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Extraction of tree parameters using terrestrial 3D LIDAR data

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Abstract
Availability of sufficient green spaces becomes one of the mandatory requirements nowadays for any cities of the world as the growing population and urban sprawl leads to reduction to green cover. Popularly called as urban green spaces (UGS), they not only help to reduce the heat islands in a city but also ensure healthy well-being of the city residents. UGS extraction from satellite images as attempted in many studies has many limitations. For example, one can see only two-dimensional spread of UGS and it may not be possible to extract the tree parameters such as height, diameter, etc. as one can measure only area of UGS that too not at individual tree level if medium and low-resolution satellite images are used. To overcome all these drawbacks with satellite images, LIDAR technology can be used by laser scanning of trees and the collected LIDAR data can then be used to built the 3D models of trees. The present study did the same by carrying out the LIDAR survey for a sample tree located on a highway side in Vellore, India. The LIDAR scans were then registered at an accuracy of 6 mm in order to get a single point cloud which is free from noises and was then used to extract the required parameters, namely, the height of tree, diameter at breast height and crown base height. The results revealed that terrestrial LIDAR survey is one of the potential data sources for extracting the tree parameters precisely.

1. Introduction

In any city or town, it is generally good to have greener in the form of trees, shrubs, meadows, grasslands, parks etc. as UGS helps to alleviate the urban heat islands in the city and also help to reduce the stress levels and improve the well-being of the city inhabitants. Even though shrubs, grasslands, and other forms of UGS play an important role, predominantly urban trees act as an important resource in order to preserve and to protect the aesthetical and ecological balance (Ning et al., 2019). Because of rapid urbanization in recent decades, migration of people in need of jobs and better life is witnessed in almost all the cities of developing nations like India and this results in increase of urban areas or lead to urban sprawl. One of the major ill effects of urban sprawl is loss of tree coverage and thereby reduction in UGS extent. Thus, it becomes essential to map urban trees in a city which will help to examine the extent of green spaces and also aid in development of planning and policy regulations. Manual survey of UGS is not an easy task as it demands high manpower, huge time and also it is a costly affair. To overcome this laborious task, researchers started using remote sensing satellite images, where the images of resolution 10 m to 60 m were mostly employed (Chen et al., 2021; Wei et al., 2023). The major advantage of using remote sensing images for UGS extraction is medium and low-resolution images can be obtained at free of cost. But the problem is it is difficult to locate individual trees on a medium and low-resolution satellite image. The alternative option is to use high- and very high-resolution satellite images but the problem is they are very costly. Apart from the cost, one major drawback of satellite images is we can only see plan view or two-dimensional representation of the UGS area and thus one cannot get three-dimensional view of trees. Because if we have 3D data, then we can easily obtain all the tree parameters such as tree height, diameter, crown area, etc. at individual tree level. Such 3D data can be obtained using advanced techniques like Light Detection and Ranging (LIDAR).

Terrestrial LIDAR, mobile LIDAR, airborne LIDAR, and Unmanned Aerial Vehicle (UAV) LIDAR are the four categories of LIDAR technology based on various platforms. In contrast to other platforms, UAV and Terrestrial LIDAR achieve a reasonable balance between practicality, spatial coverage, and data quality (Hui et al., 2021). Though there are more UAV based studies (Wagner & Egerer, 2022; Xiao et al., 2022; Yang et al., 2022), however they need more technical skills and also

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the permission issues for LIDAR data collection. On the other hand, terrestrial LIDAR technology does not require permission issues as they are tripod based and they can easily measure the 3D spatial structure of trees by gathering signals from backscattered laser pulses (Hui et al., 2021). Terrestrial LIDAR technology has been evolving incredibly as it has been the latest active distant sensing technology in recent years (Sun et al., 2022). LIDAR technology can collect data more quickly and precisely than conventional passive optical remote sensing measures. It can also acquire laser pulses from the ground, multiple stems of trees and is less impacted by the lighting conditions outside. As the laser pulses scan the trees in 360 degrees, measurements can be visualized in three-dimensional (3D) structure. As a result, LIDAR has been used extensively in forest inventories, particularly for extracting the tree parameters. Tree extraction is the process of extraction of individual trees from LIDAR point clouds in order to estimate the tree parameters such as its spatial position, tree height, diameter, and crown base height, etc. Investigating a precise, effective, and reliable method of tree extraction is of tremendous practical significance and production application value. Hence in the present study, an attempt has been made to perform LIDAR survey and carryout suitable post processing techniques for tree extraction and accurate measurement of its parameters.

