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A Novel Hybrid Technique for Sub-pixel Edge Detection using Fuzzy Logic and Zernike Moment

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Abstract— This paper is based on the development of fuzzy Logic based edge detection techniques in digital images. The proposed technique used Sobel operator, Zernike moment operator, and Fuzzy inference system in combination for edge detection purpose. Edge is a boundary between two homogeneous regions. Edge detection refers to the process of identifying and locating sharp discontinuities in an image. In this paper, the main aim of edge detection technique is to filter out unnecessary, false and double edges in the final image.

Index Term— Edge Detection, Fuzzy Logic, Image Processing, Fuzzy Infrence System, Zernike Moment

Introduction

A fundamental step in any computer vision system is to find the key features in an image. The feature extraction relies on the detection of edges. Edge detection is the name for a set of mathematical methods which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed edges. The main purpose of edge detection is to simplify the image data in order to minimize the amount of data to be processed [4]. The edges of an object rarely fall on pixel boundaries. Sub-pixel location accuracy of edges is required in many critical applications like medical image, image measurement, remote sensing, and satellite imagery.

Edge detection is an important technique in many image processing applications such as object recognition, motion analysis, etc. So far a lot of edge detection methods have been developed, among which these technique can be classified into pixel-level and subpixel-level edge detection [1].There are three methods in sub-pixel edge location: fitting-based method, interpolating-based method and moment based method [2]. In fitting based method the image data of a real edge could be similar to the ideal edge model in either one-dimensional or two-dimensional aspects. Edge fitting detection, however, requires more computation in comparison with derivative edge detection techniques. Interpolation methods are of two type's linear interpolation method and non linear interpolation method .Image Interpolation aims to reconstruct a higher resolution (HR) image of the associated low-resolution (LR) capture. But the problem of accuracy cannot be overcome with interpolation method. Some techniques such as non-maximum suppression or zero-crossing may reduce the necessity of threshold. Nevertheless, with the presence of noise, threshold is still required to distinguish real edges from noise. The focus of this paper is on moment based techniques. Among the moment based operators introduced to locate sub-pixel edges there are methods based on gray level moments, geometric moments, and Zernike moments. Lyvers et al. proposed an efficient method based on geometric moments for sub-pixel level edge detection. The method uses six spatial moments and a 3-D edge model. The computational load of this method is high [9]. Ghosal et al. introduced a new method based on Zernike moments, which only uses three masks to evaluate four parameters of ideal step edge. One important advantage of this method is that the run time can be saved 33%.

In summary, pixel-level method has the advantage of fast processing, while subpixel-level method has the advantage of detection precision. In this paper we introduce a new approach that combines pixel level method with sub pixel level method. To improve run time and precision in edge detection method we combine Sobel operator with fuzzy inference system to detect edge pixel and then actual edge is detected using Zernike moment operator.

SOBEL Operator

Sobel operator is pixel level edge detection method; it is discrete differentiation operator which computes the value of gradient of image intensity function [1]. It can detect edge by calculating partial derivatives in 3x3 neighborhoods. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations [3].

Compared to other edge operator, Sobel has two main advantages: 1. it has some smoothing effect to the random

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noise of the image. 2. Because it is the differential of two rows or two columns, so the elements of the edge on both sides has been enhanced, so that the edge seems thick and bright [5]. Sobel operator is highly sensitive to noise and represent it in form of edges therefore it is strongly recommended to use it for data communication applications.

Edge detection helps to understand image features. Edge consist of useful information about image it also reduce image size. Most of images consist of redundancies that are removed when edge is detected [6].

The Sobel operator is used to measure 2-D gradient on images. The partial derivates in x and y direction is given as:

$$S_x = \{f(x+1,y-1) + 2f(x+1,y) + f(x+1,y+1)\} - \{f(x-1,y-1) + 2f(x-1,y) + f(x-1,y+1)\} \quad (1)$$

$$S_y = \{f(x-1,y+1) + 2f(x,y+1) + f(x+1,y+1)\} - \{f(x-1,y-1) + 2f(x,y-1) + f(x+1,y-1)\} \quad (2)$$

After this calculation gradient value for each pixel is calculated as:

$$g(x,y) = \sqrt{s_x^2 + s_y^2}$$

Then a threshold value T is selected. If the value of g(x, y) > T, that point is considered as edge point. The values S_x and S_y are calculated with the help of Sobel masks as shown in following fig.

