Performance of Non-linear Cascaded Filtering Algorithm for Removal of Impulse Noise in Digital Images

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Abstract — **The goal of impulse noise removal is to suppress the noise by preserving the integrity of edges and detail information. This paper will discuss this goal in two steps. In the first one, an overview of effective algorithms for image restoration was presented; while the second step represent a new hybrid filtering technique that suggested improving the denoising process in digital images. The filters used in this work as untrimmed decision based median filter (UDBMF) and decision based median filter (DBMF). The performance of these filters was compared based on qualitative parameters with some existing non linear filters at levels of noise up to ninety percentages. The results have shown that the suggested methodology has the potential to be applied in noise removal and a good performance is readily achievable. Also, the necessary details in image were preserved.**

Keywords - ***image restoration; impulse noise; untrimmed decision based median filter; nonlinear filters***

I. INTRODUCTION

Image is defined as an array, or a matrix arranged in rows and columns. Image processing is a form of signal processing for which the input is an image, such as a photograph or video frame; the output may be either an image or a set of characteristics or parameters related to the image. The field of digital image processing refers by means of a digital computer. It includes many techniques as: image segmentation, image recognition, image differencing, color corrections, digital composition, and image restoration, etc [1].

Digital images are often corrupted by impulse noise, due to faulty camera sensors, transmission of images over faulty channels. Impulse noise is of two types: salt and pepper noise and random valued impulse noise [2].

Image de-noising is a vital image processing task i.e. as a process itself as well as a component in other processes. There are many ways to de-noise an image or a set of data and methods exists. The important property of a good image denoising model is that it should completely remove noise as far as possible as well as preserve edges [3].

There are two types of image denoising model, linear model and nonlinear model. Generally linear model are being considered for imaged noising, the main benefits of using linear noise removing models is the speed ,while the limitation of the linear models is: the models are not able to preserve edges of the images. In an efficient manner; Non-linear models can preserve edges in a much better way than linear models but it is very slow [4].

This paper has been organized in the following manner, section II describes restoration process, section III contains sources of noise and its types,, section IV discuss the means of filters, while filtering techniques are given in section V, section VI illustrates briefly the proposed methodology, simulation and the discussions of results were presented in section VII, the conclusions were presented in section VIII, section IX give a scope of the future work. Finally, the references that used for completion of this work were incorporated.

II. RESTORATION PROCESS

Image Restoration attempts to reconstruct or recover an image that has been degraded. The objective of image restoration procedures is to suppress degradation of the image with the help of the knowledge about its nature [5]. The idea of image restoration is to balance for or unwrap a defect which corrupts an image. Degradation comes in many forms such as motion blur, noise, and camera misfocus [6].

The image restoration techniques can be broadly classified into two groups as: (1) deterministic and (2) stochastic. Deterministic method suits in restoring images with a little noise and a known degradation function. The original image can be obtained by applying a transformation inverse to the degradation of the degraded image. Stochastic technique tries to find the best restoration according to a particular stochastic criterion [7].

The possible approach for noise removal is using filters such as low-pass filters or median filters. More sophisticated methods assume a model of how the local image structures look like, a model which distinguishes them from the noise; that's by first analyzing the image data in terms of the local image structures, such as lines or edges, and then controlling

the filtering based on local information from the analysis step [5].

Restoring an original image, from the degraded image, with or without knowledge of the degradation function degree and type of noise present - is an ill posed problem [8].Fig.1. Shows block diagram for the degradation/ restoration process. The objective of restoration is to find the estimated F(x,y) that closely approximates the original input image f(x,y) [9].
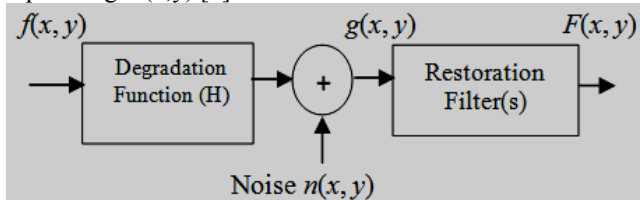

Figure 1.   Model of the image degradation/restoration process.

Where $f(x,y)$ is input image, H is degradation function, $n(x,y)$ is additive noise, $g(x,y)$ is degraded image, and $F(x,y)$ is restored image .

III.   TYPES OF NOISE IN IMAGES

Noise is a disturbance that affects a signal; it may distort the information carried by the signal. Presence of noise is manifested by undesirable information, which is not at all related to the image under study, but in turn disturbs the information present in the image. The noise is translated into values, which are getting added or subtracted to the values on the levels of image pixels. Image noise can be originated due to camera quality, acquisition condition illumination level, calibration. Image noise can also be occurred due to the electronic noise in the camera sensors, and it can be a function of the scene environment [10].

A.   Various Sources Of Noise

Reference [11] introduces noise in the image at the time of image acquisition or transmission. Different factors may be responsible for introduction of noise in the image. The number of pixels corrupted in the image will decide the quantification of the noise. The principal sources of noise in the digital image are:

- The imaging sensor may be affected by environmental conditions during image acquisition.
- Insufficient Light levels and sensor temperature may introduce the noise in the image.
- Interference in the transmission channel may also corrupt the image.
- If dust particles are present on the scanner screen, they can also introduce noise in the image.

B.   Types Of Noises

Image noise can be classified as impulse noise (Salt-and-pepper noise), Amplifier noise (Gaussian noise), Poisson noise (Shot noise), Quantization noise (uniform noise), Film grain, non-isotropic noise, Multiplicative noise (Speckle noise) and Periodic noise [11].

In signal processing or computing it can be considered data without meaning; that is, data that is not being used to transmit a signal, but is simply produced as an unwanted by-product of other activities. In Information Theory, however, noise is still considered to be information. In a broader sense, film grain or even advertisements in web pages can be considered noise [12].

