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An Assessment and Quality Based Image Noise Technique

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***Abstract* - This Paper work presents a two stage fuzzy based noise reduction-cum-edge detection filter i.e. INAFSM (image & noise adaptive fuzzy switching median) filter for efficient removal of impulse noise (salt and pepper noise) from grayscale images. So the main objective of this dissertation work is to get almost an actual image from the corrupted image and then finding the fine edges in the image using fuzzy logic. Also, it focuses on the analysis of FIDRM, FSM, NAFSM and the proposed filter (INAFSM) on the basis of PSNR (dB), and the MSE (mean square error). The analyzed results show that INAFSM is able to cope up with all types of grayscale images corrupted with impulse noise.**

***Keywords* - Digital Image, NAFSM ,Fuzzy**

I. Introduction

A digital image A[m, n] described in a 2D discrete space is derived from an analog image A(x, y) in a 2D continuous space through a sampling process that is frequently referred to as digitization. The effect of digitization is shown in Figure 1.1. The 2D continuous image A(x, y) is divided into N rows and M columns. The intersection of a row and a column is termed a pixel. The value assigned to the integer coordinates [m, n] with {m = 0, 1, 2, ..., M-1} and {n=0,1,2,...,N-1} is A[m, n]. In fact, in most cases A(x, y) which might consider to be the physical signal that impinges on the face of a 2D sensor is actually a function of many variables including depth (z), color (λ), and time (t). Unless otherwise stated, the case of 2D is considered, monochromatic, static images in this chapter. In fact, in most cases A(x, y) which might consider to be the physical signal that impinges on the face of a 2D sensor is actually a function of many variables including depth (*z*), color (λ), and time (*t*). The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with *L* different gray levels is usually referred to as amplitude quantization or simply quantization. Neighborhood operations play a key role in modern digital image processing. The images can be sampled and relates to the various neighborhoods that can be used to process an image. Neighborhood operations play a key role in modern digital image processing. The images can be sampled and relates to the various neighborhoods that can be used to process an image.

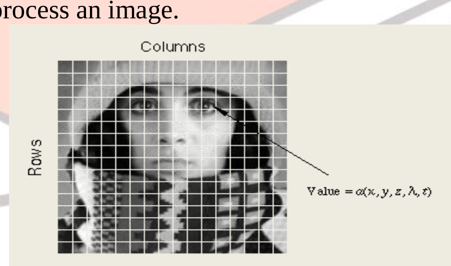


Fig.1.1 Digitization of a continuous image [1]

II. Image Metrics

There are basically two approaches for image Quality measurement:-

- Subjective measurement: A number of observers are selected, tested for their visual capabilities, shown a series of test scenes and asked to score the quality of the scenes. It is the only "correct" method of quantifying visual image quality. However, subjective evaluation is usually too inconvenient, time-consuming and expensive.
- Objective measurement: These are the automatic algorithms for quality assessment that could analyze images and report their quality without human involvement. Such methods could eliminate the need for expensive subjective studies.

Objective image quality metrics can be classified according to the availability of an original (distortion-free) image, with which the distorted image is to be compared.

2.1 Mean Squared Error (MSE)

One obvious way of measuring the similarity between two images is to compute an error signal by subtracting the test signal from the reference, and then computing the average energy of the error signal. The mean-squared-error (MSE) is the simplest, and the most widely used, full-reference image quality measurement.
This metric is frequently used in signal processing and is defined in [15].

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j)-y(i,j))^2 \qquad (1)$$

2.2 Peak Signal to Noise Ratio (PSNR)

It is inversely proportional to the MSE; its units are in decibels (dB) and are formally defined by [3]:

$$PSNR = 10\log_{10}\frac{(2^n-1)^2}{\sqrt{MSE}} \qquad (2)$$

where 255 is the maximum pixel value for an 8 bit/pixel gray-scale image

III. PURPOSED WORK

An algorithm that is especially developed for reducing all kinds of impulse noise is NAFSM (Noise Adaptive Fuzzy Switching Median Filter) [2]. The result is an image quasi without (or with very little) impulse noise so that other filters can be used afterwards. This nonlinear filtering technique contains two separated steps: an impulse noise detection step and a reduction step that preserves edge sharpness. Experimental results show that NAFSM provides a significant improvement on other existing filters. NAFSM is not only very fast but also very effective for reducing little as well as very high impulse noise. But the limitation is that it cannot perform well with all types of images. A new method INAFSM (image & noise adaptive fuzzy switching median filter) is proposed here for removing impulse noise from almost every type of grayscale image.
The paper work in this report is based on two image processing steps viz. noise reduction and edge detection as shown below in the block diagram form:

