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European Journal of Applied Engineering and Scientific Research, 2012, 1 (4):143-150
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041

Assessing the content of trees outside forest using irs high resolution satellite images

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ABSTRACT

This paper presents an automatic method to evaluate the tree crowns presented in the high resolution satellite images. This method comes into picture to reduce the manual power, time and money. Extraction of urban vegetation is a complex one. So, a couple of spectral indices called NDVI (Normalized Difference Vegetation Index) and SI (Saturation Index) are used to identify the vegetation area presented in test area. We apply thresholding techniques to identify the trees followed by edge detection using sobel operator to delineate the tree crowns presented in the test area. Finally, count the number of tree crowns by using morphological open operations (remove the noise components) and connectivity methods. The results obtained are compared with manual delineation and evaluate the accuracy in finding the tree crowns by this approach. The factors effect the performance are put forward and discussed.

Keywords- Tree crown delineation, High Resolution RS (Remote Sensing) image, Normalized difference vegetation index, Saturation Index, Edge Detection.

INTRODUCTION

Trees are an important component of the natural landscape because of their prevention of erosion and the provision of a weather-sheltered ecosystem in and under their foliage. They also play an important role in producing oxygen and reducing carbon dioxide in the atmosphere, as well as moderating ground temperatures [14].

The significance of Trees outside the Forest (TOF) can be observed in countries with low forest cover TOF resources constitute the main source of wood and non-wood "forest" products. In urban areas trees provide important aesthetic and environmental services in addition to providing shade and greatly increasing the livability of cities. [15].

Investigation of Urban vegetation plays a very important role in urban planning, environmental protection and consistency checking measures. The first step in the reconstruction of urban vegetation consists in the segmentation of vegetation areas followed by a classification of each previously identified region. An accurate automatic reconstruction of such types of vegetation areas is a real challenge due to their complex nature and to their intricate distribution between man-made objects in dense urban areas.

Many researchers' uses object oriented based methods to find out the detection, delineation and classification of tree crowns from aerial or satellite images. Tree top positions can be estimated by using object oriented methods [5] [6] [7]. There are several methods such as valley-following algorithm [8] or region growing method [9] to exploits shadows around tree crowns and to delineate their contour [10], such as other contour based methods use multi-scale analysis [2] or active contours to delineate tree crowns [11]. Apply these algorithms to forest stands, to perform well for neighbouring trees and tree species of same class and age. Applied these algorithms to urban environments, the neighbouring trees greatly vary in size and species, these algorithms perform poorly. This is mostly due to the different resolution of the input data which can induce false detections for the tree tops. Consequently, tree crowns are often over segmented during the region growing step.

Similarly, local maxima filtering algorithm to estimate tree top position and the number of trunks [4] [12]. These kinds of techniques are mostly applied on forest stands and are based on detecting local maxima on a smoothed image. Provided that the detection filter size is appropriate for the size of the trees and the image resolution, this technique usually produces good results on medium or dense forest stands as estimated tree tops often coincide with real ones.

The strategy of this approach is to detect the number of tree crowns presented in a high density urban environment. The steps involved in this approach are detecting the vegetation area by using spectral indices, detect the edges of the tree crowns by using segmentation methods and then followed by tree crown delineation and finally calculate the number of tree crowns presented in the whole area. Finally, the results obtained by this approach are compared with the manual delineation and evaluate the accuracy of the tree crown delineation.

II. Related work

Trees outside forest extracting techniques mainly depend on images taken by the different satellites. Mainly tree crown is a major parameter for finalizing the tree's location. Tree species are defined by several characteristics, such as average height, crown shape, leaf shape and colour, stem density, crown spectral characteristics, and so on.

Tree crown delineation can be obtained by using several methods such as circle unification method, $NDVI$ and RDI (Radial Distribution Image) method, DEM (Digital Elevation Model) method, Watershed Algorithm, 2d Walking Ant Histogram, Local Maxima Filtering, Texture Approach, and Image-to-Map Rectification.

Corina Iovan at el.[1], proposed a method for automatic extraction & characterization of vegetation structures in high density urban areas. They extract & characterise urban vegetation structures from high resolution images and Digital Elevation Model's. In this method, at first identify all vegetation areas in the urban environment using spectral indices. Once these regions of interest identified, they proceed to finer level of analysis of those vegetation areas, by performing the texture analysis, to differentiate lawns and trees. Trees are characterized by a higher gray level variance on the DEM , they obtain an indicator which allows us to separate lawns from tree crowns. Tree tops are detected by searching local maxima on a fixed window size in the DEM . Starting from tree tops, tree crown borders are obtained by a region growing approach based on geometric criteria's of the trees. The result analysis of this paper as, 63.6% of trees are correctly segmented, 14.6% of trees are over segmented, 9.7% of trees are under segmented and 9.7% of trees are omitted.

