Edge Detection Through Integrated Morphological Gradient and Fuzzy Logic Approach

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Abstract—This paper presents an effective comparison between various edge detection techniques and emphasizes on how fuzzy logic can be applied for edge detection. Edges provide the representation of object boundaries thus, filtering unnecessary data and that is the reason behind edge detection being an essential component in many computer image processing subfields such as classification, feature extraction, pattern recognition etc. We compare Sobel and Laplacian of Gaussian edge detector, Morphological Gradient with the integrated fuzzy logic approach(Type 1 fuzzy logic applied upon Morphological Gradient Technique). It is found that Sobelhas the highest PSNR value for noiseless images. Also these edge detectors are tested on 0.001 White Gaussian Noise images which yields integrated T1FS to be a consistent edge detector.

Keywords—*Morphological Gradient, Prewitts, Laplacian of Gaussian, Fuzzy Logic, Mamdani, Fuzzification, Defuzzification.*

I. INTRODUCTION

An edge may be the result of changes in light absorption, its shade, texture and color, and these changes can be used to determine the depth, size, positioning, alignment and surface properties of a digital image. An edge is not only the boundary between an object and the background, but also the boundary between overlapping objects. In analyzing the image digitally, edge detection involves filtering extraneous and immaterial information to select the edge points. The detection of minute changes, which may be mixed up by noise, depends on the pixel threshold of change that defines an edge. Detection of such continuous edges is very strenuous and time consuming especially when an image is corrupted by noise.

Edge detection of an image reduces significantly the amount of data and filters out information that may be regarded as irrelevant, preserving the important structural properties of an image. Therefore, edges detected from the original image contain major information, which can be stored in a very less space than the original image, with the aid of edge map,the original image can be easily restored. The main goal of the vision systems based on computational intelligence techniques is to achieve better edge detection when image processing is performed under high noise levels . The paper is organized as follows.The integrated fuzzy system is described in section ii and the simulations and results are shown in section iii. Section iv and v give the conclusion and future scope respectively.

II. FUZZY LOGIC APPROACH

Various edge detection methods have been developed in the process of finding the perfect edge detector. Most of these detectors can be categorized as gradient based and laplacian based edge detectors. In this paper, an integrated type 1 fuzzy system for edge detection is proposed.

The first step in the process is determining if the image is a color image and converting it into a graylevel image for the sake of simplified analysis.To this extracted graylevel edge map, we apply the morphological gradient.

A. Morphological Gradient

The morphological gradient of a gray scale image can be defined as the difference between intensity values of two neighboring pixels that belong to a given structural element. A classic definition of morphological gradient is given in (1)

$$\nabla(f) = \delta_g(f) - \varepsilon_g(f) \quad (1)$$

We use D instead of $\nabla(f)$. Applying equation 1 for a 3x3 matrix, we obtain the coefficients z_i with figure 2and the possible direction of edge D_i with equation 1.The edges S can be calculated with equation 3.

$$D1=\sqrt{(z_5-z_2)^2+(z_5-z_8)^2} \quad (2a)$$

$$D2=\sqrt{(z_5-z_4)^2+(z_5-z_6)^2} \quad (2b)$$

$$D3=\sqrt{(z_5-z_1)^2+(z_5-z_9)^2} \quad (2c)$$

$$D4=\sqrt{(z_5-z_3)^2+(z_5-z_7)^2} \quad (2d)$$

$$S=D1 + D2 + D3 + D4 \quad (3)$$

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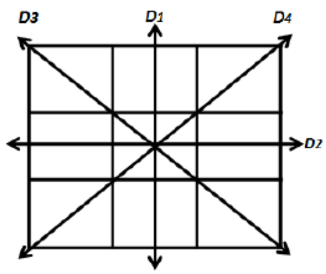

Figure 13x3 matrix indicating the directions D_i

$z_1 = f(x-1, y-1)$	$z_3 = f(x+1, y-1)$	$z_3 = f(x+1, y-1)$
$z_4 = f(x+1, y)$	$z_5 = f(x, y)$	$z_6 = f(x+1, y)$
$z_7 = f(x-1, y+1)$	$z_8 = f(x, y+1)$	$z_9 = f(x+, y+1)$

Figure 23x3 matrix indicating the coefficients Z_i.

B. Fuzzy Inferance System

The outputs $D_i$of the morphological gradient, are given as the inputs to the mamdani fuzzy inference system. The basic block diagram of fuzzy logic system is shown in figure 3. The crisp inputs are fuzzified using the fuzzification process where the fuzzy sets are created based on the gray scalevalue of images and membership functions are assigned. The membership functions are shown in figure(4). Gaussian membership functions are used in the entire approach.

