ESTIMATION OF PHYSICAL PARAMETERS OF INDIVIDUAL TREES BY LIDAR DATA

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ABSTRACT: Light detection and ranging (LIDAR) is one of the effective technologies for monitoring forest inventory, and importance of forestry is increasing because of its function as the sink of green house gases (GHG). This study aims at development of a methodology for better and more accurate estimation of physical parameters of individual trees by removing sudden drops of LIDAR data within a crown. Our study area is located in Aomori prefecture, the northern part of Honshu Island, with the dominant species of Japanese cedar. The results show practicality of our method in the usage of LIDAR data in the field of forest inventory.

1. INTRODUCTION

Kyoto Protocol is an international treaty that stipulates targets for the developed countries' for GHG reduction (United Nations Framework Convention on Climate Change 1997). In December 2003, the ninth meeting of the conference of the parties (COP9) has accepted afforestation and reforestation projects under the clean development mechanism (CDM), for the first commitment period (2008-2012) of the Kyoto protocol. Methodology for monitoring GHG reduction certified by such projects at a regional or a local level is under active discussion with various approaches.

Techniques for monitoring the forest parameters at a regional level are broadly developed. Delineation methodologies of individual crowns with the use of aerial images, high-resolution satellites images or LIDAR have been major focus of research in regional scale (Gougeon,1995; St-Onge et al., 2001; Andersen et. al., 2002). Also in a regional scale, estimation of carbon biomass is proposed using LIDAR and aerial images (Patenaude et. al, 2004, Teraoka et. al, 2004).

In the previous studies, the pulse density of LIDAR is getting higher and higher in accordance with the technological development. In such high-density data, some of the laser pulses are returned from objects within a crown, and they are recorded as sudden drops compared to surrounding points returned from the surface of a crown. Usually, filters such as smoothing, median, and/or average are applied to remove the effects of such sudden drops.

This paper aims at development of a methodology for removing sudden drops in a tree crown. Validations of results are examined by comparing the outcomes using the raw data and the data after the removal.

Table 1. Summary of the field measurements in the study area

Area [ha]	Number of trees	Number of trees per hectare	Year of plantation	Average height [m] (standard deviation)	Average diameter at breast height [cm] (standard deviation)
0.13	77	592	1960	25.73 (1.41)	33.77 (3.51)

2. DATA ACQUISITION

2.1. Study Area

Our study area is part of a property of Mitsubishi Paper Mills Co. Ltd with a total area of about 200 ha, and is located in Aomori prefecture, the northern part of Honshu Island (40°39' N, 141°5' E, 190 - 240 m above sea level). A plot was chosen from the study area that represents typical planted forests in Japan in regard to tree types, years from plantation, and thinning histories (Fig. 1). Dominant tree species in the plot is Japanese cedar (*Cryptomeria japonica*), with crown shapes of matured trees conforming to cylinder cones.

2.2. LIDAR Data

LIDAR is a growing technology that can acquire height information of ground surface by measuring the time interval between the emission and reception of laser pulses. LIDAR data used in this study was acquired in August 11th and 12th of 2004 from an airborne laser scanner with a cruising speed of 110 knots, height of 1830 meter, scan rate of 39.0 Hz, pulse rate of 46.0 kHz, scanning width of 647 meters, and average footprint of 0.47 meter. The scanner was ALS50, a product of Leica Geosystems, which has a horizontal positional accuracy of ± 30 cm and the vertical positional accuracy of ± 15 cm. The average density of laser reflections was about 7.82 pulse per square-square or in another way, 0.13 square-meter had one pulse in average.

