

Adaptive Weighted Trimmed Multiple Scanning Filter for Removing Salt and Pepper Noise



Engineering

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ABSTRACT

In this paper, a median filter is proposed for the purpose of discovering and removing high level of salt and pepper noise. The image is processed twice so the filter is divided into two stages viz. "Forward Scanning and Reverse Scanning". In order to reduce the error detection rate we use two windows of different dimensions and the output image of first stage serves as input for the second stage. Besides, the value of the noisy pixel is replaced by the median of the window calculated among noise-free pixels. Our results and comparison exhibits that our proposed filter has very low error detection rate and high restoration quality even with high level noise.

I. INTRODUCTION

The word "digital" seems simple and easy to spell but on the contrary is far more complex when used with devices such as Laptops, mobile phones and other portable devices. Today every individual carries his/her personal mobile phone and at times may wish to transfer some piece of information to a user located at a remote place. The information could be in the form of text, video or image, which could get corrupted either due to various environmental disturbances or faulty memory locations or even due to malfunctioning pixels in camera sensors.

Noise signifies uninvited information which worsens image quality. Noise is defined as a course (n) which affects the attained image (y) and is not part of the actual signal (x). This process can be written as :

$$y(i,j) = x(i,j) + n(i,j) \quad (1)$$

Some of its common types are salt and pepper noise (SPN) and random valued impulse noise. Pixel in an image affected by SPN takes on either maximum or minimum value resulting in white or black dots in an image. The white dot corresponds to 255 i.e. maximum value and black dot corresponds to 0 i.e. minimum value. Several methodologies have been proposed to restore images corrupted by SPN. Such as Standard Median Filter (SMF), Adaptive Median Filter (AMF), Decision Based Algorithm (DBA), High Performance Decision Based Algorithm (HPDBA), Modified Decision Based Asymmetric Trimmed Median Filter (MDBUTMF), Decision Based Coupled Window Median Filter (DBCWMF) and Adaptive Weighted Mean Filter (AWMF).

The organization of the paper trails as. Review of previous median filters is given in Sect. II. Section III focuses on the formulation of the proposed algorithm. Section IV reports a number of experimental results to demonstrate the performance of the new algorithm. Finally, conclusions are drawn in Sect. V.

II. LITERATURE SURVEY

Standard Median Filtering is the modest filtering technique where the value of every single pixel is replaced by the median of the gray levels in the locality of the corresponding pixel regardless of whether it is corrupted or not [1] and it uses a fixed window of 3×3 . Calculation of window size :

$$W_n = (2w + 1) \times (2w + 1)$$

SMF is ineffective in presence of high density noise and exhibits blurring of the filtered image if the window size is hefty. For noise level over 50% it fails to preserve the edge details of the original image. Ideally, the filtering action should be carried out

only to the noisy pixels and keeping remaining pixels of the contaminated image unchanged. Therefore, a noise detection process to distinguish between the noisy pixels and noise-free pixels, before applying nonlinear filtering operation, is essential. To fulfill the objective adaptive median filter (AMF) was attempted. AMF algorithm was capable of identifying noisy and noise free pixels. AMF is based on increasing window dimension and the maximum size of the window was set to 39 ($w = 39$). However, it lacked accuracy in error detection which resulted in poor image quality at high noise density [2].

In DBA, denoising is achieved using fixed window dimension of 3×3 . If the pixel's intensity is 0 or 255, it is treated for filtering, otherwise it is left intact. This algorithm poses a serious problem of unproductive filtering at high noise density. At a high noise density, median of the window will be again either 0 or 255 which is again a noisy pixel value. In such situation, DBA considers neighboring pixels for replacement [3]. However, repeated replacement of neighboring pixels produces streaking effect. The NAFSMF makes use of the histogram to identify noisy pixels within the corrupted image and to handle uncertainty present in the extracted local information as introduced by noise it employs fuzzy reasoning [4].

To overcome the drawbacks of DBA, Modified Decision Based Unsymmetric Trimmed Median Filter (MDBUTMF) was proposed. MDBUTMF algorithm replaces the noisy pixel by median value after trimming all 0's and 255's in the 3×3 window and if 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 particular window [5]. FEMF uses former information to get natural pixels for restoration. Despite lacking iteration, it intuitively detects impulse noises, leaving the others unaffected. So it has very fast execution speed [6]. In the new technique [7], the degraded pixels are replaced by using a median filter or, they are estimated by their neighbors values.