2. Method

2.1 Study area, Data Collection & Methodology

Figure 1 shows the flowchart of the proposed methodology. The first step is to choose a suitable LIDAR instrument for our survey. In the present study, BLK 360 laser scanner was employed. It is one of the popular laser scanners in the terrestrial category and the scanner range is 60 m which means all the objects which are at a distance of 60 m or less will be covered. The instrument is handy as it weighs less than a kg and thus easy to take to the field and perform survey. The second step is selecting a suitable location where the LIDAR survey can be carried out without any obstruction or disturbances. After seeing many locations, finally the study area was located in Tiruvalam - Katpadi road in Vellore city of Tamil Nadu, India where a tree on the roadside was found. Figure 2 shows the actual photo of the tree selected. The reason for taking this particular location is sufficient space was there on the road side at this location without any shops or houses so that tripod can be kept and survey can be carried out without any hindrances. A clear sky day was taken for the survey so that the laser scanning should not be disturbed by rain or water droplets. The BLK 360 was kept on the tripod, levelled and scanning was then started. During survey, the scan duration was set as medium so that the scan will complete in 3 minutes. Hence the scanner was kept near to the tree within a distance of 60 m so that laser scanning will cover the entire tree. The scanner can emit 360000 pulses per second, so in a 3-minute duration, millions of laser pulses will hit the target (tree) and thus finally we can get a dense point cloud of X, Y, Z values.

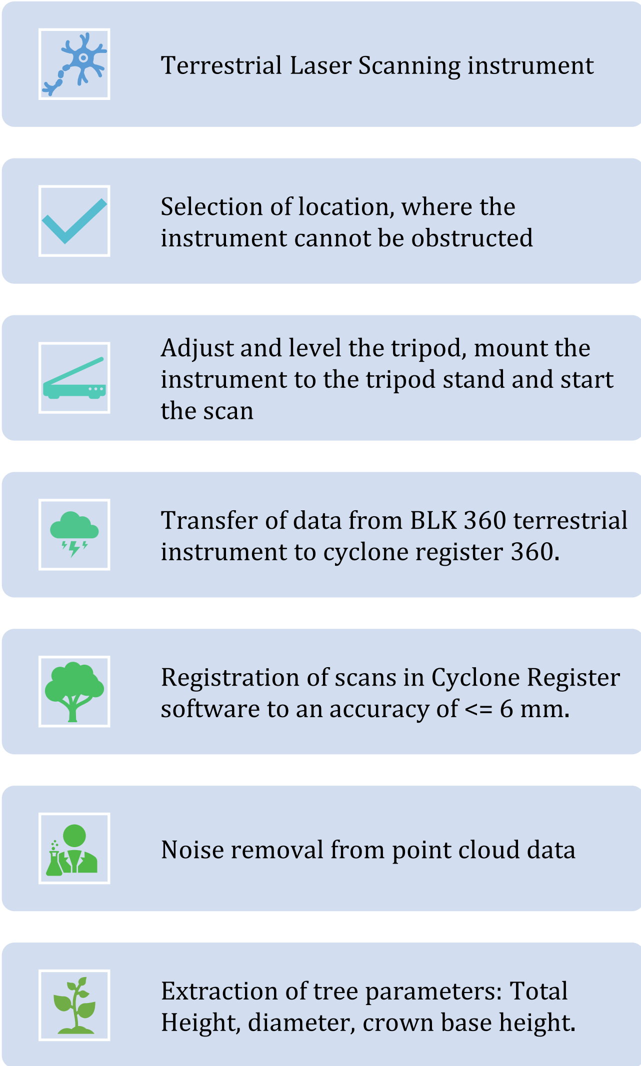

Figure 1. Methodology for tree extraction from LIDAR data

Figure 2. Photo showing the tree selected for LIDAR survey

Once the survey is over, the next step is to transfer the data to postprocessing software. Cyclone register 360 is the postprocessing software for BLK 360 and the same has been used in the present study. Each scan would normally occupy 250 MB space and hence a computer system with high end specifications would be better. The data was finally transferred to the software from BLK and the scans were registered to get an accuracy of 6 mm.