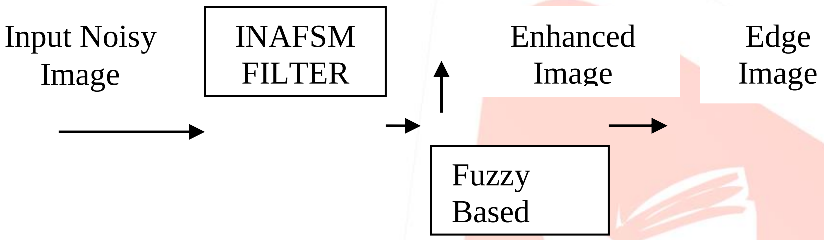


Fig 3.1 Steps in Proposed Work

The input image corrupted with any amount of impulse noise is applied to the proposed INAFSM noise reduction filter as input. The output of this filter is the enhanced image with very fine details. This enhanced image is then applied to the proposed fuzzy based image edge detector. The output of the system is the edge detected image with very fine edges. In the following sections, the FSM (fuzzy switching median) filter is discussed first with the introduction of NAFSM (noise adaptive fuzzy switching median) filter afterwards. The improvement over NAFSM i.e. the proposed method, INAFSM (image & noise adaptive fuzzy switching median filter) is then explained with the fuzzy logic edge detection algorithm applied to the enhanced image.

Noise Detection

The detection procedure of impulse noise in digital images is based on the fact that the image corrupted with impulse noise produces two peaks at minimum & maximum intensity levels in the histogram of the image [1]. The detection begins by searching the two salt & pepper noise intensities in the noisy image histogram designated as L_{salt} & $L_{pepper.}$ For the images corrupted with moderate & high intensities of impulse noise, the noise intensities would produce peaks at the ends of the noisy image histogram. Under such circumstances, the assumptions of salt & pepper noise intensities same as the noisy image histogram peaks holds true. However, with low corrupted images, the positive noise peak is lower than the group of pixels that are noiseless. Under these conditions the assumption that the peak value of noisy image histogram is also the white salt intensity goes wrong. Thus, the detection procedure instead of finding the two peak values finds the two local maxima from both sides. Local maxima are defined as the first peak encountered when traversing in a particular direction. Such a detection procedure is taken from [4] based on [2], [5]. Thus the negative noise intensity is known as L_{lower} i.e. the low end local maximum and the positive noise intensity is known as L_{upper} i.e. the upper end local maximum.

A. Noise Cancellation

After finding the two salt & pepper noise intensities, the noise cancellation begins by defining a square window W_{ij} of size 3x3. The filtering window centered around the pixel (i, j) is defined as:

The centre pixel in the square window is compared with each of the two impulse noise intensities. If the pixel value matches to either salt or pepper noise intensity, the centre pixel is most likely to be a noisy pixel. As long as the center pixel x_{ij} matches to impulse noise intensities, the absolute luminance difference in the square window is calculates as:

The fuzzy input variable $G_{i,j}$ is then determined by selecting the maximum value in the luminance difference values as given below:

$G_{i+k,j+l} = |x_{i+k,j+l} - x_{i,j}|$ with k,l € (-1,0.1) and

$$G_{i,j} = \max\{ G_{i+k,j+l} \}$$

The maximum value of the absolute gradients among the neighboring pixels of x_{ij} in the window W_{ij} is used as the fuzzy input variable. The fuzzy set shown below is used to process the input variable G_{ij} to estimate a correction term to cancel the noise.The fuzzy set shown in Figure 3.2 is taken from [4] and given in [9] described by the equation 3.2

