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WAFER – Wavelets Assisted Fuzzy Edge Refinement

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ABSTRACT

Image enhancement is a crucial pre-processing step to be performed for various applications where object recognition, identification, verification is required. Among various image enhancement methods, edge enhancement has taken its importance as it is widely used for understanding features in an image. Several types of edge detectors are available for certain types of edges. If edges are enhanced and clear, the reliability for feature extraction increases. The Quality of edge detection can be measured from several criteria objectively. In this paper, a novel algorithm for edge enhancement has been proposed for multiple types of images. The features can be extracted clearly by using this method. For comparison purpose Roberts, Sobel, Prewitt, Canny, and Log edge operators are used and their results are displayed. Experimental results demonstrate the effectiveness of the proposed approach.

Keywords

Fuzzy based enhancement; SCIENCE; Edge enhancement; edge detection operators

Academic Discipline And Sub-Disciplines

Computer Science

SUBJECT CLASSIFICATION

Image enhancement

TYPE (METHOD/APPROACH)

Provide examples of relevant research types, methods, and approaches for this field: E.g., Historical Inquiry; Quasi-Experimental; Literary Analysis; Survey/Interview

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1 INTRODUCTION

Edge detection is a critical element in image processing, since edges contain a major function of image information. The function of edge detection is to identify the boundaries of homogeneous regions in an image based on properties such as intensity and texture. Many edge detection algorithms have been developed based on computation of the intensity gradient vector, which, in general, is sensitive to noise in the image [1].

Edge enhancement enhances the edges in an image. It involves sharpening the outline of objects and features in an image with respect to their background. Edge enhancement highlight the fine detail in an image or to restore, at least partially, details that have been blurred. In medical imaging, industrial inspection, and autonomous target detection in smart weapons, maps, weather forecast, and several other fields apply edge enhancement.

For example, like fingerprint images are rarely of perfect quality due to variations in impression condition, skin condition, scanning devices or may be due to non co-operative attitude of the subject. This degraded quality of image can result in a significant number of spurious minutiae being created and genuine minutiae being ignored. The main objective of fingerprint image enhancement is to improve the ridge characteristics of the image, as these ridges carry the information of characteristics features required for minutiae extraction. Thus, the corruption or noise has to be reduced through image enhancement techniques to get enhanced definition of ridges against valleys in the fingerprint images.

Similarly for medical diagnosis for mammographic and tumour detection edge detection is must. The edges need to be detected clearly. The potency of digital mammography for detecting of breast cancer is currently under Investigation. In medical science, mammography image is to be a cornerstone for examining breast cancer in human. Screen-film mammography has limited detection ability for low contrast lesions in dense breasts. This limitation poses a problem for the estimated 40% of women with dense breast who undergo mammography [2].

If the images are noisy or low contrast, it is difficult to identify the edges in the image. If edges are enhanced it's easier to detect them. The research has been done on several methods for improving the edges in an image to detect the abnormality. In [3] a novel technique for automatic edge enhancement and detection in synthetic aperture radar (SAR) images is designed. The characteristics of SAR images justify the importance of an edge enhancement step prior to edge detection. Therefore, this paper presents a robust and unsupervised edge enhancement algorithm based on a combination of wavelet coefficients at different scales.

An algorithm[4] based on image multi-resolution decomposition by a redundant wavelet transform is designed. At each resolution, the coefficients associated with noise and the coefficients associated with edges are modelled by Gaussians, and a shrinkage function is assembled. The shrinkage functions are combined in consecutive resolutions, and geometric constraints are applied to preserve edges that are not isolated.

The paper [5] presents a new method for edge enhancement in SAR images based on the exploitation of the information provided by the wavelet coefficients. The paper performs edge detection of SAR images using geodesic active contours. Similarly in [6] Fuzzy logic helps to find and highlight all the edges associated with an image by checking the relative pixel values .Scanning of an image using the windowing technique takes place which is subjected to a set of fuzzy conditions for the comparison of pixel values with adjacent pixels to check the pixel magnitude gradient in the window.

In [7] the proposed algorithm, edginess at each pixel of a digital image is calculated using three 3x3 linear spatial filters i.e. low -pass, high-pass and edge enhancement (Sobel) filters through spatial convolution process. Taking into consideration the above methods a hybrid approach is designed to achieve better refinement.

