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A NEW HYBRID FILTERING TECHNIQUE FOR REMOVAL OF IMPULSE NOISE FROM DIGITAL IMAGES

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ABSTRACT

Removing impulse noise from digital image is a very active research area in digital image processing. In recent years, technological development has significantly improved in analyzing digital images. This paper proposes a new hybrid filtering technique (HMMF) for the removal of impulse noise from digital images, by topological approach. The quality of the noise reduction in images is measured by the statistical quantity measures: Root Mean Square Error (RMSE) and Peak Signal-to-Noise Ratio (PSNR). The performance of this filter on images tainted with various noise levels of impulse noise is compared with some existing filtering techniques.

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Keywords: *Digital Image, hybrid filter, Impulse noise, Noise reduction*

1. INTRODUCTION

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. These noises usually affect the visual quality of the original images. Several different methods are used to eliminate random impulse noise, based upon different mathematical models of the phenomenon. Noise is usually quantified by the percentage of corrupted pixels. In the literature several fuzzy and non fuzzy filters have been studied for removal of random impulse noise from digital images. In early 1970s median filter has been introduced by Tukey [9]. It is a special case of non-linear filters (non fuzzy filter) used for smoothing signals. Median filter now is broadly used in reducing noise and smoothing the images. Nachtegael et al.,[5,6] reviewed fuzzy filters for noise reduction in images and also reported a comparative study of classical and fuzzy filters for noise reduction in 2001. In 2006, Hu. H and de Haan, G.[3], introduced classification-based hybrid filters for image processing. Stefan Schulte et al.,[8] proposed FIDRM (Fuzzy Impulse noise Detection and Reduction method) for reducing all kinds of impulse noise. In 2009, an improved adaptive median filtering method for denoising impulse noise reduction was carried out by Mamta Juneja et al. [4]. Gnanambal Ilango and Marudhachalam [2] proposed different types of new hybrid filtering techniques for removal of Gaussian noise from ultrasound medical images. This work proposes a new hybrid filtering technique (HMMF) for removal of random impulse noise from digital images.

This work is organized as follows: In Section 2 basic definitions are given. Section 3 deals with proposed definition of a hybrid filtering technique for removal of random impulse noise from digital images. In Section 4, both quantitative (RMSE & PSNR) and qualitative comparisons have been provided. Section 5 puts forward the conclusion drawn by this paper.

2. BASIC DEFINITIONS

This section presents some general definitions of digital topology, which will be used along the development of this paper.

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2.1 Digital image

A digital image [7] is a function f : ZxZ $\rightarrow$ [0,1,…….N $-$1] in which N$-$1 is a positive whole number belonging to the natural interval [1, 256]. The functional value of 'f' at any point p(x, y) is called the intensity or grey level of the image at that point and it is denoted by f(p).

2.2 Neighborhood of a point

A neighborhood [7] of a point p ε X is a subset of X which contains an open set containing p. It is denoted by N (p).

2.3 4-neighbours of a point

The 4-neighbours [7] of a point p(x,y) are its four horizontal and vertical neighbours (x $\mp$1,y) and (x, y $\mp$ 1). A point 'p' and its 4-neighbours is denoted by N_4(p).

2.4 Cross neighbours of a point

The cross neighbours [2] of a point p(x,y) consists of the neighbours (x + 1,y$\mp$ 1) and (x$-$1,y $\mp$ 1). A point 'p' and its cross neighbours is denoted by C_4(p).

2.5 8-neighbours of a point

The 8-neighbours [7] ***of*** a point p(x, y) consist of its 4-neighbours together with its cross neighbours. A point 'p' and its 8-neighbours is denoted by N_8(p).

2.6 LT neighbours of a point

The LT neighbours[2] of a point p(x, y) consists of the neighbours (x$-1, y-1)$ and (x+$1, y+1)$. A point 'p' and its LT neighbours is denoted by L_3(p).

2.7 RT neighbours of a point

The RT neighbours [2] of a point p(x, y) consists of the neighbours **(**x$-1, y+1)$ and (x+$1, y-1)$. A point 'p' and its RT neighbours is denoted by R_3(p).

2.8 Definition of Fuzzy filters [5]:

Let f(p) be the input image of a two dimensional fuzzy filter, the output the fuzzy filter is defined as:

$$g(p) = \frac{\sum_{p \in N_8(p)} F(p) \cdot f(p)}{\sum_{p \in N_8(p)} F(p)}$$

where F(p) is the general 8-neighbour function.

