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High Density Salt and Pepper Noise Reduction in Color Images

Simranjit Singh[1], Raminder Singh Uppal[2]
CE/IT Department, BBSBPC, Fatehgarh Sahib,
Punjab-India

ABSTRACT
An improved decision based unsymmetrical trimmed median filter algorithm for denoising the color images that are highly corrupted by salt and pepper noise is proposed in this paper. 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. This algorithm also finds out the effect of varying window size on denoised image. In the result, it is concluded that 3x3 window size is best for removal of noise at higher density. This proposed algorithm shows better results than the existing Standard Median Filter (SMF) and Decision Based Algorithms (DBA).
Keywords:- Image Filtering, PSNR, MSE, RMSE, Median Filter.

I. INTRODUCTION

A digital color image pixel is just numbers representing a RGB data value (Red, Green and Blue). Each pixel's color sample has three numerical RGB components (Red, Green and Blue) to represent the color of that tiny pixel area. These three RGB components are three 8-bit numbers for each pixel. Three 8-bit bytes (one byte for each of RGB) are called 24 bit color. There are different types of images used in image processing like binary images, gray scale images, color images etc. Color images are considered as three band monochrome images, where each band is of a different color. Each band provides the brightness information of the corresponding spectral band. Typical color images are red, green and blue images and are also referred RGB images. While obtaining the image from the source like sensor, digital camera etc. there may happen some noises. Noise may occur due to awful climate conditions or some other interference while apprehending the image. The net effect is a corrupted image that desires to be pre-processed to decrease or eradicate the noise. Although noise presents an image a usually undesirable look, the most significant component is that noise can cover and reduce the visibility of certain characteristics inside the image. Salt and pepper noise is a type of noise where the image contains certain percentage of noisy pixels. The value of the noisy pixels is therefore completely uncorrelated with the value of the same pixel in the clean image. Salt and Pepper noise contains random occurrences of both black and white intensity values. Salt and pepper noise is an impulse type of noise, which is also referred to as intensity spikes. This is caused generally due to errors in data transmission. Image filtering is a process by which we can enhance images. Image filtering is used to remove noise, sharpen contrast or highlight contours in the images. A filter is a software routine that changes the appearance of an image or part of an image by altering the shades and colors of the pixels in some manner. Filters are used to increase brightness and contrast as well as to add a wide variety of textures, tones and special effects to a picture. Filters can enhance the images by removing imperfections like noise, blur to some portion of image so that portion will be out of focus and so on. The choice of filter is often determined by the nature of the task and the type and behavior of the data.

II. EXISTING SALT AND PEPPER NOISE REMOVAL ALGORITHMS

It has been proposed that digital image filtering refers to modifying the pixels in an image based on some function of a local neighborhood of the pixels [16]. Noise is an undesirable product of an image. The digital image acquisition process converts an optical image into a continuous stream of electrical signals which is later sampled by which noise appears in digital image [6]. Image noise is produced due to the random variation of brightness in the images that is produced by the sensors, scanners or digital cameras. Image noise is considered as an undesirable by-product of an image [8]. Noise can severely degrade the quality of an image by losing its important details .So, it is necessary to detect and remove the noise present in an image [12].Images often contain Salt and Pepper noise due to transmission errors or conversion errors. An image having Salt and Pepper noise will have dark pixels in bright areas and bright pixels in dark areas due to analog to digital converter errors or bit errors during transmission [2].Linear filters result in blurring of edges in noisy digital images. So, there is a need of non-linear filters to overcome this problem[18].Standard Median Filter (SMF) removes salt and pepper noise effectively by preserving the edges but when noise level is as high as 50%, it fails to preserve details and edges of an image [2].Adaptive Median Filter (AMF) is an enhancement over SMF as it preserves maximum amount of original information. The AMF can handle salt and pepper noise more effectively as compared to SMF. AMF works well in case of low salt and pepper noise densities but as the window size increases, it leads to distortion of image and smearing of edges [7]. Decision Based Algorithm (DBA) having a window size of 3x3 during denoising technique. If the pixel's intensity is 0 or 255, it is processed for filtering, otherwise it is left unaltered. This algorithm poses a serious problem of ineffective filtering at high noise density. At a high noise density, median of the window will be again either 0 or 255 (in the case, if a window contains 0and/or 255 pixel values only) which is again a noisy pixel value. In such situation, DBA considers neighboring pixels for replacement [17]. Repeated placement of neighboring pixels in DBA produces streaking effect [9].This problem was removed in Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUTMF) algorithm. This algorithm considers fixed window dimension of 3×3 for the denoising purpose. This algorithm performs fairly well at lower noise density. However, it poses serious problems of ineffective noise removal at higher noise density. At a higher noise density, MDBUTMF produces dark patch-like surface in the restored image [5].An algorithm based on adaptive and unsymmetrical trimmed median filter was put forward in [3][4]. This algorithm is proposed for restoration of gray-scale as well as color images which are highly corrupted by salt and pepper noise. The proposed algorithm replaces the noisy pixel by a value which is either a mean or a median of all other non-noisy pixels in the selected window.A new algorithm to remove high-density salt and pepper noise using modified sheer sorting method is proposed in [1]. The new algorithm has lower computation time when compared to other standard algorithms.A new method to remove salt and pepper noise from an image through sparse representation was suggested. The proposed method consists of two stages. In the first stage, the positions of noise pixels are detected by thresholding the absolute difference between the noisy image and its sparse representation. In the next stage, the pixels that are detected as noisy pixels are removed and then filled using image in painting through sparse representation [11]. An image quality (IQ) metric is an objective criterion to calculate the quality without the help of human observers. It is useful for measuring and rating the performance of an image processing or a computer vision algorithm [13].A new filtering technique that integrates statistical analysis of local features with a median-based noise adaptive filter was introduced which differentiates the corrupted and uncorrupted pixels and processes only the corrupted ones in order to preserve the fine details of the image[14].An improved technique that performs better than the other state-of-art methods in removing salt-and-pepper noise from digital images was proposed. The proposed technique introduces a concept of using multiple last processed pixels in case of extreme situation of high density noise [10].An efficient algorithm which can remove high density salt-and-pepper noise from corrupted digital image. This technique differentiates between corrupted and uncorrupted pixels and performs the filtering process only on the corrupted ones [15].