Many edge detection algorithms have been developed based on computation of the intensity gradient vector as well as fuzzy enhancement. Here we propose a novel algorithm to enhance the contrast of an image by pre-designed SCIENCE [8] before enhancing the edges of the image.

The rest of this paper is organized as follows. Section (2) reviews edge detection operators. Section (3) discusses the proposed edge enhancement algorithm. Section (4) shows the experimental result of proposed and other edge detection algorithms with a comparative study. In section (5) the conclusions drawn are given.

2 EDGE DETECTION OPERATORS

2.1 Zero Crossing Operator

A Laplace filter is a filter which fits in this family, though it sets about the task in a different way. It seeks out points in the signal stream where the digital signal of an image passes through a pre-set '0' value, and marks this out as a potential edge point. Because the signal has crossed through the point of zero, it is called a **zero-crossing**. The advantages of the zero crossing operators are detecting edges and their orientations is simple due to the approximation of the gradient magnitude. Secondly, the magnitude have fixed characteristics in all directions.

2.2 Roberts Operator

The calculation of the gradient magnitude of an image is obtained by the partial derivatives G_x and G_y at every pixel location. The simplest way to implement the first order partial derivative is by using the Roberts cross gradient operator. Therefore

$G_x = f(i,j) - f(i+1,j+1)$

G_y = f(i+1,j) –f(i,j+1)

It provides a simple approximation to the gradient magnitude as well as similar to Zero Crossing, it detects the edges and their orientations easily

2.3 Prewitt Edge detector

The Prewitt edge detector is a much better operator than Roberts's operator. This operator having a 3 x 3 masks deals better with the effect of noise. An approach using the masks of size 3 x 3 is given below, the arrangement of pixels about the pixels[i, j]. The partial derivatives of the Prewitt operator are calculated as

G_x = (a6+ca5+a4) – (a0+ca1+a2)

G_y = (a2+ca3+a4) – (a0+ca7+a6)

The constant c implies the emphasis given to pixels closer to the centre of the mask. G_x and G_y are the approximation at [i, j]. Setting c=1, the Prewitt operator is obtained. Therefore the Prewitt masks are as follows these masks have longer support. They differentiate in one direction and average in the other direction, so the edge detector is less vulnerable to noise.

2.4 Sobel Edge Detector

The Sobel edge detector is very much similar to the Prewitt edge detector. The difference between the both is that the weight of the centre coefficient is 2 in the Sobel operator. The partial derivatives of the Sobel operator are calculated as

G_x = (a6+2a5+a4) – (a0+2a1+a2)

G_y = (a2+2a3+a4) – (a0+2a7+a6)

Although the Prewitt masks are easier to implement than Sobel masks, the later has better noise suppression characteristics.

2.5 Laplacian of Gradient (LoG) Operator Edge Detector

The Laplacian of an image is a second order derivative defined as

$$\nabla^2 f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}$$

The Laplacian of Gradient (LoG) is usually used to establish whether a pixel is on the dark or light side of an edge.

2.6 Canny Edge Detector

Canny technique is very important method to find edges by isolating noise from the image before find edges of image, without affecting the features of the edges in the image and then applying the tendency to find the edges and the critical value for threshold. The algorithmic steps for canny edge detection technique are follows:

Algorithm: Canny Edge Detection

Step1: Convolve image with a Gaussian function to get smooth image f(r,c)

f(r,c) = f(r,c) * G(r,c,6)

Step 2: Apply first difference gradient operator to compute edge strength then edge magnitude and

direction are obtain as before.

Step 3: Apply non-maximal or critical suppression to the gradient magnitude.

Step 4: Apply threshold to the non-maximal suppression image.

Finding an error is effective by using the probability. It improves the signal with respect to the noise ratio. Through thresholding method edges can be detected in noise state also.

3 WAVELETS ASSISTED FUZZY EDGE REFINEMENT: WAFER

Wavelets Assisted Fuzzy Edge Refinement (WAFER) is a Gabor wavelet based fuzzy edge refinement method that overcomes major drawbacks of other edge operators like unnecessary edge production or fewer edge extraction. The Flow chart for the proposed method is shown in figure 1.

