

Accuracy assessment of tree crown detection using local maxima and multi-resolution segmentation

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Abstract. Diversity of trees forms an important component in the forest ecosystems and needs proper inventories to assist the forest personnel in their daily activities. However, tree parameter measurements are often constrained by physical inaccessibility to site locations, high costs, and time. With the advancement in remote sensing technology, such as the provision of higher spatial and spectral resolution of imagery, a number of developed algorithms fulfil the needs of accurate tree inventories information in a cost effective and timely manner over larger forest areas. This study intends to generate tree distribution map in Ampang Forest Reserve using the Local Maxima and Multi-Resolution image segmentation algorithm. The utilization of recent worldview-2 imagery with Local Maxima and Multi-Resolution image segmentation proves to be capable of detecting and delineating the tree crown in its accurate standing position.

1.0 Introduction

The forest canopy is responsible for the majority of material and energy exchanges which controls the processes of photosynthesis, carbon and nutrient cycling in a forested area. Unfortunately, physical and costs constrain prohibit the ability to regularize inventory evaluation by limiting field assessments required for detailed structural variability, such as height and volume, encountered in complex forest ecosystems. New and innovative approaches for improving the efficiency and accuracy of forest inventories, especially in geographically remote locations, are now in constant demand [1].

Remote sensing has been a valuable source of information over the course of the past few decades in mapping and monitoring forest activities. As the need for increased amounts and quality of information about such activities becomes more apparent, and remote sensing technology continues to improve the sensing technology over critical areas such as dense forest area [2]. Advancement in remote sensing technology allows for accurate operational and managerial inventories at a cost effective and timely manner over larger forest areas. However, the evolution of this technology needs proper image processing algorithm that can extract the information inside the forest accurately. Prior research had shown that, there were various algorithms developed to detect and delineate tree crowns such as region growing [3], marker-controlled watershed segmentation[4], and automated multi-scale approach [5][6]. In addition, [7] proved that the adopted method from top-down and contour based approaches would appropriately delineate the tree crowns over dense forest area. As [8] mentioned, each algorithm has its advantages and limitations based upon specific stand characteristics and forest type. This study intends to demonstrate the capability of the local maxima and multi-resolution image segmentation in detecting and delineating the tree crown over heterogeneous forested areas.

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2.0 Material and Method

The study area is located at 3° 9'53" North, 101°46'43" East in the Ampang Forest Reserve Kuala Lumpur. The dominant families in Ampang Forest Reserve are Dipterocarpaceae (Meranti), Myrtaceae (Kelat), Sapotaceae (Nyatuh) and Burseraceae (kedondong). Figure 1 below shows a subset of the Worldview-2 imagery over Ampang forest Area.

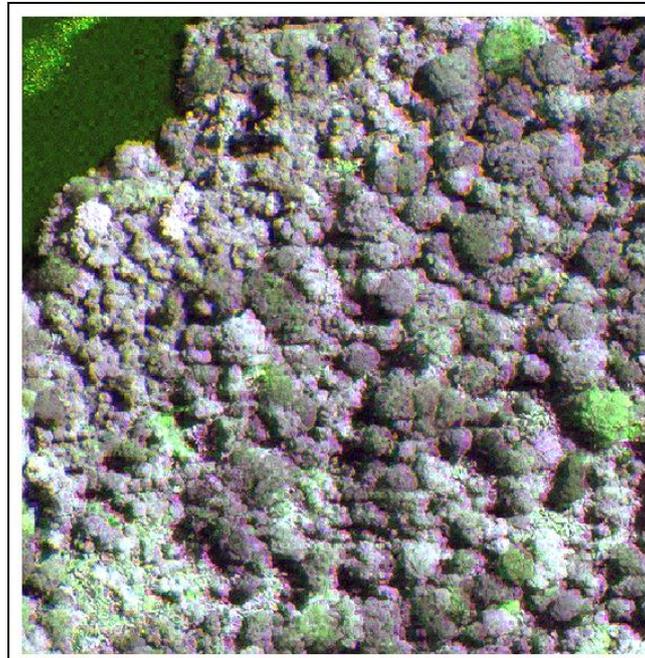


Figure 1. Worldview-2 imagery of Ampang Forest Reserve.

2.1 Data Processing

Figure 2 shows the workflow of the method undertaken, which includes the acquisition of Worldview-2 imagery, Spatial enhancement, Multi-resolution image Segmentation and identification of tree tops using local maxima algorithm and finally the accuracy assessment of extracted result assessed.

