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Image Edge Detection by combining Fuzzy Logic

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Abstract— Edge detection in digital images is one of the most important issues in image processing and it can be solved by different methods. Most of these methods can be combined with fuzzy systems. In this paper, an algorithm is proposed in which the input of applying wavelet transform at input image and the image obtained by applying a high-pass filter on the image are given to a first order fuzzy system. And based on fuzzy logic, it is decided about the probability of being edge of each pixel of the image. The results obtained by this method were compared with the results of well-known methods of edge vector. And these results show a better performance in images

Index Terms—edge detection, Wavelet transformation, fuzzy system

1 INTRODUCTION

Since the number of edges states the object forms of an image and as a result is provides many information about the image. Edge detection is so important in image processing. By using edge detection, the high volume of image is reduced and the image is prepared to a high level processing such as Pattern recognition. The edge detection algorithms are divided into three major groups which are included spatial method, frequency method and spatial-frequency method. In spatial methods, edge detection algorithms are divided into two groups. In the first group, the first derivative of the image is used. The algorithms of Sobert, Proyet, Robert are included in this categories. In the second category, first derivative of the image is used and by using zero crossing property, the place of edges is detected, for example, Laplace edge identifier is this category. Modern methods are also provided based on fuzzy method to edge detection. And in this method, the neighbors points of image are considered as categories and by using appropriate membership functions which are defined, fuzzy inference system is implemented, for example in [4], threshold limit value in edge detection is calculated by using fuzzy system. In [5], by considering neighborhood points as 3*3 sets around core points and defining membership predefined functions and creating 5 method to detecting color discontinuities in each category, edge detection is done. In [1], the adjacent points of each image are considered in 6 set and by using membership functions, a convenient value between 0 and 1 is determined for each category and based on membership degree of each category and using fuzzy rules, the fuzzy base system is used for decision making about the presence of edge and its direction. Among new methods in this context are multi-resolution based methods. [5]. Although the approaches based on these methods solve the problems related to edge detection and edge position but it is so sensitive due to high-pass features. Dyadic Wavelet transformation is an appropriate method to show the signal as a multi- resolution signal. There are many articles about information combination obtained by image wavelet transformation which are provided in different scales. For example, Mallat has obtained necessary information about edge detection based on local maximum of the size of wavelet transformation. [6] xu was doing edge detection based on sharing the edge detection with Wavelet transformation and also he had shown that that by selecting an appropriate wavelet based on the edge type in presence of noise, we will have a better edge detection [7]. Zhang and bao had used overall maximum of wavelet transformation scales to detect important signal edges. [2] generally, all articles which have used multi-dimensional image, tried to find an accurate edge detection, but we can not generalized a method which can be used for all images.

This article is composed of following sections, in second section of this article, wavelet transformation and fuzzy logic are used. In third section, the proposed approach and the obtained results are provided. Summarization and comparison are conducted in forth section and fifth section is dedicated to conclusion.

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2 WAVELET TRANSFORMATION AND FUZZY LOGIC

In this section, we investigate the applied wavelet transformation in thus article and initial definitions of Fuzzy Logic.

2-1Wavelet Transformation

Wavelet transformation of a signal $f \in L^2(\mathrm{R})$ is determined by the following equation:

$$W_s f(x) = f * \psi_s(x) \quad (1)$$

In the above equation $\psi_s(x)$ is a scale changed form of the function $\psi \in L^2(\mathrm{R})$ and it is defined as

$$\psi s(x) = \frac{1}{\sqrt{s}} \psi(\frac{x}{s})$$

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There are many wavelet transformations and continuous wavelet transformation is obtained by the following equation

$$W\psi f\,(a,b)=\frac{1}{\sqrt{b}}\int_{-\infty}^{\infty}x(t)\psi(\frac{t-a}{b})dt \quad (2)$$

In the above equation x(t) is an input and $\psi(t)$ is mother wavelet and a is position and b is scale.