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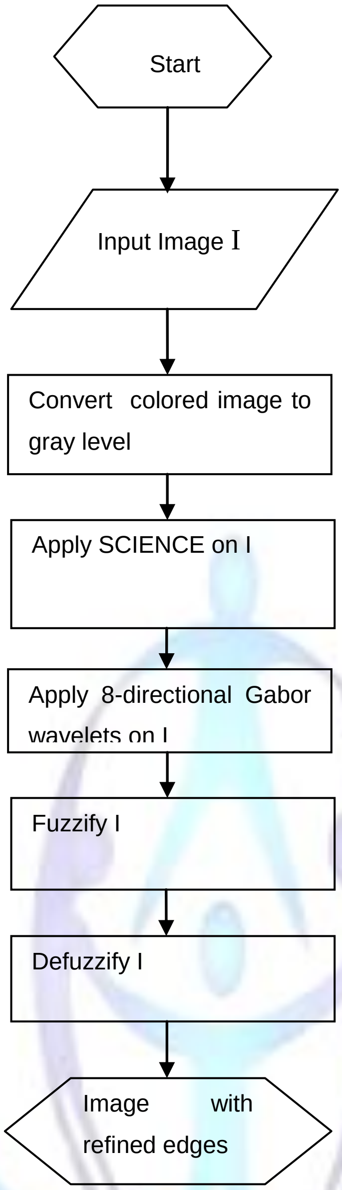

Figure 1: Flow chart for the proposed method for edge refinement

The algorithm for Wavelets assisted fuzzy edge refinement (WAFER) is given below:

Algorithm for WAFER method

Step-1 : Acquire the input image I

Step-2 : If I is a colored image, convert the image I to gray level

By applying the function rgb2gray(I) of Matlab.

Step-3 : Contrast enhance the image using SCIENCE [8]

Step-4 : Apply 8-Directional Gabor wavelets on I to improve and repair the edges.

Step-5 : Apply the fuzzy rules according to the following steps:

Step I : Specifying the input membership functions

Step II : Specifying the output membership functions

Step III : Obtaining the fuzzy system response functions F of following rules.

IF the pixel is dark, THEN make it darker

IF the pixel is gray, THEN make it gray

IF the pixel is bright, THEN make it brighter

Step IV : Construct intensity transformation function T using fuzzy system response function F

Step V : Transform the intensities of input image using T

Step IV : Fuzzify and then defuzzify the Image I

Step-6 : Refined edges of the image are obtained

The algorithm starts with acquiring the image I from the database, as already discussed a high contrast image makes it easier for edge detection operators to perform well, here we apply our proposed contrast enhancement method SCIENCE. Next step is to apply Gabor wavelet.

Wavelet transformation is one of the most popular techniques used for the time-frequency-transformations. Wavelet transform is used on dimensions to decompose the signal. The wavelets transform decomposes an input signal into low and high frequency component using a filter. Gabor increases the efficiency of low and quality of different images in Gabor.

As seen from the previous study that the imaginary part of a Gabor filter is an efficient means for edge detection. The simplified Gabor Gaussian can be obtained by selecting different centre frequencies and orientations. They are used effectively to extract features from an image. This method is known as simplified Gabor Gaussian wavelet.

Gabor filters are directly related to Gabor wavelets, since they can be designed for number of dilations and rotations. Gabor filters have been used in many applications [9], it can be viewed as a sinusoidal plane of particular frequency and orientation. The Gabor wavelet uses the imaginary part and real part of the Gabor function [10].

A Gabor filter is a linear filter whose impulse response is defined by laplacian of Gaussian function. Gabor wavelet transform is follow :

$G (X, Y, \omega; \theta, \alpha, \sigma, \gamma)$

(x) Use the row (y) use column, (ω) use center point of image and (θ) is real part, (α) imaginary part, (σ) absolute value, (γ) angle of images. Gabor function are used with different values of original image to calculate the result, (x, y) is used to the row and columns value of image and ω is for centre point of image than θ is used to real part of image and α is the imaginary part of image. (σ, γ) is used to check direction of image [11].

- Wavelength (ω) of the cosine factor of the Gabor filter and the preferred wavelength of this filter. Its value is specified in pixels. Valid values are real numbers equal to or greater than 2.
- Orientation (θ) of the normal to the parallel stripes of a Gabor function. Its value is specified in degrees. Valid values are real numbers.
- The Phase Offset (σ) in the argument of the cosine factor of the Gabor function is specified in degrees. Valid values are real numbers. The values correspond to center-symmetric ‘center-on’ and center-off’ functions.
- Aspect ratio (γ) specific the elasticity of the support of the Gabor function. For $\gamma = 1$, the support is circular. For $\gamma < 1$ the support is elongated in orientation of the parallel stripes of the function.

