Vegetation identification, segmentation and geometry assessment using airborne LiDAR

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Introduction

Remote sensing, the process of obtaining information about an object or an area from a distance (typically by a satellite or an aircraft), is a very useful technique to perform land mapping tasks and is a rapidly growing technology for forest monitoring and management.

Tasks such as construction of a forest inventory, identification of vegetation species and structure, number of trees, dimensions, etc… which previously required extensive field work, have now been replaced by easier, faster and cost effective remote sensing methods.

Compared to manned flights and satellite data, Unmanned Aerial Vehicle (UAV) based mapping offers a complementary solution that is significantly better in terms of resolution, accuracy, cost and man-effort.

In this work, we assess the advantages of UAV-based forestry mapping using Light Detection And Ranging sensors (LiDAR). For this purpose, we mapped a small forested area inside the University of Coimbra campus using two approaches: 1) LiDAR mounted on a UAV and 2) measurements using a conventional ground LiDAR. Our results reveal that UAV-based measurements present deviations in the range of 0.11m, when compared to the terrestrial delivery methods, while being far more effective in terms of time (30x faster) and effort.

Methodology

The study site, shown in **Fig.1**, was located in the University of Coimbra campus, Portugal, and is a flat ground with some ground level vegetation and randomly spaced trees.

The UAV used in this study was a DJI Matrice 600 Pro multirotor, equipped with a Velodyne VLP-16 LiDAR, as shown in **Fig.2**. For the ground measurements a Nikon® Forestry Pro hypsometer was used.

The UAV data was pre-processed in CloudCompare, an open-source point cloud processing software. The ground measurements were manually processed. This obtained LiDAR point cloud was used to create Digital Elevation Model (DEM), Digital Terrain Model (DTM) and Canopy Height Model (CHM). Based on the CHM, ITD and individual tree size measurement tasks were done.

Fig.1. Study site coordinates N 40.184902 E -8.415163.

Fig.2. UAV platform with LiDAR payload

Results

The processing of the UAV-acquired point cloud, shown in **Fig.3**, was as follows. First, a statistical outlier filter algorithm was used to remove the points that were too far away from their neighboring point clusters. After trimming the data to achieve the area of interest, a second filtering algorithm called cloth simulation filter was applied to separate the ground from the above-ground points. This filter created a mesh based on extrapolation of ground points to simulate the ground. After the above-ground points were annotated with their elevation relative to the ground, the point cloud was rasterized, resulting in the CHM of area. (R -v 4.2.0, 2021) was used for processing the CHM. A local maxima algorithm was used to count the trees in the CHM. Eight random trees were selected for collecting field measurements and these were compared with the results from the CHM. The results are shown in **Table I**. The root mean square deviation (RMSD) from the height estimation was 0.11m.

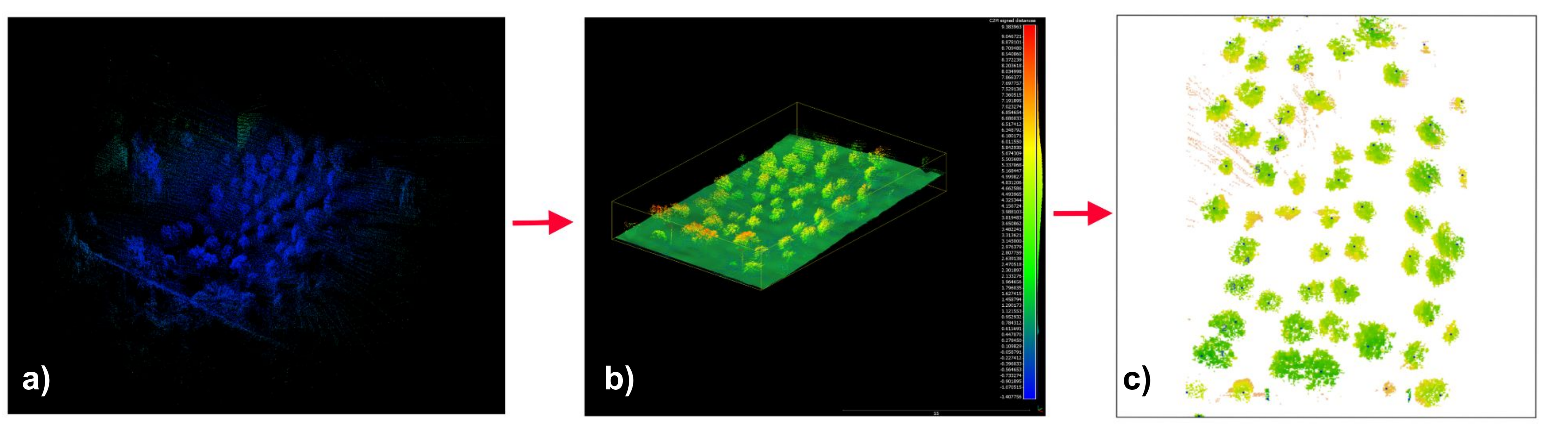

Fig.3. Processing pipeline from a **a)** raw point cloud to a **b)** model using cloth simulation filter and the **c)** canopy height model.

Table I. Results for tree height measurements for eight randomly selected trees, using ground measurement and UAV-based techniques.

Tree Tag	Ground truth height (m)	Estimated height (m)
1	8.2	8.23
2	7.7	7.81
3	6.3	6.32
4	6.6	6.50
5	7.8	7.70
6	6.4	6.50
7	5.2	5.00
8	6.0	6.13
RMSD = 0.11 m		

Conclusions

The results from the comparison between the UAV-born LiDAR mapping and ground measurements reveal that such techniques can be used as a robust measurement tool for forestry applications. The time and effort costs of UAV-born LiDAR mapping are also far lower than when compared with traditional ground measurement techniques, with the mapping process being almost fully automated and taking 30x less time to perform. A few highlights of this study are listed as follows:

1- Down-sampling algorithm (point accumulation methodology) is a critical factor. the point clusters density has a direct effect on the quality of simulation of object of interest.

2- Flight and scanning scenario are the other deciding factors on the quality of obtained result. Depending on the defined task (specific forestry parameters to be measured), scan scenarios must be defined, in terms of observed scenery, point density, energy and resources allocation.

3- The conducted flight and scan scenario is sufficient for an area with the similar characteristics as the one in this study. Denser and more complex environments require deeper and more complex scan scenarios.

The obtained data has multiple applications, including forest biomass monitoring and management for profitability and wildfire risk assessment. Furthermore, within the Safeforest project, it will be used to generate transversability and fuel maps, which will be used for the path-planning of the semi-autonomous rovers.

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