III. PROPOSED WORK

An improved DBUTMF is proposed that processes the corrupted images by first detecting the impulse noise. Each pixel in the image is checked for noise. As the name suggests Improved Decision Based Un-symmetric Trimmed Median Filter (IDBUTMF) is an enhancement over the previous Decision Based Un-symmetric Trimmed Median Filter so, like Decision Based Un-symmetric Trimmed Median Filter (DBUTMF) algorithm processes the corrupted images by first detecting the impulse noise. Each pixel in the image is checked for noise. If the processing pixel lies between maximum (255) and minimum (0) gray level value, then it is noise free pixel and it is left unaltered. If the processing pixel is equal to the maximum (255) or minimum (0) gray level then it is noisy pixel which is then processed by Improved Decision Based Un-symmetric Trimmed Median Filter. Now, we have two cases:-

First case - If all the pixel values in the selected window are 0's and 255's means are pixels are corrupted then the processing noisy pixel is replaced by mean value of all the pixels present in that selected window.

Second case - If some pixel values in the selected window lies between 0 and 255 means not all pixel values are 0's or 255's then noisy pixel values i.e. 0's and 255's are removed from the window and median of rest of the pixels is taken which is used to replace the processing noisy pixel.

The throughput of Improved Decision Based Un-symmetric Trimmed Median Filter is a noise removal image. That is, if the processing pixel lies between maximum (255) and minimum (0) gray level value then it is noise free pixel, it is left unaltered and if the processing pixel takes the maximum (255) or minimum (0) gray level value then it is noisy pixel which is processed by IDBUTMF. The steps of the IDBUTMF are given below:-

Step 1: Select 2-D window of size 3×3. Assume that the pixel being processed is Pij.

Step 2: If 0 < Pij < 255 then Pij is an uncorrupted pixel and its value is left unchanged.

Step 3: If Pij =0 or Pij =255 then Pij is a corrupted pixel then two cases are possible as given in Case 1 and 2.

Case 1: If the selected window contains all the elements as 0's and 255's. Then replace Pij with the mean of the element of window.

Case 2: If the selected window contains not all elements as 0's and 255's. Then eliminate 255's and 0's and find the median value of the remaining elements. Replace Pij with the median value.

Step 4: Repeat steps 1 to 3 until all the pixels in the entire image are processed.

The evaluation measures used in this paper are PSNR (Peak Signal to Noise Ratio), MSE(Mean Square Error) and RMSE(Root Mean Square error).

MSE=σq2= $\frac{1}{N}\sum_j \sum_k [f(j,k) - g(j,k)]_2$ ….. (1)

RMSE= $\sqrt{MSE}$ …………………….. (2)

PSNR= 20 * log10 (255 /RMSE) …… (3)

where the sum over j, k denotes the sum over all pixels in the image and N is the total number of pixels in an image and 255 represents the maximum value of each pixel.

IV. RESULTS

The experimental results of the proposed method are tested on two different colored images- Lena Image and Water drop Image as shown in figure 1. Salt and Pepper noise is added to collected images and then these images are used for salt and pepper noise removal method. This method takes the image in its original form and adds noise to it in different variance.

(a)

(b)

Figure 1 (a) Lena Image (b) Water drop image

The results of proposed colored images are shown in tables I to VI with different noise levels ranging from 70% to 90%. Line graphs from figure 2 to figure7 represent the PSNR, MSE and RMSE values of all the denoised images taken with different salt and pepper noise reduction algorithms.

