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An Optimal Fuzzy Logic Algorithm for Edge Detection of Stone Inscriptions

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Abstract. The identification of stone inscriptions is of great significance to the study of Chinese characters and the exploration of ancient history. Characters are the symbol of civilization. The identification and analysis of the stone inscriptions can determine the age when they belong, and can help to study archeology. In this paper, an optimal fuzzy logic algorithm is proposed for edge detection of stone characters. Using the adaptive median filter to denoise the stone inscriptions; using three linear filters for gradient analysis; reasonable set of fuzzy rules and fuzzy sets. During image preprocessing, three linear filters are used: the Sobel operator, which is used to estimate the derivative of the horizontal and vertical directions, the low-pass filter and the high-pass filter. The setting of parameter N enhances the adaptive ability of this algorithm and can be applied to different types of image detection. The algorithm is compared with the existing algorithms (Sobel, canny), and better results are achieved.

1. Introduction

Edge detection is a low level image processing tool and it has widespread applications that range from pattern recognition to computer vision. Feature extraction plays an important role in stone inscriptions recognition. For better feature extraction, we need to do the preprocessing for image enhance. The extraction of different kinds of stone inscription is challenging, and some characters are degraded due to some natural influences. Edge detection is a key step in preprocessing, and previous methods such Sobel and canny are not suit for the edge detecting of old stone inscriptions. Therefore, new edge detection techniques are needed to obtain better feature extraction.

Edge detection has been applied to various fields. The cell images and Kannada stone inscriptions are blurred by calculating the X-axis and Y-axis gradients, and the gradient images are added as input to the fuzzy inference system [1,2]. The proposed method employs a 3x3 mask guided by fuzzy rule set. Moreover, in case of smooth clinical images,an extra mask of contrast adjustment is integrated with edge detection mask to intensify the smooth images[3]. Three 3x3 linear spatial filters are used to detect edges with uneven illumination and double edges are effectively suppressed by judging the distribution of surrounding pixels [4]. The traditional Canny algorithm is improved by using fuzzy theory and the maximum between-classes variance [5].

The general method applied for edge detection is a linear time invariant filters. In this way, the edge is defined as a sudden change in the gray value of the adjacent pixel. However, this method is very sensitive to noise and blurred images. Now, there are many researcher who proposed more edge detection methods. Compared with traditional methods, these methods achieve good results. A two-phase fuzzy inference system is proposed to detect edges in gray level images. In the first phase the discontinuity in pixels intensity is evaluated according to various directions, while in the second phase the final decision is determined based on the results obtained from the first phase[6]. The early algorithm scans the input image by using 2 x 2 template window to detect the edge of the image. The rule-base of 16 rules has been designed to mark the pixel under consideration as Black, White or Edge [7, 8]. The authors propose an edge detector architecture for color images based on fuzzy theory and the Sobel operator. The experimental results achieved in FPGA demonstrate the effectiveness of the method based on fuzzy control [9].

In this paper, noise is removed by adaptive median filter during image preprocessing, and gradient analysis is performed by linear filter, low-pass filter and high-pass filter. We define different types of membership functions and fuzzy rules of fuzzy inference system. This algorithm is compared with the previous traditional algorithm.

2. Algorithm steps

Step 1: Because the color image matrix used is three-dimensional, the first step is to convert a color image to a grayscale image.

Step 2: An adaptive median filter is used to remove noise like salt and pepper on the image.

Step 3: Fuzzy logic tool box operates on double-precision data so the grayscale level byte array is converting into double array.

Step4: Calculate the image gradient in the X-axis and Y-axis directions, and perform two-dimensional convolution using the high-pass filter and the low-pass filter core and the image. The fuzzy inference system specifies the input and output and defines the member function. Specify Fuzzy Interface rule using Fuzzy Interface system and display of Edge detection image.

Step5: The edge detected image features were extracted and Feed into Advance Recognition Algorithm for recognition.

3. Implementation of the FIS System Applied to Edge Detection

The method used in this paper is based on fuzzy logic. Fuzzy logic is very helpful in edge detection because it can handle the problem of decision making in partially true and partially false values in between completely true and completely false values. Given the kernel associated with each filter, the filtered image is computed by two-dimensional convolution operation. A fuzzy inference system is designed that takes these processed values as input. These values are subsequently converted into the fuzzy plane. A fuzzy rule set is defined that determine and show the edge pixels in the output image. The output of the system is calculated based on centroid method and defuzzification is performed based on Mamdani implication. Block diagram of the proposed methodology is shown in Fig.1.

