MATCHING OF HIGH RESOLUTION SATELLITE IMAGE AND TREE CROWN MAP

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ABSTRACT:

In forest area, there are few landmarks to be ground control points (GCPs) used for registration of satellite images or maps. Additionally, geographic information from the Global Positioning System (GPS) in field measurement survey is insufficient accuracy to identify individual tree crowns from satellite image. In this study, we propose the method of identifying individual tree crowns from satellite image using field measured data. First, in order to obtain the field measured data, we collected several information of individual trees in the test site. These are the tree stand locations, the distances between the tree trunk and outermost branch in eight directions, the diameter at breast height, and tree species. Then, using the field measured data, we created the projected on-ground crown map which has the location and shape of individual trees. The each shape of tree crown is octagonal. Next, we detected the regions of tree crown from IKONOS panchromatic image. Watershed algorithm was used for image segmentation, based on mathematical morphology considers gray-scale images to be sets of points in a three-dimensional space, the third dimension being the gray level. The segmented regions were classified to discriminate tree crown using the feature of spectral signature. Finally, we found out individual tree crowns related with field measured data from satellite image. Using a GCP by GPS equipment, we performed roughly registration of the satellite image to the projected on-ground crown map. For each tree crown in the map, we found out the same tree, which has the highest corresponding possibility to the tree crown in the map, among segmented regions obtained from satellite image. This tree-to-tree matching algorithm was performed using the fitness value of the location and octagonal shape of both tree crowns in image and map. We could obtain the optimum registration by affine transformation of highest fitness value without ground control points. Consequently, we could identify individual tree crowns from satellite image by image-to-map rectification.

1 INTRODUCTION

Forest composed of many trees has an important role in maintaining environmental conditions suitable for life on the earth. Satellite remote sensing technology is the effective method for management and monitoring of forest resources.

In recent years, high spatial resolution satellites were launched, thereby it is possible to obtain detailed information about earth's surface. The IKONOS satellite image can recognize and identify an individual tree crown, it is suitable to monitor a forest covering wide-area. In order to obtain forest management inventories at the stand level, IKONOS satellite images are analyzed instead of the interpretation of aerial photographs(Gougeon and Leckie, 2006).

To identify tree crown detected from satellite image using field measured data, we requires high-accuracy image-to-map rectification. However, geographic information from GPS in field survey is insufficient accuracy to identify individual tree crowns from satellite image. Additionally, in forest area, there are few landmarks to be GCPs used for registration of satellite images or maps.

In this study, we propose the method to identify individual tree crown from satellite image by image-to-map rectification. This method is useful for forest management and monitoring.

2 DATA SET

The Kitasaku test site of this study is located in the deciduous mixed forest of Nagano prefecture in Japan. This area is 140 meter from west to east and 60 meter from north to south. In this site, there are two flux towers to measure the exchanges of carbon dioxide between forest and atmosphere. In addition, the grid of 10 meter mesh is constructed using piles labeled alphabet and numeric characters. The illustration of this site is shown in Figure 1.

2.1 Field Measured Data

Field measurement survey was carried out on 28 Octorber 2007. 102 canopy trees with height of 16 to 18 meter were selected in order to create the projected on-ground map. The relative location of the tree in this area is acquired by measuring the location in the labeled block where the tree stands. The following are the measurement parameters of each canopy tree in this survey:

(1) tree stand location (x, y) in the labeled block;

(2) distances between the tree trunk and outermost branch in eight directions (N, NE, E, SE, S, SW, W, NW);

(3) diameter at breast height.

The positional information of the flux tower was also recorded. The illustration of the field survey is shown in Figure 1.

2.2 Satellite Image

The satellite data used in this study is an IKONOS panchromatic image. The spatial resolution of analysis image is 1 meter by pixel. It can be recognized and identified an individual tree crown

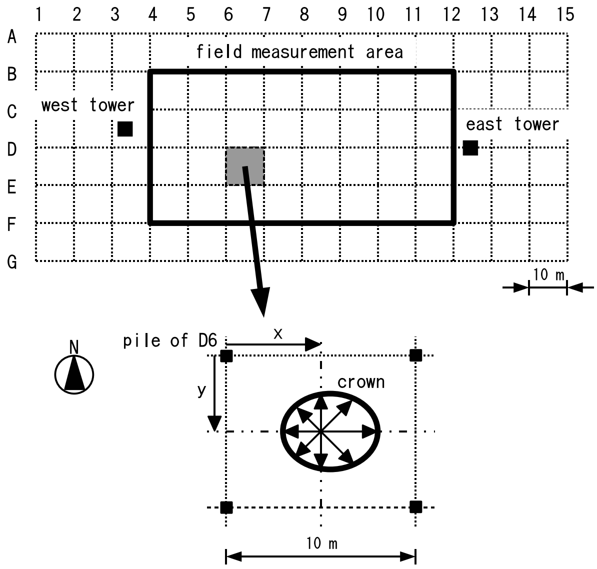

Figure 1: The illustration of test area. The grid of 10 meter mesh is constructed using piles labeled alphabet and numeric characters. There are two flux towers to measure the exchanges of carbon dioxide between forest and atmosphere. The field measurement area is 80 meter by 40 meter.