-1	0	1
-2	0	2
-1	0	1

-1	-2	-1
0	0	0
1	2	1

Fig 1: Mask of Sobel Operator

Fuzzy Logic based image processing

Fuzzy logic works in the same way as human brain works. Fuzzy logic is an approach to computing based on "degree of truth" rather than discrete values such as 0 and 1. In this paper, fuzzy logic based approach to edge detection is proposed [7]. All edge points detected with Sobel operator are filtered using Fuzzy inference system. Fuzzy image processing is the collection of different fuzzy approaches to image processing such as image fuzzification, modification of membership values and fuzzy defuzzification [8].

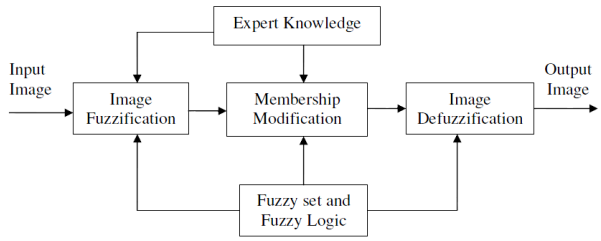

Fig 2: The general structure of Fuzzy Image Processing

Image fuzzification and defuzzification processes are necessary because we do not possess fuzzy hardware. Therefore coding of image data i.e. fuzzification and decoding of result i.e. defuzzification make it possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step as shown in Fig 2 i.e. membership function modification. Firstly image data are transferred from gray scale level to the membership plane, then membership function are modified by using appropriate fuzzy techniques. This technique can be fuzzy rule based approach, fuzzy clustering, fuzzy integration approaches so on.

Fuzzy Set and Membership Function

The system implementation is carried out by considering the input edged image obtained after image is processed by Sobal operator and the output image obtained after defuzzification are both eight bit quantized, this way their gray levels are always between 0 and 255. Fuzzy sets are created to represent variable's intensities; these sets are associated with linguistic variables for input and output as shown in the following figures. Figure 3 represent the FIS created for edge detection named EDGE. The Sugeno method is chosen as defuzzification method , which means that the output membership functions are constants as shown in the figure 5 named as K1, K2,K3,K4 and K5 the values representing edge intensities . Figure 4 describe input variable designed as VL, LO, MD, HI, VH. Figure 6 show different rules used for fuzzy inference system here IF THEN rules are used.