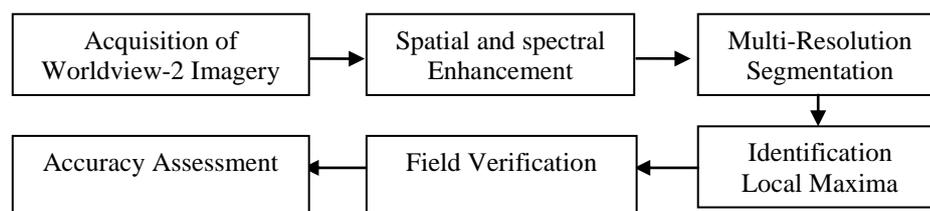


Figure 2 Methodological workflow

2.2 Acquisition of Worldview-2 Imagery

Digital Globe World-view 2 is a spaceborne remote sensing sensor that provides high spatial resolution with multispectral remote sensing images. Worldview-2 multispectral imagery has 8 bands with 2.5m spatial resolution and panchromatic imagery has 0.5m spatial resolution. The dataset is crucial in terms of its panchromatic band and the radiometric information from this band is a basis for study of individual tree detection and delineation.

2.3 Spatial and Spectral Enhancement

Spatial enhancement is a process to enhance the spatial resolution of the multispectral imagery. In this study, the multispectral imagery was fused with the panchromatic image using the resolution merge tool. The image that used for further process consists of 0.5m spatial resolution with 8 bands. Then

the correlation for each bands was computed so that the less correlated band can be selected which enhance the visual appearance of the features. In this study, the band selected for further process is 1,5,7 band combination. Table 1 shows that this combination have less correlated and the combination of red(band 5) and near infrared (band 7) will enhance the tree attributes as compared to the gaps and other features.

Table 1. Correlation of worldview 2 imagery

	Band 1	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7	Band 8
Band 1	1	0.769	0.675	0.74	0.644	0.109	0.008	0.02
Band 2	0.769	1	0.764	0.78	0.726	0.164	0.078	0.072
Band 3	0.675	0.764	1	0.9	0.719	0.586	0.506	0.484
Band 4	0.74	0.78	0.9	1	0.763	0.513	0.386	0.396
Band 5	0.644	0.726	0.719	0.763	1	0.257	0.187	0.167
Band 6	0.109	0.164	0.586	0.513	0.257	1	0.959	0.964
Band 7	0.008	0.078	0.506	0.386	0.187	0.959	1	0.97
Band 8	0.02	0.072	0.484	0.396	0.167	0.964	0.97	1

2.4 Multi Resolution Segmentation

Multi-resolution image segmentation is a bottom up algorithm that used a pair wise region merging technique. This algorithm was developed to extract the image objects. In this study, the setting parameters are 30 scale parameter, 0.5 compactness and 0.1 shapes. If the scale parameter is below and above 30, then small object will be under-segmentation while larger object will be over-segmentation respectively.

2.5 Identification of Local Maxima

The brightness value of individual pixel for tree compartment is based on the convex grey level curvature meaning that the tree top should be giving highest reflectance (local maxima) whilst the crown edge giving lowest reflectance (local minima). Detection of local maxima provides the location for individual tree and the identification of the local minima drew the crown boundary which separates the tree crown from gaps and shadows.

2.6 Field Verification of Tree Stand Position

Ground truth survey was conducted in order to verify the tree stand positions of trees. Altogether, 40 number of trees with >30cm diameter at the breast height has been checked and identified.

2.7 Accuracy Assessment

The tree stand positions detected and delineated from multi-resolution segmentation via local maxima algorithm were then checked against the actual tree stand position on the ground. The accuracy measure used is the Root Mean Square Error (RMSE).

3.0 Result

This study area has a scattered distribution of trees with small gaps contribute to the certain degree of difficulties in detecting and delineating individual tree crown. Figure 3 shows the distribution map of tree position extracted using multi-resolution segmentation with local maxima algorithm. Notice that tree canopy polygons (in green) extracted are in many different shapes. The yellow point symbol represents the (centroid) tree stand position derived from the local maxima algorithm. While the actual tree stand position verified on ground is shown in red (point) symbol.

