

An Efficient Algorithm for Image De-noising by using Adaptive Modified Decision Based Median Filters

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Abstract

INTRODUCTION: In image processing noise removal is a hot research field. Lots of studies have been carried out and many algorithms and filters have been planned to improve the image information. There are various noise removal procedures to identify and remove the corrupted pixels. But several image denoising algorithms apply the filter to the overall image to filter non-corrupted pixels also. To overcome these weaknesses, we proposed an efficient denoising algorithm by cascading Adaptive Median Filter (AMF) with Modified Decision Based Median Filter (MDBMF).

OBJECTIVES: To acquire an efficient denoising algorithm for impulse noise reduction by combining AMF and MDBMF methods which are effective, efficient for denoising various kind of images.

To retain the edges, prevent signal deterioration, and ensure non-corrupted image pixels are remaining intact, regardless of various degrees of noise in the image.

To avoid the condition where noisy pixels are replaced by other noisy pixels to maintain the quality of images from its degraded noise version such as blur which often takes place during transmission, acquisition, storage, etc.

METHODS, RESULTS AND CONCLUSION: The performance corroboration of the proposed efficient denoising algorithm is accomplished employing nine standard gray scale images. The size of all standard images kept 256x256 pixels in this research. The proposed image denoising system has experimented on those images affected with 10% to 90% salt & pepper noise density. Additionally, the performance of the existing state-of-art denoising techniques like AMF, MF, WMF, UMF, and DBMF are contrasted with the proposed hybrid approach. The results showed that de-noised images obtained for 10% to 90% densities level by proposed hybrid approach are quite better than the quality of denoised images achieved from WMF, UTMF, AMF, and DBMF methods. The proposed algorithm effectively eradicates salt and pepper noise for lower to higher image noise densities levels.

Keywords: Image Denoising, Spatial Filtering, Salt and Pepper Noise.

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1. Introduction

Noise is the diminishing outcome in the intensity of an image. This is triggered by various means like little light, slow speed of the shutter, sensor errors, and sensor temperature, faults of the channel, etc. A sharp and quick interruption in the signal of an image can generate white or

black spots, recognized as Impulse Noise. It is as dissipated both white and dark pixels. Numerous mechanisms have been intended to lessen or eliminate salt and pepper noise and generate an output for the given image, close to the primitive image. The variables, for example, distinctness in noise decrease or the imperfection of the denoising algorithm make it exceptionally hard to acquire the primitive image precise replica after processing. Comparably, a little dark blot involving single or numerous

pixels in the consistent green territory of an image does not mean that it is really noise. Also, these pixels maybe also in a symmetrical or asymmetrical form. Symmetrical forms might be created because of the imperfection in the sensor while the asymmetrical form is maybe an exact aspect of the required image. There are also, a few situations in which noise diminution is not a major problem to separate minor data enclosed around a cluster of noise, like astronomical images. Moreover, inexact approaches generate issues like eliminating significant features of images or no filtering for some of the noise [1]. All denoising procedures survive specific qualities, and shortcomings to achieve denoising of the images, therefore challenging more research to deliver further progresses in this zone of study.

A digital image is a two-dimensional array of real numbers that represent visual information. 2-D images are categorized into N-rows and M-columns, integration of these rows and columns is termed as pixels [2].

In the excessive use of the internet and technology, one medium of communication is, through transmitting digital images. But unfortunately, digital images are corrupted due to different kinds of noise throughout, when it is passed from different mediums. While capturing, pictures of camera sensors are also stricken by some circumstances like noise, lighting, shadow, glowing, etc. One of the well-known types of noises is impulse noise [3], which is generated through irregular voltage of the communication medium. The impulse noise generates two intensity values in the pixels one is 0 which is called “pepper noise” and the other is 255, referred “salt noise”. For an impulse noise the noise model is calculated using equation (1) as shown below:

$$C_i = \begin{cases} 0, & \text{with probability } P_a \\ 255, & \text{with probability } P_b \\ P_i, & \text{with probability } 1 - (P_a + P_b) \end{cases} \quad (1)$$

Where C_i represents corrupted image pixel, P_i represents the pixel, P_a denotes the probability of the pixel corrupted by pepper noise, and P_b is corrupted by salt noise. If $P_a = 0$ or $P_b = 0$ then it is called unipolar impulse noise but if $P_a \approx P_b \neq 0$, called salt and pepper noise or bipolar noise. Normally p_a is equal to 0(Black) and P_b is equal to 255(White). Normally p_a is equal to 0(Black) and P_b is equal to 255(White).

In image processing noise removal is a hot research field. Lots of studies have been carried out and many algorithms and filters have been planned to improve the image information. There are various noise removal procedures to identify and remove the corrupted pixels. But several image de-noising algorithms apply the filter to the overall image to filter non-corrupted pixels also [4].

The denoising filtering mechanism involves regions with a certain type of noise. In filtering de-noising mechanism, those regions are notified which contains a certain type of noise after that map of noise composed and then passed to the required filter, while ignoring that region which has no

noise. These types of filtering de-noising mechanisms are based on identifying and evaluating those pixels which are influenced by impurity (noise). Filtering mechanisms are based on the identification and evaluation of noise. A good filter can evaluate and identify noisy pixels rapidly like a median filtering mechanism [5]. Median filtering performing enrichment of images, maintaining regions excellently [6].

The basic function in image processing to accomplish several tasks for instance noise diminution, interruption, and re-sampling is filtering. The selection of filter is decided with the type of the job achieved from the filter as well as the performance, nature of given data. Filters are utilized to eliminate noise from digital images but also to conserve the required parts of the images for further processing.

Noise filtering approaches fall into linear filtering and non-linear filtering [7].

1.1 Linear Filters:

The linear filtering approaches apply the algorithm linearly to every part of the image with no concept of the image as affected or unaffected by noise. For removing impulse noise, also known as salt and pepper noise linear filtering approaches are not efficient because the algorithm scans corrupted as well as uncorrupted pixels also. These filters also tend to disrupt the sharp edges, ruin the lines and other useful details of the required image. These approaches are fast, but they do not maintain properly the details of the image. Gaussian filters or averaging, mean filter are also called as linear filter [8]. These types of linear filters tend to convolute an image matrix with the mask of the filter to produce a linear increase of neighbourhood values. This type of linear filtering is the fundamental and simplest way of noise exclusion, though they frequently make unwanted quantity of smoothing of edges, localization of low feature and wastage of image details [9]. Due to these limitations, another approach is necessary, called a non-linear filtering approach. On the contrary, a non-linear filtering approach [10] is a two-stage filtering procedure. The pixels in the image are recognized as corrupted or uncorrupted in the first phase while applying a particular algorithm to filter corrupted pixels in the second stage.