When an image is processed by a Gabor filter, the output is the convolution of the image $I (x, y)$ and the Gabor function

$g (x , y)$, i.e., $r (x , y) = g (x , y) * i (x , y)$

where * denotes the two dimensional convolution. This process can be used at different frequencies and different orientations, and the result is a multichannel filter bank [12] (shown in fig. 2).

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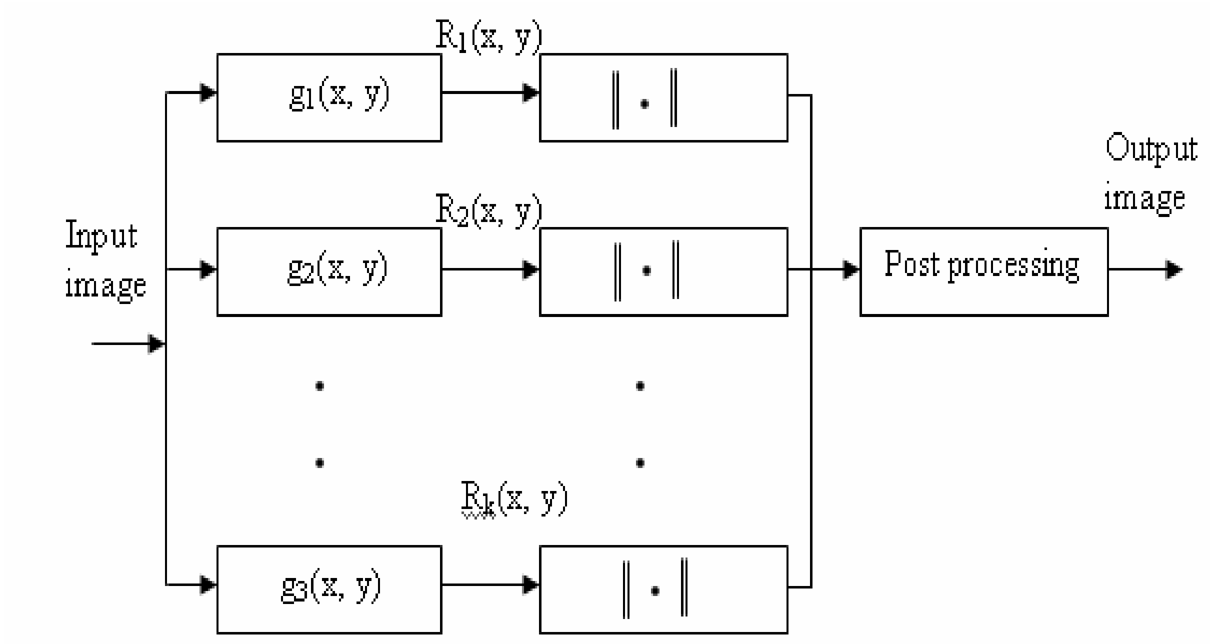

Figure 2 : Multichannel Gabor system.

$$g(x,y,\omega,\theta,\sigma) = \frac{1}{2\prod\sigma^2}\exp\left(\frac{-(x^2+y^2)}{2\sigma^2}\right)\exp\left(i\left(\omega_x\cos\theta+\omega_y\sin\theta\right)\right)$$

We choose 8 different orientations along 0^o, 22.5^o, 45^o, 67.5^o, 90^o, 112.5^o, 135^o and 157.5^o (shown in fig. 3). The central frequency is selected according to the image dimension. The radial frequencies are all 1 octave apart. Low frequency corresponds to smooth variations and constitutes the base of an image and high frequency presents the edge information which gives the detailed information in the image.

