Robust Tree Crown Delineation Using Novel Marker Controlled Watershed Segmentation Algorithm

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Abstract

Forest Management is vital for maintaining environmental stability and ecological biodiversity. Tree Crown Delineation and Counting of Trees using Satellite Imagery provide an efficient means to acquire information for forest management. Satellite image is useful to observe large areas periodically. The manual analysis of satellite image loads heavy work on the operator. If automatic analysis is done the amount of work on the operator is reduced. The purpose of this study is to analyze the number of trees in a satellite image using image processing. First in order to detect the individual tree crowns, the outline of the tree crown is detected. The presented approach develops a mathematical morphology based marker-controlled watershed segmentation algorithm for tree crown delineation with histogram equalization.

Keywords- Forest Management, Satellite Image, Tree Crown Delineation, Marker-Controlled Watershed Segmentation Algorithm, Histogram Equalization.

I. Introduction

Forests play a vital role in maintaining environmental condition. Forests have seasonal cycles and change from year to year. Forest inventories regularly capture tree data all over the world. Early work concentrated on ground base monitoring for forest inventory. Manual counting of trees is costly, time consuming and not applicable to large or isolated areas. The first trial of the use of aerial images for forest purposes was performed in 1897 since that time the forest scientific community has been working on improving methods for the extraction of tree parameters from aerial images such as the tree type and health status, the height and crown size, the stem diameter at breast height, and the stem volume. Aerial photo interpretation method requires practice of studying aerial photographs under stereoscope and it is highly subjective.

Satellite remote sensing plays a key role in generating information about forest cover, vegetation type and land use changes. Remote sensing has made enormous progress over the last decades. The high spatial resolution remote sensing image makes it possible for the first time to analyze surface areas in more details such as color, size, shape, context and texture. And it provides more detailed knowledge of forest stand which are the basic units for forest management. Inevitably, stand measurement involves the measurement of individual trees within the stand. Image analysis techniques for individual tree crown detection have become more common in recent years. To determine the density of a forest stand, first tree positions need to be determined, and secondly individual tree crowns need to be delineated. Finally forest density can be determined based on the number of individual trees per unit of area. Usually this figure is presented according to the number of individual trees per hectare or by calculating the aerial percentage of tree crown coverage per hectare. More complex tree crown shapes present a challenge when accurately delineating the tree crown contours.

II. Related Work

As per literature, many approaches were proposed for tree crown delineation, they include valley following, template matching, region growing, and watershed algorithm. Each of the approach is explained in detail.

1. Valley-Following Approach

The radiometric properties of a tree can be described through a mountainous landscape in which peaks are approximate crown apexes, and surrounding valleys represent the space between crowns or where crowns overlap or touch [1]. Valley-following technique developed by Gougeon follows this concept and try to find the local minima (i.e. valleys) [2, 3]. The way to find these valleys is just like waking in the valley towards ‘saddle points’ defined by two valleys meeting between tow tops. First, all local minima are found by using a 3 × 3 moving filter. If all other pixels beside the centre pixel of the filter have greater grey values, the centre pixel is a local minimum. Then the neighborhood of these valley pixels is further examined using a four-directional filter to include more valley pixels. The four scanning are repeated until no further valley pixels are found. Oppositely, local maxima approaches assume that tree tops have higher radiometric values [4, 5]. As computing local maxima on discrete pixel values on images is time consuming tasks, local maxima is usually computed on windows with the fixed size $N \times N$ which is similar to finding the local minimum. For both local maxima and minima approaches, a moving window is used to float over the image to locate maxima/minima values. They work extremely well where trees have the constant tree spacing and crown sizes (e.g. man-made forest) [6]. However, the accuracy largely depends on the appropriate selection of window size. Large window leads to missing trees because the window contains multiple tree apexes, while small one does not always include a tree apex [7]. This method work fine in dense canopies and can provide fairly accurate delineation results. The valley-following approach uses an assumption that there exist dark shaded pixels between the tree crowns. Bright pixels represent mountains or high altitude while dark pixels represent valleys or low altitude. However, this assumption is not always true [8]. In some real situations, multiple trees touch closely and have no distinct dark boundary between tree crowns. However, the accuracy largely depends on the tow assumptions. If either of the assumptions is not met, there will be a great error.

