Annals of Fuzzy Mathematics and Informatics Volume 13, No. 3, (March 2017), pp. 421–435 ISSN: 2093–9310 (print version) ISSN: 2287–6235 (electronic version) http://www.afmi.or.kr

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Noise removal from images using intuitionistic fuzzy logic controller

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Received 18 March 2016; Revised 16 May 2016; Accepted 6 August 2016

ABSTRACT. Information obtained from the real world problems are often complex and left incomplete. The concept of intuitionistic fuzzy system including intuitionistic fuzzy sets and intuitionistic fuzzy logic by Atanassov was based on the elements of uncertainty. A common architecture of intuitionistic fuzzy logic controller (IFLC) is designed and proposed in this paper. The capability of the proposed architecture is clearly elucidated through the experimental results.

2010 AMS Classification: 03B52, 03E72, 28E10, 03B70, 03B80, 68U10, 94D05

Keywords: Intuitionistic fuzzy set, Intuitionistic fuzzy image processing, Intuitionistic fuzzy logic controller, PSNR values.

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1. INTRODUCTION

The design of traditional logic controller usually requires a mathematical model of the process involved. The construction of such model is difficult for many real world problems due to partial or unreliable information. The imprecise description of the problem can be handled as an alternative approach by expert human operators. This modeling leads to the usage of fuzzy concepts which is close to human perception than traditional logical system. Fuzzy set theory introduced by Zadeh deals with an uncertain information in any field where issue of complexity arises [8, 26].

Data given as inputs to a fuzzy logic system and data used for tuning, are often noisy, thus bearing an amount of uncertainty. Designing of fuzzy logic controller (FLC) involves definition of fuzzy sets. Most commonly used FLC are direct closed loop controller such as mamdani (linguistic) controller and Takagi sugeno (supervisor) controller. An appropriate selection of membership function is essential to define each input and output variable in the FLC design. An important method of assessing the effectiveness of control involves in the shape of the membership function. FLC for noisy images is designed using fuzzy filtering techniques applied in inference engine.

Many research works are going in filtering techniques from non-fuzzy to fuzzy. Traditional statistical filters are defined in digital image processing by Gonzalez [21]. In literature, several authors were working on fuzzy filters and their extensions. Pal, et. al worked on image enhancement using fuzzy set [14] and designed an algorithm using contrast intensification operator. Sharmistha Bhattacharya, et. al [23] proposed a Contrast removal fuzzy operator in image processing. C.V. Jawahar [12] developed fuzzy statistics for digital images which is an alternative representation to hard statistics.

Various emergent techniques based on fuzzy logic have entered the area of nonlinear filters and variety of methods have been recently proposed to perform detail preserving smoothing of noisy image data yielding better results than classical operators. Farizio Russo [22] presented an overview of non-linear fuzzy filters focussing on their similarities and differences.

Mike Natchtegael, et. al presented an overview of existing classical and fuzzy filters for noise reduction and a comparison study has been reported in [13].

Ville. D. Nachtegael, D. Weken, E. Kerre, W. Philips and I. Lemahieu introduced a two staged noise reduction technique corrupted with additive noise by fuzzy image filtering [25].

J. Sorubal Marcel, et. al proposed fuzzy approach for detecting and removing salt and pepper noise. An overview of existing fuzzy filters for image noise reduction is illustrated and comparitive study of classical and fuzzy filters for image noise reduction is made. Jagadish H. Pujar [11] described a robust fuzzy median filter for impulse noise reduction of gray scale images. In order to improve the performance of classical median filter, a median filter based on fuzzy logic technique is proposed which includes two stages of identifying impulse noise pixel and denoising it using fuzzy median filter.

Bhavana Deshpande designed a fuzzy based median filtering for noise removal along with the fuzzy rule based approach to improve the filter performance in saltand-pepper noise detection and cancellation [6].