2.9 FH3F

In fuzzy hybrid max filter, the general 8-neighbour function is defined as:

$$F(p) = \begin{cases} 1 & for\ \ f(p) = hmv(p), \mathrm{p} \in \mathrm{N}_8(\mathrm{p}) \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

where hmv(p) is the hybrid max value, which is the maximum of median pixel value of *LT* neighbours of a point `*p*', median pixel value of *RT* neighbours of a point `*p*' and pixel value of `*p*'.

2.10 Median filter (MF)

The best-known order-statistic filter in digital image processing is the median filter. It is a useful tool for reducing salt-and- pepper noise in an image. The median filter [9] plays a key role in image processing and vision. In median filter, the pixel value of a point p is replaced by the median of pixel value of 8-neighborhood of a point 'p'. The operation of this filter can be expressed as:

g(p) = median$\{f(p), where\ p \epsilon N_8(p)\}$

2.11 Mean filter (MNF)

Mean Filter [9] is a simple linear filter, intuitive and easy to implement method of smoothing images, i.e. reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images. The mean filter

is defined as the pixel value of a point p is replaced by mean of pixel value of 8-neighborhood of a point 'p'. The operation of this filter can be expressed as:

$$g(p) = \text{mean}\{f(p), where\ p\epsilon N_8(p)\}$$

2.12 M3 filter (M3F)

The M3 filter is hybridization of mean and median filter. This replaces the central pixel by the maximum value of mean and median for 8-neighborhood of central pixel. It is expressed as M3-filter, the intensity values are reduced in the adjacent pixel and it preserves the high frequency components in image. This filter is defined as

$$g(p) = max\begin{Bmatrix} \text{mean}\{f(p),\ p\epsilon N_8(p)\}, \\ \text{median}\{f(p),\ p\epsilon N_8(p)\} \end{Bmatrix}$$

2.13 Enhanced Hybrid Median Filter (EHMF)

An enhance hybrid median filter will do the median filtering by using square-mask, plus-mask and x-mask separately to get the median values for each of them. These median values will be sorted to get the median value. The center pixel from the sorted values will be used as the median value. This filter is defined as

$$g(p) = median\begin{Bmatrix} median\{f(p), p \in N_4(p)\}, \\ median\{f(p), p \in C_4(p)\}, \\ median\{f(p), p \in N_8(p)\}, \end{Bmatrix}$$

3. DEFINITION OF HYBRID FILTERING TECHNIQUE

In this section, the definition of a new hybrid filter is given. The image processing function in a spatial domain can be expressed as

$$g(p) = \Upsilon(f(p)) \tag{1}$$

where Υ is the transformation function, f(p) is the pixel value (intensity value or grey level value) of the point p(x,y) of input image and g(p) is the pixel value of the corresponding point of the processed image.

3.1: Hybrid Min Filter (H_2F)

Hybrid min filter [2] is not a usual min filter. Min filter [2] recognizes the darkest pixels gray value and retains it by performing min operation. In min filter each output pixel value can be calculated by selecting minimum gray level value of the $N_8(p)$. H_2F filter is also used for removing the salt noise from the image. Salt noise has very high values in images. It is expressed as:

$$g(p) = min\begin{Bmatrix} \text{median}\{f(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{f(p),\ p\epsilon R_3(p)\}, \\ f(p) \end{Bmatrix} \tag{2}$$

In hybrid min filter, the pixel value of a point p is replaced by the minimum of median pixel value of LT neighbours of a point 'p', median pixel value of RT neighbours of a point 'p' and pixel value of 'p'.

3.2: Hybrid Max Filter (H_3F)

Hybrid max filter [2] is not a usual max filter. The brightest pixel gray level values are identified by max filter. In max filter[2] each output pixel value can be calculated by selecting maximum gray level value of the $N_8(p)$. H_3F filter is also used for removing the pepper noise from the image. It is expressed as:

$$g(p) = max\begin{Bmatrix} \text{median}\{f(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{f(p),\ p\epsilon R_3(p)\}, \\ f(p) \end{Bmatrix} \tag{3}$$

In hybrid max filter, the pixel value of a point p is replaced by the maximum of median pixel value of LT neighbours of a point 'p', median pixel value of RT neighbours of a point 'p' and pixel value of 'p'.

