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Mixed Noise Image Filtering with Switching Median Filters and Fuzzy Rules

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Abstract: Pixels of the digital images has been corrupted by noises came out of faulty communication channel or non-linear sensors. Such noise models can be either Salt & pepper noise (impulse noise) or Gaussian noise. Sometimes both of the noises corrupt the same image; such combination of two noise model is called as mixed noise. These noises can be removed by using image filtering algorithms. The most popular image filtering algorithm is median filters. Two models of median filters, that are simple median filter and switching median filter has been discussed in this paper. Fuzzy logic controller has been discussed in details so that its combination with median filters can be discussed for future work. Terminologies like fuzzy logic operator, membership functions and fuzzy rules have been discussed. Quality parameter PSNR (Peak Signal to Noise Ratio) has been studied to find the quality of image numerically.

Keywords: Switching median filter, Fuzzy logic rules, Mixed noise, PSNR, Membership functions, Fuzzification, Image filtering.

I. INTRODUCTION

Communication channels like air for wireless communication, USB cables for wired communication add noises in the data transfer via them. Some noises are also added because of the non-linear nature of sensors like defected camera sensor added unwanted noise by corrupting pixels of image. Most frequently added noises are impulse noise and Gaussian noise. A combination of above two noise is called as Mixed noise [1]. In all applications of image processing, image pre-processing is applied as a first step to remove noises so that these noises will not affect the final outputs. Median filters are very popular in removing such noises up to satisfactory level.

To avoid the damage of uncorrupted pixels, the switching based median filter was introduced where noise detection algorithm is followed by noise filtering algorithm [2]. Impulse noise can be defines as a set of random pixels with very high contrast value as compared to the surroundings. It means impulse noise appears as a sprinkle of bright or dark spots on the image [5].

Mixed noise can be removed from corrupted image in two steps, first by the application of filter which suits best to remove salt & pepper (impulse noise) noise and then suitable filter to remove Gaussian noise [2]. But application of two different filter increases the computation cost therefore in place of two, only one filter that is switching median filter is used. Switching filters make use of the concept that they first detect impulses and then remove them using a suitable technique [3].

Fuzzy logic is one of the important decision-making techniques of artificial intelligence. Although it has been subjected to criticisms since its birth, especially in recent years, fuzzy logic has been proven to be applicable in almost all scientific fields. This shows that the concept of fuzzy logic will maintain its validity and the number of fields where it draws attention will increase further [5]. Therefore, implementation of fuzzy logic with switching median filters can provide better quality of image filtering. In this paper, different median filters and fuzzy logic rules has been discussed to find the possibilities of using fuzzy logic in combination with median filters for better image filtering results.

II. FUZZY LOGIC CONCEPTS

The use of linguistic knowledge in the form of IF-THEN rules gives a fuzzy system the ability to work as universal approximate to nonlinear functions [5]. Fuzzy logic is an approach for computing and it is based on "degrees of truth" unlike the usual "true or false" Boolean logic on which modern computers are based. Fuzzy logic is a similar concept on which our brain works. Unlike the programming methods which make use of numeric values for decision making, the Fuzzy Set Theory provides means for converting non-numeric linguistic variables into exact outcome. The general fuzzy logic controller is shown in Fig. 1 below.

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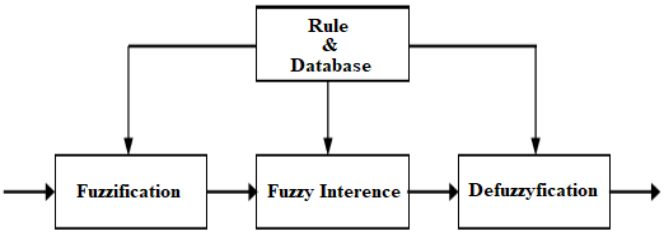

Fig. 1: General Fuzzy Logic Controller

The Fuzzification block works on converting crisp sets into the fuzzy sets. Pre-defined membership functions are used for process of conversion. Where Inference Engine uses if-then rules which are defined in rule editor to analyze fuzzy sets and then provides the output on the basis of those rules. The Defuzzification Module works on converting fuzzy sets back to the crisp form so that the output in user understandable format can be created [1] [7].

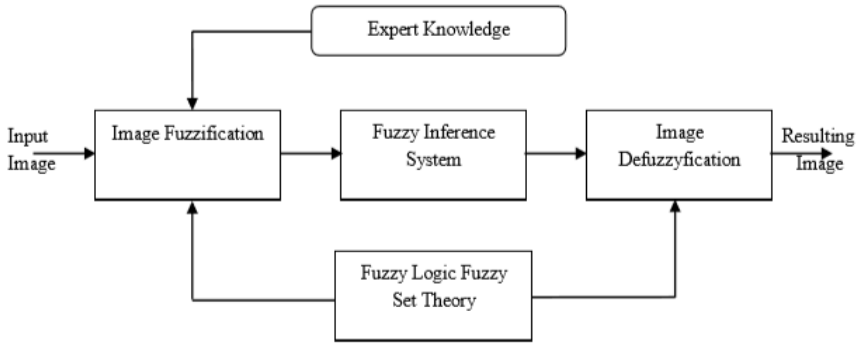

Fig. 2: The General Structure of Fuzzy Image Processing.