Among extensions of fuzzy sets, Atanassov's intuitionistic fuzzy sets (IFSs) [4, 5] provide a intuitive framework to deal vagueness from imprecise information by taking into account non-membership values in addition to membership values. Intuitionistic fuzzy set theory plays an important role in the field of engineering, statistics, graph theory, image processing, signal processing, medical diagnosis [10], pattern recognition, decision making and expert system.

Ioannis, et. al [9] initiated an attempt towards intuitionistic fuzzy image processing and presented an intuitive approach for intuitionistic fuzzification of images. Moreover, an issue of applying the theory of IFSs in the field of image processing is discussed, which is the first stage of IF image processing. Tamalika chaira [24] presented a novel method for IF segmentation and edge detection of medical images. Parvathi, et. al [15, 16] developed a method based on intuitionistic fuzzy approach for image enhancement using contrast intensification operator. Also some IF statistical tools for filters have been developed by Parvathi, et. al [17] which is an initiative towards IF filtering.

Agarwal, et. al presented the design of a probabilistic intuitionistic fuzzy rule based controller. Akram, et. al [1] describes intuitionistic fuzzy logic controller for heater fans. Akram [2] developed fuzzy logic controller for washing machines. Thus, so far IFLCs are designed to specific applications. In this paper, a common intuitionistic fuzzy logic controller is designed so that it can be used for any kind of controlling system. An example in image processing (filtering techniques) is discussed to verify the validity of the proposed architecture.

Designing of a common IFLC is not found anywhere in the literature. It is therefore necessary to employ IFLC as a tool to deal the issue. Angelov have defined defuzzification over intuitionistic fuzzy sets in [3]. The authors have already worked on intuitionistic fuzzification functions [19] and intuitionistic defuzzification functions [20] which are important components of the proposed IFLC. As filtering techniques in images are considered to verify the validity of the proposed IFLC, work on filtering techniques are presented below.

IFS theory provides a tool to derive filters for image processing in IF environment. IF statistical tools like mean, median, mode for IF data defined by Parvathi, et.al [7, 17, 18] is very helpful for developing IF filters in image processing. Further, the authors proposed to apply IF operators in intuitionistic fuzzy inference engine to establish a flexible mathematical framework for image processing.

The remaining part of the paper is categorized as follows. Section 2 deals with the basic definitions of IFS operators. The architecture of intuitionistic fuzzy logic controller is discussed in Section 3. Section 4 describes the proposed intuitionistic fuzzy filtering algorithm. The results and performance analysis are also discussed in Section 4. Section 5 concludes the paper.

2. Preliminaries

Image Processing is a form of information processing for which the input is an image, such as a photograph or video frame, the output may be either an image or a set of characteristics related to the image where, an image is defined as an array, or a matrix, square pixel arranged in rows and columns. Most image-processing techniques involve treating the image as a two-dimensional representation and applying standard processing techniques to it.

Noise is an unwanted effect in an image which degrades the image to different extend during image acquisiton or transmission. A noisy image can be modeled as

$$C(X,Y) = A(X,Y) + B(X,Y),$$

where A(X, Y) is the original image, B(X, Y) is the noise in the image and C(X, Y) is the resulting noisy image. Common types of noise in images are impulse noise and random noise.

Salt and pepper noise is a special case of impulse noise. Noise reduction is an important task in image processing and filters perform a very strong noise cancellation without degrading the image structure. The simplest traditional way to remove

salt and pepper noise is by windowing the noisy image with the conventional median filter. As a result the noise suppression is effective only at low densities. To overcome this drawback fuzzy filters were introduced. As an extension, IF filters were proposed to improve filter performance in salt and pepper noise detection and cancellation.

Consider a grayscale image 'x' defined as $m \times n$ matrix, where x(i, j) represents the intensity of the pixel at the i^{th} row and the j^{th} column. The intensity is stored in an 8-bit integer, giving 256 possible gray levels in the interval [0, 255]. In this interval, a salt and pepper noise takes minimum and maximum intensity and appears in digital image with equal probabilities. The noise can be positive or negative. Positive impulse appears as white (salt) points with intensity 255 and negative impulse appears as black (pepper) points with intensity 0.

