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Fuzzy Detection on Color Image

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Abstract

This paper describes a new color image edge detection method. Edge detection application based on fuzzy set theory is introduced in this paper. First of all, we design fuzzy inference engine to detect image edges. In inference engine step, two Gaussian membership functions in two directions (horizontal and vertical) are used for input signals. Finally, two triangle and one Gaussian membership functions were used for defuzzification step. By using fuzzy process and defuzzification, we obtain a relationship between input and output values. Simulation results show the proposed method outperformed conventional edge detection methods.

Keywords*: color image, membership function, quality enhancement, fuzzy model*

1. Introduction

Fuzzy technique is the fuzzy logic which is a feature of various valued logic [1-3]. Fuzzy technique is a method that describes features with artificial intelligence way, such as fuzzy sets. FST (fuzzy sets theory) is especially helpful in dealing different uncertainties in image processing applications [4-6]. There have been many images processing technique using FST, and one may can use particular fuzzy technique to solve the given problem [7]. Applications based on FST are edge detection, color image processing, image segmentation, and format conversion [8-10].

There are few steps in FST [11]. They are fuzzification step, inference step, and defuzzification step. In general, image enhancement using FST is gray level mapping into membership function with fuzzy strengthening factors [12-16]. The process of FST can be drawn in Figure 1.

The goal of edge detection is to recognize points in a digital image where the image intensity varies sharply. In other words, discontinuity is searched in edge detection process. The edge detection helps a system to notice important events and varies in properties of the world. Edge detection is one of the important steps in image processing, image analysis, image pattern recognition, and computer vision.

One of the earliest methods of edge detection is the Canny edge detection. The Canny edge detector uses a multi-step method to discern a wide range of edges in a given image. The step of the Canny edge detector is as follows:

Step 1: In order to remove noise from a given image, smoothing filter (Gaussian filter) is used.

Step 2: Intensity gradients of an image are evaluated.

Step 3: The non-maximum suppression is applied to remove false signal for the edge detection

Step 4: Double threshold is used to correctly conclude possible edges

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Step 5: Finish the edge detection by stopping all the other edge information and only strong edges are remained.

In this paper, a new edge detection method is proposed. Two famous conventional edge detection methods (Sobel and Prewitt) and the proposed method are described in Section 2. Simulation results are provided in Section 3, where visual quality of each method is compared. Finally, conclusion remarks are described in Section 4.

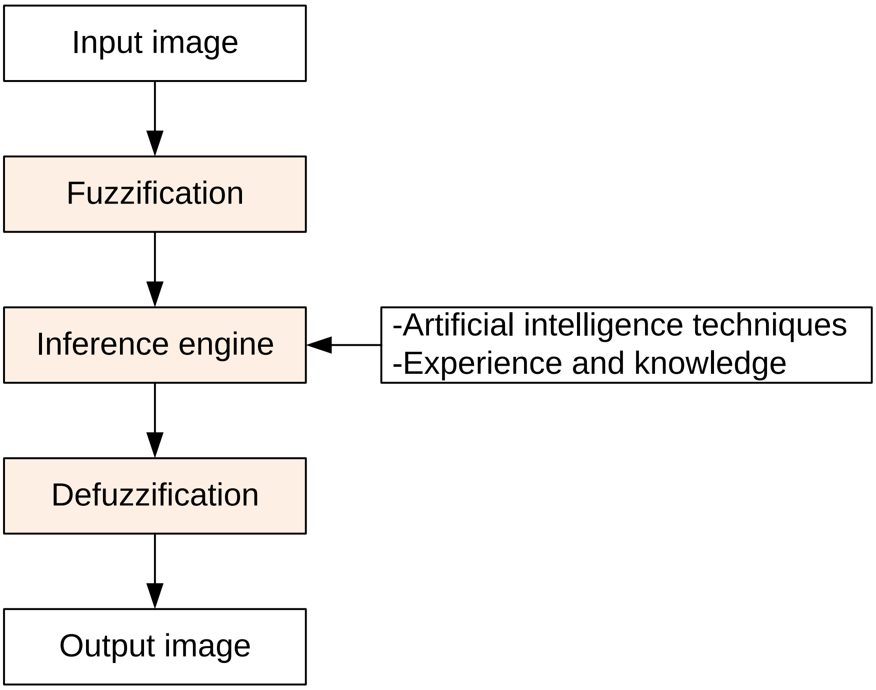


Figure 1. General Fuzzy Sets Based Image Processing Procedure

2. Proposed Method

There are two well-known conventional edge detection methods: Prewitt and Sobel. In a technical manner, both methods are discrete differentiation operators, calculating gradient approximations of the image brightness function. From each point in an image, Prewitt and Sobel operators' results are either the corresponding gradient signal or the norm of this signal. The Prewitt and Sobel operators are based on convolving the image with an *N*-by-*N* given size, separable, and integer valued filter in both of horizontal and vertical directions.

