Detection of Individual Tree Stands by a Fusion of a Multispectral High-resolution Satellite Image and Laser Scanning Data

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Abstract: A methodology of the integrating the similar color circle search of the spectral data and segmentation of the height data is developed. The method is then applied to study areas, and the results by IKONOS, LIDAR and data fusion are verified with the ground truth, and examined in terms of the accuracy. Results show that with the data fusion the accuracy are improved by about 15% in most of the study areas. The methodology for the detection of individual tree stands by data fusion is explored, and the utility of combinatorial use of the spectral and the height information is demonstrated.
Keywords: IKONOS, LIDAR, Individual tree detection

1. Introduction

To estimate CO_2 absorption at the national scale, forest parameters such as area, average height, crown cover ratio and biomass are used [1]. At the same time, in the local and regional scales, vegetation monitoring, selective cuts, and estimation of CO_2 absorption by afforestation are increasing the demands of precise forest managements.

Techniques to estimate the forest parameters are broadly developed in each scales level, and the delineation of individual crowns with use of aerial images, high-resolution satellites images, or LIDAR are major in regional scale [2][3]. Looking at the technology development in the near future, the simultaneous data acquisition of height and spectral data would be available. Although there is a possibility to improvement of estimation of forest parameters by data fusion not much works are done [4]. Considering the estimation of CO_2 absorption from the regional scale, methodologies for such data fusion should be explored.

This paper aims at the development of the data fusion of spectral and height data. Thus it challenges known including anthropogenic objects and vegetation consisted with several types and species.

2. Material and Methods

1) Study Site and Field Survey

Target area is set to Showa Kinen Park in Tokyo, Japan. The park comprised of area of 138 hectares containing variety of trees with blend of the different combination and density. Human made objects such as roads and buildings are also found in the park. Study sites are selected from this park because the park contains different types of naturally vegetated areas and the ground truths for the verification of those areas are easily obtained by the field survey. Four sites, named A, B, C, and D, are selected regarding to the tree types, the height, and the density. Detail information are shown in the table 1.

Field surveys are conducted in the all sites on August 17 and 21 of 2003. For each tree, the position, the height, the diameter, and the species are obtained as the ground truth. Precise positions of every tree are specified using the differential GPS, and the height are acquired with the laser measurement instrument. Information about the diameter and the species are based on the actual measurement. However in the site C, positions were not measured because the high density of stems and canopies make it difficult to utilize the GPS measurement.

2) Multispectral Satellite Image

IKONOS (digital geo product) of this study site are taken in August 11 of 2001. Data include panchromatic

Table 1. Detail of subsets and ground truths (true value, average height and diameter, remarks) of each site.

	p.s.	t.p.	t.v.	aveH (s.d.)	aveD (s.d.)	Remarks
A	250 x 100	16153	74	8.4 (3.7)	26.2 (12.2)	b, l, s
B	150 x 100	13299	121	9.2 (3.3)	27.4 (12.1)	b, h, s
C	200 x 300	57059	138	N.A.	36.3 (16.4)	b, m, d
D	100 x 100	6936	23	189.0 (1.2)	46.0 (5.8)	c, h, d

p.s. = plot size (pixels), t.p. = target pixels (pixels), t.t. = true value (number of tree stands), aveH = average height (m), s.d. = standard deviation, aveD=average diameter (cm) , c = coniferous, b = broad-leaf, h = high, m = middle, l = low, d = dense, s = sparse and multi-spectral (red, green, blue and near infrared) image with the spatial resolution of 1 meter.

3) LIDAR data

LIDAR (LIght Detection And Ranging) is a growing technology that can acquire height information of ground surface by measuring the time interval between the emission and reception of laser pulses. The data is acquired in November 19 in 2001 from an airborne laser scanner with the height of 2590 meter, the scan rate of 18.5 Hz, and the average footprint of 0.66 meter. The scanner is a product of Ener Quest System which has the horizontal accuracy of $\pm$ 30 cm and the vertical accuracy of $\pm$ 15 cm was used. The average density of laser reflections is about 2.5 meter square.