The remaining part of this section is devoted to the basic definitions and concepts of IFS theory required for this work.

Definition 2.1 ([5]). Let the universal set E be fixed. An intuitionistic fuzzy set A in E is defined as an object of the form $A = \{\langle x, \mu_A(x), \nu_A(x) \rangle : x \in E\}$, where the functions $\mu_A : E \to [0,1]$ and $\nu_A : E \to [0,1]$ define the degrees of membership and non-membership of the element $x \in E$ respectively, and for every $x \in E$ in A, $0 \le \mu_A(x) + \nu_A(x) \le 1$ holds.

Let for every $x \in E$, $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ denotes the degree of uncertainty.

Let $A = (A_1, A_2 \cdots A_n)$ be a sample of n intuitionistic fuzzy data, let E be a fixed non-empty set. Let $\langle \mu_{A_i}(x), \nu_{A_i}(x) \rangle$, $i = 1, 2 \cdots n$ be the membership and non-membership values of x in the intuitionistic fuzzy sample IFSp -A.

Definition 2.2 ([17]). The mean of IFSp -A, denoted by $IF_{\bar{A}}$, is defined as

$$IF_{\bar{A}} = \left\{ \left\langle x, \frac{\sum\limits_{i=1}^{n} \mu_{A_i}(x)}{n}, \frac{\sum\limits_{i=1}^{n} \nu_{A_i}(x)}{n} \right\rangle : x \in E \right\}.$$

Definition 2.3. The median of an IFSp -A, denoted by $IF_{med}(A)$, defined as $IF_{med}(A) = \{\langle x, med(\mu_{A_i}(x), med(\nu_{A_i}(x))\rangle : x \in E\}.$

Definition 2.4 ([17]). Let A be an IFS in E, then its normalization denoted by Nor(A), is defined as

$$Nor(A) = \left\{ \left\langle x, \mu_{Nor(A)}(x), \nu_{Nor(A)}(y) \right\rangle : x \in E \right\},$$

where $\mu_{Nor(A)}(x) = \frac{\mu_A(x)}{\sup(\mu_A(x))}$ and $\nu_{Nor(A)}(x) = \frac{\nu_A(x) - \inf(\nu_A(x))}{1 - \inf(\nu_A(x))}.$

Definition 2.5 ([17]). The following are the steps to calculate the mode of an IFSp -A

Step 1. Normalize the data using

$$\mu_{Nor(A_i)}(x) = \frac{\mu_{A_i}(x)}{\sup(\mu_{A_i}(x))}, \nu_{Nor(A_i)}(x) = \frac{\nu_{A_i}(x)}{\sup(\nu_{A_i}(x))}.$$

Step 2. Choosing minimum of normalized membership values and maximum of non-membership values for the IF mode denoted by $IF_{mode}(A)$.

Definition 2.6. The maximum of an IFSp -A, denoted by $IF_{max}(A)$, defined as $IF_{max}(A) = \{ \langle x, max(\mu_{A_1}(x), \mu_{A_2}(x) \cdots \mu_{A_n}(x)), min(\nu_{A_1}(x), \nu_{A_2}(x) \cdots \nu_{A_n}(x)) \rangle : x \in E \}.$

Definition 2.7. The minimum of an IFSp -A, denoted by $IF_{min}(A)$, defined as $IF_{min}(A) = \{ \langle x, min(\mu_{A_1}(x), \mu_{A_2}(x) \cdots \mu_{A_n}(x)), max(\nu_{A_1}(x), \nu_{A_2}(x) \cdots \nu_{A_n}(x)) \rangle : x \in E \}.$