3.3: HMMF

HMMF filter is a hybridization of hybrid max filter and hybrid min filter. It is used for removing the salt and pepper noise from the image. It is expressed as:

$$g(p) = min\left\{\begin{matrix} \text{median}\{f(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{f(p),\ p\epsilon R_3(p)\}, \\ f(p) \end{matrix}\right\} \quad (4)$$

$$h(p) = max\left\{\begin{matrix} \text{median}\{g(p),\ p\epsilon L_3(p)\}, \\ \text{median}\{g(p),\ p\epsilon R_3(p)\}, \\ g(p) \end{matrix}\right\} \quad (5)$$

In this filter the input image is processed by hybrid min filter and output of H_2F filter is processed by hybrid max filter (H_3F).

4. EXPERIMENTAL RESULT ANALYSIS AND DISCUSSION

The proposed hybrid filtering technique have been implemented using MATLAB 7.0. The performance of a hybrid filtering technique is analyzed and discussed. The measurement of noise reduction is difficult and there is no unique algorithm available to measure noise reduction of digital images. So we use statistical tool to measure the noise reduction of ultrasound images. The Root Mean Square Error (RMSE) and Peak Signal-to-Noise(PSNR) are used to evaluate the reduction of impulse noise from digital image.

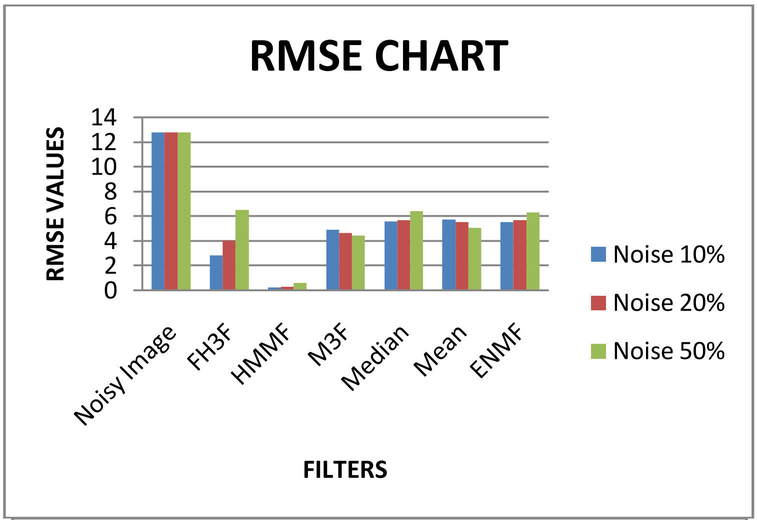
$$\text{RMSE} = \sqrt{\frac{\Sigma(f(i,j)-h(i,j))^2}{mn}} \quad (6)$$

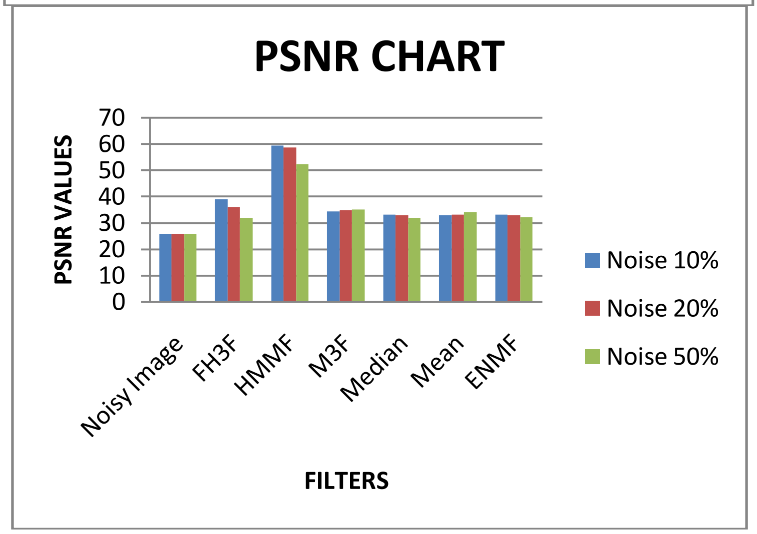
$$\text{PSNR} = 20\log_{10}\frac{255}{RMSE} \quad (7)$$