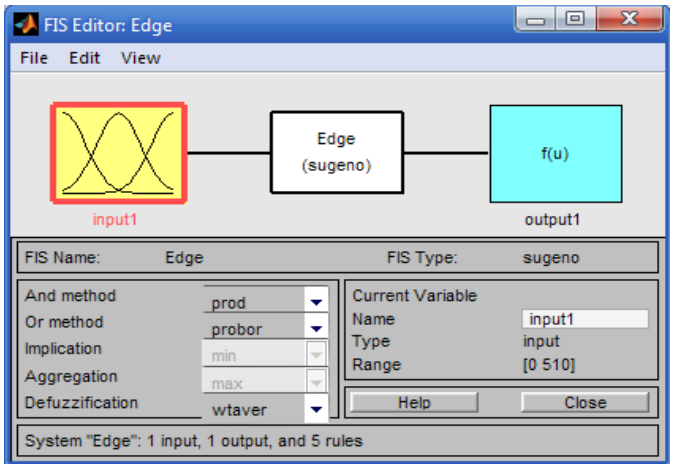

Figure 3: Fuzzy Infrence System Edge

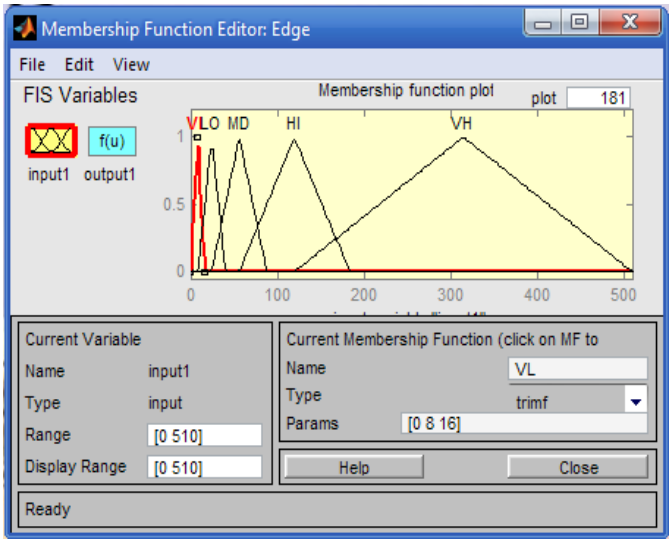

Figure 4: FIS Membership Function (INPUT)

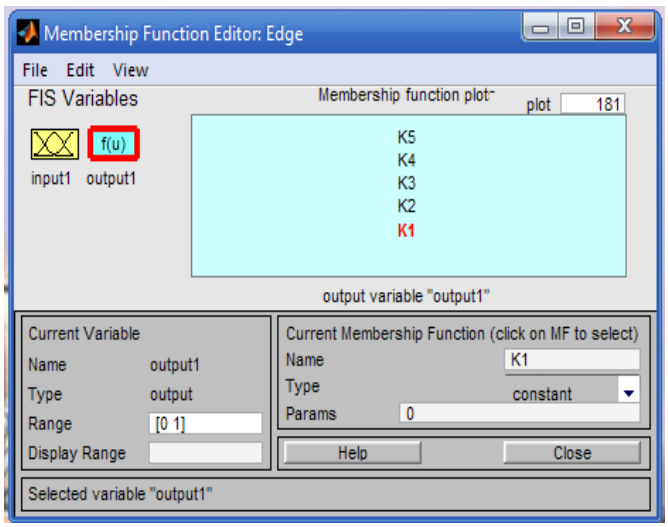

Figure 5: FIS Membership Function (OUTPUT)

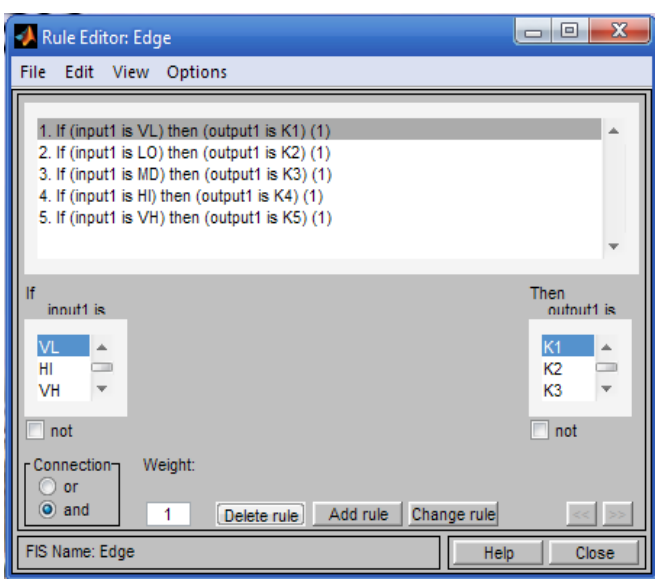

Figure 6: FIS Rules

Zernike Moment Operator

Discontinuities in any image are called edges. Detection of these discontinuities is necessary in many image processing tasks such as object recognition, medical diagnosis, weather forecasting, motor analysis etc. Most of edge detection work is limited to pixel level edge detection. Current trends of digitization of analog images also motivate the field of pixel level edge detection toward sub-pixel level edge detection [6].