Noise is undesired information that contaminates the image. In the image denoising process, information about the type of noise present in the original image plays a significant role [13]. If an image is being sent electronically from one place to another via satellite or wireless transmission or through networked cables, the expecting errors may be occurred in the image signal [14]. These errors will appear on the image output in different ways depending on the type of disturbance in the signal as:

1) Amplifier Noise (*Gaussian noise*): The standard model of amplifier noise is additive, Gaussian, dependent at each pixel and dependent of the signal intensity, caused primarily by Johnson–Nyquist noise (thermal noise), including that which comes from the reset noise of capacitors ("kTC noise"). It is an idealized form of white noise, which is caused by random fluctuations in the signal [14]. Amplifier noise is a major part of the noise of an image sensor, that is, of the constant noise level in dark areas of the image. In Gaussian noise, each pixel in the image will be changed from its original value by a (usually) small amount. A histogram, a plot of the amount of distortion of a pixel value against the frequency with which it occurs, shows a normal distribution of noise. While other distributions are possible, the Gaussian (normal) distribution is usually a good model, due to the central limit theorem that says that the sum of different noises tends to approach a Gaussian distribution [15].

2) Impulse Noise: Impulse noise is a short duration noise that affects the contents of digital images. Impulse noise is normally produced due to electromagnetic interference, errors and scratches on recording disks, malfunctioning of pixel elements in the camera sensors, faulty memory location and erroneous synchronization in digital recording and communication equipment [16]. Impulse noise distorts image pixels where replacing the original value either by fixed value or random value. Two types of impulse noise are fixed value impulse noise and random-valued impulse noise. Fixed value impulse noise e.g. Salt and pepper noise in which the gray value takes a value of either 255 or 0, Random-valued impulse noise, in which noise is dispersed uniformly. It may take any value in the dynamic range of [0,255]. It is therefore apparent that the original pixel and the random-valued impulse noise have the same range of values. Random valued impulse noise is difficult to remove [17].

In salt and pepper noise model, there are only two possible values ʻaʼ and ʻbʼ. The probability of getting each of them is less than 0.1 (else, the noise would greatly dominate the image). For 8 bit/pixel image, the intensity value for pepper noise typically found nearer to 0 and for salt noise it is near to 255. Salt and pepper noise is a generalized form of noise typically seen in images [13]. In image criteria the noise itself represents as randomly occurring white and black pixels. An effective noise reduction algorithm for this type of noise involves the usage of a median filter, morphological filter [4].

3) Multiplicative Noise (*Speckle noise*): This kind of noise is also called as the speckled noise. This noise gives a 'magnified' view of the original image. For example, when this noise is applied to high pixel intensities or bright area in an image, a higher random variation will be observed. On the other hand, when this noise is applied to a darker region in the image, the random variation observed is not that much as compared to that observed in the brighter areas. Thus, this type of noise is signal dependent and distorts the image in a big way [10].

Speckle noise is a granular noise. This noise generally degrades Synthetic Aperture Radar (SAR) images to large extent. This noise is generally caused due to random ups and downs in the signal coming back from an object that is smaller than a single image-processing element. It is also caused by consistent processing of backscattered signals from a no of distributed targets. This noise also increases the mean grey level of affecting image. This noise creates a lot of difficulty in interpreting the image [18].

4) Poisson Noise (*Shot Noise*): The dominant noise in the lighter parts of an image from an image sensor is typically that caused by statistical quantum fluctuations, that is, variation in the number of photons sensed at a given exposure level; this noise is known as photon shot noise. Shot noise has a root mean- square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows a Poisson distribution, which is usually not very different from Gaussian. In addition to photon shot noise, there can be additional shot noise from the dark leakage current in the image sensor; this noise is otherwise known as "dark shot noise" or "dark-current shot noise"[15].

5) Quantization Noise (*Uniform Noise*): The Uniform noise caused by quantizing the pixels of image to a number of distinct levels is known as Quantization noise. It has approximately uniform distribution. In this type of noise, the levels of the gray values of the noise are uniformly distributed over a specified range. It can be used to create any type of noise distribution. This type of noise is mostly used to evaluate the performance of image restoration algorithms. This noise provides the most neutral or unbiased noise [19].

6) Film Grain: The grain of photographic film is a signal-dependent noise, related to shot noise. That is, if film grains are uniformly distributed (equal number per area),

and if each grain has an equal and independent probability of developing to a dark silver grain after absorbing photons, then the number of such dark grains in an area will be random with a binomial distribution; in areas where the probability is low, this distribution will be close to the classic Poisson distribution of shot noise; nevertheless a simple Gaussian distribution is often used as an accurate model [15].

7) Non-Isotropic Noise: Some noise sources show up with a significant orientation in images. For example, image sensors are sometimes subjected to row noise or column noise. In film, scratches are an example of non-isotropic noise. While cannot completely do away with image noise, it can certainly reduce some of it. Corrective filters are yet another device that helps in reducing image noise. [15].

8) Periodic Noise: If the image signal is subjected to a periodic rather than a random disturbance, obtaining an image corrupted by periodic noise. The effect is of bars over the image [15]. Figure2 represents different simulated noisy images.