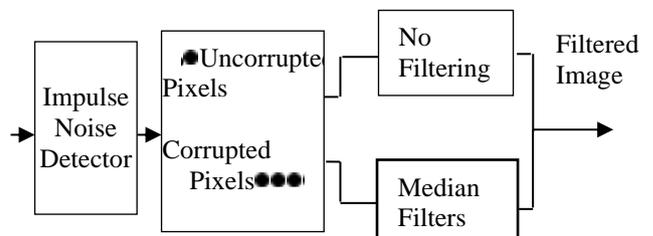


Figure 1. Non-Linear Filtering approach

Non-linear filters can clear away salt and pepper noise, conserve the edges and other useful details of the required image.

The mechanism of nonlinear filters is depicted in Figure1.

1.2 Non-linear filters:

In image processing exclusion of noise is one of the very crucial roles to be accomplished, because of noise yields inaccuracy in the image [12]. An excellent noise filter is essential to achieve two conditions, the first one is noise reduction and the second one is valuable details suppression in the given signal. The basic objective of image denoising is to improve those pixels which are corrupted by noise and look like original pixels [13]. The techniques or methodologies or algorithms or some type of mathematical equation with the help of which we can wash impurities, noise, redundant areas from the degraded images is called Filter.

The process of filtering is called filtration.

The method of denoising an image by using different types of filters is called filtration. Filtering is a procedure for image enhancement. Thus, image enhancement filters are used.

1.2.1 Standard Median Filter (SMF):

Tukey introduced in 1971 [14] the standard median filter (SMF). This nonlinear filter using the approach of the sliding window of different sizes, where the median value of the neighbour pixel replaces the value of the centre pixel. On the other hand, the effectuation of the SMF is not high when the noise level is higher than 60%. For high-level noise removal, good performance of SMF can be achieved via a large size filter. Though, a large size filter will degrade the quality of image [15]. Even at low noise level SMF blurs the image and removes thin lines also. The main reason for SMF is that it treats all pixels of an image equally, either the pixel exists noise or noise-free [16]. The SMF has some weaknesses, numerous developments have been planned to eliminate these weaknesses.

1.2.2 Weighted Median Filter (WMF):

The processes associated with WMF are the same as to SMF, but the difference is that WMF possesses weight connected through all its filter components. For the computation of the median value, the WMF weights are used. Many modifications have been done by the researcher to enhance the capabilities of WMF. [18] proposed 100+ Times Faster Weighted Median Filter (WMF) reduces the computational complexity of WMF.

A new approach ASWMF [19] is projected to restore the required image from impulse noise, conserving basic structure, edge information smoothly.

1.2.3 Adaptive Median Filter (AMF):

To overcome downsides of SMF is that it removes thin lines or edges and blurring useful detail of an image at a low-density noise level, an Adaptive median filter has been developed by Tao Chen and Hong Ren vul [20].

When the images are degraded by means of salt & pepper noise, level of intensity of noise is distinct inside for different parts of the image. Hence, the area with a small amount of noise level will be filtered by the small sliding window, whereas the area with a high-level amount of noise

will necessitate a larger filter size. Therefore, the filter requires to adapt its size corresponding to the level of noise when performing the filtering. This sort of filter is referred to as an Adaptive Median Filter [21]. Though, commonly, the filter will start its size of the window to '3x3' pixels initially. Then, the size of the window will increase according to processing and will stop the increase of the window according to certain criteria.

1.2.4 Un-trimmed Median Filter (UMF):

The basic reason for TF (Trimmed Filter) is to discard those pixels which possesses noise from the given '3x3' window. Asymmetrical filter ATMF (Alpha Trimmed Mean Filtering) where the symmetric trimming at either end can be done. With this technique, the corrupted, as well as uncorrupted pixels are trimmed. An Un-symmetric Trimmed Median Filter (UTMF) is proposed to decrease the downside of ATMF [22].

In UDBMF, the elements are organized in any increment or decrement order of the selected '3x3' window. The median calculated value of leftover pixels is taken after removing the values "0's" and "255's" from the given image. To replace noise pixels these median values are used. When values 0's and 255's are eradicated from the chosen window, so in this scenario, this filter is termed trimmed median filter. The condition is applied to processing pixels for checking either it contains noise or free from noise. It means, if the running pixel rests between upper bound and lower bound gray-level values, the pixel is noise-free, remains unchanged. If the processing pixel yields the upper bound or lowers bound of gray-level, then the pixel is noisy which is treated with an untrimmed decision-based median filter [23].

1.2.5 Decision Based Median Filter (DBMF):

DBMF search and evaluate that the pixels values are corrupted by "Salt-and-Pepper noise" or not. In this mechanism first, it evaluates that the processing pixel is corrupted or not, after evaluating the condition is applied $0 < P_{xy} < 255$ here P_{xy} is the pixel value lie at position (x,y).

If the above condition satisfies correctly then the pixel is uncorrupted, and its value will be unaffected. This type of pixel is the noise-free pixel. But when the condition is not satisfied, the value of P_{xy} becomes '0' or '255', so the pixel is distorted which is further processed by DBMF [11, 24].

1.2.6 Modified Decision Based Median Filter (MDBMF):

In MDBMF (Modified Decision-based Median Filter), the corrupted pixel is processed via an alternative way. For DBMF selected window '3x3' is used. MDDBF algorithm, the window initialized of size '3x3'. When all processing pixels are found to be corrupted in the existing processing window the window size expanded from '3x3' to '5x5'. This increase in window size for a good result of the median value. Finally, the pixel is substituted with the median value of the total pixels that exist in the current window. But when the entire pixel is also found to be corrupted in the 5x5 window, then for the replacement previous pixel value is

considered [25]. MDBMF preserves image details efficiently.

