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A Combined Approach for Edge Detection in Images with Gaussian and Salt-And-Pepper Noises Using Fuzzy Logic and Traditional Sobel Method

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Abstract - *In this paper, using a combination of fuzzy inference rules and traditional Sobel method, a method is presented for edge detection in digital images with noise. In the proposed method, at first an image is scanned by a 2 × 2 mask and at each step of the survey 4 pixels are sent to the input of Gaussian membership function. The membership function classifies the pixels based on fuzzy logic. The values of fuzzy sets made are adjusted by 16 rules and then the main edge candidates are introduced. In the next step the output of fuzzy approach is multiplied by a 5 × 5 Gaussian mask to reduce the residual noise in the image and the obtained output is detected by traditional Sobel detector. The results of this simulation shows the high performance of fuzzy logic and Gaussian filter to reduce noise; so that the proposed method shows a good resistance against salt-and-pepper and Gaussian noises compared to traditional Sobel method. Also this method does not have the problem of pointed images and detects the edge as continuous and smooth.*

Key Words: Sobel edge detector, edge detection, fuzzy membership function, fuzzy logic, Gaussian noise, salt-and-pepper noise

1. INTRODUCTION

Edges are an important element in image processing [1]; because if the edges in an image are specified, the location of all objects in the image can be specified and their basic properties such as surface, environment and etc. can easily be measured. In past years, researchers have considered the problem of edge detection but despite the extensive work done in this field, no appropriate and comprehensive solution have been provided for the accurate detection of edges or the edge of the image regardless of scale or shape of the edge. Also, in recent years a variety of edge detection methods have been studied. Using Fuzzy Cellular Automata [2], the fuzzy- competitive detector [3], using fuzzy systems type 2 [4] using fuzzy – neural system [5], multi-scale wavelet transform [6], Boolean derivatives [7] and ant colony search algorithm [8] are the methods for edge detection based on artificial intelligence. Among the intelligent algorithms, fuzzy logic has achieved acceptable results in terms of accuracy and performance compared to other edge detection methods due to its high flexibility. There are many studies on different fuzzy systems for edge detection in digital images that try to improve the noise reduction and edge detection. [9-12]. In this regard, in the next paragraph several methods have been mentioned that tried to improve edge detection and provide edges with higher quality under different conditions.

Aborisade in [13] proposed an algorithm based on fuzzy logic in which the edges were calculated at each pixel using three 3 × 3 linear spatial filters namely low-pass, high-pass and edge enhancement filter (Sobel) through the spatial convolution process. Then, the edge strength values obtained from the three masks are used by three sets as the fuzzy system input and the decision is made based on the Gaussian membership functions and fuzzy system rules about whether the target pixel belongs to an edge or not.

In another work by bhagabati and Das, an edge detection method was provided based on fuzzy rules. They surveyed the image by a 2x2 mask and at each stage of survey entered the value of 4 neighbor pixels to classify the membership function. After the classification, 10 inference rules modified the pixel values [14]. Surykant and colleagues in [15] presented a fuzzy algorithm that did not use any threshold value to remove the strong edges. Their proposed system had eight inputs and one output that specified the output value of pixels containing "black", "white" or "edge". In a similar work [16] the authors proposed the use of membership functions, with eight inputs and one output with the difference that the number of inference rules used in the system is less than the method [15].

An important theme in the work done in this field appears only in the performance of these algorithms is tested on noise-free images. That occurs when the noise has a large impact on the quality, accuracy, position and affiliation lines of the final image. According to the important characteristic of uncertainty in fuzzy logic, we try to offer a fuzzy method based on Sobel edge detection techniques. It should be noted that the Sobel edge detector is a simple and effective method, but is sensitive to noise and this is one of the problems with this method. Sobel method has also another problem that is the dual edges [16]. The aim of this study is to introduce a hybrid algorithm which has good resistance to deal with images containing noise and prevents double edges.