Both manual and automatic registration options were available in the postprocessing software. As the scans were taken within the range of 60m, they were automatically registered by the software with an accuracy of 6 mm. Once the registration is over, the next step is removal of noise. Because sometimes, the collected LIDAR data may have unwanted noises such as adjacent trees, buildings, electric wires, vehicles, roads, pedestrians, etc. Those noises need to be removed and the same has been done in Cyclone register 360 during the postprocessing stage. Once the noise removal is done, the last step is to extract the required tree parameters such as height, diameter, etc. using the measurement tool in Cyclone register 360. Finally, the required tree parameters were extracted precisely using the point cloud data as it contains millions of accurate X, Y, Z values.

3. Results

The result of point cloud data before removal of noises is shown in Figure 3. We can see adjacent trees and other noises in Figure 3 which need to be removed before we can start the measurement process. The 3D model of the tree as seen from Figure 3 can be obtained only from LIDAR surveys and not from conventional field surveys or satellite imaging approaches, where only two-dimensional representation of tree is possible.

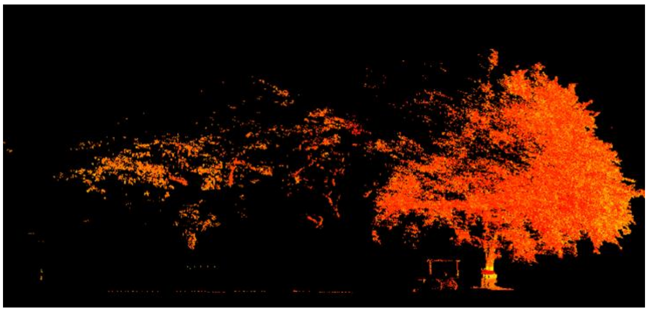

Figure 3. Side view of the LIDAR point cloud before noise removal

The point cloud data after removal of noises is shown in Figure 4. Though the trees in Figure 4 a & b looks slightly different, but they are actually the same tree. Figure 4a is the side view of the tree taken in Cyclone Register 360 software and 4b is the same tree viewed in ArcGIS software. The advantage of ArcGIS software is we can view in different angles by converting the data to LAS dataset and view it using 'LAS dataset 3D view' tool in ArcGIS software. Once the tree is extracted as shown in Figure 4, the next step is to perform the required measurements in Cyclone Register 360 using the measurement tool. In the present study, three parameters were measured from the point cloud data, namely, height of the tree, diameter at breast height and crown base height.

To measure the tree height (TH) in cyclone software, we zoomed to the maximum extent of the individual tree to clearly see the bottom and top points of the LIDAR data. Then using measuring tool, the total height of the tree from bottom to top was then measured accurately as shown in Figure 5a. Traditionally the diameter at breast height (DBH) should be measured around the trunk of the tree at 1.3m height from the base. In case if tree has a split in trunk portion at 1.3m height from the base, then we need to take an average of the trunks diameter to get the DBH. However, in our case, we didn't find any split-ups in the trunk portion of the tree at 1.3 m from base and splits were there only above 1.3m as seen from Figure 4b. As like before, using the measuring tool of Cyclone software, the DBH was measured as shown in Figure 5b. Finally, crown base height (CBH) was measured from bottom of the tree points to the slit where the living branches of the tree begin as shown in Figure 5c. Thus, the TH, DBH, CBH was calculated as 13.135 m, 3.252 m and 2.11 m respectively. It is important to mention here that, with the help of 3D LIDAR data, one can easily measure the required tree parameters in a precise manner which is not possible with even very high satellite images as they are limited to exhibit only two-dimensional representation of any objects on the earth.