Although there is a time lag between IKONOS and LIDAR, little difference of seasonal change is confirmed by the field survey in both months in these study sites.

3. Methods

1) Preprocessing

Fig. 1 shows the flowchart of outline. First of all, subsets of the all sites are produced from both data and masks are applied to target pixels (e.g. Fig2.a.). Noise removal is operated to IKONOS images by applying the median filter with the window size of 3 x 3. Also, with the band math of the near infrared and the red bands, NDVI (Normalized Differential Vegetation Index) is calculated from -1 to 1. Then areas of non-vegetation are removed with the threshold of zero. From LIDAR data, DSM (Digital Surface Model) and DEM (Digital Elevation Model) are calculated by interpolating the original data with 1 meter mesh to be aligned with the spatial resolution of IKONOS data. After that, nDSM (Normalized Digital Surface Model) considered as the height above the ground level, are calculated by subtracting DEM from DSM.

2) IKONOS images

In this paper, a SCC (similar color circle) search method is adopted [5], and applied to the spectral information of the study sites. A SCC is defined as circular area with the pixel values within a certain domain set by histogram analysis, and the size of a SCC is recognized as a size of a tree crown. This operation is based on the assumption that a tree crown is usually forming circular shape and has similar colors within it. In the process of searching SCCs, a circle is drawn from the reference pixel with radius staring from 1. If the all values within a circle are in the domain, radius is increased by 1 and continued until it fails to satisfy the domain. After defining radius of SCC in every target pixel, overlapping circles are removed in order to merge small circles within a one crown.

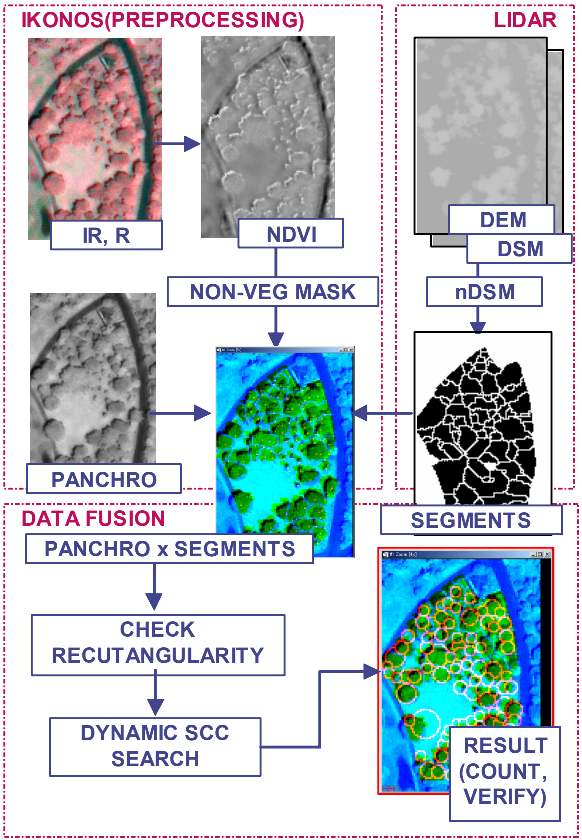

Fig.1. Flowchart of procedures for IKONOS, LIDAR and data fusion.

3) LIDAR data

Segmentation based on the watershed algorithm is applied to the height information of nDSM. After the segmentation, segments with maximum height of less than 1 meter and area of less than 3 meter squared are removed to neglect lawn and subtle detection.

Fig. 2. Example results by detection of individual tree stands with various approach; a) target area with t.v. (red points), b) result of IKONOS, c) result of LIDAR, d) succeed examples of data fusion, e) failed example of data fusion.

4) Fusion of IKONOS and LIDAR

In combination process of IKONOS and LIDAR data , dynamic SCC search is developed to decompose the merged segments.

