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Statistical Moments and Fuzzy Logic Based Classification of Noise Present in Digital Images

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Abstract: In this paper we proposed, a method which effectively classifies noise present in the images using statistical moment based feature extraction and continuing with fuzzy based classification. Noise in corrupted information that may hide the original information of an image. To identify which type of noise exactly present in the digital images fuzzy logic method is used in this work. The feature value helps us to distinguish between the noises. In order to remove the noise from the images one should know which type of noise present in that image. As the step of identifying of noise completes it makes easy for the researcher to remove the noise present in the image Gaussian noise, Salt and pepper noise, Speckle noise have an different feature value which is generated by skewness and kurtosis and also are the type of noises that are identified in this paper using Fuzzy Classification.

Keywords: kurtosis, skewness, Gaussian noise, Salt and pepper noise, Speckle noise, Fuzzy classification.

I. INTRODUCTION

NOISE can be systematically introduced into images during acquisition and transmission. A fundamental problem of image processing is to effectively remove noise from an image while keeping its features intact. The nature of the problem depends on the type of noise added to the image. Fortunately, three noise models can adequately represent most noise added to images: additive Gaussian noise, impulse noise and multiplicative noise. [1].

To keep original information of an image after removing the noise from an image is a major problem. The problem depends on the nature of noise present in the image. Fortunately, two noise models can adequately represent most noise added to images: additive noise and multiplicative noise.

Image processing is an Electronic Domain wherein image is divided into small unit called pixel, and then various operation has been carried out. In the Digital Image Processing field, Enhancement and removing the noise from the image is the critical issue. Gaussian noise (White noise) Salt & Pepper noise and Speckle noise are the types of noises which are generally found in Images [5].

Sometimes, we need to know the type of the noise that is appear in the noisy image depending on the application that we need. Having identified the noise, the appropriate filter can be used to enhance the quality of the given digital image. [4] Gaussian noise (White noise) Salt & Pepper noise and Speckle noise are the different nature of noises that are ,. Noise is information which may destroy the image completely. So to save the image from noise we should remove the noise and for that we should know the nature of noise.

This paper proposes a fuzzy technique for identification of the type of noise present in an image, which can be further used to find better filter for de-noise an image.

II. DIFFERENT TYPE OF NOISE MODEL

Noise is information that may destroy the original information of images many types of noises exist today. They are mainly classified as follows

A. *Additive noise*

Thermal noise is a random fluctuations present in all electronic systems. [6] The additive noise is primarily caused by thermal noise (fundamental noise), which comes from the reset noise of capacitors. The mathematical model given for additive noise type is:

$$s(i, j) = n(i, j) + h(i, j) \qquad (1)$$

Where $1 \le i \le M$, $1 \le j \le N$.

Let M and N be the size of the original image n(i, j), h(i, j) be the noisy image and S(i , j) is the noisy image.

B. *Multiplicative Noise*

This noise gives a magnified view of the area and there is a higher random variation observed. On the other hand, when this noise is applied to a darker region in the image, the random variation observed is not that much as compared to that observed in the brighter areas. Thus, this type of noise is signal dependent and distorts the image in a large way [6]. The speckle noise comes under multiplicative noise. This kind of noise is also called as the speckle noise. The mathematical model for multiplicative noise type is:

$$s(i, j) = n(i, j) * h(i, j) \qquad (2)$$

where $1 \le i \le M$, $1 \le j \le N$

Let M and N be the size of the original image n(i, j), h(i, j) be the noisy image and S(i , j) is the noisy image.

C. *Impulsive Noise*

Impulsive noise is sometimes called as salt-and-pepper noise or spike noise. This kind of noise is typically seen on digital images. It represents itself as randomly occurring

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white and black pixels. An image containing this type of noise will have dark pixels in bright regions and bright pixels in dark regions. It can be caused by dead pixels, analog-to-digital converter errors, bit errors in transmission, etc. [6] Impulsive noise is sometimes called as salt-and-pepper noise.

III. TYPES OF NOISE

A. *Gaussian Noise*

The Gaussian distribution has an important property that in order to estimate the mean of a stationary Gaussian random variable, one cannot do any better than the linear average. [2] *Gaussian noise* is one of the most comely problems that occur in images. The high quality images may also contain this Gaussian noise. It is an additive in nature means some of noisy pixels may added to the real and original pixel of an image.

Fig1 Gaussian noise

Mathematical formula

$$\frac{1}{\sqrt{2\pi b}} e^{-(z-a)^2/2b^2}$$

B. *Salt And Pepper Noise*

This noise arises in the image because of sharp and sudden changes of image signal. Dust particles in the image acquisition source or over heated faulty components can cause this type of noise. [8] In the salt-and-pepper noise model there are only two possible values, a and b, and the probability of each is typically less than 0.1. With numbers greater than 0.1 values, the noise will dominate the image. For an 8-bit image, the typical value for pepper-noise is 0 and for salt-noise 255. [4] Salt-and-pepper is an impulsive noise that may also see in the images. Salt and pepper noise is a noise was some pixel in a digital image may contain black pixel and some pixel contain white pixel.

