Leaf vein extraction and angle measurement using hue information and line detection

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***Abstract*—Leaf vein features play an important role in botanical studies. It is also a significant and challenging task in the field of computer vision. This paper proposes a new method of leaf vein extraction and angle measurement. The angle is between the primary vein and the secondary vein. We focus on the leaves whose leaf veins are straight. The algorithm's procedure is as follows: first, through contour extraction we segment foreground and background, get clean images of leaves. Second, change the color space from RGB to HSI, separate the hue component and enhance it. Third, get adaptive thresholds for canny detection based on Otsu algorithm. Then using canny edge detection and Hough transform to detect lines, most of them are leaf veins. We need to select the right lines. And finally we can get the angles between the primary vein and the secondary veins through these lines. Experiments have been conducted with a lot of leaf images. Experimental results show that this method can be used to extract leaf veins and measure angles, even when leaf veins are a little blurry.**

Keywords- leaf vein extraction, hue saturation intensity model, Hough transformation

I. INTRODUCTION

Plants are vital in ecosystem. There leaves play important roles during plant development for their function of photosynthesis and transpiration. Thus, we can judge growing conditions of plants from foliar morphological parameters. For instance, leaf area is the main parameter to quantitatively analyzing photosynthesis and transpiration, also an indicator of plants' growing stage[1]. So it makes sense to measure leaf area accurately and quickly. Also, leaf veins are primary channels to transport water and nutrients. Analysis of the distribution of veins can implicate the plant's growing status as well.

Though it is important to get leaf veins and their angles quickly and accurately, in the field of plant research, most experts in China still use a traditional method, the manual measurement method, to assist their research. They have to observe and measure with the naked eye, under the help of instrument like protractor. This method is laboursome and time-consuming. Besides, the accuracy cannot be guaranteed since the measuring results are subjective. Another shortcoming can't be ignored is that such methods do harm to plants because they must pick up leaves first. In this paper, we introduce an improved method based on computer vision. We use scanned images of leaf and image processing technology, not only objective and accurate, but also avoid the harm to plants if we use a hand held scanner.

Leaf vein extraction seems similar to edge detection, whereas it's not. Most edge operators such as Laplacian, Prewitt and Sobel, can catch a sudden variation in the gray level. However for vein detection, usually vein and mesophyll can be almost concolorous. What's worse, veins are not always clear as we wanted, they may be blurry because of pathological changes. A number of researchers have made great efforts on leaf vein extraction. For example, YunFeng Li[2] came up with a method based on snakes technique, combing with cellular neural networks. XiaoDong Zheng[3] used gray-scale morphology to deal with it. Hong Fu[4] proposed a two-stage approach for leaf vein extraction. An approach based on Gabor filter combined with principal component analysis and annealing simulation algorithm is presented by Michels, used on grape leaves[5].Cope presents an approach discussing the ant colony algorithm[6].At the first stage, use the intensity histogram to roughly estimate regions of vein pixels. Then at the second stage, use a trained artificial neural network classifier to do more-refined segmentation. These researchers didn't do further study after extracting leaf veins. Besides, method based on machine learning needs advanced training, and sometimes may be non-universal since leaves differ in thousands ways.

In this paper we come up with a more universal method for leaf vein extraction and angle measurement. First, through contour extraction we segment foreground and background, get clean images of leaves. Second, change the color space from RGB to HSI, separate the hue component and enhance it. Third, get adaptive thresholds for canny detection based on Otsu algorithm[7]. Then using canny edge detection and Hough transform[8] to detect lines, most of them are leaf veins. We need to select the right lines. And finally we can get the angle between the primary vein and the secondary vein through these lines. There are two key points in this method. One is how to get the two thresholds for canny detection. The other is how to select the right lines after line detection. They will be discussed later.

The rest of the paper is organized as follows: Section 2 introduces the proposed method in detail. Section 3 shows the experimental results. Section 4 is a summary. The paper finishes with suggestions for future research.

II. PROPOSED ALGORITHM

A. Image Capture

The leaf images we used are all scanned images of real leaves. These images are provided by Professor Huang in Zhejiang A&F University.

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B. Background Segmentation

In this step we segment leaves and the background. First, binarize the images as a preparation. Second, get contours and delete those which don't belong to leaves. And then, clean leaf images are obtained. This step will make subsequent steps easier and more accurate.

C. Hue Extraction and Enhancement

Red green blue (RGB) color space is suitable for visual presentation, but it has limitations in image processing. Here, we change it into hue saturation intensity (HSI) [9]color space to do further procedures. HSI color space reflects how human visual system perceives color. This kind of color model separates intensity component, hence it alleviates the influence caused by illumination. Assume 'max' and 'min' denote the maximum and the minimum of RGB value respectively. Then the reduction formula from RGB to HSI is shown in Eq.(1).