Definition 2.8 ([19]). S-shaped intuitionistic fuzzification function (Siff) of A takes the form

$$\langle \mu_A(x), \gamma_A(x) \rangle = \begin{cases} \langle 0, 1-\epsilon \rangle & \text{if } x \leq a \\ \left\langle 2(\frac{x-a}{b-a})^2 - \epsilon, 1-2(\frac{x-a}{b-a})^2 \right\rangle & \text{if } a < x \leq \frac{a+b}{2} \\ \left\langle 1-2(\frac{x-b}{b-a})^2 - \epsilon, 2(\frac{x-b}{b-a})^2 \right\rangle & \text{if } \frac{a+b}{2} \leq x < b \\ \left\langle 1-\epsilon, 0 \right\rangle & \text{if } x \geq b , \end{cases}$$

where ϵ is an arbitrary parameter chosen in such a way that $\mu_A(x) + \gamma_A(x) + \epsilon = 1$ and $0 \le \epsilon < 1$.

Definition 2.9 ([20]). S-shaped intuitionistic defuzzification function (Sidf) takes the form

$$C(y) = \begin{cases} \leq a & \text{if } y = 0\\ a + \frac{(b-a)\sqrt{y+\epsilon}}{\sqrt{2}} + (\mu * (c_1 - \gamma))^2 & \text{if } 0 < y \leq 2(\frac{x-a}{b-a})^2 - \epsilon\\ b - \frac{(b-a)\sqrt{1-(y+\epsilon)}}{\sqrt{2}} - (\mu * c_2 * \gamma)^2 & \text{if } 2(\frac{x-a}{b-a})^2 - \epsilon \leq y < 1 - 2(\frac{x-b}{b-a})^2 - \epsilon\\ \geq b & \text{if } y \geq 1 - \epsilon \end{cases}$$

where c_1 and c_2 are arbitrary constants.

3. Architecture of an intuitionistic fuzzy logic controller

The basic structure of an intuitionistic fuzzy logic controller is shown in Figure 1. The controller includes the following components.



FIGURE 1. Block diagram of an intuitionistic fuzzy logic controller

(1) Intuitionistic fuzzifier

Intuitionistic fuzzification transforms input crisp values into intuitionistic fuzzy values. Nine types of intuitionistic fuzzification functions are defined on the basis of different shapes of the membership and non-membership

functions [19]. Appropriate intuitionistic fuzzy membership function can be selected for intuitionistic fuzzification. Here, intuitionistic fuzzy S-shaped function is used for fuzzification process.

(2) Intuitionistic fuzzy inference engine

intuitionistic fuzzy values are then used by intuitionistic fuzzy inference engine where necessary modifications (using either IF or IF-THEN rules or intuitionistic fuzzy logic or intuitionistic fuzzy operators) are done to obtain the desired result.

(3) Intuitionistic defuzzifier

Intuitionistic defuzzification function transforms intuitionistic fuzzy (output from inference engine) values into crisp values. Various types of intuitonistic defuzzification functions such as triangular, trapezoidal, L-trapezoidal, R- trapezoidal, Gaussian, S-shaped, Z-shaped functions are defined [20]. Suitable intuitionistic fuzzy defuzzification function can be selected for defuzzification.

Remarks:

- (1) If any of the defined fuzzification functions is not found suitable for the specific problem, the user can define a required fuzzification function, based on the requirement.
- (2) Unlike defuzzification to single value in fuzzy controller, intuitionistic defuzzification gives a matrix of defuzzified values in [0,1], corresponding to the gray levels of the given image.

4. An application of intuitionistic fuzzy logic controller

Digital images are often corrupted by different kinds of noise due to errors that occur in the process of transmission in the communication channels and need to be processed to improve their pictorial information for better human interpretation. In order to get a noise free image, several linear and non-linear filtering techniques are used.

Filters increase the brightness and contrast as well as to add wide variety of special effects to an image. There are many types of filters and among them mean, median, mode play an important role in filtering. In recent years, many fuzzy filters have been designed to provide better results than traditional filters.

