Leaf vein extraction using a combined operation of mathematical morphology

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***Abstract*—The type of the leaf vein can be a useful parameter in automatic identification of plant species. Leaf vein extraction is the precondition of discriminating the leaf vein type. In this paper a new method is presented for leaf vein extraction based on mathematical morphology. Firstly, the color image of the plant leaf is transformed to gray image according to the hue and intensity information. Secondly, a combined operation of mathematical morphology is applied to the image to eliminate the color overlap between the whole leaf vein and the whole background. Thirdly, image segmentation is performed with OSTU method. Finally, the leaf vein can be got after some processing on details. Experiments have been conducted with several images and the results show the effectiveness of the method. The basic idea of the method is also applicable to other linear objects extraction.**

Keywords—leaf vein; linear object; mathematical morphology; image segmentation

I. INTRODUCTION

Leaf is one of the important organs of the plant. A botanical expert can identify the plant species according to the features of a plant leaf. Image processing techniques can be applied to leaf feature extraction to achieve automatic recognition of plant species, which is helpful to intelligent agricultural production and studies on botany.

Leaf vein is an integral part of the leaf. The type of the leaf vein can be a useful parameter in automatic identification of plant species [1, 2]. The leaf vein should be extracted from the leaf before identifying its type. Several methods [3-7] have been proposed for leaf vein extraction, including methods based on mathematical morphology, 2D structure tracking, artificial neural network, snakes technique, independent component analysis, etc. Some of these methods can not achieve accurate results. The others have poor adaptabilities in application, for almost all of the parameters in them need to be adjusted in application to new plant species.

In this paper a new method is proposed for leaf vein extraction based on mathematical morphology. The leaf veins which can be detected by human eyes in an image can be found with the new method. If the method is applied to a new plant species, only one parameter in the method needs to be adjusted. The method is also applicable for uneven illumination images.

The paper is organized as follows. After a short description of the research background in Section I, the new method is described via an example in Section II. Some experiments are shown in Section III and discussions are given in Section IV.

II. METHOD

It is because of the color difference in an object and its background that people can identify the object in an image with eyes. If the computer is applied to identify the object in the image, the color data difference in the object and its background should be found firstly. The color data differences can be found using clustering or other methods if the color difference is holistic in an object and its background. If the color difference is partial, that is, there is color overlap in object and its background, the edge based method and image blocked based method are usable. However, the methods of edge based and image blocked based are limited to the image in which the object is highly collective; for example, the object is just one block. If the object is linear or point-like, the methods can not achieve satisfactory results. Leaf vein extraction is just the case. In an image of a plant leaf, as show in Fig. 1(a), the leaf vein is linear and each part is not same in width and direction. If the image blocked based method is used to extract the leaf vein, it is difficult to choose the size and moving direction of the block. If the edge based method is used, much noise will be introduced to the result, for the leaf vein is so thin.

The problem of leaf vein extraction can be taken into account from other point of view. Leaf vein distributes on the leaf surface and have a lower aggregation. So it can be seen as noises on leaf surface and methods of noise extraction may be usable for leaf vein extraction. Following such an idea, the new method of leaf vein extraction is designed based on mathematical morphology. It consists of gray transformation, mathematical morphology processing, image segmentation and processing on details.

A. Gray transformation

Gray transformation is to turn the color image to gray image. The purpose of gray transformation is to reduce the amount of color data in the image so as to speed up the following processing. The difference in leaf vein and its background in color image should be kept as well as possible in the result image.

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Equation (1) is often used for gray transformation. R, G and B in (1) are the three components of color in RGB color space; Y is the transformation results, the gray value. Equation (1) highlights the intensity information and discards the color information, and therefore is not applicable to images with obvious hue changes.

$$Y = 0.299R + 0.587G + 0.114B \qquad (1)$$

Aiming at leaf vein extraction, a new method is designed for gray transformation, in which both hue and intensity information are used, as (2) shows. H and V are hue and value components of color in HSV color space.

Colors of leaves are usually green, yellow or red, while the colors on both sides of 0 degree line of hue are red in HSV color space. Considering the characteristic of leaves, the 0 degree line of hue is set as the original 270 degree line of hue in (2).