2. TIDA Algorithm

The Tree Identification and Delineation Algorithm (TIDA) was developed to automatically delineate tree crowns in high spatial resolution digital imagery as a means of providing forest canopy structural information at the individual tree scale. Results indicate that TIDA is most suited to application in forests with high canopy cover and high crown cover. The structural complexity of forest canopies, represented by the diameter and overlap of tree crowns and tree height, had a relatively small impact on TIDA performance. TIDA is a top-down spatial clustering algorithm designed specifically for the delineation of tree crowns in remotely sensed imagery. The spectral maxima and minima are the primary image features used for the identification of crowns, being indicative of crown centroids and boundaries respectively. Local maxima are used to calculate the position of ‘seeds’ which define the image coordinates of likely crown peaks. Local minima are used to construct a network of absolute (constraining) boundaries during the threshold-based clustering process. The term 'clustering' is used to describe the spatial aggregation of contiguous pixels into spatially unique objects. In keeping with this terminology, the tree crowns (canopy objects) delineated by TIDA are referred to in an abstract sense as 'clusters'. [9, 10]

3. Template Matching

Template matching for single tree detection does not rely on clearly visible tree crown boundaries or large contrast between different tree crowns [4]. Instead, template matching finds the best match between a synthetic template representing a crown and an equally large region in the image. The synthetic template is constructed by assuming the tree crowns are rotationally symmetric about a vertical axis. Thus, a tree crown can be modeled by a generalized ellipsoid and different trees with various crown shapes can be modeled by changing the parameters that deform the ellipsoid surface [11].Trees that have the highest correlations with the template are considered as likely trees. Since the number of templates is finite, the exact shape of tree crown is not easy to find, only a rough approximation to the actual shape of the tree crown is obtained [8].Generally, in template matching, a generalized rotational ellipsoid and a distributed function is usually used to model the density of branches and leaves. The template is generated by considering the geometry of the sensor, data capture time, illumination, and reflectance of trees and grounds [12]. In addition, templates vary depending on sizes of tree crown shapes. The more tree structures vary, the more templates are needed. Template based approaches work well on images that contain mostly trees (i.e., forest). In some real situations, multiple trees touch closely and have no distinct dark boundary between tree crowns. Research indicates that in this case template matching gives the best results, however it is very time consuming [13].

4. Region Growing Approach

Region growing algorithm mainly depends on the assumption that the intensity of color is high at top of tree but it is gradually decreased towards tree crown boundary. If different tree species are standing close to each other, the variation within a tree's crown is less than the variation among different trees. Based on this assumption, Mats Erikson develops a region growing method for individual tree crown segmentation in which a region is grown from a seed point based on expansion algorithms [14, 15]. Usually the image is initially smoothed with a Gaussian filter and then the local maxima are found. These maxima are viewed as the seeds. The algorithm includes seven concrete steps:

(1) Find a starting point with local maximum filter;

(2) calculate the eight-connected regions of the starting point using the expansion algorithm;

(3) Estimate the new starting point based on the created regions in step 2;

(4) Create a new region as an approximate tree on the basis of new starting point;

(5) Use each pixel in the approximation of tree to generate new regions as the candidate regions of the tree;

(6) Select the best region among the candidates and remove all starting points inside and outside the selected region from the original image;

(7) repeat from step 1 until no further starting points are found.

In region growing methods, the numbers of seeds and expansion methods to include the surrounding points are very important as the number of seed points should be equal to the actual number of tree crowns [16]. For dense forest, region growing seems a better choice than other approaches. But they do not work well in the case where a forest is so parse that ground patches exist between crowns [17].

5. Circle Expression and Watershed Algorithm

Watershed algorithm assumes that shape of crown resembles circle and calculates circle radiuses showing crown size. Calculated radius is larger as similar brightness region became wide. The radius at each pixel position is calculated and the result was used as the radius distribution image (RDI). In the RDI, the radius was larger as the position became close to center part of crown. If radius value is considered as elevation, RDI seems to be DEM (Digital Elevation Model). The value of each pixel of RDI was inverted and inverse radius distribution image (IRDI) is calculated. In the IRDI, it is expected that a cone-shaped geographical feature is on the crown region and each crown region make each watershed. Then crown regions were calculated applying watershed algorithm to IRDI. The watershed area of each lake is calculated and becomes a crown region. Steps include Calculation of radius of crown circle and Modification of value of radius, Inversion of the radius value, Pouring water in the basin, Calculation of watershed area. Advantage is for large crowns it is applicable but for small crowns results is not accurate.