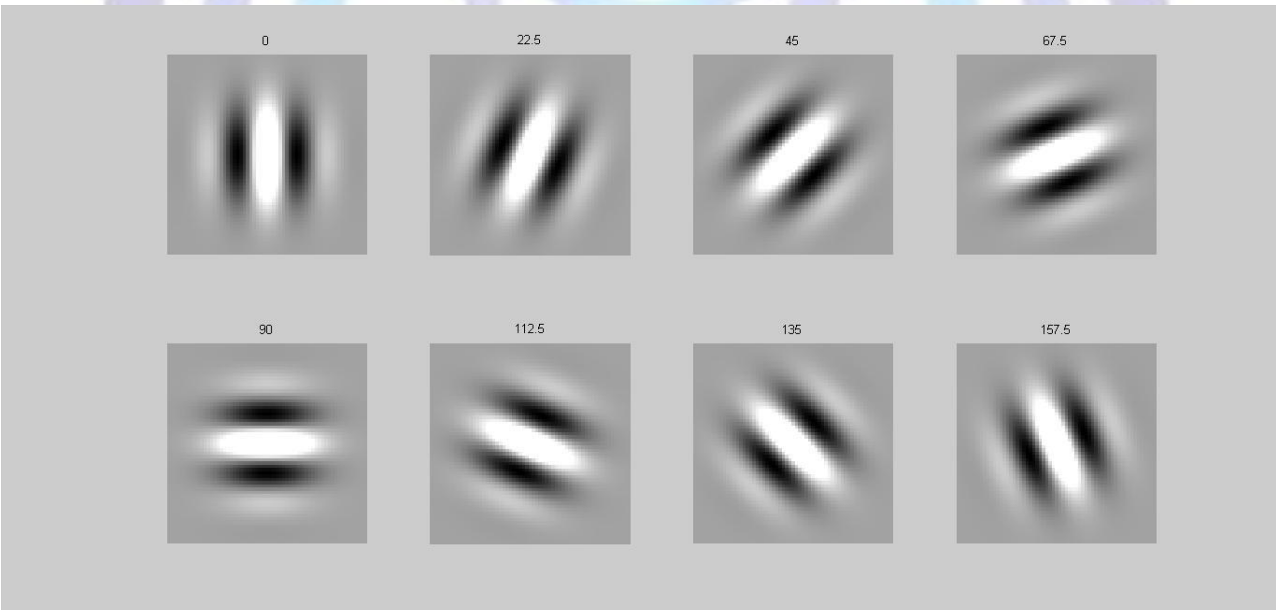

Figure 3 : The 8 different orientations selected for Gabor Wavelet

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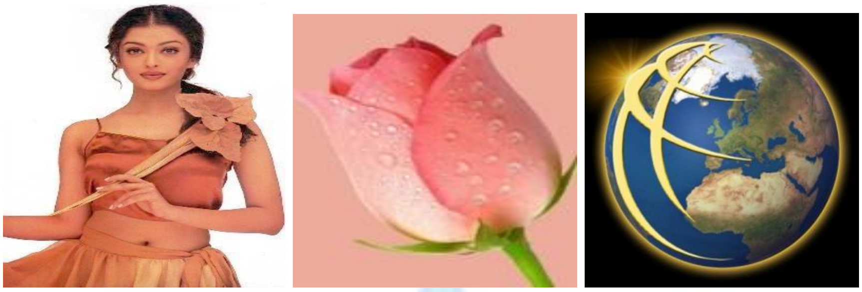
4 EXPERIMENTAL RESULTS AND COMPARATIVE STUDY

4.1 Experimental Data

Different types of images were taken from several databases to find the result of proposed algorithm on different images. Some of the images taken for experiment are shown in the figure 4.



