DETECTION OF INDIVIDUAL TREE IN ARTIFICIAL FOREST IN JAPAN USING HIGH-RESOLUTION REMOTE SENSING IMAGERY

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KEY WORDS: Individual tree, high-resolution imagery, artificial forest, Local Maximum Filtering

Abstract: It can be possible to grasp the distribution of individual tree in the forest, mainly due to the increasing availability of high-resolution images in recent years. The positions and sizes of trees are the fundamental information for the forest management. The automatic detection of individual tree is one of the effective methods for providing such information in lower costs and resources. This study aims to develop the method to detect individual tree using high-resolution remote sensing imagery. Our method is based on the combination of basic image processing techniques, image smoothing and Local Maximum Filtering (LMF). In image smoothing, three types of smoothed image are generated by means of pixel averaging of 1×1, 3×3 and 5×5 pixels of original image. These images are, subsequently, processed by LMF with the window sizes of 3×3, 5×5, 7×7, 9×9, 11×11 pixel. The test sites are the artificial forests, dominated by Japanese cedar and Japanese cypress, located in Kochi prefecture, Japan. Remote sensing images with wide varieties of combination of canopy size and pixel resolution are selected in order to analyze the relationship between sizes and resolutions. The results will be evaluated by the comparison of ground truth data, and discussed from the viewpoint of the relation of tree density and spatial resolution.

1. INTRODUCTION

Decreasing and aging of forest holders are the serious problems in Japanese forestry. The timing of logging has been elongated due to the lack of resources and slumping economic condition. One type of forest management that based on the intensive care of small number of trees has been tested instead of the conventional stand-based management in order to adjust the situations.

The positions and sizes of trees are the fundamental information for the forest management (Larsen, 1998). It is getting easier to acquire the high-resolution remote sensing images in recent years. Therefore we can grasp the distribution of individual tree in the forest. The automatic detection of individual tree is one of the effective methods for providing such information in lower costs and resources. Local Maximum Filtering (LMF) is the most common method to detect individual tree. Using LMF, Pouliot and King (2005) researched in regenerating coniferous forest, and Pitkanen (2001) was detected individual tree in southern Finland. This study aims to develop the method to detect individual tree using high-resolution remote sensing imagery. Individual tree is detected by using LMF. The accuracy of the detection depends heavily on the relative sizes of canopy and pixel. We research the relations between the accuracy of LMF and canopy size, and the relation between image resolution and LMF.

2. MATERIALS AND METHODS

2.1 Materials

This study used aerial photos of five test sites in Kochi prefecture, Japan. All sites are dominated by needle leaf artificial forests of Japanese cedar and Japanese cypress. Each site has different tree density in order to analysis the resolution between tree density and spatial resolution. The spatial resolution of the photo is approximately 30 cm ×30 cm, and size of image is 180×180 pixels. Another set of images which has a size of 90×90 pixels was generated from original images by means of the averaging of two by two pixels block. These images were assumed to have the spatial resolution of 60 cm. Aerial photos of test sites with original resolution are shown in figure 1.