Fig2 Salt and pepper Noise

Mathematical formula

$$\begin{cases} a \ \ for\, z = a \\ b \ for\, z = b \\ 0 \ \ otherwise \end{cases}$$

C. *Speckle Noise*

It is a multiplicative noise in nature means we generally multiply the corrupted pixel to an original pixel. Laser system and SAR images is sources from where this noise is mostly generated. Another common form of noise is data dropout noise generally referred to as speckle noise. This noise is, in fact, caused by errors in data transmission. [2] Speckle noise can also be called as multiplicative noise.

Fig3 Speckle Noise

Mathematical Formula

$$\begin{cases} ae^{-az} \ \ for\, z \geq 0 \\ 0 \ \ for\, z \geq 0 \end{cases}$$

IV. STATISTICAL FEATURE

In this paper we have generally used two different types of feature measure to classify noises.

A. *Kurtosis*

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. That is, data sets with high kurtosis tend to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Data sets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. A uniform distribution would be the extreme case. Kurtosis is the standardized fourth central moment of the probability distribution. [3]

S=$(E(Z-\mu)^4/\sigma^4) - 3$ (3)

B. *Skewness*

Skewness is a measure of symmetry and it is the standardized third central moment of the probability distribution. Skewness is the standardized third central moment of the probability distribution. [3]

S = $E(Z-\mu)^3/\sigma^3$ (4)

Where the (-3) term makes the value zero for a normal distribution. Both the type of feature value can able to classify the nature of noise in the images.

V. IMAGE FILTER METHOD

A. *Median Filter*

The Median filter is a nonlinear filtering technique, and commonly used to remove the noise present in the image. Normally filters are used to remove noise from images.

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Filters are classified into two types,
(1) Linear Filters
(2) Non-linear Filters

Linear filters too tend to blur sharp edges, destroy lines and other fine image details, and perform poorly in the presence of signal-dependent noise. With non-linear filters, the noise is removed without any attempts to explicitly identify it. The median filter was one of the most popular nonlinear filters for removing Salt & Pepper noise. The noise is removed by replacing the window centre value by the median value of centre neighbourhood. [9]

z(t) = median((x(m-M/2),x(m-M1+1),…,x(m),…,x(m +M/2)). (5)

In the above equation t is the size of the window in a median filter. For the two dimensional data, there are two-dimensional filters used in digital image processing.

B. *Wiener Filter*

Wiener filter is a method through which we can filter the noisy images or signals. The goal of the Wiener filter is to filter out noise that has corrupted a signal. It is based on a statistical approach. Typical filters are designed for a desired frequency response. The Wiener filter approaches filtering from a different angle. One is assumed to have knowledge of the spectral properties of the original signal and the noise, and one seeks the LTI filter whose output would come as close to the original signal as possible. Wiener filters are characterized by the following: [7]

a. Assumption: signal and (additive) noise are stationary linear random processes with known spectral characteristics.
b. Requirement: the filter must be physically realizable, i.e. causal (this requirement can be dropped, resulting in a non-causal solution)
c. Performance criteria: minimum mean-square error

$$\mu = \frac{1}{NM}\sum_{n_1,n_2} x(n_1,n_2)$$

$$\sigma^2 = \frac{1}{NM}\sum_{n_1,n_2} x^2(n_1,n_2) - \mu^2$$

The filter output is given by:-

$$y(n_1,n_2) = \mu + \frac{\sigma^2 - E\xi^2}{\sigma^2}(x(n_1,n_2) - \mu)$$

VI. FUZZY LOGIC CLASSIFICATION

Over the past few decades, fuzzy logic has been used in a wide range of problem domains. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The process of fuzzy inference involves: membership functions, fuzzy logic operators and if-then rules. [10]

The Fuzzy Logic Toolbox is a GUI toolbox that makes easy to design an Fuzzy system for any problem. There are generally two type of system available in the toolbox

- Fuzzy Inference System (FIS) and
- Adaptive Neuro-Fuzzy Inference System (ANFIS).

A. *Fuzzy inference system*

Inference system is a method to evaluate by matching from a given output to an input and then output is shown. The steps which is generally involves in the system is as: mf, operators (And, OR) and if-then rules. There are generally two types of systems which can be implemented using toolbox:

- Mamdani-type and
- Sugeno-type.

In the fuzzy methods their generally and widely used system is a Mamdani's inference system method and it expects the output mf to be fuzzy sets. After the process of a fuzzification, each of the output variable may have thee own fuzzy set and one process should be done called de-fuzzification.

The output mf of an second type (Sugeno-type systems) of system is generally contain either linear or constant value. This fuzzy inference system was come in to known in 1985. Takagi-Sugeno-Kang is another name that is called. A generally rules in a Sugeno inference system is as follow:

The main step of the inference process namely
1) Fuzzification the inputs.
2) Applying the fuzzy operator.