1.3 Scope:

The fundamental scope of this research is to implement the AMF algorithm and modified decision based median filtering (MDBMF) algorithm, to notify wisely, the stabilities and shortcomings of the given algorithm. The new hybrid image denoising algorithm is accomplished to detach the deficiencies and to decrease further, such as to avoid signal weakening (objects counters and edges blurred), to decrease the time complexity of the algorithm, to identify, reserve, detect boundary features, and to make sure non-corrupted (good) image pixels are left intact, regardless of the volume of noise in the images. The planned research is carried out in MATLAB software and checked on standard images as well as on two medical images also. The result of the implemented work is compared with the outcome of the application of the AMF, MF, WMF, UMF algorithm, and the DBMF algorithm to determine and evaluate the proficiency of the intended hybrid algorithm.

1.4 Problem Statement:

Because of the deficiencies of the Standard Median Filter, numerous transformations or improvements of the Standard Median Filter have been proposed by scientists. Among these procedures is the Simple Adaptive Median filter [26]. This method is easy to be executed, and effective to filter noise, even at significant degree of corruption. In any case, because of track down the best filter size for every pixel, long preparing time is expected to totally channel a picture. But, on the other hand because of determining the finest filter size for every pixel, lengthy time processing is expected to totally filter the image. Consequently, adjustment to this filter, which is known as the Quantized Versatile Exchanging Middle (QSAF) filter [27] has been presented. Even though the performance of QSAM is superior to the Adaptive Median Filter regarding accuracy and handling time, but the precision is still comparatively minimal. Hence, there is still an opportunity to enhance the accuracy and precision of filters by cascading these filters to de-noise images at highest degrees of salt & pepper noise.

1.5 Research Objectives:

The main aim of this research is to restructure or regain the image that is affected and degraded through salt & pepper noise and enhance it by implementing the median filtering algorithm.

Following are the core research objectives:

- To acquire a new efficient denoising algorithm for impulse noise reduction by combining AMF and

MDBMF methods which are effective, efficient for denoising various kinds of images.

- To equate the outcomes of the recommended filter with other median filters for distinct kinds of noisy images.
- To retain the edges, prevent signal deterioration, and ensure non-corrupted image pixels are remaining intact, regardless of various degrees of noise in the image.
- To avoid the condition where noisy pixels are replaced by other noisy pixels to maintain the quality of images from its degraded noise version such as blur which often takes place during transmission, acquisition, storage, etc.

2. Related Work

The main concept in the lack of the proposed methodology is the valuation of the denoise image from the noisy image, also known as “image denoising” to repossess an image from its degraded form by having preconception of the degradation procedure. Therefore, the denoising process is a crucial and essential step before the analysis of images data. There are numerous techniques to recover an image from its noisy version. The implementation of an efficient denoising technique is essential to counteract such type of data loss and corruption. Choosing a suitable approach performs the main task of acquiring the required upgraded result.

Several non-linear filters are recently intended to overcome the weakness appeared in the linear filter. As a comparison nonlinear filter gives better result than linear filters.

The most popular and most broadly utilized approach to deal with impulse noise is the median filter. Median filtering has been considered as a solid technique to eliminate impulse noise without harming edge details. But the core downsides of Standard Median Filter (SMF) are that this filter frequently shows distorting for large window size and efficiency for low noise densities. SMF works better when noise level is below than 50%, when higher than 50% blurring occurs in the original image. Computational complexity is better for small size fixed window [28].

Conventional Adaptive Median Filter [29] is also efficient at lower noise densities, however at higher noise densities most of the noisy pixels are replaced by median values, due to the fact the windows size is also increased which effects and produce blurring in the image.

In current few years, a well-known digital non-linear filter named decision based-median filter (DBMF). studied broadly. It works on decision that the pixel is corrupted or not corrupted. The noisy pixels are separated and then replaced with median values by neighbour pixels. DBMF conserves details of the image when compared with standard median filter because the uncorrupted pixels are untouched. It works better than SMF.

The significant downside of this technique is that defining a vigorous decision is not easier and quickly. Similarly, these filters are not protecting local features effectively such as details and edges of the images, specifically when the noise density is high.

To overcome these weaknesses, we proposed an efficient denoising algorithm by cascading Adaptive Median Filter (AMF) with Modified Decision Based Median Filter (MDBMF). The proposed algorithm removes noise effectively at higher noise densities, preserves details and edges smoothly. The subsequent output illustrates that the proposed technique delivers improved performance than other filters.

3. Proposed Efficient Algorithm

In this paper an efficient algorithm using Adaptive Modified Decision Based Median Filter (AMDBMF) is proposed. The performance of the proposed algorithm is compared with MF, AMF, WMF, UTMF and DBMF. The resulting output shows that the proposed algorithm provides improved enhancement at high noise density than other filters.

The steps for our proposed hybrid approach are depicted in figure 2.

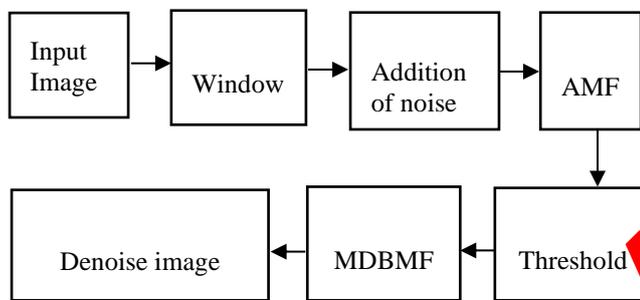


Figure 2. Proposed Efficient Denoising Algorithm Framework

In the intended system, AMF is merged with MDBMF. The core advantage of this new efficient de-noising algorithm is to remove salt & pepper noise, level for impulse noise, reduce distortion and saves the edges of the image. This new efficient de-noising algorithm also identifying corrupted or degraded pixels in an image after identification the corrupted pixels are processed for denoising.

Initially, Lena, Cameraman, Baboon, Living Room, Parrot, House, Horses, Chest, and Liver images of dimensions 256×256 are one by one inputted by using down sampling technique with the help of MATLAB code, after the selection of input image window is selected e.g., 3×3 .

After window selection, some percentage of noise 10%, 20%, 30%, 40%, 50%, 60%, 80%, and 90% respectively added to the input image, and the given image is passed through the adaptive median filter.

In the first stage, AMF will process that image that is previously inputted.