Later, Aswini Kumar Samantaray and Priyadarshi Kanungo proposed First Order Neighborhood Decision Based Median Filter (FONDBF) which was further enhancement of MDBUTMF. FONDBF uses a fixed window of 3×3 and spots noisy pixels and considers first order neighborhood pixels of the spotted noisy pixels for further decision. If all the first order pixels are 0's and 255's, then the noisy pixel is replaced with the mean value of these first order pixels and when all the first order pixels are not noisy then by trimming all 0's and 255's median value is calculated among the noise free pixels. As it uses the fixed window of size 3×3 it results in insufficient noise suppression at high noise density [8]. High Performance Decision Based Median Filter (HPDBMF) was proposed which proved to be further form of

DBA. In HPDBMF the maximum window size W_{max} i.e. is limited to 7×7 . As the window size increases the probability of finding noise free pixel also increases and this is the main reason behind the concept of using increasing window dimension. Even if no noise free pixel is found in 7×7 window then the center pixel value is replaced by the last processed pixel if it is noise free. But if the last processed pixel is noisy then it switches the window size to 15×15 and counts the total number of 0's and 255's and replaces the processing or center pixel by 0 or 255 which is more in number in the selected window [9]. However, repeated replacement by 0 or 255 induces streaking effects making HPD-BMF unsuitable for high noise density.

Another algorithm which could remove high density salt-and-pepper noise from corrupted digital image using multiple last processed pixels was proposed. This technique differentiates between noisy and non-noisy pixels and performs the filtering operation only on the noisy ones. This algorithm utilizes noise free pixels in the processing window to calculate the median value and replaces the center degraded pixel with the median value. It expands its window size in search of noise free pixels to a maximum limit. In case of high noise density where no noise-free pixel is found, this algorithm uses last processed pixels if the maximum size of the window is reached [10].

Decision Based Coupled Window Median Filter (DBCWMF) is based on increasing window dimension and the maximum size of the window is set to 4 i.e. ($w = 4$). Here, initially 3×3 window is selected. The size of the window is increased until no noise free pixels are found in the selected window. If noise free pixels are found then after trimming all 0's and 255's the median is calculated using the remaining pixel values. However, if the maximum size of the window is reached and no noise free pixels are found then the algorithm reinitializes window size to 1 i.e. $w = 1$ and replaces the processing pixel value with the mean of the selected window [11]. In Adaptive Weighted Mean Filter (AWMF) we initially determine the window size by continuously expanding the window size until the maximum and minimum values of two consecutive windows are equal respectively. Then the current pixel is regarded as noise candidate if it is equal to the maximum or minimum values, otherwise, it is regarded as noise-free pixel [12]. Finally, the noise candidate is replaced by the weighted mean of the current window, while the noise-free pixel is left unchanged.

III. PROPOSED ALGORITHM

Our algorithm is based on increasing window dimension with the maximum limit set to 39. It initializes the window size to 1 and makes use of two windows in order to reduce the detection error rate. The proposed filter is named as Adaptive Weighted Trimmed Multiple Scanning Filter abbreviated as AWTMSF. Flow chart for the algorithm is provided below. The algorithm is divided into two stages: (i).Forward Scanning (ii).Reverse Scanning.

In both stages the algorithm computes five values at the beginning namely

$$S_{i,j}^{min}(w), S_{i,j}^{max}(w), S_{i,j}^{mean}(w), S_{i,j}^{min}(w+1) \text{ and } S_{i,j}^{max}(w+1).$$

In the first/forward scanning stage after computing the above five values the filter compares the minimum and maximum values of the two successive window and checks if they are equal i.e.

$$S_{i,j}^{min}(w) = S_{i,j}^{min}(w+1), S_{i,j}^{max}(w) = S_{i,j}^{max}(w+1) \text{ and } S_{i,j}^{mean}(w) \neq -1.$$

The center pixel is regarded as noise-free candidate if its value lies between $S_{i,j}^{min}(w)$ and $S_{i,j}^{max}(w)$ otherwise it is regarded as noisy and replaced with the median value. It must be kept in

mind that $S_{i,j}^{mean}(w)$ is only used as a conditional statement just to confirm that the entire window isn't noisy. For example: If the entire window is noisy then in such case, $S_{i,j}^{mean}(w) = -1$. However, if the minimum and maximum values are not equal the algorithm then increments the window size by 1 and starts the process again until the maximum window size is reached. There might be a case when the two extremities (minimum and maximum) are not equal with the window size at its maximum possible value in such case the center processing pixel is left unchanged and will be processed later in the second filtering stage.