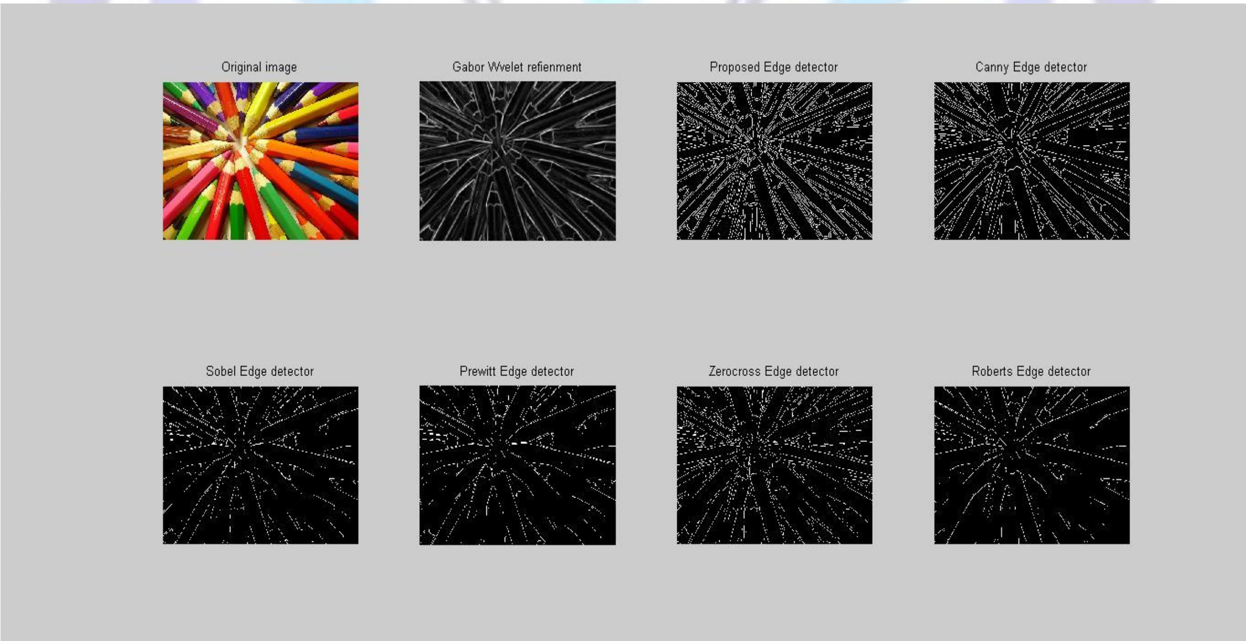
Aish (267 x 383) Rose (240 x 320) Logo (625 x 625)

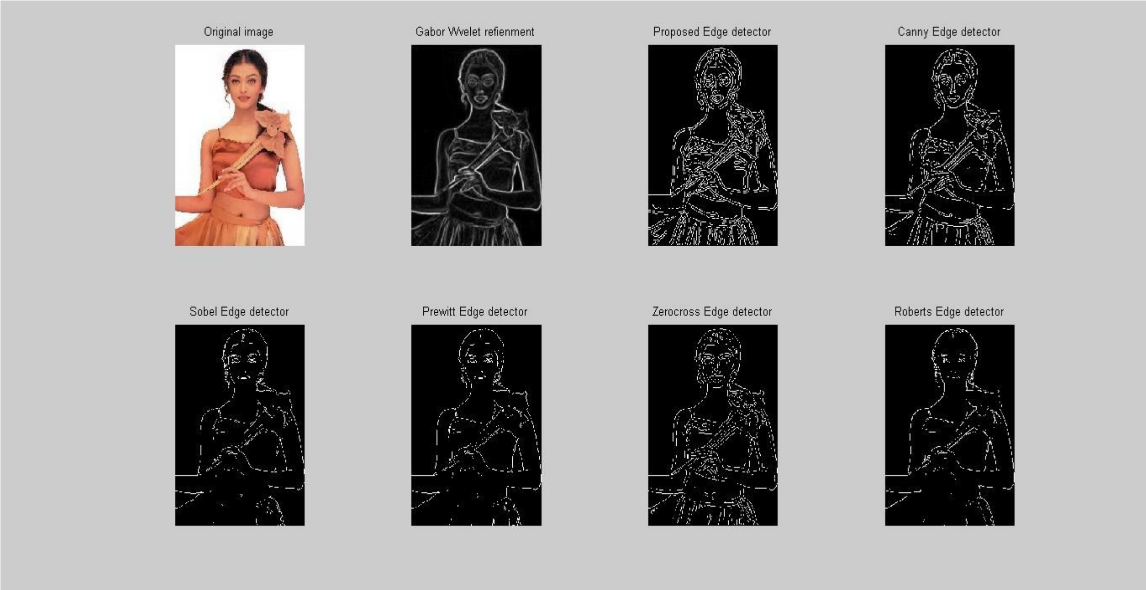
Crayon (500 x 375) Clown (185 x 126)