The Prewitt and Sobel operators use two 3-by-3 kernels which are convolved with the original signal to compute approaches of the derivatives. Two directions are used: horizontal and vertical. Let us assume *Im* as the original image, and D_H and D_V are two images which at each point include the horizontal and vertical derivative approaches.

$$D_H^P = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} * \mathrm{Im} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 1 \end{bmatrix} * \mathrm{Im}, \tag{1}$$

$$D_V^P = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} * \mathrm{Im} = \left(D_H^P\right)^T. \tag{2}$$

Here, * stands for the one-dimensional convolution operation. In the same manner, Sobel operations are determined as,

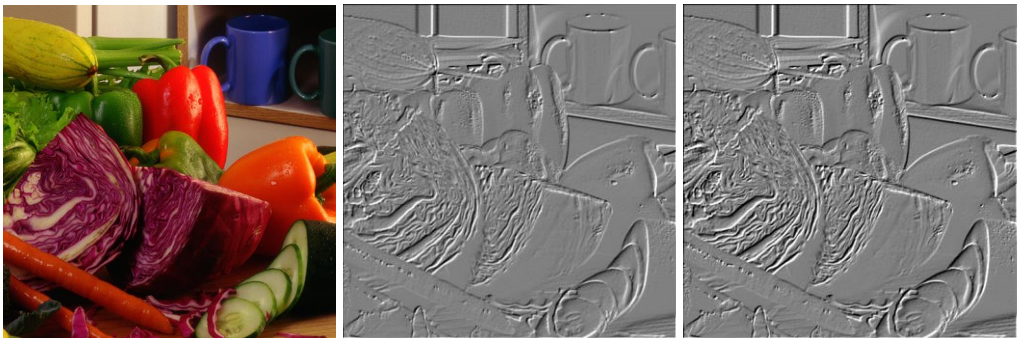
$$D_H^S = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * \mathrm{Im} = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 1 \end{bmatrix} * \mathrm{Im}, \tag{3}$$

$$D_V^S = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * \mathrm{Im} = \left(D_H^S \right)^T. \tag{4}$$

Figure 2 shows examples of Prewitt and Sobel operators. Figures 2(a), 2(b), and 2(c) are the original image, Prewitt and Sobel operators applied results. It can be found that Figure 2(b,c) are similar to each other.

In this paper, we first transform original RGB color image into YCbCr image and obtain luminance information Y. A command rgb2ycbcr is used to transform three channels RGB image into YCbCr. Now, the fuzzy logic is applied in Y signal. The fuzzy logic edge direction method depends on the image gradients. We used simple Robert operators to obtain horizontal and vertical gradients, and we note them as Rx and Ry. Parameters Rx and Ry are ordinary gradient filters. Convoluted results of both parameters Rx and Ry and Im, gradients of Y are computed. It is noted that all gradients values are limited [-1 1].

Figure 3 shows The proposed edge detection method. Figure 3(a) shows original #10 McM image, and detected edges in three directions, horizontal, vertical and diagonal, are provided.