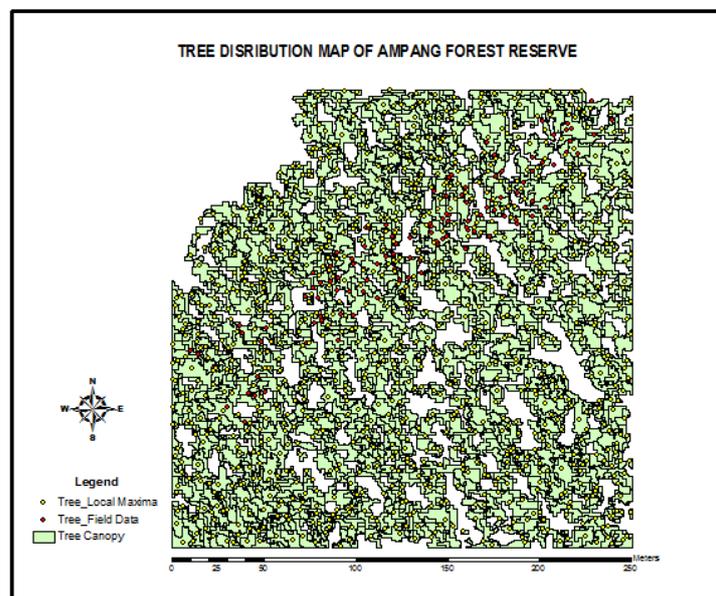


Figure 3 Tree Distribution Map of Ampang Forest Reserve

The Root Means Square Error (RMSE) of X-coordinate and Y-coordinate of tree extracted from local maxima algorithm compared to tree position obtained through field measurement is $\pm 0.296\text{m}$ and $\pm 0.285\text{m}$ respectively. Figure 4 below shows an example of the difference between tree stand positions extracted from local maxima algorithm and data that measured on site.

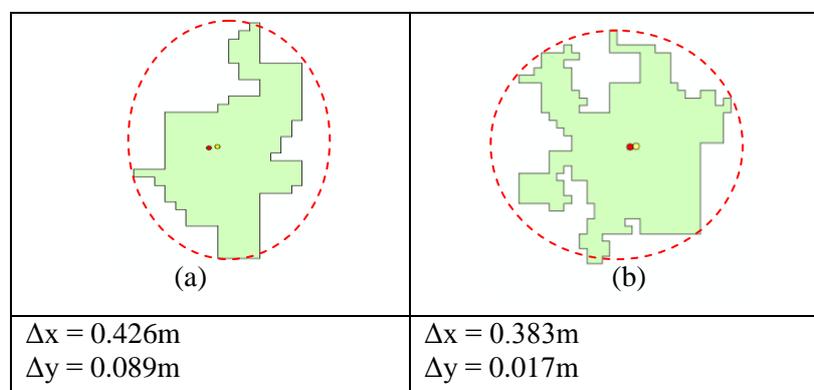


Figure 4 Discrepancies in X-coordinate (a) and Y-coordinate (b)

Figure 4 (a) shows the difference in X-value is 0.426m and difference in Y-value is 0.089m. Figure 4 (b) shows the difference in X is 0.383m and difference in Y is 0.017m. The amount of the difference

is distributed randomly. Visually, no indication could be deduced on how their differences were to be understood.

There are several factors that could affect high discrepancy in value in tree stand position between results extracted from local maxima and field measurement. The main factor is that the tropical forest area is a very dense area and heterogeneously scattered with various tree species and irregularities of crown shape. Due to the size and height of the tree, the centre of the tree trunk was determined based on the circumference measure made against the trees at breast height.

In this study the mean of the Diameter at breast height (DBH) is 0.505m. Thus, there are constant errors in between centre and circumference of the trunk which is $\pm 0.253\text{m}$ as shown in Figure 5 below. It should be noted that due to the irregularities of the tree canopy shape indicated that tree tops do not always coincide with the centre of the tree (i.e. the middle of the trunk)

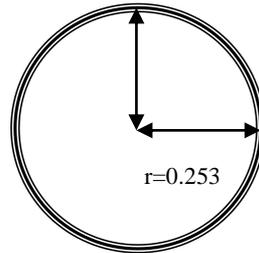


Figure 5. Radius at diameter at breast height

4.0 Conclusion

The potential of high spatial remote sensing imagery in detecting and delineating tropical forest stands was examined here. The result from this study shows that identification of local maxima with multi-resolution image segmentation provides accurate tree position in a dense forest area. The RMSE for x-coordinate is $0.296\text{m} \pm 0.253\text{m}$ and the RMSE of y-coordinate is $0.285\text{m} \pm 0.253\text{m}$ where $\pm 0.253\text{m}$ is the constant error in this measurement. Since the segmentation output is very sensitive to the selection of parameters for the multi-resolution segmentation algorithm, it has to be carefully adjusted and tested before final application. The findings from this research will form the basis for further analyses in regard to forest application. The utilization of local maxima and multi-resolution segmentation proves to be capable of detecting the tree position based upon the crowns centre in an accurate standing position.

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