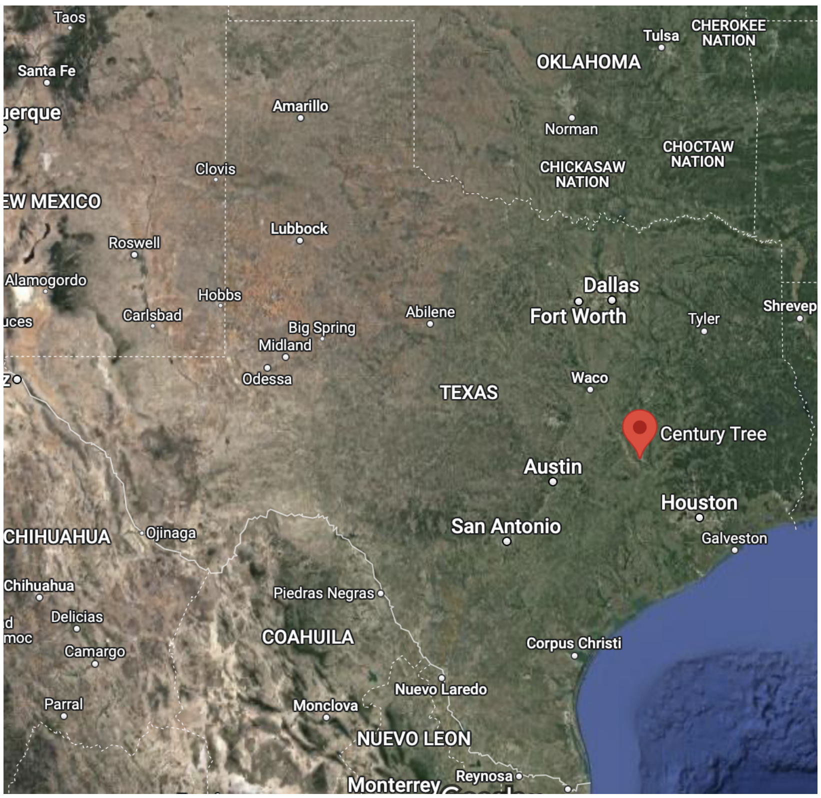



Figure 2. Location of study site at Texas A&M University Main Campus. Imagery provided by Google Earth images.

Four ground control points (GCPs) were placed at the margins of the site. We collected GPS locations at each point using a survey tripod mounted with a GNSS Trimble Geo 7x and a Zephyr 2 sensor. We then utilized a GeoSLAM ZEB Horizon scanner (GeoSLAM, Nottinghamshire, United Kingdom) to complete our laser scans. The GeoSLAM equipment is a lightweight hand-held mobile laser scanner (weight: 3.5 kg) containing an eye-safe laser that emits 300,000 lasers per second with a maximum laser beam length of 100 meters (Sofia et al., 2021). The GeoSLAM scanner was used to complete three scans along unique walking paths around the tree. Once the scans were complete, we had three observers collect a total of 12 height estimates using a rangefinder so we could average the values for comparison with the laser scans. Dbh measurements were collected using a forestry tape in April 2023 due to logistical constraints.

*2.2 Processing Approach*

The MLS scan was georeferenced with the GCPs in GeoSLAM Hub. The georeferenced data were converted into LAS files for export to Quick Terrain Modeler (QTM 8.07.1, Applied Imagery, Chevy Chase MD) and included the entire academic plaza (Fig.3). The Century Tree was cropped from the surrounding landscape and visuals of people walking nearby were removed to minimize noise. An above ground level analysis was performed to measure the physical parameters of the tree. This analysis was repeated for each scan. A line of mensuration was drawn to utilize the profile analysis tool, which verified the accuracy and completeness of the point clouds (Fig. 4a-b). Dbh measurements were collected at 1.3 meters above ground for each scan, and we replicated the procedure across two planes (X and Y) to account for variation in trunk shape. These values were recorded for comparison to manual measurements and for use in allometric equations. Finally, using QTM movie maker, visualizations of the tree perimeter and the inner canopy were created (Fig. 6-7).

