Airborne Laser Scanning Data for Tree Characteristics Detection

Y. F. Vazirabad [a,*], M. O. Karslioglu [a,b]

[a] Geodetic and Geographic Information Technologies Dept., Middle East Technical University, 06531 Ankara, Turkey - (e169670, karsliog)@metu.edu.tr
[b] Civil Eng. Dept., Geomatics Eng. Division, Middle East Technical University, 06531 Ankara, Turkey - karsliog@metu.edu.tr

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ABSTRACT:

Airborne laser scanning (ALS) technology provides a distinctive, innovative, accurate and cost effective approach to forest inventory. ALS data is used for information extraction with respect to the detection of tree characteristics like height, diameter at breast height (dbh) and crown diameter. Also, timber volume and biomass can be estimated from this information. Forest studies and applications aim to achieve the operational fast methods and reliable results. It is possible if the data contain dense point clouds. The first step to generate high resolution canopy height model (CHM) is to normalize digital surface model (DSM) by subtracting DTM from DSM. Thus, CHM contains the same X, Y coordinates as DTM and tree height as Z value. CHM accuracy is mostly affected by the accuracy of DTM and DSM. The interpolation method in high density point does not cause considerable error while corresponding filtering methods have the most effect. Recent studies show that, moderate to dense forest, estimations tend to underestimate tree height. In this work a technique based on the searching of local maximum canopy height is used to detect individual tree with variable window size and shape. The performance of this technique for the detection of the tree height is more than 90 %.

1. INTRODUCTION

1.1 Motivation

Measurements of tree characteristics by photogrammetric or field survey methods are time consuming and expensive for large areas. As an alternative tree heights have been derived from ALS data sets and compared with ground based canopy height measurements (Young et. al., 2000; Persson et. al., 2002; Popesco et. al., 2003; Breidenbach and Kublin, 2004). Also in ALS data sets there are the underestimation in tree height detection which has reported from previous works (Hyypa et. al., 2001). So, this underestimated tree heights are named as dominant tree height and introduced a portion for correctness of height values.

1.2 Related Works

Two approaches were used to estimate the tree height (Popesco et. al., 2002). The first one is based on using the height of all canopy height, and the second method is based on single tree identification. Vazirabad and Karslioglu (2009) conclude that technique of estimating tree height by detecting single tree performed better than the first method (correctness of tree height more than 90 %). Single tree detection technique explained by local maximum filtering canopy height with variable window size. Clustering analysis is a well known statistical tool for dividing features space into areas counting values similar to each other. The similarity is determined with a specific metric. Segmentation clustering method for individual tree (Hyyppae et. al., 1999) from ALS data developed by (Marsdorf et. al., 2003) analyzing the segment sizes. They conclude that applying local maximum method provides more significant results in detecting tree height than estimating their location using segments (because of segmentation shifts).

The use of tree characteristics detection provides new possibilities on remote sensing of forest vegetation and especially for wild fires damages, logging operations, which are mentioned by Danilin and Medvedev (2004) for an example in Siberia. The objectives of many previous studies (Wack et. al., 2002; Heurich et. al. 2004; Breidenbach and Kublin, 2004; Popesco et. al., 2004; Yu et. al., 2005; Hollaus et. al. 2007; Popesco, 2007; Wack, 2007) were to validate the tree detection, tree height estimation, crown diameter estimation for volume and biomass estimation of different forest types. The aim of this study is to increase the quality of single tree detection based on the searching of local maximum canopy height.

2. MATERIALS AND DATA

2.1 Study Area

Study site is 1*1 Kilometre area located in Fraser Alpine in Colorado which is placed within generally South-North faced area. The mean elevation is 3066 m. The highest elevation areas in the south are mainly rocky mountains covered by alpine tundra. The mountain areas in between are dominated by dense coniferous forest, generally with spruce-fir forests. All data sets and field measurements are gathered by NASA (CLPX) cold land processes and field experiment project (Cline et al., 2001).

* Corresponding author.

2.2 Field Measurements

The ground measurements are forest inventory as tree height, diameter at breast height (dbh, breast height is 1.37m), and crown diameter are measured for 258 trees in the field. In the regression model dbh and crown diameter are given as the functions of tree height. The result of modeling is calculated in terms of R^2 equal 0.91 and 0.78 respectively (figure 1). The tree height model shows that tree heights vary between 2 m to 25 m. The relation between tree height and crown size indicates that it would be between 1.5m to 7m.