Pixel level edge detection methods are capable detecting edges at fast speed but with low precision. There are many applications where high precision in edge detection is required. Sub pixel level methods are efficient to solve the problem of detecting precision. To improve the precision in edge detection there are various methods such as improving image sensor system , improving imaging device , improving magnification of object in imaging device .But all these methods are hardware dependent and that are limited by cost. Therefore software based subpixel level methods have become hotspot for current research in image processing. This method is based on set of orthogonal complex moments of image known as Zernike moments. Zernike moments are mapping of image data onto set of complex Zernike moments. Zernike moments can represent the properties of image data with no information redundancy and without any overlapping of information because Zernike polynomials are orthogonal to each other. Fig 7 show two dimensional sub pixel edge detection model:

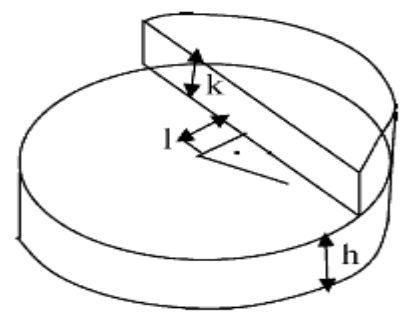

Figure 7: 2-D Sub Pixel Edge Detection Model

Here k is the step height, h is the background gray level, l is the perpendicular distance from center of circular kernel, and edge makes an angle of Ǿ with respect to the x-axis [1]. Zernike Moment of order n and repetition m is defined as:

$$A_{nm} = \frac{n+1}{\pi} \iint_{x^2+y^2 \le 1} f(x,y)\, V^*_{nm}(\rho,\theta)\, dx dy \quad (1)$$

Where f(x, y) is the image intensity function and Vnm, (ρ ,Ǿ) = $R_{nm}(\rho)e^{jm\text{Ǿ}}$. n >0, and n – mod(m) is even positive integer. Rnm (ρ) is a radial polynomial defined as:

$$R_{nm}(\rho) = \sum_{s=0}^{(n-|m|)/2} \frac{(-1)^s [(n-s)!]\rho^{n-2s}}{s!\left(\frac{n+|m|}{2}-s\right)!\left(\frac{n-|m|}{2}-s\right)!} \quad (2)$$

The term outside the integral is a normalizing factor and is ignored. After rotation under Zernike moments phase changes but magnitude remains same. Due to this property Zernike moments are called rotational invariant. In proposed approach we apply Zernike moment operator over edged image detected by Fuzzy inference system which filter out edges detected by Sobal operator. By this problem of precision, false edges. Double edges etc are removed which is helpful in image segmentation techniques.

Test Result and Discussion

The proposed system is tested with different images such as medical images, satellite images natural images etc. Its performance is compared with edge detected image with Sobel operator, and then Fuzzy-Zernike moment operator. Following Fig 8 is used as comparative model for Sobel operator and Fuzzy-Zernike moment operator edge detection methods. The original image is shown in part a Fig. 8. The edge detection Based on Sobal operator using the image processing toolbox in MATLAB is illustrated at the part b. This is the edge detected image by Sobal operator but the edge pixels are filtered out by Using Fuzzy inference system. Thus we can also say that this is edge detected image by fuzzy-Sobel operator. Part c of Fig 8 show the new purposed method that is Fuzzy Zernike moment operator method which further filter out the edges from edged image detected by fuzzy-Sobel method. It is found that the modified version of edge Map has less noise and less edge corruption.