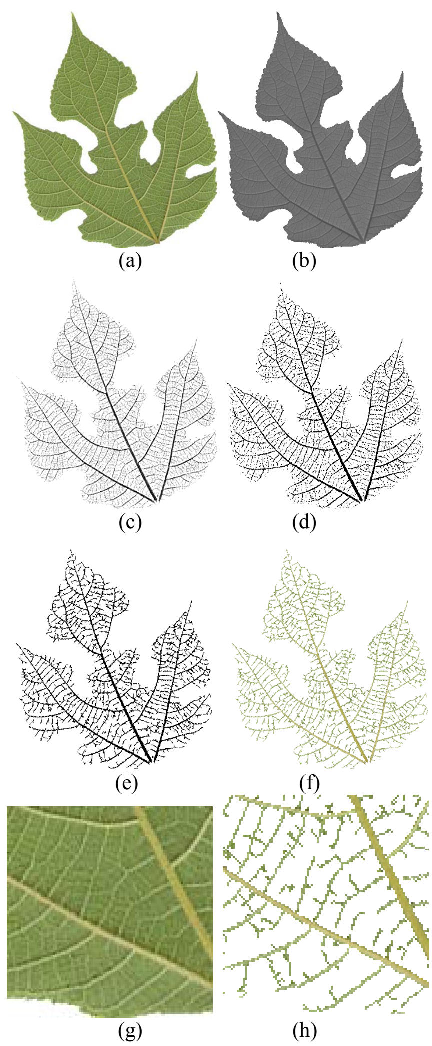

Figure 1. An example of leaf vein extraction. (a) original image (b) result of gray transformation (c) result of mathematical morphology processing (d)result of image segmentation(e) result of processing on details (f) leaf vein (g) portion of the original image（h）portion of the leaf vein

$$Y = (((H + 90)\%360)/360 + 1 - V)/2 \qquad (2)$$

Fig. 1(b) is the result of gray transformation of Fig. 1(a). It can be seen that the color difference in leaf vein and its background in the original image is well reserved in the gray image.

B. Mathematical morphology processing

The gray difference in leaf vein and its background is local in the gray image and there is gray overlap in the whole leaf vein and the whole background. The purpose of mathematical morphology processing is to eliminate the gray overlap. The local difference in leaf vein and its background would be well kept or even enhanced in the result image.

Mathematical morphology provides four fundamental operations of dilation, erosion, opening, and closing in image processing. Let f be a gray image and b be a structuring element. The four operations are defined respectively as,

$$(f \oplus b)(s,t) = \max\{f(s+x,t+y) + b(x,y) \mid (s+x,t+y) \in D_f, (x,y) \in D_b\} \qquad (3)$$

$$(f \Theta b)(s,t) = \min\{f(s+x,t+y) - b(x,y) \mid (s+x,t+y) \in D_f, (x,y) \in D_b\} \qquad (4)$$

$$f \circ b = (f \Theta b) \oplus b \qquad (5)$$

$$f \bullet b = (f \oplus b) \Theta b \qquad (6)$$

The combinations of the four fundamental operations of mathematical morphology can play important roles in image processing [8-10], such as image segmentation, image filtering, image enhancement etc.

In the gray image the leaf vein is usually darker than the background. The bot-hat transformation [11, 12] helps to enhance the dark details in the gray image, as shown in (7), where g is the result image.

$$g = f \bullet b - f \qquad (7)$$

In practical application uneven illumination often occurs in the image. The bot-hat transformation can not avoid the disturbance of the bright spots. The top-hat transformation [11, 12] can be a useful supplement, as shown in (8), which helps to eliminate the disturbance of the bright spots.

$$g = f - f \circ b \qquad (8)$$

Equation (9) shows the complete mathematical morphology processing.

$$g = (f \bullet b - f) - (f - f \circ b) \qquad (9)$$

The b structuring element is very important in mathematical morphology operations, including its shape and size. As the orientations of the leaf vein varying with the position, square is chosen as the shape of the b structuring element. The width of the b structuring element should be chosen according to the width of the leaf vein in the image, which should be no less than the maximal width of the leaf vein.

Fig. 1(c) is the result of mathematical morphology processing of Fig. 1(b), in which the visual difference in leaf vein and its background is more obvious.