Traditional Sobel edge detection operator

Sobel algorithm is one of those traditional algorithms that use the first derivative of the image for edge detection. This algorithm uses the derivative value of each pixel and its neighbors to determine whether the pixel is on the edge or not. In traditional edge detection, no filter is used for image smoothing and they have been based on a discrete differential operator. Usually, these methods are simply calculated and have the ability of edge detection but given the lack of smoothing steps, its techniques are very sensitive to noise and error. Sobel operator is known among more traditional methods. In Sobel edge detector, the complexity operations of the image gradient is applied to a two-dimensional space and the mask convolution , that has been demonstrated in equation (1), is used for to calculate the gradient in two directions (rows and columns), so that the final gradient of the pixels are achieved by equation (2).

$$gx = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}, gy = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \quad (1)$$

$$g = |gx + gy| \quad (2)$$

After calculating the gradient, the pixels intensities should be controlled in the range [255 ... 0] to display the edge detected image. The Sobel algorithm performs this task through a threshold, so that if the pixel intensity was more than threshold is considered as 255 and if it was smaller is considered as zero. Sobel edge detector is a simple and effective method, but is sensitive to noise. In addition, the thickness of detected edges may not be suitable for the applications that require detecting the utmost boundary in an object.

2. The proposed method

The proposed method is a hybrid algorithm which consists of three parts. First, the matrix values of the image intensity are adjusted by the fuzzy method. In this case, the fuzzy system receives four neighboring pixels P1, P2, P3, P4 through surveying the image using a 2 × 2 mask and then delivers the pixels in 4-item categories as input to a Gaussian membership function. Input membership functions shown in Figure (1) divide fuzzy black and white pixels into two categories. As shown in Figure 1, the x-axis in this function is in the range 0 to 255 because our input image is 8-bit and the values of the intensity matrix is a number between 0 and 255; Also since our membership function is a fuzzy membership function the y-axis of this function is in the range 0 to 1. With this definition, we can say that at this stage the intensity values have been fuzzificated in the range of 0 to 1. The range considered for the pixel intensity values of the membership function is as follows (Figure 1).

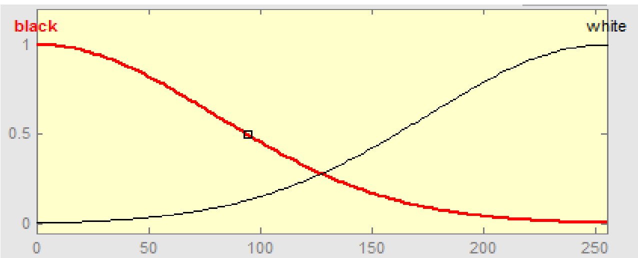


Figure 1: Gaussian membership function defined for input pixels

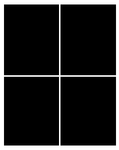
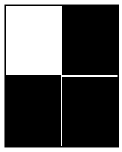
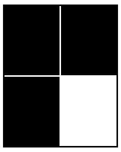
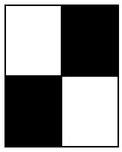
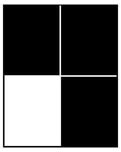
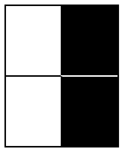
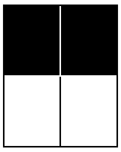
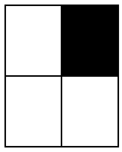
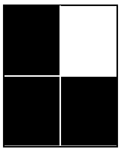
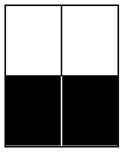
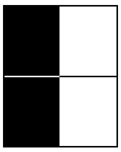
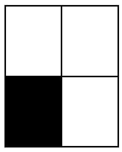
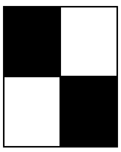
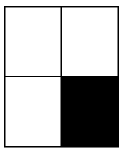
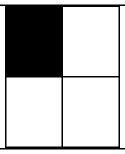
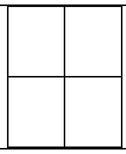
Black = [0 0 120 180]
White = [102 172 256 256]

After this stage, the fuzzy rules are extracted that is considered as the most important component of the fuzzy system because it adjusts the membership function and specifies the edges of the image. It should be noted that the rules have been experimentally obtained and the operator "and" is sued between if statement (if - then). These the rules are defined regarding the weight of the neighboring pixels P1, P2, P3, and P4 that have two quantities of black and white. When the adjustment was done by these rules, all rules are combined in a fuzzy set operator "or" (maximum) and are defuzzificated in the final part of fuzzy output by Mamdani defuzzificator to obtain the output. In our method, the final data is calculated through Centroid method and this method is for obtaining a single value from the collected output by fuzzy that calculates the center below the curve. In this study, 16 rules have been used for edge detection and Table 1 shows the above inference rules.