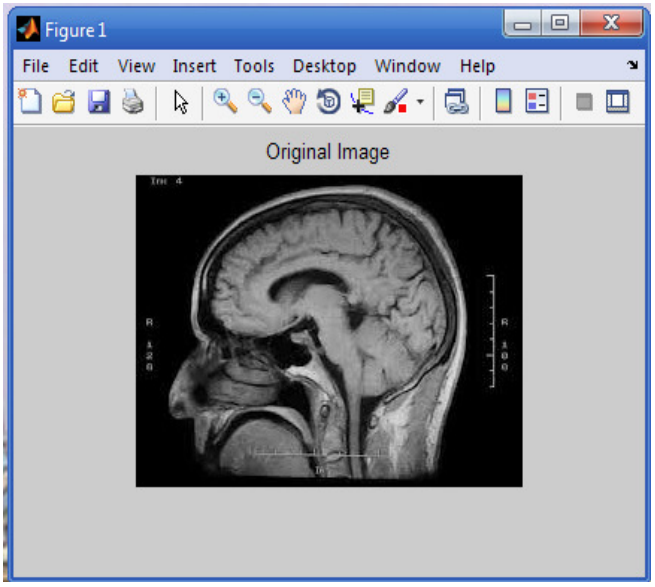

Figure 8: Original Medical image to be edge detected

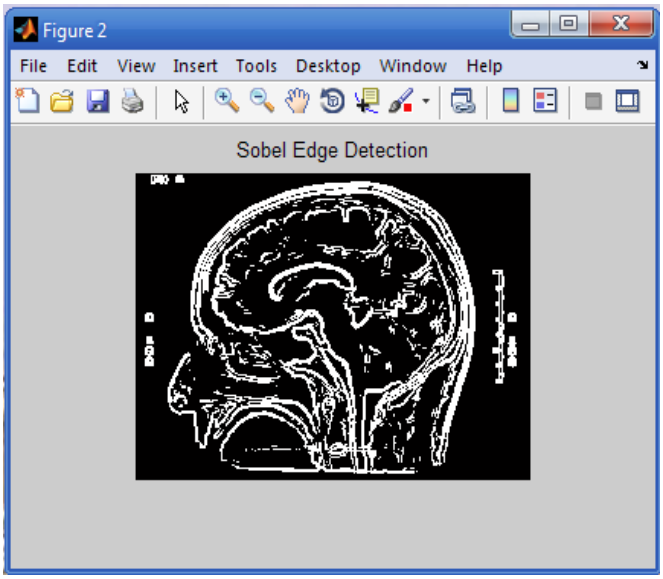

Figure 8(b): Sobel edge detected image

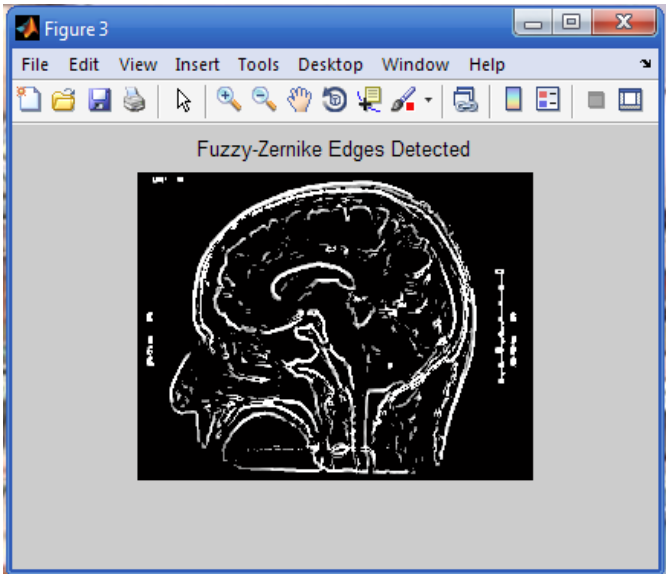

Figure 8(c): Fuzzy-Zernike Edge detected image

For segmentation task, a thin edge is better because we only want to preserve the edge rather than the details in the neighborhood. The values of edge map are kept in the interval of 0 to 255 to represent the edginess membership value. The Benefit if FIS system is that it allows edges to be detected even in low contrast regions. This is due to the different treatment of fuzzy rules.

In Fig 9(a) natural image of a lady is shown part a. When Sobel operator is applied to this image false edge are appeared in the image shown in Fig. 9(b). Adoption of Fuzzy Rules with Zernike moment operator solves this problem as shown in Fig 9(c).

