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Filter for Removal of Impulse Noise by Using Fuzzy Logic

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***Abstract*— Digital image processing is a subset of the electronic domain wherein the image is converted to an array of small integers, called pixels, representing a physical quantity such as scene radiance, stored in a digital memory, and processed by computer or other digital hardware. Fuzzy logic represents a good mathematical framework to deal with uncertainty of information. Fuzzy image processing [4] is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. This paper combines the features of Image Enhancement and fuzzy logic. This research problem deals with Fuzzy impulse noise detection and removal Method (FIDRM), especially developed for reducing all kinds of impulse noise. FIDRM is not only very fast, but also very effective for reducing little as well as very high impulse noise. This paper focuses on the removal of the impulse noise with the preservation of edge sharpness and image details along with improving the contrast of the images which is considered as the one of the most difficult tasks in image processing. These results are also compared to other filters by numerical measures and visual inspection.**

Keywords- Fuzzy filter, image processing, impulse noise, Additive noise, edge preserving filtering, fuzzy image filtering, membership functions, *noise reduction.*

I. INTRODUCTION

A. Image Processing

An image is digitized to convert it to a form which can be stored in a computer memory or on some form of storage media such as hard disk or CD-ROM. This digitization procedure can be done by scanner, or by video camera connected to frame grabber board in computer. Once the image has been digitized, it can be operated upon by various image processing operations.

Image processing operations [1] can be roughly divided into three major categories, Image Compression, Image Enhancement and Restoration and Measurement Extraction. Image International Journal of Image Processing (IJIP) Volume(3), Issue(5) 196 compression involves in reducing the amount of memory needed to store a digital image. Image restoration is the process of taking an image with some known, or estimated, degradation, and restoring it to its original appearance. Image restoration is often used in the field of photography or publication where an image was somehow degraded, but need to be improved before it can be printed. Image enhancement is improving an image visually.

The main advantage of IE is in the removal of noise in the images. Removing or reducing noise in the images is very active research area in the field of DIP.

B. Noise in Images

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is generally regarded as an undesirable by-product of image capture. Although these unwanted fluctuations became known as "noise" by analogy with unwanted sound, they are inaudible and actually beneficial in some applications, such as dithering.

The impulse noise (or salt and pepper noise) is caused by sharp, sudden disturbances in the image signal; its appearance is randomly scattered white or black (or both) pixels over the image.

Fig. 1 shows an original image and the image which is corrupted with salt and pepper noise.

Noise filtering can be viewed as removing the noise from the corrupted image and smoothen it so that the original image can be viewed. Noise filtering can be viewed as replacing every pixel in the image with a new value depending on the fuzzy based rules. Ideally, the filtering algorithm should vary from pixel to pixel based on the local context.

(a) (b)

Figure. 1: Noise in Images (a) Original Image (b) Image with noise

C. Objectives

The objective of the paper is to give a new better, faster and efficient solution for removing the noise from the corrupted images. The main point under consideration is that the noise-free pixels must remain unchanged. The main focus will be on:

1. Removal of the noise from the test image.
2. Noise free pixels must remain unchanged.
3. Edges must be preserved.

II. PROPOSED WORK

In literature several (fuzzy and non-fuzzy) filters have been studied [2] [3] [5] [6] for impulse noise reduction. These techniques are often complementary to existing techniques and can contribute to the development of better and robust methods. Impulse noise is caused by errors in the data transmission generated in noisy sensors or communication channels, or by errors during the data capture from digital cameras. Noise is usually quantified by the percentage of pixels which are corrupted. Removing impulsive noise while preserving the edges and image details is the difficult issue.

Traditionally, IE techniques such as mean and median filtering have been employed in various applications in the past and are still being used. Although these techniques remove the impulsive noise but they were unable to preserve the sharpness of the edges. They smooth the noise as well as the edge sharpness. They were unable to improve the contrast of the image. A fuzzy theory based IE avoids these problems and is a better method than the traditional methods. The proposed filter provides an alternative approach in which the noise of colored image is removed and the contrast is improved.

To achieve a good performance, a noise reduction algorithm should adapt itself to the spatial context. Noise smoothing and edge enhancement are inherently conflicting processes, since smoothing a region might destroy an edge, while sharpening edges might lead to unnecessary noise. Many techniques to overcome these problems have been proposed in literature. In this thesis a new filter, based on the concepts of IE and FL have been introduced that not only smooth the noise but also preserves the edges and improve its contrast. The test images taken into consideration have impulse noise or salt and pepper noise.

The noise intensity in the same test image varies as 5%, 7%, 9% and 10%. For each case the PSNR and Execution time is calculated.

A. Removal of Impulsive Noise

For each pixel (i, j) of the image (that isn't a border pixel) we use a 3×3 neighborhood window. For each pixel position we have the gradient values. The two related gradient values for the pixel in each direction are given by the following table:

TABLE 1. Basic and two related gradient values for each direction.