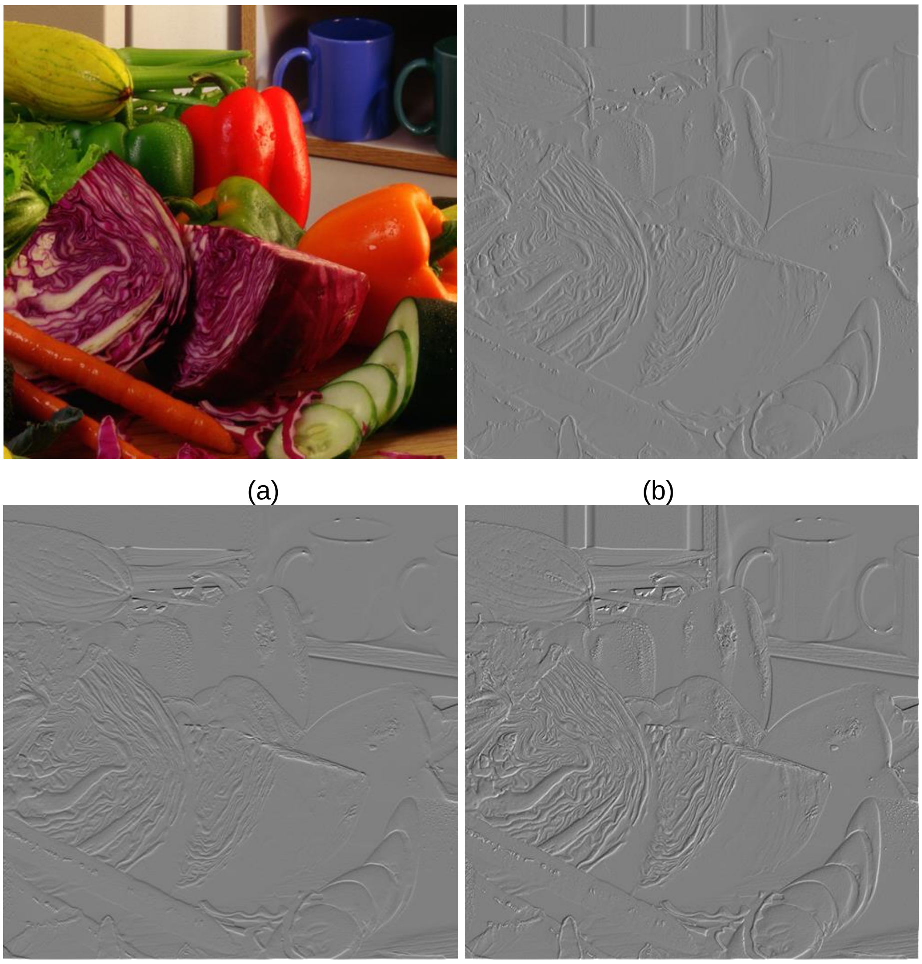


(a) (b) (c)

Figure 2. Conventional Edge Detection Method on #10 McM Image: (a) Original, (b) Prewitt, and (c) Sobel

Defining fuzzy inference engine (FIE) is important step for detecting image edges. To do so, we used two Gaussian membership functions in horizontal and vertical directions as input signals as shown in Figure 4. Normally, a membership function is a curve that describes how each pixels in the input space, universe of discourse, is transformed to a degree of membership which has value between [0 1].

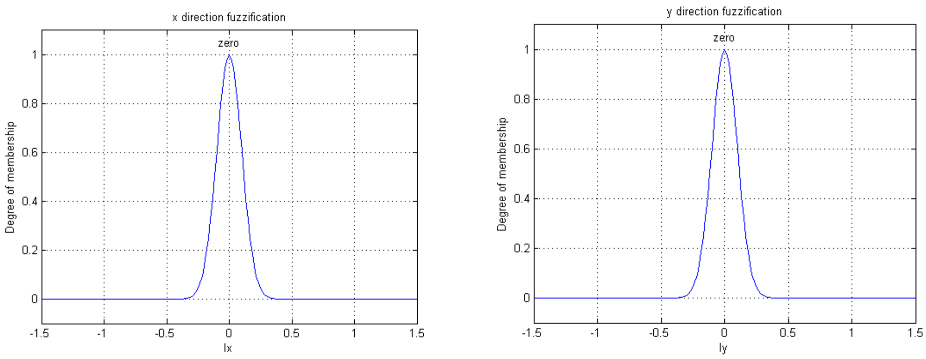
For output signal, we used two triangle membership functions and one Gaussian membership function (Figure 5). To obtain out signal we need defuzzification process which is of generating a quantifiable signal in fuzzy logic, provided FS and matching membership degrees (MD).



(a) (b)

(c) (d)

Figure 3. Proposed Edge Detection Method: (a) Original #10 McM Image, (b) *x* Direction, (c) *y* Direction, and (d) Diagonal Direction



(a) (b)

Figure 4. Fuzzification Process: Gaussian Membership Functions in Horizontal and Vertical Directions as Input Signals

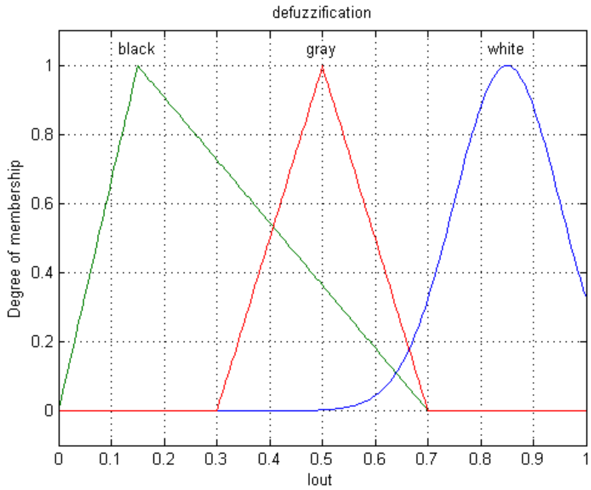


Figure 5. Two Triangle Membership Functions are used for 'Black' and 'Gray'. One Gaussian Membership Function is used for 'White'

