SHAPE-BASED TREE CROWN DETECTION AND DELINEATION IN HIGH SPATIAL RESOLUTION AERIAL IMAGERY

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ABSTRACT: For the purpose of forest management, the ground survey has long been used for the investigation of the forest resources. A lot of automatic researches on remote sensing images have been developed to improve the efficiency of the ground survey, especially in the domain of treetop detection and tree crown delineation. The purpose of this study is to develop an image processing technique to detect and to delineate the tree crown from high spatial resolution aerial photography. The major concept of the method is to design the tree morphology to perform the tree detection and delineation. The methodology can be dividing into three steps: (1) the extraction of the tree objects, (2) the construction of the tree structure for the morphological operation, and (3) the accomplishment of the tree detection and delineation. The proposed method is tested for aerial photography, and the results of this study show that the tree crowns can be successfully detected and delineated from the remote sensing images.

1. INTRODUCTION

The survey of forest resources is an important task for the management and protection of the forest. Traditionally, such an essential task is heavily dependent on the labor-intensive ground survey. Although numerous state-of-the-art equipments have been developed to improve the efficiency of the ground survey [1, 2], a lot of researches have been put into the development of automated techniques for forest survey from the remote sensing images, especially in the domain of treetop detection and tree crown delineation [3, 4, 5, 6].

It is observed that trees illustrate some special characteristics in the spectral domain, for example, the treetop has higher radiometric values while the tree crown has lower ones. Therefore, a number of studies based on the spectral values in the images have been proposed to detect trees. In the treetop detection procedures, Gougeon [7] used a fixed-size filter to find the treetop. Pollock [8] proposed a template matching method, which found out the optimal match of geometric shapes with local radiometric values. The concept of the enhancement is adopted by Wang [9], by using the smoothing and high-pass filter, the noise will be decreased and the treetop can be enhanced. Culvenor [10] considered about the non-uniform spectral distribution of tree; accordingly, a dynamic-size filter was employed to search the local maximum along the 8-connected directions. In the tree crown delineation procedures, Gougeon [7] developed a valley-following algorithm to trace the boundary of crowns. By clustering the neighbor pixels with similar features, Culvenor [10] performed the region growing method to delineate the trees. The segmentation algorithms were used to perform tree crown delineation by [11, 12]. In order to avoid the over segmentation caused by watershed segmentation algorithm, Wang [9] developed the maker-controlled watershed segmentation to improve the tree crown segmentation.

In this study a new approach for tree detection and delineation would be presented. Because the spectral difference of the tree and background, the outline of the tree can be easily depicted in the image; therefore, the concept of the morphology can be applied to detect trees. This study consists of three major steps: (1) the extraction of the tree objects, (2) the construction of the tree structure for the morphological operation, and (3) the accomplishment of the tree detection and delineation. The detail of the three steps will be presented in the following sections. The framework of this paper is as follows: the methodology will be introduced in the next section, the test data and the experimental results will be presented in section 3 and the conclusions will be discussed in section 4.

2. METHDOLOGY

The proposed tree crown detection is based on the conception of mathematical morphology. The algorithm consists of three main steps and the following sections describe each step in detail.

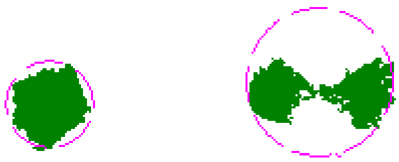
2.1 The Extraction of the Tree Objects

It is well known that the NIR values of trees represent a relatively high response in the remotely sensed images. This gives rise to the first step, which is to extract trees from the background in the image. The idea is based on the facts that vegetation absorbs well in red spectral band and reflects strongly in NIR spectral band. Consequently, Normalized Difference Vegetation Index (NDVI) is used to obtain a NDVI image and to transfer the NDVI image into a binary image by setting a threshold. Then the pixels of the trees are labeled to generate numerous tree objects.

2.2 The Construction of the Tree Structure for the Morphological Operation

The purpose of this step is to construct the Structure Element (SE) of tree based on the morphology. The SE will then be used in this section to detect and delineate trees. This step would be performed in the following progress.

