ISSN: 0976-9102 (ONLINE)
DOI: 10.21917/ijivp.2021.0345

EVALUATION OF IMPROVED FUZZY INFERENCE SYSTEM TO PRESERVE IMAGE EDGE FOR IMAGE ANALYSIS

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Abstract

There are numerous applications based on edge detection have been used in the area of image analysis. The technique of edge detection is an important step towards the visual system reliability and security that delivers a better understanding in many applications like object recognition classification, photography, and many more others computer vision application such as pedestrian detection for a vehicle on the road, face detection in biometric, and video surveillance. We know that detection of edge detection is a scientific technique that is practiced to provide better image analysis and towards this purpose, lots of edge identification approach was already implemented by the researchers in the image processing era, but they do not achieve acceptable results for all types of the image that can help in the image analysis. In this research, we introduced a comparative evaluation of edge detection algorithms for instance Sobel, Canny, and Fuzzy logic-based edge detector with an Improved Fuzzy Inference (IFI) system is presented to preserve image edge for image analysis. The key contribution of this research is developing a new hybrid edge mechanism by utilizing the gradient and standard deviation based fuzzy logic approach to achieve better edge detection efficiency. To provide a better edge or non-edge region from an image the proposed IFI has its impact on quality parameters, for instance, Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Entropy and Structural Similarity (SSIM) with the execution time. At last, the performance parameters of the proposed IFI system is compared with other edge technique and we observed that the achieved results justify the proposed work in image processing.

Keywords:

Edge Detection, Fuzzy Logic, Fuzzy Inference, Gradient, Standard Deviation

1. INTRODUCTION

We know that an image is a collection of pixels in terms of two dimensional array that depicts the visual perception artifacts. One of the most important artifacts of an image is its edges and the edges of the image are directly connected or related with the shape of objects and their variations in the distribution of pixel intensities [1]. For the analysis of an image briefly, the edges are carrying significant substantiation about available objects in an image [2]. So, for better image analysis edge detection technique persistently considered as an elementary and initiative operation to achieved better performance of the various computer vision applications in day to day human life. There are two basic image edge detection approaches are available such as [3]:

- Thresholding-based edge detection approach
- Pixels fitting-based edge detection approach

The first method of edge detection is developed by utilizing the concept of the ideal edge pixels of an image and based on the threshold value, edge pixels and non-edge pixels are separated. After that the concept of pixels fitting-based edge detection approach is developed by the researcher but, the thresholding-based edge detection approach is still superior and the most useful approaches and the involved steps in these techniques are demonstrated in Fig.1.

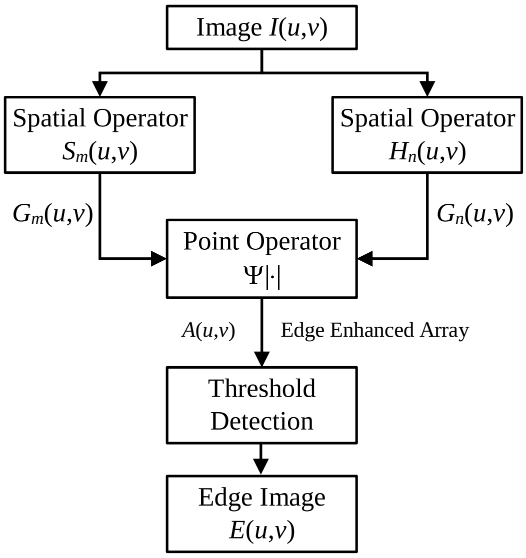


Fig.1. Thresholding-based Edge Detection System

In 1998, the first fuzzy logic-based edge detection was developed by the F. Russo [4] for the successful finding of edges from an image without being misled by the noises using the concept of reasoning rule sets. Thereafter lots of research and improvement were made by the time by utilizing the concept of threshold-based as well as pixel fitting-based method for the elimination of noise and edge detection from the image. At this time, lots of researchers have committed their efforts to design an effective edge detection technique for better analysis of an image [5]. The edge of an image and object available in the image depending on the angle of image viewers and the results may vary from angle to angle for an image. So, researchers used the concept of the rule-based fuzzy logic algorithm to solve this problem, where a lot of rule is designed to detect the edge of an image according to many factors like viewer angle, pixel intensity, object shapes, etc. There are lots of traditional edge detection methods (Sobel, Canny, Prewitt, etc.) are available but they are limited for images or image with noise [6]. Edge is the unexpected variations of gaps in an image and the detection of the edge is a challenging task for research without losing the exact information or object's shape [7]. Generally, edges may be of three types in an image:

- *Horizontal Edges*: It is produced by using the value of gradient in the image based on the vertical analysis, and can be enhanced with a vertical gradient detector.

