Modified Decision Based Algorithm Unsymmetric Hybrid Trimmed Median Filter Approach for Removing Salt and Pepper Noise in Ultrasound Images

V. R. Vinothini, P. Thangaraj

Abstract*— Removing impulse noise from digital image is a very challenging research area in digital image processing. In recent years, technological development has significantly improved in analyzing digital images. This paper proposes a modified decision based unsymmetrical trimmed median filter algorithm for the restoration of gray scale and color images that are highly corrupted by salt-and-pepper noise from digital images, by topological approach. The proposed algorithm replaces the noisy pixel by trimmed median value when other pixel values, 0's and 255's are present in the selected window and when all the pixel values are 0's and 255's then the noise pixel is replaced by mean value of all the elements present in the selected window. 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 proposed algorithm shows better results than the Standard Median Filter (MF), Decision Based Algorithm (DBA) and Modified Decision Based Algorithm (MDBA).

***Index terms*— Hybrid Filters, Median Filter, Noise reduction, Salt-and-Pepper noise, Ultrasound image, Unsymmetrical trimmed median Filter**

I. INTRODUCTION

The impulse noise (or salt–and-pepper noise) is a noise seen on images. 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. There are two types of impulse noise, they are salt and pepper noise and random valued noise. Salt-and-pepper noise can corrupt the images where the corrupted pixel takes either maximum or minimum gray level. Several different methods are used to eliminate random impulse noise, based upon different mathematical methods 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 1970's median filter has been introduced by Tukey [13].It is a special case of non-linear filters used for smoothing signals.

Manuscript Received on September 2014.

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Median filter is broadly used in reducing noise and smoothing the images. The standard median filter has been established to remove the Salt-and-pepper noise without damaging the edge details. In 2006, Hu. H and de Haan, G. [4], introduced classification-based hybrid filters for image processing. However the major drawback of standard Median filter is effective only at low noise densities [1].when the noise level is over 50% the edge details of the original image will not be preserved by standard Median filter. Adaptive Median filter (AMF) [8] perform well at low noise densities. But at high level densities the window size has to be increased which may give blurring the image. In switching median filter [3], [4] the decision is based on a pre-defined threshold value. The major drawback of this method is that defining a robust decision is difficult. To overcome these drawback, Decision Based Algorithm (DBA) is proposed [12].In this, image is denoised by using a 3x3 window. At high noise density the median value will be 0 or 255 which is noisy. In such case, neighboring pixel is used for replacement. This gives the streaking effect of the pixels. In order to avoid this drawback, Decision Based Unsymmetrical trimmed median Filter (DBUTMF) is proposed [10]. At high noise densities, if the selected window contains 0's and 255's or both cannot be obtained.so this algorithm does not give better results at very high noise density. The proposed Modified Decision Based Unsymmetric Hybrid Trimmed Median Filter (MDBUHTMF) algorithm removes this drawback at high noise density and gives better Peak-Signal-to-Noise Ratio (PSNR). This work is organized as follows: In section II basic definitions are given. Section III deals with a brief introduction of unsymmetric trimmed median filter. Section IV describes about the proposed definition and different cases of algorithm. Simulation results both quantitative (RMSE and PSNR) and qualitative comparisons have been provided in section V. Finally conclusions are drawn in section VI.

II. BASIC DEFINITIONS

A. Digital Image

A digital image [9] is a function $f : z \times z \rightarrow [0,1,.......N-1]$ in which N-1 is a positive whole number belonging to the natural interval [0,255].

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The functional value of f at any point $p(x,y)$ is called the intensity or gray level of the image at that point and it is denoted by $f(p)$.

B. Neighborhood of a Point

A neighborhood [9] of a point $p \in X$ is a subset of X which contains an open set containing p. It is denoted by $N(p)$.

C. 4-Neighbours of a Point

The 4-neighbours [9] of a point $p(x,y)$ are its four horizontal and vertical neighbors $(x \mp 1, y)$ and $(x, y \mp 1)$. A point 'p' and its 4-neighbours is denoted by $N_4(p)$.