2-2Multi-Scale edge detection with dyadic wavelet transformation

This continuous wavelet transformation has discontinuous coefficients and it used a power 2 scale. In many articles, this type of transformation is used as discontinuous wavelet, directly. In this transformation, softener function $\theta(x)$ which its integral is zero and it converges to zero. Wavelet function $\psi(x)$ is defined as $\psi(x)=\frac{d\theta(x)}{dx}$ and they are calculated in scales which are power of 2. So, dyadic mother wavelet function is defined as $\psi_{2j}(x)=\frac{1}{2^j}\psi(\frac{x}{2^j})$ and wavelet transformation of the f(x) function is defined as follows:

$$W_i f(x)=f*\psi_{2j}(x)=2^j\frac{d}{dt}(f*\theta_j)(x) \quad (3)$$

(3
)

2-3 Two-dimensional Edge Detection

In this section, we investigate two-dimensional wavelet detection. For this purpose, two-dimension softener functions are used. First, two wavelet functions are used in this article and we investigated them. First function is a partial derivative of a two-dimensional softener function $\theta(x,y)$ along with x pivot $\psi^1(x,y)=\frac{\partial\theta(x,y)}{\partial x}$ and second function is a partial de rivative along with y pivot . $\psi^2(x,y)=\frac{\partial\theta(x,y)}{\partial y}$ The function of s is defined in two functions of $\psi^1(x,y),\psi^2(x,y)$ by equations 4 , 5.

$$\psi_s^{\,1}(x,y)=\left(\frac{1}{s}\right)^2\psi^1(\frac{x}{s},\frac{y}{s}) \quad (4)$$

$$\psi_s^{\,2}(x,y)=\left(\frac{1}{s}\right)^2\psi^2(\frac{x}{s},\frac{y}{s}) \quad (5)$$

Where

$s=2j,\ j\in z,\ j\in(-\infty,+\infty)$

The wavelet of signal f is defined as

$$W_s^{\,1}f(x)=f*\psi_s^1(x,y)\ \text{and.}\ W_s^{\,2}f(x)=f*\psi_s^2(x,y)$$

2-4 Fuzzy Logic

Fuzzy logic believes that ambiguity is in the science nature. Deterministic sets are natural and normal sets which are defined first of set classic theorem. Adding deterministic property creates a distinction aspect and by using it creates one of the critical and innovative concepts in fuzzy logic in mind which is called membership function. In deterministic sets, membership function only has two value in its range that this two elements are yes or no (one, zero), there are two possible value in a classic tw0value logic. So:

$$\mu A(x)=\begin{cases}1 & if x\in A\\ 0 & if x\notin A\end{cases} \quad (6)$$

In which $\mu_{A(x)}$ is the membership function of element x in A deterministic set. Fuzzy systems are described by a set of linguistic sets based on expert knowledge. And it includes 4 fuzzifiers section, knowledge base, inference engine and defuzzifier. In a fuzzy system, knowledge base includes basic data and basic statements. Basic data include a set of membership functions and input-output variables.

And it produces necessary information for the performance of fuzzifier section, inference engine, anddefuzzufier. The fuzzifier produces input deterministic signals by using fuzzy set theory to fuzzy signals which are linguistic variables. Fuzzy inference engine transforms the situation from input to output, by using fuzzy rules and finally it transforms the defuzzfier of fuzzy outputs to clear and deterministic control signals.

3 Proposed Method and Obtained Results

In this section, we investigate the proposed method of this article in edge detection, first, we detect the inputs of fuzzy system. First input of fuzzy system is an image that its discontinuous wavelet is obtained by an algorithm which is provided in article [7]. Obtained picture can considers noise and arbitrary resolution due to the selected scale. If the scale is bigger, the width of mother wavelet is bigger and as a result, frequency separation is getting worse but it creates a better time resolution. In this article, we use scale 2 for discontinuous wavelet. To determine first input in scale2, we obtain the following statement.

