Comparison of Different Leaf Edge Detection Algorithms Using Fuzzy Mathematical Morphology

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Abstract - Extraction of the Edge in leaf images is the important step in leaf inspection by computer. It is important to detect edge and keep detail texture information of leaf such as vein, color etc. The original leaf image is captured by a digital camera. The obtained leaf is then first processed by a membership function. After that a fuzzy mathematical morphology algorithm is used to detect the edge [1]. Efficiency of edge detection based on the fuzzy mathematic morphology is proved by comparing with the results of the other edge detection algorithms like binary morphology, Sobel under different conditions.

Keyword: Edge detection; Fuzzy Mathematical Morphology, Moment-Preserving

I. INTRODUCTION

Plants play an important role in both human life and other lives that exist on the earth. Due to environmental deterioration and lack of awareness, many rare plant species are at the margins of extinction. Despite the great advances made in botany, there are many plants yet to be discovered, classified, and utilized; unknown plants are treasures waiting to be found. Leaf classification and recognition for plant identification plays a vital role in all these endeavors. Detection of edges is considered to be one of the vital steps of preprocessing during leaf identification and recognition system. The current need is to have an edge detector which is both fast and efficient in identifying edges of a leaf image. In order to detect edge and keep detail texture information such as vein, the original leaf images obtained by a digital camera are processed by a membership function at first. Then a fuzzy mathematical morphology algorithm is used to detect the edge. Efficiency of edge detection based on the fuzzy mathematic morphology is proved by comparing with the results of the other algorithms under different conditions [1]. In the first process of digital images of leaves, it is necessary to segment the pixels which belong to a leaf from the whole image. The accuracy of image segmentation will impact the efficiency of succeeding tasks. Among many algorithms of image segmentation, the segmentation algorithms based on edge detection are widely used because of good accuracy and high speed. The main advantage comes from the fact that gray-scale values at edges change largely compared with the other places. Therefore, it is a good idea to find edges first and then connect them to form the outline of the leaf. At present, the edge detection algorithms based on spatial-domain differential operator such as Roberts, Sobel, Prewitt etc. are used widely [3]. They carry out edge detection pixel by pixel. All of these operators are based on the change of derivative impacted by gray-scale mutation. The weakness of these operators is that there is a trade-off between the noise immunity and the precision of edge detection. The size of the leaf, the length of the vein and the amount of texture are very important clues to grade leaves. In order to get these values, the edge of leaf and the vein has to be detected. For example, determination of leaf length requires locating the longitudinal axis, which is the line stretching through the gravity center of the leaf and the connecting the leaf edge and the central vein. For an unbroken leaf, the length is surely the distance between its tip and its handle. In order to get a better result, a fuzzy mathematical morphology algorithm is suggested for edge detection in this paper. Mathematical morphology is a method based on set algebra. It describes geometric structure quantitatively by set theory. At present, mathematical morphology is widely used in computer vision, image analysis and pattern recognition such as color image segmentation in 3-D space [4], edge detection method of remotely sensed image [5] and medical image processing [6] etc. The main idea of mathematical morphology is to measure and detect the corresponding object by a structural element which has a specific sharp. The result has a close relationship with the size and sharp of the structuring element. Different sizes and sharps of structuring element will lead to different results and perform different kinds of image analysis. As an extension of set-theory-based binary morphology which is used in binary images, the fuzzy mathematical morphology has its origin in fuzzy set theory. The membership of pixels in leaf image is calculated firstly to show to what degree they are likely a part of leaf. The value of pixels takes a value in [0, 1] instead of a value in {0, 1} of the binary image. After calculating the degree of membership, further processing can be performed by fuzzy mathematical morphology to reach the target of edge detection.