Information on gray level of images are always not of certain nature. In such situation, fuzzy logic is used to process imperfect data which arises due to vagueness and ambiquity. Inspite of vast applications, FSs are not always able to model uncertainties associated with imperfect information. This is due to the fact that their membership functions are themselves crisp. Data given as inputs to an fuzzy logic system and data used for tuning, are often noisy, thus bearing an amount of uncertainty.

Intuitionistic fuzzy sets (IFSs) provide a intuitive framework to deal vagueness from imprecise information by taking in to account non- membership values in addition to membership values. IFLC for noisy images is designed using intuitionistic fuzzy filters applied in inference engine and the proposed technique removes or effectively suppresses the noise in the image and enhances the image quality without any loss of edge information. Four different filtering techniques namely intuitionistic fuzzy (IF) mean, IF median, IF max, IF min filters are defined and their filtering performance on impulse noise is presented. The performance of the proposed method is evaluated in MATLAB simulations for an image that has been subjected to various degrees of corruption with impulse noise[27]. The results demonstrate the effectiveness of the algorithm.

4.1. **Proposed algorithm.** In this section, IF filtering algorithm is designed for noise reduction and image enhancement. The proposed technique removes the noise and improves image quality without any loss of information and following are the steps listed to develop the proposed model:

- Read the noisy image and obtain the gray level matrix.
- Choose $a = \min \max \max b = \max \max \max b$.
- Define the membership function

$$\mu_A(x) = \begin{cases} 0 & ; \quad x \le a \\ 2(\frac{x-a}{b-a})^2 - \epsilon & ; \quad a < x \le \frac{a+b}{2} \\ 1 - 2(\frac{x-b}{b-a})^2 - \epsilon & ; \quad \frac{a+b}{2} \le x < b \\ 1 - \epsilon & ; \quad x \ge b, \end{cases}$$

where x is the gray level of the pixel which is to be fuzzified.

• Calculate the non-membership values in terms of membership values.

$$\nu_A(x) = \begin{cases} 1-\epsilon & ; \quad x \le a \\ 1-2(\frac{x-a}{b-a})^2 & ; \quad a < x \le \frac{a+b}{2} \\ 2(\frac{x-b}{b-a})^2 & ; \quad \frac{a+b}{2} \le x < b \\ 0 & ; \quad x \ge b \end{cases}$$

such that $0 \le \mu_A(x) + \nu_A(x) + \epsilon_A(x) \le 1$.

- Modify membership and non-membership values $\langle \mu'_{mn}, \nu'_{mn} \rangle$ using any one of the intuitionistic fuzzy filters namely IF mean, IF maximum, IF minimum, IF median [using Definition 2.2, 2.6, 2.7, 2.3] respectively.
- Calculate the new gray level using the modified membership and non-membership values. $g'_{A} = \begin{cases} a + \frac{(b-a)\sqrt{y+\epsilon}}{\sqrt{2}} + (\mu * (C_{1} * \nu))^{2} ; & 0 \le y \le 2(\frac{x-a}{b-a})^{2} \epsilon \\ b \frac{(b-a)\sqrt{y+\epsilon}}{\sqrt{2}} (\mu * (C_{2} * \nu))^{2} ; & 1 2(\frac{x-b}{b-a})^{2} \epsilon \le y < 2(\frac{x-a}{b-a})^{2} \epsilon, \\ where C_{1} \text{ and } C_{2} \text{ are arbitrary constants.} \end{cases}$
- Display noise-free output image.

4.2. **Results and discussion.** Intuitionistic fuzzy statistical tools find better performance to handle imprecision in gray distribution. Experimental analysis is performed in two different ways. (i) Based on the image performance. (ii) Based on the statistical measures (Peak to signal noise ratio (PSNR)).

To illustrate, a gray scale lena image of size 256×256 with 8 bits per pixel tone resolution with 20% of salt and pepper noise is considered for analysis. IF filter of window size 3×3 is applied. Gray value of the image, membership and nonmembership values of the distored image and restored image are shown in Example 4.1, which interprets IF median filter perform better for elimination of salt and pepper noise. In the proposed system, non-membership values have also been included which makes difference in the output.