- *Vertical Edges*: It is detected in an image by using the concept of a horizontal gradient operator based on a threshold to detect the extreme values of the gradient.
- *Diagonal Edges*: It is a combination of both horizontal as well as vertical edges, so we can say that it is neither horizontal nor vertical. It is most effective than other approaches.

The example of Horizontal, Vertical, and Diagonal edges is illustrating in Fig.2.

(a) (b) (c) (d)

Fig.2. Edge (a) Original Image (b) Horizontal Edges (c) Vertical Edges and (d) Diagonal Edges

We know that an image is a collection of pixels where utmost of the shape information of an image from image analysis purpose is enclosed in edges. So, for better image analysis, the identification of these edges in an image, and by using the different approaches will increase the image analysis performance and the image will become clearer [8].

Their lots of edge detection techniques from an image is already proposed by different authors using different concept but in the existing model, the concept of fuzzy logic-based approaches is more effective. But researchers faced many basic problems mainly in the case of horizontal as well as vertical edge detection using fuzzy logic for the low-intensity images and so need to attention regarding this problem [9]. So, the main motivation behind the development of an Improved Fuzzy Inference (IFI) system to preserve image edges for better image analysis and solve the existing drawbacks by utilizing the concept of the diagonal edge analysis method. We introducing an IFI system for edge detection from the low-intensity image as well as high-intensity image also with diagonal gradient detection and the major contributions in this research are listed as:

Hybridization of horizontal and vertical gradient detection is presented to detect the best possible edges from an image with low as well as high pixel intensity.

The concept of Fuzzy Logic-based (IFI system) edge detection algorithm along with hybridization of diagonal gradient and the standard deviation is used to identify the exact edges of an object using their pixel pattern from images.

To validate the proposed IFI system, a comparative analysis with the existing edge detection procedures are performed on the behalf of performance parameters alike Mean Square Error, Peak Signal to Noise Ratio, Entropy and Structural Similarity with execution time.

We introducing the concept of enhanced detection of edge-based on fuzzy logic approach that is known as the IFI system using hybridization with diagonal gradient detection for better image analysis and the remaining paper is outlined as follows. The correlated works in the era of edge detection are reviewed in Sect. 2 and Sect. 3 defines the structure with used material and method of IFI system. Where the experimented simulation results of the introduced model are designated in Sect. 4 and in Sect. 6, the conclusion with the future possibilities of improvisation in edge detection techniques is presented.

2. RELATED WORK

For the detection of edges in the image processing area, the proposal of a dynamic fuzzy inference system for edge detection has been proposed in work by Song et al. [10]. In this research, the authors developed a model for edge detection from the stone inscriptions images and used the concept of the variable membership function for the fuzzy logic. Because for better edge detection the membership function of fuzzy logic must be changed according to the image pixels or their information. They proposed a fuzzy logic-based edge detection algorithm with variable membership function and dynamic generation of fuzzy interface system (FIS) for better image analysis and the proposed approach was compared with existing traditional algorithms such as Sobel and Canny to validate the system. In this research, the author does not consider the quality-based performance parameters for the comparison, so exact validation is not possible of the proposed model. But the basic idea of fuzzy logic-based edge detection was adopted by the Russo, in which an edge detection approach for noisy images using fuzzy logic with reasoning rule was introduced. This method uses irrational thinking to extract the edges without being deceived by the noise present in the image and the test outcomes illustrate that the proposed work performs better than other traditional methods. But, at this time, researchers need a novel edge detection approach that considers the pictorial as well as quality-based comparison of performance parameters for made s better decision about the edge detection mechanism.

Mittal et al. [11] had researched edge detection methods with qualitative and quantitative performance parameters like PSNR, MSE, Entropy, SSIM, etc. In this research, they worked on the two fundamental edge detection limitations, first is the edge connectivity and second is the thickness of edges that is already used, various researchers. They introduce the concept of selection of an optimal threshold for effectual and accurate edge detection form the images. Most researchers have used the process of finding a canny edge on the edge that focuses on choosing two different thresholds and are still facing some problems to get results at the edges. To capture the existing depth of canny or other ways to get to the edge, they chose three-dimensional pathways that made it look at the main drawbacks of existing methods such as contrast, selection of effective edge pixels, error thresholding, and similarity of the ground truth. To validate the proposed work, they find out the qualitative and quantitative performance parameters and compare them with existing works.