*2.3 Estimation of Values using Allometric Equations*

Once we collected the estimates of dbh from our point clouds, we averaged all of the values for use in the allometric equations (Table 2.). These equations and their constants were developed by the U.S Department of Agriculture and were intended for use in urban settings. The equations and constants are listed below:

$$GUBTV = 0.0002835 * dbh\ (in\ cm)^{2.310647}$$
$$DW\ for\ Quercus\ virginiana = 800\ kg/m^{3}$$
$$Aboveground\ DW\ biomass\ (kg) = DW * GUBTV$$
$$Total\ DW\ biomass\ (kg) = Aboveground\ DW * 1.28$$
$$Estimated\ stored\ C\ (kg) = Total\ DW\ biomass * 0.5$$
$$Estimated\ stored\ CO^{2} = Stored\ C * 3.67$$
$$Hardwood\ sawlogs\ price\ (\$) = DW\ (Tons) * 33.27$$

Where *GUBTV* is General Urban Broadleaf Tree Volume, *DW* is dry weight, and *C* is carbon. All constants were derived from the Urban Tree Database and represent species-specific values (McPherson et al., 2016). The estimations for commercial values utilized the aboveground biomass value calculated from dbh. This value was converted to US Tons and priced accordingly with the Texas A&M University Forest Service timber prices from 2022 ("Stumpage Price Trends", 2022). The dollar value used in this calculation was based on a simple average of weighted and unweighted average statewide prices for hardwood sawlogs.

## 3. Results

**Table 1. Century Tree height field measurements collected in meters.**

| Observation method | Height (m) | | | |
|---|---|---|---|---|
| *Field-based* | | | | |
| 1 | 13.4 | 13.8 | 13.4 | 14.2 |
| 2 | 12.8 | 12.7 | 13 | 12.3 |
| 3 | 13.6 | 14.3 | 13.6 | 12.8 |
| | | | | ***Field average = 13.3*** |
| *Point cloud* | | | | |
| 12-41 | 14.2 | | | |
| 19-04 | 14.2 | | | |
| 31-06 | 14.3 | | | ***Point cloud average = 14.2*** |

**Table 2. Century Tree diameter at breast height (DBH) in centimeters**

| Observation method | DBH (cm) | |
|---|---|---|
| *Field-based* | | |
| 1 | 116.84 | |
| *Point cloud (y)* | | |
| 12-41 | 99.99 | |
| 19-04 | 140.79 | |
| 31-06 | 145.23 | ***Point cloud (y) average = 128.67*** |
| *Point cloud (x)* | | |
| 12-41 | 114.91 | |
| 19-04 | 113.51 | |
| 31-06 | 137.99 | ***Point cloud (x) average = 122.14*** |

**Table 3. Summary of calculated physical parameters**

| | |
|---|---|
| Tree volume | 19.99 cubic m |
| Aboveground DW biomass | 15,999.56 kg |
| Total DW biomass | 20,479.43 kg |
| Stored C | 10,239.72 kg |
| Stored CO2 | 37,579.76 kg |
| Standing timber price | $586.75 |

