INDIVIDUAL TREE CROWN DELINEATION USING MULTI-SCALE SEGMENTATION OF AERIAL IMAGERY

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1. INTRODUCTION

With the development of remote sensing techniques, parameters of individual trees for forest inventory can be extracted efficiently from high-resolution remote sensing imagery or LiDAR (light detection and ranging) data rather than using field surveys [1]-[4]. As a prerequisite step, individual tree crown (ITC) delineation from high-resolution imagery or LiDAR data is one critical issue in current forest study. Many ITC delineation algorithms were developed, such as the valley-following [5], region growing [6], edge detection [7]-[11], template matching [12], [13], watershed segmentation [14], [15], and 3D model-based methods [16].

In most of ITC delineation algorithms, treetops are first detected and then used as reference points for crown delineation, and it is typically assumed that a treetop is a radiometric maximum and is geometrically adjacent to the center of the corresponding tree crown. However, it is difficult to find an appropriate low-pass filter to extract all of the trees of different sizes simultaneously. Even if the filter size varies with tree heights, the low correlation between tree height and crown width [15] makes it difficult to obtain accurate treetops.

Based on the similarity between the tree crown surfaces of forests and terrain surfaces, the watershed segmentation algorithm is used to segment monochromic images for ITC delineation. Since the traditional algorithm typically yields serious commission errors, mark-controlled watershed algorithm is widely used.

Objects in a forest, such as branches, small trees, large trees, and stands, are of multi-scale. Although it is difficult to extract the different-size objects of interest simultaneously, the objects can be separated to multi-scale layers, in each of which the objects have a similar size. Then, the extracted objects of different scales are linked to form a hierarchy. Finally, the trees of different sizes are merged into a thematic map. This proposed ITC delineation method is based on Watershed segmentation and Multi-scale analysis techniques and thus called WM.

2. METHODOLOGIES AND EXPERIMENT

Figure 1 shows the flowchart of the WM delineation method. The main steps are as follows.

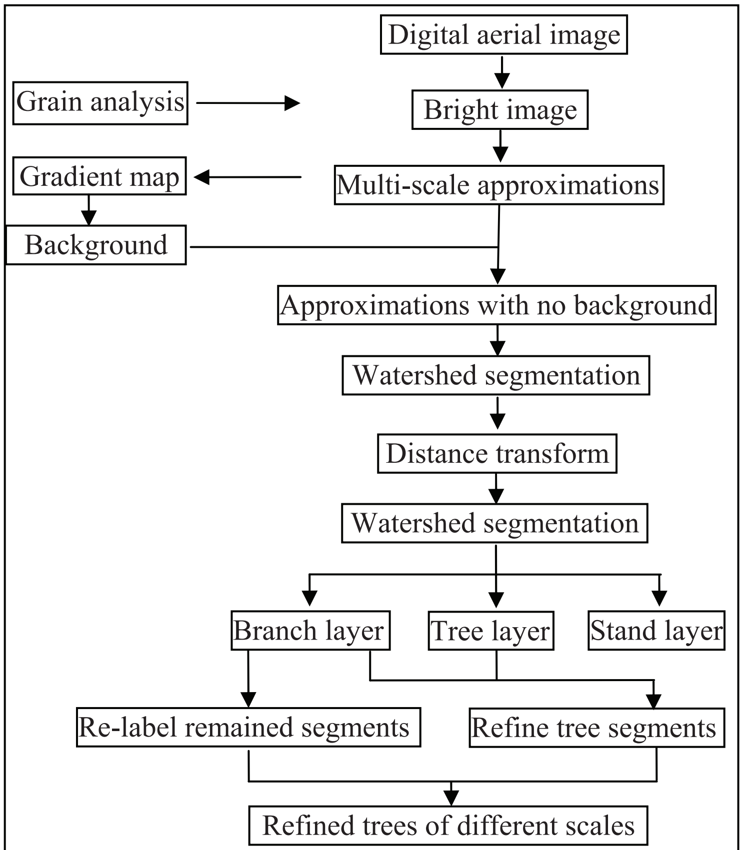

Figure 1. The flowchart of the WM delineation method.

As shown in figure 1, for a multispectral (MS) image, its bright image can be its first principle component or a generalized intensity component as an average of all the MS bands. The grain analysis of the bright image can offer the dominant scales of the objects: branches, large trees, and stands.

Instead of the wavelet transform and Gaussian pyramid techniques, a simple image decomposition approach with a random decimation factor of k is applied to the bright image as follows: reduce the image by a factor of k to generate an approximation using an averaging approach, and then bicubically expand the approximation by a factor of k. The resulting approximation image has the same pixel size as the original image. Employing this image decomposition approach and setting the decimation factor to be half of the scales of the branches, trees, and stands, three different-scale approximation images can be generated, containing branches, trees, and stands, respectively. The three approximation images are then consequently applied with the traditional watershed segmentation algorithm, the distance transform [14], [15], and then the traditional watershed segmentation algorithm, resulting in the branch, tree, and stand layers, respectively.