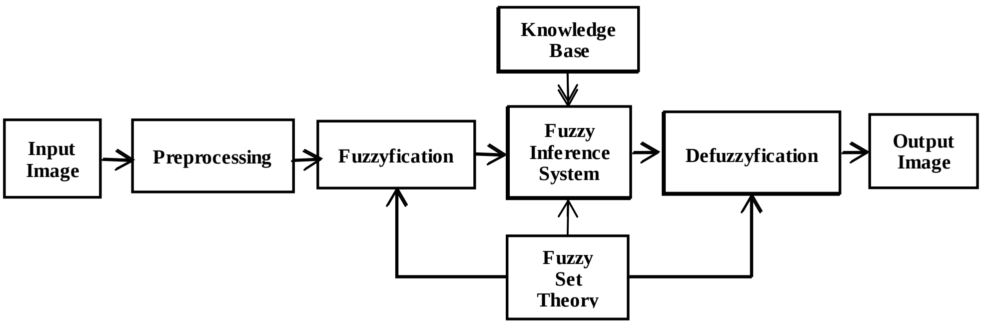


Fig. 1. Block diagram of the image edge detection.

3.1 Image preprocessing.

Computation with 2-D array is simple than computation with 3-D array, the captured image contains red, green, blue intensities so standard NTSC conversion formula used to calculate the effective luminance of each pixel. Instead rgb2gray function can also be used.

$$\text{Igray} = 0.2989*\text{Irgb}(:,:,1)+0.5870*\text{Irgb}(:,:,2)+0.1140*\text{Irgb}(:,:,3) \tag{1}$$

3.2 Adaptive median filter.

Adaptive median filter by changing the size of the template window, and noise points and signal points using different processing methods, so as to achieve the effect of noise removal. In the process of denoising, the adaptive median filter algorithm outputs a single value by changing the template window size, which is used instead of the pixel value at the center point (x, y) of the template. For a size m×n image, let F_{xy} be the working window when the current pixel (x, y) is denoised; $F_{\max}$ is the maximum allowed filtering window; $f(x,y)$ is the gray value of the pixel (x, y); $f_{\min}$ Is the minimum pixel gray value; $f_{\max}$ is the maximum pixel gray value; f_{med} is the median. Adaptive median filter specific implementation steps are as follows:

Step 1: Initialize the filter window size α = 3;

Step 2: Calculate the minimum value of the gray value of the current template window $f_{\min}$, the maximum value $f_{\max}$, the median f_{med};

Step 3: If $f_{\min} < f_{med} < f_{\max}$, then turn Step5; otherwise increase the window size so that α=α+2;

Step 4: If $\alpha \le F_{\max}$, then turn Step2; otherwise use the template window within the median f_{med} instead of the current pixel, that is $f(x,y) = f_{med}$;

Step 5: If $f_{\min} < f(x,y) < f_{\max}$, then the point is not a noise point, the filter output is still $f(x,y)$; otherwise, f is replaced by $f(x,y)$, $f(x,y) = f_{med}$.

3.3 Calculate the filtered image.

In the input image preprocessing stage, 4 linear filters are used, where the convolution kernel of Sobel operator with two directions in horizontal and vertical directions is 3x3, which is expressed as follows:

$$G_x = \frac{1}{N}\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \tag{2}$$

$$G_y = \frac{1}{N}\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{3}$$

N is the influence parameter, and its value directly affects the detection effect. According to the repeated experiment value of 1/3, the best effect is obtained. The high-pass filter allows a filter to pass higher frequency than a certain frequency, while greatly attenuating a lower frequency of the filter; the low-pass filter allows the signal to pass below the cutoff frequency. The kernel associated with it is as follows:

$$\mathrm{G}_h = \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix} \tag{4}$$

$$\mathrm{G}_l = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{5}$$

The filtered image can be calculated by a two-dimensional convolution operation:

$$\mathrm{GX} = G_x * I \tag{6}$$

$$\mathrm{GY} = \mathrm{G}_y * I \tag{7}$$

$$\mathrm{GH} = \mathrm{G}_\mathrm{h} * I \tag{8}$$

$$\mathrm{GL} = \mathrm{G}_\mathrm{l} * I \tag{9}$$

3.4 Fuzzy Sets and Fuzzy Membership Functions Definitions.

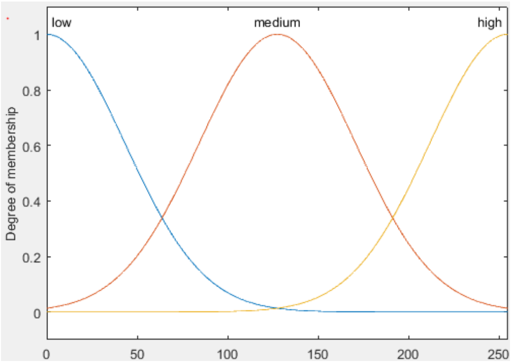
Membership Functions (MFs) play important role in fuzzy logic. They are the key ingredients of the fuzzy set theory and they calculate the fuzziness in the fuzzy set. As the MFs have effects on the fuzzy inference system, therefore the type and shape of the MFs should be selected carefully based on the nature of problem. For the proposed algorithm, the Gaussian and S-type membership functions are used, in which the output function is used Gaussian type, as they have advantages of being smooth and non-zero at all points.

The mathematical expression of the Gaussian membership function is as follows:

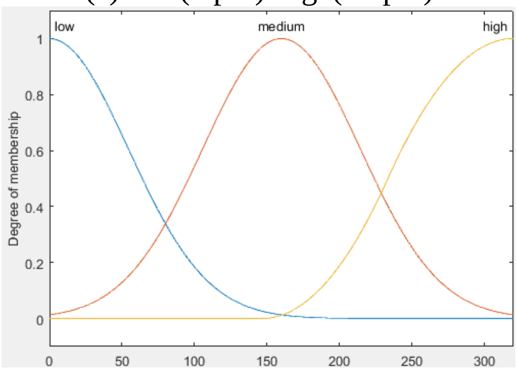
$$f\left(x,b,c\right)=e^{-\frac{(x-c)^2}{2b^2}} \tag{10}$$

Where c is the abscissa corresponding to the maximum value of the Gaussian function and b is the standard deviation. Besides these, three fuzzy sets were created to represent each variable's intensities; these sets were associated to the linguistic variables "low", "medium" and "high".

The membership function of the fuzzy set associated with the input variable GL and the output variable is a Gaussian function whose mean is 0, 127.5 and 255, as shown in Fig. 2 (a). For the sets associated to the other input images, Gaussian functions were also adopted for the linguistic variables "low" and "medium", but for the variable "high" a sigmoid function was chosen, as shown in Fig. 2 (b).



(a) GL(input)Edge(output)



(b) GX/GY/GH(inputs)

Figure 2: Membership functions of the fuzzy sets associated to the output and to the input GL (a) and to inputs GX, GY , GH (b).

3.5 Fuzzy Logical Operations and Defuzzification Method Definitions.

The functions adopted to implement the "and" (norm-T) and "or" (norm-S) operations were the minimum and maximum functions, respectively. The Mamdani method was chosen as the defuzzification procedure, which means that the fuzzy sets obtained by applying each inference rule to the input data were joined through the add function; the output of the system was then computed as the centroid of the resulting membership function.

3.6 Inference Rules Definitions.

In fuzzy inference system, fuzzy rule base or knowledge base is a set of linguistic descriptions. They play an important role as they make decision related to categorizing an input or adjusting and stabilizing the output. Fuzzy rule base for the proposed edge detection algorithm consists of the following linguistic descriptions as listed in Table I.

Table I. Fuzzy Rule Base For The Proposed Edge Detection Algorithm

Rules	Inputs				output
	GX	GY	GH	GL	Edge
1	low	low	none	none	low
2	medium	medium	none	none	high
3	high(OR)	high	none	none	high
4	medium	none	low	none	high
5	none	medium	low	none	high
6	low	none	low	none	low
7	none	low	low	none	low
8	none	high	none	low	medium
9	high	none	none	low	medium
10	medium	none	none	low	low
11	none	medium	none	low	low
12	high	none	none	medium	high
13	none	high	none	medium	high

