Detection of individual tree crowns in high spatial resolution remote sensing imagery

著者	Kubo Mamoru, Muramoto Ken-ichiro
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Detection of Individual Tree Crowns in High Spatial Resolution Remote Sensing Imagery

Mamoru Kubo and Ken-ichiro Muramoto
Graduate School of Natural Science and Technology, Kanazawa University, Japan
*corresponding author: email: kubo@ec.t.kanazawa-u.ac.jp

Key words: tree crown, detection, high spatial satellite image

Abstract

In this study, individual tree crowns in high spatial remote sensing imagery are detected. Currently, foresters have forest type maps of tree species. However, they do not have the location and the size of individual trees required for forest management. The spatial resolution of an IKONOS satellite imagery is very high so that the visual interpretation of individual tree crown can be carried out.

The purpose of this study is detecting tree crowns from these images of forest, and classifying into some types. First, in order to detect individual tree crowns, the outline of a tree crown is extracted using the watershed segmentation algorithm. Next, a supervised maximum-likelihood classification is performed using the spectral and textural features of each area of the tree crown.

IKONOS data is four bands of red, green, blue and near-infrared, and the spatial resolution is 1m per pixel. Since the individual tree crown in these images consists of several pixels, it can be identified separately. Principal component analysis of the multispectral data was carried out, and the first component image was used for detection processing of individual tree crowns. After smoothing the image using a small Gaussian filter, the watershed segmentation was applied for detection of each tree crown. The segmented objects were well in agreement with the tree crowns by visual inspection. The supervised classification based on maximum likelihood decision rules was performed using the spectral features of each tree crown and the textural feature using gray level co-occurrence matrices. The forest map with the location and the shape of individual tree crowns was produced by our methods.

1. Introduction

Currently, forest management requires that forest resources be efficiently managed not only for timber production, but also for such purposes as maintaining biodiversity and estimating the source of absorption of carbon dioxide. It is necessary to increase the detailed knowledge of wide forest stands using satellite data.

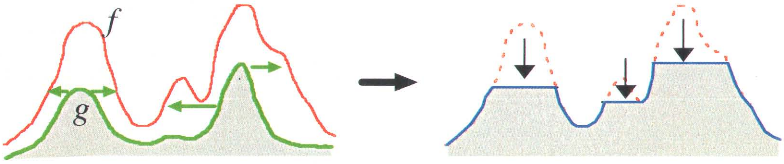
In this study, individual tree crowns in high spatial remote sensing imagery are recognized. Foresters have forest type maps of tree species. However, they do not have the location and the size of individual trees required for forest management. The spatial resolution of IKONOS satellite imagery is very high so that the visual interpretation of individual tree crown can be carried out (Carleer, 2004; Franklin, 2000).

The purpose of this study is detecting tree crowns from these images of forest, and classifying into some types. Various algorithms have been developed for automatic individual tree recognition (Culvenor, 2002; Gougeon, 1995; Pouliot, 2002; Wang, 2004; Wulder, 2000). In this study, first, in order to detect individual tree crowns, the outline of a tree crown is extracted using the watershed segmentation (Shafarenko, 1997). Next, a supervised maximum-likelihood classification is performed using the spectral and textural features of each area of the tree crown. This method is the object-oriented classification technique, not pixel-based (Al-Khudhairy, 2005; Wang, 2004).

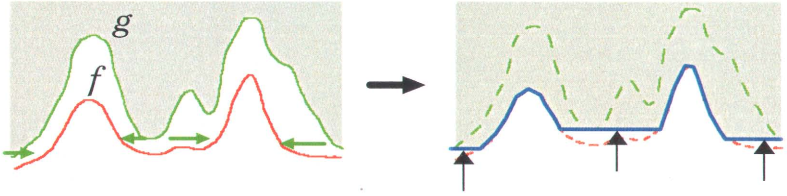
2.Methods

The processing method consists of the following five steps:

1. Principal component analysis is carried out to the four band images of IKONOS pan-sharpened data, and the first component image is created.
2. In order to detect an individual tree crown, the smoothing processing which makes each tree crown into one peak, is required before segmentation. First, smoothing weakly by Gaussian filter, high spatial frequency components are removed from source image. Next, we perform morphological reconstruction by dilation and erosion operations. Figure 1 shows reconstruction of function f from function g. Dilation of g is repeated to the neighboring pixels until they reach f. Erosion operation is also made in the same way, but in the opposite direction. This process is intended to keep the boundary shape of any tree crown.