The second/Reverse scanning stage is almost similar to the Forward scanning stage except the filtering process is performed in opposite direction and if two extremities are not equal with " $w = 39$ " then the algorithm is left with no choice then to replace the center processing pixel with the mean of the window.

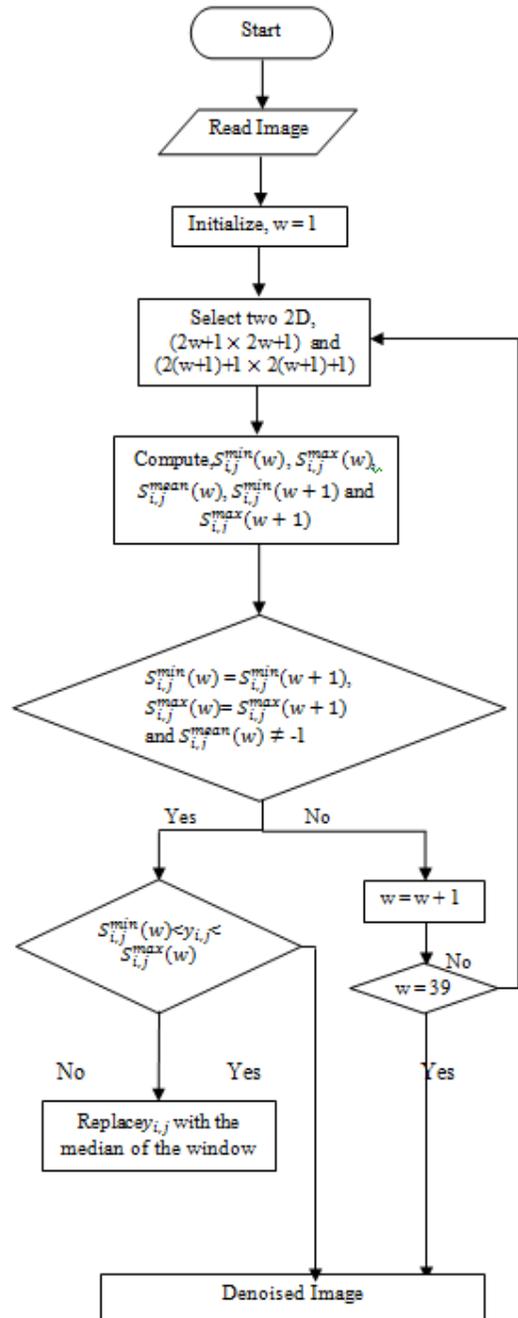


Fig.1 Flow Chart of Stage I: Forward Scanning (Upper Left to Lower Right)

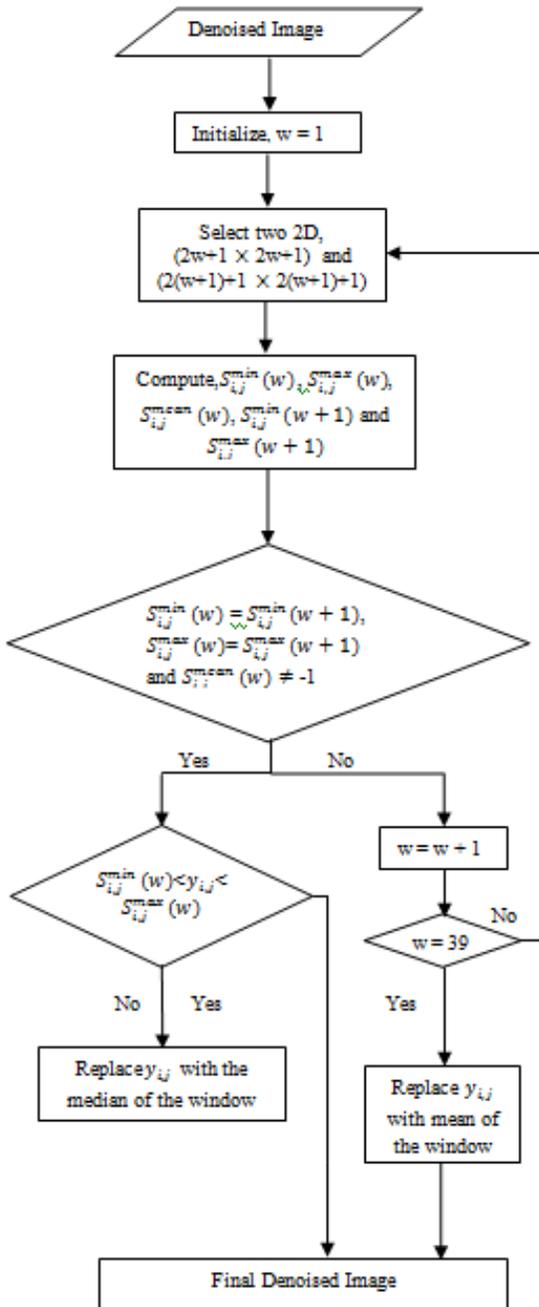


Fig. 2 Flowchart of Stage II: Reverse Scanning (Lower Right to Upper Left)