After AMF, threshold upper bound, and lower bound (less than or greater than 255), MDBMF is applied to denoise the required image.

After the application of AMF and MDBMF, the result will be observed and PSNR and MSE, IEF, and SSIM is calculated.

The non-linear filters remove noise from an image effectively for low noise densities conversely weakly for high noise densities. The most important goal of our intended algorithm is to shrink the noise by two combined processes specifically, AMF and MDBMF.

The proposed algorithms works better in benchmark images as well as on medical images in varied noise ratios. Fig. 3 depicts the proposed efficient denoising algorithm.

Further, Table. 1 narrates pseudocode of proposed image denoising approach

Table. 1 Steps of proposed efficient image denoising approach

- Step 1:** Set $W=3$, $W_{Max}=21$, $W_{Min}=3$
- Step 2:** $[M, N]=S(img)$ number of rows and columns in the image
- Step 3:** LET $Pixel=P_{xy}$, $P_{upp}=255$, $P_{low}=0$
- Step 4:** Find P_{med}
- Step 5:** IF $W \leq P_{upp}$ THEN goto step 5 ELSE $W=W+2$ increase the window size by 2
- Step 6:** IF $P_{xy} \leq P_{upp}$ THEN goto step 3 Pixel (x,y) corrupted replaced by P_{med} ELSE Pixel (x,y) not corrupted
- Step 7:** IF $P_{low} < P_{xy} < P_{upp}$ THEN Pixel (x,y) uncorrupted and it is left unchanged.
- Step 8:** IF $P_{xy} \neq 0$ && $P_{xy} \neq 255$ THEN Pixel (x,y) corrupted replaced by P_{med} .
- Step 9:** IF $P_{xy} == 0 || 255$ && neighbour-pixels $== 255$ THEN $W=W+2$ (Increment Window Size) END IF
- Step 10:** MOVE W TO $P_{x,y}$
- Step 11:** Repeat from step 1 to step 10 until window reaches the last pixel.

Usually, standard median filters tend to change equally corrupted and non-corrupted pixels throughout their non-linear filtering mechanism. As a result, efficient exclusion of salt and pepper noise triggers obscure and distorted characteristics in the denoised image. Hence, to segregate between corrupted and non-corrupted pixels (preceding to standard median filtering approach); DMF is employed. Although, Decision Median Filter caused downgrading at high noise density in performance. Contrarily, noisy pixel and substituted median pixel values are correlated to a smaller extent in AMF. As a result, there exist failure of estimation of local information, blurring effect along with unreserved edges. Based on the above perception, the efficient image denoising algorithm proposed in this work hybridizing AMF and MDBMF utilizing a variable window not a fixed window. The main idea of our intended denoising approach is to deliberate only those pixels which are noisy while the non-noisy pixels unprocessed as far as possible and then employing the hybrid filtering method to those corrupted pixels only.

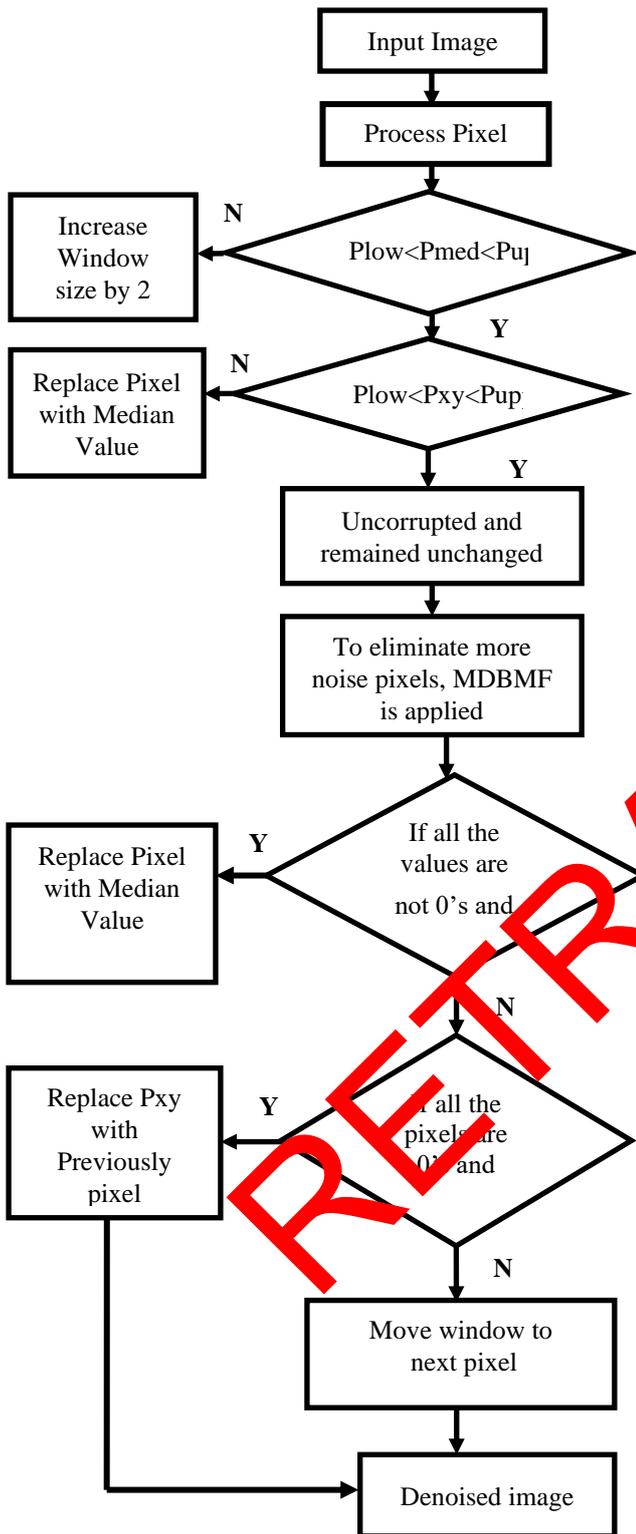


Figure 3. Flowchart of proposed algorithm

We have applied the proposed image denoising approach for noise exclusion from the standard state of the art images and medical images. This approach initially creates the