Firstly, it is necessary to find out the objects consist of only isolated trees before constructing the SE. There is an assumption that the contour of a tree crown is similar to the shape of a circle. Therefore, a circle is circumscribed for each tree object, and then the areas of each object as well as its circumscribed circle are calculated. If the object consists of an isolated tree, the area of this object and its circumscribed circle will be approximately equal Fig.1. In the domain of Mechanical Engineering, Nodularity is a terminology and it represents the degree to which the object is similar to a circular shape. So, Nodularity can be used to describe the ratio of the area of each object to its circumscribed circle in this study (Eq. (1)).



A. Isolated tree B. Tree clump

Fig.1 The circumscribed circle of tree objects. (A) Isolated tree, (B) Tree clump

$$\text{Nodularity} = \text{the area of the object} / \text{the area of its circumscribed circle}. \quad (1)$$

The following is the brief description of the decision that the object is an isolated tree or the tree clump. Where N is the Nodularity of each tree object in the image and T is the threshold of the Nodularity.

If (N > T)
N is the object with an isolated tree
Else N is the object with more than one single tree (tree clump)

After the above operation, each tree object can be assigned as the isolated tree or the tree clump. Consequently, all isolated trees can be detected and the crown boundary of each isolated tree can be delineated. Then, the average length of circumscribed circles of all the isolated trees can be used to characterize the crown boundary of the isolated tree and construct the size of structure element (SE). In next section, the operation of the moving SE is adopted to detect the isolated trees from the tree clump.

2.3 The Accomplishment of the Tree Detection and Delineation

Since the tree clump may contain more than one isolated tree, the main aim of this section is to use the SE to separate each isolated tree from the tree clump. In general, the SE is regarded as a mask of isolated tree and used as a moving window in the processing of the image. During the moving process, if the pixels of the tree clump belong to the SE, the pixel values will change to one, and others are given as zero. As a result, a similarity map will be constructed based on the number of ones in the SE. The position with relatively higher similarity can be regarded as the location of the treetop. After determining the treetops of the tree clump, each isolated tree can be separated effectively from a tree clump. One remaining task in this step is how to delineate the tree crown of each isolated tree from the tree crimp. One simple approach will start from the spectral response of the tree boundary. However, because the spectral responses of each isolated tree are normally similar to each other, one geometric assumption is made in this study that each isolated tree has an equal size. Therefore, in theory, the border between two isolated trees should pass the midpoint of the adjacent treetops; consequently, the approximate tree crown can be delineated automatically by constructing the perpendicular bisector line of the neighboring treetops. As a result, the tree crown of each isolated tree inside a tree clump can be detected and delineated.

3. Test Data and Experimental Results

The test image used in this study is a digital aerial photograph taken by the Ultra Cam. The spatial resolution of the image is 0.1m and including four spectral bands: blue (430-470 nm), green (500-590 nm), red (610-680 nm), and near-infrared (NIR, 790-890nm). The size of the test image is 510 by 308 pixels. The results of each step in this study are shown from Fig. 2 to Fig. 7. The result obtained from labeling the tree objects in the NDVI image is shown in Fig. 3. The black indicates the image background and the white depicts the tree objects. In Fig. 4, the tree objects are circumscribed by dotted circles, which include both the isolated trees and the tree clumps. In Fig. 5, the objects circumscribed by circles are detected as the isolated trees (with the threshold of 0.55 Nodularity). The numbers of the isolated tree are 34 and the corresponding size of SE is 42 pixels. Fig. 6 shows that the 20 single trees (thin circles) are separated from the tree clumps. In Fig. 7, the tree crown of each isolated tree are depicted by the polygons The results indicate that the proposed image processing algorithm can successfully detect and delineate the tree crown of a single tree either appeared on an isolated tree or separated from a tree clump.

