ESTIMATION OF FOREST BIOMASS BASED ON SEGMENTATION USING AIRBORNE LIDAR DATA

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ABSTRACT

Forest biomass is now recognized as a reliable alternative plan to reduce green house gases not only by substituting fossil fuel but by also increasing the carbon absorption of a forest. This study proposes a method that estimates forest biomass using airborne LiDAR data. The proposed method is composed of three main parts. Firstly, a Digital Elevation Model (DEM) is generated through segmentation method, the extraction of ground points using an area-based filter, return information and local minimum and refinement processes. Secondly, Canopy Height Model (CHM) is created by subtracting the DEM from DSM, and then individual tree is extracted through Watershed segmentation algorithm. Diameter at Breast Height (DBH) is estimated by regression equation based on in-situ data. Lastly, forest biomass is determined by applying an estimation formula using canopy height and DBH estimated. The estimated result showed reliable accuracy. We expect that the proposed method in this paper will be utilized as an important instrument in the handling of climate change and tree-planting resulting in the effective reduction and management of green house gases.

Keywords: Forest biomass, Airborne LiDAR, Segmentation, DEM

INTRODUCTION

Carbon dioxide is transformed into carbon and stocked in biomass or soil. The amount of carbon stock is determined by the biomass of a stand. Therefore, it is important to be able to estimate biomass. The measure of forest biomass is mostly conducted through on-site investigations. While this method enables relatively accurate results, it is not efficient in terms of time or economy. A method using remote sensing, such as satellite image and airborne LiDAR data, can acquire various forest information quickly and efficiently (Kim, 2007). For this reason, many studies have been conducted on estimating forest biomass using a satellite image (Federico et al., 2006; Ranson et al., 2007; Kim et al., 2009; Kim et al., 2011). However, with a satellite image, it is difficult to get canopy height and extract individual trees. As a practical solution to this problem, airborne LiDAR data that provides height information of objects on the surface is actively used for the estimation of forest biomass (Gibbs et al., 2007, Chang and Kim, 2008; Wu et al., 2009). Therefore, the objective of this study is to generate forest biomass map using airborne LiDAR data for a coniferous forest. In order to estimate forest biomass, segmentation algorithm for DEM generation, Watershed segmentation algorithm, and regression method estimating DBH were used in this study.

STUDY AREA AND DATA SET

The study used Airborne LiDAR data around the Independence Hall of Korea (36° 7’ 78” N, 127° 3’ 88” E). There are forests dominated by conifers and a few artificial objects in the area. LiDAR data were acquired on 1 September 2009 at an altitude of 1300 m using an Optech ALTM 3070 instrument, and the point density was approximately 4.3 points per m².

Two 20 m × 20 m plots and four 10 m × 10 m plots were selected in the study area. A detailed field survey
was conducted in April 2011 to construct the reference data set, including tree positions, DBH, crown diameter, and tree height in some cases. The tree locations were acquired at the breast height of individual trees, based on their positional relationship with neighboring objects on the ground, using a Juno SB hand-held GPS manufactured by Trimble.

**METHOD**

**Generation of CHM**

The proposed method transforms LiDAR data based on positional point data defined by X, Y, and Z coordinates to raster data. It also performs preprocessing to remove outliers with high values or negative values in a histogram showing the height distribution of the LiDAR data.

It is important to generate accurate DEM because it is directly related to canopy height, which is used to estimate forest biomass. This study used the labelling method to generate accurate DEM of forest area. Labelling method using mean plane shows good performance not only for the forest area but also for the urban environment, and it is easy to operate. After generating DEM, we can get CHM by subtracting DEM from DSM composed of first return pulse. CHM and nDSM are similar concepts, and the concept of CHM is usually used in the forest field.