$$H = \begin{cases} 0, & if \max = min \\ 60 * \frac{g-b}{max-min} + 0, & if \max = r \ and \ g \geq b \\ 60 * \frac{g-b}{max-min} + 360, & if \max = r \ and \ g < b \\ 60 * \frac{b-r}{max-min} + 120, & if \max = g \\ 60 * \frac{r-g}{max-min} + 240, & if \max = b \end{cases}$$

$$S = \begin{cases} 0, & if \ I = 0 \ or \max = min \\ \frac{max-min}{max+min}, & if \ 0 < I \leq \frac{1}{2} \\ \frac{max-min}{2-max-min}, & if \ I > \frac{1}{2} \end{cases}$$

$$I = \frac{1}{2}(max + min) \tag{1}$$

For scanned images, intensity difference is not obvious. Also for a same leaf, saturation is also mainly uniform. But leaf vein and mesophyll have difference in hue, thus we choose hue component to distinguish them. For better segmentation, the difference between vein and mesophyll should be enlarged. The formula is shown in Eq.(2).

$$H = 255 * \left(\frac{H-H_{min}}{H_{max}-H_{min}}\right)^t \tag{2}$$

In the formula above, 'Hmin' is the minimum in all the hue values, and 'Hmax' is the maximum. When 't' gets larger, interference gets smaller, but more effective information will be lost. Through tests, 't' equals '3' is the best balance. Thus, we get leaf images in hue plane after enhancement.

D. Adaptive Thresholds Calculation for Canny Detection

Since Hough line detection needs binary image, we do canny edge detection first. Canny edge detection[10] uses gradient differences to distinguish edge and else part. The main shortcoming is that two thresholds are fixed, it makes the results inaccurate. So an adaptive thresholds calculation method is proposed. This method refers to Otsu algorithm. The core idea of Otsu algorithm is to make the divided two classes have maximum between-cluster variance. Based on this idea, the adaptive thresholds calculation method is as follows. First of all, get gradients of the whole image. The gradient calculation formula is shown in Eq.(3).

$$\nabla f(x, y) = \sqrt{Gx(x,y)^2 + Gy(x,y)^2}$$

$$\theta(x, y) = \arctan\left(Gx(x, y)/Gy(x, y)\right) \tag{3}$$

In the formula above, '∇f' indicates the value of gradient, ' θ ' indicates the direction of gradient. Then using non-maximum suppression to handle the gradients. After that, we put pixels into three classes named C1, C2 and C3. C1 includes edge pixels. C2 includes pixels which need to be judged whether they are on the edge. C3 includes pixels which are not on the edge. The between-cluster variance can be defined as Eq.(4).

$$\delta^2(t1,t2) = (E_1(t1) - E)^2 * p(t1) + (E_2(t1,t2) - E)^2 * p(t1,t2) + (E_3(t2) - E)^2 * p(t2) \tag{4}$$

Here, 'E' indicates the expectation gradient of the whole image, 'E1' 'E2' and 'E3' indicate the expectation gradient of 'C1' 'C2' and 'C3' respectively. 'p(t1)' 'p(t1,t2)' and 'p(t2)' indicate the percentage of pixels in 'C1' 'C2' and 'C3' respectively. When $\delta^2(t1, t2)$ gets maximum, 't1' and 't2' are the most suitable thresholds for canny detection. Use the thresholds calculated above, we can employ canny edge detection to get edges.

E. Line Detection Based on Hough Transformation

After canny edge detection, leaf veins appear but not in lines, always in discrete dots. So the purpose of this step is to connecting dots by line detection based on Hough transformation. The basic idea of Hough transformation is that collinear dots in image space corresponding to intersectant lines in parameter space. The transformation equation is shown in Eq.(5).

$$\rho = x\cos\theta + y\sin\theta \tag{5}$$

Then we can get lines and some of them are exactly leaf veins. Since lines are stored by starting point coordinate and end point coordinate, it is very convenient to get the slope.

F. Angle Measurement

After line detection, leaf veins clearly appeared. By the way, for eudipleural leaves, if a portion of a leaf is contaminated, we can use symmetry principle to recover it. This step focuses on measuring angles between the primary vein and the secondary veins.

The procedure is as follows:

1) Determine the primary vein: the lines segments that represent the primary vein should have the slope near infinity. At the meantime, according to leaf contour we can get the x-coordinate value for the primary vein. On the basis of these two parameters, the primary vein's location can be ensured.

2) Find the secondary veins: on the left hand of the primary vein, the slopes of the secondary veins should be minus and on the right hand it should be positive number.

Also, the slopes won't get too close to zero or infinity. Besides, extend the secondary veins, they will intersect with the primary vein on the primary vein.
3) According to the primary vein and the secondary veins, angles can be calculated.

III. Experimental Results

Based on the algorithm flow designed above, we expand the experimental sample. For example, compare the automatic measurement results with manual measurement results of 100 pieces of leaves, we can calculate the accuracy basically around 87.5%. Both qualitative and quantitative results show that once enough data is collected, we can easily get the accurate leaf shape parameters by computer automatically.

(a) Original image (b) After contour detection (c) After leaf vein detection

IV. Summary

In this paper, a method of obtaining leaf shape parameters based on non-destructive testing is proposed. We can automatically obtain the leaf shape parameters by a series of image processing methods based on the color images of the leaves obtained by scanning. These parameters can be widely used in digital plant area, plant growing monitoring area and so on. For future work, some other algorithms may be involved or combined with for even better results. Besides, the sample library will be expanded to accommodate varieties of plants.

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