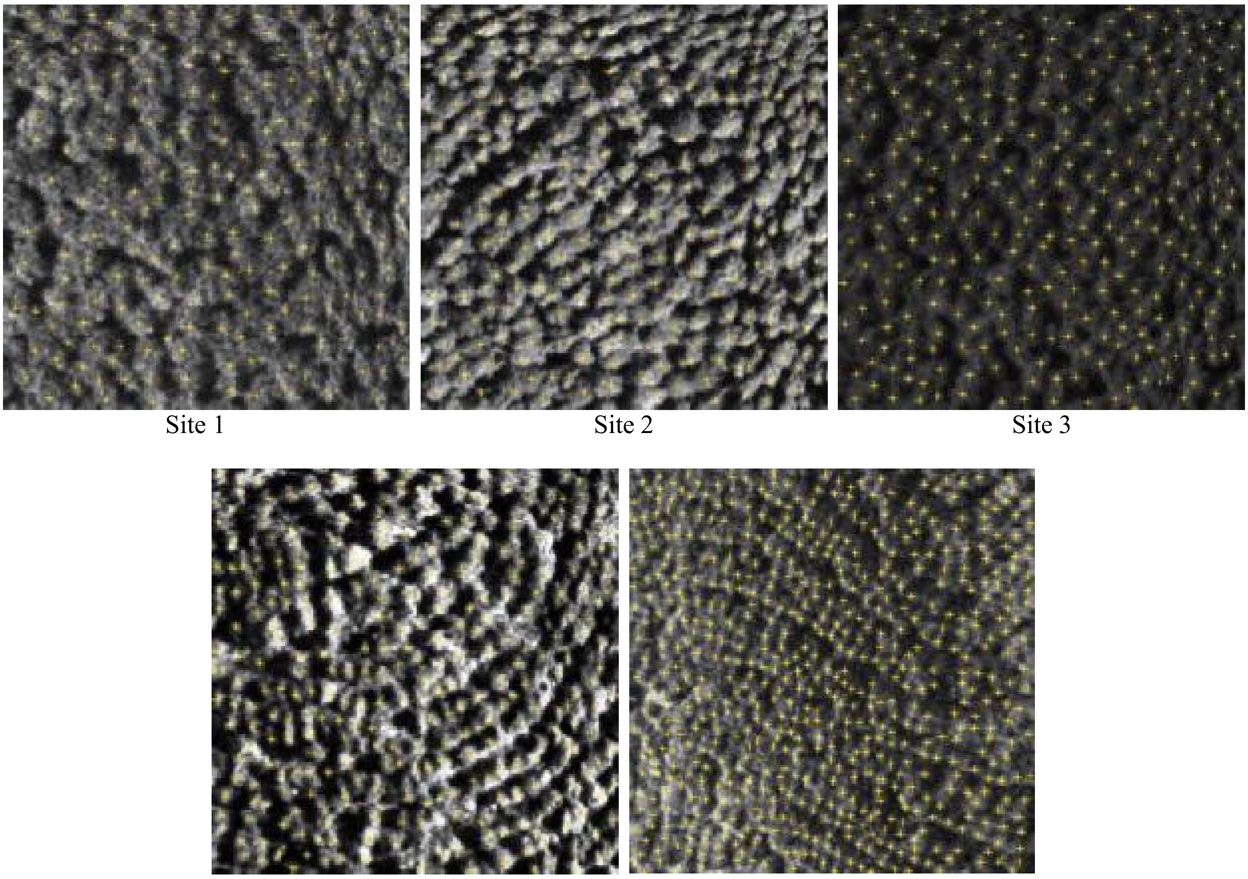


Figure 1: Test sites of this study with reference trees (cross)

2.2 Methods

Local maximum filtering is one of the frequently-used methods for detecting individual tree(Ke and Quackenbush, 2011). In LMF method, odd size of moving block window is settled on the grayscale image. If the brightness of center pixel is highest among the window, it is detected as the top of the canopy. This method is based on the feature that top of tree crown can be seen bright in aerial image of coniferous forest, and it can be possible to detect tree location using this feature. In this study, we adopted five sizes of window size (3×3, 5×5, 7×7, 9×9, 11×11 pixels).

One large drawbacks of LMF method is vulnerability against the noises. The noises cause additional local maxima and it resulted in over-detection of trees, therefore, high resolution imagery needs to be smoothed for eliminating the noises. In this study, three types of smoothed image were generated by means of pixel averaging of 1×1, 3×3 and 5×5 pixels of original two resolutions of images, as a result, 150 examinations (= 5 sites × 2 resolutions × 5 LMF window sizes × 3 smoothing window sizes) were carried out.

Tree locations were identified from original highest resolution image by visual interpretation, and this data were used as reference (ground truth). The numbers of trees are 219, 260, 292, 320 and 618 in site 1 to 5, respectively. These locations were shown in Figure 1 with yellow crosses.

The detection accuracy was evaluated by an accuracy index (AI), shown as equation (1). Omission errors are the number of reference trees that is not detected by LMF method. Commission errors are the number of trees that incorrectly detected such as multiple detections on single crown or miss detection. AI was applied by Pouliot *et al.* (2002) and Pouliot and King (2005) to show whole accuracy. In the calculations of omission and commission errors, the threshold distance is generally applied for accepting small difference of tree positions. In this study, average of distance between reference trees and nearest neighbors were derived, and three eighth of the distance were used for threshold by sites. This corresponds to roughly 75% of tree crown size, because all sites were densely covered by crowns.

$$\mathrm{AI} = [\frac{(n-o-c)}{n}] \times 100, \quad (1)$$

where n: reference tree count
o: omission errors
c: commission errors.

3 RESULTS AND DISCUSSIONS

Figure 2 shows the relation of LMF window size and accuracy index (AI) with the window sizes of smoothing. The N means the numbers of the reference trees. In sites 1 to 3, where the numbers of trees are smaller, AI was highest in the case that LMF window size is 7 and smoothing window size is 5. On the other hand, site 4 and 5, lager numbers of trees, AI was highest in LMF window size: 5 and smoothing size: 3. It means that density of trees is negatively correlated with the set of window sizes of LMF and smoothing. The scores of the highest AI were approximately 50% in all sites. In the research of Pouliot *et al.* (2005) for natural forest, the score was approximately 30 to 70 %.