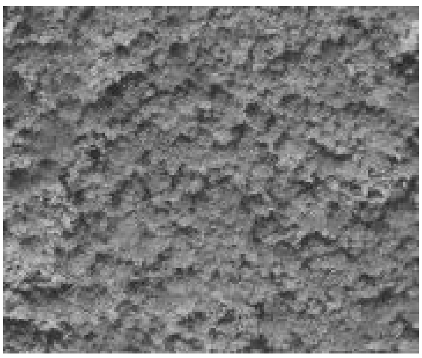

Figure 2: The IKONOS panchromatic image of the study area. This area is 180 meter by 150 meter. (C)Japan Space Imaging Co.

whose radius is more 2 or 3 meter. The image was acquired on 25 August 2003. Figure 2 shows the IKONOS image of the study area. The size of image is 180 meter by 150 meter.

3 METHODS

Figure 3 shows the illustration of image-to-map rectification. First, using the field measured data, we create the projected on-ground map which has the location and shape of canopy trees. Next, we detect the region of tree crown from satellite image. Then, we perform roughly registration of the satellite image and the projected on-ground map. This is initial registration. Finally, performing tree-to-tree matching algorithm(Xiaowei et al., 2006), we obtain the optimum registration and identify individual tree crowns.

3.1 The Projected On-Ground Map

The projected on-ground map is a figure that represents the location of canopy tree and the shape. The shape of tree crown in

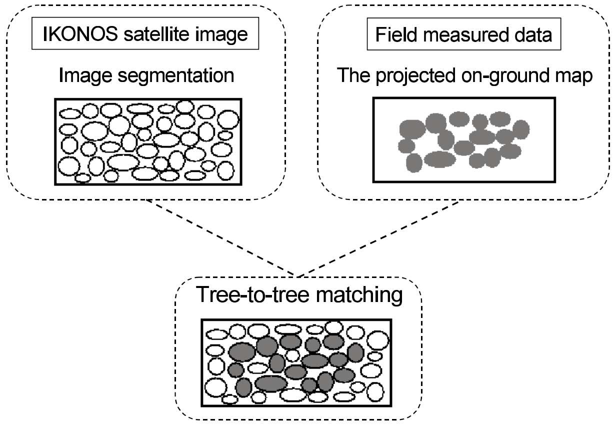

Figure 3: The illustration of image-to-map rectification.

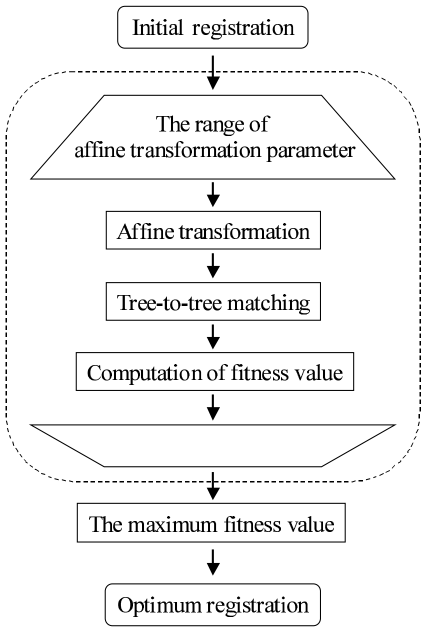

Figure 4: Flow diagram of tree-to-tree matching.

this study is octagonal. We obtained the projected on-ground map from the measurement data of 102 canopy trees.

3.2 Image Segmentation

The IKONOS panchromatic image was segmented using watershed algorithm(Kubo and Muramoto, 2005). Then, the segmented regions were classified to discriminate tree crowns using the feature of spectral signature.

3.3 Tree-to-Tree Matching

Using the positional information of the east tower by GPS equipment, we performed roughly registration of the satellite image to the on-ground map. This is initial registration. Then, using affine transformation, the projected on-ground map is translated, rotated and scaled in order to find the optimum registration. In each overlap of registration, we performed tree-to-tree matching algorithm and calculated fitness value. When the fitness value becomes the maximum, we obtain the optimum parameters of affine transformation for rectifying satellite image to the map coordinate, and identify tree crowns. Figure 4 shows the flow diagram of tree-to-tree matching.