Each tree segment in the tree layer has a coarse boundary and superimposes multiple branch segments in the branch layer. A tree segment can be refined so that some of its main branch segments combine to form a refined version of the tree segment with higher roundness, whereas other main branches are separated as adjacent small trees.

3. EXPERIMENT

3.1. Study area and test data

A digital aerial image over Swan Lake area of Ontario, Canada, acquired in September 2005 was used as test data (45°28′N, 78°42′W), ranging from 412-587 m above the sea. The image consists of 0.33-meter MS bands of blue, green, red, and near-infrared. The size of the MS image is 512 columns × 512 rows.

3.2. Grain analysis of the bright image

Figure 2 shows the size distributions of the bright image of the aerial image. As indicated in the figure, there are several dominant scales of objects in the bright image. The first significant scale is 9 pixels, indicating the scale of the branches in the bright image. The second significant scale group is composed of 17, 19, and 23 pixels, indicating the scales of trees. The scale of stands is approximately 29 pixels.

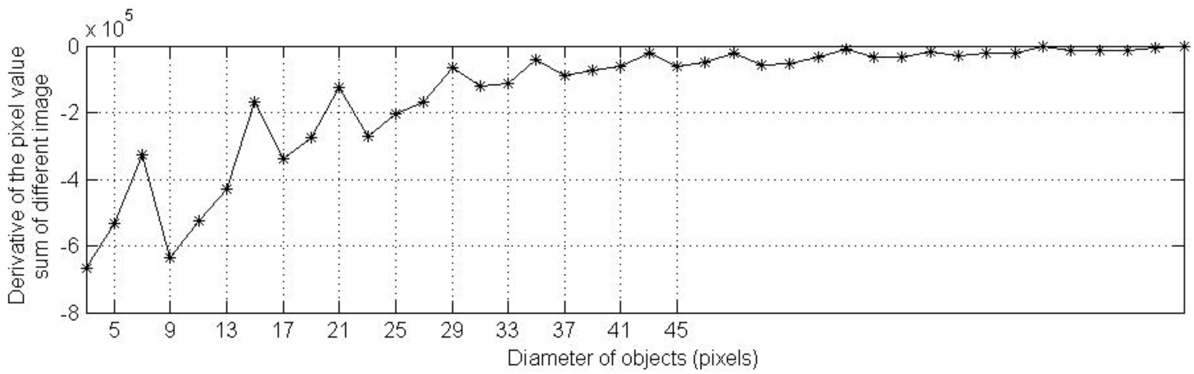

Figure 2. The size distributions of the bright image.

3.3. Segmentation and refining processes

Figure 3 shows a few critical results in the WM delineation process. Figure 3(a) is a bright subset of the original aerial image, and figures 3(b)-(d) are the corresponding branch, tree, and stand layers with the original aerial image as background, respectively. Figure 3(e) is an overlay of the branch and tree layers. It is manifest that for a tree segment in one color in figure 3(e), its boundary seldom coincides with that of the combination of the branch segments superimposed. Using the refining approach in the WM method, the branch segments in figure 3(b) and the tree segments in figure 3(c) combine, the resulting big tree segments (figure 3(f)) have accurate boundaries and more compact shapes, and some small adjacent trees are separated.

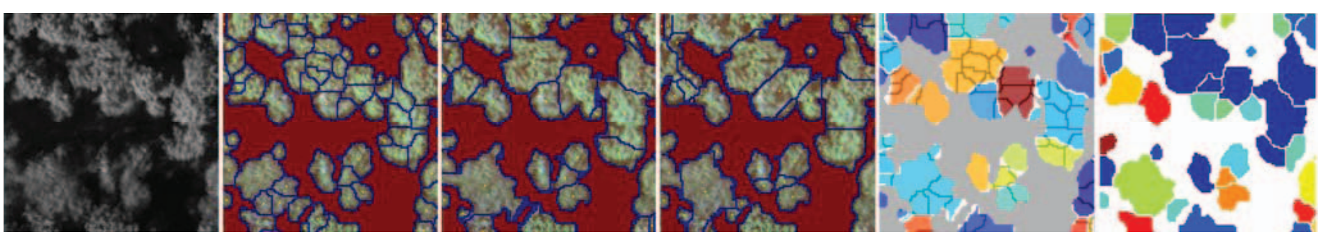

Figure 3. Multi-scale image segmentation and fusion. From left to right. (a). Bright image. (b). Branch layer. (c). Tree layer. (d). Stand layer. (e). Overlay of the tree and branch layers. (f) Refined tree layer.

3.4. Validation of the results

A test plot of 50 m × 50 m covered by the test image was surveyed regarding inventory parameters such as tree position, tree counts, tree species, crown size, and diameter at breast height (DBH). In the comparison with ground truth, the delineated crowns obtained using the WM delineation method contain insignificant omission and commission errors, which are typically severe in ITC delineation. Moreover, the original aerial image was manually segmented and the resulting delineated crowns were compared with the WM delineated ones regarding tree number, crown positions, and crown boundaries. The comparison proves that both sets of crowns highly coincide.

4. REFERENCES

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