Fig. 2 Original image of the study area

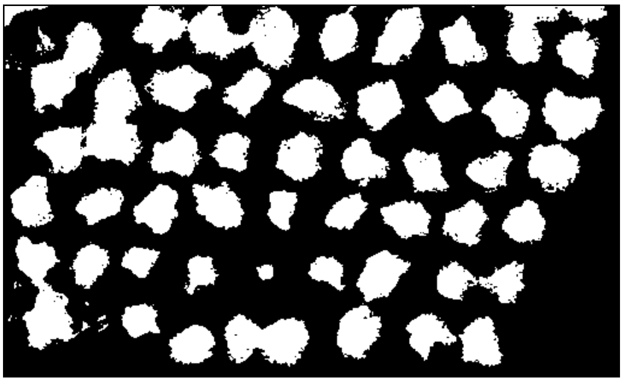


Fig. 3 NDVI: 0.42 and object labeling: 105

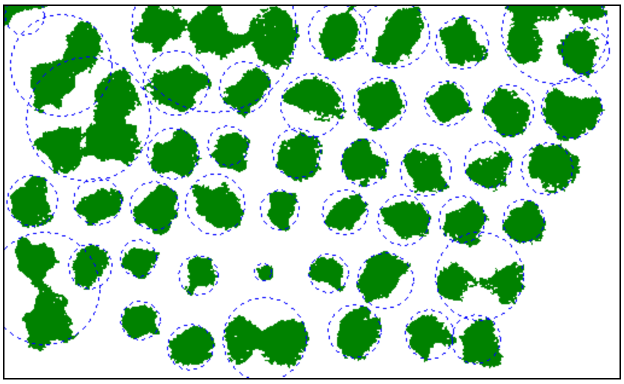


Fig. 4 The circumscribed circles of the objects

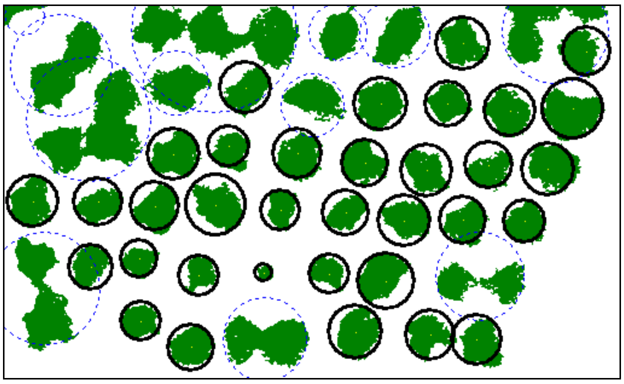


Fig. 5 Nodularity:0.55, Isolated trees:34, SE:42 pixels

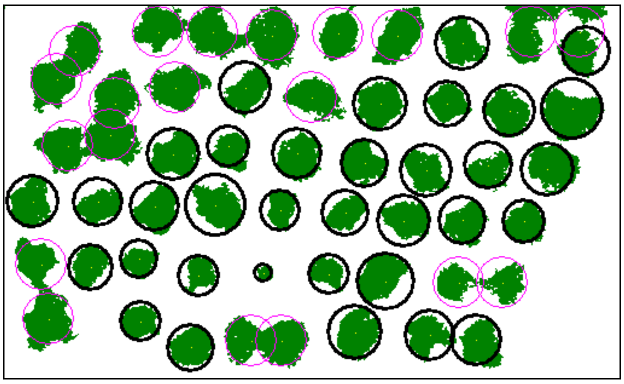


Fig. 6 The number of trees in tree clumps:20

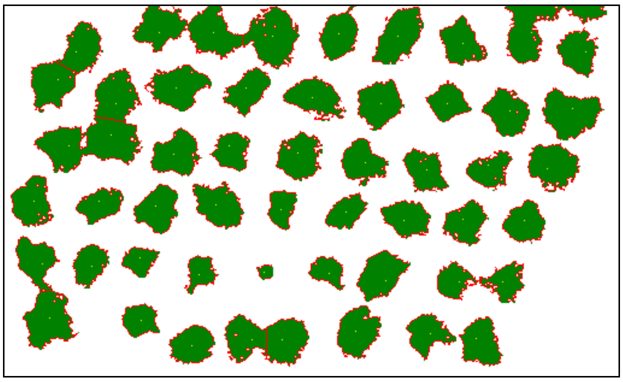


Fig. 7 Delineation of the boundaries of the tree crowns.