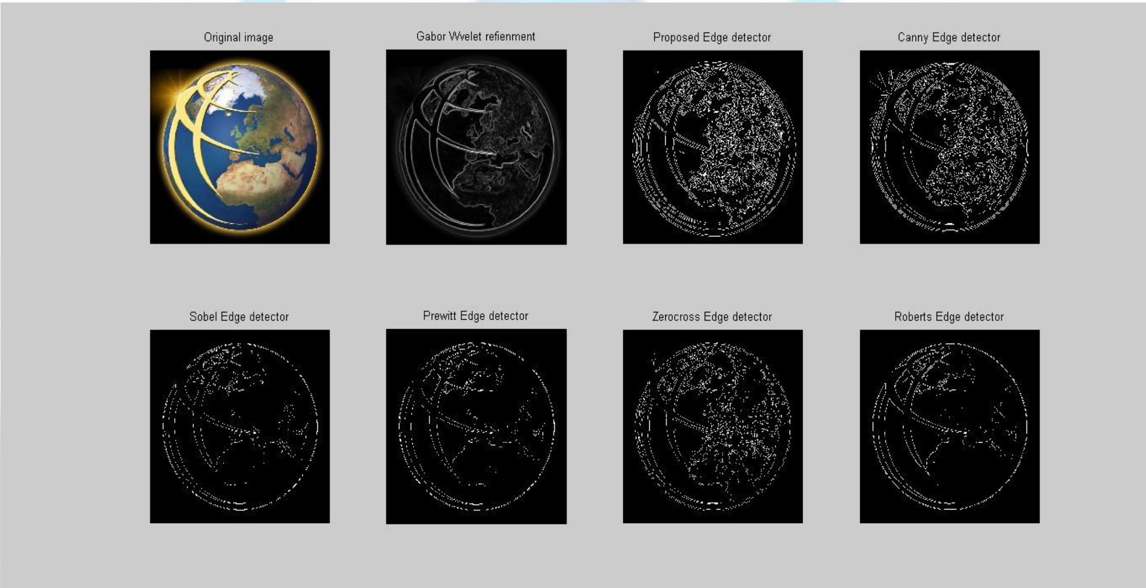
Figure 4 : Images of different sizes for edge enhancement

4.2 Experimental Results

The original images of section 4.1 were enhanced using Robert, Sobel, Prewitt, Canny LoG and Zero crossing edge operators and the proposed method. Results of some of these images alongwith their enhancement through different operators and proposed methods are shown in figure 5.




Original image
Gabor Wvelet refienment
Proposed Edge detector
Canny Edge detector
Sobel Edge detector
Prewitt Edge detector
Zerocross Edge detector
Roberts Edge detector