When fuzzy logic is used with image processing, then the sequence of processes will be as shown in fig. 2. Where expert knowledge block contains the information regarding the application where fuzzy logic controller is used like in case of image processing, this block contains the information regarding image processing rules.

III. FUZZY LOGIC OPERATOR

Fuzzy set is the extension of crisp set, the binary Boolean logic (crisp set) is extended to fuzzy logic by also allowing truth values between zero and one. The Boolean negation (¬), conjunction (∧) and disjunction (∨) for fuzzy set is given by some definitions.

Negator (NOT Logic) N has a mapping that coincides with the Boolean negation on {0, 1}, i.e., N (0) = 1 and N (1) = 0. The best known negator can be derived from an equation, that is

Conjunctor (OR Logic) C has a mapping that coincides with the Boolean conjunction on {0, 1}, i.e., C (0, 0) = C (0, 1) = C (1, 0) = 0 and C (1, 1) =1.

Disjunctor (AND Logic) D has a mapping that coincides with the Boolean disjunction on {0, 1}, i.e., D (1, 1) = D (0, 1) = D (1, 0) = 1 and D (0, 0) = 0.

IV. MEMBERSHIP FUNCTION

Membership function of the fuzzy set A on the universe of discourse X is defined as $\mu A: X \rightarrow [0, 1]$, where each element of X is mapped to a value between 0 and 1. The value of μA is called or degree of membership or membership value or the grade of membership of the element in X to the fuzzy set A.

By using membership functions we can represent a fuzzy set in graphically form. The y axis represents degrees of membership in the [0, 1] interval, x-axis represents the universe of discourse.

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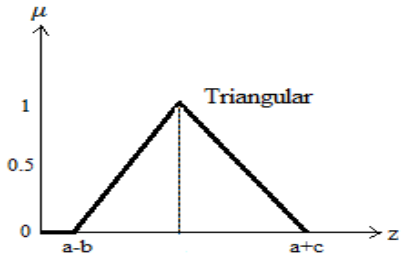

Fig. 3: Triangular membership function Trapezoidal function:

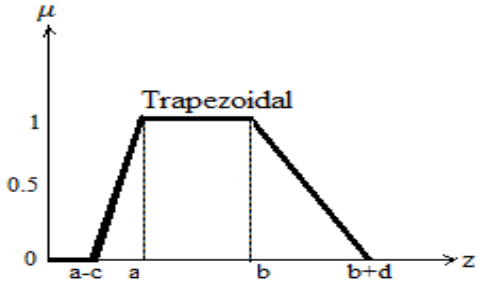

Fig. 4: Trapezoidal membership function

Fig. 3 shows triangular membership function's graphical view while Fig. 4 shows the trapezoidal membership function's graphical view. These membership functions can be used to define either input or output to fuzzy logic block.

V. FUZZY IF-THEN RULES

All fuzzy logical operators are basically used to calculate the activation degree of a fuzzy if-then else rule. These rule gives the degree of membership of output when output is depend upon large number of input and each input has different membership degree for different membership function.

IF (a is A OR b is B) AND c is not C THEN d is D

In this rule,

A ∈ F(X1), a ∈ X1,
B ∈ F(X2), b ∈ X2,
C ∈ F(X3), c ∈ X3 and
D ∈ F(X4), d ∈ X4.

The degree D(d) to which d is D (belongs to D), i.e., the degree to which the result (output) of the rule is true, equals the activation degree of the rule, i.e., the degree to which the antecedent of the rule is true. So, use a conjunctor C, a disjunctor D and a negator N for the AND, OR and NOT-operator respectively.

VI. NOISES IN IMAGE PROCESSING

A. Salt & Pepper Noise

One of the most popular types of impulse type is Salt and pepper noise, it is also called as intensity spikes. Generally, data transmission caused this type of noise. It affects with only two possible intensity, *a* & *b*. Their probability is typically less than 0.1. Minimum or the maximum value is set alternatively in the corrupted pixels, which gives a "salt and pepper" like look to the image while the unaffected pixels do not change. For a gray scale 8-bit image, the usual value for pepper is 0 and for salt is 255 [9][11]. It is generally occurred due to malfunctioning of pixels while dealing with camera sensors, timing errors in analog to digital conversion process or faulty memory locations. The PDF (probability density function) for this noise is in Fig. 5. with a variance of 0.05. Salt and pepper noise look as shown in Fig. 6.