In order to estimate the accuracy of the proposed method, this study manually sketches the tree crown of each isolated tree on the monitor. The overall accuracy of the tree detection is defined as Eq. (2). AI is an accuracy index in percent, O and C represent the number of omission and commission errors respectively, and n is the total number of trees detected on the monitor. In order to evaluate the accuracy of the individual tree crown, the accuracy index as a percentage is calculated as Eq. (3). In Eq. (3), "Automatic" and "Manual" represent the area of each single tree produced by automatic and manual methods.

$$AI(\%) = [(n-(O+C))/n] \times 100 \qquad (2)$$

$$Accuracy(\%) = \frac{Automatic \cap Manual}{Manual} \times 100 \qquad (3)$$

In this study, the accuracy of the tree detection is 100% because the omission and commission errors are both equal to zero. The overall accuracy of tree crown delineation is 90%. Fig. 8 illustrated the statistical summery of the delineation accuracy of each isolated tree.

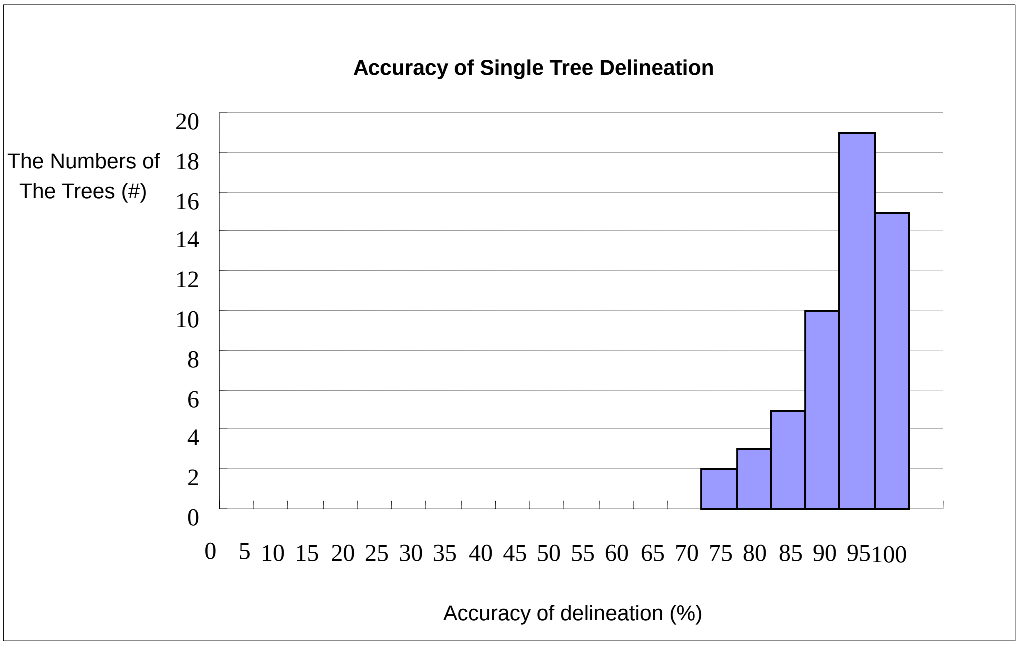


Fig. 8 Accuracy of single tree delineation

4. Conclusion

This paper introduces a new approach for automatic detection and delineation of tree crown in the remote sensing images. It is observed that the isolated trees and the tree clumps normally mix up in the in the remote sensing images The mixture of the isolated trees and the tree clumps in the image causes the difficulty to detect and delineate each single tree using an universal approach. The problems are mainly raised from the inevitable clustering of the isolated trees inside the tree clump. This study adopts the morphological concept to develop a two-step algorithm for tree detection and delineation. To begin with, the tree objects are detected by using NDVI and object labeling techniques. Then, after calculating the nodularity, the single trees in the image can be extracted automatically; in addition, the tree structure element is constructed on the basis of the information of the single trees. Finally, by moving the structure element, each isolated tree can be separated individually from the tree clump. The test results indicate that the proposed two-step image processing algorithm can successfully detect and delineate the tree crown of a single tree either appeared on an isolated tree or separated from a tree clump.

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