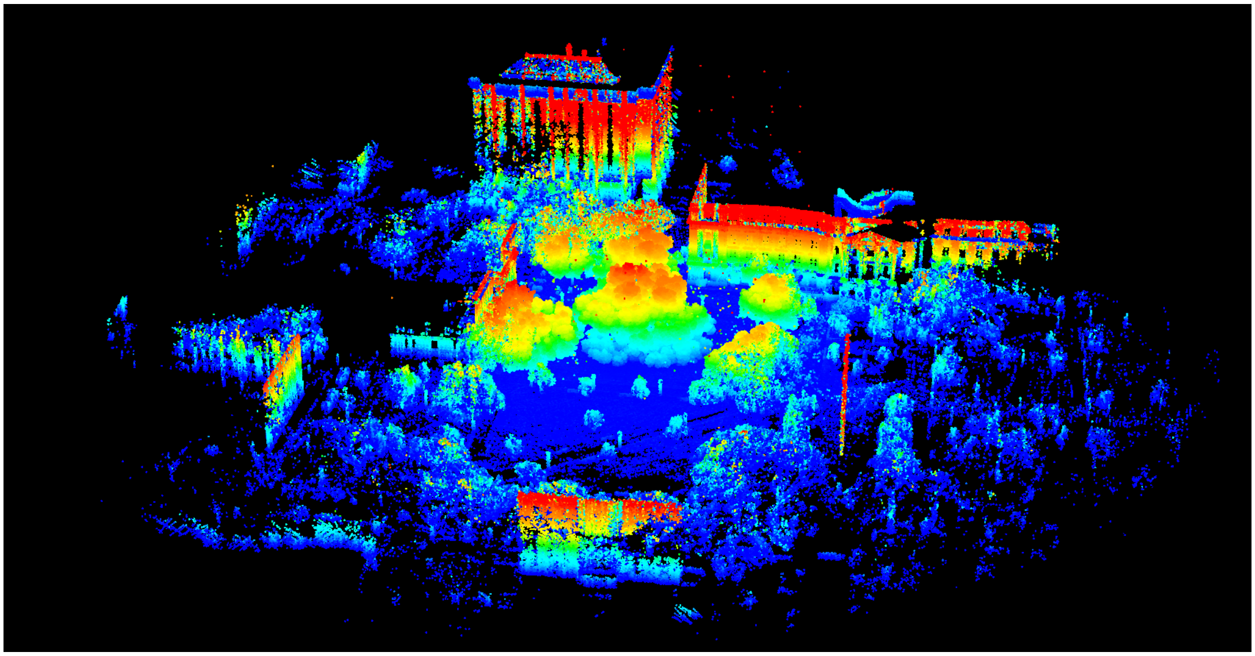


Figure 3. The recorded point cloud file at full extent.


Figure 4a. A profile analysis of the Century tree.

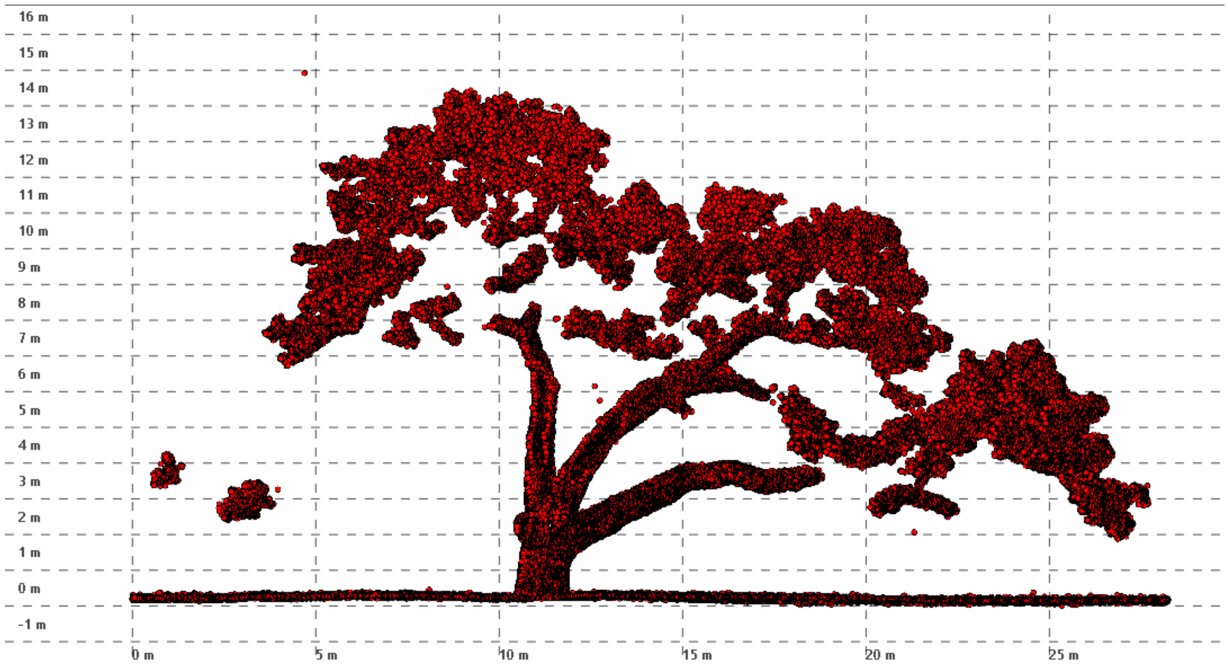



Figure 4b. A profile analysis of the Century tree.