Dilation: Peak smoothing



Erosion: Valley smoothing

Fig.1 Morphological reconstruction of *f* from *g*

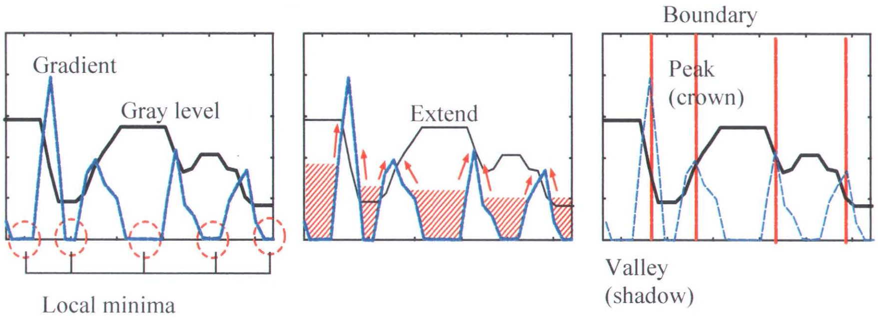


Fig.2 Watershed algorithm

3. Watershed algorithm as segmentation is used for detection of Individual tree crowns. Figure 2 shows this process that consists of the three steps. First, in order to find peaks or valleys, gray level gradients are calculated. Next, the regions are extended from local minima of gradient. Finally, the boundaries of each region are detected. The segmented peak or valley region is equivalent to a tree crown or a shadow, respectively.

4. The features for classification are the following three:

$$NDVI = \frac{1}{N_X}\sum_p \frac{I_{\mathrm{NIR}}(p) - I_{\mathrm{Red}}(p)}{I_{\mathrm{NIR}}(p) + I_{\mathrm{Red}}(p)}$$

$$Entropy = -\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} p(i,j,d,\theta)\log(p(i,j,d,\theta))^2$$

$$Intensity = \frac{1}{N_X}\sum_p \frac{I_{\mathrm{Blue}}(p) + I_{\mathrm{Green}}(p) + I_{\mathrm{Red}}(p)}{3}$$

The intensity of a tree crown is calculated as the average of the brightness value in each region from blue, green, and red data. NDVI (normalized difference vegetation index) is calculated as the average value in each region from red and near-infrared data. Entropy is a kind of textural feature calculated using the gray level co-occurrence matrix (GLCM) (Maillard, 2003). The p(i,j,d,q) is the (i,j)th element of a N * N GLCM, indicating the relative frequency that gray levels i and j are found at a distance d in the relative direction q.

5. The classification technique uses the maximum likelihood decision rule. In this study, the segmented regions are classified to the six classes; broadleaf, conifer, shrub, soil, water and shadow. Training regions of each class are determined manually.

4.Results

The satellite data used by this study is shown in Fig. 3. This area is the forest of Arimine area in Toyama prefecture in Japan. The altitude is 1000 meter or more. The acquisition date is June 1, 2002. The spatial resolution of this IKONOS pan-sharpened data is 1 meter per pixel, and the data is four bands of blue, green, red, and near-infrared band. Since the individual tree crown in these images consists of several pixels, it can be identified separately.

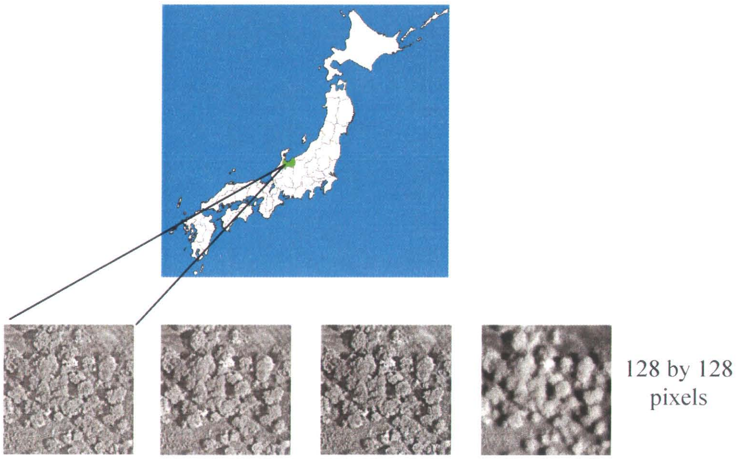
Principal component analysis of the multispectral data was carried out, and the first component image was used for detection processing of individual tree crowns. If segmentation is carried out on the left image, the small peaks in the left graph will result in over-segmentation. The results of the PCA and smoothing are shown in Fig. 4. These graphs show the gray level values on each red line. The high spatial frequency components in each tree crown were removed from the left image.

