Tree Crown Delineation from High Resolution Satellite Images

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Abstract

This paper presents the comparison of two different algorithms for detection and counting of individual tree crowns from high resolution satellite images. Trees can be detected from the high resolution satellite images using the different algorithms like K-means clustering, Circle Unification, Watershed segmentation and Normalized Difference Vegetation Index (NDVI). In this paper Watershed segmentation algorithm and NDVI performance are improved for the detection and counting the trees in the satellite images. The fundamental process of algorithms and results are compared to find the better approach for the detection of the trees.

Keywords: NDVI, Satellite Images, Trees, Watershed Segmentation

1. Introduction

Trees are an important component of the natural land because of their prevention of destruction and providing weather-sheltered ecosystem in and beneath their vegetation. Trees play an important role in sustaining Environmental conditions fit for life on the Earth. Now-a-days Deforestation is increased due to lack of Knowledge and for other purpose of Industrialisation. This leads to Natural Disasters like Landslides, Floods and also increases Global Warming. For this we need to know how many trees are present in a Particular area by using different algorithms. The tree crown of a plant denotes the totality of the plants above ground including stems, leaves and re-forming structures extending from the main stems. Hence the number of trees can be known by counting the number of crowns in the image.

Study of Urban vegetation plays an important role in urban planning, environmental protection and reliability checking measures. In olden days' tree crowns are counted manually but it is labour intensive and includes too much of cost gives less accurate count. Recently, Remote Sensing Techniques helps to obtain the Information from

High Resolution Satellite Images. Tree top positions can be assessed by using object oriented methods. There are numerous methods such as valley-following algorithm or region growing method to detect shadows around tree crowns and to delineate their outline, such as other contour based methods use multi-scale analysis. Some algorithms are failed to identify the number of tree crowns in confound scene images because different kinds of objects are present like buildings, vehicles etc. By using different algorithms like watershed segmentation, NDVI and K-Means clustering can be done to detect and delineate the tree crowns in complicate scene images.

2. Methods for Delineation of Trees crown using

2.1 Watershed Segmentation

In this method, Principal Components Analysis (PCA) is used to obtain a suitable singleband image. Principal Component Analysis is utilized to convert a group of images into a new group of images with a slight correlation among them. The first component contains the most variance, and each successive component contains less
variance than the previous components. Fig.1.3 shows the PCA output image. The first principal component that can be used for edge-detection processing is a single band image. For the PCA image edge detection is applied by using Sobel operator. Euclidean distance transform is applied to the image which allocates each pixel by a value that designates the distance between the pixel and to the nearest nonzero pixel. The corresponding output is shown in Fig.1.3. Tree crowns are interpreted using edge detection operation. For the edge detection sobel operator is used. Fig.1.5 shows the output of the edge detection.

Watershed segmentation is applied to the previous output image. The watershed segmentation algorithm is used for image segmentation. The watershed transform finds the edges in the image by treating light pixels with high elevation and dark pixels with low elevation. The output image contains integer values more prominent than or equivalent to zero. The elements labelled zero doesn’t belong to a single watershed region. Let f be a digital grey value image. Initially, we assume that f is lower complete, that is, each pixel which is not in a minimum has a neighbor of lower grey value. The lower slope of image at a pixel, is defined as the highest slope linking pixel to the adjacent pixel with lower altitude.

\[ LS(p) = \text{MAX}_{q \in N(p) \setminus \{p\}} \left( \frac{f(p) - f(q)}{d(p,q)} \right) \]

Where \( LS(p) \) represents lower slope of image, \( f \) represents image, \( p \) represents pixel, \( N(p) \) is the set of neighbours of pixel \( p \) on the grid \( G = (V,E) \), and \( d(p,q) \) is the distance associated to edge \( (p,q) \). Note that always \( LS(p) \geq 0 \), and that \( LS(p) = 0 \) if and only if \( f \) has a local minimum at \( p \). The set of lower neighbours \( q \) and \( p \) for which the slope \( (f(p) - f(q))/d(p,q) \) is maximal, i.e. equals the value \( LS(p) \), is denoted by \( \Gamma(p) \). The output of the watershed segmentation is shown in Fig.1.6 and the tree crowns are delineated by overlaying output of the edge detected image to the original image. The delineated tree crowns are shown in Fig.1.7.

### 2.2 Normalized Difference Vegetation Index (NDVI)

In this method initially decorrelation stretch is implemented to visual enhancement of the input image. The output of the decorrelation stretch is shown in Fig.2.2. Later vegetation areas are detected based on the vegetation index values of the image. Once vegetation areas are detected by applying the thresholding trees are separated from the remaining objects. For this edge detection is implemented and it is used to demarcate the individual tree tops and finally the counted number of the tree crowns is presented.

**NDVI**: Normalised difference vegetation index utilized visible and near infrared to obtain remote sensing measurements. Healthy vegetation area absorbs more visible light and reflects large amount of near-infrared light. The area with unhealthy vegetation like grass lands and less dense forest places reflects more amount of visible light compared to near-infrared light. The area with Bare soils reflects moderately both the red and infrared light. Meanwhile the behavioural model for trees in electromagnetic spectrum is known, by using this information we compare the satellite bands to find out the vegetation information. The output of NDVI is obtained using the equation (2)

\[ NDVI = \frac{(NIR - VIS)}{(NIR + VIS)} \]

where VIS and NIR represents visible (red) and near-infrared regions. In the above resultant NDVI of image may contain other than trees due to presence of the same colour objects like trees. In order to remove the unwanted objects and to detect vegetation area thresholding is implemented by selecting a particular value of the threshold by optimisation. The output corresponding to image is shown in Fig.2.3.