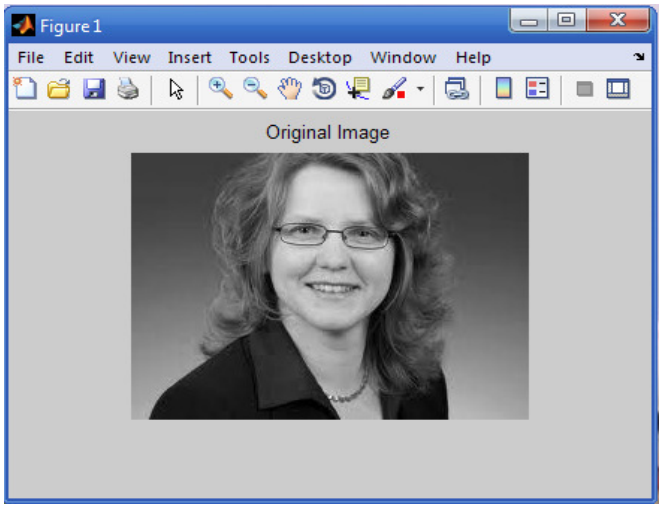

Figure 9(a): Original edge detected image

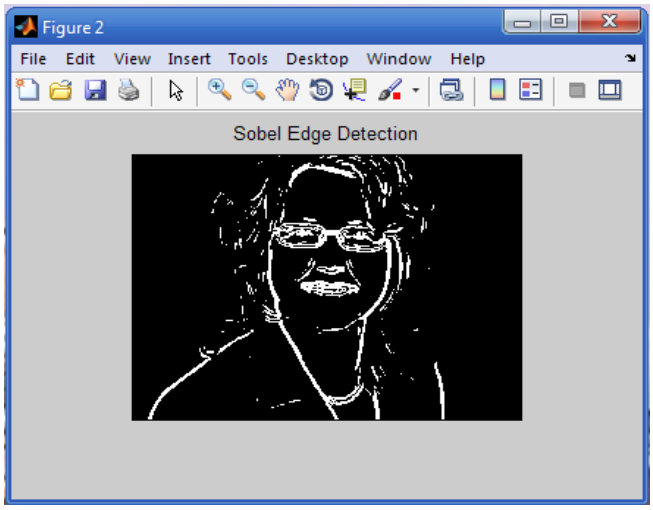

Figure 9(b): Sobel edge detected image

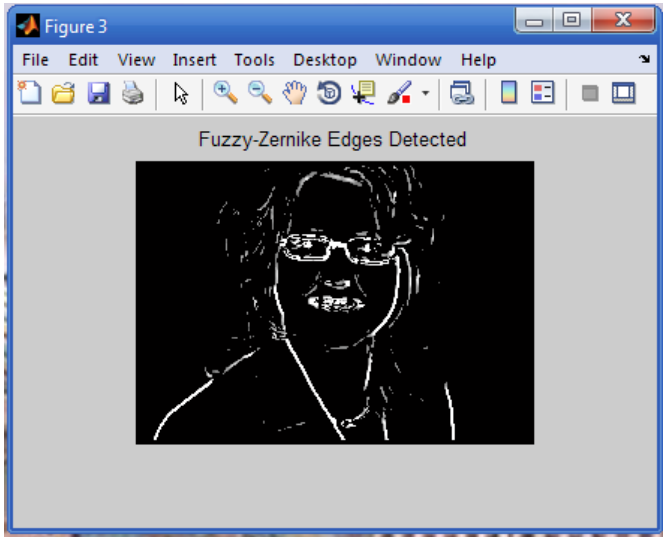

Figure 9(c): Fuzzy-Zernike edge detected image

To demonstrate the enhancement of the performance on the edge detection, with different gray level image of the satellite are shown in Fig 10. The resulting images of our Fuzzy-Zernike moment techniques are seem to be much smoother with less noise in the flat areas and sharper in the edgy regions than the conventional edge detection techniques.