9)
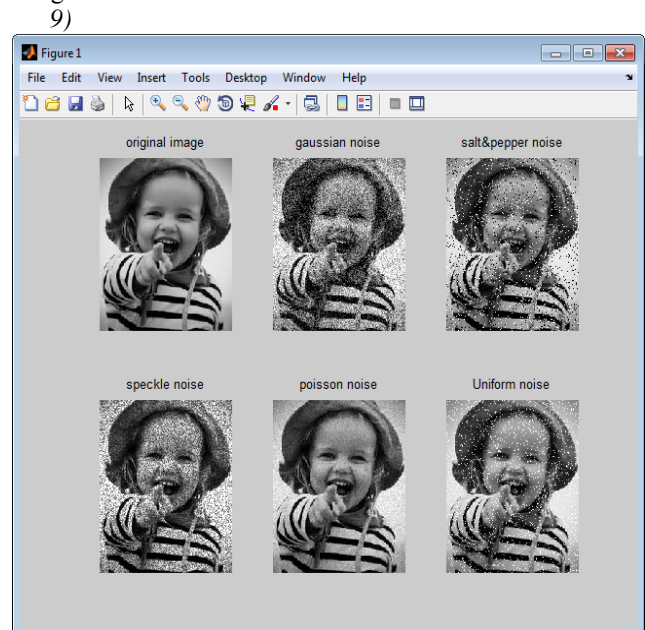
Figure 2. Simulation for different noises: Original image, Gaussian, Salt and pepper, Speckle, Poisson, and Uniform noise.

IV. THE MEANING OF FILTERS

Elimination of noise is one of the major works to be done in image processing, as noise leads to the error in the image [1]. A good noise filter is required to satisfy two criteria namely, to reducing the noise and suppressing the useful information in the signal [20].

In early times, as the signals handled, the analog, filters were used. Gradually digital filters were took place because of their flexibility, low cost, programmability, reliability, etc [1].

A digital filter is used to remove noise from the degraded image. Thus filters are used for image enhancement, as it removes undesirable signal components from the signal of interest. Filters can be represented as different linear or nonlinear types [21].

The design-of digital filters involves three basic steps: (1) the specification of the desired properties of the system, (2) the approximation of these specifications using a causal discrete time system, and (3) the realization of the system using finite precision arithmetic [1].

V. FILTERING TECHNIQUES

Filtering is a technique for enhancing the image. Linear filtering is the filtering in which the value of an output pixel is a linear combination of neighborhood values, which can produce blurring in the image. Thus a variety of smoothing techniques have been developed, that are non linear filters [1].

A. Method Used

The standard median filter (SMF) has good denoising power and computational efficiency. But the main drawback of this filter is that it is effective only for low noise densities. At high noise densities, SMF often exhibit blurring for large window size and insufficient noise suppression for small window size [22]. When the noise level is over 50% the edge details of the original image will not be preserved by SMF. However, most of the median filters operate uniformly and it modifies both noise and noise-free pixels, and causes information loss. Ideally, the filtering should be applied only to corrupted pixels not to uncorrupted ones [23].

The weighted median filter (WMF) is one of the branches of median. WMF was first introduced in 1981. The operations involved in WMF are similar to SMF, except that WMF has weight associated with each of its filter element. These weights correspond to the number of sample duplications for the calculation of median value. However, the successfulness of weighted median filter in preserving image details is highly dependent on the weighting coefficients, and the nature of the input image itself. Unfortunately, in practical situations, it is difficult to find the suitable weighting coefficients for this filter, and this filter requires high computational time when the weights are large [24].

The adaptive wiener filter (AWF) is a real time optimal filter renovated from the Wiener filter technology, which became available in 1940. Wiener filter is a linear adaptive filter, tailoring itself to the local image variance. Where the variance is large, Wiener filter performs little smoothing, where the variance is small, it performs more smoothing. This approach often produces better results than other linear filters. It is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. However, Wiener filter requires more computation time compared to other linear filters. The Wiener filtering is optimal in terms of the mean square error, i.e. it minimizes the overall mean square error and noise smoothing. Wiener filtering is a linear estimation of the original image. However, Wiener filtering is usually used to remove additive noise and not the impulsive noise. With Wiener filter alone, we cannot remove the salt-and-pepper noise efficiently [25].

In (DBMF), the noisy and noise-free pixels in the image are detected by checking the pixel values against the maximum and minimum values which will be in the dynamic range (0, 255).If the pixel is being currently processed has a value within the minimum and maximum values in the currently processed window, then it is a noise-free pixel and no modification is made to that pixel. If the value doesn't lie within the range, then it is a noisy pixel and will be replaced by either the median pixel value or by the mean of the neighboring processed pixels [26].

In (UDBMF), the selected 3 x 3 window elements are arranged in either increased or decreased order This filter is called trimmed median filter because the pixel values 0's and 255's are removed from the selected window, then the median value of the remaining pixels is taken in consideration. This median value is used to replace the noisy pixel. The processing pixel is checked whether it is noisy or noisy free. That is, if the processing pixel lies between maximum and minimum gray level values then it is noise free pixel, it is left unchanged. If the processing pixel takes the maximum or minimum gray level then it is noisy pixel which is processed by untrimmed decision based median filter [27][28].

B. Mathematical Analysis

To assess the performance of the proposed filters for removals of impulse noise and to evaluate their comparative performance, different standard performance indices have been used[2],[10],[29]– [30] .These are defined as follows:

*1) Mean Squared Error (MSE):*It is computed pixel-by-pixel by adding up the squared difference between the uncorrupted (original) image $s(i , j)$ and the restored image $r(i, j)$ and dividing by the total pixel count., it is defined as:

$$MSE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} \left(s(i, j) - r(i, j)\right)^2 \qquad (1)$$

Where $m \times n$ is image size, the minimum value of *MSE* reflects the better visual.

2) Peak Signal to Noise Ratio (PSNR): is the ratio between the maximum pixel value of an image and the mean square error. It is measured in decibel (dB) and for gray scale image it is defined as:

$$PSNR(dB) = 10 \log_{10} \left[\frac{(255)^2}{MSE} \right] \qquad (2)$$

The higher value of the *PSNR* in the restored image, the better is its quality.

