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Detection of Tree Apexes from Helicopter-borne Scanning Lidar Data Using Local Maximum Filtering

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Key words: Tree apexes, helicopter-borne scanning lidar, local maximum filtering, commission error, omission error.

Summary

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To examine different methodologies in the estimation of carbon stocks in forest, many studies were conducted in the past using remotely sensed imagery. One of which, reported estimation from a digital canopy height model (DCHM) image obtained from a helicopter-borne scanning lidar system using a correlation between tree height and carbon stock.

If tree apexes are automatically detected from the DCHM image, the tree heights can be directly obtained at the locations of detected apexes. In this study, hence, the LM filtering was examined to detect tree apexes automatically. After a 3x3 pixel median filter and some common smoothing filter were used to remove spike noises and complicated unevenness on a surface of the DCHM image, the LM filtering was done to get the tree apexes.

To get a result with lower error possibly, every parameter was tuned tentatively before calculating semivariance values or slope breaks from the DCHM image. Finally the LM filtering correctly detected 69% of the total apexes in the study area and resulted in commission error (false positive apexes) of 31% and omission error (missed apexes) of 30%. These errors were caused by complicated canopy surface and nonconformity in window size of LM filter. First, LM filter could work to detect some tree apexes but even detected small unevenness, which were not tree apex, on the canopy surface. Second, calculation of semivariance value and slope breaks failed to compute appropriately and could not allocate mask size suitable to each canopy. In consequence, the LM method at this stage is not adequate to high spatial resolution DCHM images.

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Introduction

Analyses of forest certainly give us many benefits but accurate estimation of forest structure is very difficult for both the ground measurement and the remote sensing. The difficulties of the investigations are caused by complexity of forest structure and its huge area. Lidar system that directly measures 3-dimensional (3-D) distribution of plants has been developed in forest survey (LEFSKY & al. 2002). Recent progresses of lidar technology show that it is possible to cover the entire ground surface with high scanning frequency and small footprint and that high-resolution lidar images can be acquired. With these high-resolution images, we measured tree height of Japanese cedar (*Cryptomerica japonica*) as accurately as ground measured data (OMASA & al. 2000, 2003). At the same time, they indicated that the tree height correlates with the amount of carbon stock. However, complicated up surface of tree canopy can increase the difficulty to detect tree apexes. In the conventional method, the locations of treetops in lidar images were determined by human's eye and then the calculated height at the location in the 3-D lidar images was assigned as corresponding tree height. It is highly required to develop a more realistic method to detect tree locations, numbers and heights in large forests. One of the potential methods to detect tree location is local maximum (LM) filtering (WULDER & al. 2000). With that technique, they assessed the ability to locate trees with 1-m spatial resolution airborne multispectral imagery. The object of this study is to detect tree apexes with high-resolution 3-D lidar images by LM method and estimate the method's accuracy of detection.

Material and Methods

The study area is a Japanese cedar forest, which locates near Tanzawa Lake, Akita prefecture, Japan and lidar images for the whole area were taken and ground investigation was achieved for the experimental area. Measurement was made in the end of May 1998 by using a scanning lidar system (ALTM 1025 special model; Optech Co. and Aero Asahi Co., Kawagoe, Japan) from a helicopter. The scanning lidar system has first pulse mode, which acquires canopy elevation data, and the last pulse mode, which acquires terrain elevation data. By subtracting terrain elevation from canopy elevation on the same position, a digital canopy height model (DCHM) was obtained (OMASA & al. 2000, 2003). Fig.1 shows this DCHM image of the study area. The mesh size of the DCHM is 10 cm by 10 cm. On the ground, we measured the location and number of all trees within the study area.

3-D lidar Images were processed by some basic programs written by us and analysed with program written upon the study with LM method (WULDER & al. 2000). The original DCHM image usually includes spike noises, which can seriously affect the accuracy of final results. To delete these noises, the 3-D image was pre-treated by median filtering. Our early study showed that compared with non-filtering treatment and treatments with different sized filters, a filter with a size of 3×3 pixels is suitable for tree height estimation (OMASA & al. 2000). In this study we also use the median filter of 3×3 pixels to pre-treat the DCHM image.

