Comparing portable MLS to TLS and UAV-LS derived individual tree parameters

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1. Introduction

LiDAR is becoming an important technique for forest monitoring. The 3D representation through LiDAR scans can give valuable insight in to forest functioning and changes there in (Calders et al., 2020) or give us individual tree biomass (Gonzalez de Tanago et al., 2018).

LiDAR can be used to derive forestry parameters in different setups. Terrestrial Laser Scanning (TLS) has been used to measure and monitor forests for many years, and is especially valued for the high accuracy of TLS measurements and derived parameters. Unoccupied Aerial Vehicle laser scanning (UAV-LS) has become available over the last years and has shown to be an effective system to investigate forests that cannot be entered by foot, or facilitates covering larger areas in a shorter time. Mobile laser scanning (MLS) is one of the techniques to acquire forest understory 3D data (Liu et al., 2021). The technique uses the simultaneous localization and mapping (SLAM) algorithm to efficiently create 3D point clouds.

Mobile LiDAR scanners could prove very useful in circumstances where traditional TLS systems face difficulty, and where UAV-LS is prohibited or too costly. However, the precision of MLS in comparison to TLS and UAV-LS dictates the usefulness of the mobile systems to measure and monitor trees in forests and urban environments. Further testing is required to show the applicability of MLS in forests (Calders et al., 2020).

Different platforms all have their pros and cons, where mainly the acquisition speed is a point of interest. The practical problem is that for subsequent sampling (e.g. for forest monitoring), TLS is too slow and labour intensive. UAV-LS could partly fill this gap, but the operation is complicated and costly in comparison to MLS. A UAV-LS vs TLS comparison was done by Brede et al. (2017), who showed that both techniques have the potential to derive tree metrics, like tree height and diameter breast height (DBH). Previously, MLS and TLS were compared by Bauwens et al. (2016), but the MLS technique has further developed, which has resulted in increased measurement range and point densities.

The objective of this paper is to benchmark the performance of a backpack MLS system against TLS and UAV-LS for the estimation of some common tree parameters. This is done in two case studies: the MLS vs UAV-LS comparison is done for a small forest area, while a comparison of MLS and TLS is done for trees in an urban area.

2. Data and Methods

The data for the MLS vs UAV-LS comparison has been acquired in the Oostereng, a forest in the Veluwe area, the Netherlands. The trees in the investigated forest plot are of the species Douglas fir (*Pseudotsuga menziezii*), and all data has been acquired in February 2021. MLS data were collected with the Greenvalley LiBackpack DGC-50, a dual LiDAR backpack system, composed of two Velodyne VLP-16 scanners, Inertial Measurement Unit, GNSS, 360 degree camera and processing unit. Initial data processing through SLAM is done on the processing unit itself, but integration of GNSS data and data point coloring is done during post-processing. UAV-LS data were acquired on the same day using a Riegl Ricopter with a VUX-1UAV scanning system. Flights were conducted at 90 m above ground level and processing to a geo-rectified pointcloud was done following the procedures described in Brede et al. (2017). A 25 m x 25 m subset of the forest plot was selected for further analysis, where 12 trees were visually identified and manually segmented using CloudCompare (Cloudcompare, 2020). Tree height was calculated by subtracting the minimal z value from the maximal z value for each of the tree segments. The DBH was calculated with ordinary least squares circle fitting implemented in the

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lsfit.circle function from the R package “circular”. The DBH was calculated at 1.3 m above ground, with a 5 cm buffer. The subsets were visually inspected to filter out points that were not situated around the trunk of the trees. Two trees needed adjustments to create a correct subset of the trunk at DBH height.

Data for the MLS vs TLS comparison were collected in January 2021 on the Wageningen University and Research campus in Wageningen, The Netherlands. The 22 selected deciduous trees, growing next to a road, were scanned with the Riegl VZ-400. Ten scan locations were chosen and for co-registration of the individual scans, six reflectors were installed on both sides of the road. MLS data of the same area were acquired using the Greenvalley LiBackpack DGC-50 system. Extraction of individual tree point clouds was done with Cloud Compare software in a manner similar to Lau et al. (2018). Tree height was deduced by taking the distance between the top and bottom point. Crown diameter was calculated the average of the the largest lengths of the crown in the North-South and East-West directions.

For both cases the different point clouds were first coarse registered by manually selecting corresponding points and performing a rigid body transformation. Fine registration was done with the Iterative Closest Point algorithm in CloudCompare.