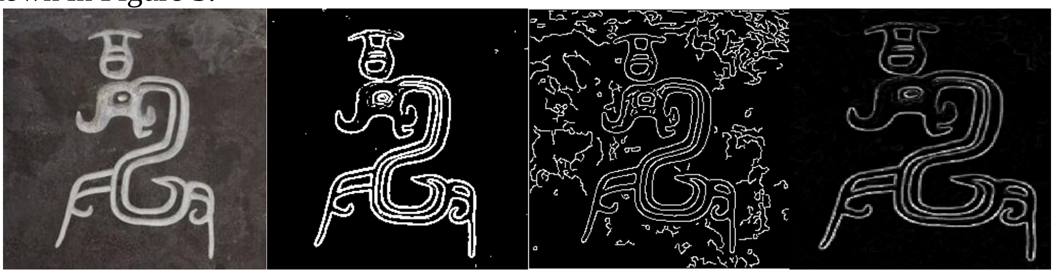
The first 3 rules are used to determine pixels with high gray level variations in vertical or horizontal directions. The fuzzy set composition operator of the third rules is "or", the others are "and".

Rules 4 to 7 are to ensure that the edges of the low contrast area are detected. Other rules are to prevent noise interference and suppress false edges to make it easier to detect the edges of the low contrast region.

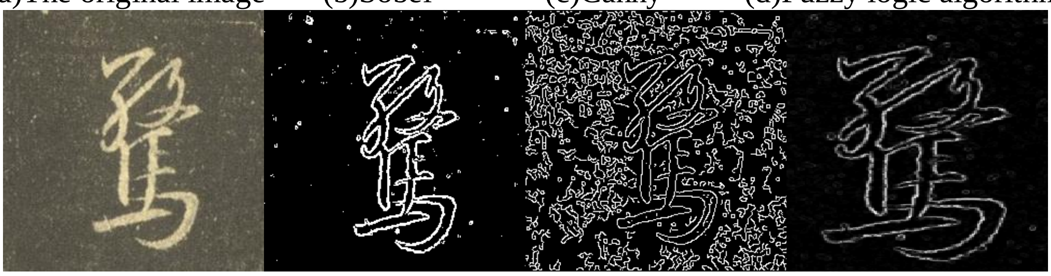
4. Results and Discussion

In this paper, the edge of the stone inscriptions is used for edge detection, and compared with Sobel and Canny algorithm. It is very difficult to extract the stone inscriptions because of the natural factors affected by the long time of the stone.

In this paper, the adaptive median filter is used to denoise the stone inscriptions. The algorithm based on fuzzy control is used to obtain the image gradient value, and then the high-pass filter and the low-pass filter are used to carry out two-dimensional convolution operation. Finally, according to the fuzzy rules, 20 groups of inscriptions on the edge of the stone detection, of which two groups of results shown in Figure 3.



(a)The original image (b)Sobel (c)Canny (d)Fuzzy logic algorithm



(a)The original image (b)Sobel (c)Canny (d)Fuzzy logic algorithm

Figure 3:Comparison of fuzzy logic edge detection image and Sobel edge detection image

It can be seen from the experimental results of two groups that the Sobel algorithm detects discontinuities in inscriptions of degraded stone. Sobel algorithm is not based on gradient analysis. The Sobel algorithm cannot detect the edges of the low contrast region. Canny algorithm has a large number of pseudo-edge, the edge of the stone inscriptions edge detection there is a serious interference. In some discontinuous regions, the proposed algorithm can better detect the edge of the degenerated stone inscriptions. The proposed algorithm incorporates an adaptive filter and achieves better results than some previous fuzzy logic algorithms.

5. Conclusion And Future Work

It the extraction of the edges of the degraded stone inscriptions is a great challenge. In this paper, different degrees of deterioration of the stone inscriptions have been tested and achieved good results. When the corrosion of the stone inscriptions to be detected, the algorithm still needs to be improved. This paper is an algorithm based on fuzzy inference system and an adaptive filter is added. The setting of parameter N enhances the adaptive ability of this algorithm and can be applied to different types of image detection. The algorithm has a very good effect on noise suppression, and overcomes the shortcomings of the first and two order edge detection algorithms. From the experimental results, we can conclude that the algorithm based on fuzzy logic is applied to the edge detection of degraded stone inscriptions, and can detect clear edges.

In the future work, we are currently considering how to apply the proposed algorithm to edge detection of medical images, satellite images, and fingerprint images.

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