The correction term used by fuzzy switching median filter for replacing the current pixel x_{ij} was taken from [3] and given in [5] given as:

$$Y(i,j) = (1-F_{ij}) .x_{ij} + F_{ij}.M_{ij}$$

Where M_{ij} is the median of the pixels in the 3x3 window given as below:

\

$$M_{i,j} = \text{median}(x(i-1,j-1), x(i-1,j),\ldots, x(i,j),\ldots\ldots, x(i+1,j), x(i+1, j+1)) \quad (3.2)$$

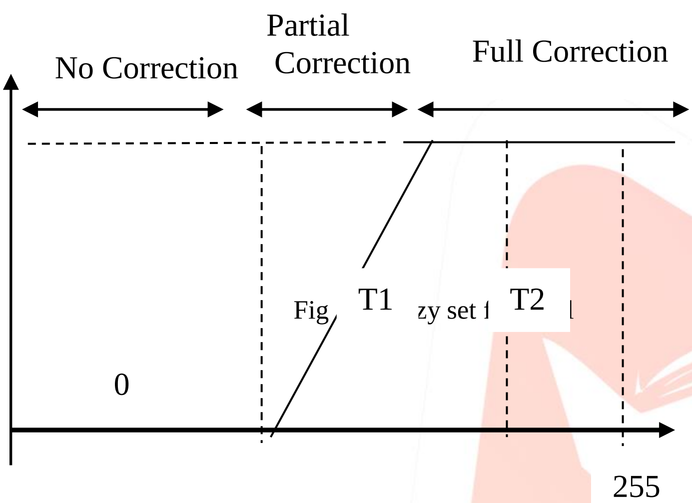


Fig 3.2 Fuzzy set for pixel restoration

The restored pixel Y_{ij} depends on the linear combination of the median M_{ij} and the original pixel x_{ij}. The membership degree F_{ij} lends a weight on whether more of the median pixel M_{ij} or the original pixel x_{ij} should be restored. The processing time is reduced by calculating the fuzzy derivative value only when the pixel x_{ij} is detected to be noisy. If the center pixel does not match to any of the salt & pepper noise intensities, the fuzzy membership values F_{ij} is set to zero. If the center pixel x_{ij} is detected to be noisy, then the absolute luminance difference ($G_{i+k,j+l}$) between the center pixel and the neighborhood pixels is large when the center pixel is an isolated impulse in the square window. other is corrupted with pepper noise. Thus in that case, the two extreme intensities in the window are the two impulse noise intensities i.e. 0 and 255. Hence the maximum absolute difference in this case is 255

		255
0	Noisy x_{ij}	

Fig 3.3 The test window corrupted with 30% impulse noise

As a consequence of this, the fuzzy membership degree results to zero (F_{ij} = 0) if the maximum luminance difference is 0 while Fij =1 if the maximum luminance difference is 255. So the noisy pixel x_{ij} here is restored without any correction. Two different cases are considered here:

Case 1: Using minimum operator, $G_{ij} = 0$, hence $F_{ij} = 0$

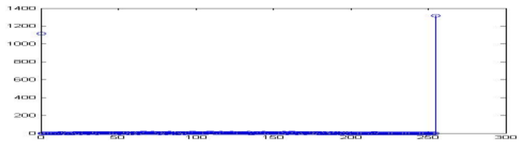
$$Y(i,j) = (1 - 0).Xij + 0.M_{ij} = Xij$$

Here, the noisy pixel is restored when a correction is.
Case 2: Using maximum operator, $G_{ij} = 255$, hence $F_{ij} = 1$