IV. SIMULATION AND RESULTS

In our tentative experiments, we use two approaches to repair images which have different levels of SPN. The tested images are 'Lena', 'Camera' and 'Gold Hill' with size 512 x 512 . The proposed filter results is matched AMF and AWMF. Besides, the proposed filter is much more efficient than any previous existing median filters.

Performance of different methods is evaluated based on the values obtained using signal-to-noise ratio (PSNR). Consider x as clean image and z as the restored image. A, B denotes rows and columns of an image.

The PSNR is defined as

$$PSNR(dB) = 20 \log_{10} \left(\frac{255}{MSE} \right) \quad (2)$$

$$MSE = \frac{1}{A \times B} \sum_{i=0}^{A-1} \sum_{j=0}^{B-1} [x(i, j) - z(i, j)]^2 \quad (3)$$

$$IEF = \frac{\sum_{i=1}^A \sum_{j=1}^B [y(i, j) - x(i, j)]^2}{\sum_{i=1}^A \sum_{j=1}^B [z(i, j) - x(i, j)]^2} \quad (4)$$

$$\text{Bit Error Rate (BER)} = \frac{1}{PSNR} \quad (5)$$

IMAGES	FILTERS	NOISE DENSITY (%)				
		30	50	70	90	AVG.
LENA	AMF	32.48	28.89	25.50	20.74	26.90
	AWMF	35.06	32.62	29.50	25.04	30.55
	AWTMSF	41.32	38.88	36.87	34.37	37.86
CAMERA MAN	AMF	27.07	23.94	21.30	17.53	22.46
	AWMF	29.07	26.70	24.23	20.73	25.18
	AWTMSF	41.60	39.33	37.37	34.80	38.27
GOLD HILL	AMF	28.36	25.67	23.16	19.72	24.22
	AWMF	30.94	28.34	25.97	22.85	27.02
	AWTMSF	38.46	36.34	34.53	32.60	35.48

TABLE I - RESULTS OF PSNR(DB) FOR VARIOUS FILTERS DEALING WITH VARYING NOISE LEVELS (GRAYSCALE IMAGE)

IMAGES	FILTERS	NOISE DENSITY (%)				
		30	50	70	90	AVG.
CAMERA MAN	AWTMSF	852.99	842.02	748.57	531.30	743.72

TABLE II - RESULTS OF IEF FOR AWTMSF DEALING WITH VARYING NOISE LEVELS (GRAYSCALE IMAGE)

IMAGES	FILTERS	NOISE DENSITY (%)				
		30	50	70	90	AVG.
LENA	AWTMSF	44.71	42.45	40.58	38.62	41.59

TABLE III - RESULTS OF PSNR(DB) FOR AWTMSF DEALING WITH VARYING NOISE LEVELS (COLOUR IMAGE)

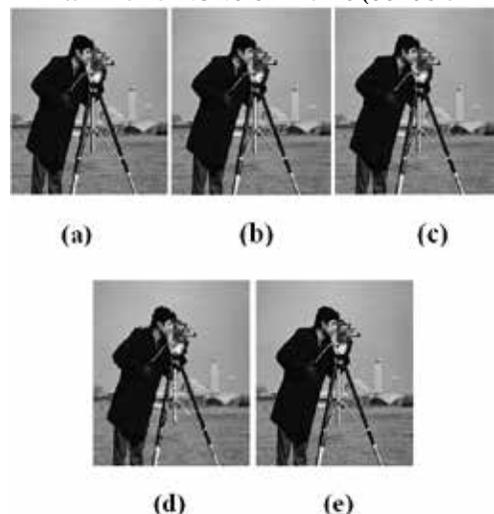


Fig3. Restoration results for Camera Man image using AWTMSF (a) 30% Noise (41.60dB) (b) 50% Noise (39.33dB) (c) 70% Noise (37.37dB) (d) 90% Noise (34.80dB) (e) Original Image