Gandhi et al. [12] had researched edge detection from the non-symmetrical images. This research was focused on the improvisation of pre-processing techniques, so they developed an edge detection approach excluding the background noise in an image and for the designing and testing, they used image processing toolbox in MATLAB software.

Liu et al. [12], proposed a model for edge detection using some classical operators with the concept of fuzzy logic. In this research, the author aims to present a comparative model by using seven different Edge detection algorithms to find the edges of the panel and mathematically relate their performance with the utilization of the two structural scenarios in the construction sites. They also present solid log-based conceptual findings and the outcomes illustrate the improved performance of the fuzzy logic algorithm because it properly identify the clear edges of the installed panels as compared to other methods. From the above analysis, we conclude some major challenging issues about the edge detection that is given below:

2.1 CHALLENGING ISSUES

- The selection of smoothing factor is the most common issues faced by the researchers during the detection of edges
- Implementation of thresholds is the biggest challenging task for researchers for edge detection
- The connectivity loss of edges is faced by researchers in the case of tradition as well as edge detection model based on fuzzy logic.
- The loss of information form the images is more by utilizing the available edge detection approaches.
- Edge detection is pervasive in several applications such as fingerprint matching, medical diagnosis, and license plate detection. These applications highlight the areas where image intensity changes drastically and ignore everything else and for such application preservation of pixels of an image is an important and major challenging factor for researchers.

Based on the above survey of existing research in the area of edge detection from the images for better image analysis, we concluded and decided to present a comparative edge detection model and we focus to develop a new approach with the hybridization of fuzzy logic with diagonal gradient detection to preserve the edge of an image. We try to make an edge detection technique and the developed model is known as the IFI system and the structure with implementation steps are described in the next section of this research article.

3. IFI SYSTEM STRUCTURE

The used material and method for the proposed IFI system to preserve image edge for image analysis is explained in this section of the research article using the concept of hybridization of diagonal gradient detection technique with fuzzy logic. We present a comparative analysis in this article for the edge detection techniques by comparing the simulation results of the IFI system using an edge detection approach based on fuzzy logic and compare with the traditional edge detection approaches for instance, Sobel, Canny, etc. The brief details about the proposed IFI system are given in the below section of this paper with a flowchart in Fig.3.

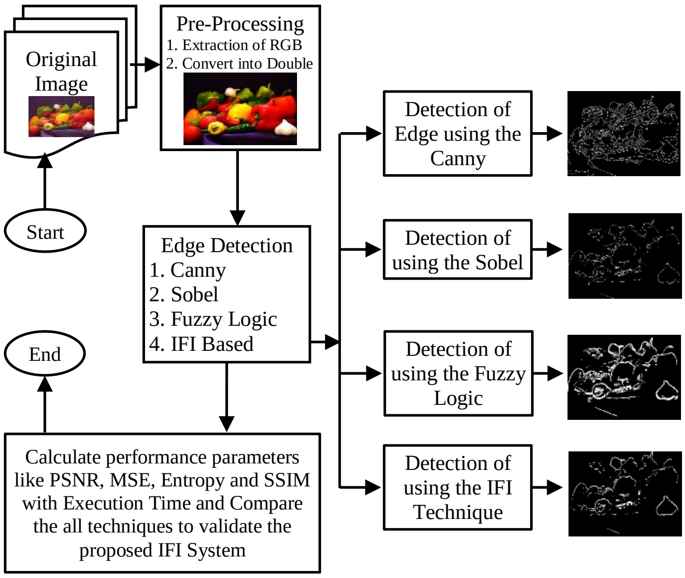


Fig.3. Flowchart of Proposed Comparative Analysis of Edge Detection Techniques

Above Fig.3 shows the comparative flowchart with the proposed work using the concept fuzzy logic with diagonal gradient detection or we can say IFI system for edge detection. Here, we explain the working of each as well as the proposed IFI system. So, firstly we discussed the possible types of edges in an image because the goal of the edge detection algorithm is to ascertain the sharp variations in the direction of the pixels in an image. Within an image, the brightness and identification of the accurate edges of the available object in the image help to find out the outline, area, perimeter, and more features of objects. There is some type of edges are shown in Fig.4 that are encounter in the image processing.