$$M_s f(x,y)=\sqrt{(((w_s^{\,1}f(x,y))^2+(w_s^{\,2}f(x,y))^2)} \quad (7)$$

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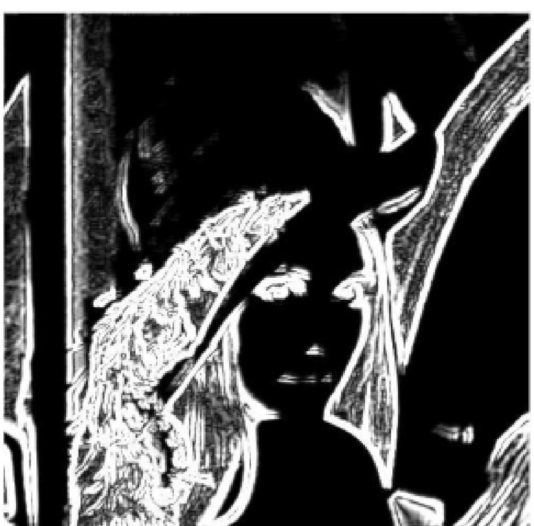
A)

B)



C)

D)

E)

Figure 1: A) original image of Lena and B, C, D, E) edge taken images of lena with wavelet in different scales.

The size of obtained wavelet function from equation 7 is calculated for different scales. Membership functions for first input of fuzzy system are shown in figure 2 and they are obtained by experiment and trial and error method.
Another input of fuzzy system is the result of applying high-pass filter matrix on digital image. The feature of high-pass filter is to find points in the image which have high frequency; edges are points that their frequency is high. The stated matrix is a high-pass matrix. And due to the sensitivity range to edge, we can change its coefficients. Membership functions are shown for the second input of fuzzy system in figure 4 and these membership functions are obtained by using experiment and trial and error method.Figure 3 is the obtained image by applying high-pass filter on the lena image. (figure 1 from 1)

$$\begin{bmatrix} -\frac{1}{16} & -\frac{1}{8} & -\frac{1}{16} \\ -\frac{1}{8} & \frac{3}{4} & -\frac{1}{8} \\ -\frac{1}{16} & -\frac{1}{8} & -\frac{1}{16} \end{bmatrix}$$

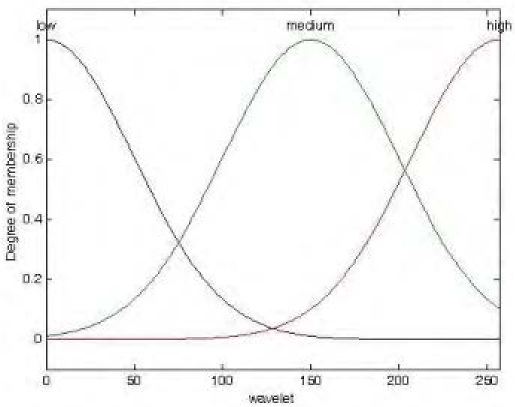


Figure 2: membership function of wavelet input of fuzzy system

Figure 3: obtained image by using high-pass filter on lena picture

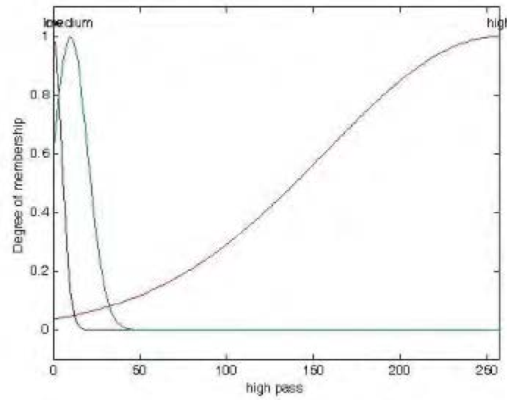


Figure 4: membership functions of second input of fuzzy system obtained by applying high-pass filter on picture.