6.Marker-controlled Watershed segmentation Algorithm

Individual tree-crown boundaries and treetop locations are derived under a unified framework. A two-stage approach with edge detection followed by marker controlled watershed segmentation is implemented. A Laplacian of Gaussian edge detection method at the smallest effective scale was employed to mask out the background. An eight-connectivity scheme was used to label the remaining tree objects in the edge map. Subsequently, treetops are modeled based on both radiometry and geometry. More specifically, treetops are assumed to be represented by local radiation maxima and also to be located near the center of the tree crown. As a result, a marker image was created from the derived treetop to guide a watershed segmentation to further differentiate touching and clumping trees and to produce a segmented image comprised of individual tree crowns. [18]

III. Proposed Approach

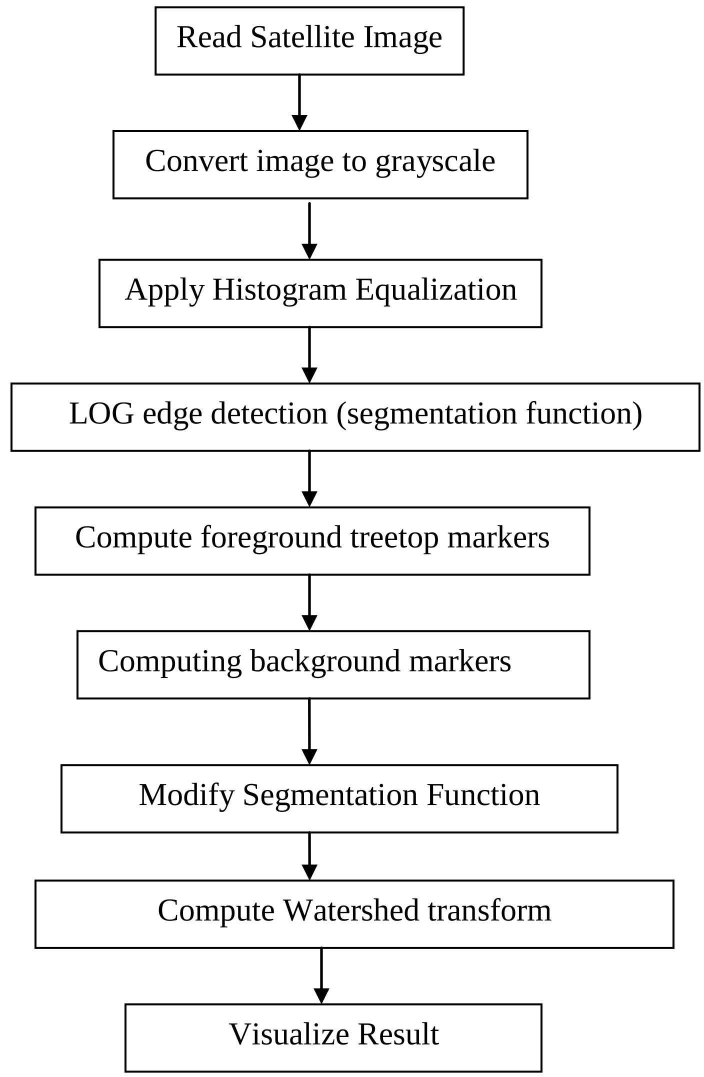

Fig 1: Block diagram of Proposed Approach

The main part of tree crown recognition algorithm is based on the radiometric properties of tree crown, which is after the above vegetation information enhancement, for single tree detection and crown delineation or cluster trees detection and delineation.

The steps of the novel marker-controlled watershed segmentation algorithm are described in succession.

1. Read the color image, and then convert it to gray image.
2. Apply Histogram Equalization.
3. A segmentation function is computed which put image's dark regions as the objects you are trying to segment and LOG edge detection is applied.
4. Compute foreground treetop markers after morphological reconstruction by opening and closing for filtering. The connected blobs of pixels within each of the crown like objects are treated as foreground treetop markers. These operators can create flat maximum in the object in which 1 means the treetop and 0 means the others. When take the morphological reconstruction by opening and closing, the shape and size of structural elements must be considered. We use disk shape and 1*1 window sizes for not missing small trees.
5. Computing background markers for identifying crown area. The boundary of isolated crown or grouped crowns can be got after mathematical morphology distance transformation. A distance transform, also known as distance map. The map labels each pixel of the image with the distance to the nearest obstacle pixel. A most common type of obstacle pixel is a boundary pixel in a binary image. The image value means the geodesic distance from each inner pixel to the each treetop marker, the procedure of decision its crown boundary is the process to building the skeletons by influence zones (SKIZ).
6. Modifying the segmentation function so that it only has minima at the foreground tree top and background crown boundary marker locations. This step is different from the traditional marker controlled watershed segmentation algorithm by segmenting the each object not the whole image to avoid the background disturbing.
7. Computing the watershed transform of the modified segmentation function.
8. Result visualization by putting the foreground treetop markers,

background markers and crown boundary on the original image.