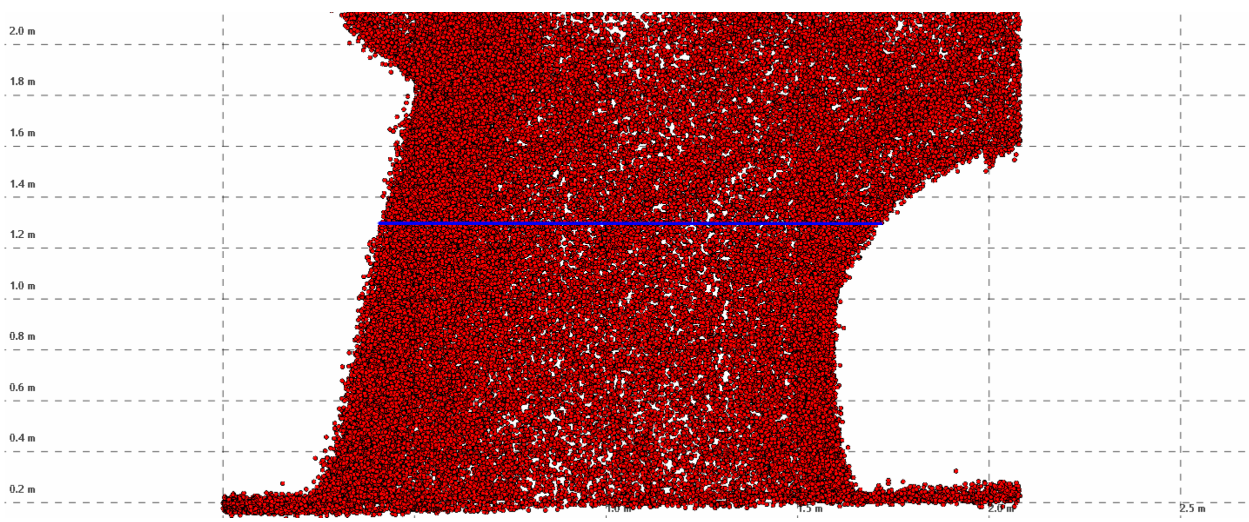
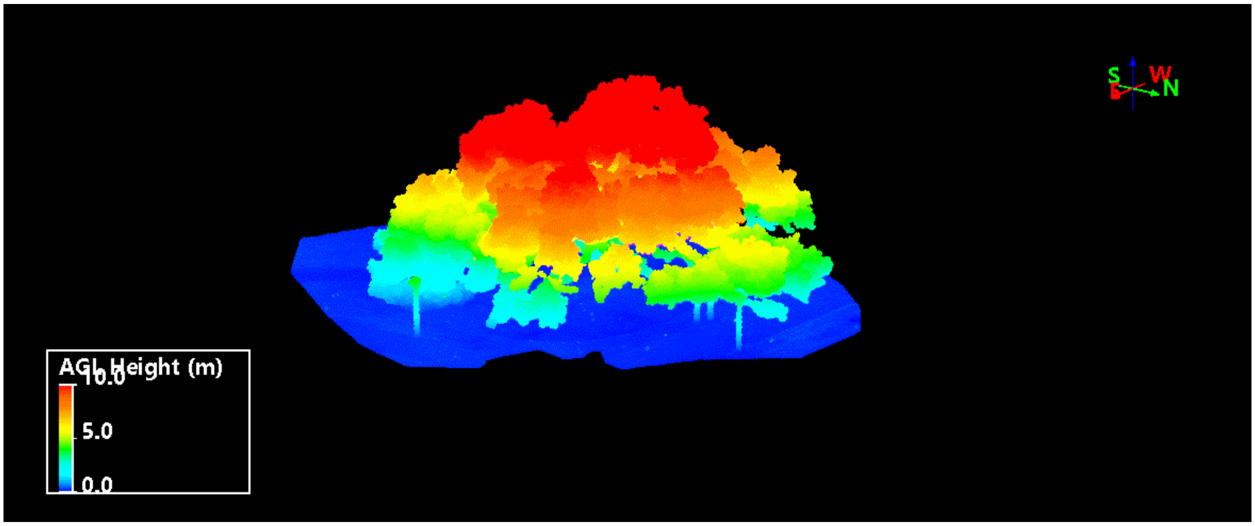
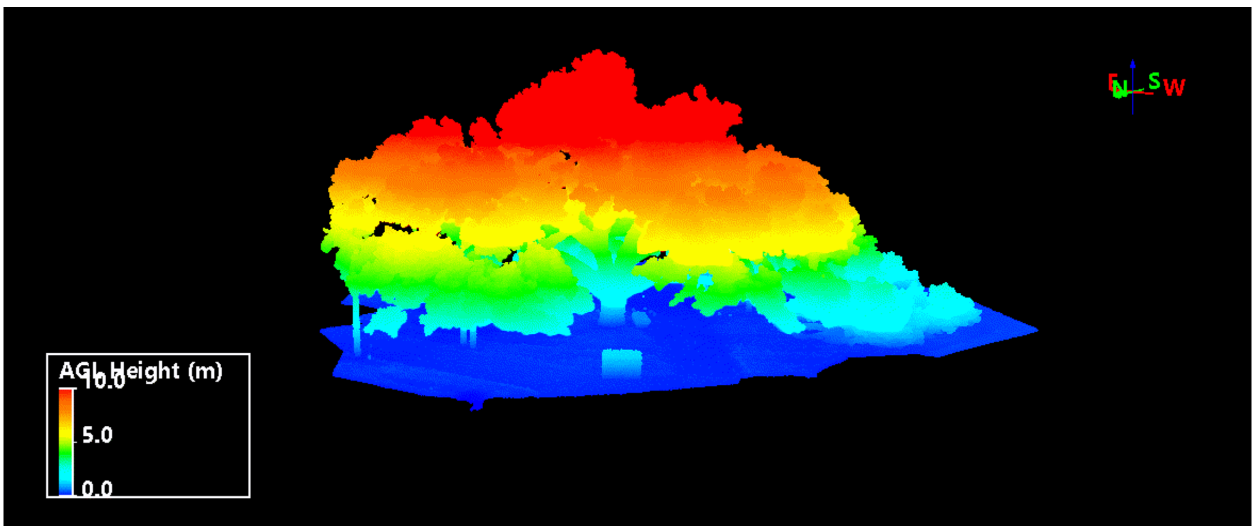