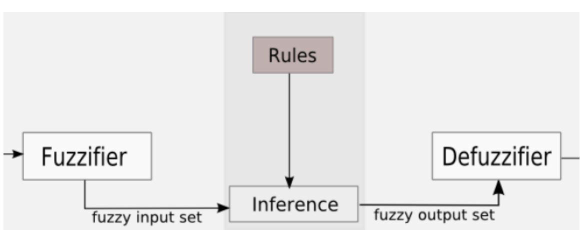

Figure 3**Block diagram of fuzzy inference system.**

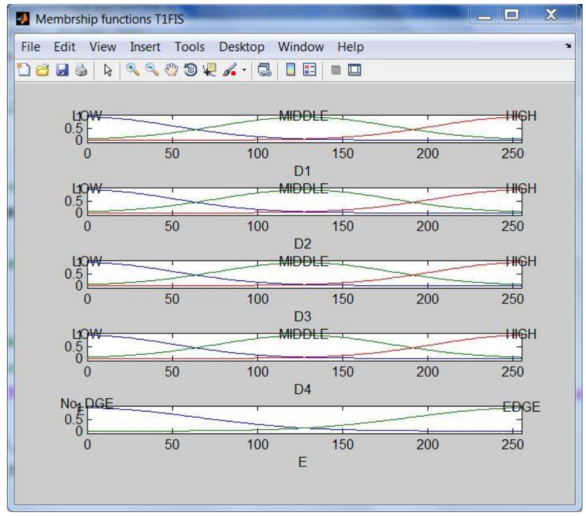

Figure 4Fuzzy membership functions

$$low_i = \min(D_i) \quad (4)$$
$$high_i = \max(D_i) \quad (5)$$
$$medium_i = low_i + (high_i - low_i)/2 \quad (6)$$
$$\sigma_i = high_i/5 \quad (7)$$
$$edge_i = 1 \quad (8)$$
$$no\_edge_i = 0 \quad (9)$$
$$\sigma_i = edge/4 \quad (10)$$

Next, we use 3 rules that help describethe existing relationship between the image gradients. Thefuzzy rules are the following.

a) If (D1 is HIGH) or (D2 is HIGH) or (D3 is HIGH) or (D4is HIGH) then (S is EDGE)

b) If (D1 is MEDIUM) or (D2 is MEDIUM) or (D3 isMEDIUM) or (D4 is MEDIUM) then (S is EDGE)

c) If (D1 is LOW) and (D2 is LOW) and (D3 is LOW) and(D4 is LOW) then (S is NO_EDGE).

The outputs are now defuzzified using the centroid method and we get the final edge map.

III. SIMULATION RESULTS

The simulation results of the edge detectors in MATLABR2010a are shown.This simulation is done on the three test images lena, baboon, peppers and two synthetic images, square and polar shown in figure 8, both created in MATLABR2010a. The results of Morphological gradient, Type 1 fuzzy logic system and Integrated T1FIS is shown.

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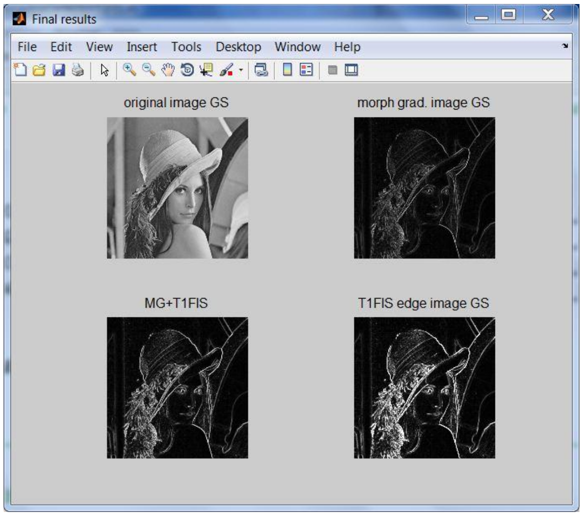

Figure 5Simulation result with the test image lena.