3. Results and Discussion

In the forest plot the MLS measured tree height of most trees is within 0.5 m of the UAV-LS tree height (Figure 1). However, when the canopy is denser the MLS system has difficulties to reach the top of the canopy, which is shown by a lower tree height measured with MLS compared to UAV-LS. For the 12 trees in the subplot this results in an RMSE for the tree height of 1.61 m, which is almost solely a result of the 4 trees of which the upper canopy was not properly sampled.

The DBH calculated from the UAV-LS point clouds is generally larger than for the MLS data, which is summarized in an RMSE of 9 cm between both acquisition methods. This is largely the result of one tree where the DBH estimates had a great deviation. .

Differences between calculated tree height and DBH of MLS and UAV-LS datasets were statistically analysed using linear regression and paired t-tests. The calculated tree height was significantly larger for a tree from the UAV-LS dataset compared to the MLS dataset ($t = 2.254$, $df = 11$, $p = 0.0456$) . The same pattern was observed for DBH ($t = 3.619$, $df = 11$, $p = 0.0040$).

For the campus site the tree height and crown diameter were compared, and MLS and TLS give very comparable results in this case (Figure 2). Since all trees are free standing and relatively low there is very low occlusion, and as a result the estimated height of the trees is almost identical (RMSE = 0.01 m). Also the crown dimensions are comparable between the systems.

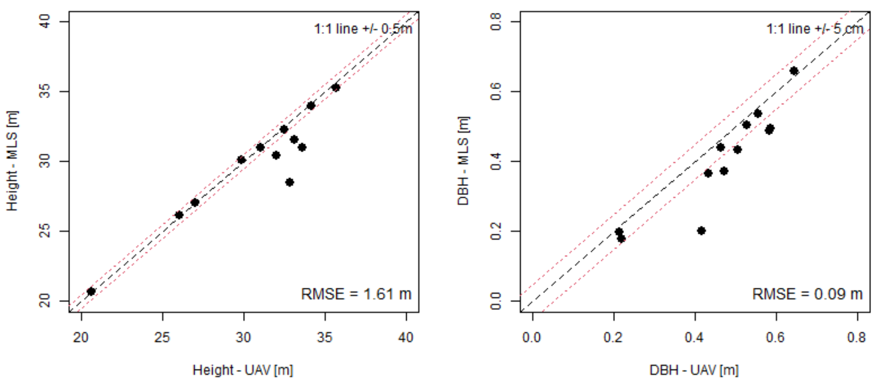

Figure 1: scatterplots of MLS vs UAV-LS derived individual tree height (left) and DBH (right). The dashed black line indicates the 1:1 line and the dashed red lines show the 1:1 line +/- 0.5m or 0.05m respectively.

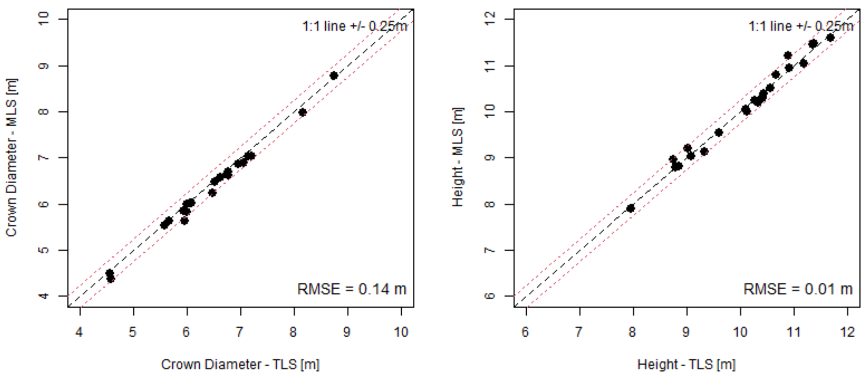

Figure 2: scatterplots of MLS vs TLS derived individual crown diameter (left) and tree height (right). The dashed black line indicates the 1:1 line and the dashed red lines show the 1:1 line +/- 0.5 m or 0.05 m respectively.

In terms of acquisition time, the LiBackPack DGC-50 MLS system outperforms both other systems. The point cloud quality of the TLS is better, but for the derived tree parameters it does not make a large difference. MLS shows to be an acceptable alternative to UAV-LS in forested areas, but with dense canopies data are to be treated with care. An improvement of the measurement strategy could still lead to better sampling of the upper parts of the canopy.

4. Conclusions

In a more open environment, the MLS and TLS tree height and crown diameter are comparable, but for a more dense canopy MLS tends to miss the treetops regularly, when compared to UAV-LS. For DBH differences are observed between systems, but evaluation against ground truth measurements has to show which is more accurate. The MLS system shows much potential in terms of usability. The scans made with the Greenvalley LiBackpack DGC-50 were made more quickly and with more ease than those made with the Riegl VZ-400 and the Riegl Ricopter.

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