3) Image Enhancement Factor (*IEF*)*:* is a measure of Image quality, and is defined as**:**

$$IEF = \frac{\sum_i \sum_j [\psi(i,j) - s(i,j)]^2}{\sum_i \sum_j [r(i,j) - s(i,j)]^2} \quad (3)$$

Where $\psi(i,j)$ is the pixel value of corrupted image. The higher value of *IEF* reflects the better visual, and restoration performance.

4) Mean Absolute Error (*MAE*)*:*is a quantity used to measure how close as restored image are to the original, and it is defined as:

$$MAE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} |r(i,j) - s(i,j)| \quad (4)$$

Where $r(i,j)$ and $s(i,j)$ are the pixel values of restored and original images respectively at the location (i,j).The minimum value of *MAE* reflects the better visual.

5) Correlation ratio (*CORR*)*:* measures the degree to which two images vary together or oppositely and taking values from 0.0 to 1 .0 and it is defined as:

$$CORR = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2 (y_i - y_m)^2}} \quad (5)$$

Where x_i is the intensity of the ith pixel in original image, y_i is the intensity of the ith pixel in the restored image, x_m is the mean intensity of the original image, and y_m is the mean intensity of the restored image. The value of *CORR* which gets close to 1.0 reflects the better visual impression.

VI. SUGGESTED METHODOLOGY

The method that suggested in this paper includes a proposed algorithm which can be described in two steps as: In the first step, read input image then salt and pepper as an impulse noise were added with different levels of noise densities beginning with 10% up to 90%, after having noisy image different non linear filters were applied as SMF, AWF, WMF, DBMF and UDBMF then a quantitative & qualitative parameters as MSE, PSNR, IEF, MAE, and CORR are calculated for each filter for comparison. In the second step, after achieving a restored image, the filtering operation repeated again using the filters that has the best results. The filtering applied based on cascaded- hybrid filtering idea as: DBMF was repeated two times (DBMF/ DBMF), and (UDBMF/DBMF) refers to DBMF is used in first filtering and UDBMF in second, while (DBMF/UDBMF) means that UDBMF was apply in first filtering and DBMF in second, and (UDBMF/ UDBMF) signify that UDBMF was repeated twice. Quantitative and qualitative parameters were calculated for each cascaded filters for comparison. Figure.3. illustrates the flow chart of the computerized program that used to satisfy the suggested methodology.
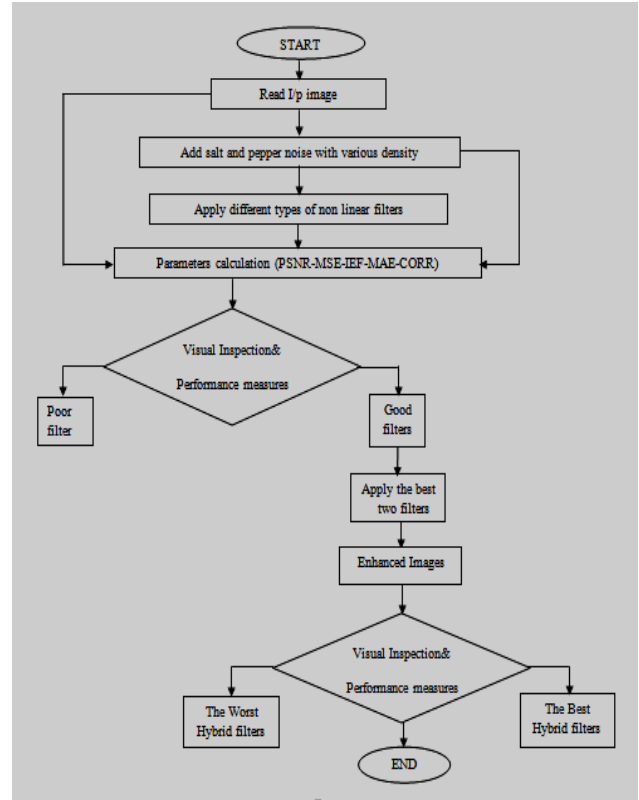
Figure 3. Flowchart of suggested methodology.

VII. SIMULATION RESULTS & DISCUSSIONS

To validate the proposed suggested methodology, a Barbara 512×512 PNG image is used in the simulation at different levels of noise densities. The proposed algorithm has been implemented using eight programs that designed under MATLAB 7.10.0.499 (R2010a); as a language of technical computing. The performance of the proposed algorithm is evaluated with comparable study for various standard filters as: [SMF, WMF, AWF**,** DBMF, and UDBMF] were used for first filtering operation, while, [DBMF/ DBMF, UDBMF/ DBMF, DBMF/ UDBMF, and UDBMF/ UDBMF] were used at second filtering stage. Figures (4-8) give the used noisy images and the restored images. The comparison was done in terms of MSE (1), PSNR (2), IEF (3), MAE (4), and CORR (5); where the results are illustrated in Figure 9.

Figire 4. Results for 10% noise corrupted Barbara image: (a) Original image, (b) Noisy image, (c) AWF, (d) WMF, (e) SMF, (f) DBMF, (g) UDBMF (h) DBMF/ DBMF, (i) DBMF/ UDBMF, (j) UDBMF/ UDBMF, and (k) UDBMF/ DBMF.

Figure 6. Results for 50% noise corrupted Barbara image:(a)Noisy image, (b) AWF, (c) WMF, (d) SMF, (e) DBMF, (f) UDBMF, (g) DBMF/ DBMF, (h) DBMF/ UDBMF, (i) UDBMF/ UDBMF, and (j) UDBMF/ DBMF.

Figure 5. Results for 30% noise corrupted Barbara image:(a)Noisy image, (b) AWF, (c) WMF, (d) SMF, (e) DBMF, (f) UDBMF, (g) DBMF/ DBMF, (h) DBMF/ UDBMF, (i) UDBMF/ UDBMF, and (j) UDBMF/ DBMF.

