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Accurate Estimation of Tree Positions in *Larix leptolepis* Forest using Portable Imaging Lidar Data by Hough Transform

By

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Key words: Hough transform, Japanese larch (*Larix leptolepis*) forest, portable imaging lidar, remote sensing, tree position.

Summary

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It was reported in IPCC 2000 that forest is one of the most important carbon sinks on Earth. Forests alleviate effects of global warming and absorb air pollutants as well. Essentially, forest management plays an important role in tackling environmental problems.

Mapping exact position of trees in forest, which is one component of forest management, is not easy. Due to forests' complex structure and undergrowths, measuring works are difficult and take longer time by manual method.

In this study, a ground-based remote sensing technique to estimate tree positions in forest has been developed using a portable imaging lidar. The lidar is a portable measuring instrument which uses near infra-red laser. The lidar system is only controlled by one man and measurements of tree positions only take a shorter time (i.e. about 8 minutes).

Normally, natural trees do not grow straight and lean to other directions. In this case, the lidar can not directly measure the foot of the trees because of the undergrowths. Hence, the tree positions that were estimated from the center of the stem at measurable height (in most cases the measurable height is 2 m or more) are quite different from the actual tree position and the error is about 0.81 m in RMSE (Root Mean Square Error). A Hough transform method was therefore used to enable the measurement of leaning trees as well as those covered with thick undergrowths.

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By comparing the estimated tree positions using Hough transform and the manual measurements of 24 trees in about 1200 m² Japanese larch (*Larix leptolepis*) forest, statistical results showed an accuracy of 0.16 m in RMSE.

Introduction

An established practice of measuring tree position is by the use of some traditional measuring instruments such as measuring tape, clinometers, and pocket compasses (AVERY & BURKHART 1983, HUSCH & al. 1982, NAGUMO & MINOWA 1990, NISHIO 1998). However, the use of these methods is difficult and entails too much time and manpower (JAPAN ASSOCIATION OF FORESTRY TECHNIQUE 1998). Hence, measurements of each tree by airborne lidar system were studied (OMASA & al. 2000, 2003) and measurements of each tree by ground-based portable imaging lidar have been examined (OMASA & al. 2002, URANO & OMASA 2003), which revealed that the measurements were much easier and did not need much manpower.

Based on the results, measurement errors comparing to actual tree positions measured by existing methods using traditional instruments were 0.81 m in RMSE (Root Mean Square Error) (URANO 2004). An attempt was therefore made to further improve this accuracy. Because tree position was regarded as the center of tree stem at a height, if a tree leans to other directions, the tree position will be different from the actual depending on leaning degree and measurement height. Consequently, in this study we developed a method using Hough transform to consider leaning trees and so improve the estimation of tree positions in Japanese larch (*Larix leptolepis*) forest with thick undergrowths using a portable imaging lidar. In order to detect tree positions of each Japanese larch by the lidar on the ground, each stem was measured at much higher level from the bottom due to forests' complex structure and undergrowths.

Material and Methods

A Japanese larch forest with thick undergrowths was selected for the study. The forest has been managed for ecological studies for years. Trees are about 40 years old and about 13 to 15 m in height. In this forest, 24 Japanese larches in an area of about 1200 m² were measured using LPM-25HA, a portable imaging lidar system produced by RIEGL. Its measurable range is between 2 m and 60 m with range accuracy of about 8 mm, and horizontal and vertical angular accuracies are 0.009 degrees. The lidar was set at a point where it can recognise as many Japanese larches as possible in the area. The land gradient was confirmed by measuring a point on the ground from plural directions by the lidar. First, we detected the stem shape of each tree using 3-dimensional data obtained by the lidar. The stem center, which was lead by the stem shape at a measurable height, was estimated by a method described by OMASA & al. 2002. In order to estimate accurate tree positions, which meant the center of the tree bottom, we used Hough transform (HOUGH 1962, NAKAGAWA 1999) using points of stem centers in 3-dimensional coordinate (Fig. 1.). The intersection point between the line calculated by Hough transform and the ground surface was regarded as the tree position.

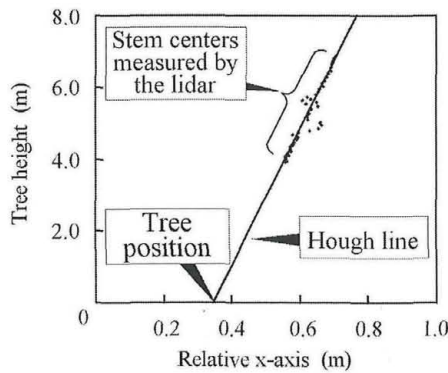


Fig. 1. Estimation of a tree position in x-axis by Hough transform. Although this figure only shows x-axis and height, lidar data include 3-dimensional coordinates (x and y-axis and height).

Results and Discussion

Fig. 2 shows the distribution of trees at the study site. As a result, estimation by Hough transform was more accurate than estimation by existing method comparing to the actual. Fig. 3 shows the error variations of both estimations with distance from the lidar. The errors of the estimation by existing method are increasing as the distance from the lidar becomes longer. This is expected since the accuracy of existing method becomes worse as the distance from the lidar becomes longer. On the other hand, estimation by Hough transform improve the accuracy regardless of the distance from the lidar. Both statistical results showed an accuracy of 0.81 m and 0.16 m in RMSE, respectively.

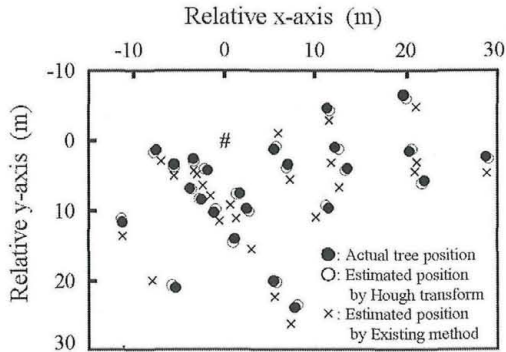


Fig. 2. Tree position map of Japanese larch forest. X and y-axis mean relative coordinates on the ground surface as the lidar set point is the origin (x,y) = (0,0) shown "#" in the figure.

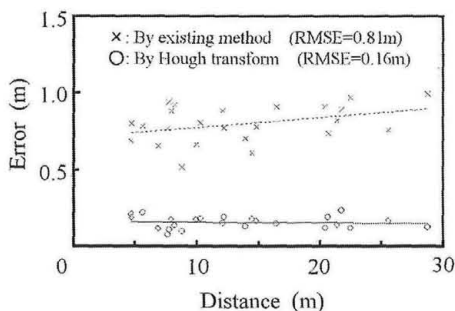


Fig. 3. Error variations of estimations by Hough transform and by existing method comparing to the actual with distance from the lidar. Broken and solid lines represent each linear approximation.

Consequently, this study concluded that measurements by the lidar and estimations by Hough transform were regarded as an accurate method to detect tree positions in a forest with thick undergrowths. This method also gives other advantages such as few workers are needed, takes lesser time and no special skills and trainings are required.

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