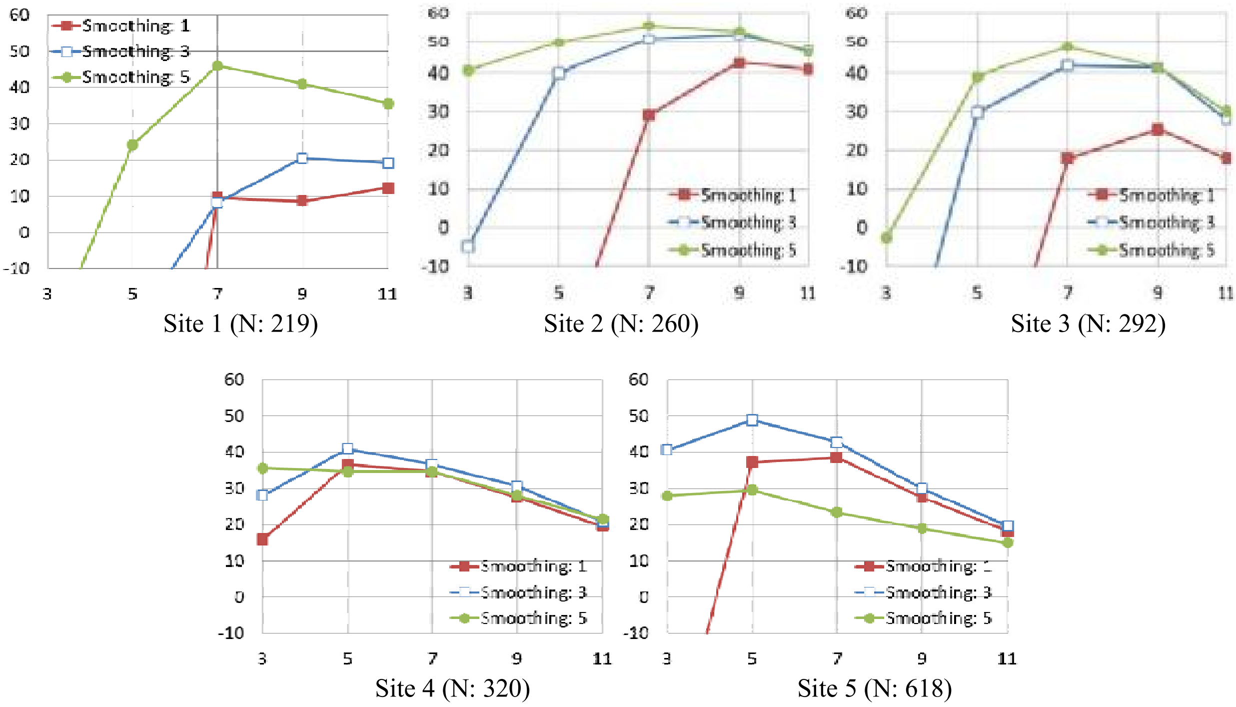
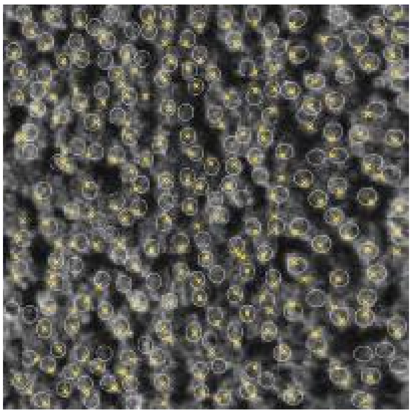
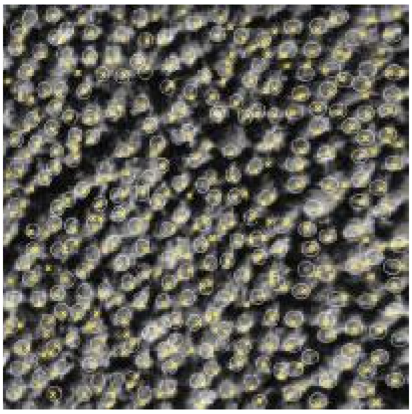


Figure 2: Relation between LMF window size and AI

Figure 3 showed the positions of reference (circle) and detected (cross) trees. These were the highest AI cases, derived by the set of three parameters (image size, smoothing window size and LMF window size) indicated by three sets of numbers. The radiuses of circle correspond to the threshold distances used in the calculation of AI. It is clear that the method missed the detection of darker and smaller treetops.