Figure 7. Results for 70% noise corrupted Barbara image:(a)Noisy image, (b) AWF, (c) WMF, (d) SMF, (e) DBMF, (f) UDBMF, (g) DBMF/ DBMF, (h) DBMF/ UDBMF, (i) UDBMF/ UDBMF, and (j) UDBMF/ DBMF

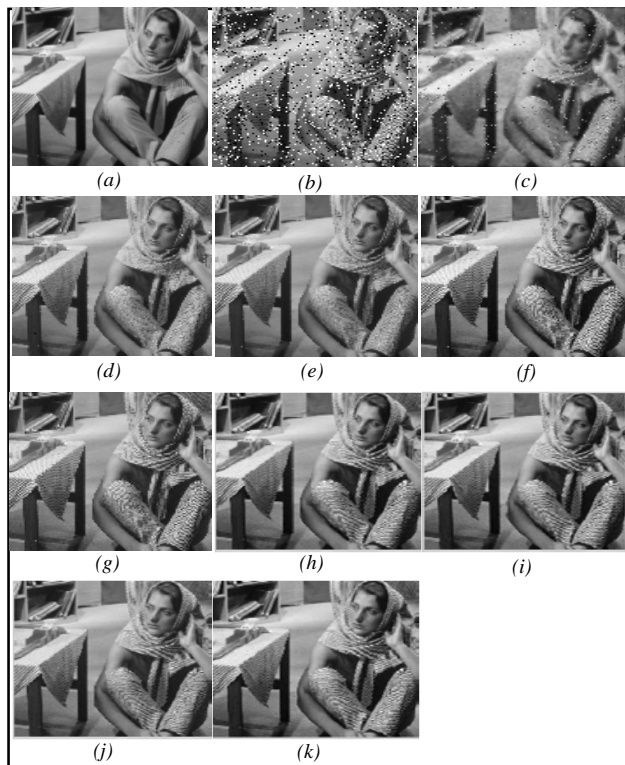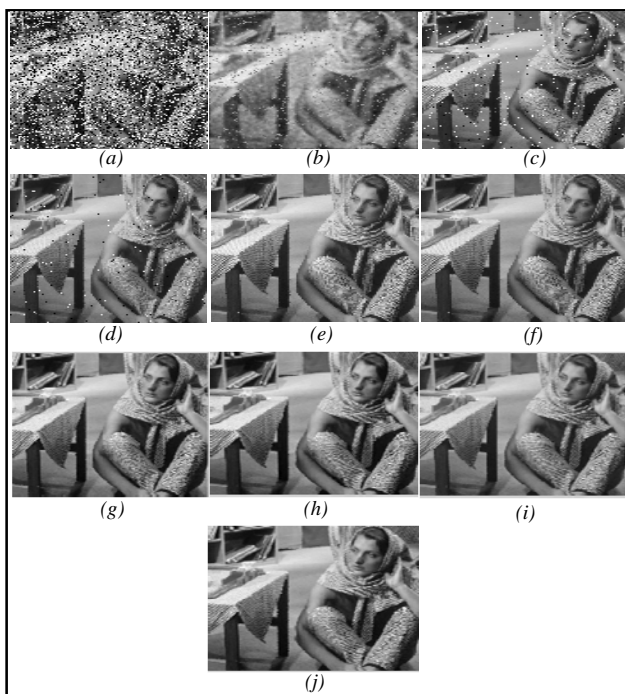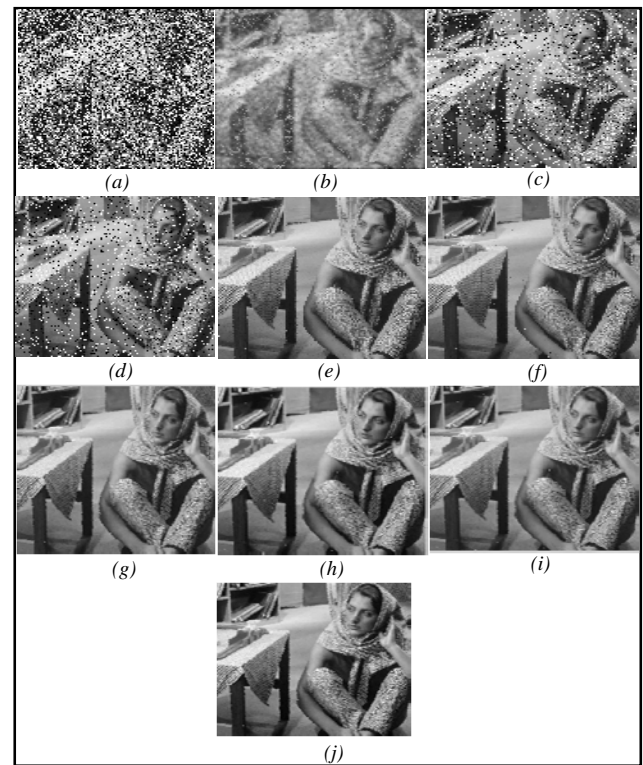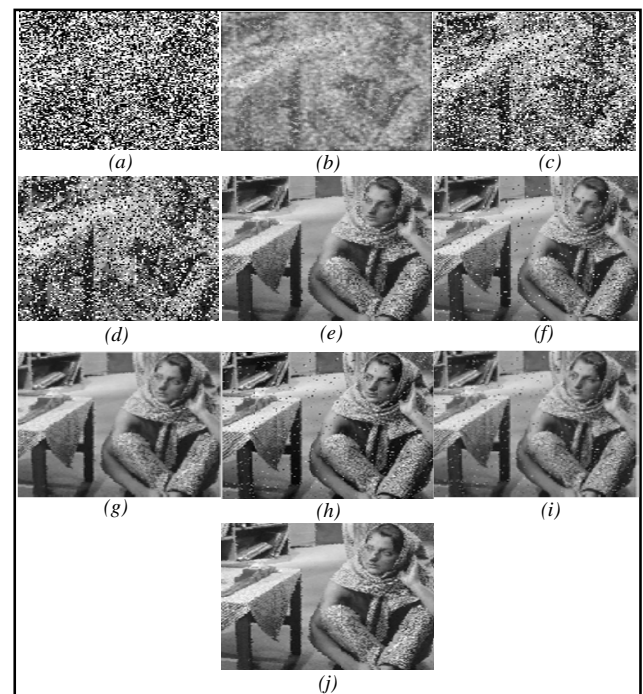Figure 8. Results for 90% noise corrupted Barbara image:(a)Noisy