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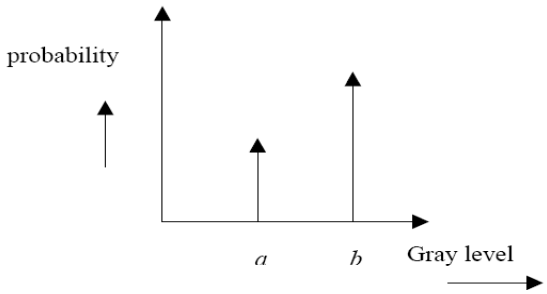

Fig. 5: PDF for salt and pepper noise

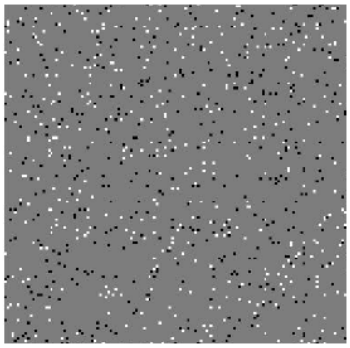

Fig. 6: Salt and pepper noise

B. Gaussian Noise

It is also called as electronic noise because it arises in amplifiers or detectors. Gaussian noise caused by natural sources such as thermal vibration of atoms and discrete nature of radiation of warm objects [11]. Gaussian noise mathematical model represents the correct approximation of real world scenarios. In this noise model, the mean value is zero, variance is 0.1 and 256 gray levels in terms of its PDF, which is shown in Fig. 7.

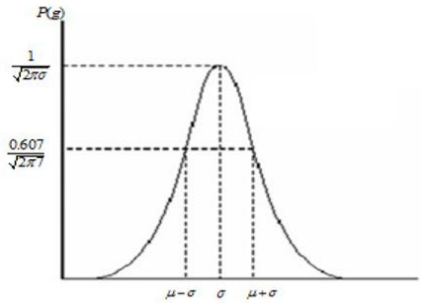

Fig. 7: PDF for Gaussian noise

Fig. 6: Gaussian noise

VII. MEDIAN FILTER ALGORITHM

Median filter is very popular in image filtering. Median filter is actually a low pass filter which blocks all high frequency components of the image like noise and edges. For the filtering of high density corrupted image need large window size so that the sufficient number of noise free pixels will present in the window. So the size of the sliding window in the median filter is varying according to the noise density. The window size 3×3, 5×5, 7×7, and 9×9 median filter are mainly applicable. Output of the median filter is given by

$$y(i,j)=\text{median}\{x(i-s,j-t),x(i,j)/(s,t)\in W,(s,t)\neq(0,0)\} \quad (1)$$

where {x} is the noisy image and y(i,j) is the recovered image with preserve edges [12].

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VIII. SWITCHING MEDIAN FILTER

Switching median filter uses a threshold value to detect the noise in the pixel. If the intensity difference between the center pixel value and median value in the window is greater than the threshold value then center pixel is considered as a noisy pixel and replaced by median value, otherwise center pixel is considered as non-noisy and remain unchanged [10]. Difference in intensity between the center pixel value and median value in the window is given by,

$$\Delta x=|x(i,j)-x\_med| \quad (2)$$

where median value in the window x_med is given by x_med={x(i-N,j-N),….w_c*x(i,j),….x(i-N,j-N)} (3)
Here w_c is the weight of the center pixels.

Suppose {X} is the noisy image and (2N+1) × (2N+1) is the sliding window size, centered at (i, j). The adjustment of the center pixel is given by following equation,

$$y(i,j)=\begin{cases} x_{med}, & \Delta x \geq T_i \\ x(i,j), & \Delta x < T_i \end{cases} \quad (4)$$

y(i,j) is the recoverd image with preserve edges.

IX. QUALITY PARAMETERS

PSNR calculation**,** if the actual image is represented by $o(i,j)$, corrupted image by $x(i,j)$ then the PSNR is given by,

$$PSNR = 10\log_{10}\frac{(Imax)^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(o(i,j)-x(i,j))^2} \quad (5)$$

Here M and N denotes resolution of the image. Imax is the maximum gray scale intensity level that is 255 which in actual represents white color [4] [6].

X. CONCLUSION

Fuzzy logic controller and its terminologies have been discussed. Terms like fuzzy logic operators, membership functions, Fuzzy rules have been studied. Mixed noise is consisted of salt & pepper noise and Gaussian noise. PDF of both the noise modeled has been discussed. Various median filter algorithms are equated and discussed. It is found that median filter is very capable of reducing noise. But median filter also blurs the image therefore switching median filter is implemented which is a combination of two stages. First is noise detection and second is noise filtering. Quality parameter PSNR is used to determine the quality of filtering numerically.

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