P1	P2
P3	P4

Mask 2×2

Table 1: inference rules defined to modulate the intensity values of neighboring pixels in the

	If P1,P2,P3,P4 is Black Then P4 is Black		If P2,P3,P4 is Black and P1 is White Then P4 is edge
	If P1,P2,P3 is Black and P4 is White Then P4 is edge		If P2,P3 is Black and P1,P4 is White Then P4 is edge
	If P1,P2,P4 is Black and P3 is White Then P4 is edge		If P2,P4 is Black and P1,P3 is White Then P4 is edge
	If P1,P2 is Black and P3, P4 is White Then P4 is edge		If P2 is Black and P1,P3,P4 is White Then P4 is edge
	If P1,P3,P4 is Black and P2 is White Then P4 is edge		If P3,P4 is Black and P1,P2 is White Then P4 is edge
	If P1,P3 is Black and P3,P4 is White Then P4 is edge		If P3 is Black and P1,P2,P4 is White Then P4 is edge
	If P1,P4 is Black and P2,P3 is White Then P4 is edge		If P4 is Black and P1,P2,P3 is White Then P4 is edge
	If is Black and P2,P3,P4 is White Then P4 is edge		If P1,P2,P3,P4 is White Then P4 is White

Our desired output value is 3:
1 - Black 2 - Edge 3 – white that were used for Gaussian bilateral membership functions to produce the output. Above inference rules specify the value of each category and send to the final output. For the output, such as membership functions input a range is specified for the black, white and edge pixels which represents the intensity value of the pixel in the final image (Figure 2).
Black = [1 3 1 4]
Edge = [1 132 1 133]
White = [1 250 1 251]

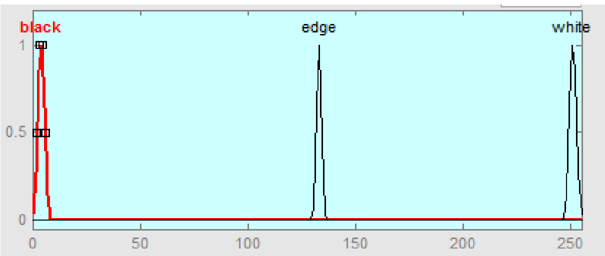


Figure 2: Composite bi-lateral Gaussian membership function to determine the values of output pixels

Gaussian filters are used extensively in biomedical image processing and are extremely useful for edge detection. Gaussian-based edge detection is able to perform the analysis of scale-space edge based on biological observations on some important properties of the Gaussian function. Gaussian filter should be used in the image before the edge detection and its aim should be reducing the sensitivity to noise and edge detectors, so that the residual noise on the edge reaches to its lowest amount.
In the second part of the algorithm, the defuzzificated image in the previous step with a 5 × 5 Gaussian mask with standard deviation of 1.4, which was demonstrated in equation (3), is convoluted by equation (4). In explaining the relationship between two-dimensional convolutions, it must be said that in this equation if a, b are the function of two discrete variables such as n2, n1, then the two dimensional convolution formulas a, b can be obtained as follows. The result of the operation is a smoothed image. A better definition is that the Gaussian filter fades the noises in the image that have not been classified well in the fuzzification adjustment.

$$\frac{1}{115}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} \quad (3)$$

$$c(n_1,n_2) = \sum_{k_1=-\infty}^{\infty}\sum_{k_2=-\infty}^{\infty} a(k_1,k_2)b(n_1-k_1,n_2-k_2) \quad (4)$$

In the third part, which is in fact the final step of the algorithm, we need to detect edges in the image. For this purpose, we automate the output of the previous section that corresponds to the convolution of the image with a Gaussian mask as the input through Sobel edge detection method with a estimated threshold and the edge detection operations are done based on this algorithm.