image, (b) AWF, (c) WMF, (d) SMF, (e) DBMF, (f) UDBMF, (g) DBMF/ DBMF, (h) DBMF/ UDBMF, (i) UDBMF/ UDBMF, and (j) UDBMF/ DBMF.
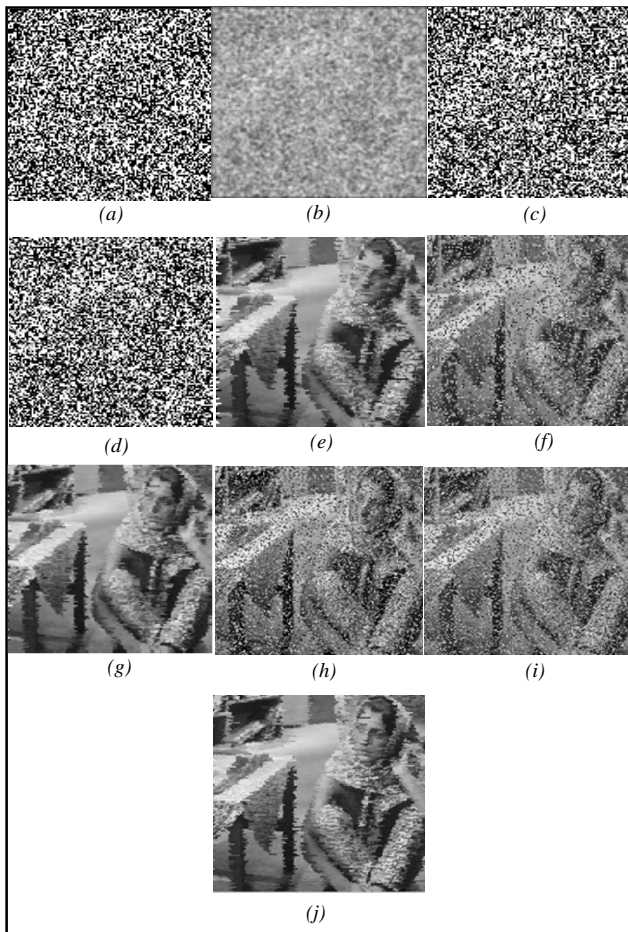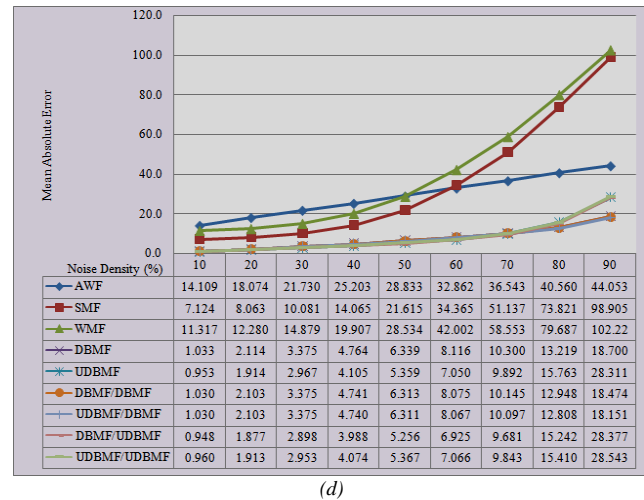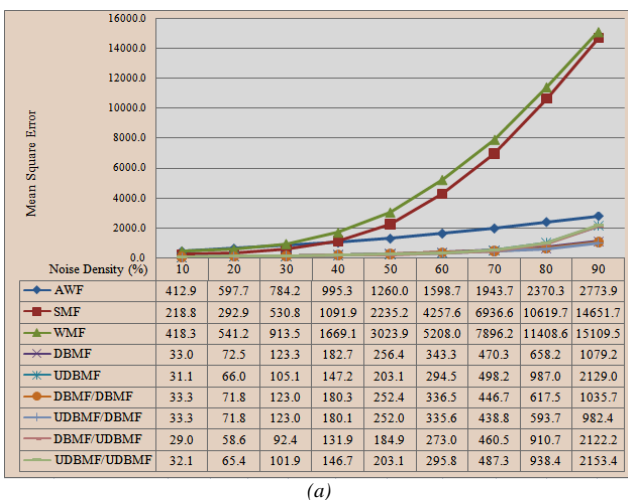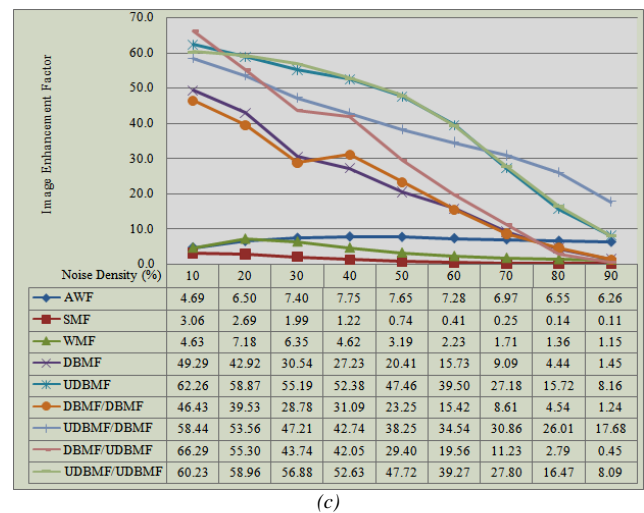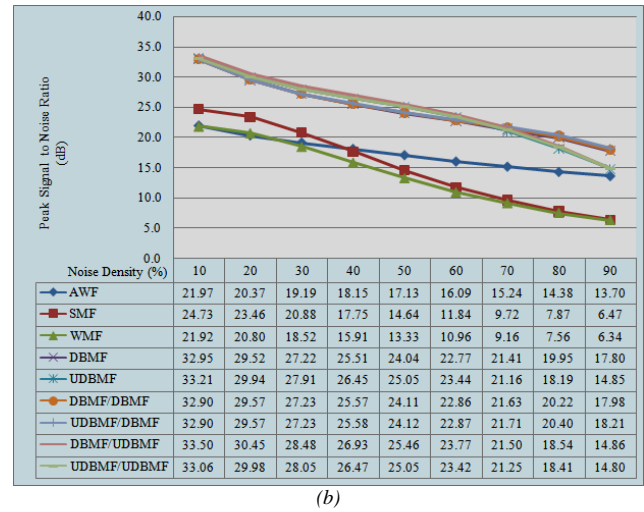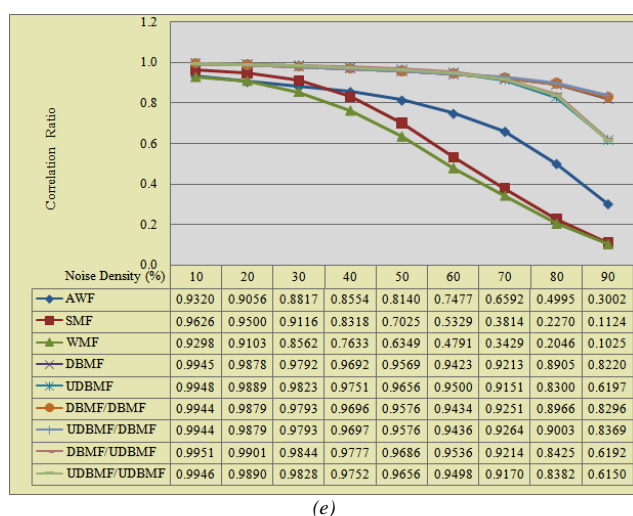
(b) Peak Signal to Noise Ratio (dB)