II. PROPOSED ALGORITHM

2.1 EDGE DETECTION IN LEAF IMAGE BASED ON FUZZY MATHEMATICAL MORPHOLOGY

Before detecting the edge of leaf by fuzzy mathematical morphology, it is necessary to calculate the degree of membership of every pixel in the image under the framework of fuzzy mathematics

STEP 1: The Membership Function of Leaf Image

For a leaf image taken by a CCD camera, the membership of a pixel can be calculated by applying a membership function to the value obtained from the RGB values. The definition of membership function is shown in Fig.

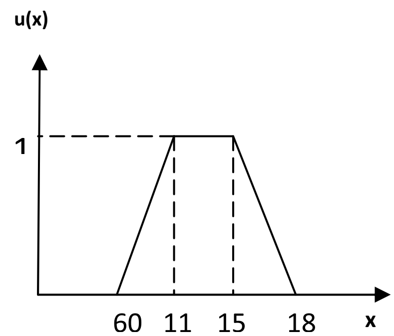


Fig 1 Processing of membership function

In Fig.1, the horizontal axis x represents the G component value of RGB, while u(x) represents the possibility of a pixel belonging to leaf. The reason why only G component is used is that according to the statistical information of the leaf images, most of the pixels which belong to leaf have the G component value in [52, 252], furthermore the pixels with the G component value in [54, 254] has the 100% probability to leaf. Other pixels which has the value in [0, 16] or [89, 255] has very high probability to background or noise. So we can measure the membership of pixels by their G component values of RGB.

STEP 2: The Basic Operations of Fuzzy Mathematical Morphology

The basic operations of fuzzy mathematical morphology include dilation, erosion, opening and closing. The fuzzy structuring element can work as a mask. The dilation and erosion can be carried out by the way that the mask is shifted over the image which has been processed by a membership function firstly. Let A represent the original image, A' represent the image which has been processed by a membership function, B represent the fuzzy structuring element. The formulas below are the basic operations of fuzzy mathematical morphology [8]. In below, S is the standard element of the same size as the structuring element, for example, 3*3, 5*5 sizes, and has all ones in the values.

Erosion: E (A', B) = arg min {S - |A' - B|} **(1)**

Dilation: D (A', B) =S - E (S - A', B) **(2)**

Opening: O (A', B) = S - E (S - E(A', B), B) **(3)**

Closing: C (A', B) = E (S - E (S - A', B), B) **(4)**

It is not hard to see that the operations of dilation, opening and closing are based on the operation of erosion. In fact there are different kinds of definition about erosion in fuzzy mathematical morphology. They have a little difference to each other but (1) is the fastest.

STEP 3 : The Structuring Element

The structuring element is the basic element in morphology. The effect and quantity of image processing is much affected by the size and sharp of the structuring element. Therefore, the width, length and sharp of structuring element have to be chosen carefully. In binary morphology, the value of a unit in structuring element is 0 or 1 where 0 means that the unit is not involved in computing while 1 means that the unit is involved in computing. In the fuzzy mathematical morphology, a value in [0, 1] of structuring element represents the possibility of the unit being involved in fuzzy mathematical morphology operation. For edge detection of tobacco leaf image, the 3*3-size structuring element is the most effective to attain both high speed and fine result. According to the characteristics of leaf a all-directional structuring element with a crisscross sharp is selected. The upper, lower, right, left and central units of a 3*3 sizes structuring element are involved in the performance of fuzzy mathematical morphology algorithms, so the structuring element is like B as shown in Fig 2

$$\underset{S}{\begin{array}{|c|c|c|}\hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline 1 & 1 & 1 \\ \hline \end{array}} \qquad \underset{B}{\begin{array}{|c|c|c|}\hline 0 & 1 & 0 \\ \hline 1 & 1 & 1 \\ \hline 0 & 1 & 0 \\ \hline \end{array}} \qquad \underset{A'}{\begin{array}{|c|c|c|}\hline 0.3 & 0.2 & 0.1 \\ \hline 0.4 & 0.9 & 1 \\ \hline 0.9 & 1 & 1 \\ \hline \end{array}}$$