3. COMPARISON

In the last section, our proposed strategy for edge detection in noisy images has been illustrated. In this section, we compare the output of our proposed method by implementing on images containing Gaussian and salt and pepper noises in order to show the performance of our algorithm against noise. Sobel edge detection algorithm is one of the discussed algorithms in the area of edge detection that is used in most articles due to its favorable results in the area of edge detection. We have also used this algorithm and compared the simulation results with a fuzzy edge detection algorithm. It should be noted that the simulation and comparison of our results were performed in 2012 version of MATLAB software and the selected threshold is automated.

4. STUDYING THE SOBEL EDGE DETECTION ALGORITHM ON IMAGES WITH GAUSSIAN AND SALT AND PEPPER NOISES

As shown in Figures (4 and 3), the Sobel operator in images edge detection with Gaussian noise has three basic problems: first it failed to eliminate the noise in the image and there are scattered noises in many parts of the image. Second, the detected edges are not separable, for example on the camera's stands the upper and lower edges are conjoined; and the last problem is that the n conjunction of detected edges is weak.
About the addition of salt and pepper noise in figures (6, 5), it should be noted that Sobel algorithm could not control the noise in the image and the image noise can be observed in all areas.

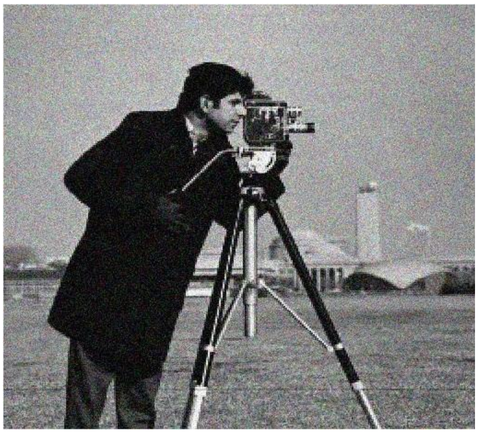
5. COMPARING THE PROPOSED METHOD WITH FUZZY METHOD

Figure (7) shows that the proposed method is superior to the output of a fuzzy method [13] because in the lamp image the thickness of detected edges is thinner. The effects of noise have been completely lost. Another problem in the output of the fuzzy method is that in the bottom of the lamp image an area of several neighbor pixels have been considered as edges that have led to the deterioration of the original edge. In the proposed method, there are not such problems and it could solve one of the major challenges of edge detection that is detected edges with high thickness. The proposed method is considered superior by comparing the output of the proposed method with the output of the fuzzy method in the glass image, because the detected edges by this method are much smoother and have more powerful edges. Another comparison shows that n in the upper part of the glass image (input), we see a noticeable change that the fuzzy algorithm failed to identify the change while the proposed method identified the intensity of pixels.

6. CONCLUSION

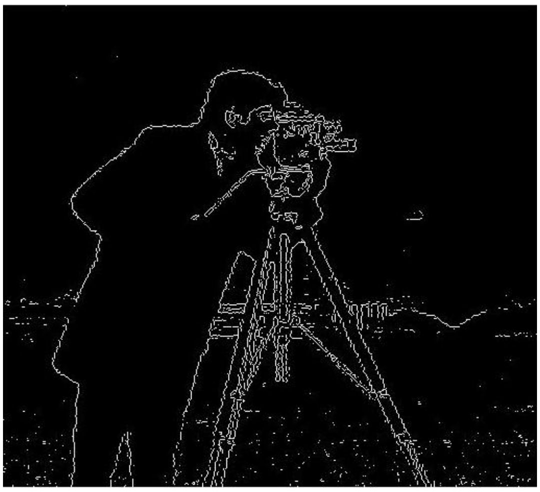
It can be said that one of the major challenges in the field of image processing is to detect and reduce the noise from the obtained data. This paper presents a new method for edge detection that provides the ability to detect and remove Gaussian and salt and pepper noises. We used the ability of fuzzy method in separating the strong edges from the weak ones and the ability of Gaussian filter to reduce the algorithmic noise. The results of comparing several noise images with Sobel and fuzzy algorithms showed that this approach presents better results than the methods presented above in dealing with the noise, so that:

1. It prevents the creation of sub-edges caused by noise.
2. In addition to the removal of noise, the structures of edges are protected well and show the edges continuous, thin and separable.
3. Unlike the Sobel method, it could identify the main edges of the image while not sacrificing the noise removal for the edge removal.