Tomas at el.[2], presents an automatic multiple scale algorithm for delineation of individual tree crowns in high spatial resolution infrared colour aerial images. In this method at first, the tree crown contours were identified as zero-crossings, with convex gray-level curvature, which were computed on the intensity image for each image scale. A modified centre of curvature was estimated for every edge segment pixel. For each segment, these centre points formed a swarm which was modelled as a primal sketch using an ellipse extended with the mean circle of curvature. The model described the region of the derived tree crown based on the edge segment at the current scale. The sketch was rescaled with a significance value and accumulated for a scale interval. In the accumulated sketch, a tree crown segment was grown, starting at local peaks, under the condition that it was inside the area of healthy vegetation in the aerial image and did not trespass into a neighbouring crown segment. The method present in this paper identified on the average, 7 out of 10 manually interpreted tree crowns, if the very small trees are omitted. The omission error consisted of very small tree crowns or dark crowns that were below the estimated global threshold. On an average of the whole data set, 54% of the physical tree crown diameter was visible in the image. The main drawback in this method is light sun patches on the ground were identified as tree crowns.

III. Proposed Method

This section presents our approach to detect and characterise urban vegetation areas. We first present our approach to detect vegetation areas based on the use of vegetation indexes. Once Vegetation areas identified, we proceed to their edge detection and then pass on to delineate individual tree crowns and finally, count the number of tree crowns presented in the image. The entire process is as shown in the below flowchart.

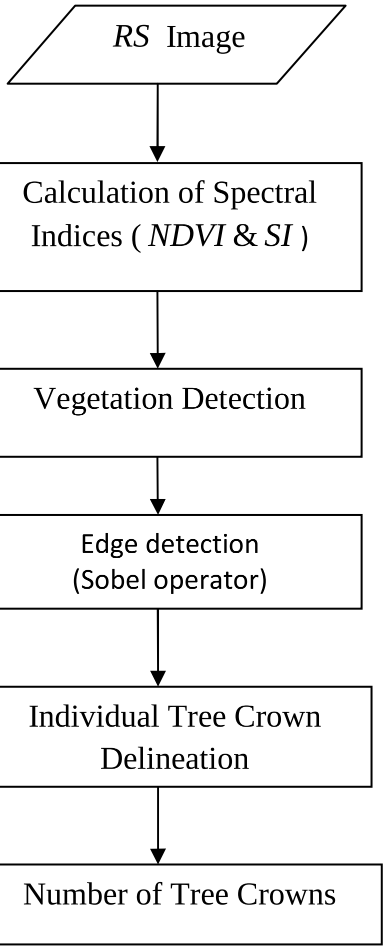


Fig (*i*): **Flow chart of the proposed method**

A. Calculation of Spectral Indices
To detect the tree crowns in a complex urban environment a couple of spectral indices are required. Those are normalised difference vegetation index and saturation index.

Normalized Difference Vegetation Index ($NDVI$ **)**
$NDVI$ is representative of the plants photosynthetic efficiency and provides per-pixel vegetation distribution. This index allows the creation of a gray-level image, the $NDVI$ image, obtained by computing this index for each pixel in our images according to equation 1 is as below [3].

$NDVI$ is calculated from the visible and near-infrared light reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. The numbers on the figure above are representative of actual values, but real vegetation is much more varied.

$$NDVI = (NIR - VIS)/(NIR + VIS) \qquad (1)$$

Where NIR and VIS are the values of the pixels respectively in the near infrared and visible red band. This index highlights area with a higher reflectance in the infrared band than in the red band (i.e. vegetation). Applying an automatic threshold on the $NDVI$ image gives a coarse segmentation of the urban scene in vegetation areas and non-vegetation areas, where the output masks obtained for all vegetation areas can be observed. As there are also other materials present in an urban environment with a high reflectance in the infrared band, were fine vegetation classification results using a second spectral index.

Saturation Index (SI)

Saturation index is used to find any other materials present in an urban environment with a high reflectance in the infrared band. Due to complex structure of urban environment the reflectance values are vary from object to object. Due to some dust particles the reflectance value changes, which causes the false identification of vegetation in $NDVI$ method. So, by using another spectral index called saturation index to identify vegetation exactly. The saturation index can be calculated by using equation 2 is as shown below.

$$SI = (R - B)/(R + B) \qquad (2)$$

Where R and B are the values of the pixels respectively in the red and blue band.

B. Vegetation Detection

The urban environment is a mixture of different proportions of treed areas, bare soil lawns, shrubs, building areas as well as streets. Therefore, the spectral response of urban vegetation is altered by the presence of such different types of elements, having similar spectral signatures. Moreover, the atmospheric conditions over urban areas are greatly influenced by the presence of pollutant gas and dust issued from industrial plants which are mainly located around big cities. All these factors induce great variations in the spectral reflectance of the same urban material.