**Extraction of Individual Trees**

It is necessary to segment the forest to individual trees to estimate biomass. LiDAR data has advantages compared to satellite and aerial images for extracting the boundary of individual trees in a forest because it is based on height information. To identify the boundaries, a watershed algorithm is used in this study as one of the segmentation algorithms. The watershed algorithm extracts robust results by utilizing a hydrological approach with a clear and simple concept, and satisfies the need for homogeneity and connectivity.

After extracting individual trees using the watershed algorithm, height threshold is used for each tree extracted. Height threshold is 5m, which is the defined minimum height of a tree (Korea Forest Research Institute 2008). If canopy height of a tree is less than 5m, the tree is removed. Through this process, lower vegetation such a shrubs and grass are removed.

**Estimation of DBH**

It is necessary to get canopy height and DBH in order to estimate forest biomass. Canopy height and crown diameter are directly acquired, while DBH is not acquired directly because Airborne LiDAR data provide only the height information of objects. Therefore, DBH is estimated using canopy height and crown diameter.

To estimate DBH, crown diameter and DBH of 63 coniferous trees were measured through in-situ. From in-situ data, regression equation was derived and equation (1) shows the relationships of these. $R^2$ is 0.506. DBH of individual tree used to estimate biomass was extracted from equation (1).

$$ y = 0.0135x + 0.3088 \text{ (unit: meter)}$$  \hspace{1cm} (1)

$x$: Canopy diameter,

$y$: Estimated DBH

**Generation of Biomass Map**

Using Canopy height and DBH, regression equation to estimate biomass is

$$ W = 10^{(a \log(DBH^2 - H) + b)} \text{ (unit: meter)}$$  \hspace{1cm} (2)

$W$: Biomass (Kg/tree),

$H$: Canopy height,

$DBH$: Diameter at Breast Height

Equation (2) can be used to estimate biomass of stem, branch, and leaf, and acquire total biomass by adding the three values (Yim et al., 1982). Coefficients of each part are shown in table 1 for coniferous tree. This regression equation showed accurate results in estimating biomass of coniferous tree (Chang and Kim, 2008).
Table 1. Coefficients of regression equation for biomass estimation

<table>
<thead>
<tr>
<th>Coniferous tree</th>
<th>Coefficients</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Stem</td>
<td>0.81</td>
<td>1.88</td>
<td></td>
</tr>
<tr>
<td>Branch</td>
<td>1.47</td>
<td>-0.57</td>
<td></td>
</tr>
<tr>
<td>Leaf</td>
<td>0.84</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>

RESULT AND DISCUSSION

After pre-processing LiDAR data, we generated DEM using the MPF algorithm, and then acquired CHM of forest area. Watershed algorithm was applied to CHM in order to segment forest area to individual trees. As a result, 3074 trees were extracted, and DBH and canopy height were calculated.

Based on canopy height and DBH estimated, biomass distribution of individual tree was from 57 Kg to 2780 Kg. Total forest biomass of study area was 950,480 tons. Figure 1 shows first return pulse conducted pre-processing, and biomass map generated by the proposed method. Biomass of individual trees in the study area was well extracted except for lower vegetation with height less than 5m. However, a problem occurred in which artificial objects having sloping roof were not removed because only LiDAR data was used. Therefore, we judge that total forest biomass of study area was over-estimated.

![Figure 1. LiDAR data of study area after pre-processing (left) and biomass estimated by proposed method (right).](image)

CONCLUSION

This study estimated the biomass of a coniferous forest using airborne LiDAR data. Watershed algorithm was used to extract the individual trees, and regression equation to estimate DBH was derived from in-situ data of study area. The total biomass of study area was estimated using canopy height and DBH, and the value of total biomass was 950,480 tons. However, total biomass was over-estimated because the artificial objects were not perfectly removed in the proposed process.

Therefore, future work will be focused on removing the artificial objects having sloping roof. We expect that the proposed method in this paper will be utilized as an important instrument in the handling of climate change and tree-planting, leading to the effective reduction and management of greenhouse gases.
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