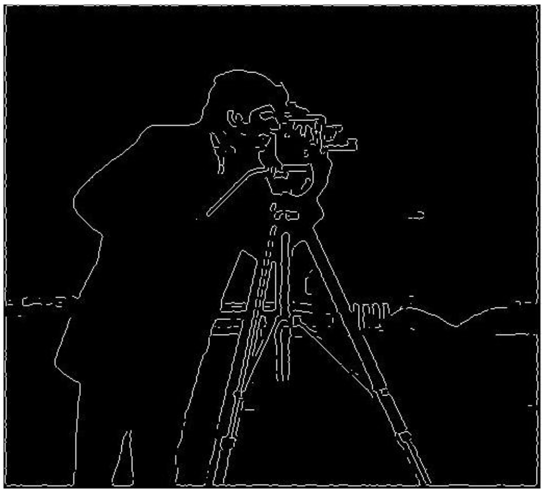


The original image

Image with Gaussian noise



A) The output of the Sobel algorithm



B) The output of the proposed method

Figure 3: Comparison of the performance of the proposed method with Sobel algorithm in cameraman image with Gaussian noise

The original image

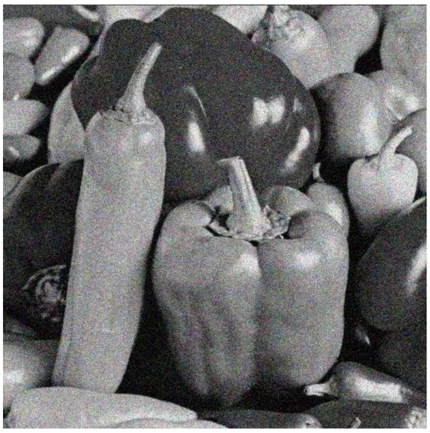


Image with Gaussian noise

A) The output of the Sobel algorithm

B) The output of the proposed method

Figure 4: Comparison of the performance of the proposed method with Sobel algorithm in pepper image with Gaussian noise