If the location of a tree is known, tree height can be determined with the DCHM image. LM filtering detects tree apexes automatically and directly from the 3-D image. The LM filtering is a simple method to pick up local maximum points. LM filter uses a mask that is passed over all the pixels in the mask and determines if a given pixel has higher value than other pixels within the mask. The pixels identified as the highest value within the mask are noted as tree locations. Because the peak of conifer tree is the highest value within the tree crown, only tree apex will be detected. However, plants in forests are heterogeneously distributed and their sizes are also different. Hence, to allocate mask size to every location based on local spatial structure, either semivariance or slope breaks were calculated beforehand. Semivariogram is often applied image processing technique in remote sensing (CURRAN & ATKINSON 1998) and it is necessary to set some parameters when semivariance is calculated. Slope break is a simple mean measuring number of pixels from central pixel to the first inflection point in the gradient of pixel value around the tree. This number is calculated in all eight cardinal directions and the mean value of them is used as a custom mask size. The values made by these two calculations indicate pixel self-similarity over surrounding pixels. Then, based on the values that represent this structural correlation, LM filtering was carried out over the pre-treated DCHM image. The detail descriptions of every procedure are followed the original study (WULDER & al. 2000).

Even after median filtering, many uneven areas remained in the DCHM image. This unevenness on the canopy surface was thought to affect processes in calculating semivariance or slope breaks and detecting tree apexes by LM filtering. As additional pre-treatment, common smoothing filter, or a weighted averaging filter was tried to remove the complicated structure on canopy surface and then LM filtering was conducted again with the smoothed DCHM image.

Results and Discussion

To apportion adequate mask size to every pixel in the image, it is necessary to compute the structural correlation with semivariance or slope breaks. The parameters to calculate values of these values were tuned to seek the best condition for tree detection by LM filtering. The results of LM method were shown in Table1 below. The total errors in Table1 are the results of the lowest error, in other words, the most accurate results in each process. LM method of every procedure resulted in more than 61% in total error. High values of omission and commission errors were thought to be due to a same factor. High spatial resolution image was approximate to the complicated real canopy surface. The complicated structure made the calculation for semivariance or slope breaks difficult and those values, which represent pixel self-similarities over surrounding pixels, could not correctly reflect the structures of DCHM surface. Mask size on every pixel was decided by the value of semivariance or slope breaks. Therefore, appropriate sizes could not be assigned to masks on every pixel in LM filter processing. Consequently, LM filtering missed large number of trees and detected many false points. Additionally, it is thought that a single processing that detected tree apexes directly from a DCHM caused this filtering a lot of error. Generally, it is difficult to extract specific information, which is tree apex in this study, from enormous amount of data.

High spatial resolution forest data will give us valuable information. However, tree detection by LM method could not work with high accuracy. If higher spatial resolution forest image is used for its analysis, it will be more difficult to gain useful information we expect. The result of this study indicated that LM method does not have enough technical flexibility to heterogeneousness of real forests. Hence, new structure analysis techniques should be developed as an alternative to calculation for semivariance or slope breaks. At the same time, an entirely new method may be composed. We believe that new challenges will overcome these problems.

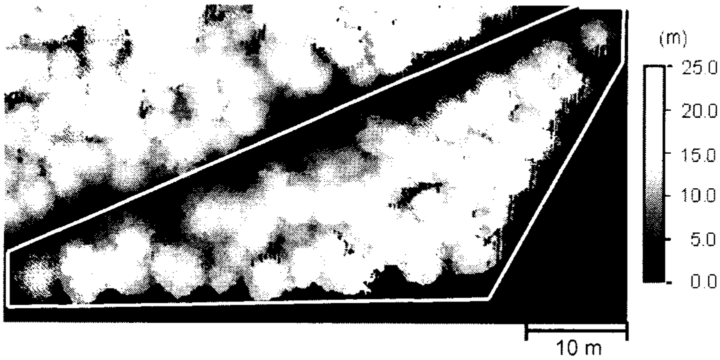

Fig. 1. The DCHM image of study area (the study area is surrounded by line.)

Table 1. Results of LM filtering. The results are categorized by processes of pre-treatment. Error is the ratio to all trees in the study area (%). "Missed" represents omission error and "false positive" represents commission error. "Total" is the sum of omission and commission error.

		Error (%)		
	Smoothing	Missed	False positive	Total
Semivariance	-	41	25	66
	+	43	34	77
Slope break	-	44	28	72
	+	31	30	61

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