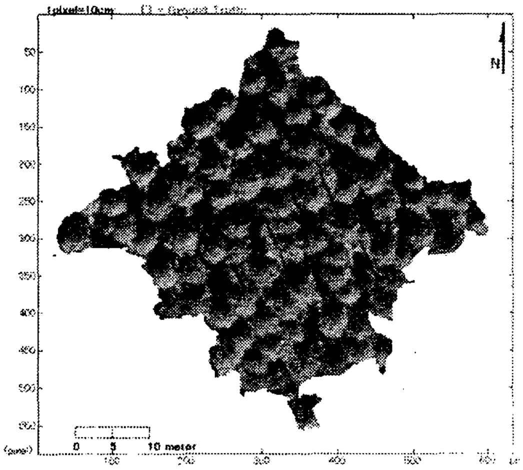

Figure 1: Aerial photograph of study area

2.3. Field Survey

A field survey was conducted in the first week of August 2004. Within the plot, the position, height, diameter at breast height (DBH), and specie of each tree were sampled as the ground truth data. Precise positions of every tree were sampled using the differential GPS, and the height were acquired with the LaserACE300 (Measurement Devices Ltd., U.K.) laser measurement instrument. Details of the plot are shown in table 1. Additional survey was carried out on July 11th 2005 for the measurement of crown width and height of crown.

3. METHODOLOGY

3.1. Removing Sudden Drops in LIDAR Data

LIDAR data from a foliage crown area contains some sudden drops compared to the surface of the crown because of the penetration of laser pulses through the crown. They are not error data since the laser pulses are returned from inner objects. In the process of extraction of an individual tree crown and estimation of a timber volume, those sudden drops affect the results. In this study, following algorithm was developed and applied to overcome the problem of sudden drop. Firstly, three-dimensional triangular irregular network (TIN) based on XY-plane is calculated from LIDAR data (Fig. 2). Then an index d is calculated for every LIDAR data in order to extract the sudden drops.

$$d = average\,(z_i) - z_0 \qquad (1)$$

where, z_i is the height of the LIDAR data around the target point, and z_0 is the height of the target points. In this study, a threshold was defined empirically, and the points with the d value over 1.0 meter were removed from the further processes.

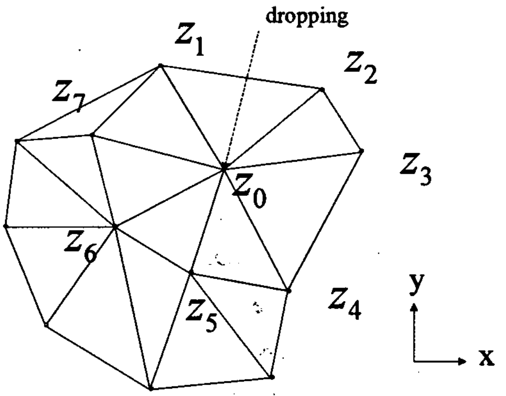

Figure 2: Removing sudden dropping points by using TIN and height data

3.2. Template Matching by Quadric Surface Parabola

Crown forms are represented as a quadric surface parabola, generalized ellipsoids following Sheng et al.(2001), where the space occupied by the foliage within an individual tree crown is determined by six parameters: 2-D coordinate of the crown top(X, Y), tree height (cz), crown width (cw), crown height (ch), and crown curvature (cc). The surface of a tree crown is then given by the following mathematical expression in equation (2) :

$$\frac{(cz+ch)^{cc}}{ch^{cc}} + \frac{(X^2+Y^2)^{cc/2}}{cw^{cc}} = 1 \qquad (2)$$

A template was defined with following parameters: cw=2.3m, ch=2.3m, cc=1.0, and the correlation coefficient (R) is calculated with respect to Z-axis.