D. Cross Neighbors of a Point

The cross neighbors [11] of a point $p(x,y)$ consists of the neighbors $(x+1, y \mp 1)$ and $(x-1, y \mp 1)$. A point 'p' and its cross neighbors is denoted by $C_4(p)$.

E. 8-Neighbours of a Point

The 8-neighbours [9] of a point $p(x,y)$ consist of its 4-neighbours together with its diagonal (cross) neighbors. A point 'p' and its 8-neighbours is denoted by $N_8(p)$.

F. Mean Filter

Mean filter or average filter is a simple linear filter, which smooth images. The basic idea behind filter is for any element of the image take an average across its neighborhood. 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

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

G. Median Filter (MF)

The best known order-statistic filter in digital image processing is the median filter. Median filtering is done one neighborhood at a time; however the mask that it uses is not a linear function. A median filter replaces the pixel with the median of the neighborhood. This is useful in removing salt-and-pepper noise from an image. The median filter plays [11] a key role in image processing. 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

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

H. Adaptive Median Filter (AMF)

The Adaptive Median Filter performs spatial processing to determine which pixels in an image have been affected by impulse noise. The Adaptive Median Filter classifies pixels as noise by comparing each pixel in the image to its surrounding neighbor pixels. The size of the neighborhood is adjustable, as well as the threshold for the comparison. A pixel that is different from a majority of its neighbors, as well as being not structurally aligned with those pixels to which it is similar, is labeled as impulse noise. These noise pixels are then replaced by the median pixel value of the pixels in the neighborhood that have passed the noise labeling test. This is useful in removing salt-and-pepper noise from an image and preserves the object boundaries. Consider the following notations:

z_{min} = Minimum intensity value in S_{xy}
z_{max} = Maximum intensity value in S_{xy}
z_{med} = Median of intensity values in S_{xy}
z_{xy} = intensity value at coordinates (x,y)
S_{max}= Maximum allowed size of S_{xy}

III. HYBRID FILTERING TECHNIQUES

In this section, the definition of a new hybrid filter is given. The image processing function in a spatial domain can be expressed as $g(p) = \gamma(f(p))$, where γ is the transformation function, $f(p)$ is the pixel value or intensity value or gray 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.

A. Hybrid Mean Filter

Hybrid Mean Filter is a simple nonlinear filter. It is intuitive and easy to implement of smoothing images. In hybrid mean filter, the pixel value 'p' is replaced by the mean of the mean pixel value of 8-neighborhood of a point 'p' mean pixel value of cross neighbors of a point 'p' and pixel value of 'p'. It can be expressed as

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

B. Hybrid Median Filter

Hybrid Median Filter is a nonlinear that removes impulse noise while preserving edges. This filter is defined as

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

A hybrid median filter preserves edges much better than a median filter. In hybrid median filter the pixel value of a point p is replaced by the median of median pixel value of 8-neighborhood of a point p.

C. Hybrid Mean and Median Filter

The hybrid mean and median filter replaces the central pixel by the maximum value of mean and median for 8-neighborhood of central pixel. This filter, reducing the intensity values in the adjacent pixel and its preserves the high frequency in image. It is defined as

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

D. Hybrid Min Filter

Hybrid Min Filter plays a significant role in image processing and vision. Min filter 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 $N_8(p)$. It is proposed for noise removal from the image. It can be expressed as

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

E. Hybrid Max Filter

Hybrid Max Filter plays a key role in image processing and vision. The brightest pixel gray values are identified by max filter. In max filter each output pixel value can be calculated by selecting maximum gray level value of the $N_8(p)$. It can be expressed as

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

IV. UNSYMMETRIC TRIMMED MEDIAN FILTER

The idea behind a trimmed median filter is to reject the noisy pixel from the selected 3x3 window. Alpha Trimmed Mean Filtering (ATMF) is a symmetrical filter where the trimming is symmetric at either end. In this procedure, even the uncorrupted pixels are also trimmed. This leads to loss of image details and blurring of the image. In Unsymmetric Trimmed Median Filter (UTMF) the selected window elements are arranged in either increasing or decreasing order [10]. Then the pixels values are responsible for salt-and-pepper noise in the image are removed .Then the median value of the remaining pixels are taken. This median value is used to replace the noisy pixel. This filter is called trimmed mean filter. This procedure removes noise in better way than the ATMF.