The experiment is conducted on satellite image and the results are given below. The novel marker controlled watershed segmentation algorithm works well for separating touching crowns or overlapping crowns.

IV. Results

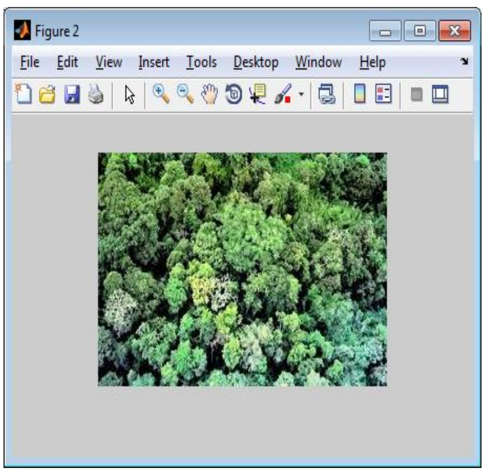

Fig 1: Original Image

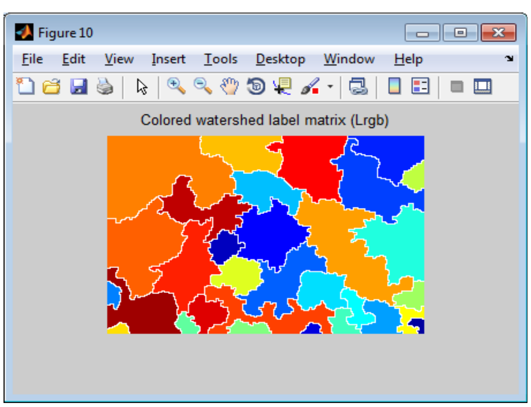

Fig 2: Color Watershed Label Matrix

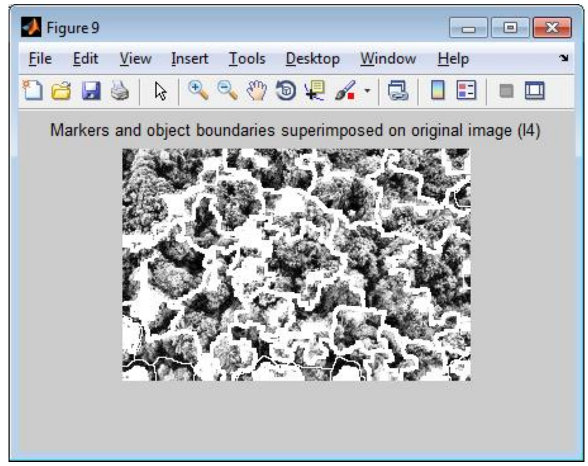

Fig 3: Markers and Object Boundaries Superimposed On Original Image

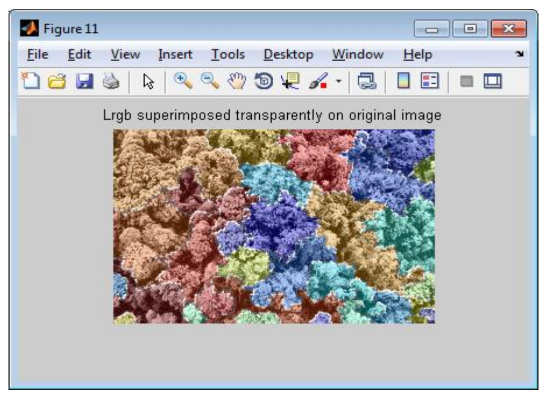

Fig 4: Novel Marker-Controlled Watershed Segmented Image

V. CONCLUSION

The proposed method novel marker controlled watershed segmentation algorithm is an effective way to get segmented tree crowns in real stand image.

Experimental results show that proposed method is easy to implement tree crown delineation using satellite image. Based on the segmentation results counting of trees can be done.

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