Original image
Gabor Wvelet refienment
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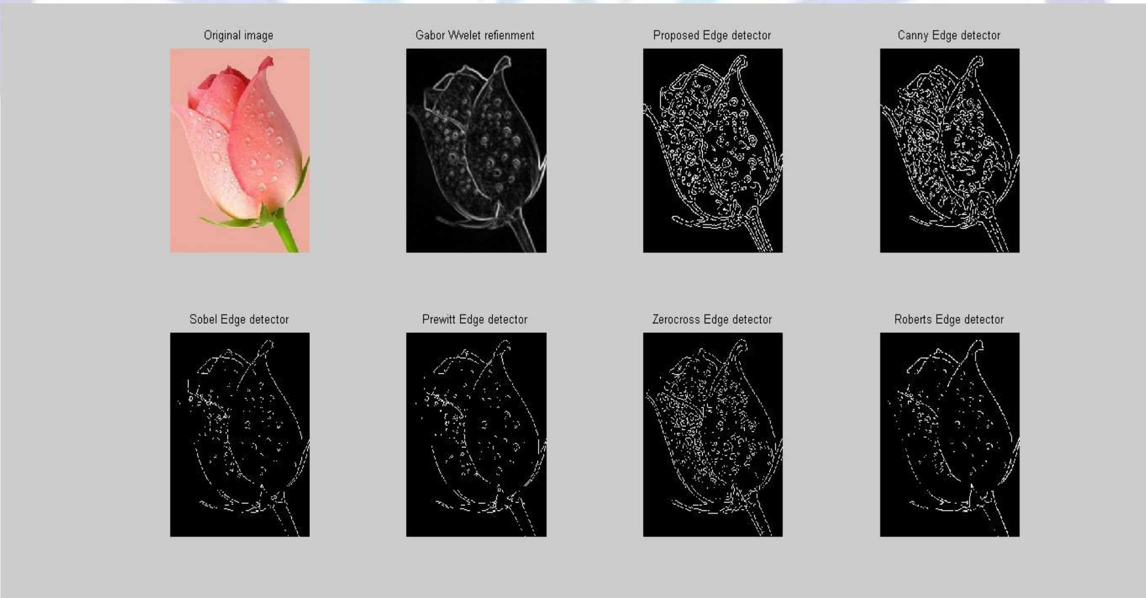
Original image
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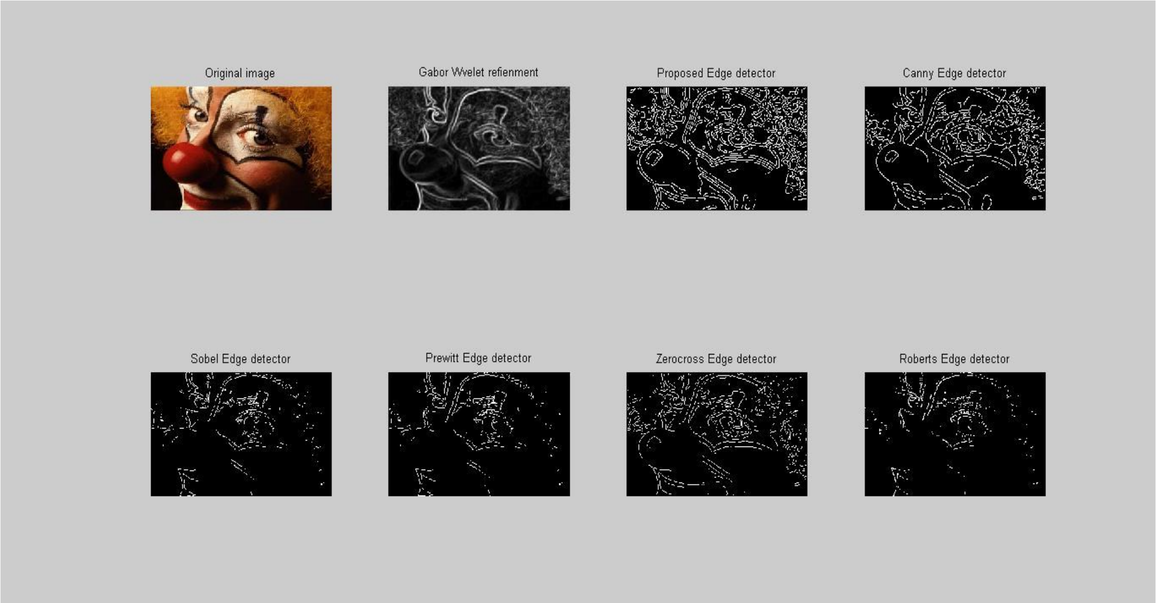

Figure 5 : Results of different edge detection methods including proposed method (WAFER) based edge detector

From above sections, it is observed that the performance of the traditional methods are performing well but still all have some or the other disadvantages which can be seen in the result. Some create more edges while some delete the essential edges. The fuzzy based method shows better results, it not only detects the edges but refines the edges for feature detection.

After comparing the images obtained from the different methods applied on 50 images we found the result satisfactory. The figure 5 shows the result of the above methods. The proposed method gives better results for most of the cases when visually the images are compared with each other. The figure shows the results obtained are much better as compared to other techniques.

In the comparative study, it is found that the proposed method not only enhances the image, but also develops the broken or spurious edges and keeps the enhanced image near to the original image.

5 CONCLUSIONS

Experiments show that the proposed algorithm not only improves the contrast but also preserves the brightness, edges, and other details of the images. It is concluded that the proposed fuzzy image enhancement algorithm is effective to enhance edges for different types of images with even very low contrasts.

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Author’ biography

Kumud Saxena received the degree in Master of Computer Applications from U. P. Technical University, Lucknow, UP, India in 2004. She is doing her Ph.D. in Computer Science, title “Design of image enhancement techniques using soft computing”. Currently, she is assistant professor in MCA department at R.B.S.M.T.C., Agra, UP, India. She has published many papers in several reputed journals such as IJCA, International Journal of Advanced Computing, etc. Her research interests include image enhancement, soft computing, etc.

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Prof. Sushma Lehri received the M.Tech. degree in Computer Science from the DOEACC, India in 2000. She received the Ph.D. degree in Solid State Physics from Dr. B.R. Ambedkar University, Agra, UP, India in 1980. She has also been the Director of I.E.T., Dr. B. R. Ambedkar University. She has many publications in national & international journals. She has many awards such as research fellowship and postdoctoral fellowship by university grant commission (UGC), New Delhi to her name. Her research interests include image processing, network security, and solid state physics.