A. Maximum of Hybrid Median Filter and Hybrid Mean Filter

The maximum of hybrid mean filter and hybrid median filter is a nonlinear filtering technique. It plays a significant role in image processing and vision. It is expressed as:

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

In this filter each output pixel value is calculated by the maximum of output pixel value of hybrid median filter and hybrid mean filter.

Proposed Algorithm

The proposed Modified Decision Based Unsymmetric Hybrid Trimmed Median Filter (MDBUHTMF) algorithm processes the corrupted images by first detecting the salt-and-pepper noise. The pixel is checked whether it is noisy or noisy free. That is, if the pixel lies between maximum and minimum gray level and pixel value then it is noise free pixel it is left unchanged. If the pixel takes the maximum or minimum gray level or pixel value or intensity values then it is noisy pixel which is processed by MDBUHTMF.

Algorithm

Step 1: Select image from computer memory into current program. Any given digital image is represented as an array size M*N pixels.

Step 2: Apply digital topology concept which will help in selecting the neighborhood of a pixels in an image.

Step 3: Select the dimension size of an image in order to calculate the values of pixel in a current image which will also help in obtaining end of file.

Step 4: Repeat the following steps until all the pixels of an image is not checked and end of file is not conquered.

Step 5: Collect the pixels from mask of size 3*3 in order to obtain pixels values in a selected mask.

Step 6: Check whether value of center pixel is 0 which represent pepper noise or 255 which represent salt noise is present or not.

Step 7: If the pixel values 0 or 255 then the pixels are corrupted and then we have two cases:

Case i): If the selected window contains all the elements as 0's and 255's. Then replace with the mean of the element of window.

Case ii): If the selected window contains not all elements as 0's and 255's. Then eliminate pixel values 0's and 255's and find the median value of the remaining pixels.

Step 8: Apply median filter which is the combination of hybrid and relaxed median filter to calculate value of median of remaining pixels which will be used to replace center corrupted pixel in a mask.

Step 9: Move mask on each pixels of an image in order to remove all salt noise and pepper noise from current image.

Step 10: When all the corrupted pixels are removed we will obtain the filtered image.

V. SIMULATION RESULTS

The proposed hybrid filtering techniques have been implemented using MATLAB 7.0. The performance of the proposed algorithm is tested 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 images. The noise density (intensity) is varied from 10% to 90%.Denoising performances are quantitatively measured by the PSNR and RMSE as defined in (1) and (2) respectively.

$$RMSE = \sqrt{\frac{\sum_{i}\sum_{j}[f(i,j)-h(i,j)]^2}{M \times N}} \qquad \ldots\ldots\ldots\ (1)$$

$$PSNR = 20\log_{10}\frac{255}{RMSE} \qquad \ldots\ldots\ldots\ (2)$$

Here $f(i,j)$ is the pixel value of the original image, $h(i,j)$ is the pixel value of the filtered image and M and N are the total number of pixels in the horizontal and vertical dimensions of the image. The PSNR and RMSE values of the proposed algorithm are compared against the existing algorithms by varying the noise intensity are shown in Table 1. If the value of RMSE is low and the value of PSNR is high then the noise reduction approach is better. Table 1 shows the proposed hybrid filtering technique is compared with some existing filtering techniques namely Mean Filter, Median filter, HMMF,AMF,DBA,DBUTMF MDBUHTMF with regard to digital images for various noise levels.