Table 1: The affine transformation parameters, range and step for search

Parameter	Range	Step
Translation:dx, dy	$-25.0 \leq dx, dy \leq 25.0$	0.1 meter
Rotation :θ	$-5.0 \leq \theta \leq 5.0$	0.5 degree
Scaling :s	$-0.90 \leq s \leq 1.10$	0.01

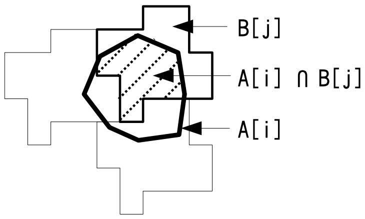

Figure 5: The illustration of tree overlap. $A[i]$ is the tree crown in the projected on-ground map. $B[j]$ is the segmented region from satellite image.

3.3.1 Initial Registration Using the positional information of the east tower, we performed roughly registration of the satellite image to map.

3.3.2 Finding The projected on-ground crown map was overlapped to the satellite image using affine transformation. In order to find the optimum registration, we performed tree-to-tree matching and calculated fitness value in each overlap. The equation of the affine transformation is defined as:

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} s & 0 \\ 0 & s \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \end{pmatrix} + \begin{pmatrix} dx \\ dy \end{pmatrix} \quad (1)$$

where (x_0, y_0) is the location of the east tower at initial registration. The affine parameters range of search and step size are shown in Table 1.

3.3.3 Matching For each tree crown in the map, we find out the same tree among segmented regions from satellite image, which has the highest corresponding possibility to the tree crown in the map. Figure 5 shows illustration of tree overlap.

The degree of tree overlap is defined as:

$$OL[i][j] = \sqrt{\frac{A[i] \cap B[j]}{A[i]} \quad \frac{A[i] \cap B[j]}{B[j]}} \quad (2)$$

where $A[i]\{i = 1 \ldots N\}$ is the tree crown in the projected on-ground map, and $B[j]\{j = 1 \ldots M\}$ is the segmented region from satellite image. The region $B[k_i]\{k_i = 1 \ldots M\}$ of the highest value is defined as:

$$OL[i][k_i] \geq OL[i][j] \quad \text{for} \quad j = 1 \ldots M. \quad (3)$$

3.3.4 Fitness value The tree-to-tree matching algorithm is performed using the fitness value of the location and octagonal shape of both tree crowns in the satellite image and the projected on-ground map.

The fitness value P at each overlap by affine transformation is defined as:

$$P(dx, dy, \theta, s) = \frac{1}{N} \sum_{i=1}^{N} OL[i][k_i]. \quad (4)$$

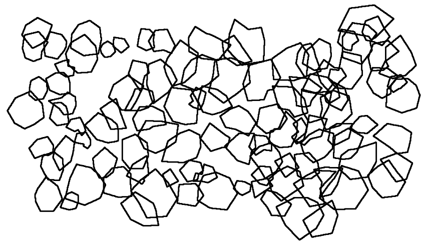

Figure 6: The projected on-ground map of 102 canopy trees.

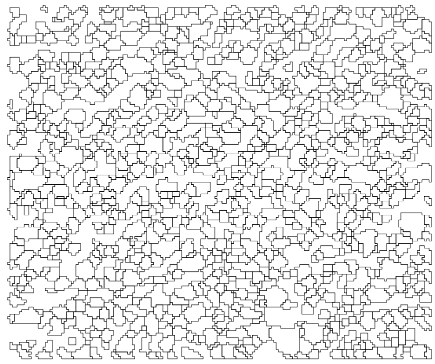

Figure 7: 911 regions of tree crown were detected by classification after segmentation from satellite image.

When the fitness value becomes the maximum, we obtain the optimum parameters of affine transformation for rectifying satellite image to the map coordinate, and identify tree crowns.

4 RESULTS

4.1 The Projected On-Ground Map

The projected on-ground map created from the measurement data of 102 canopy trees is shown in Figure 6.

4.2 Image Segmentation

The tree crowns were detected by classification. Figure 7 shows the 911 regions of tree crown.