determination of the given pixel whether it contains noise or not. Fig.3 depicts flowchart of the proposed approach. To detect the pixel polluted by noise, when P_{xy} (working pixel) assures the situation i.e. $P_{low} < P_{xy} < P_{upp}$ or $0 < P_{xy} < 255$, while P_{xy} is the value of the pixel exist at (x,y) point, then P_{xy} is noiseless, furthermore unchanged. But when the pixel value P_{xy} has the value '0' or '255', so the pixel is treated as noisy and treated. To this step, our method is like the preceding approach stated in DBMF [10]. We removed noise from corrupted pixels in various ways in our hybrid image denoising approach. The authors used a fixed window size of 3x3 for DBMF. In our planned system, the window "W" is initialized of size 3x3. The window is incremented by 2 in that situation when overall pixels are discovered noisy. This step is accomplished because, when all the pixels in the process area are polluted by noise, this one creates a median value that is also noisy. Therefore, for getting a better median value the window size is increased. Finally, noisy pixels (x,y) swapped through the median values (P_{med}) exists in process window. If every pixel in the incremented window (5×5) are also noisy, then P_{xy} is replaced with Previously pixel. Lastly, when there is no noisy pixel in the operating window then it is moved to the next processing pixel.

3.1 Performance Matrices:

The performance of the proposed image denoising approach is authenticated by subjective along with quantitative valuation methods. For subjective assessment, the resultant image must perceive by a visual observation while the quantitative estimation of an image is achieved by error related quality processes. The denoising images performance is calculated by Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Image Enhancement Factor (IEF), and Structural Similarity Index (SSIM). These metrics are broadly used to estimate the quality of the restored image. The performance assessment procedures are described as follow:

3.1.1 PSNR and MSE:

The PSNR is the basic equation used for the proportion of the highest conceivable value of a signal to the power of distorting noise, influences the quality of its depiction. Since various signals have an incredibly broad range, (the ratio between the highest and lowest achievable values of an alterable quantity) the PSNR is typically denoted in reference to the logarithmic decibel value. The PSNR is utilized for calculating the enhancement of an image after restoration. Mathematically PSNR is expressed as in equation (2):

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

Whereas the MSE (Mean Squared Error) is represented as in equation (3):

$$MSE = \frac{\sum_{i=1}^r \sum_{j=1}^c \{Y(i, j) - Y(i, j)\}^2}{m \times n} \quad (3)$$

The above two equations can also be expressed as:

$$MSE = \left(\frac{1}{r * c}\right) * \text{sum}(\text{sum}((o - d).^2) \quad (4)$$

$$PSNR = 20 * \log (\max(\max(o)) / MSE)^{0.5} \quad (5)$$

Where:

o represents our original image matrix data.

d represents our degraded image matrix data.

r represents image numbers of rows of pixels and **i** is the index of the given row.

c represents image number of columns of pixels and **j** is the index of the given column.

SUP_r represents the largest signal value or supreme value that presents in our original image.

3.1.2 SSIM:

SSIM is the recently recommended technique for image quality measurement. It is the approach for assessing the resemblance between the original and denoised image. The values extend between [0,1]. If the value is **1** then the two images are symmetrical conversely there is a difference.

For original and denoised images **A** and **B**, correspondingly, the SSIM is described as in equation (6):

$$SSIM(A, B) = [L(A, B)]^x [C(A, B)]^y [S(A, B)]^z \quad (6)$$

Where **L**, **C**, and **S** stands for luminance, contrast and structural components correspondingly. Also, **x**, **y**, **z** = 0 monitor the relative impact of each of these terms, namely luminance, contrast, and structural components of the index.

3.1.3 IEF:

Image Enhancement Factor (IEF) is another quality performance metric for evaluating the enhancement of the restored image. IEF relies on the inputted original image, noisy image, and denoised image and mathematically it is expressed as under in equation (7):

$$IEF = \frac{\sum_{i=1}^r \sum_{j=1}^c [N(i, j) - O(i, j)]^2}{\sum_{i=1}^r \sum_{j=1}^c [D(i, j) - O(i, j)]^2} \quad (7)$$

Where **O(i, j)**, **N(i, j)**, and **D(i, j)** denotes an original, noisy, and denoised image of dimensions **r** and **c** respectively.

4. An Evaluation Dataset of the Proposed Efficient Algorithm

The performance corroboration of the proposed image denoising algorithm is accomplished employing nine standard Gray-scale images. Figure 4 demonstrates the required images utilized in this work. The main processes of the new hybrid images denoising algorithm are the finding of the noisy pixel and change them into noise-free pixel using an adaptive median filter and the modified decision based median filter combinedly.



Figure 4. Benchmark images used in the proposed hybrid system

In the given section the simulation results are carried out and the comparison has been done of our proposed denoising system with another state-of-art existing denoising algorithms, like AMF, MF, WMF, UMF, as well as DBMF are evaluated.

Subjective assessments, as well as quantitative assessments, are made to examine the proposed denoising system effectively.

4.1 Subjective Analysis of Algorithm:

To check and confirm the intuitive quality of the de-noised images attained through the new efficient image denoising system, subjective valuation is carried out for each benchmark image. The size of all standard images kept 256x256 pixels in this research.

The proposed image denoising system has experimented on those images affected with 10% to 90% salt & pepper noise density. Additionally, the performance of the existing state of art denoising filters such as AMF, MF, WMF, UMF, and DBMF are contrasted with the proposed efficient algorithm.

Table 1. Results of non-linear filters on both standard images and medical images affected by salt & pepper noise.

Images	Noise %	AMF	MF	WMF	UMF	DBMF	Proposed (AMF+MDBMF)
--------	---------	-----	----	-----	-----	------	----------------------

Img1	10%							
Img2	20%							
Img3	30%							
Img4	40%							
Img5	50%							
Img6	60%							
Img7	70%							
Img8	80%							
Img9	90%							

Table 1 shows the perceptible quality of de-noised images by the proposed approach in contrast with AMF,

MF, WMF, UMF, and DBMF approaches for 10% to 90% noisy images correspondingly.

The understandings of the results by the subjective evaluation are as follows:

It is noted from the Table 1 that the existing methods such as MF, WMF works properly for the images corrupted by 10% to 20% Salt-and-pepper noise density.

However, rising the density of noise from 30% to 50 %, MF and WMF methods weaken to remove the noisy pixels. As a result, it considerably decreases the visual quality of the denoised images. But AMF, UMF and DBMF approaches accomplishes good quality for all images.