Noise Density (%)	10	20	30	40	50	60	70	80	90
AWF	21.97	20.37	19.19	18.15	17.13	16.09	15.24	14.38	13.70
SMF	24.73	23.46	20.88	17.75	14.64	11.84	9.72	7.87	6.47
WMF	21.92	20.80	18.52	15.91	13.33	10.96	9.16	7.56	6.34
DBMF	32.95	29.52	27.22	25.51	24.04	22.77	21.41	19.95	17.80
UDBMF	33.21	29.94	27.91	26.45	25.05	23.44	21.16	18.19	14.85
DBMF/DBMF	32.90	29.57	27.23	25.57	24.11	22.86	21.63	20.22	17.98
UDBMF/DBMF	32.90	29.57	27.23	25.58	24.12	22.87	21.71	20.40	18.21
DBMF/UDBMF	33.50	30.45	28.48	26.93	25.46	23.77	21.50	18.54	14.86
UDBMF/UDBMF	33.06	29.98	28.05	26.47	25.05	23.42	21.25	18.41	14.80

(c) Image Enhancement Factor

Noise Density (%)	10	20	30	40	50	60	70	80	90
AWF	4.69	6.50	7.40	7.75	7.65	7.28	6.97	6.55	6.26
SMF	3.06	2.69	1.99	1.22	0.74	0.41	0.25	0.14	0.11
WMF	4.63	7.18	6.35	4.62	3.19	2.23	1.71	1.36	1.15
DBMF	49.29	42.92	30.54	27.23	20.41	15.73	9.09	4.44	1.45
UDBMF	62.26	58.87	55.19	52.38	47.46	39.50	27.18	15.72	8.16
DBMF/DBMF	46.43	39.53	28.78	31.09	23.25	15.42	8.61	4.54	1.24
UDBMF/DBMF	58.44	53.56	47.21	42.74	38.25	34.54	30.86	26.01	17.68
DBMF/UDBMF	66.29	55.30	43.74	42.05	29.40	19.56	11.23	2.79	0.45
UDBMF/UDBMF	60.23	58.96	56.88	52.63	47.72	39.27	27.80	16.47	8.09

(a) Mean Square Error

Noise Density (%)	10	20	30	40	50	60	70	80	90
AWF	412.9	597.7	784.2	995.3	1260.0	1598.7	1943.7	2370.3	2773.9
SMF	218.8	292.9	530.8	1091.9	2235.2	4257.6	6936.6	10619.7	14651.7
WMF	418.3	541.2	913.5	1669.1	3023.9	5208.0	7896.2	11408.6	15109.5
DBMF	33.0	72.5	123.3	182.7	256.4	343.3	470.3	658.2	1079.2
UDBMF	31.1	66.0	105.1	147.2	203.1	294.5	498.2	987.0	2129.0
DBMF/DBMF	33.3	71.8	123.0	180.3	252.4	336.5	446.7	617.5	1035.7
UDBMF/DBMF	33.3	71.8	123.0	180.1	252.0	335.6	438.8	593.7	982.4
DBMF/UDBMF	29.0	58.6	92.4	131.9	184.9	273.0	460.5	910.7	2122.2
UDBMF/UDBMF	32.1	65.4	101.9	146.7	203.1	295.8	487.3	938.4	2153.4