The original image

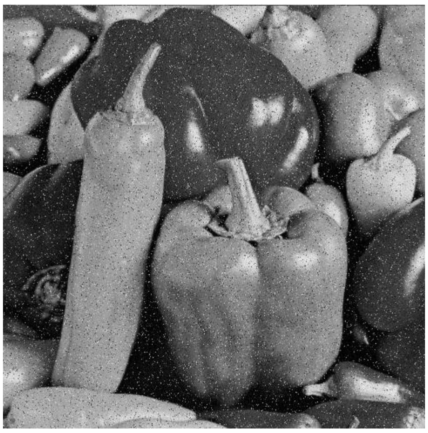


Image with salt and pepper noise

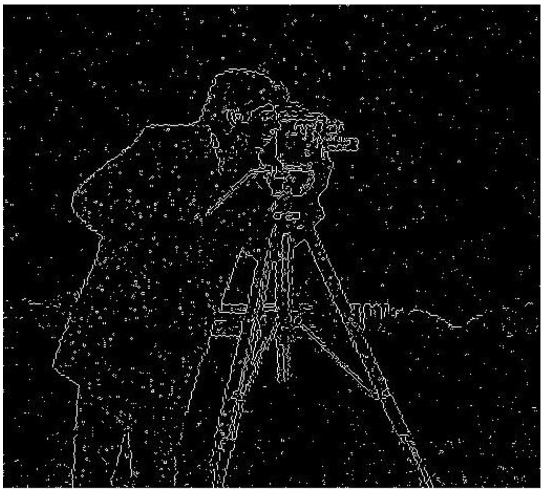
the output of the Sobel algorithm

B) The output of the proposed method

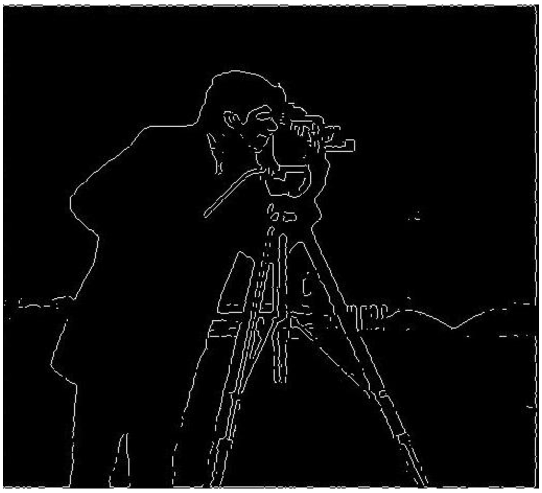
Figure 5: Comparison of the performance of the proposed method with Sobel algorithm in pepper image with salt and pepper noise

The original image

Image with salt and pepper noise

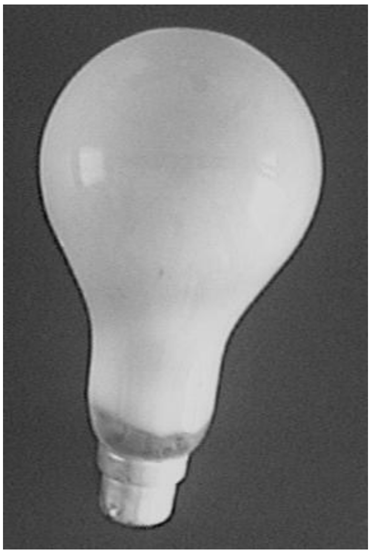


The output of the Sobel method

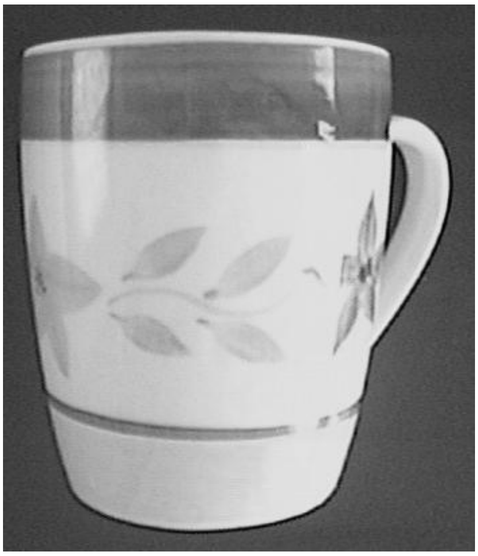


The output of the proposed method

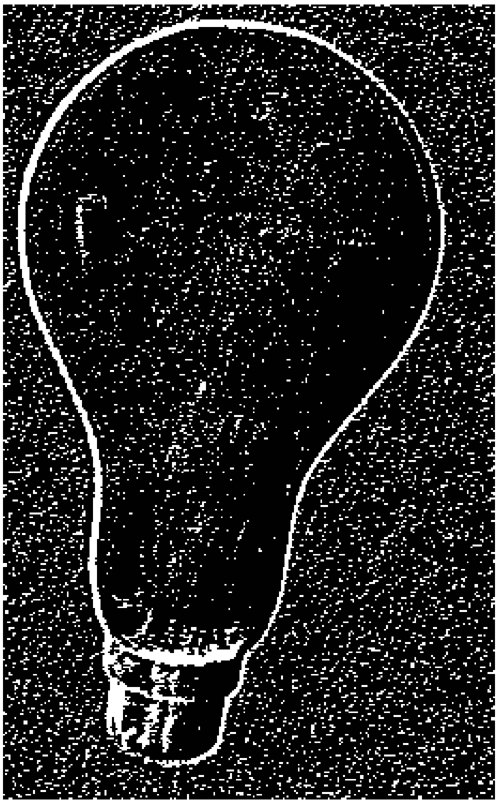
Figure 6: Comparison of the performance of the proposed method with Sobel algorithm in cameraman image with salt and pepper noise