A. Figures

(a) Noisy Image

(b) AMF

(c) HMMF

(d) DBA

(e) DBUTMF

(f) Proposed Method

Fig. 1 Shows the Restoration Results of Different Filters for the Ultrasound Image

B. Tables

Table I: Comparison of PSNR values of different algorithms for Ultrasound image at different noise densities

Noise in %	PSNR in dB						
	Mean filter	MF	AMF	HMMF	DBA	DBUT MF	MDBU HTMF
10	32.93	33.2	38.43	39.32	36.4	47.91	56.34
20	33.29	33.0	27.4	38.45	32.91	34.78	48.48
50	34.05	36.0	23.32	36.12	26.41	28.18	51.29
70	19.72	33.9	19.23	33.24	22.62	39.3	47.73
90	29.26	32.5	7.92	30.42	17.14	18.4	48.12

Table II: Comparison of RMSE values of different algorithms for Ultrasound image at different noise densities

Noise in %	PSNR in dB						
	Mean filter	MF	AMF	HMMF	DBA	DBUTMF	MDBUHTMF
10	5.7539	5.5624	4.9308	4.2884	3.264	2.3682	0.2757
20	5.5154	5.692	4.2288	5.5411	3.984	1.3659	0.3032
50	5.3619	5.9714	5.3211	3.0248	3.421	2.3442	0.7125
70	5.2279	6.1072	4.497	2.9987	3.561	1.2922	0.6932
90	5.0619	6.3874	4.7392	4.0123	2.649	1.9545	0.9646

Chart 1: Analysis of PSNR values of Ultrasound images corrupted by salt-and-pepper noise

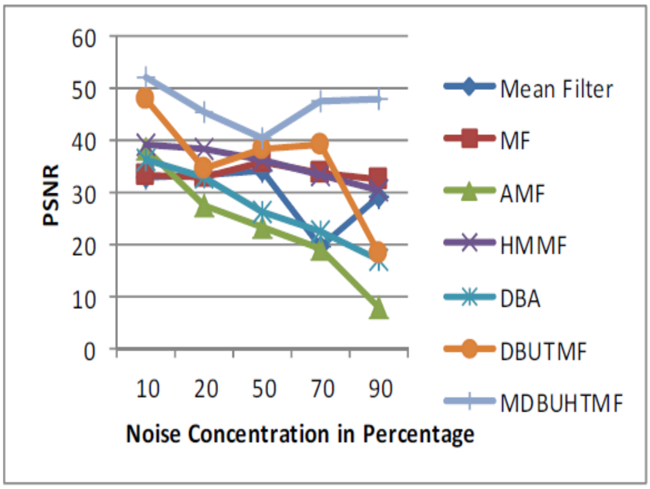
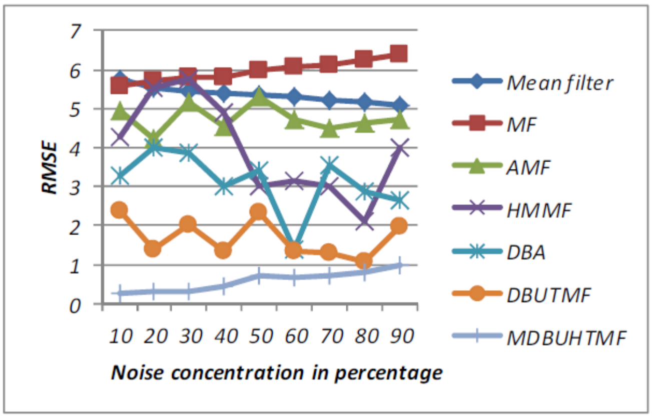


Chart 2: Analysis of RMSE values of Ultrasound images corrupted by salt-and-pepper noise



VI. CONCLUSION

In this work, a new hybrid filtering technique for removal of random impulse noise from digital image is introduced. A new algorithm (MDBUTHMF) is proposed which gives better performance in comparison with other existing noise removal algorithms in terms of PSNR and RMSE. The performance of the algorithm has been tested at low, medium and high noise densities of images. The experimental results indicate that the proposed MDBUTHMF performs significantly better than other existing techniques and it gives the best results. The proposed algorithm is effective for salt-and-pepper noise removal in images. Filtering methods along with detection algorithms shows better results and once the filtering schemes are done in ultrasound images.

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