Fig.2 shows in size of the 3*3 sizes S, B and A' respectively

STEP 4 : Edge Detection by Fuzzy Mathematical Morphology

The formula to detect the edge of tobacco leaf image in fuzzy mathematical morphology is given like 5. Here X is the result of the fuzzy dilation and Y is the result of the fuzzy erosion. Both X and Y comes from the same image processed by the same structuring element. Then X and Y are compared by (5). In (5), d1 and d2 are the two maximum values between corresponding pixels in the X and Y inside a 3*3 window centered on the pixel (i, j), together with the difference d(i, j) computed on the corresponding pixels (i, j). The same will go on until the 3*3 window shifts over the whole image matrix. The edge of gradient can be detected in this way. Note that the pixels in the outmost of an image cannot be involved in the algorithm because they do not have 8 neighbors around them. However it is not a large problem because no edge exists in the area.

$$F\,(X(i,j), Y(i,j)) = \sqrt{d(i,j)\frac{d(i,j) + d1 + d2}{3}} \qquad \textbf{(5)}$$

STEP 5: Image Reconstruction

The value of pixel processed by fuzzy mathematical morphology is in [0, 1], therefore binarization is necessary. In this step, the value of pixel is transferred into 0 or 1 by a moment-preserving algorithm. The proposed algorithm for image reconstruction using the moment-preserving is described as follows.

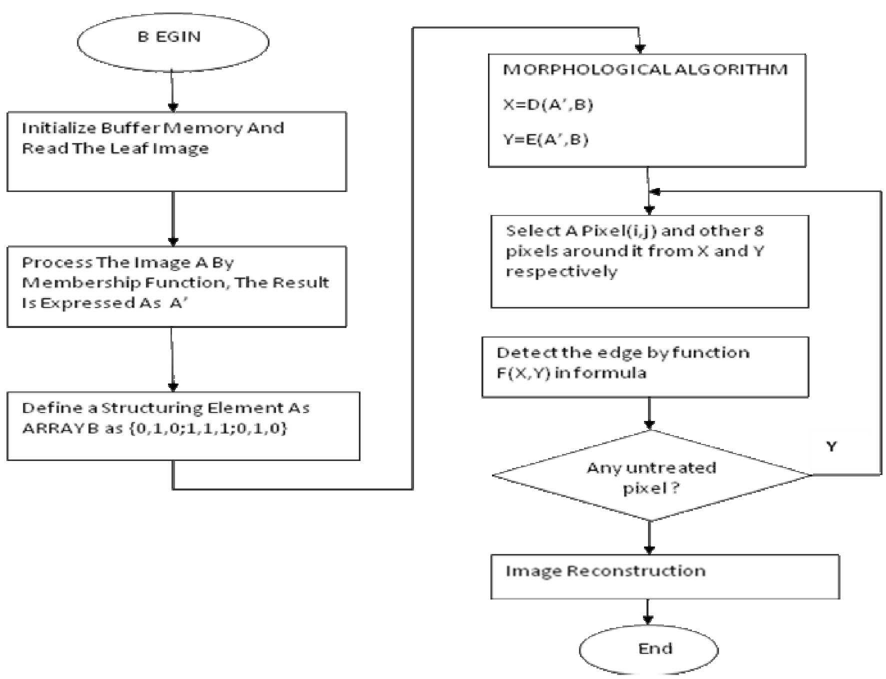
Step 1: Read the image f and partition it into nonoverlapping 4 x4 blocks f_j .

Step 2: Take a block f_j of f and perform the following steps.

1) Compute a set of moments of the gray components values of the pixels in f_j.
2) Evaluate the number of uniform spectral bands based on the variances of the gray component values of the pixel in f_j.
3) Generate a 4x4 bit map for f_j by assigning 0 or 1 to each pixel p_i of f_j according to whether the new gray value of p_i <t1.

Step 3: Stop when all blocks of *f* have been processed.

