An Efficient Fuzzy Based Gradient Edge Detection Technique

M.R.Vimala Devi
Assistant Professor/Research Scholar, Arasu Engineeering College/VIT University, Kumbakonam, Tamilnadu, India

Abstract – Edge detection is the method which aims at identifying points in a digital image at which the image brightness changes sharply or at its discontinuities. Edge detection in images is one of the important aspects, in order to enhance its feature detection and extraction. In this project fuzzy inference system and an adaptive threshold generation technique along with non-maximal suppression are used to filter the edges from its background in the gray scale and colour images. We have implemented the algorithm directly on the images without decompression process. The proposed method finds application to detect cracks in bones and rail roads. Based on the quantitative analysis it has been proved that proposed method performs better than existing techniques.

Index Terms – Edge, Feature, Brightness, Gray Scale, Fuzzy Inference System.

1. INTRODUCTION

Edge detection is a very important low-level image processing operation, which is essential in order to carry out various higher level tasks such as motion and feature analysis, understanding, recognition and retrieval from databases [1]. Application of derivative operators on intensity image produces another image, usually called gradient image as it reveals the rate of intensity variation. This image is made to undergo thresholding and/or edge linking in order to yield contours [2]. Thus the image is decomposed into various regions resulting in another kind of segmentation. The various edge detection methods implemented are

1. Gradient Method
2. Fuzzy Canny Method
3. Proposed Method

2. GRADIENT METHOD

A 5 X 5 convolution mask is used to enhance the image, one estimating the gradient in the X direction, the other estimating the gradient in the Y direction [3]. In this mask higher weights are assigned to the pixels close to the candidate pixel.

So a gradient of the pixels is calculated as:

$$G_X \quad \begin{bmatrix} 1 & 1 & 4 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ -2 & -2 & -8 & -2 & -2 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 4 & 1 & 1 \end{bmatrix} * \text{INPUT}$$

$$G_Y = \begin{bmatrix} 1 & 0 & -2 & 0 & 1 \\ 1 & 0 & -2 & 0 & 1 \\ 4 & 0 & -8 & 0 & 4 \\ 1 & 0 & -2 & 0 & 1 \\ 1 & 0 & -2 & 0 & 1 \end{bmatrix} * \text{INPUT}$$

$$G=\sqrt{\{[G_x]^2 + [G_y]^2\}}$$

Figure 1 Gradient mask

The methodology of the gradient method is as shown below in figure.2.

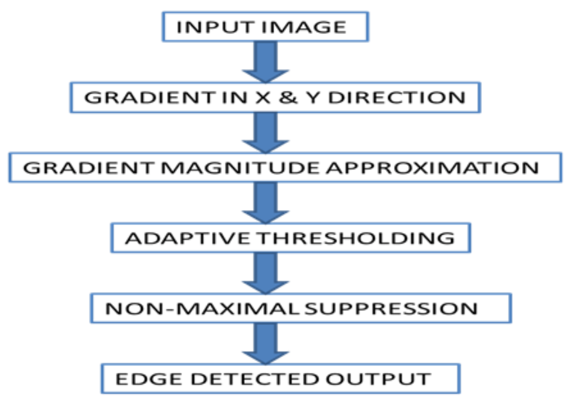


Figure 2 Gradient Method

2.1 Adaptive Thresholding

Image thresholding is a segmentation technique because it classifies pixels into two categories.

Category1: Pixels whose gray level values fall below the threshold.

Category2: Pixels whose gray level values are equal or exceed the threshold.

In gray level image, range of input data set is [0, 1]. After thresholding, output data set contains only two values 0 and 1. Thus, thresholding creates a binary image. If T is a threshold value, then any pixel (x, y) for which $f(x, y) > T$ is called an object point; otherwise the pixel is called a background pixel. For thresholding we compute adaptive threshold of local intensity variations as:

1. First the overall mean value of the gradient image is calculated. So the pixels having lower edge strength than this mean value are already discarded. T1 = mean (G) is computed.

2. Then a 3 X 3 window is splits over the gradient image where the mean, variance and standard deviation of the gradient image within this window are calculated. Then taking the sum of the overall mean value (T1) and standard deviation and this is considered as the threshold value of that pixel. T=T1+SD is computed.

Now if the gradient of this image exceeds this threshold then the pixel is treated as edge [5].