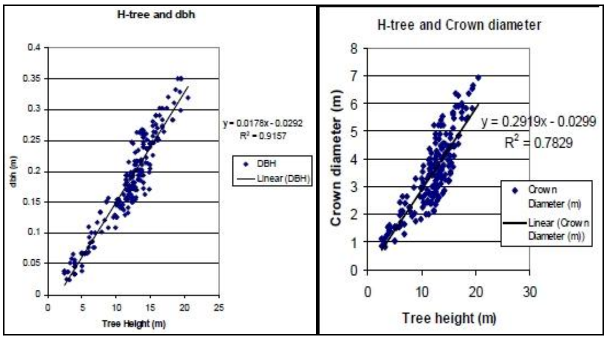

Figure 1. Tree Height (H-tree), dbh relation in the left figure; H-tree, crown diameter relation in the right figure, based on field measurements

There is also an orthophoto image (figure 2) available from dry season in order to generate the reference data to find out the location of trees.

Figure 2. Orthophoto image (Cline et. al. 2001)

2.3 ALS Data

The data set contain first pulse returns of ALS. The ALS system specifications are 4000 meter for fly altitude, 5000 meter laser swath width, 75^o max laser scan FOV, up to 70 Hz (FOV dependent) scan rate, 24-25 kHz laser pulse rate, 3 at 45 kHz or 5 at 38 kHz laser returns and less than 30 centimetres RMSE absolute X, Y, Z positional accuracy (table 1). The average point density is 0.8 point/m^2 with approximately 0.05 meters vertical tolerances.

Measuring frequency	24-25 kHz
Scanning angle	75^o max
Scanning frequency	70 Hz
Max. Operating altitude above ground	4000 m

Table 1. ALS system specifications (Cline et. al. 2001)

3. METHODS AND TECHNIQUES

3.1 Point Cloud Filtering

The terrain points extracted from point cloud of ALS first pulse data set is used as an input to generate DTM. The first pulse data sets contain vegetation points and terrain points in the forest area. We use a filtering method to classify terrain points and vegetation points first. Numerous kinds of filtering methods are developed to do this classification in the point cloud (Pfeifer et. al., 2004; Tovari and Pfeifer, 2005). The experimental comparison of filtering algorithms with manual methods for DTM extraction is introduced by Sithole and Vosselman (2004) to show the suitability of filters with the terrain shape. In comparison with other filtering methods, segment base filter is turned out to be a more reliable method in steep slope terrain extraction using a surface growing method (Sithole and Vosselman 2005). The most important part in this method is the accuracy assessment and parameter tuning. These processes for the chosen method are done before by Vazirabad and Karslioglu (2009) for the same data set as shown in figure 3. Segmented terrain points are coloured as brown and green while the vegetation terrain points assumed to be on vegetation in forest area as white.

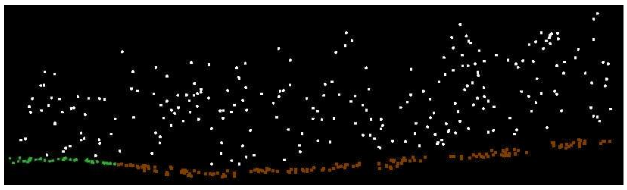

Figure 3. Segmentation method, point cloud from vertical view

3.2 Removing Vegetation Points and Generation of DTM

The purpose of filtering is to remove the vegetation points. The filtered points are shown in figure 4. It shows all points before filtering (figure 4, left) and terrain points after filtering (figure 4, right). In this step we could count the percentage of vegetation points to the all points.

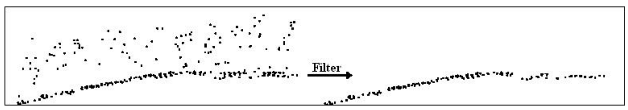

Figure 4. Removing vegetation points

3.3 DSM subtracting of DTM and Generation of CHM

The tree canopy height model (CHM) is a digital description of the difference between tree canopy points and the corresponding terrain points (figure 5).

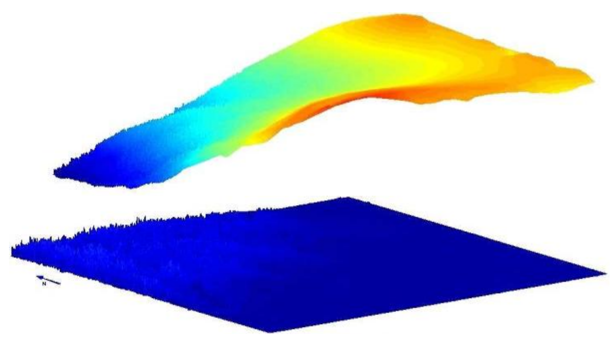

Figure 5. DSM (up) and CHM (down)

Tree canopy points or vegetation points were interpolated to regular grid that corresponds to the DSM (van Aardt et al., 2006). The CHM covering 1 km^2 is represented in figure 5, along with the orthophoto of the entire area covered by ALS data.