Two membership functions used in this paper are gaussmf and trimf. Both membership functions are defined as

$$gaussmf = f(x;\sigma,c) = e^{\frac{-(x-c)^2}{2\sigma^2}}, \tag{5}$$

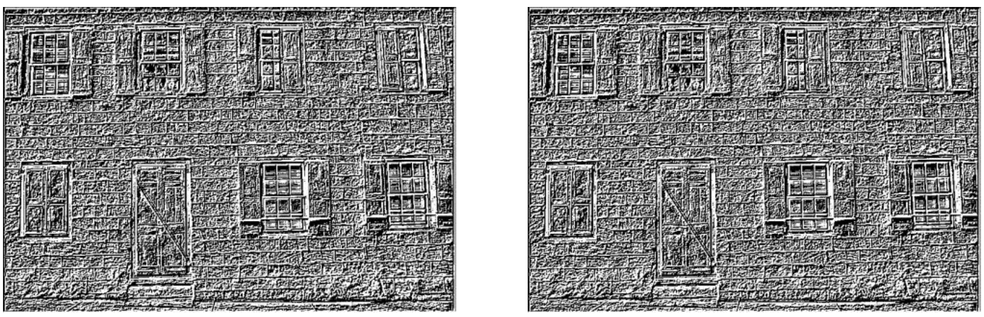
$$trimf = f(x;a,b,c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases}, \tag{6}$$

$$trimf = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right). \tag{7}$$

Our employed fuzzy if-then rules are defined as follows:

if condition is A, ***then*** employed operation is result$_A$., (8)

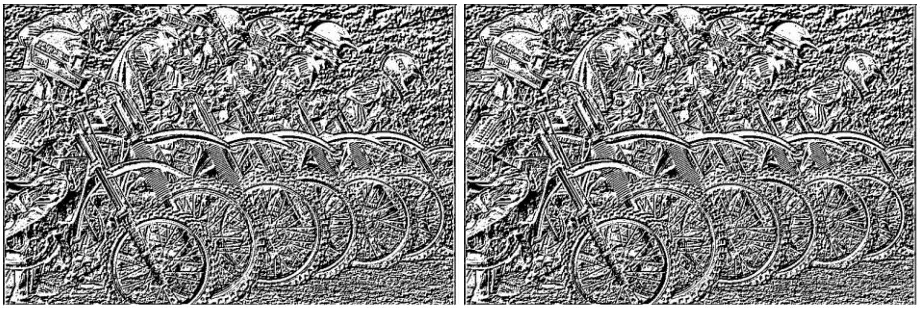
3. Experimental Results



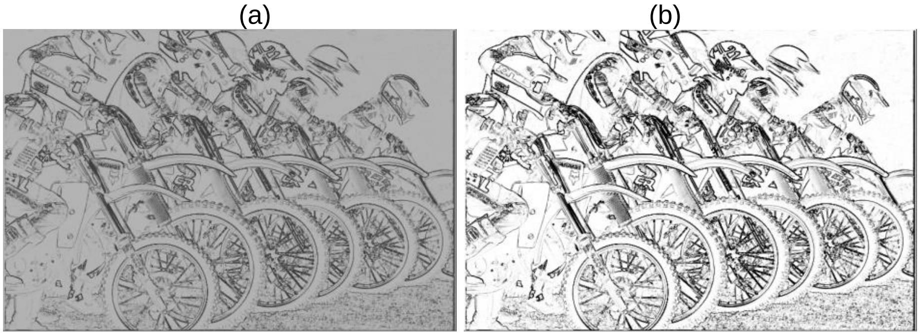
(a) (b)

(c) (d)

Figure 6. Edge Detection Comparison On #1 Kodak Image: (A) Prewitt, (B) Sobel, (C) Proposed 1, and (D) Proposed 2

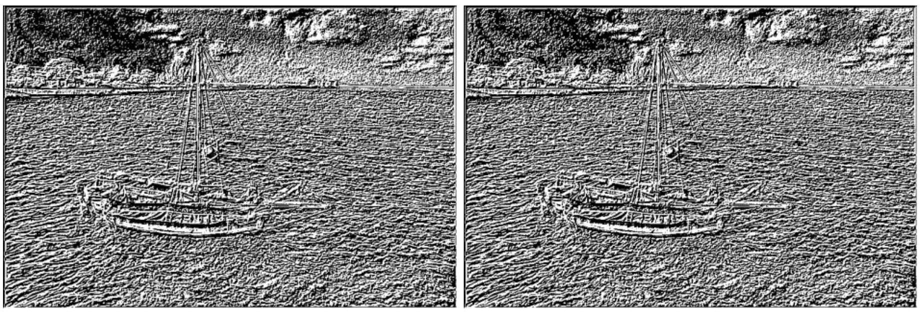


(a) (b)