Example 4.1. For illustrative purpose, a particular part of the image is extracted and used for analysis.

Step(i): Original gray level of the given image are converted into double type.

0.623529	0.639215	0.643137
0.631372	0.639215	0.639215
0.639215	0.635294	0.635294
0.6431372	0.639215	0.631372
0.647058	0.639215	0.635294
0.631372	0.631372	0.627450
0.615686	0.623529	0.623529
0.615686	0.627450	0.631372
0.615686	0.619607	0
0.623529	0.623529	0.627450

Step(ii): Choose $a = \min \max \max b = \max \max \max b$

Step(iii): The intuitionistically fuzzified values of the gray level are displayed as below:

Array-me	embership v	alues	Array-noi	n-membersh	ip values
0.716439	0.739569	0.745197	0.283460	0.260330	0.254702
0.728127	0.739569	0.739569	0.271772	0.260330	0.260330
0.739569	0.733879	0.733879	0.260330	0.266020	0.266020
0.745197	0.739569	0.728127	0.254702	0.260330	0.271772
0.750765	0.739569	0.733879	0.249134	0.260330	0.266020
0.728127	0.728127	0.722314	0.271772	0.271772	0.277585
0.704505	0.716439	0.716439	0.295394	0.283460	0.283460
0.704505	0.722314	0.728127	0.295394	0.277585	0.271772
0.704505	0.710503	0	0.295394	0.289396	0.999900
0.716439	0.716439	0.722314	0.283460	0.283460	0.277585

Step(iv): The modified membership and non-membership values using IF median filter are calculated and tabulated as follows:

Modified	membershi	ip values	Modified nor	n-membersh	ip values
0.716439	0.739569	0.739569	0.283460	0.260330	0.260330
0.728127	0.739569	0.739569	0.271772	0.260330	0.260330
0.733879	0.739569	0.739569	0.266020	0.260330	0.260330
0.739569	0.739569	0.733879	0.260330	0.260330	0.266020
0.728127	0.733879	0.733879	0.271772	0.266020	0.266020
0.716439	0.728127	0.728127	0.283460	0.271772	0.271772
0.704505	0.722314	0.722314	0.295394	0.277585	0.277585
0.704505	0.710503	0.716439	0.295394	0.289396	0.283460
0.704505	0.716439	0.722314	0.295394	0.283460	0.277585
0.710503	0.716439	0.716439	0.289396	0.283460	0.283460

Step(v): Intuitionistic defuzzification is done as shown below.

⁴²⁸

Newly	generated	gray level	l pixel	values	of	\mathbf{class}	\mathbf{type}	double

0.582287	0.602146	0.602146
0.592214	0.602146	0.602146
0.597180	0.602146	0.602146
0.602146	0.602146	0.597180
0.592214	0.597180	0.597180
0.582287	0.592214	0.592214
0.572377	0.587249	0.587249
0.572377	0.577329	0.582287
0.572377	0.582287	0.587249
0.577329	0.582287	0.582287

New gray level values generated in Step (\mathbf{v}) gives the restored image. Hence, it is inferred that noisy white regions are suppressed by the proposed method and filtered image is obtained.

The original lena image and salt and pepper noisy image are shown in Figure 2(a), Figure 2(b) and corresponding restored image (IF median filtered) are exhibited in Figure 2(c).



FIGURE 2. Final image obtained after IF median filtering. Figure (a) Input image, (b) Salt and pepper noisy image, (c) Restored image (IF median filtered)

Example 4.2. In order to compare the performance of traditional, fuzzy and intuitionistic fuzzy filters, a standard cameraman image of size 256×256 with salt and pepper noise is taken for analysis as shown in Figure 3.





Figure (a)

Figure (b)

FIGURE 3. (a) Input image, (b) Salt and pepper noisy image.