Each segment derived from nDSM is examined for its rectangularity. This is based on the empirical observation, that a segment containing a neighborhood tree crown is likely to be rectangular. Rectangularity check is operated by drawing an outer circle and an inner circle for each segment, and thus radii of both circles are defined as r^{outer} and r^{inner}. If the difference between both radii is less than 2, a segment is interpreted as a square shape. On the other hand, if the r^{outer} is more than twice as much as r^{inner}, a segment is expected to be rectangular shape, and further SCC search starts in such segment.

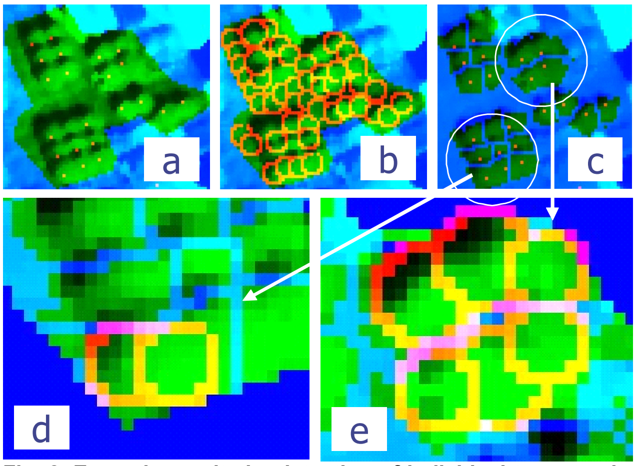

Fig. 2. Example results by detection of individual tree stands with various approaches; a) site D with t.v. (red points), b) result of IKONOS, c) result of LIDAR, d) succeeded example, and e) failed example of data fusion.

4. Results and Verifications

1) IKONOS

In the all sites, detection from the spectral information shows overestimation of tree stands. Sample results are shown in Fig.2.b. In sites A, B and D, overestimations are caused by the vegetation areas of lawn (Table 2. column 4). In site C, twice as much tree stands are counted because of crowns branched from broad-leaf trees.

2) LIDAR

In the all sites, results are underestimating the true values (Table 2. column 5). Sample results are shown in Fig.2.c. In site A and B, the smooth rooftops formed by the natural growth of trees are causing the low accuracy. In site C, however, with the same reason with the result of IKONOS, the branched trees are the reason of the high count. With coniferous trees in site D, it is still missing some tree stands.

3) Fusion of LIDAR and IKONOS

In sites A, B and D, the accuracy improved 14 – 16% by the proposed method (Table 2. column 6). Dynamic SCC searches are basically successful in the most segments (e.g. Fig.2.d), however, still failed in some areas (e.g. Fig.2.e). In site C, some segments are removed and accuracy is decreased after data fusion because circles with radius of 1 meter are omitted in SCC search process.

However, when several trees form a square shaped segment, it failed to start searching a SCC. Also, when spectral data of neigh hood trees are contained in a segment, it failed to drawn appropriate SCCs in a segment. These errors could be caused by data and natural factors, and are difficult to avoid. But it is still possible to overcome with acquisition of height and spectral data with the higher resolution and the precise registration.

Table 2. Accuracy (% in brackets) assessment of results with IKONOS, LIDAR and data fusion.

	t.v.	IKONOS	LIDAR	FUSION
A	74	114 (144.3)	45 (57.0)	57 (72.2)
B	121	162 (131.7)	74 (60.2)	116 (94.3)
C	138	269 (193.5)	137 (98.6)	129 (92.8)
D	23	31 (134.8)	20 (87.0)	25(108.7)

Accuracy = [counted value/ true value] (%)

5. Conclusions

A new method for the data fusion of spectral and height information is developed. Results of individual tree detection by IKONOS, LIDAR and data fusion are examined. Results of IKONOS showed incapability of recognizing trees and lawns. On the other hand, results of LIDAR revealed the difficulties in delineating smooth rooftop formed by merged tree crowns. Although there are some difficulties still remain, the new method presents the possibility for the practical use of data fusion between spectral and height information.

The achievement of this paper is concluded as the successful development of methodology for the simultaneous data acquisition of spectral and height information when it becomes available. Future works still remain in decomposition of squared segments, semi-automatic methods for the SCC search and the precise geometric registrations.

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