2.2 Non-Maximal Suppression (NMS)

The edges obtained now has to be sharpen and thin for this reason Canny pointed out that there should only be one response of an edge detection system to a single edge in the image[6]. The NMS operation considers the fact that an edge at a pixel is legitimate only when the gradient magnitude at that pixel assumes a maximum in the gradient direction within a local surrounding. We calculate the gradient direction at each location in the image under consideration using the following expression:

(1) $\Theta = \arctan(GY / GX)$

For simplicity, the values of the directions obtained are then approximated as $\Theta x,y$ to the closest among the following set, [0, 45, 90,135]. We then retain only those Gx,y which are greater than the other gradient values in local surrounding and in the corresponding gradient directions $\Theta x,y$.

3. FUZZY CANNY METHOD

The input image is pre-processed by smoothening in order to eliminate noise. Then canny operators are applied to the smoothened image to estimate its derivatives in horizontal and vertical direction (Gx & Gy filters).

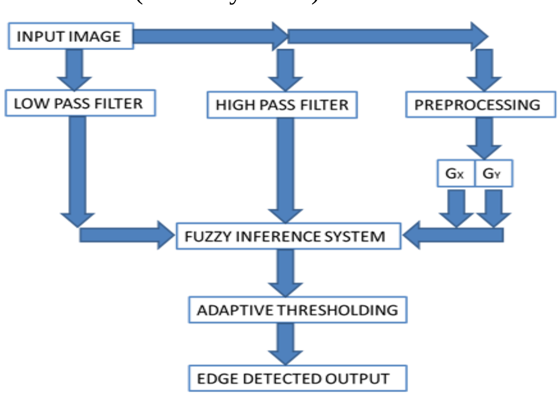


Figure 3 Fuzzy Canny method

$$G = 1/115 * \begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} *input$$

$$Gx = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} *G$$

$$Gy = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} *G$$

Figure 4 Gaussian gradient masks

A low pass (mean) filter and a high pass filter are also applied to the original image. The outputs of these filters are taken as input to the FIS system.

$$Mf = 1/25 * \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} *input$$

$$hp = 1/16 * \begin{bmatrix} -1 & -2 & -1 \\ -2 & 12 & -2 \\ -1 & -2 & -1 \end{bmatrix} *input$$

Figure 5 Filter mask values

The adopted membership functions ("low"," medium" and "high") for the fuzzy sets associated to the low pass input(Mf) and to the output are Gaussian functions with means 0,127.5,255. For the sets associated to the other inputs Gx,Gy, and hp, Gaussian functions are adopted for the linguistic variables "low" and "medium", but for the variable "high" a sigmoid function is chosen, since in this case we cannot guarantee that the input values will be restricted to the interval [0.255]. The mamdani method is chosen as the defuzzzification procedure, which means that the fuzzy sets obtained by applying each inference rule to the input data are joined through the odd function; the output of the system is then computed as the centroid of the resulting membership function [7].

3.1 Inference rules

The fuzzy inference rules are defined in such a way that the FIS output is high only for those pixels belonging to edges in the input image. A robustness to contrast and lighting variations are also kept in mind when these rules are established.

- Gx low and Gy low = edges low
- Gx medium and Gy medium = edges high
- Gx high and Gy high = edges high
- Gx medium and hp low = edges high
- Gy medium and hp low = edges high
- Gy medium and Mf low = edges low
- Gx medium and Mf low = edges low
- Gy high and Gy(i+1,j) high = edges medium
- Gx high and Gx(i,j+1) high = edges medium
- Gy medium and Gy(i+1,j) high = edges low
- Gx medium and Gx(i,j+1) high = edges low
- Gy(i,j+1) low and Gx(i+1,j) low and Gy(i,j-1) low and Gx(i-1,j) low = edges low

Then adaptive thresholding the output of the fuzzy system followed by its non maximal suppression results in an edge detected image.

4. PROPOSED METHOD

In order to detect the edge in the image, a fuzzy inference system has been designed which take different pixel value as inputs, fuzzify these inputs i.e. convert it into fuzzy plane and then using some predefined rule mark the considered pixel as edge ,Black, White. Mamdani method is chosen as the defuzzification method and the output of the system is calculated as the centroid of the resulting membership functions.

Fuzzy inference system for this algorithm has four inputs and one output. Since in this algorithm 2×2 window mask is used for scanning purpose, therefore four- pixel values obtained by this mask is used as four inputs . A 2×2 mask used in this algorithm is shown in Fig. 2,P1 is black and

P2,P3,P4 are white therefore as per the rule shown in Table 2 the output pixel P4out is marked as white.