**Edge Detection**: The process that removes the unwanted objects by cross correlating with the kernel that can be obtained from the canny’s method. This process is divided into four steps

i. Noise can be removed by using Gaussian filter method. Therefore, false detection can be minimized. Gaussian filter kernel convolves with the respective pixels of image. The equation of Gaussian kernel is given by

\[ H_g = \frac{1}{2\pi \sigma^2} \exp \left( -\frac{(i-(k+1))^2 + (j-(k+1))^2}{2\sigma^2} \right), \]

\[ 1 \leq i, j \leq (2k+1) \]

where \( k \) represents the gradient values in the horizontal and vertical direction in equation 4. From this the gradient and the slope of the edge can be determined.
\[ G = \sqrt{G_x^2 + G_y^2} \]  
(4)

\[ \theta = \frac{\pi}{2} \text{atan} 2(G_y, G_x) \]  
(5)

ii. The edges that are obtained are still blurred. In order to reduce that effect a threshold value is taken based on tree crown grey level values, the values that are below this will be nullified which represent the sharpest change in the intensity value.

Due to the presence of noise more edges are detected. In order to remove such responses, A conditional threshold values are taken into consideration. Let us say \( T_h \) is upper threshold value and \( T_l \) is the lower threshold value and \( G_p \) is the grey level value the pixel.

- If \( G_p > T_h \) \( \Rightarrow \) Strong Edge
- \( T_l < G_p < T_h \) \( \Rightarrow \) Weak Edge
- Else \( G_p < T_l \) \( \Rightarrow \) Edges are nullified

Here \( T_h \) and \( T_l \) values chosen differently for different images.

**Counting The Tree Crowns:** After the delineation of the tree crowns structural element process followed by morphological dilation operation to find out the number of tree crowns presented in the image. The morphological open operation is used to thicken the edges presented in the image and count the number of tree crowns presented in the image accurately which is shown in the fig 2.5.

### 3. Simulation Results

The proposed algorithms are implemented with MATLAB. The following two algorithms are tested and verified on 20 different test data obtained from internet resources and the results are satisfactory with giving a tree count of near or equal to specified percentage of tree count in the following figures.

#### 3.1 Watershed Segmentation

Fig.1.1 shows the input image for which watershed segmentation is applied to detect and delineate tree crowns.

For the input image decorrelation stretch operator is implemented to improve image color separation and increases the visual perception. The output of decorrelation stretch is shown in the Fig.1.2

After that Primary Component Analysis (PCA) is applied on the decorrelated image which gives single band grey color image. PCA reduces dimension of the data. The output image of PCA is shown in the Fig.1.3

After that simple thresholding operation is applied on the PCA image in order to detect trees based on the threshold value. Therefore, proper threshold value is chosen to detect tree areas by optimization. The output image is shown in the Fig.1.4

After that edge detection is applied using sobel operator. The output of the edge detection is shown in the below Fig.1.5
Tree Crown Delineation from High Resolution Satellite Images

Figure 1.4 Thresholded image.

Figure 1.5 Edge detection (Sobel operator).

After that watershed segmentation is applied to separate tree crown area from the background. The output of the watershed segmentation is shown in the Fig.1.6

Figure 1.6 Watershed Segmentation.

In order to delineate the tree crowns the edge detected image is overlapped on the decorrelated image, for this fusion operator is implemented. The delineated tree crowns are shown in the below Fig.1.7.

Figure 1.7. Tree crown Delineation.

The total number of tree crowns can be obtained from the MATLAB command window, as shown in Fig.1.8

Figure 1.8 Number of tree crowns obtained in command window.

NDVI

For NDVI also same input image taken which is used for watershed segmentation. A Comparison of these two techniques is well observed.

Figure 2.1 Test Area.

Decorrelation stretch operator is applied to enhance the visual perception of the input image, so that objects can be differentiated due to enhanced color separation of the image. The output of decorrelation stretch is shown in the Fig.2.2

Figure 2.2 Decorrelated Image.

For decorrelated image NDVI is applied to find out vegetation area. In the Fig.2.3 we can observe that tree area is highlighted with the dark color.
Otsu thresholding is applied to the output of the NDVI in order to separate trees from the background. After that edge detection is applied using canny operator to form the tree crown boundaries. Output of the edge detection is shown in Fig.2.4

The output of the edge detected image is overlapped on the original image so that tree crowns are delineated as shown in the Fig.2.5

The number of tree crowns calculated are shown in the command window of MATLAB as given Fig.2.6 below

<table>
<thead>
<tr>
<th>Name of the Algorithm</th>
<th>Approximate count of number of trees</th>
<th>Count of Trees using algorithm</th>
<th>%Tree Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed Segmentation</td>
<td>105</td>
<td>95</td>
<td>90.4</td>
</tr>
<tr>
<td>Normalised Difference Vegetation Index</td>
<td>105</td>
<td>101</td>
<td>96.1</td>
</tr>
</tbody>
</table>
From the above results we can observe that by using watershed segmentation only 90.4% of trees crowns are detected i.e. 95 trees are detected from the total 105(Approximately) trees. And by using Normalised Difference Vegetation Index(NDVI) 96.1% of tree crowns are detected.

4. Conclusion

The simulation results showed that the NDVI algorithm performs better than Watershed segmentation algorithm. It is concluded that Normalised Difference Vegetation Index(NDVI) detects 6% more number of trees than watershed segmentation algorithm. However, NDVI and watershed segmentation algorithms can be implemented to detect for different multispectral images.

5. Acknowledgement

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6. References

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