Figure 5. A line drawn on the profile analysis at 1.3 meters to record dbh.




<u>Figure 6.</u> Digital visualization of Century Tree perimeter created in QTM.




<u>Figure 7.</u> Digital visualization of Century Tree inner canopy created in QTM.

<u>4. Discussion</u>

The results of our study would suggest that MLS measurements are more precise than traditional field measurements. This is best demonstrated by our height measurements in <u>Table 1.</u>, as our point cloud values had significantly less variation than our field values ($\sigma^1$ = 0.058, $\sigma^2$ = 0.618). We saw a similar effect with our measurements of dbh, which showed more similarity between the point cloud values than the field values (<u>Table 2.</u>). Dbh was more difficult to analyze, however, as there may have been discrepancies due to support wires along the trunk surface and difficulty in using the forestry tape. As for the commercial values in <u>Table 3.</u>, we would like to note that the standing timber price is only an estimation, as timber prices are highly variable based on market conditions, interior condition, harvesting method, and species. Future efforts to digitize natural features such as the Century Tree may benefit from the inclusion of a RGB sensor on their MLS device, so their visualizations could be done in true color.

<u>5. Conclusion</u>

Our digitalization ensures the preservation of the Century Tree and its traditions for future generations. Our final products are intended to contribute to the Texas A&M Traditions Council, an organization devoted to the promotion and preservation of university traditions. Additionally, our work can serve as a point of reference for future monitoring by the Department of Ecology and Conservation Biology as the tree continues to grow.

The use of LiDAR as a measurement tool in forestry continues to show immense promise. Our study is one of many that have demonstrated the value of remote sensing data as an alternative to conventional techniques. The framework introduced in this study could benefit the preservation of other famous natural features as a non-invasive alternative to traditional procedures. Although the results identified some discrepancies between the two methods, our LiDAR scans demonstrated the preciseness of remote sensing methods in evaluating physical parameters from 3D point clouds. This work contributes to the continued use of remote sensing methods across a wide array of fields, and will hopefully lead to a better understanding of the use of LiDAR in cultural preservation.

## 6. Statement of Contributions

Conceptualization by M. Nelson, H. Schmidt, S. Popescu, and S. Arias. Data collection and processing by J. Jones, M. Nelson, and H. Schmidt. Data visualization, writing, and figure presentation by H. Schmidt and M. Nelson. The authors declare no conflict of interest.

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