3.3. Fitting of Quadric Surface Parabola

After the template matching, fitting operation was carried out from XY-positions with the highest R value. Parameters were examined with the combination of cw of 0.9-4.1 m by every 0.4 m, ch of 1.5-5.5 m every by 0.5m, cc of 0.8-2.0 by every 0.4, respectively. Fitting results are evaluated by R between the parabola and LIDAR points in three-dimensional space. (Fig. 3)

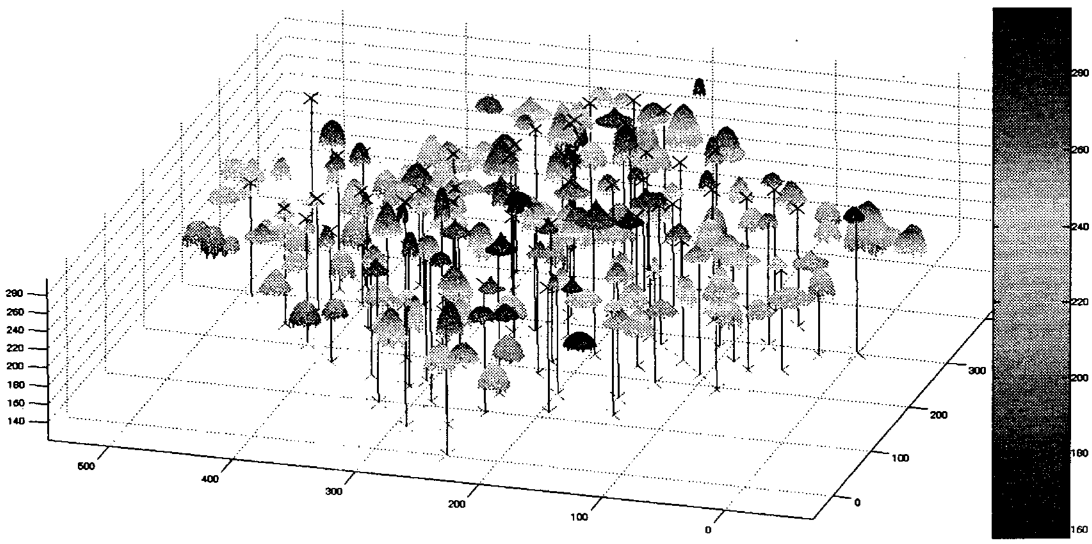

Figure 3. Three-dimensional perspective view of the estimation results

4. Results and Discussion

Figure 4 shows the line plots of R between the parabola and LIDAR points and the root mean square error (RMSE) both in three-dimensional space. From the results, removal of sudden drops contributes to both increase in R and decrease in RMSE. The average value of R and RMSE from raw data and after the removal has changed from 0.65 to 0.79 and 1.79 to 1.25, respectively.

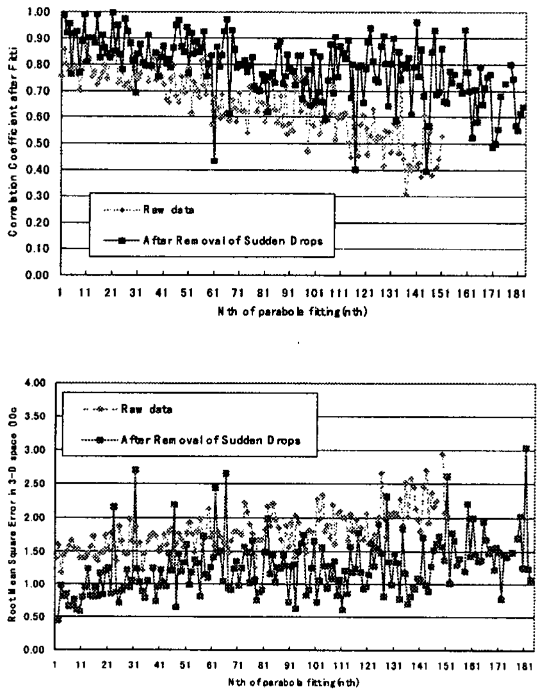

Figure 4: Line plot of correlation coefficient (upper) and RMSE distance (bottom) with respect to nth of parabola fitting

5. Conclusion

We tried to develop methodology for removal of sudden drops in a crown, and showed effectiveness of the proposed methodology. Further validation should be carried out for sensitive analysis of template matching and evaluation of the parabola fitting with different tree height, tree density and tree types.

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