For 60% to 90% noisy density, the denoising performance of AMF, UMF and DBMF approaches is lower than our proposed approach (AMF+MDBMF) because of inadequate noise suppression at higher noise densities.

It is observed from the given table 1, that the performance of the proposed algorithm denoising capability up to 90% noise density is better than the existing algorithms for the benchmark images used.

4.2 Objective Evaluation:

The comparative analysis is conducted to determine the performance of the proposed new hybrid image denoising

algorithm and equate the same with AMF, MF, WMF, UMF, and DBMF.

To assess the performance of the proposed hybrid algorithm different factors such as PSNR, MSE, SSIM and IEF are calculated. The experiments are performed on standard images as well as on two medical images: Lena, Living room, Baboon, Boat, Parrot, House, Horses, Chest, and Liver. The implementation of this algorithm is examined for several stages of noise degrees from 10% to 90%. Also, the performance measures of the proposed approach are contrasted with an existing approach such as AMF, MF, WMF, UMF, and DBMF are shown in table 2 and table 3 correspondingly for all images. To accurately examine the performance of the proposed system, graphical interpretations of individual images are demonstrated in figure 5 and 6.

It is clearly observed from the table 2 and table 3 that this proposed approach performs well as compared to other methodologies in terms of PSNR and MSE, SSIM and IEF. Also, the graphical interpretation in figure 5 and 6 obviously shows the performance of proposed denoising system for noise elimination and edge conservation.

Table 2. Comparison of PSNR values on different images.

Images	Noise %	AMF	MF	WMF	UMF	DBMF	Proposed (AMF+MDBMF)
Img1	10%	40.3935	29.5162	39.5208	41.6611	36.5658	42.8348
Img2	20%	39.1531	27.2304	33.5305	40.3633	37.5613	40.3797
Img3	30%	36.5041	21.6876	31.8830	39.1212	34.8407	39.3296
Img4	40%	30.1815	17.6928	33.5166	36.4873	24.3197	37.8436
Img5	50%	33.8731	14.0689	31.9667	36.1013	22.9458	36.5575
Img6	60%	35.5655	11.1585	31.4121	34.8138	22.2303	35.8570
Img7	70%	31.2265	9.5107	30.8971	31.7239	15.3721	32.8672
Img8	80%	32.9694	7.3588	29.9654	29.2082	15.0648	33.2287
Img9	90%	31.7120	5.9004	29.9209	26.7994	7.9744	32.9353

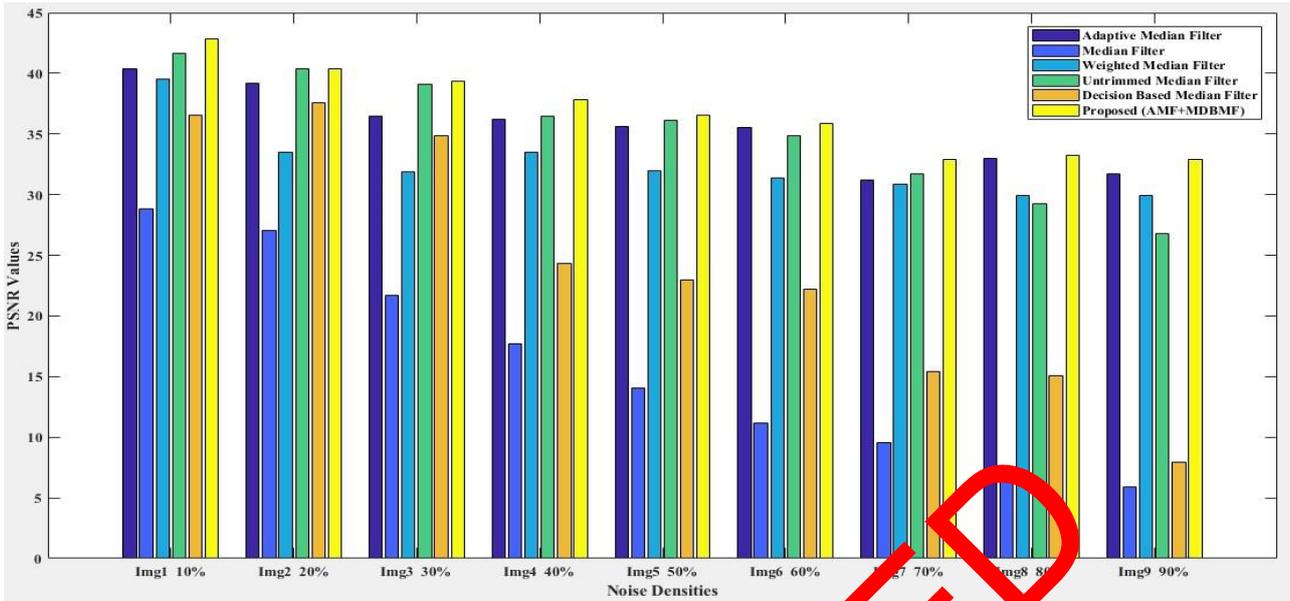


Figure 5. Comparison of PSNR values on different images

Table 3. Comparison of MSE values on different images.

Images	Noise %	AMF	MF	WMF	UMF	DBMF	Proposed (AMF+MDBMF)
Img1	10%	5.9392	15.3305	7.2611	4.4357	3.8015	3.3853
Img2	20%	7.8785	32.0952	23.8426	5.9807	6.7796	5.9582
Img3	30%	14.5435	50.0531	42.1485	7.9609	9.2733	7.5878
Img4	40%	15.6651	82.2100	28.9347	14.600	15.5688	13.9324
Img5	50%	17.7612	159.4002	41.3434	15.9568	18.2368	14.3659
Img6	60%	18.0521	181.9268	46.9756	21.4636	19.8026	16.8803
Img7	70%	49.0264	300.9887	52.8902	43.7206	43.6149	33.6019
Img8	80%	3.8297	293.1720	65.5446	78.0293	45.1856	30.9177
Img9	90%	34.0003	337.2924	66.2202	135.8744	102.2163	32.0005