If Input1 = u *and Input2* = v, *then Output is* q = ru + sv + t
For a zero-order Sugeno model, the output level *z* is a constant *(a=b =0).* Membership function is the mathematical function which defines the degree of an element's membership in a fuzzy set.

There are generally 11 different types of mf available in fuzzy toolbox. These functions are built from several basic functions:

- Piecewise linear functions, The Gaussian distribution function, the sigmoid curve and Quadratic and cubic polynomial curve.

B. *Fuzzy logic operators*

In fuzzy logic operator, in the fuzzy values are kept of 1 (fully true) and 0 (fully false). That is, A AND M operator is replaced with minimum - *min* (A,M) operator, A OR M with maximum - *max* (A,M) and NOT M with 1-M.

C. *If-Then rules*

In fuzzy logic we can say that fuzzy set is an subject and operators are verbs. The rules that can be used to express knowledge are as follows:-

If u is X Then v is Y

Where u and v are the variables used in fuzzy and X and Y are values used in fuzzy. According to the above rule we say that if part is "*u* is *X*" is called the *antecedent* or premise, while whereas the then rule "*v* is *Y*" is called the *consequent* or conclusion. Both *antecedent and*

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consequent are called as 'AND' and 'OR'. In the if-then rule, the word "is" is totally dependence on the value.

VII. METHODOLOGY

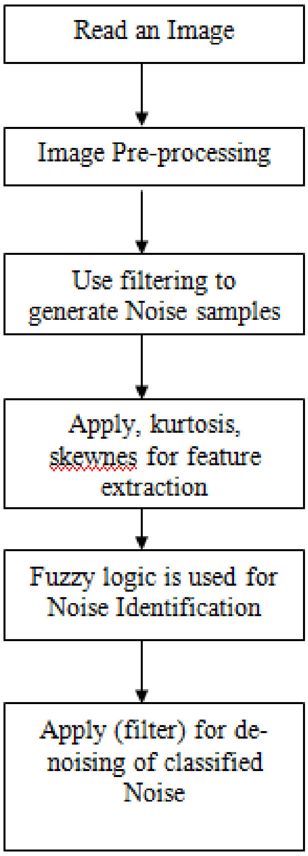

Fig.4 Steps in the proposed technique

Steps of the algorithm to classify noise are detailed in figure 4. The major steps used in our paper they are: image acquisition, pre-processing of images, filtering, noise pattern extraction, feature extraction, classification and de-noising. In the initial steps we introduced noises namely Gaussian, impulse and speckle to the pre-processed images. Then we filtered the noisy images using two commonly used filters, wiener filter and median filter. To get the noise patterns, filtered images have been subtracted from the noisy images .Once the noise patterns are acquired, the kurtosis and skewness statistical feature are used to generate features. Finally, the training and testing performed quite well with fuzzy logic classification.

VIII. EXPERIMENTAL RESULTS

All experiments were carried out using Matlab. Matlab function "imnoise" is used to generate Gaussian white noise, speckle noise and salt-and-pepper noise. We have conducted simulations on different image sequences. Figures 1, 2 and 3 represent one of the noisy image sequences as an example. With three different types of noise inputs, the calculated kurtosis, skewness and identified noise types are shown in Table I.

We conducted testing of training set to different images by adding different percentage of noise for all the three types. The obtained results are shown in table I and the result of %of noise vs. accuracy is plotted as shown in figure 5.

Table I Accuracy of three types of Noise

% of noise	Images Tested	Salt and pepper Correct (Accuracy)	Speckle Correct (Accuracy)	Gaussian Correct (Accuracy)
10	20	1 (5%)	12 (60%)	16(80%)
20	20	2 (10%)	15 (75%)	17(85%)
30	20	13 (65%)	17 (85%)	17(85%)
40	20	18 (90%)	19(95%)	18(90%)
50	20	18 (90%)	17(85%)	18(90%)

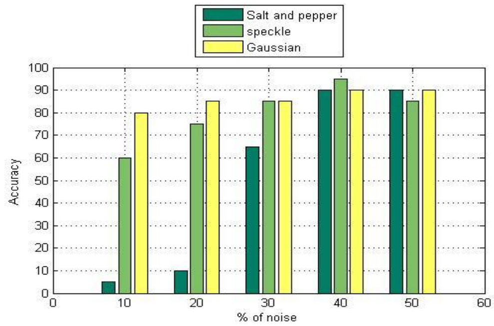

Fig 5 % of Noise vs. Accuracy

IX. CONCLUSION

A Fuzzy logic and statistical measure based technique for identifying the type of noise present in a noisy image is proposed in this paper. The proposed method exhibits fast training process. The proposed technique is also used for further de-noising. The result shows that are capable to classify the type of noise present in the image.

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