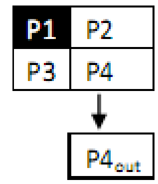


Figure 6 Window mask

4.1 Membership Function

The choice of membership function is problem dependent. In this algorithm Triangular Membership functions is used for input as well as for output.

Table.1 Fuzzy Inference Rules

Fuzzy Rule Fuzzy Input				Fuzzy Output
P1	P2	P3	P4	P4out
B	B	B	B	B
B	B	B	W	E
B	B	W	B	E
B	B	W	W	E
B	W	B	B	E
B	W	B	W	E
B	W	W	B	E
B	W	W	W	W
W	B	B	B	E
W	B	B	W	E
W	B	W	B	E
W	B	W	W	E
W	W	W	B	E
W	W	B	W	E
W	W	W	B	E

The proposed method is depicted in Figure 4.

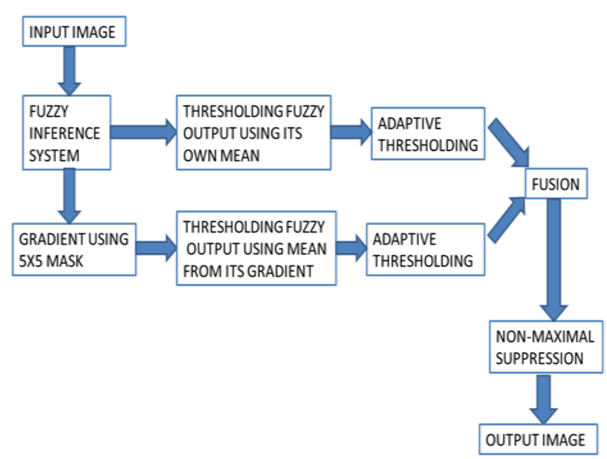


Fig.7 Block Diagram of the proposed method

4.2 Algorithm

Algorithm follows the steps as

1. Input theP1, P2,P3,P4 pixel from the scanned window to FIS system and fuzzify it into different degree of Black and White.

2. Then apply Fuzzy t-norms operator (MIN) for calculating firing strength.

3. Fire the fuzzy rules for each crisp input.

4. Apply the MAX operator(s-norm) to get the aggregate resultant output.

5. Apply the Defuzzification step using centroid method.

6. Get the crisp P4out pixel which may come under White, Black or Edge category.

7. Thresholding the output of the FIS system using its own mean and then performing adaptive thresholding will give one edge detected output(out1).

8. Calculate gradient values Gx Gy & G for the FIS output and threshold it using the mean of its total gradient (G). Next perform adaptive thresholding for the gradient image(out2).

9. Then fuse the two outputs using maximum intensity value (out).

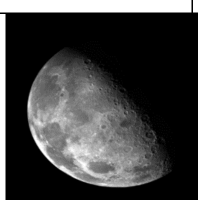
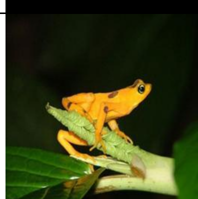
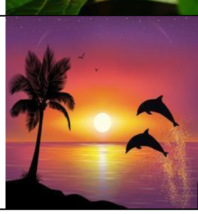
$$out(i,j) = out1(i,j) \text{ if } out1(i,j) > out2(i,j)$$

$$= out2(i,j) \text{ otherwise} \quad (2)$$

5. QUANTITATIVE ANALYSIS

The quantitative analyses of three images are as shown in the table below.

Table. 3 Quantitative Analysis

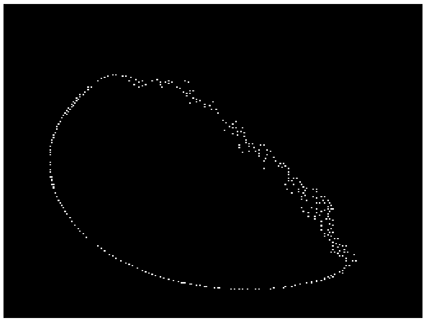
INPUT IMAGE	MEAN			STANDARD DEVIATION		
	Gradient method	**Fuzzy Canny method**	**Proposed method**	**Gradient method**	**Fuzzy Canny method**	**Proposed method**
	0.4640	1.2549	9.9095	10.8676	17.8846	49.2738
	1.7406	3.0614	9.4275	20.9957	27.7723	48.1159
	5.3621	4.4014	36.8693	16.6185	13.9261	89.6792

6. RESULTS AND DISCUSSION

a.INPUTIMAGE

b. GRADIENT METHOD

The results has been demonstrated for three inputs namely moon,hand and scene color images.Input images are shown in (a).Existing methods are shown in (b) and (c).The proposed method is shown in (d). From the results, it is clear that the proposed method detects edges than existing methods.