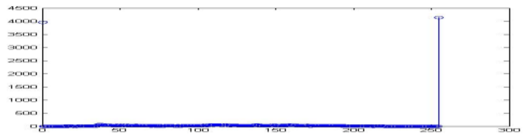
$$Y(i,j) = (1 - 1).Xij + 1.M_{ij} =$$

IV. RESULTS

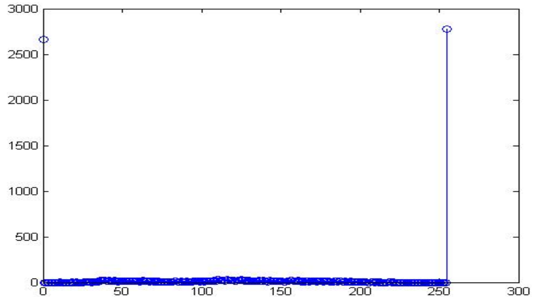
The various standard images were tested for analyzing the performance of the proposed method. For comparative analysis, other fuzzy based filters such as fuzzy impulse noise detection & reduction method (FIDRM), fuzzy switching median filter (FSM), noise-adaptive fuzzy switching median filter (NAFSM) are also tested with the same images. Figure 4.1 shown below are the histogram plots of Lena image corrupted with varying levels of impulse noise i.e. 10%, 50% and 90& respectively.



(a)

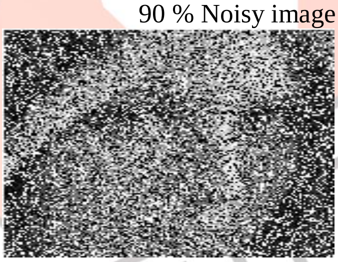
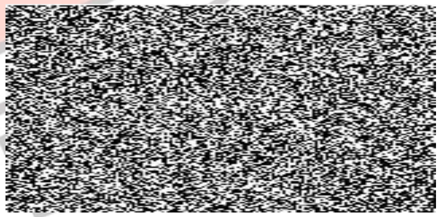


(b)



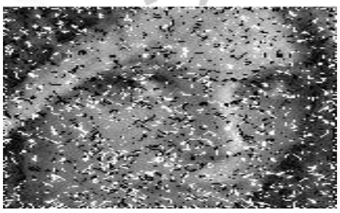
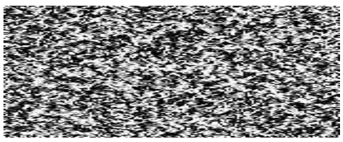
(c)

Fig. 4.1 Noisy Lena Image Histogram (a) Histogram of 10 % Noisy image (b) Histogram of 50 % Noisy image (c) Histogram of 90 % Noisy image

(a) (b) (c)

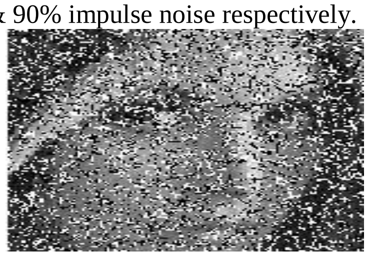
Fig 4.2 (a), (b) & (c) Lena Image corrupted with 10%, 50% & 90% impulse noise respectively.

(a) (b) (c)

Fig 4.3 (a), (b) & (c) Lena Image filtered by FIDRM with 10%, 50% & 90% impulse noise respectively.





(g) (h) (i)

Fig 4.4 (a), (b) & (c) Lena Image filtered by FSM with 10%, 50% & 90% impulse noise respectively

Figure 4.2 shows the standard Lena image corrupted with 10%, 50% and 90% impulse noise respectively. At high levels of noise, the image details are totally invisible and hence very difficult to extract. Figure 4.3 shows the filtering performance of fuzzy impulse noise detection and reduction method. Further, Figure 4.4 analyze the performance of fuzzy switching median filter at different noise levels. The FIDRM filter works well for low levels of impulse noise but degrades after moderate or high levels of noise. However, the FSM filter works well at low and moderate impulse noise levels but performs poor at high levels of noise.

V. CONCLUSION

The proposed filter (INAFSM) is able to suppress very low to very high density of noise from digital images of various types. The visual results along with peak signal-to-noise ratio and mean square error plots explain the excellent performance of the proposed technique over other methods discussed in this report. Further, the fuzzy logic based edge detector performs well in the presence of noise as compared to other edge detectors discussed.

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