The results of morphological reconstruction are shown in Fig. 5. Dilation operation smoothed peaks, and erosion operation smoothed valleys. The pixel values in each tree crown became independent peaks by this process.

After smoothing the image, watershed segmentation was applied for detection of each tree crowns. The supervised classification based on maximum likelihood decision rules was performed using the spectral features of each tree crown and the textural feature using gray level co-occurrence matrices. The results of watershed segmentation and classification are shown in a Fig. 6. The segmented objects were well in agreement with the tree crowns by visual inspection. Automatic classification results were 80% correct compared with visual interpretation (Table 1).

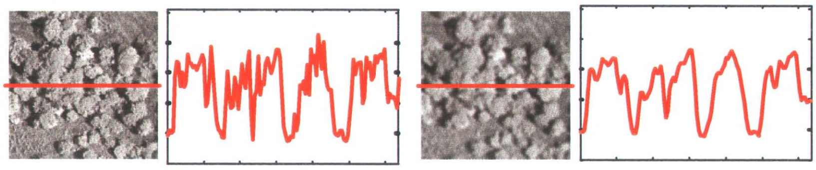
4.Conclusions

In this study, we detected individual tree crowns from forest imagery by IKONOS and classified segmented regions. In detection process, watershed segmentation was used after principal component analysis, smoothing by Gaussian filter and morphological reconstruction. In classification process, two spectral features and one textural feature calculated using gray level co-occurrence matrix were used by maximum likelihood classifier. Classification accuracies on the order of 80% were achieved. The forest map with the location and the shape of individual tree crowns was produced by our methods.



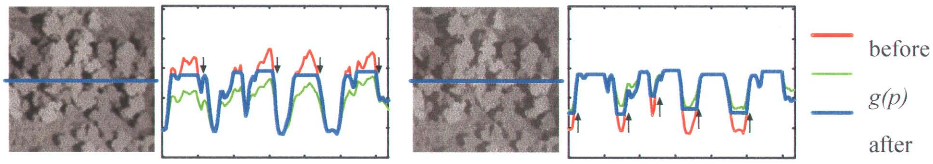
Blue Green Red Near-infrared

Fig.3 IKONOS pan-sharpend data.



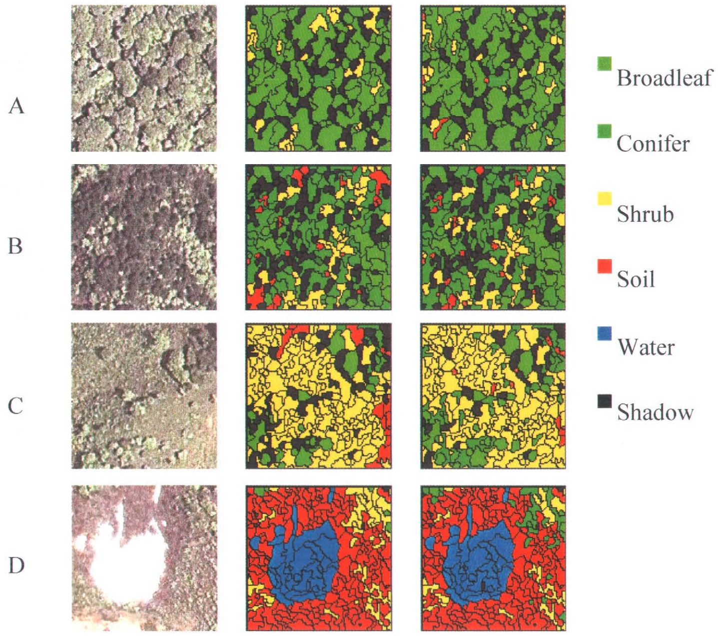
First component Weak smoothing

Fig.4 Results of smoothing processing by Gaussian filter.



Dilation: peak smoothing Erosion: valley smoothing

Fig.5 Results of morphological reconstruction.



(a) (b) (c)

Figure 6. Results of segmentation and classification.
(a) Composite color images; (b) segmented and classified regions;
(c) Manually classified regions

Table1. Classification accuracies compared with visual interpretation.

Area	Total number of region	Number of correct region	Accuracy [%]
A	174	144	82.8
B	230	216	93.9
C	216	180	83.3
D	221	200	90.5

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