Once the spectral indices are calculated then identify the vegetation by using one of the above two spectral indices or by combining these two spectral indices by using logical and. Vegetation obtained by combining these two spectral indices. Once vegetation is identified set the threshold value to separate the trees from all other objects presented in the image.

C. Tree Crown Delineation

Edge Detection

Once the region of interest is identified, we proceed to next level of analysis, called edge detection. Edge detection is used to detect the edges or boarders of the objects presented in the image. Here the edge detection uses sobel operator [13].

The Sobel operator is used in image processing, particularly within edge detection algorithms. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. At each point in the image, the result of the Sobel operator is either the corresponding gradient vector or the norm of this vector. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations. On the other hand, the gradient approximation that it produces is relatively crude, in particular for high frequency variations in the image.

Mathematically, the gradient of a two-variable function (here the image intensity function) is at each image point, a 2D vector with the components given by the derivatives in the horizontal and vertical directions. At each image point, the gradient vector points in the direction of largest possible intensity increase, and the length of the gradient vector corresponds to the rate of change in that direction. This implies that the result of the Sobel operator at an image point which is in a region of constant image intensity is a zero vector and at a point on an edge is a vector which points across the edge, from darker to brighter values.

Mathematically, the operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives - one for horizontal changes, and one for vertical. If we define A as the source image, and G_x and G_y are two images which at each point contain the horizontal and vertical derivative approximations, the computations are as follows:

$$G_x = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} * A \quad \& \quad G_y = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} * A$$

Where $*$ here denotes the 2-dimensional convolution operation.

Since the Sobel kernels can be decomposed as the products of an averaging and a differentiation kernel, they compute the gradient with smoothing. For example, G_x can be written as $[-1 \quad 0 \quad 1]$

$$\begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} [-1 \quad 0 \quad 1]$$

The *x*-coordinate is defined here as increasing in the "right"-direction, and the *y*-coordinate is defined as increasing in the "down"-direction. At each point in the image, the resulting gradient approximations can be combined to give the gradient magnitude, using:

$$G = \sqrt{G_x^2 + G_y^2}$$

Using this information, we can also calculate the gradient's direction:

$$\theta = a\tan 2(G_{y,} G_x)$$

Where, for example, θ is 0 for a vertical edge which is darker.

The result of the Sobel operator is a 2-dimensional map of the gradient at each point. It can be processed and viewed as though it is itself an image, with the areas of high gradient (the likely edges) visible as white lines. Once the edges of trees are identified place the edge detection image on original image to identify the delineation results.

D. Detection of number of tree crowns

After, the delineation of tree crowns apply structural element process followed by morphological open operation to find out the number of tree crowns presented in the image. The morphological open operation is used to remove the small elements presented in the image and count the number of tree crowns presented in the image accurately.

RESULTS

This section presents evaluation of results of the tree crown identification and detection of number of tree crowns. The input image taken is a complex urban area with many greened and treed areas, highly intermingled with buildings is as shown in below $Fig\ ii(a)$. The decorrelation stretch image is as shown in below $Fig\ ii(b)$. The decorrelation stretch operation is to extract the different colour bands to calculate $NDVI$ & SI.

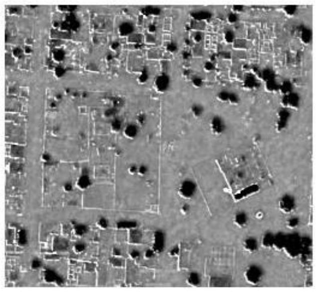
After extracting the *NIR* (Near Infrared), Red and Blue components from decorrelation stretch calculate the $NDVI$ & SI. The results obtained are as shown in below $Fig\ ii(c)$ & $Fig\ ii(d)$ respectively. The vegetation (Region of Interest) is obtained by setting proper threshold value for $NDVI$ and SI. The results presented in $Fig\ ii(e)$ emphasizes all vegetation area is as shown below.

Edge detection using sobel operator is applied for above treeded image to get the edges of the tree crowns and place the edge detection image on original image to get the tree crown delineation exactly is as shown in below $Fig\ ii(f)$ & $Fig\ ii(g)$ respectively.

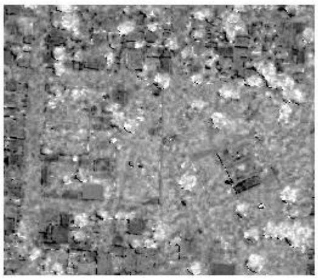
By applying structural element and morphological open operations we identify the number of tree crowns accurately by removing the unwanted objects presented in the image is shown in below $Fig\ ii(h)$. The number of tree crowns obtained by automatic delineation was 81 is shown in the below $Fig\ ii(i)$.

