Automatic Tree Breast Height Diameter Estimation from Laser Mobile Mapping Data in an Urban Context

Herrero Huerta, Monica; Lindenbergh, Roderik

Publication date
2015

Document Version
Final published version

Published in
Proceedings of SilviLaser 2015: 14th conference on Lidar Applications for Assessing and Managing Forest Ecosystems

Automatic Tree Breast Height Diameter Estimation from Laser Mobile Mapping Data in an Urban Context

Mónica Herrero-Huerta[1] and Roderik Lindenbergh[2]

[1] *Department of Cartographic and Land Engineering, University of Salamanca, Higher Polytechnic School of Avila, Hornos Caleros 50, 05003, Avila, Spain. Phone number: 0034-920353500-3820, monicaherrero@usal.es*
[2] *Department of Geoscience and Remote Sensing, Delft University of Technology, 2628 CN Delft, The Netherlands.*

Highlights: This study focuses on developing an innovative methodology to automatically estimate the diameter at breast height (DBH) of urban trees sampled by a Laser Mobile Mapping System (LMMS). The high-quality results confirm the feasibility of the proposed methodology, providing scalability to a comprehensive analysis of urban trees.

Keywords: *breast height diameter, LiDAR, urban trees, laser mobile mapping system, estimation.*

Introduction

Accurate measures of structural parameters of urban trees and monitoring their changes over time are essential to inventory of urban trees and growth models, modelling of carbon cycle and management systems of urban trees [1]. The estimation of these variables has traditionally been done with field inventories via pilot samplings. The advent of recent remote sensing technologies has opened up a new field of possibilities for carrying out such work through non-destructive methods, providing advantages regarding the economic costs involved, the time invested and estimation errors.

Among the various urban tree measurements, DBH (stem diameter at 1.3 m height) is an important tree inventory attribute because it serves as a fundamental parameter in tree allometry and estimation of basal area, thus providing valuable information about individual trees and tree stand structure. Many countries store the DBH of urban trees in cadaster databases for monitoring purposes .

The application of LMMS (Laser Mobile Mapping System) enables to fast and accurately capture 3D data of individual urban trees along the road. However, no research has been done on retrieving DBH using this technology. LMMS operates at the suitable work scale between manual and airborne LiDAR measurements. The latter fails to capture the complete vertical distribution of the canopy [2]. Terrestrial Laser Scanning has been used for estimating tree parameters[3], but being time-consuming compared with LMMS in an urban context. However, the method proposed has to face additional difficulties due to the specific acquisition geometry of the technology mentioned, such as the partial 3D data (only one side view), or having to deal with occluding vegetation, leading to underestimations compared to manually collected field data [4].

The aim of the present work is to develop an efficient and precise methodology in a novel way, to obtain DBH of urban trees destined for inventories based on point clouds coming from LMMS. Additionally, the influence of the density of points on the accuracy of deriving DBH estimations were investigated.

Materials and Methods

Laser Mobile Mapping System

For this work, data acquired by Fugro Drivemap is considered. This LMMS is composed of two high performance laser scanners type Riegl VQ250, a four-wheeled all-terrain vehicle and a navigation unit. The Global Positioning System has 10 Hz of positioning rate and the laser pulse rate is 1.333·106 pulses/s, being the maximum density 115000 points/m^2, the field of view 360^{o}x 26.8^o, the ranging accuracy less than 2cm and the maximum range 30 m.

Ground Inventory Data

The ground truth of the DBH was established using a measurement tape by a qualified operator at 5 centimeter precision. It should be remarked that the studied trees are less than 10 meters from de road.

DBH tree extraction Methodology

Before estimating the DBH, the extraction of individual trees of the point cloud is necessary through an automated workflow by voxel analysis (not the aim of this study). For the DBH tree extraction methodology the following steps are performed for each tree (Figure 1):

1). Outliers removal.