R	basic gradients	related gradients
NW	$\nabla NW\ A(i,j)$	$\nabla NW\ A(i+1,j-1), NW\ A(i-1,j+1)$
N	$\nabla N\ A(i,j)$	$\nabla N\ A(i,j-1), N\ A(i,j+1)$
NE	$\nabla NE\ A(i,j)$	$\nabla NE\ A(i-1,j-1), NE\ A(i+1,j+1)$
E	$\nabla E\ A(i,j)$	$\nabla E\ A(i-1,j), E\ A(i+1,j)$
SE	$\nabla SE\ A(i,j)$	$\nabla SE\ A(i-1,j+1), SE\ A(i+1,j-1)$
S	$\nabla S\ A(i,j)$	$\nabla S\ A(i,j-1), S\ A(i,j+1)$
SW	$\nabla SW\ A(i,j)$	$\nabla SW\ A(i-1,j-1), SW\ A(i+1,j+1)$
W	$\nabla W\ A(i,j)$	$\nabla W\ A(i-1,j), W\ A(i+1,j)$

These values indicate in which degree the central pixel can be seen as an impulse noise pixel. The fuzzy gradient value $\nabla_R^F\ A(i,j)$ for direction R (R ϵ {NW, N, NE, E, SE, S, SW, W}), is calculated by the following fuzzy rule:

If $|\nabla_R\ A(i,j)|$ is large AND $|\nabla'_R\ A(i,j)|$ is small

OR

$|\nabla_R\ A(i,j)|$ is large AND $|\nabla''_R\ A(i,j)|$ is small

OR

$|\nabla_R\ A(i,j)|$ is big positive AND $|\nabla'_R\ A(i,j)|$ AND $|\nabla''_R\ A(i,j)|$ are big negative

OR

$|\nabla_R\ A(i,j)|$ is big negative AND $|\nabla'_R\ A(i,j)|$ AND $|\nabla''_R\ A(i,j)|$ are big positive

Then $\nabla_R^F\ A(i,j)$ is large.

Where $\nabla_R\ A(i,j)$ is basic gradient and $\nabla'_R\ A(i,j)$ and $\nabla''_R\ A(i,j)$ are the two related gradient values for the direction R. Because "large", "small", "big negative" and "big positive" are nondeterministic features, these terms can be represented as fuzzy sets. Fuzzy sets can be represented by a membership function. Examples of the membership functions LARGE (for the fuzzy set *large*), SMALL (for the fuzzy set *small*), BIG POSITIVE (for the fuzzy set *big positive*) and BIG NEGATIVE (for the fuzzy set *big negative*)

When we get the gradient values we apply the similarity function. The similarity function is μ: [0 ;∞) →R. We will need the following assumptions for μ:

1. μ is decreasing in [0 ;∞),
2. μ is convex in [0 ;∞),
3. μ (0) = 1, μ (∞) = 0.

In the construction, the central pixel in the window W is replaced by that one, which maximizes the sum of similarities between all its neighbors. Basic assumption is that a new pixel must be taken from the window W. Each of the neighbors of the central pixel is moved to the center of the filtering window and the central pixel is rejected from W. For each pixel of the neighborhood, which is being placed in the center of W, the total sum of similarities is calculated and then compared with maximum sum. The total sum of similarities is calculated without taking into account the original central pixel, which is rejected from the filter window. In this way, the central pixel is replaced by that pixel from the neighborhood, for which the total similarity function, which is a sum of all values of similarities between the central pixel and its neighbors, reaches its maximum. The filter tends to replace the original pixel only when it is really noisy and preserves in this way the image structures.

III. RESULTS

The test images are operated on different intensities of noise as 5%, 7%, 9%, and 11%. Different PSNR and evaluation time are calculated for each image with different noise intensities. The results are shown:

A. Results of FIDRM

Fig. 2 Real Lena's image

a) Lena image corrupted with 5% noise

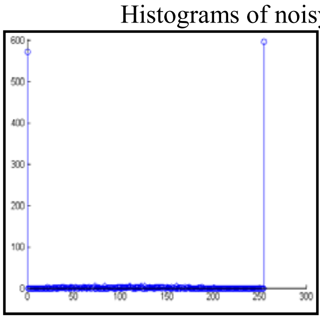
b) Lena image corrupted with 7% noise

c) Lena image corrupted with 9% noise

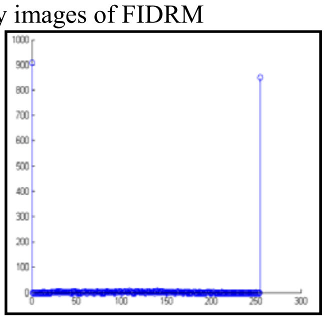
d) Lena image corrupted with 11% noise

Fig 3 Lena image corrupted with different impulse noise intensities

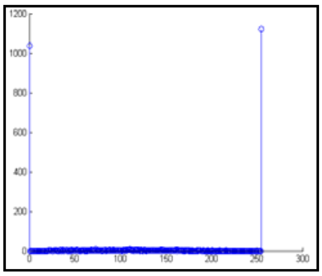
Histograms of noisy images of FIDRM



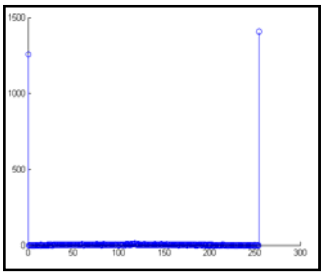
a) Histogram of 5% noisy image



b) Histogram of 7% noisy image



c) Histogram of 9% noisy image



d) Histogram of 11% noisy image

Fig.4 Histograms of four noisy images of Lena describe in Fig.3 respectively

Noise free images

a) Noise free image(5% noise)

b) Noise free image(7% noise)

c) Noise free image(9% noise)

d) Noise free image(11% noise)