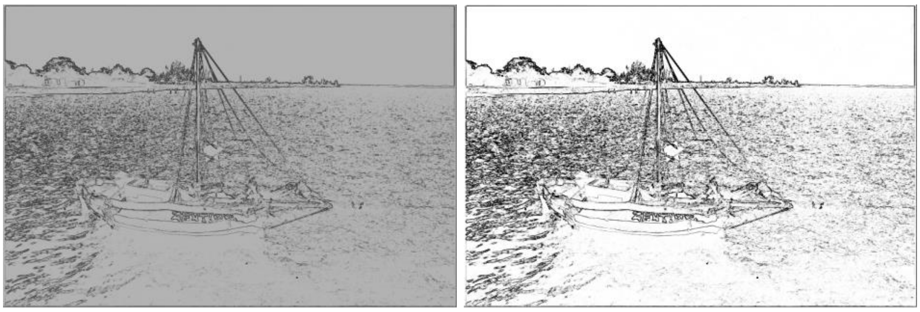


(c) (d)

Figure 7. Edge Detection Comparison on #5 Kodak Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2

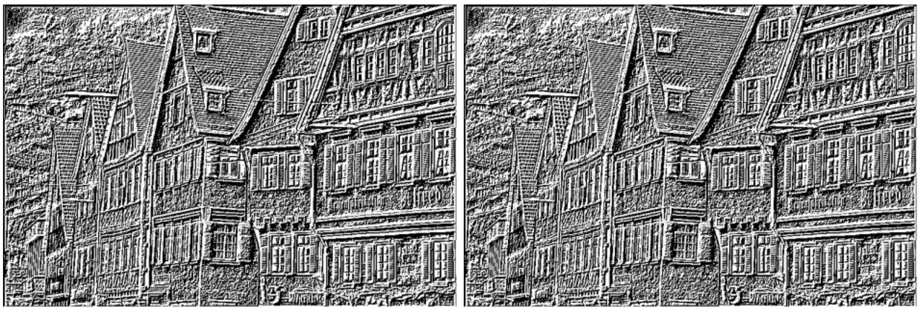


(a) (b)

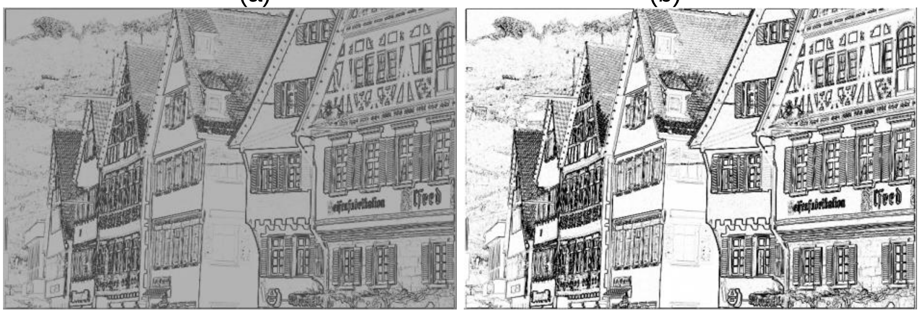


(c) (d)

Figure 8. Edge Detection Comparison on #6 Kodak Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2

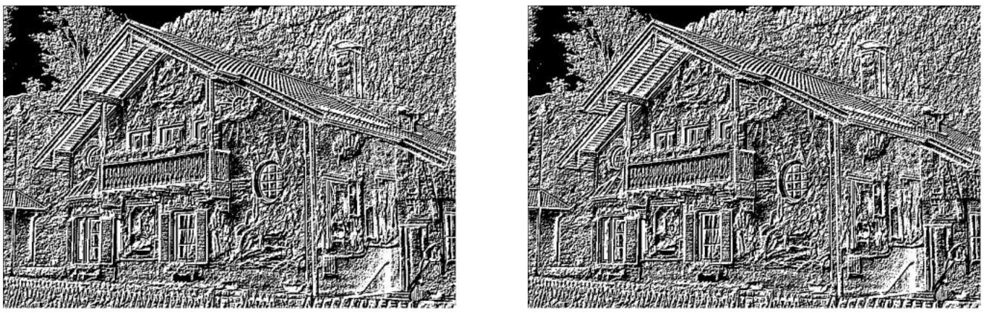


(a) (b)