A statistical analysis on each point's neighbourhood is performed by assuming a Gaussian distribution. All points whose mean distance is outside an interval defined by the global mean distance and standard deviation are considered as outliers and removed from the dataset.

2). Extraction of trunk data.

The limit between the trunk and canopy is calculated by the curvature change of the histogram that represents the number of filled voxels of 0.25 cm^3 size as a function of height.

If the histogram shows there are ramifications in the trunk, k-means is used to assign a cluster (k clusters) to each data point ($\mathbf{x}_i$,i=1...n). K-means is a clustering method that aims to find the positions μ_i,i=1...k of the clusters that minimize the Euclidean distance from the data points to the cluster (Equation 1):

$$\arg min_c \sum_{i=1}^{k} \sum_{x \in c_i} d(x, \mu_i) = \arg min_c \sum_{i=1}^{k} \sum_{x \in c_i} ||x - \mu_i||_2^2 \quad (1)$$

where $\mathbf{c}_i$ is the set of points that belong to cluster i.

3). Determining the orientation of each trunk by Principal Component Analysis (PCA) and projecting the trunk points into a plane orthogonal to the axis corresponding to the principal direction.

A classical approach consists in performing a PCA of the 3D coordinates of the point cloud of the trunk. This statistical analysis uses the first and second moments of the point cloud, and results in three orthogonal vectors centered on the centroid of the point cloud. The PCA synthesizes the distribution of points along the three dimensions, and thus models the principal directions and magnitudes of variation of the point distribution around the center of gravity [6].

4). Fitting a circle to the projected trunk points by using RANSAC (RANdom SAmple Consensus) to mitigate the influence of outliers [7].

DBH was retrieved from laser datasets by circle fitting at different height bins. This can be done because of the assumption that the diameter is not significantly varying along a short length of the stem for mature trees.

Points that deviated most from a fitted circle were considered noise and removed for DBH estimations through the RANSAC method.

5). Quality control by obtaining the RMSE of the DBH estimated and measured at different height bin sizes.

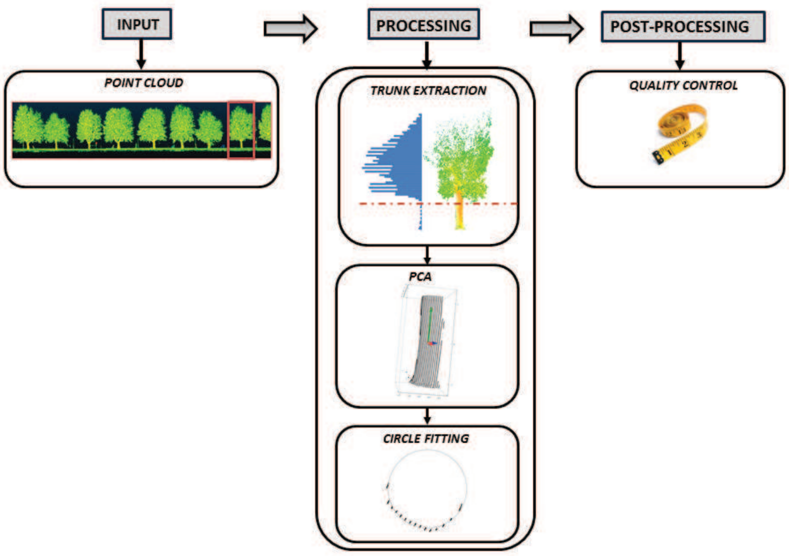

Figure 1. Workflow of the DBH Methodology

Experimental Results

The study area is located at the Delft University of Technology campus (lat. 52º00´ N; long. 4º22´ E; 1 m asl, The Netherlands) and tree species include Plantanus and Quercus. Data collection was performed on the 4th of November 2014 covering an area of approximately 750 x 1200 m on a day without wind. The dataset consists of 53,958,666 points, with the x, y and z coordinates and intensity. A pre-processing step of this dataset was carried out in order to obtain the individual trees of the zone of interest. After that, the point cloud has 1,860,156 points with no intensity. There are 29 trees in total, 14 Platanus and 15 Quercus. The diameters of the first one are bigger than the others.