3.4 Tree detection with Variable Window Size and Shape

Throughout previous study on tree location, height, and number of tree detection, the local maximum detection method is introduced (Vazirabad and Karslioglu, 2009). It presents the method using canopy height based on variable window size. Window size selection is related to the height and density of trees. High trees were easier to detect with large windows while short trees were easier to detect with small windows. The derivation of appropriate window size to search for tree tops is based on the assumption that there is a relation between the height of trees and their crown size. The correctness of single tree detection was calculated approximately 91%. The main reason for 9% error is referred to the not detected trees which are located in the corners and edges of searched patch. To deal with this problem, in this work we use the standard rectangle windows, variable size and variable shape (figure 6).

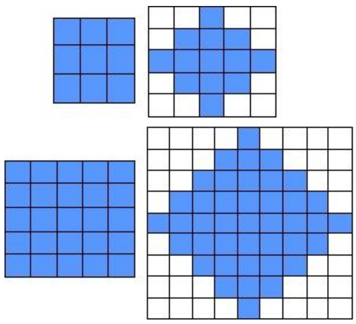

Figure 6. Search windows

We used four sizes, standard 3*3, standard 5*5, rotated 3*3 (5*5), and rotated 5*5 (9*9) windows (each pixel represents one meter).

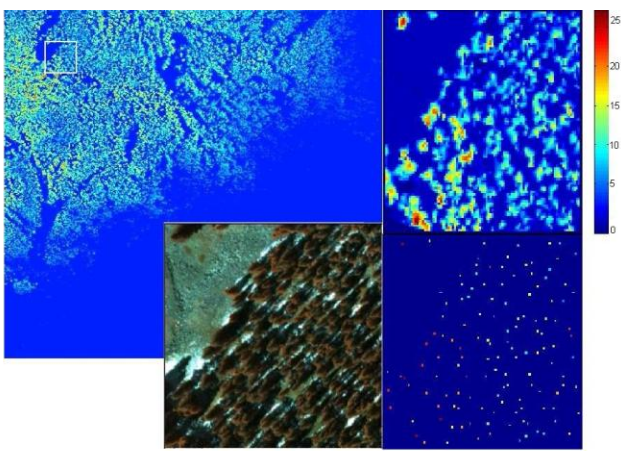

Figure 7. Single tree detection, CHM horizontal view (back), test patch 5 (top right), respected orthophoto (bottom center), and result (bottom right)

Tree heights from CHM shows that tree height vary between 2m to 25 m (figure 7, bottom right). The single tree detection method works in several steps. First the generation of a tree height model is required to obtain the tree height. Using this model the algorithm looks for all nonzero values and creates a sorted list depending on the point height above ground (here reducing data makes searching procedure faster). In the second step a tree height specific filtering is accomplished, by moving the window pixel by pixel over the tree height model. By changing the window size and shape repeatedly the procedure is continuing up to the end. Six reference patches are provided for counting manually the number of trees by using orthophotos. Density and height of trees are variable inside the patches.

4. RESULTS AND CONCLUSION

As an average result, a total of 930 trees from 1002 trees (correctness of approximately 93%, see table 2) could be detected correctly. Table 2 shows that 7% of trees could not be detected or wrongly detected. The reason for this error is the low trees next to the high dense forest areas which are not detected correctly by windows. Moreover reference data may be overestimated in the patches because of the fact that the counting the number of trees by pure eye from figure 2 can be confused by the shape of the trees.

Patch	Reference trees	Correctly detect	Correctness %	Incorrectness %
1	191	175	91.6	8.4
2	162	151	93.2	6.8
3	160	148	92.5	7.5
4	163	151	92.6	7.4
5	139	133	95.7	4.3
6	187	172	92	8
Average			93 (%)	7 (%)

Table 2. Tree detection and validation

On the other side, Figure 8 shows a good relation between detected number of trees and the percentage of vegetation points from section 3.2. In this graph (figure 8) the results of 63 patches which contain vegetation in the study area are compared.

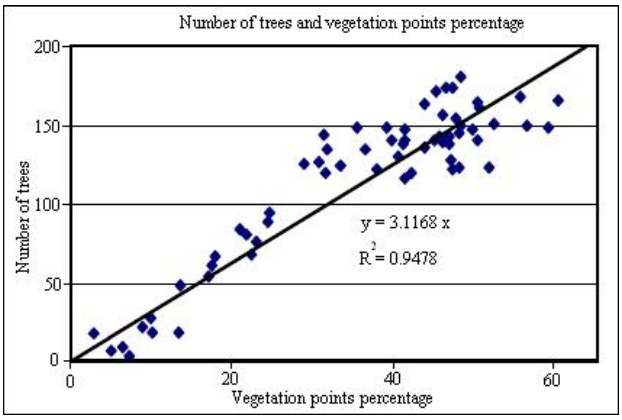

Figure 8. Vegetation points percentage and number of trees

The method we used for single tree detection based on local maximum filter detects tree locations, number of trees, and the height of each single tree by generating tree height model. The accuracy of the method is increased to 93% with respect to the previous works. The corner tree detection problem is solved with applying window shape changes. In the additional comparison we can conclude that vegetation percentage is a good indicator of vegetation cover of the area.

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