4.3 Tree-to-Tree Matching

The affine transformation parameters at optimum image-to-map rectification is shown in Table 2. The initial registration of tree-to-tree matching and the histogram of tree overlap are shown in Figure 8. The optimum registration of tree-to-tree matching and the histogram of tree overlap are shown in Figure 9. The average of the tree overlap at the optimum registration was increased from 0.437 to 0.509 compared to the initial registration. The locations of the towers in the projected on-ground map overlapped with the locations of the towers by visual inspection in satellite image. Using the method in this study, we obtained equivalent result with the accuracy of image registration by using ground control points. By the method in this study, the optimum registration were obtained without ground control points. Figure 10 shows rendering the satellite image on the octagonal shapes of tree crown. Figure 11 shows perspective projection of canopy 3D model using OpenGL.

Table 2: The affine transformation parameters at optimum image-to-map rectification

Translation: dx, dy	-2.7, 16.2 meter
Rotation : θ	-1.0 degree
Scaling : s	1.01

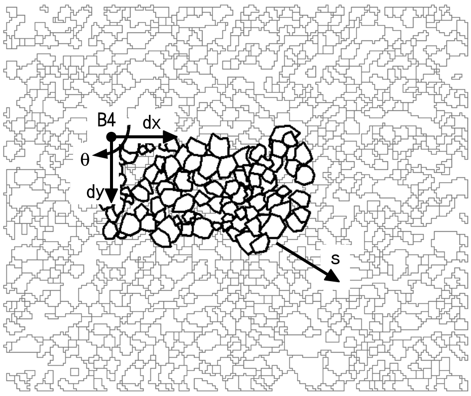

Figure 8: The initial registration of tree-to-tree matching and the histogram of tree overlap. $P = 0.437$

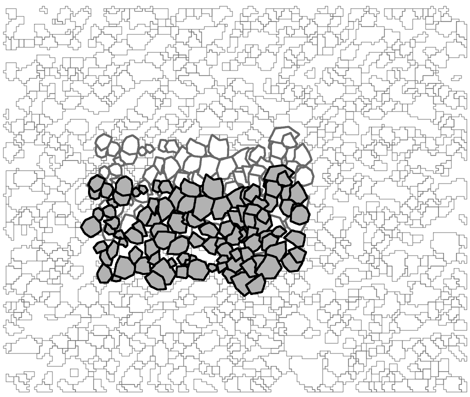

Figure 9: The optimum registration of tree-to-tree matching and the histogram of tree overlap. $P = 0.509$

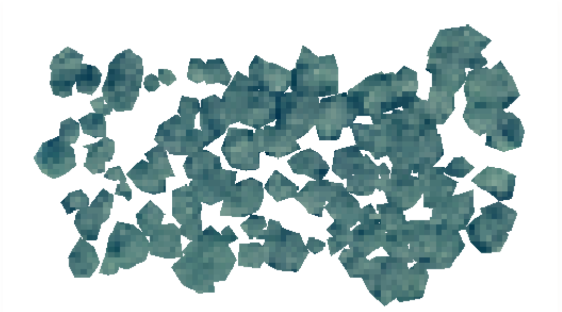

Figure 10: Rendering the satellite image on the octagonal shapes of crown.

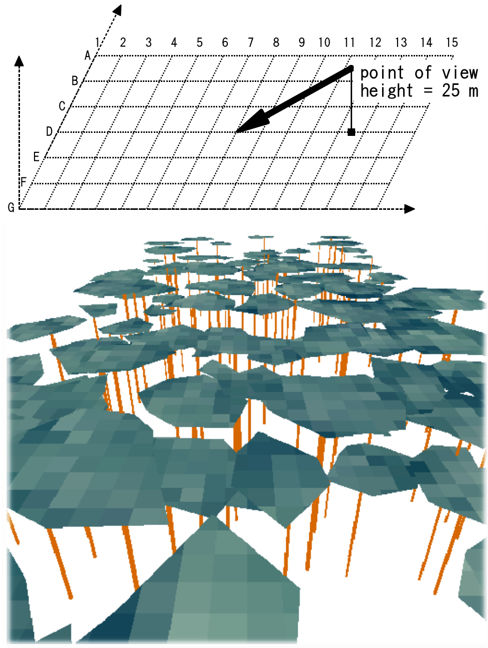

Figure 11: Perspective projection of canopy 3D model using OpenGL.

5 CONCLUSION

In this study, we proposed the method to identify tree crown from satellite image by image-to-map rectification. The tree-to-tree matching algorithm was performed using the fitness value of the location and octagonal shape of both tree crown in satellite image and field measurement map. We could obtain the optimum registration by affine transformation of highest fitness value without ground control points.

Furthermore, it became possible to obtain the spectral information such a normalized difference vegetation index (NDVI) from multi-spectral satellite data, about individual trees. This method is useful for forest management and monitoring.

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