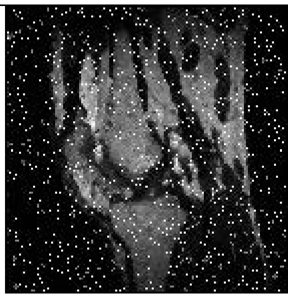
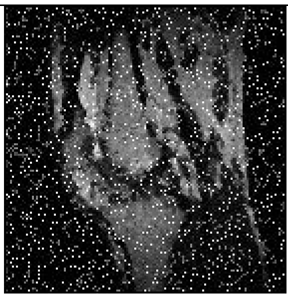
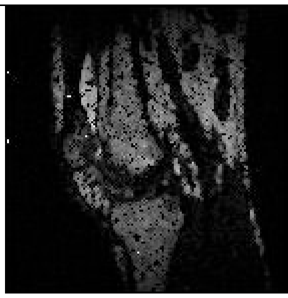
Here f(i,j) is the pixel value of original image , h(i,j) is the pixel value of filtered image and m and n are the total number of pixels in the horizontal and the vertical dimensions of the image. If the value of RMSE is low and value of PSNR is high then the noise reduction approach is better. Table 4.1 shows the proposed hybrid filtering technique is compared with some existing filtering techniques namely, FH3F, M3F, EHMF, Median filter and Mean filter with regard to digital images for various noise levels. Fig.4.1 shows the restoration results of different filters for the "knee" image.

Filters	RMSE			PSNR		
	10%	20%	50%	10%	20%	50%
Noisy Image	12.753	12.753	12.753	26.0191	26.0191	26.0191
FH3F	2.848	4.0529	6.4893	39.0406	35.9759	31.8872
HMMF	0.2757	0.3032	0.6125	59.3237	58.4959	52.3894
M3F	4.9104	4.6295	4.4376	34.3089	34.8205	35.1882
Median	5.5624	5.692	6.3874	33.226	33.026	32.0247
Mean	5.7539	5.5154	5.0619	32.9319	33.2996	34.0449
EHMF	5.5522	5.7006	6.2971	33.2419	33.0128	32.1484

Table 4.1





 Original Image	 Noisy Image
 FH3F	 HMMF

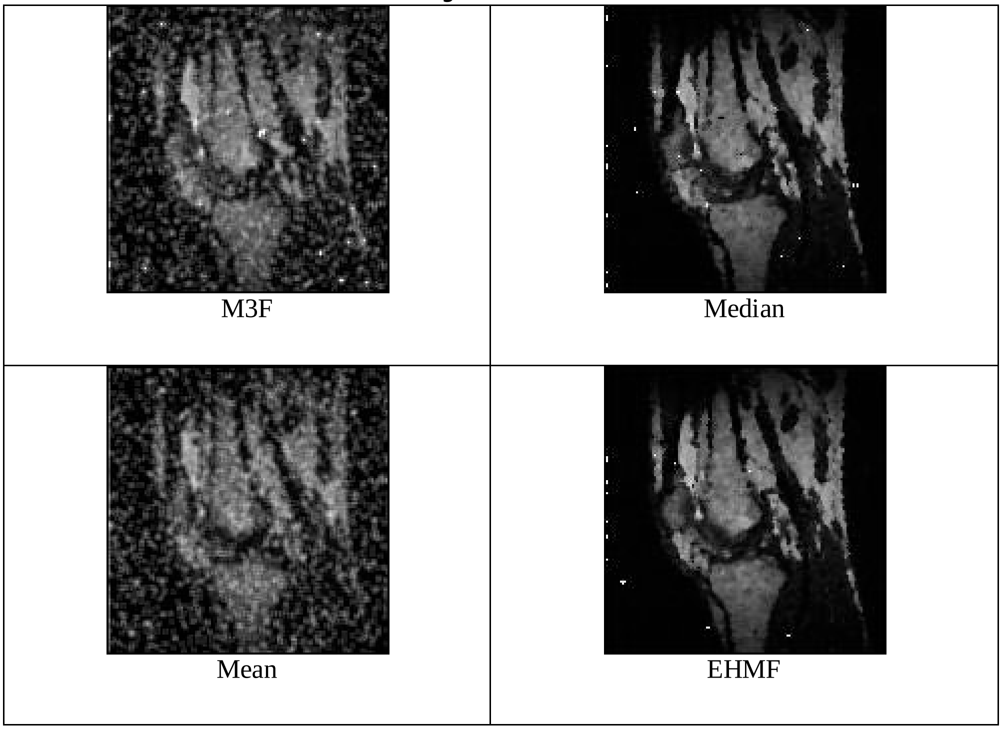


Fig. 4.1

5. CONCLUSION

In this work, a new hybrid filtering technique for removal of random impulse noise from digital image is introduced. To demonstrate the performance of the proposed technique, the experiments have been conducted on digital images and compared our method with other well known techniques. The experimental results indicate that the proposed hybrid filter (HMMF) performs significantly better than other existing techniques and it gives the best results. The proposed method is simple and easy to implement.

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