Obtained inputs are given to Mamdani fuzzy system and the output is obtained based on membership function of figure 5. These membership functions are obtained based on trial and error experiment. Figure 1 shows the rules of conducted fuzzy system.

first input / second input	low	medium	High
Low	low	medium	High
Medium	medium	medium	High
High	high	high	High

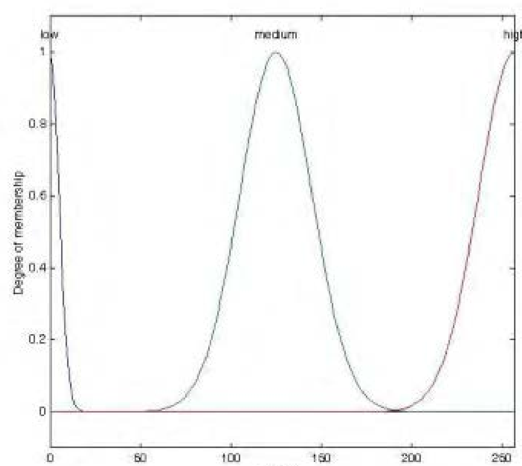


Figure 5:output membership function to edge detection of a picture

Finally, we can use threshold to extenuate the obtained edges.

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4 SUMMARIZATION AND COMPARISON

The proposed algorithm is done on Matlab software. Since there is no specific method to detect performance and priority of proposed algorithms except visual method, proposed method can be run on a number of images and we compared the obtained results by using Priot method by traditional edge detection methods. In figures 6,7, the results of proposed method and priot method [1] are shown on lena and camera man pictures. Obtained images show that proposed method has a hogher performance in edge detection than priot method. By using threshold level, we can reduce the edge width

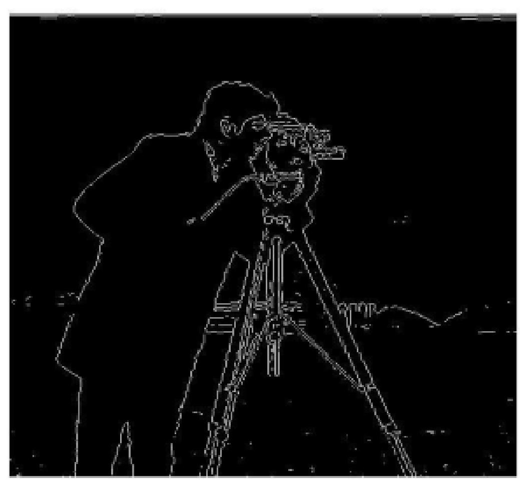
A)

B)

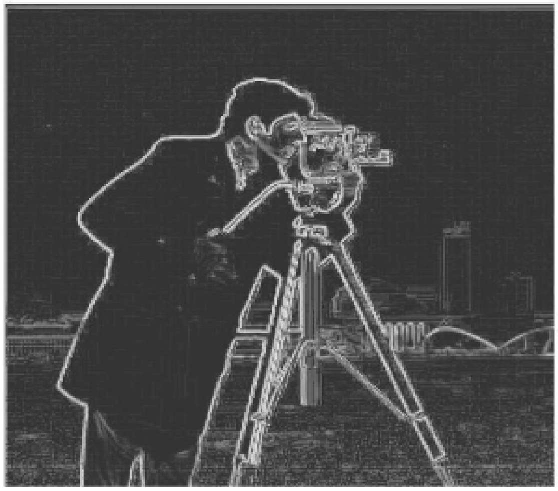
C)

Figure 6: A)original picture, B) edging by priot and C) edging by proposed algorithm

A)



B)



C)

Figure 7: A)original picture, B) edging by priot and C) edging by proposed algorithm

5 Conclusion

Edge detection plays an important role in image processing since its implementing success ensures the success on other stages of image processing. The proposed method in this article is a combination method of two methods of edge detection with wavelet and fuzzy system and it includes the advantages of two methods. Also, by selecting appropriate scale, we can reduce noise and on the other hand, by using fuzzy logic against ambiguities and image opaque which can be problematic for edging and by this, we can increase the performance of edge detection.

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