(d) Mean Absolute Error

Noise Density (%)	10	20	30	40	50	60	70	80	90
AWF	14.109	18.074	21.730	25.203	28.833	32.862	36.543	40.560	44.053
SMF	7.124	8.063	10.081	14.065	21.615	34.365	51.137	73.821	98.905
WMF	11.317	12.280	14.879	19.907	28.534	42.002	58.553	79.687	102.22
DBMF	1.033	2.114	3.375	4.764	6.339	8.116	10.300	13.219	18.700
UDBMF	0.953	1.914	2.967	4.105	5.359	7.050	9.892	15.763	28.311
DBMF/DBMF	1.030	2.103	3.375	4.741	6.313	8.075	10.145	12.948	18.474
UDBMF/DBMF	1.030	2.103	3.375	4.740	6.311	8.067	10.097	12.808	18.151
DBMF/UDBMF	0.948	1.877	2.898	3.988	5.256	6.925	9.681	15.242	28.377
UDBMF/UDBMF	0.960	1.913	2.953	4.074	5.367	7.066	9.843	15.410	28.543

Noise Density (%)	10	20	30	40	50	60	70	80	90
AWF	0.9320	0.9056	0.8817	0.8554	0.8140	0.7477	0.6592	0.4995	0.3002
SMF	0.9626	0.9500	0.9116	0.8318	0.7025	0.5329	0.3814	0.2270	0.1124
WMF	0.9298	0.9103	0.8562	0.7633	0.6349	0.4791	0.3429	0.2046	0.1025
DBMF	0.9945	0.9878	0.9792	0.9692	0.9569	0.9423	0.9213	0.8905	0.8220
UDBMF	0.9948	0.9889	0.9823	0.9751	0.9656	0.9500	0.9151	0.8300	0.6197
DBMF/DBMF	0.9944	0.9889	0.9793	0.9696	0.9576	0.9434	0.9251	0.8966	0.8296
UDBMF/DBMF	0.9944	0.9879	0.9793	0.9697	0.9576	0.9436	0.9264	0.9003	0.8369
DBMF/UDBMF	0.9951	0.9901	0.9844	0.9777	0.9686	0.9536	0.9214	0.8425	0.6192
UDBMF/UDBMF	0.9946	0.9890	0.9828	0.9752	0.9656	0.9498	0.9170	0.8382	0.6150

(e)

Figure 9. Comparison graphs and results for: (a) MSE, (b) PSNR, (c) IEF, (d) MAE, and (e) Correlation ratio for Barbara image at different noise densities.

From Figure 9, it can be illustrated that (SMF,WMF, and AWF) filters didn't give better results when they are compared with (DBMF-UDBMF) filters at different noise densities from (10% to 90%).In first filtering stage, the results of DBMF and UDBMF give lower (MSE,MAE), and higher (PSNR,IEF,CORR) and it can be observed that the performance of the UDBM filter is superior to the other filters at these percentages of noise density MSE(10% - 60%),MAE(10% - 70%),IEF(10% - 90%),PSNR(10% - 60%) and CORR (10% - 60%), but the DBM filter is the best at MSE values (70% - 90%),MAE (80% - 90%), PSNR (70%-90%), and CORR(70% - 90%). In second filtering stage, the results of DBMF/UDBMF and UDBMF/DBMF give lower (MSE,MAE), and higher (PSNR,IEF,CORR), besides it can be observed that the performance of the DBMF/UDBMF is superior to the other filters at these percentages of noise density MSE(10% - 60%),MAE(10% - 70%),IEF(10%),PSNR (10% - 60%) and CORR(10% - 60%), but the UDBMF/DBMF is the best at MSE values (70% - 90%),MAE(80% - 90%),IEF(70% - 90%),PSNR (70% - 90%), and CORR (70% - 90%).

For noise densities above 40%, bad impressions are given by the existing filters such as SMF, WMF, and AWF. For noise densities above 70%, the filters as DBMF, DBMF/DBMF, and UDBMF/DBMF can remove noise at high densities, but the other filters produce streaking effect for noise densities.

Related to the calculated parameters; at noise10% DBMF/UDBMF give higher values for PSNR, IEF, and CORR (up to 33.50, 66.29, and 0.9951 respectively). The lower values for MSE and MAE satisfied when using DBMF/UDBMF, where it gives (29.0 and 0.948) as minimum values respectively. At noise 90% UDBMF/DBMF give higher values for PSNR, IEF, and CORR (up to 18.21, 17.86, and 0.8369 respectively). The

lower values for MSE and MAE satisfied when using UDBMF/DBMF, where it gives (982.4 and 18.151) as minimum values respectively.

VIII.   CONCLUSION

In this work, filters have been used as a tool for removing low and high density salt and pepper noise with edge preservation in digital images. The second filtering stage was used for enhancing and gaining better quality on areas of contrast, sharpness, edges, reducing noise etc.

As a visual inspection; for low noise density up to 30%, one can note that all filters perform well in removing the salt and pepper noise.

Both visual and quantitative results are demonstrated that the DBMF/UDBMF is effective for salt and pepper noise removal in images at noise densities up to 60% and the UDBMF/DBMF is effective for salt and pepper noise removal in images at noise densities above 70%.

IX.   FUTURE SCOPE

The comparative study can be further extended by including more noise types like Exponential noise, an isotropic noise, film grain… etc in different types of images.

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