FLOW CHART

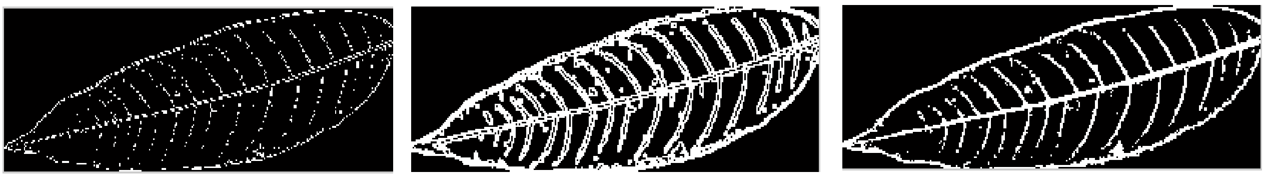


III. COMPARISON OF RESULTS

In this section, we compared the result by the proposed algorithm with the results of the other algorithms

A. The Results under Noise-Free Condition

Fig. 5(a) and Fig.5(b) are the results of edge detection without noise based on Sobel operator and Binary morphology algorithm.

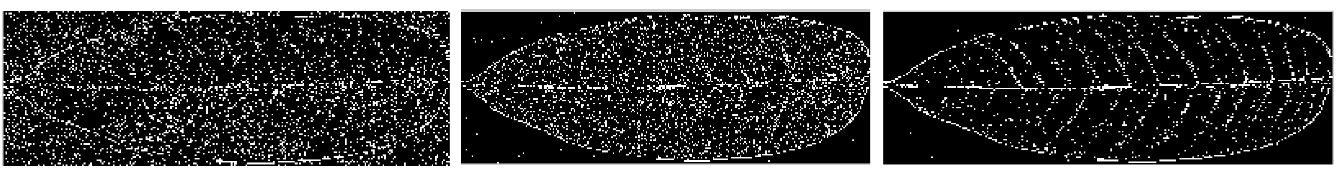


(a) Binary Morphology **(b) Sobel** **(c) Fuzzy Mathematical Morphology**

It is easy to see that the result of edge detection based on Binary Morphology Operator does not detect all the necessary edge of leaf. About 1/4 edge of the leaf is not detected by this algorithm. Sobel Operator detected all the boundary of leaf, but the details of texture such as the vein are not successfully detected. Compared with these algorithms, the result of the proposed algorithm outperforms the others in these respects.

B. The Results under Noise Condition

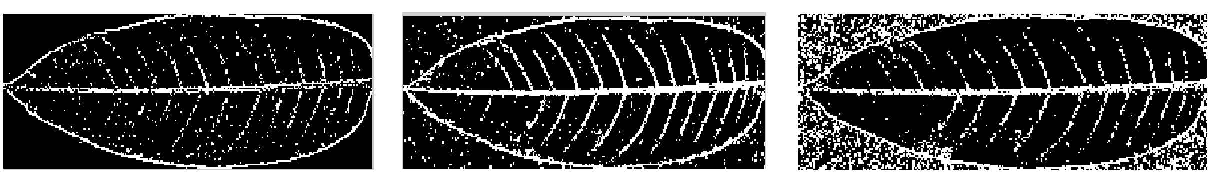
Binary Morphology



(a) Gaussian noise **(b) Poisson noise** **(c) Speckel Noise**

Fig 6(a) through (c) result of edge detection using binary morphology

Fuzzy Mathematical Morphology



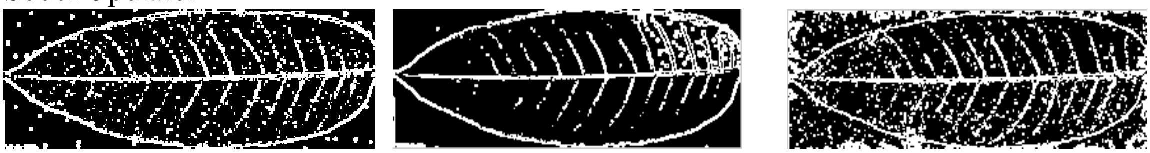
(a) Gaussian noise **(b) Poisson Noise** **(c) Speckle Noise**