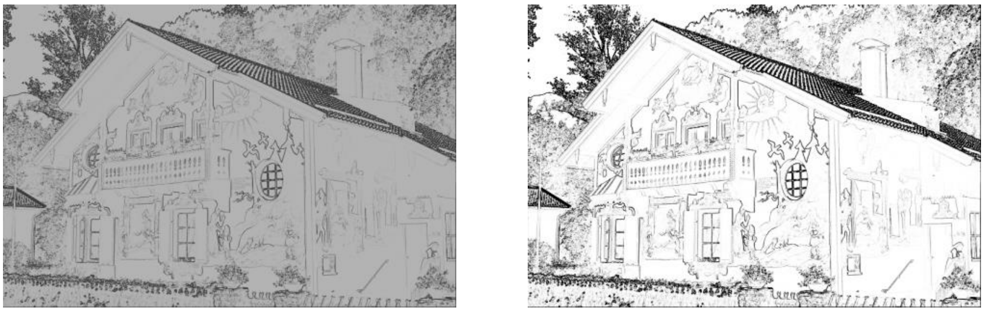


(c) (d)

Figure 9. Edge Detection Comparison on #8 Kodak Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2



(a) (b)



(c) (d)

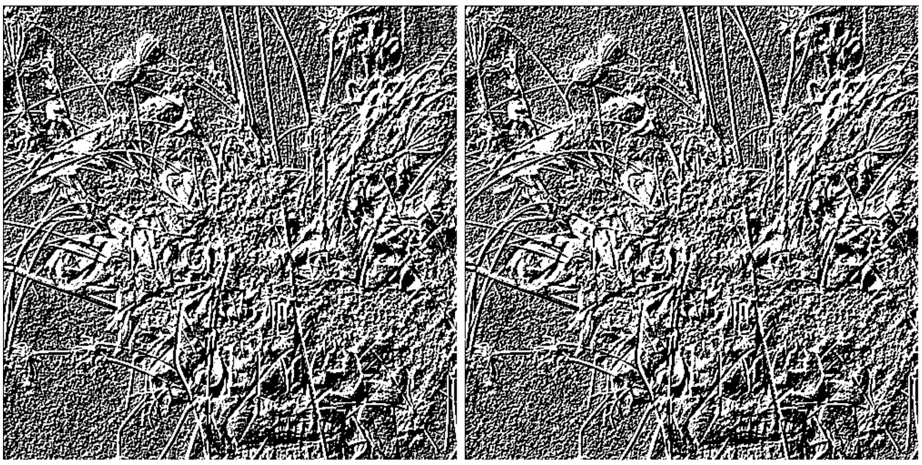
Figure 10. Edge Detection Comparison on #24 Kodak Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2

The proposed approach is tested using MATLAB 7.0 on 24 Kodak and 18 McM dataset. Their subjective performance is compared and displayed. Kodak dataset has 24 images with 768×512 and McM dataset has 18 images with 512×512.

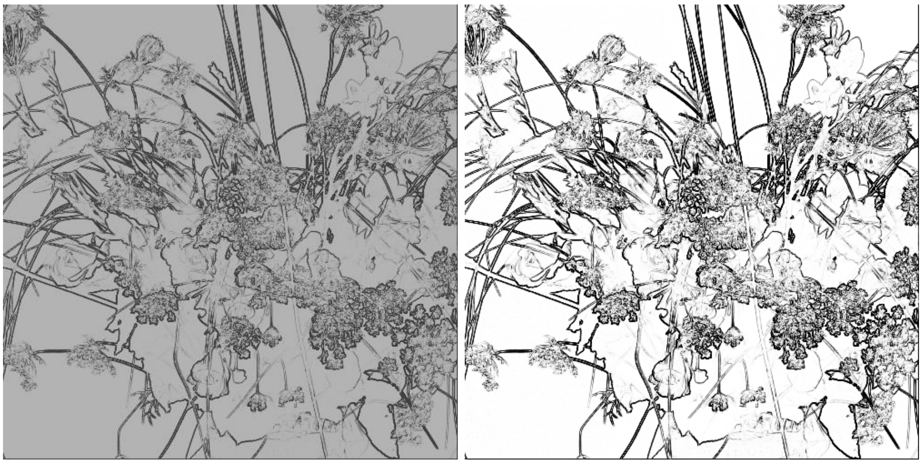
Figures 6-10 show visual comparison on five Kodak images. They are #1, #5, #6, #8, and #24. Images (a) of Figure 6-10 are Prewitt operation applied images and images (b) of Figure 6-10 are Sobel operation applied images. Images (c) of Figure 6-10 are proposed results using fuzzy theory. Finally, images (d) of Figure 6-10 are its normalized results, of which minimum value is 0 and maximum value is 1.