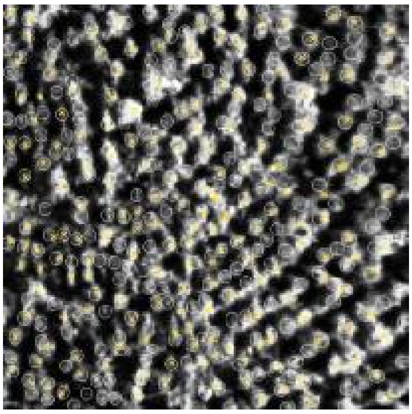


Site 1 (180×180, 5×5, 7×7)

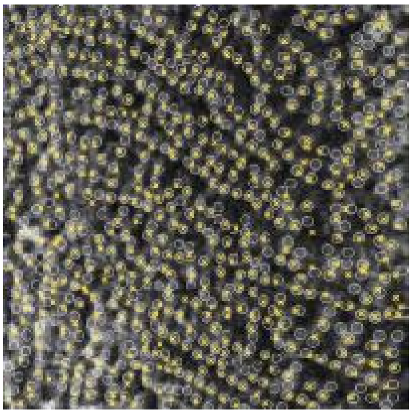


Site 2 (180×180, 5×5, 7×7)

Site 3 (90×90, 3×3, 3×3)



Site 4 (180×180, 3×3, 5×5)



Site 5 (180×180, 3×3, 5×5)

Figure 3: Positions of reference and detected trees

Relation between the density of trees and accuracy index (AI) was represented in Figure 4. Horizontal axis is the numbers of trees per pixels and represents the relative density of trees. For instance, 0.1represents that there is one tree per 10 pixels, 0.01 represents that there is one tree per 100 pixels. Lager value shows relatively the higher tree density or lower image resolution. The scores of AI had not large difference in smaller window size of LMF with 3×3 and 5×5, however, it were largely changed in larger window size as 7×7, 9×9 and 11×11.The variation of AI with the relative density of trees was small in smoothing 1, while large in smoothing 5. The figure showed that the accuracy was significantly decrease by increasing the window size of smoothing, especially in the sites of higher tree densities.The value of AI was changed by the window size of LMF in smoothing 1. This means that the lack of window size in one or both of LMF and smoothing causes the incorrect detection of the tree. It is thought that the effect of the window size of LMF becomes large when the effect of smoothing is small.

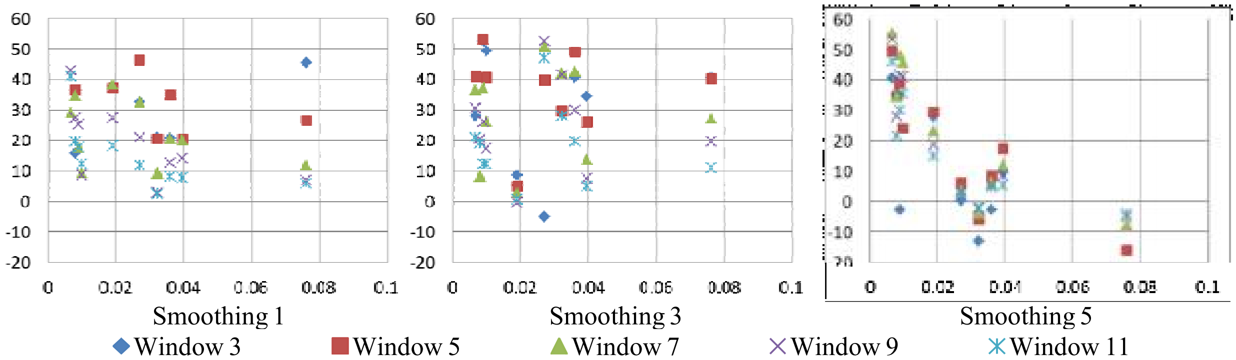


Figure 4: Relation between the density of trees and AI

4 CONCLUSIONS

We investigated the relations of the accuracy of individual tree detection by LMF and three parameters: LMF window size, smoothing window size and image resolution. The examination using aerial photo of five sites with a variety of tree densities showed that the accuracy of LMF was changed by these parameters, and AI showed highest scores in the case that parameters match the size of tree crown. This result indicates that it is necessary to know the optimum size of canopy prior to LMF. We also found a correlation of relative image resolution and accuracy. The detailed investigation will be carried out by considering the changes of omission and commission errors.

ACKNOWLEDGEMENTS

This research was supported by KAKENHI (22710011) and Foundation for International Collaboration of Kochi University.

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