(a) Test area

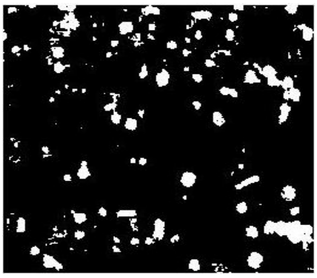
(b) Decorrelated Image



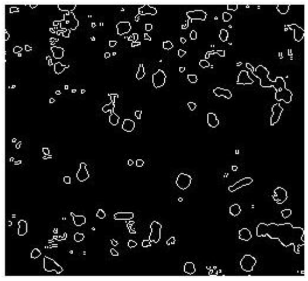
(c) $NDVI$ **image**



(d) SI **image**

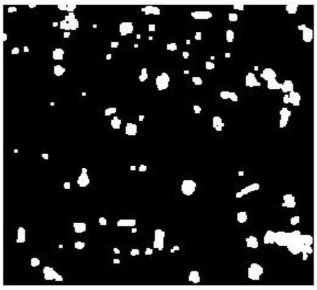


(e) Vegetation image

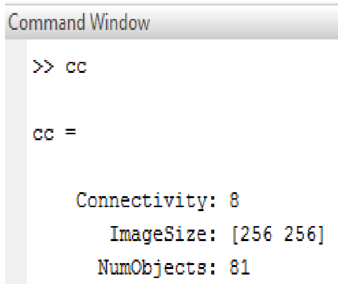


(f) Edge detection using sobel operator

(g) Outline of the tree crowns.



(h) Tree crowns after removing the noise elements



(i) Number of tree crowns obtained in the command window

$Fig(ii)$: **Simulation results of tree crown delineation**

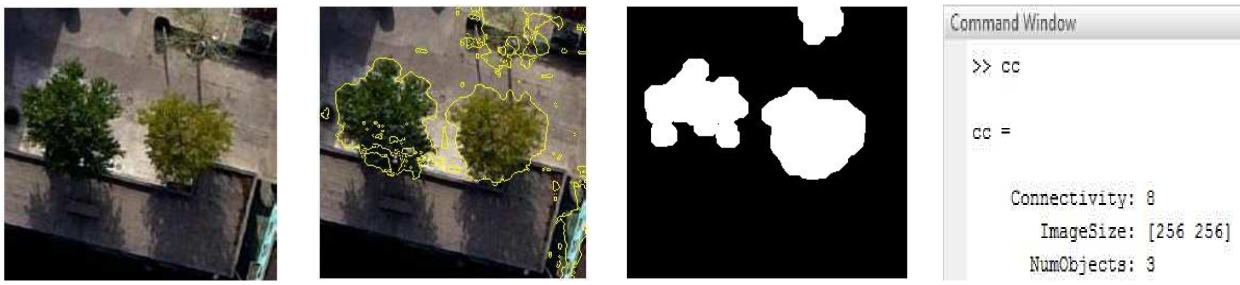
The number of tree crowns obtained by automatic delineation was 81 is shown in above figure. But the total number of tree crowns obtained by manual delineation is 92. So, by using spectral indices method we obtain 88.52% of total number of trees presented in the image.

Tree Crown Detection Assessment

In $Fig\ iii(a)$ the number of tree crowns presented is 8 out of 8 and in $Fig\ iii(b)$ the number of tree crowns presented is 3 out of 3. In the below two cases the accuracy of counting the tree crowns is 100%.

Test Image **Delineated Image** **Tree crowns after removing the noise elements** **Number of tree crowns obtained in the command window**

(a)



Test Image **Delineated Image** **Tree crowns after removing the noise elements** **Number of tree crowns obtained in the command window**

(b)

$Fig\ (iii)$: **Delineation of tree crowns**

But, in the above case the accuracy shown in $Fig\ (ii)$ was 88.52%. Due to overlapping of tree crowns we can't obtain 100% accuracy. This is the main drawback in this algorithm. The results of applying our algorithm to the two images are illustrated in $Fig\ (iii)$.

CONCLUSION

We presented in this paper a complete workflow to extract and count the number of tree crowns presented in the urban vegetation structures from high resolution images. The proposed approach is a hierarchical one.

The first step is the identification of all vegetation areas in the urban environment, using spectral indices. Second step is a finer level of analysis called edge detection to delineate the tree crowns and finally, identify the number of tree crowns presented in the image by using structural element and morphological open operations. The spectral indices method gives accuracy up to 88.53% of the trees presented in the image.

The advantage of this method is shadow removal. Results obtained by this approach are very promising, but there is a room for improvement on two aspects: where the over detections and lawn detections (lawn is treated as tree) occur. The tree structure parameters such as tree crown shape and tree height are extracted to our future work perspectives to separate the lawns from trees. Reconstruct of 3D city modelling image reduce the concept of overlapping of tree crowns and it is separate lawns from tree crowns and gives the better results and also useful for tree species classification.

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