The same approach has been applied to McM dataset. Two images were used for visual performance comparison: #3 and #4. Images (a) of Figure 11 and 12 are Prewitt operation applied images and images (b) of Figure 11 and 12 are Sobel operation applied images. Images (c) of Figure 11 and 12 are proposed results using fuzzy theory. Finally, images (d) of Figure 11 and 12 are its normalized results, of which minimum value is 0 and maximum value is 1.

Histogram analysis results are shown in Figure 13 and 14. In Figure 13 and 14, histograms of #3 and #4 of McM image are shown. Images (a), (b), (c), (d) are Prewitt, Sobel, proposed 1, and proposed 2, respectively.

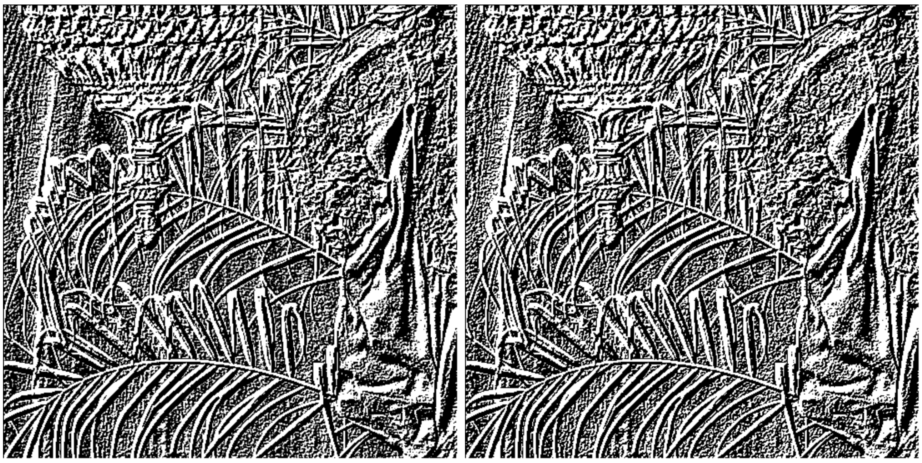


(a) (b)

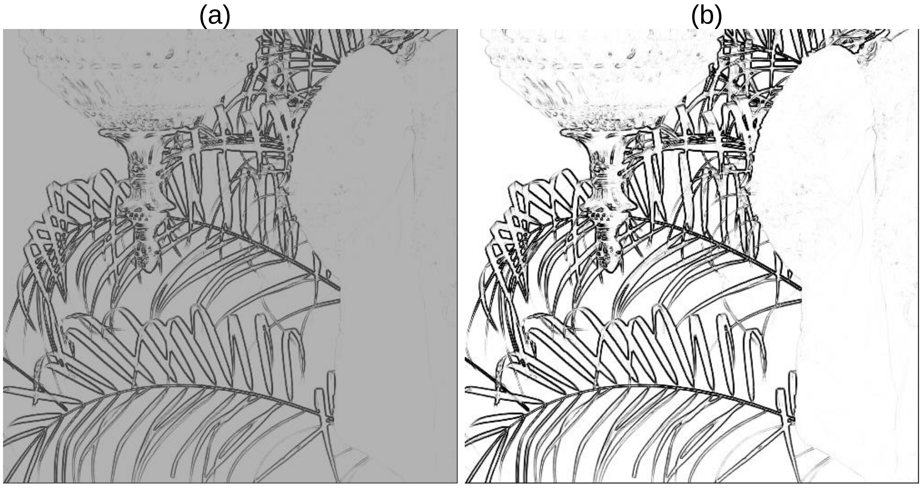


(c) (d)

Figure 11. Edge Detection Comparison on #3 McM Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2



(a) (b)



(c) (d)

Figure 12. Edge Detection Comparison on #4 McM Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2