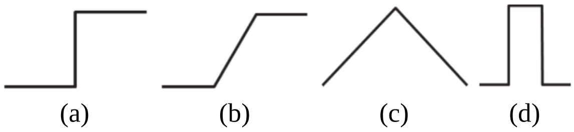


Fig.4. (a) Step Edge (b) Ramp Edge (c) Roof Edge and (d) Spike Edge

In the past two decades, lots of edge detection algorithms developed to extract the contour of the homogeneous areas in the image and much attention is focused on finding the edge of the image with minimum information losses. For any edge detection approach, the first stage is derivatives evaluation of the image intensity and usually, gradient operators are used for derivatives evaluation in any edge detection techniques. Gradient edge operator in image processing is used to calculate a certain value relative to the slope size of a subdued image slope where the image pixel values are detected. So, the first step of the proposed work is gradient detection then we move to edge detection approaches.

Gradient Operators: For edge detection from an image, the first or second derivative of an image pixel level based gradient operators are used. Where the first derivative is used to mark edge points within an image and the second derivative is used to returns two impulses of an edge in terms of side of the edge. In the edge detection algorithms, the gradient of image is computed using the first-order deviation and if the gradient is overhead the threshold value, then the algorithm considered there is an object in the image. Let consider an example of gradient detection for an image $I(m,n)$, the gradient of point of $I(m,n)$ is calculated using the given Eq.(1) as follows:

$$\nabla I(m,n) = [G_m\ G_n] = [\partial I/\partial m\ \ \partial I/\partial n] \quad (1)$$

where the weight of the image vector is calculated using Eq.(2) as follows:

$$\nabla I = \|\nabla I\| = \sqrt{G_m^2 + G_n^2} \quad (2)$$

And its direction is calculated using the given Eq.(3) as follows:

$$\varnothing(m,n) = \arctan(G_m/G_n) \quad (3)$$

The pixel size of each image is calculated using the three-above equation. A small regional pattern convolution is used to process the image. The gradient operator counted in Robert, Prewitt, and Sobel operator. This is easy to use There are many algorithms for the acquisition of the edges whose performance is based on gradient operators like Canny, Robert, Prewitt, Sobel, based on Fuzzy, etc. In this algorithm, the efficiency of Canny, Sobel, and Fuzzy-based non-detection of other algorithms. So, in this research article, we present a comparative analysis of the IFI system with theses algorithms only in detail.

Canny Edge Detector: It was proposed to enhance the edge detection accuracy for digital images and for this purpose three important detection condition were taken into consideration such as:

- To detect all the important edge points in the original image that helps to achieve lower the detection error rate.
- Try to detect the points to be closer to the true edge and point out them that is known as localization.
- The third condition uses to find out only a single reply to a single edge.

The implementation of the canny edge detector is relying upon these detection conditions and needs to smoothen the image to dispense with presents noise in a picture. Then the gradients of the image are computed to point out those regions where the difference of gradient is extreme, that have high spatial differences. At last, track along these regions and discards any pixel that defines weakly an edge (non-maximal suppression) to make the edges thinner. The working of the canny edge detector is divided into five steps that are given as:

Step 1: **Smoothing**: Firstly, we convert the input image into grayscale by fine-tuning their intensity, contrast, and brightness. Then, to filter out the noise of the present in an image to make the location and detection edge efficient. For the image smoothing purpose in canny, a Gaussian filter is used, then move to the next step.

Step 2: **Gradients Determination**: The sharp change in gray level values is called image edge pixels and these are categorized by computing the gradient of the image. The gradient of an image is an element vector that points toward maximum intensity changes in the image's pixels. So, in this step of the Canny edge detector, the vertical, as well as the horizontal components of the gradient, are computed, and then finally, we compute the magnitude and direction of the gradient.

Step 3: **Non-maxima Suppression**: This is the third step of a Canny edge detector in which converts the thick edges into thin and sharp edges based on their gradient magnitudes. The maximum edge thinning operations are performed in this step but edge with already thin are not considered.

Step 4: **Double Thresholding**: To solve the problem of the third step, we set two thresholds, T_1 = High and T_2 = Low Threshold. The pixels (P) satisfy $P>T_1$ is strong edge pixels, and if $P<T_2$ are weak edge pixels that are denoted as a non-edge region. If the P is between T_1 and T_2, then edge probability is reliant on its neighboring pixels.

Step 5: **Tracking of Edge by Hysteresis**: It is the last step in which those edges are discarded that do not connect to a very certain (strong) edge. Create a final edge image with strong edges and weak edges that relate to strong edges are included in an image. The example of canny edge detection is illustrated in Fig.5.