C. Image segmentation

After mathematical morphology processing we deem that there in no gray overlap in the whole leaf vein and the whole background. The problem of leaf vein extraction is simplified to a classification problem. If only the parts of leaf vein which can easily be detected with eyes wanted, the OSTU method may be a good choice.

The leaf in Fig. 1(c) is divided into two parts, the leaf vein and the background, using a threshold computed by OSTU method. The result is a binary image, as Fig. 1(d) shows.

D. Processing on details

There are some noises in the result of image segmentation, including scattered points and discontinuous curves. Some processing on details should be done. Firstly, remove the black pixels which have little black neighbors in their neighborhoods. Then connect the discontinuous curves. Finally remove the isolated and small black pixel blocks.

Fig. 1(e) is the result of processing on details of Fig. 1(d). According to Fig. 1(a) and Fig. 1(e), it can be got of the color information of the leaf vein, as shown in Fig. 1(f).

To illustrate the effect of the method, the corresponding parts of Fig. 1(a) and Fig. 1(f) are enlarged, as shown in Fig. 1(g) and Fig. 1(h). Almost all parts of the leaf vein which can be noticed by human eyes are extracted.

III. Experiments

Some experiments have been executed on several images, which were captured with a set of HP scanner. The parts of the leaf vein which can be noticed by human eyes are extracted. Fig. 2 shows some experiments, include the original images of three plant leaves and result images of their veins.

Although the right part of the third leaf in Fig. 2 is much brighter than other parts of the same leaf, some of the leaf veins in the brighter region still have been extracted, as shown in Fig. 2.

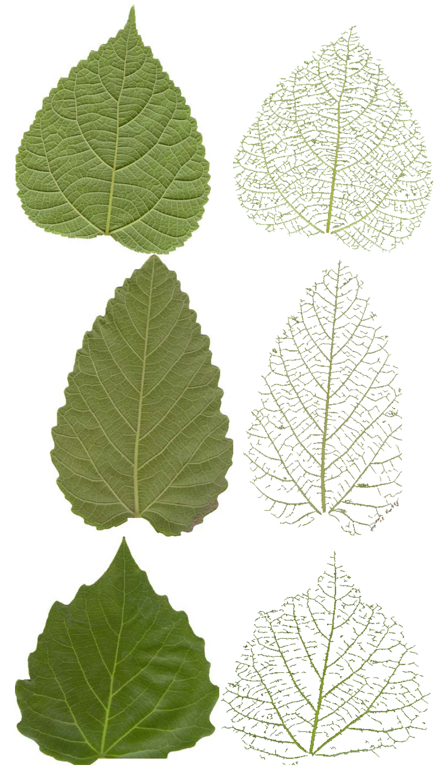

Figure 2. Experiments

IV. Discussions

The hue and intensity information are used in gray transformation. Such a method of gray transformation is more applicable than the common one. But it is not applicable to all kinds of image, for example, an image with great hue difference in object and background. Fortunately, this seldom occurs on the surface of the plant leaf and the method is applicable to plant leaf.

The bot-hat transformation and the top-hat transformation are combined in mathematical morphology processing. The bot-hat transformation is used to enhance the dark details in the gray image and the top-hat transformation to eliminate the disturbances of the bright spots. The top-hat operation can be omitted if there is no uneven illumination in the image, while which seldom happens in practice.

The key parameter of the method is the width of *b* structuring element, which should be no less than the maximal width of the leaf vein. It may need to be revised if the type of the plant leaf or the resolution of the image acquisition device changes. But it is not a complex work, just a simple work. Users can do it themselves.

It can be seen in Fig. 1(h) that the leaf vein is discontinuous in some locations. The reason is that the color of the leaf vein is so close to its background in the original image. If more accurate result expected, further research should be conducted in processing on details.

V. Conclusions

In this paper a new method for leaf vein extraction is presented based on mathematical morphology. The main idea of the method is treating the leaf vein as the noises on the leaf surface and applying the method of noise detection to extract leaf vein. The experiments show the method is feasible. Compared with the former research, the new method is more practical and can get more accurate result.

The basic idea of the method is also applicable to other linear objects extraction, such as cardiovascular, cracks on road, etc.

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