The accuracy of DBH estimation is influenced by several factors. Different height bins for determining the number of points to fit the circle, were tested to derive reliably DBH estimations. In addition, DBH estimation errors were confronted with the number of points to fit the circle but a relation was not seen.

Table 1 collects the robust statistical parameters of the linear regression stablished between the actual and the estimated DBH at different height bin sizes. The probability of success to achieve a right DBH defined by this parameters, is also included. From this analysis, it is possible to conclude that 20 cm height bin provides better results, from 1.20 m to 1.40 m height of each individual tree.

Table 1. Correlation coefficients and probability of success at different bin sizes

Circle Fitting Height Bin (m)	R^2	RMSE (cm)	Probability of Success (%)
1,25-1,35	0,792	5,67	62,1
1,20-1,40	0,837	4,35	79,3
1,10-1,50	0,688	6,45	75,9
1,00-1,60	0,600	12,12	86,2

Conclusions

This research presents a non-invasive method with application to urban tree inventory that consists of DBH estimation. The method is fast, reliable, robust and objective, and could serve to take decisions in advance regarding actions to be taken in urban trees and planning the management and maintenance optimally. This study also discussed the influence of the number of points to fit the circle and circle fitting height bin size on the influence of DBH estimation accuracy, validated against field measurements. Regarding these variables, the results show that there is no significant relation between the number of points and the DBH estimation errors. A 20 cm height bin provides better results, reaching a R^2 value of 0.84 and a RMSE of 4.35 cm with a probability of success of 79.3%. In addition, the results show that working only on one side of the tree, the visible side from the road, is still feasible for approximating the DBH with an accurate and precise fit.

This methodology can be extrapolated to a comprehensive study of urban trees.

It should be mentioned that the proposed methodology is part of a robust and efficient workflow which considers the automated, large scale extraction of tree sizes and locations sampled by a laser mobile mapping system. It includes tree location, level height and crown width throw a sensitivity analysis.

Acknowledgements

Authors would like to thank FUGRO GeoServices B.V. for providing the dataset. The result is partly funded by the IQmulus project (FP7-ICT-2011-318787).

References

[1] Næsset, Erik. "Practical large-scale forest stand inventory using a small-footprint airborne scanning laser." Scandinavian Journal of Forest Research 19.2 (2004): 164-179.

[2] Lim, K., Treitz, P., Wulder, M., St-Onge, B., & Flood, M. (2003). LiDAR remote sensing of forest structure. Progress in physical geography, 27(1), 88-106.

[3] Srinivasan, Shruthi, et al. "Terrestrial Laser Scanning as an Effective Tool to Retrieve Tree Level Height, Crown Width, and Stem Diameter." Remote Sensing 7.2 (2015): 1877-1896.

[4] Moskal, L. M., & Zheng, G. (2011). Retrieving forest inventory variables with terrestrial laser scanning (TLS) in urban heterogeneous forest. Remote Sensing, 4(1), 1-20.

[5] Hartigan, J. A., & Wong, M. A. (1979). Algorithm AS 136: A k-means clustering algorithm. Applied statistics, 100-108.

[6] Van Goor, B., Lindenbergh, R. C., & Soudarissanane, S. S. (2011, August). Identifying corresponding segments from repeated scan data. In ISPRS Workshop Laser Scanning 2011, Calgary, Canada, 29-31 August 2011; IAPRS, XXXVIII (5/W12), 2011. International Society for Photogrammetry and Remote Sensing (ISPRS).

[7] Schnabel, Ruwen, Roland Wahl, and Reinhard Klein. "Efficient RANSAC for Point Cloud Shape Detection." Computer graphics forum. Vol. 26. No. 2. Blackwell Publishing Ltd, 2007.