Fig.5. (a) Original Image and (b) Canny Edge

Sobel Edge Detector: The Sobel edge detector measures a 2-Dimensional spatial gradient and finds out regions of the huge spatial gradient in an image to detect their edges. To identify the gradient magnitude at each point in a grayscale image, it is used, only gradient operators. The gradient computed in the form of 3×3 neighborhood pixels of an image and there are various pairs of such as 3×3, 5×5, 7×7, 9×9, etc. convolution kernels may be used. Suppose G_m and G_n is the gradient of the Sobel mask.

$$G_m = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix} \text{ and } G_n = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 0 & 1 \end{pmatrix} \quad (4)$$

where,

G_n is obtained after rotating the G_m anticlockwise direction by 90°. The implementation steps of the Sobel edge detector are written as:

Step 1: Load an input image for edge detection.

Step 2: Perform masking on a given image and calculate the G_m using the above example.

Step 3: Apply rotation of 90° with the anticlockwise direction to calculate the G_n gradient.

Step 4: On the input image, apply G_m and G_n mask manipulation in both the directions.

Step 5: Ascertain the absolute magnitude of the gradient.

The absolute magnitude of the input image is the output edge image. The example of Sobel edge detection is illustrated in Fig.6.

Fig.6. (a) Original Image and (b) Sobel Edge

Fuzzy Logic-based Edge Detector: When we apply fuzzy logic-based edge detection approach then we convert an image into grey level using their bands such as Red (R), Green (G) and Blue (B) component by using the equation 4 written as:

$$G_{Image} = 0.299R+0.587G+0.114B \quad (5)$$

where,

G_{Image} is the grey level image that is obtained after the color conversion then we apply the pre-processing of the further processing using the written algorithm:

Algorithm 1: Pre-processing

Input: Image→Original image for quality improvement for edge detection

Output: P_{Image}→Pre-processed enhanced image for edge detection

Start pre-processing

Suppose Image having dimension of Row=200, Col=200 and Plane=3 (For Color Image, Size = 200×200×3)

Convert into grey level using Eq.(5)

G_{Image} = *RGB* to *Gray* (Image)

Define color fidelity coefficient, *zeta*=0.9

Covert into double data type, $D_{Image} = (G_{Image}/255)$

RGB-Plane = D_{Image}(:,:,1/2/3) where, 1 for Red (*R*), 2 for Green (*G*) and 3 for Blue (*B*) Plane of Image

Set threshold according to color component in an image,

Tao-RGB = [R=0.5, G=0.4, B=0.6]

$$RGB_{img}=([R\text{-min}(R])/(\max(R)\text{-min}(R)) \quad (6)$$

For *J*=1→All Row

For *K*=1→All Col

If *R* image(*J*,*K*) ≤ *Tao-RGB*(0.5, 0.4, 0.6)

$$RGB(j,k) = 2\times(RGB_{img}(J,K)^2) \quad (7)$$

Else

$$RGB(j,k) = 1\text{-}2\times(1\text{-}RGB(J,K)^2) \quad (8)$$

End If

End For

End For

$$RGB = (RGB)^{Tao\text{-}RGB+zeta}$$

P_{Image} = (RGB(R)+RGB(G)+RGB(B))

Return: P_{Image} as a pre-processed enhanced image

End Algorithm

This algorithm helps to enhance the input image that is used in the edge detection mechanism and after that, we apply the fuzzy logic on the image using the given rules sets:

1. If (p_1 is black) and (p2 is black) and (p3 is black) and (p_4 is black) then (pout is black) (1)
2. If (p_1 is black) and (p2 is black) and (p3 is black) and (p_4 is white) then (pout is edge) (1)
3. If (p_1 is black) and (p_2 is black) and (p_3 is white) and (p_4 is black) then (pout is edge) (1)
4. If (p_1 is black) and (p_2 is black) and (p_3 is white) and (p_4 is white) then (pout is edge) (1)
5. If (p_1 is black) and (p_2 is white) and (p_3 is black) and (p_4 is black) then (pout is edge) (1)
6. If (p_1 is black) and (p_2 is white) and (p_3 is black) and (p_4 is white) then (pout is edge) (1)
7. If (p_1 is black) and (p_2 is white) and (p_3 is white) and (p_4 is black) then (pout is edge) (1)
8. If (p_1 is black) and (p_2 is white) and (p_3 is white) and (p_4 is white) then (pout is white) (1)
9. If (p_1 is white) and (p_2 is black) and (p_3 is black) and (p_4 is black) then (pout is black) (1)
10. If (p_1 is white) and (p_2 is black) and (p_3 is black) and (p_4 is white) then (pout is edge) (1)
11. If (p_1 is white) and (p_2 is black) and (p_3 is white) and (p_4 is black) then (pout is edge) (1)
12. If (p_1 is white) and (p_2 is black) and (p_3 is white) and (p_4 is white) then (pout is edge) (1)
13. If (p_1 is white) and (p_2 is white) and (p_3 is black) and (p_4 is black) then (pout is edge) (1)
14. If (p_1 is white) and (p_2 is white) and (p_3 is black) and (p_4 is white) then (pout is edge) (1)
15. If (p_1 is white) and (p_2 is white) and (p_3 is white) and (p_4 is black) then (pout is edge) (1)
16. If (p_1 is white) and (p_2 is white) and (p_3 is white) and (p_4 is white) then (pout is white) (1)

In the ruleset, p1 is the first input of the fuzzy logic where p2, p3, and p4 are the second, third, and fourth input respectively. The output of the fuzzy logic is denoted by pout as edge image and the membership graph is illustrated in Fig.7.

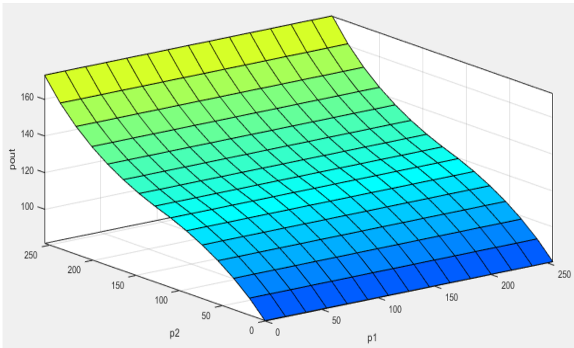


Fig.7. Membership Surface Viewer

We apply the first derivative gradient (GR) on the input image and set a default threshold value is T=30. If any pout<T, then those removed and considered as non-edge portion in an image.

By utilizing this concept, we obtained a better edge for input (Lena) image and the example of Fuzzy Logic-based edge detection is illustrated in Fig.8.

Fig.8. (a) Original Image and (b) Edge Image

To calculate the output edge image, we used the given Eq.(9) written as:

$$p_{out} = \left(\frac{G - \min(G)}{\max(G) - \min(G)} \right) \times 255 \quad (9)$$

IFI Edge Detector: When we apply an improved fuzzy logic-based edge detection approach, firstly we need to convert image into a grey level by using equation 4. After that, we find out the gradient (*GR*) and Standard Deviation (SD) of grey-level image and define the rule sets that are given below:

1. If (*GR* is low) and (*SD* is low) then (*edginess* is black) (1)
2. If (*GR* is low) and (*SD* is medium) then (*edginess* is black) (1)
3. If (*GR* is low) and (*SD* is high) then (*edginess* is gray) (1)
4. If (*GR* is medium) and (*SD* is low) then (*edginess* is black) (1)
5. If (*GR* is medium) and (*SD* is medium) then (*edginess* is white) (1)
6. If (*GR* is medium) and (*SD* is high) then (*edginess* is white) (1)
7. If (*GR* is high) and (*SD* is low) then (*edginess* is gray) (1)
8. If (*GR* is high) and (*SD* is medium) then (*edginess* is white) (1)
9. If (*GR* is high) and (*SD* is high) then (*edginess* is white) (1)

Here, we only use the nine rules this is one of the biggest advantages of proposed IFI system for the edge detection. The proposed IFI system's function is shown in Fig.9.

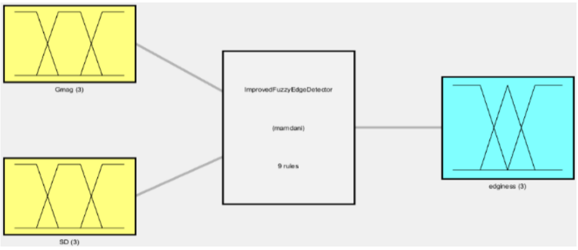


Fig.9. Function of IFI System

From the figure, we can see there is two input first is GR and second is DS of the image, and based on these parameters we obtained an edginess as an output in terms of the edge image. The selection condition for a pixel as an edge region or non-edge region is clearly defined in the rule setlist of the proposed IFI system. The algorithm of the proposed IFI system is written as:

Algorithm 2: IFI System

Input: P_{Image}→Pre-processed enhanced image for edge detection

Output: E_{Image}→Edge image

Start edge detection

Suppose Image having dimension of Row=200, Col=200 and Plane=3 (For Color Image, Size = 200×200×3)

Try to convert into grey using Eq.(5)

If *Plane*>1

G_{Image} = RGB to *Gray* (P_{Image})

Else

$G_{Image} = P_{Image}$

End If

Calculate the Gradient,

GR = gradient (G_{Image})

SD = Standard Deviation (G_{Image})

Apply fuzzy logic with above-mentioned rule sets as a condition to find out an edge

Evaluate Fuzzy Logic

For *i* = 1→Row×Col

$I_{evaluate}$ = evals([*GR SD*)

End For

If $I_{evaluate} > 0.20$

$E_{Image} = I_{evaluate}$ value = Edge Region

Else

$E_{Image} = I_{evaluate}$ value = Non-Edge Region

End If

Return: E_{Image} as an Edge Image

End Algorithm

Using the above algorithm of IFI system the obtained membership surface viewer is shown in the below Fig.10 in a three-dimensional plane.

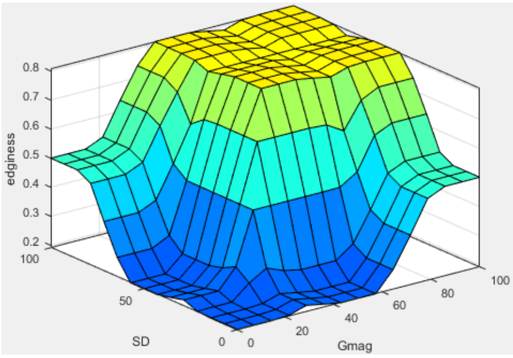


Fig.10: IFI System Membership Surface Viewer

By utilizing this concept horizontal and vertical gradient as well standard deviation of an image, we obtained a better edge for input (Lena) image as compare to the existing edge detection techniques and the example of IFI system-based edge detection is shown in the Fig.11.

(a) (b)

Fig.11. (a) Original Image and (b) Edge Image

At last of simulation, the performance parameters of the proposed IFI system are calculated and compare with exiting edge diction technique that is explained in the above section of the research article in terms of PSNR, MSE, Entropy, and SSIM with execution time. The above structure and edge detection algorithms are shows procedural steps of the proposed IFI system as well as other traditional techniques. By using the above procedure, we achieve better experimental and detection results that are well described in the next section of this research paper on behalf of some sample images. The list of used sample images is illustrated in Fig.12.

Fig.12. Database of Sample Images

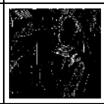
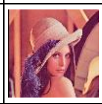
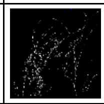
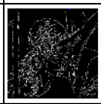
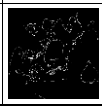
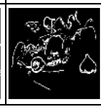
Above Fig.12 represents the used sample image in the proposed comparative model to detect the edge of an image for better image analysis. In the figure, Baboon, Barbra, Lena, and Peppers images are shown and their details are given in Table.1 with the description.

Table.1. Description of Sample Images Database

Image Name	Format	Size
Baboon	JPG	12.7 KB (13,106 bytes)
Barbra	JPG	99.8 KB (102,245 bytes)
Lena	JPG	103 KB (105,865 bytes)
Peppers	JPG	48.1 KB (49,339 bytes)

The goal of this research work is to provide a comparative analysis for research on image edge and gradient detection and we try to achieve better results in this area that helps to analyze an image properly. The simulation results of the proposed comparative model are described in the Table.2 with the original images.

Table 2. Edge Detection Comparison

Image Name	Original Images	Pre-processed Images	Edge Images			
			Sobel	Canny	Fuzzy	IFI
Baboon						
Barbra						
Lena						
Peppers						

Based on the above-mentioned dataset of a sample image that is used for the testing of the proposed comparative model of the image edge detection using the hybridization of fuzzy logic with the gradient as well standard deviation mechanism. The simulation results of the proposed model are shown in the next section of the research article.

4. RESULTS AND ANALYSIS

In this section, we describe the simulation results of the proposed comparative mode for the edge detection for better image analysis, and the simulation results based on the PSNR of the image is given in Table.3.