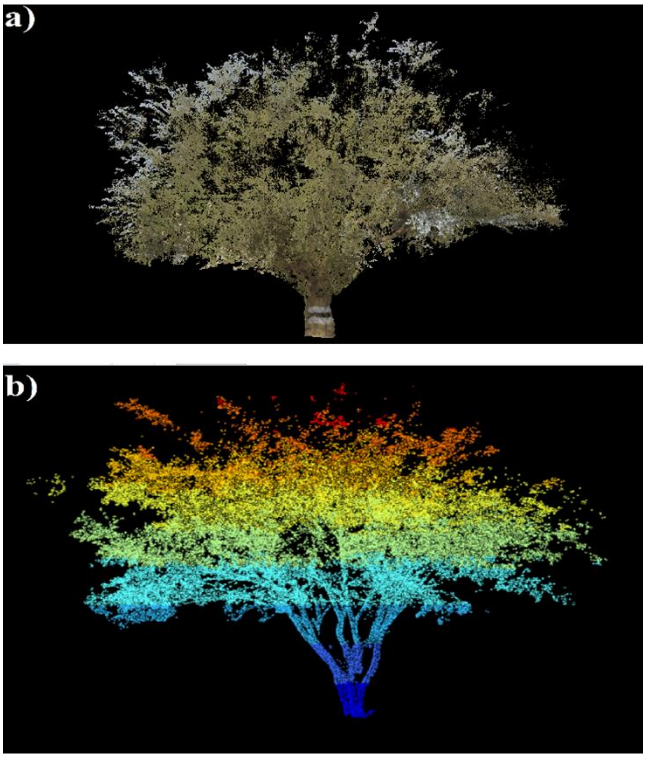

Figure 4. Tree after removal of noises a) View from Cyclone Register 360 b) View from ArcGIS after LAS conversion

4. Conclusion

UGS in any city or town is essential both from environmental and social point of view as it helps to reduce the city heat waves and at the same time ensure healthy well-being of the city residents. UGS extraction from satellite images as attempted in many studies has many limitations such as only two-dimensional representation possible, insufficient data for extracting tree parameters, etc. Hence the feasible option is to use the LIDAR data where one can built 3D models easily and accurately and the same can be used to extract the required parameters too. The present study showed the same for a sample tree on a highway by performing LIDAR survey and postprocessing of the collected data.

The tree was extracted by removing all the unwanted noises and required parameters such as height, diameter were then extracted. The results suggests that LIDAR data is a promising data source for extracting tree level data.

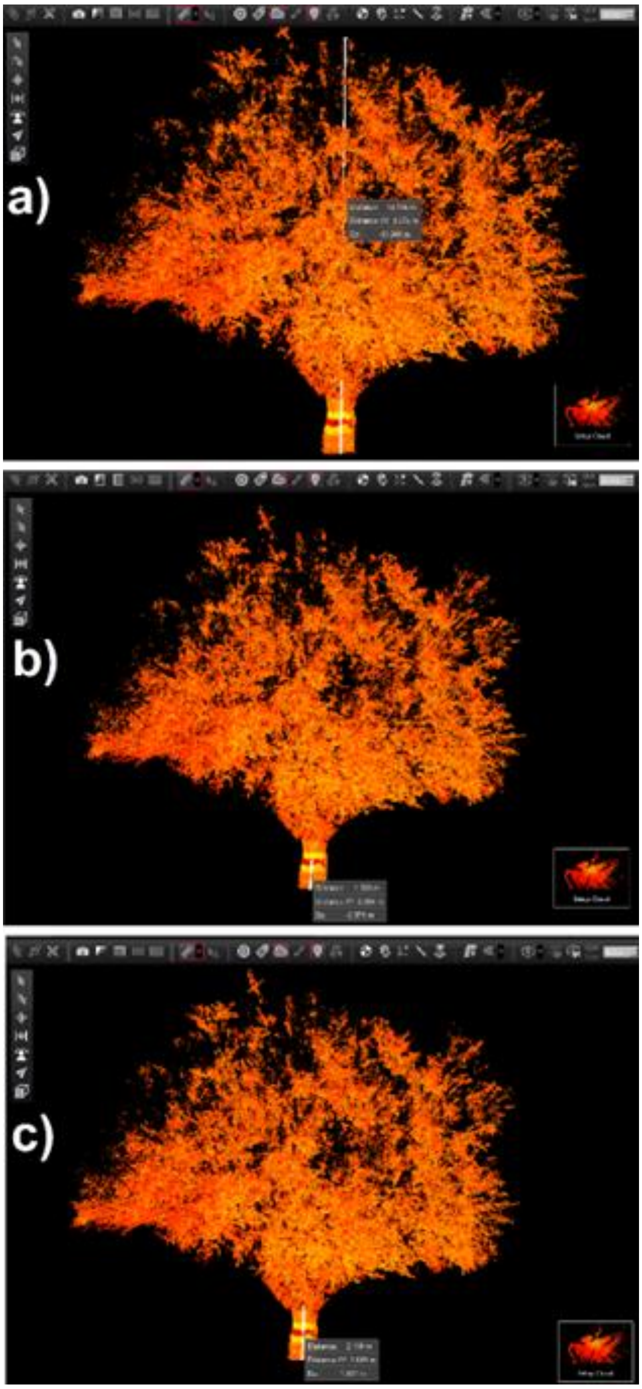

Figure 5. Extracting tree parameters: a) Tree height, b) Diameter at breast height, c) Crown base height

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