Fig. 5 Images of Lena after filtered through one step FIDRM

B. Results of Two step FIDRM

Reference image is same as described in fig. 2

a)Noisy image(5% Impulse noise)

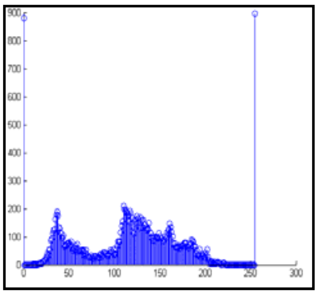
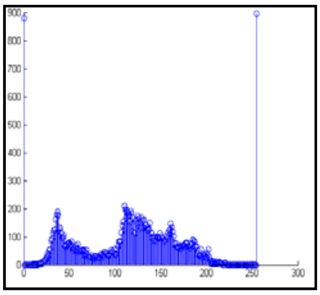
b)Noisy image(7% Impulse noise)

c)Noisy image(9% Impulse noise)

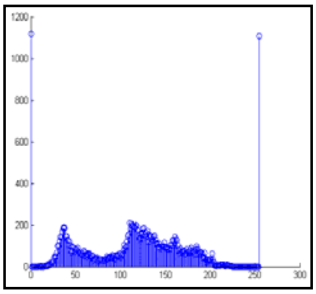
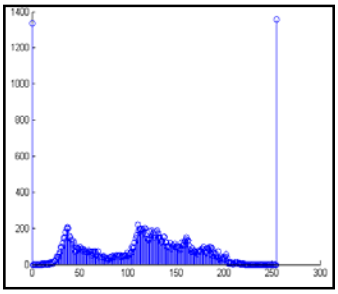
d)Noisy image(11% Impulse noise)

Fig. 6 Images corrupted by impulse noise of different intensites

Histograms of Two step FIDRM

a) Histogram of noisy(5%) image b) Histogram of noisy(7%) image

c) Histogram of noisy(9%) image d) Histogram of noisy(11%) image

Fig. 7 Histogram of impulse noise corrupted images in fig. 6

Noise free images


a) Noise free image(5% noise) **b) Noise free image(7% noise)**


c) Noise free image(9% noise) **d) Noise free image(11% noise)**

Fig. 8 Two step filtered images corrupted by impulse noise

Table 2. Comparison of one step and Two step FIDRM (PSNR)

Noise	1 Step	2 Step
5%	37.97	38.89
7%	35.66	35.48
9%	33.88	33.13
11%	31.90	31.79

Table 3. Comparison of one step and Two step FIDRM (MSE)

Noise	1 Step	2 Step
5%	10.44	8.45
7%	17.76	18.52
9%	26.79	31.84
11%	42.24	43.38

Table 4. Comparison of one step and Two step FIDRM (Time taken)

Noise	1 Step	2 Step
5%	15.9	21.71
7%	17.0	23.23
9%	17.42	24.80
11%	16.78	24.87

From these results it is proved that Two step FIDRM is better than One step FIDRM in terms of picture quality, edge noise removal, PSNR ratio.These filters are also compared with conventional filters which are described in section 2.2. Their results in terms of PSNR(db) is compared with One step FIDRM and Two step FIDRM in Table 5.

Table 5. Comparison with other conventional fillters

Filters	**PSNR(db)**
Rank order mean filter	31.01
Progressive switching median filter	31.28
AWCM	34.77
Differential ranked impulse detector	36.01
Enhance ranked impulse detector	36.06
Tristate median filter	36.06
Two output filter	24.92
One step FIDRM	37.97
Two step FIDRM	38.89

IV. CONSLUSION & FUTURE WORK

Four parameters of a test window are supplied to a fuzzy membership function. Upon constructing the consequent membership function and subsequent defuzzification a decision is made on the noise status of the center pixel of the window. The restored images of these two schemes exhibit the desirable properties of edge and detail preservation. The inherent correlation among the pixels is exploited in these two schemes. However, it has a drawback of not making the threshold as adaptive.

Various test images of different extensions are fed to the system. The images are corrupted with salt and pepper noise. The filter is seen to preserve intricate features of the image while removing heavy impulse noise where as the conventional mean and median filters fail in this context even at low corruption levels. The learning of fuzzy rules in a fuzzy image filter with a true hierarchical fuzzy logic structure where the output of the first layer is fed in to the second layer to obtain an 'improved' final output. The evaluation parameters PSNR and Evaluation time taken are evaluated. The program generates positive PSNR and is above 20dB which is considered to be the best ratio. The overall execution time which the program takes is approximately 15 seconds. In future, modification of fuzzy rules can produce better result.

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