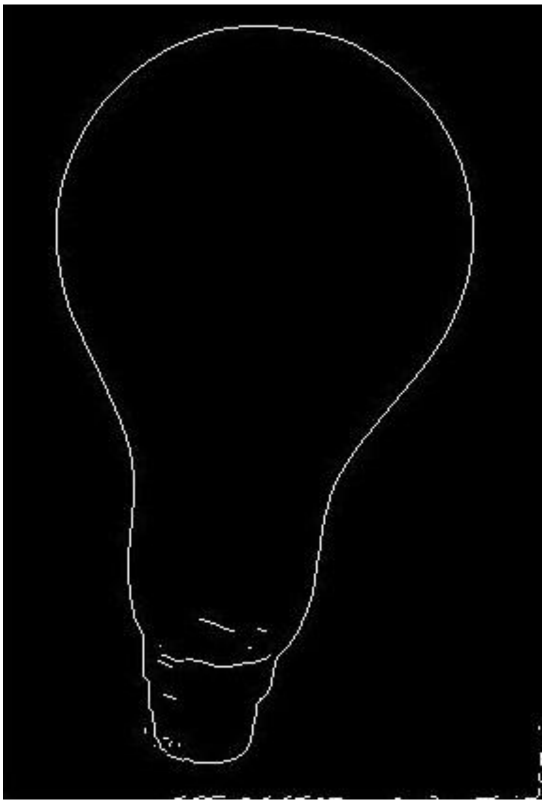
Input image 1



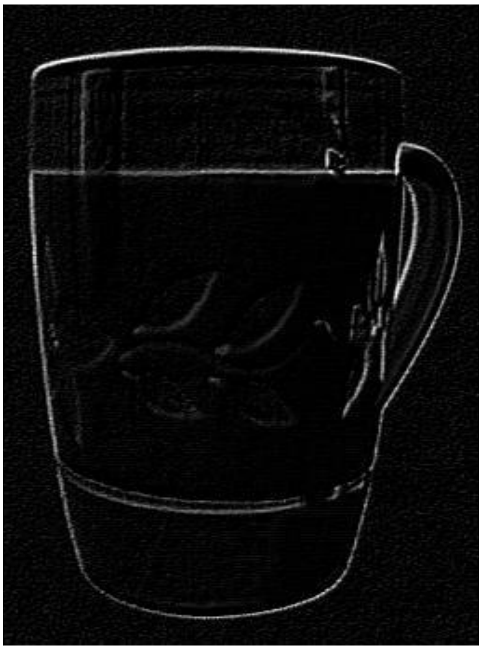
Input image 2



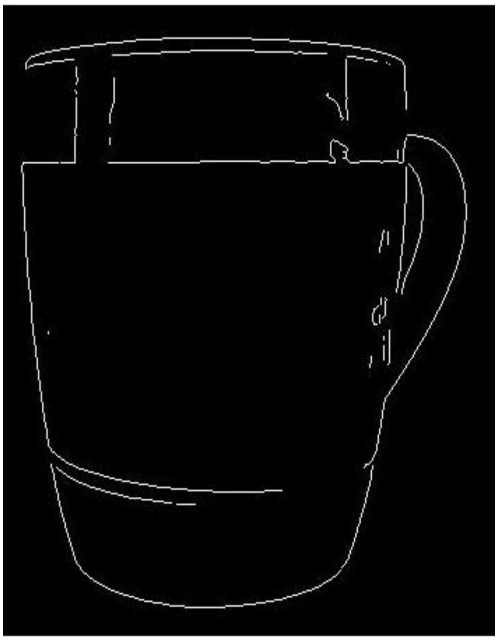
The output of fuzzy method



The output of the proposed method



The output of fuzzy method



The output of the proposed method

Figure 7: Comparison of the performance of the proposed method with fuzzy algorithm Figure 7: Comparison of the performance of the proposed method with fuzzy algorithm [13]

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