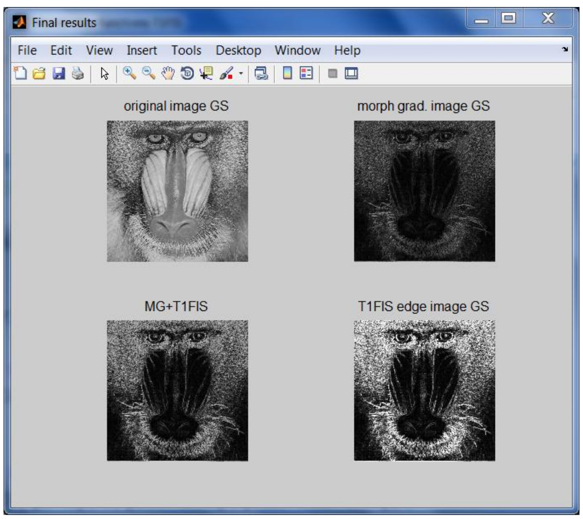

Figure 6Simulation result with the test image baboon.

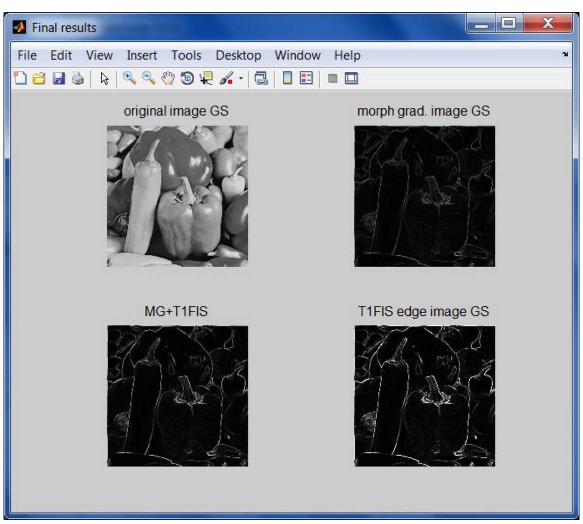

Figure 7Simulation result with the test image baboon.

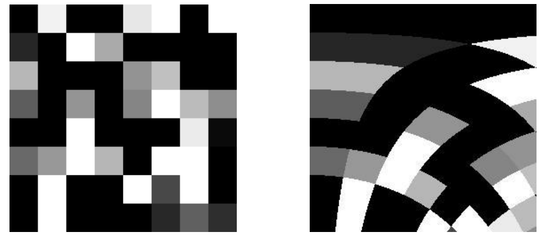
Figure 8Square and Polar Synthetic Image

The simulation results for the three test images are shown in figure 5, 6, 7.The Peak Signal to Noise Ratio values of these edge detectors with the synthetic image in noiseless conditions are tabulated in table 1.

Table 1 PSNR and PFOM values for noiseless synthetic images

Edge Detector Used	Type of Image	PSNR (in dB)	PFOM
Sobel	Square	15.7709	0.7422
	Polar	13.9139	0.7153
Laplacian of Gaussian	Square	12.1094	0.7572
	Polar	11.5846	0.7263
Morphological Gradient	Square	12.5984	0.7883
	Polar	12.2434	0.7739
T1FS +MG	Square	13.6835	0.8794
	Polar	13.6456	0.8426

Considering the noisy conditions, the results become more interesting. The results for all the discussed edge detectors with the synthetic images added with 0.001 additive white gaussian noise are shown in the table 2. Also, the % difference between the PSNR values of the noiseless synthetic images and images added with 0.001 Gaussian noise are shown.

Table 2PSNR values for synthetic images added with 0.001 white Gaussian noise.

Edge Detector Used	Type of Image	PSNR (in dB)	% decrease in PSNR value.
Sobel	Square	10.5571	0.330
	Polar	8.5888	0.382
Laplacian of Gaussian	Square	8.3432	0.311
	Polar	8.3241	0.281
Morphological Gradient	Square	12.2460	0,027
	Polar	12.1133	0.010
T1FS + MG	Square	13.6229	0.004
	Polar	13.4606	0.013

IV. CONCLUSION

The two popular edge detectors, Sobel and LoG are compared with Morphological Gradient edge

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detectorand the Integrated T1FS edge detector. The simulation results are shown. The values of PSNR and PFOM are given which shows that for the given synthetic images, sobel has the highest PSNR value, but for the images added with noise,the PSNR value of sobel decreases by 0.330% and 0.382% for square and polar synthetic images respectively. while the value of integrated T1FS remains almost the same. The value of integrated T1FS has the highest value for PFOM.But, it is to be noted thattheir performance might vary with the image it is tested upon.

V. FUTURE ENHANCEMENTS.

This integrated fuzzy logic technique can be further used on videos and probably extended for uses in motion detection etc. It can also be tested on various other types of images like the salt and pepper noise, shot noise etc.

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