Fig 7(a) through (c) result of edge detection using fuzzy mathematical morphology

Fig. 6 (a) is the image of leaf with Gaussian noise. The Gaussian noise is added by function *imnoise (A, 'gaussian',0, 0.02)* in MATLAB. It means that the Gaussian noise added to image A has the mean with 0 and standard deviation with 0.02.

Fig.7(a**)** is the result of edge detection based on fuzzy mathematical morphology. We can see from the image that the noise did not cause a serious problem on the result. The main reason of success is that the affection by noise in the image of leaf is reduced by the membership function, so the noise had little impact on result. Fig.6 (b) and Fig.6(c) are the results of edge detection based binary morphology under Poisson noise and Speckle noise respectively. In Fig.6(b), the boundary is clear but the texture is lost completely. There are also some noise spots filled in the leaf. In Fig.6(c), the result is filled with the noise spots so that the edge and the details of leaf are hard to be extracted.

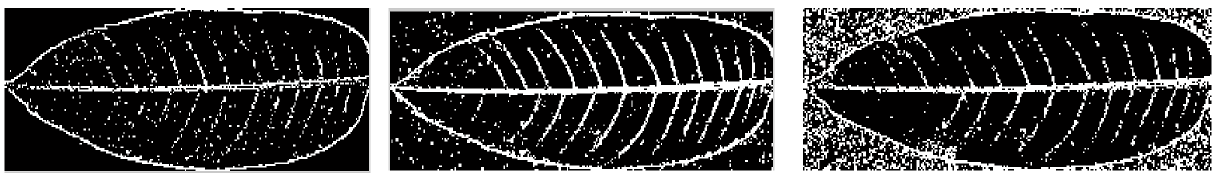
Sobel Operator



(a)Gaussian noise **(b) Poisson noise** **(c) Speckle Noise**

Fig 8(a) through (c) result of edge detection using Sobel**.**

Fuzzy Mathematical Morphology



(a) Gaussian noise **(b) Poisson Noise** **(c) Speckle Noise**

Fig 9 (a) through (c) result of edge detection using fuzzy mathematical morphology

Fig.8(a) is the image of leaf with Gaussian noise. The Gaussian noise is added by function *imnoise (A, 'gaussian',0, 0.02)* in MATLAB. It means that the Gaussian noise added to image A has the mean with 0 and standard deviation with 0.02. **Fig.9(a)** is the result of edge detection based on fuzzy mathematical morphology. We can see from the image that the noise did not cause a serious problem on the result. The main reason of success is that the affection by noise in the image of leaf is reduced by the membership function, so the noise had little impact on result.

Fig. 8(b) and **Fig.8(c)** are the results of edge detection based on Sobel operator under Poisson noise and Speckle noise respectively. In **Fig. 8(b)**, the boundary is clear but the texture is lost completely. There are also some noise spots in the lower- right corner. In **Fig. 8 (c)**, the result is filled with the noise spots so that the edge and the details of leaf are hard to be extracted.

IV. CONCLUSION

The theory about fuzzy mathematical morphology is growing and being used in more and more fields. The contribution of this paper is that it confirms the efficiency of applying the fuzzy mathematical morphology to edge detection of leaf images. For edge detection of leaves, the algorithm based on fuzzy mathematical morphology showing its high effectivity. Compared with other image algorithms such as Sobel and binary morphology, the edge detection algorithm proposed by this paper has obvious advantages: no threshold required, high immunity to noise, extraction of detailed texture and the vein. Further research is to compute the area of leaf and the length of vein based on the result of edge detection. Once enough data is collected from the leaf images, the grading of the leaf would be carried out by computer automatically using some kinds of algorithm.

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