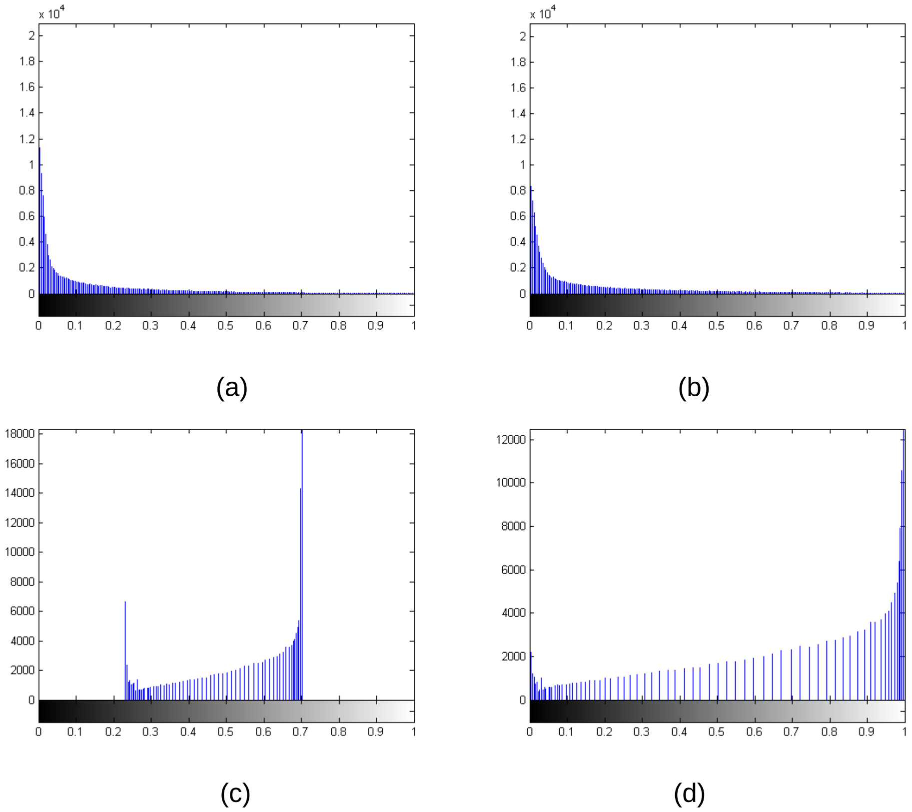


Figure 13. Histogram of #3 McM Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2

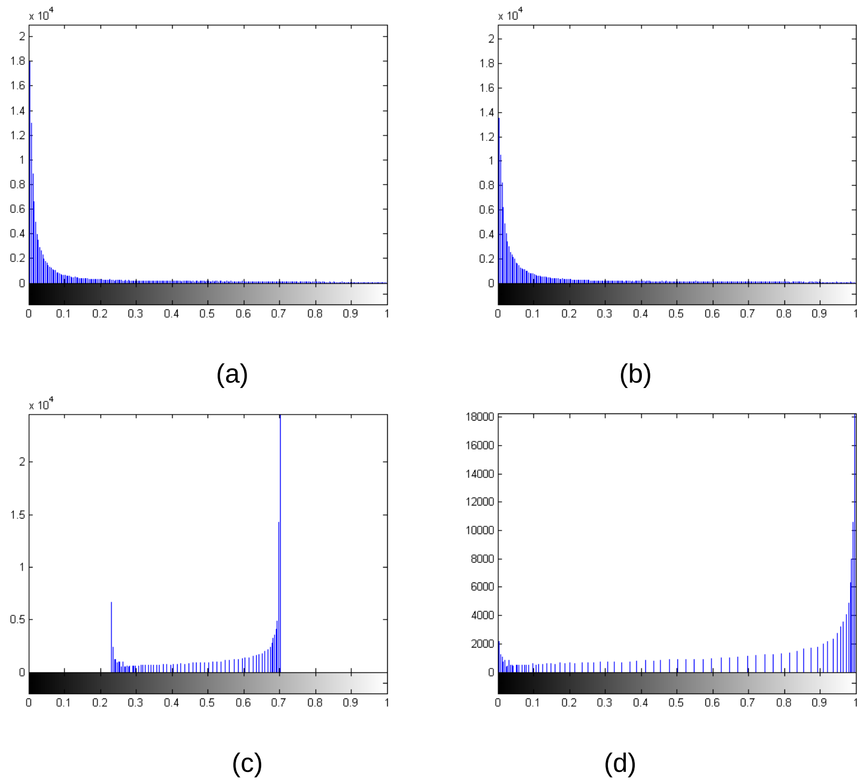


Figure 14. Histogram of #4 McM Image: (a) Prewitt, (b) Sobel, (c) Proposed 1, and (d) Proposed 2

4. Conclusions

In this paper, we studied a new color image edge detection algorithm. The fuzzy inference engine was defined and used for detecting image edges. Some membership functions (Gaussian membership functions and triangle membership functions) were used for designing fuzzy inference system. By applying fuzzification and defuzzification, we found a relationship between input and output values. Experimental results show the proposed method outperformed conventional edge detection methods.

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