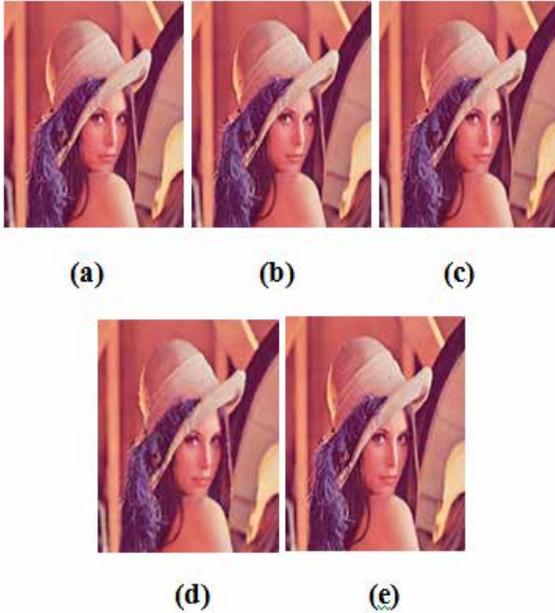


Fig3. Restoration results for Colored Lena image using AWTMSF (a) 30% Noise (44.71dB) (b) 50% Noise (42.45dB) (c) 70% Noise (40.58dB) (d) 90% Noise (38.62dB) (e) Original Image

IMAGES	FILTERS	NOISE DENSITY (%)				
		30	50	70	90	AVG.
LENA	AWTMSF	603.16	591.09	37.14	430.47	540.46

TABLE IV

RESULTS OF IEF FOR AWTMSF DEALING WITH VARYING NOISE LEVELS (COLOUR IMAGE)

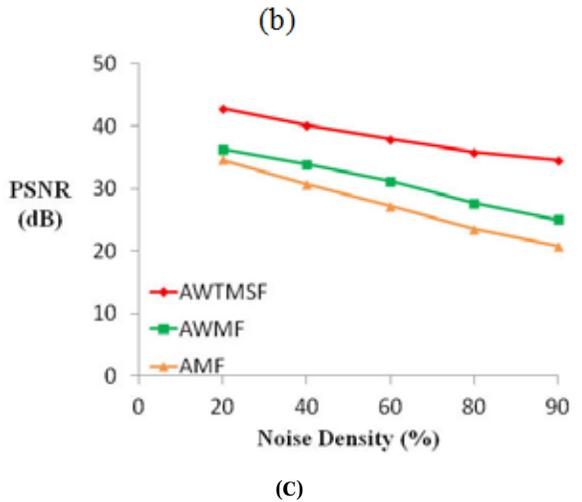
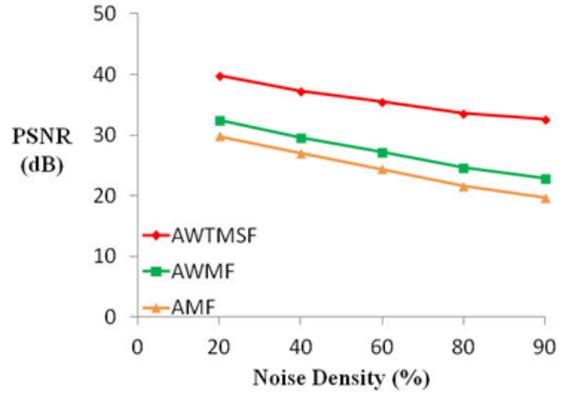
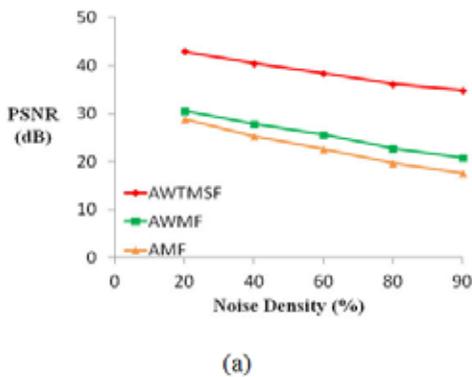


Fig4. PSNR curve after filter operation for various gray scale images (a) 'Camera Man' (b) 'Gold Hill' and (c) 'Lena' All tests are accomplished under Windows 7 HP 64-bit and MATLAB R2012b with Intel Core i5-2450M CPU@2.50 GHz and 4 GB memory. The programming language is MATLAB.

V. CONCLUSION

In this paper, we have proposed an improved median filter that is capable of restoring image degraded by high levels of SPN. It has much elevated detection precision than AWMF especially for high-level SPN. Experimental tests show that our proposed method performs much better than any previous existing filters.

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