The results of denoising using traditional, fuzzy and intuitionistic fuzzy filters are displayed in Figure 4. In Figure 4, first column refers to traditional filtered image, second and third column refers to fuzzy and intuitionistic fuzzy filtered images respectively. In order to remove impulse noise several intuitionistic fuzzy filtering techniques are employed. Four different filtering techniques namely intuitionistic fuzzy (IF) mean, IF median, IF max, IF min filters are applied and their filtering performance on impulse noise is presented.

It is inferred that from Figure 4, traditional filters often tend to blur sharp edges, and affect the edge details. They remove smaller percent of noise and performance is slow in presence of high noise. Fuzzy based filtering approach perform better noise removal and have great deal with low level noise to high level noise corrupted in the images. In addition, intuitionistic fuzzy filters perform better than fuzzy by giving stability in accuracy.



FIGURE 4. Comparison of filters (a)traditional, (b)fuzzy and (c)intuitionistic fuzzy filters.

4.3. **Performance analysis.** IF filtering algorithms are used to reduce image noise in cameraman and lena images and to enhance the image quality. This technique performs well and provides clear image to the human observer. Experimental results indicate that the proposed method performs significantly better in preserving image details and also preserving image edge information. The proposed method achieves better results when applied to images corrupted by impulse noise (salt and pepper). Performance of the filters are tested at different level of noise densities on the basis of PSNR values. PSNR is usually expressed in terms of the logarithmic decibel (dB) scale.

Restored image performance is quantified using PSNR as defined below:

(4.1)
$$PSNR = 10 \log_{10} \frac{255^2}{\frac{1}{mn} \sum_{i,j} (r_{i,j} - x_{i,j})^2},$$

where r - original image, x - restored image and mn - size of the image.

Comparison on the performance of proposed method to existing methods for median filter is shown in Table 1.

Type of filter	Salt and pepper noise densities				
	20~%	30~%	50~%	80~%	
Adaptive median	35.57	30.72	27.37	22.39	
Standard median	41.59	33.75	26.43	14.57	
Fuzzy median	53.28	37.38	33.65	27.71	
IF median	68.96	59.58	56.98	52.23	

 TABLE 1. Performance comparison of proposed method to existing methods for median filter

The noise density levels vary from 20% to 80% and the performance are quantitatively measured by PSNR. For 20% noise level, PSNR value for adaptive median filter is 35.57, for standard median and fuzzy median filter, PSNR values are 41.59 and 53.28 respectively. Here, IF median value is 68.96. Similarly, for other noise density levels, the PSNR value of IF median is higher than other filters. The higher values of PSNR infer that proposed median filter is in acceptable ratio. Hence, from Table 1, it is obvious that IF median filter performs better.



FIGURE 5. Graphical representation of PSNR Vs Noise densities (in %)

The graphical representation of PSNR Vs Noise densities (in %) is shown in Figure 5. Comparison on the performance of traditional median, fuzzy median and intuitionistic fuzzy median are plotted in the graph. The noise levels vary from 20% to 80% and the corresponding PSNR values vary from 14 to 69 dB. From Figure 5, it is inferred that for 20% noise level, PSNR value for standard median is 41.59 and for fuzzy median and IF median filter, it is 53.28 and 68.96 respectively.

It is observed that, increase in noise level results more stability in accuracy, comparing with other existing filtering techniques. It is evident from the graph that, the proposed IF median filter stands top in removing the noise and preserves the image details.

5. Conclusion

In this paper, an architecture of intuitionistic fuzzy logic controller is newly designed as a mathematical tool in modeling uncertainty and verified with suitable examples. Comparitive analysis of intuitionistic fuzzy filters with traditional and fuzzy filters is done, experimental results illustrate the validity of the proposed technique and provided that intuitionistic fuzzy filter gives better performance. Hence, it is concluded that this work will also pave way for the researchers working on mathematical models in intuitionistic fuzzy environment.

Acknowledgements. The author R.Parvathi would like to thank University Grants Commision, India for its financial support to the Major Research Project F.No: MRP - 43 - 418/2014 (SR) dated August 2014.

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