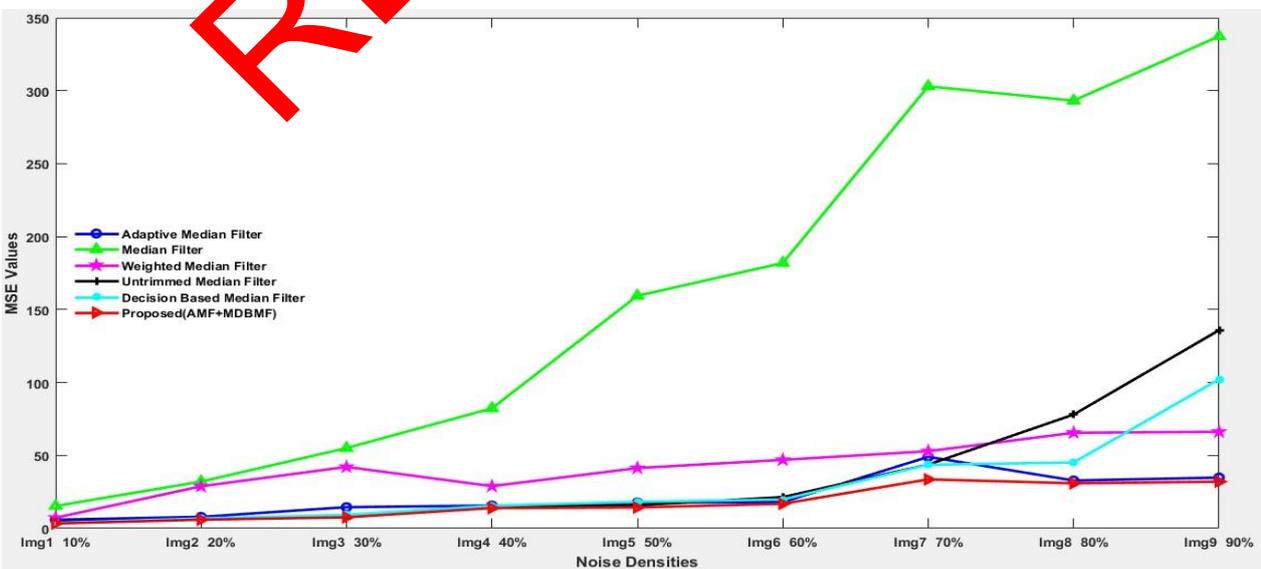


Figure 6. Comparison of MSE values on different images

Table 4. Comparison of IEF values on different images.

Images	Noise %	AMF	MF	WMF	UMF	DBMF	Proposed (AMF+MDBMF)
Img1	10%	68.3662	11.9768	0.0104	206.891	189.06	263.3411
Img2	20%	178.715	7.1785	0.0621	211.128	208.264	211.4888
Img3	30%	131.335	3.6807	0.0168	237.045	175.941	234.4453
Img4	40%	101.378	2.6106	0.0721	98.9475	82.3089	103.4642
Img5	50%	89.5403	4.2711	0.074	557.88	492.468	622.6818
Img6	70%	208.533	3.3845	0.5482	170.406	424.242	641.6436
Img7	70%	23.0689	2.3821	0.1842	114.403	114.958	193.6784
Img8	80%	69.3509	1.1921	0.0318	16.8291	50.1852	107.192
Img9	90%	94.6464	0.8517	0.0203	5.2486	9.2743	102.2447

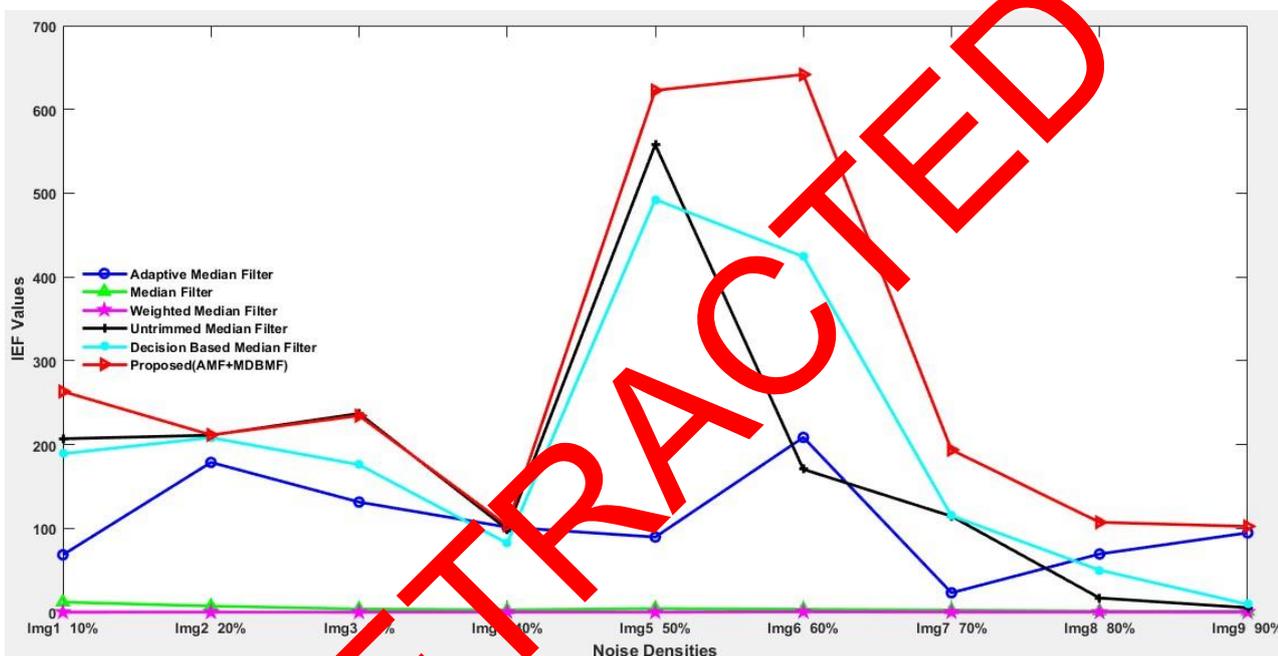


Table 5. Comparison of SSIM values on different images [30, 31, 32].