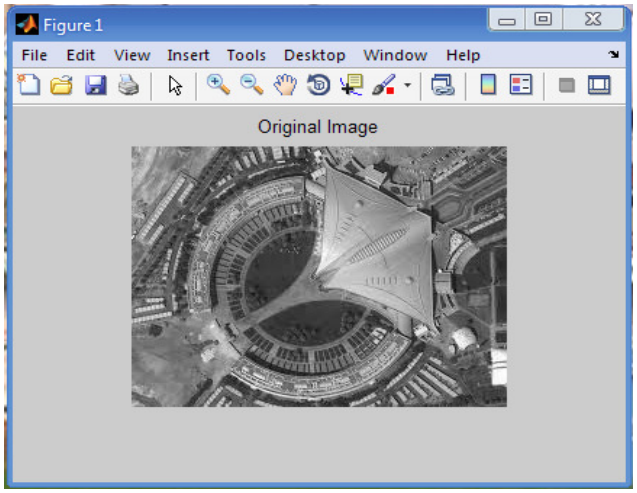

FIGURE 10(a): Original satellite image to be edge detected

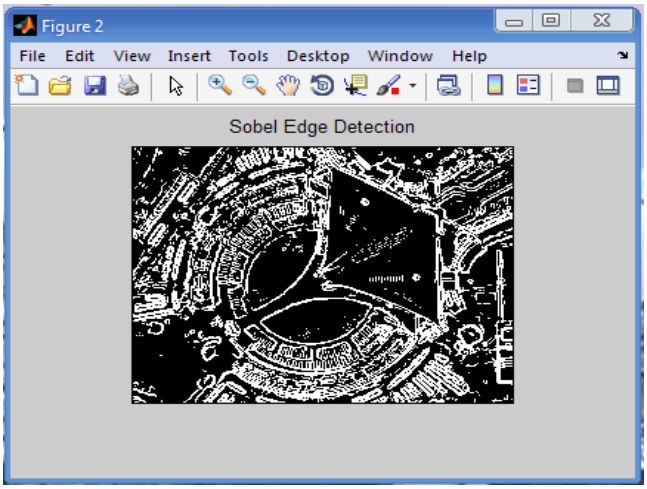

FIGURE 10(b): Sobel edge detected image

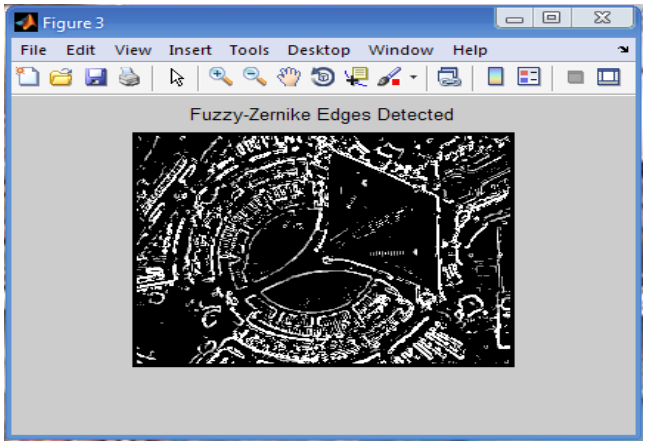

Figure 10(c): Fuzzy-Zernike edge detected image

Conclusion

Fuzzy image processing is a powerful tool form formulation of expert knowledge and the combination of imprecise information from different sources. The designed Fuzzy rules are an attractive solution to improve the quality of edge as much as possible. The other reason of using Fuzzy image processing is the presence of many uncertainties in the conventional images processing methods. In our approach for edge detection we combine Fuzzy inference system with Sobel operator and then with Zernike moment operator and results allow us to conclude that:

- The implemented FIS system with Sobel operator filter out the unnecessary edges from the edged image thereby helps in image segmentation.
- Then use of FIS with Zernike moment operator do further filtering and improves precision in detected edges and avoid double edge problem.

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