Table.3. PSNR Comparison

Images	Sobel	Canny	Fuzzy	IFI
Baboon	48.65	52.93	56.45	60.64
Barbra	56.87	62.41	66.45	78.12
Lena	52.38	57.34	63.82	78.08
Peppers	55.73	59.83	68.18	76.38
Average	53.41	58.13	63.72	73.31

For better image analysis for a digital image, the proposed IFI system has achieved better performance in terms of PSNR that is shown in Table.3 based on the comparison with existing edge detection algorithms such as Sobel, Canny and Fuzzy logic based work.

To calculate the PSNR, we use the given Eq.(10) of PSNR:

$$Image_{PSNR} = 10 \times \log \frac{255^2}{MSE} \tag{10}$$

where, *MSE* id calculated using the given Eq.(11):

$$MSE = \frac{1}{mn}\sum_{i=0}^{m}\sum_{j=0}^{n}\left[I(i,j)-E(i,j)\right]^2 \tag{11}$$

where,

m and *n* is the row and column of an image and

I is original image and

E is an edge image.

According to the above figure, we observed that the PSNR value in the case of the proposed IF system is better as compared to the others like Sobel, canny, and fuzzy-based methods. The average PSNR of the proposed IFI system is recorded 73.31 and if the PSNR of the IFI system is more, then the MSE is minimum that is given in the Table.4.

Table.4. MSE Comparison

Images	Sobel	Canny	Fuzzy	IFI
Baboon	0.6474	0.5973	0.5482	0.2645
Barbra	0.4955	0.3743	0.1451	0.0483
Lena	0.3654	0.1773	0.0819	0.0557
Peppers	0.7456	0.3483	0.1365	0.0977
Average	0.5634	0.3743	0.2279	0.1165

The graphical representation of the MSE comparison of the proposed IFI system with other methods are is shown in Table.4 with existing edge detection algorithms such as Sobel, Canny, and Fuzzy logic based work.

We also compare some other parameters like Entropy, SSIM, and Execution time of proposed IFI system with existing edge detection algorithms such as Sobel, Canny, and Fuzzy logic based work in Table.5 - Table.7, respectively.

Table.5. Entropy Comparison

Images	Sobel	Canny	Fuzzy	IFI
Baboon	0.514	0.563	0.644	0.983
Barbra	0.527	0.583	0.738	0.836
Lena	0.503	0.527	0.736	0.936
Peppers	0.512	0.534	0.672	0.873
Average	0.514	0.552	0.697	0.907

Table.6. SSIM Comparison

Images	Sobel	Canny	Fuzzy	IFI
Baboon	0.893	0.918	0.943	0.958
Barbra	0.891	0.911	0.938	0.947
Lena	0.916	0.926	0.966	0.984
Peppers	0.929	0.937	0.975	0.998
Average	0.907	0.923	0.955	0.972

Table.7. Execution Time Comparison

Images	Sobel	Canny	Fuzzy	IFI
Baboon	1.855	2.646	4.644	12.45
Barbra	1.367	1.754	3.774	11.47
Lena	0.975	4.466	5.756	14.85
Peppers	1.745	2.556	5.744	13.57
Average	1.485	2.856	4.979	13.085

From the tabular data, we concluded that the execution time of the proposed IFI system is more otherwise all factors are better as compare to the other techniques of edge detection.

Above simulation results based on the Entropy, SSIM and Execution Time, the effectiveness of proposed IFI system have its impact and also show the improved results with the major impact of gradient and standard deviation-based hybridization of fuzzy logic approach technique for the edge detection of an image in the area of image analysis for various real-time applications.

5. CONCLUSION AND FUTURE WORK

In this paper, a comparative evaluation of the edge detection algorithm with the IFI system is presented to preserve the image edge for image analysis. The main contribution of this research is developing a new hybrid edge mechanism by utilizing the gradient and standard deviation based fuzzy logic approach to achieve better edge detection efficiency. We present a comparative study of traditional edge detection algorithms with the proposed IFI system to validate the efficiency of this research regarding better image analysis. The obtained and achieved results of the proposed IFI system in terms of PSNR, MSE, Entropy, SSIM, and Execution time have a great impact in the area of edge detection. The obtained parameter values are favorably acceptable under consideration to show the effectiveness of the proposed IFI system as compare to the traditional edge detection technique like Sobel, Canny, and Fuzzy logic-based edge detector. In the future, the proposed IFI system could be developed for medical data like x-ray images based on the artificial intelligence approach to reduce the execution time of the system.

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