Images	Noise %	AMF	MF	WMF	UMF	DBMF	Proposed (AMF+MDBMF)
Img1	10%	0.2445	0.7694	0.232	0.9523	0.9391	0.9644
Img2	20%	0.1156	0.7243	0.1072	0.943	0.9317	0.9522
Img3	30%	0.1049	0.6383	0.0981	0.9278	0.9031	0.9368
Img4	40%	0.068	0.3544	0.0632	0.8418	0.8033	0.8436
Img5	50%	0.0451	0.2293	0.0477	0.7936	0.7636	0.8286
Img6	60%	0.0183	0.0689	0.0195	0.6483	0.6614	0.7572
Img7	70%	0.0309	0.0543	0.0305	0.4954	0.4873	0.6048
Img8	80%	0.0232	0.031	0.0199	0.2407	0.3944	0.5383
Img9	90%	0.0067	0.0104	0.0086	0.0862	0.1777	0.2763

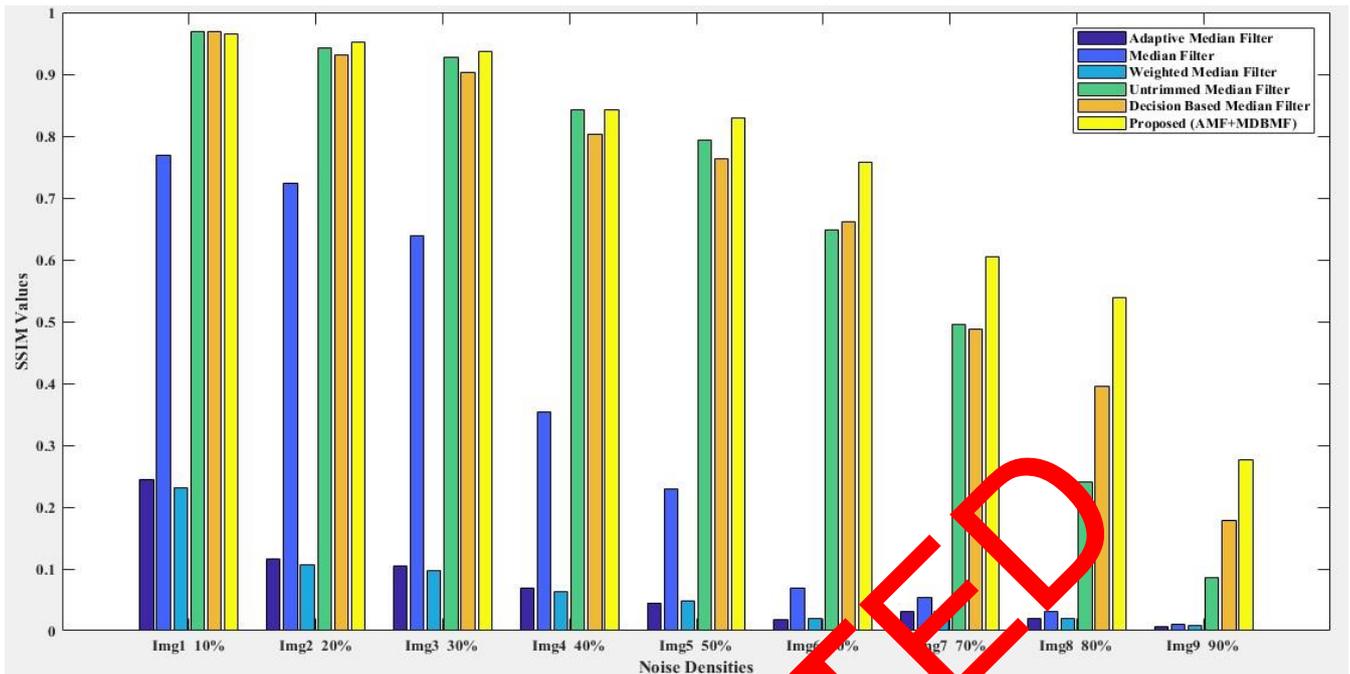


Figure 8. Comparison of SSIM values on different images

It is clearly observed [33, 34, 35] from tables 2 to 5 that the proposed hybrid algorithm performs well as compared to other methodologies after the computation of PSNR, MSE, IEF and SSIM. Also, the graphical interpretation in Figures 5 to 8 obviously demonstrates the achievement of the proposed denoising system for noise elimination and edge conservation. The interpretations made from the objective evaluation are as under.

The MF and WMF filters demonstrate good performance only on the minimal noise degree.

The AMF, UMF, and DBMF provide better performance than MF and WMF filters for all given benchmark images.

The Proposed (AMF+MDBMF) approach is very efficient in the containment of salt & pepper noise, edge preservation, and efficient image restoration under a high level of noise intensities.

The PSNR, IEF, and SSIM of the proposed approach are higher than existing approaches regardless of noise intensity available in the provided image. The MSE of this hybrid algorithm is also lower as matched to other existing approaches.

5. Conclusion

In this research work, an efficient algorithm for image denoising by using Adaptive Modified Decision Based Median Filters (AMDBFM) was presented for the removal of salt and pepper noise from grayscale images. The proposed algorithm was evaluated on salt and pepper noise for varying noise densities levels: 10% to 90% over different

benchmark images such as Lena, Living Room, Baboon, Boat, Parrot, House, Horses, and few medical images namely, Chest and Liver.

Comparative analysis was performed to determine quantitative as well as visual analysis with existing state-of-the-art approaches: MF, WMF, UMF, AMF, and DBMF. The well-known quantitative de-noising metrics namely, PSNR, MSE, IEF, and SSIM were used for objective evaluation. The results showed that de-noised images obtained for 10% to 90% densities levels by proposed hybrid approach are quite better than the quality of denoised images achieved from WMF, UTMF, AMF, and DBMF methods.

From obtained results, finally, it can be concluded that proposed algorithm effectively eradicates salt and pepper noise for lower to higher image noise densities levels.

In future, we shall extend this research work on other noise types such as Gaussian noise, Speckle noise, Rayleigh noise, and Random noise for medical Images. And plan to investigate other techniques for image denoising namely, fuzzy logic and neural networks for the sake of more accurate results. We will train the models with frameworks which better suits for these types of noises.

Also, as we know that, a very few Convolutional neural network (CNN) techniques were used for medical images denoising. It will be inspiring if more CNN approaches might be employed to denoise medical images. The establishment of more memory allocations for the CNN task will be exceptionally effective.

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