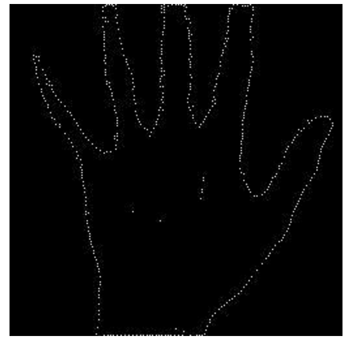
c. FUZZY METHOD

d. PROPOSED METHOD

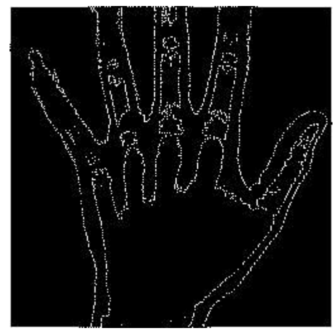
Figure 8 Results-moon image(a-d)

a.INPUT IMAGE

b.GRADIENT METHOD



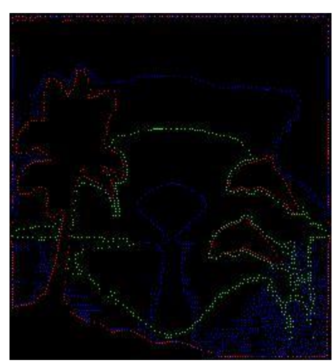
c. FUZZY METHOD



d. PROPOSED METHOD

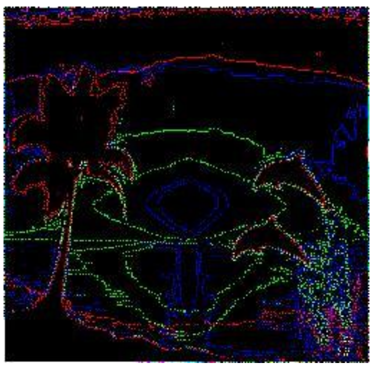
Figure 9 Results – hand image(a-d)

a. INPUT IMAGE



b. GRADIENT METHOD

c. FUZZY METHOD



d.PROPOSED METHOD

Figure 10. Results – Scene image(a-d)

6. CONCLUSION

Thus we have developed an efficient fuzzy based edge detection technique using fusion for gray scale images, color images and then highlighted using mean and standard deviation with comparison to gradient technique and fuzzy based canny edge detection. The proposed method is detecting edges well for real time images and noisy images. The proposed method can be extended to various real time applications such as detection of cracks in bones, railroads etc.,

REFERENCES

[1] Debabrata Samantaa & Goutam Sanyalba," Novel Approach of Adaptive Thresholding Technique for Edge Detection in Videos", International Conference on Communication Technology and System Design 2015.

[2] Sunitha Sarangi & Dr.N.P.Rath,"Performance Analysis of Fuzzy-based Canny Edge Detector", International Conference on Computational Intelligence and Multimedia Applications 2007.

[3] Aijaz Ur Rahman khan & Dr. Kavita Thakur, "An Efficient Fuzzy Logic Based Edge Detection Algorithm for Gray Scale Image" , International Journal of Emerging Technology and Advanced Engineering, August 2012,Volume 2,Issue 8.

[4] Fuzzy logic toolbox help in matlab 2009.

[5] Raman Maini & Dr. Himanshu Aggarwal," Study and Comparison of Various Image Edge Detection Techniques" International Journal of Image Processing (IJIP), Volume (3) , Issue 1.

[6] Ehsan Nadernejad," Edge Detection Techniques:Evaluations and Comparisons",Applied Mathematical Sciences, Vol. 2, 2008, no. 31.

[7] Gautam Appasaheb Kudale & Mahesh D. Pawar," Study and Analysis of Various Edge DetectionMethods for X-Ray Images",International Journal of Computer Science and Application Issue 2010.

[8] Rafael C.Gonzalez & Richard E.Woods,"Digital Signal Processing", edition 2 Pearson Education 2007.

[9] Arivalzhagan S,Henry Selvaraj,Brijesh Verma and Andre de Carvalho,"International Conference Computational Intelligence and Multimedia Appilications",volume 3 2007.