TABLE I

PSNR, MSE AND RMSE VALUES FOR LENA IMAGE WITH 70% NOISE DENSITY

Algorithm/Parameter	MSE	RMSE	PSNR
SMF	48.7768	6.9840	31.2488
UMF	16.0223	4.0026	36.0844
DBUTMF 3*3	3.7436	1.9348	42.3982
DBUTMF 5*5	5.1068	2.2597	41.0499
DBUTMF 7*7	5.8807	2.4250	40.4367

TABLE II

PSNR, MSE AND RMSE VALUES FOR WATER DROP IMAGE WITH 70% NOISE DENSITY

Algorithm/Parameter	MSE	RMSE	PSNR
SMF	55.0477	7.4192	30.7238
UMF	22.1903	4.7092	34.6745
DBUTMF 3*3	7.5271	2.7434	39.3653
DBUTMF 5*5	10.2519	3.2018	38.0230
DBUTMF 7*7	12.1993	3.4924	37.2690

TABLE III

PSNR, MSE AND RMSE VALUES FOR LENA IMAGE WITH 80% NOISE DENSITY

Algorithm/Parameter	MSE	RMSE	PSNR
SMF	71.0018	8.4262	29.6182
UMF	32.6573	5.7145	32.9914
DBUTMF 3*3	4.5594	2.1353	41.5418
DBUTMF 5*5	5.9521	2.4394	40.3859
DBUTMF 7*7	6.0985	2.4687	40.2841

TABLE IV

PSNR, MSE AND RMSE VALUES FOR WATER DROP IMAGE WITH 80% NOISE DENSITY

Algorithm/Parameter	MSE	RMSE	PSNR
SMF	76.5272	8.7478	29.2931
UMF	39.3381	6.2681	32.1935
DBUTMF 3*3	8.7005	2.9492	38.7379
DBUTMF 5*5	11.4189	3.3791	37.5549
DBUTMF 7*7	12.2933	3.5038	37.2458

TABLE V

PSNR, MSE AND RMSE VALUES FOR LENA IMAGE WITH 90% NOISE DENSITY

Algorithm/Parameter	MSE	RMSE	PSNR
SMF	76.4529	8.7436	29.2971
UMF	39.2098	6.2616	32.1975
DBUTMF 3*3	4.3912	2.0954	41.7058
DBUTMF 5*5	5.7260	2.3929	40.5527
DBUTMF 7*7	5.3200	2.3063	40.8731

TABLE VI

PSNR, MSE AND RMSE VALUES FOR WATER DROP IMAGE WITH 90% NOISE DENSITY

Algorithm/Parameter	MSE	RMSE	PSNR
SMF	100.8308	10.0413	28.0951
UMF	69.4029	8.3223	29.7347
DBUTMF 3*3	5.6446	2.3745	40.6178
DBUTMF 5*5	5.8525	2.4073	40.5442
DBUTMF 7*7	8.7712	2.9444	38.7999

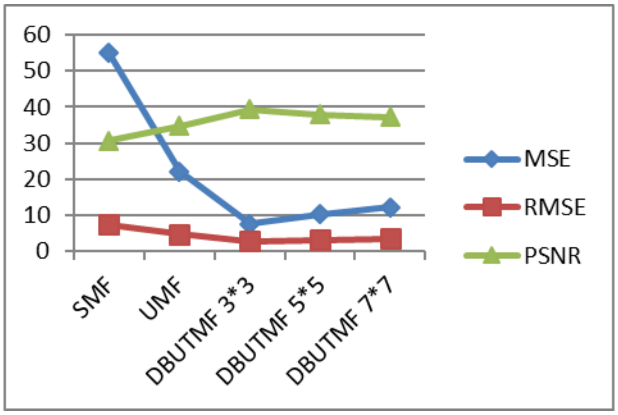

Figure 2 Line graph of PSNR, MSE and RMSE of Lena image with 70% noise intensity

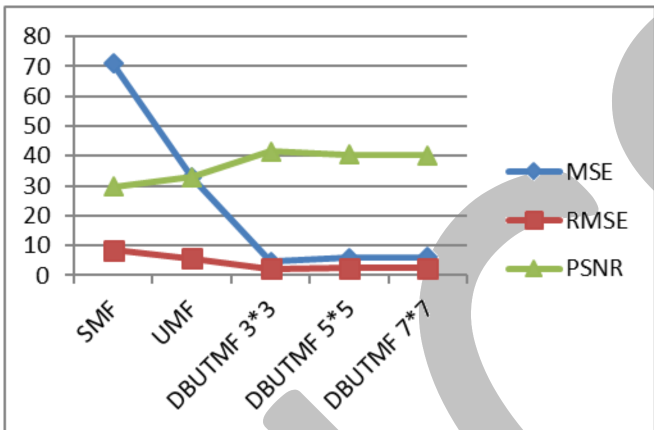

Figure 3 Line graph of PSNR, MSE and RMSE of Water drop image with 70% noise intensity

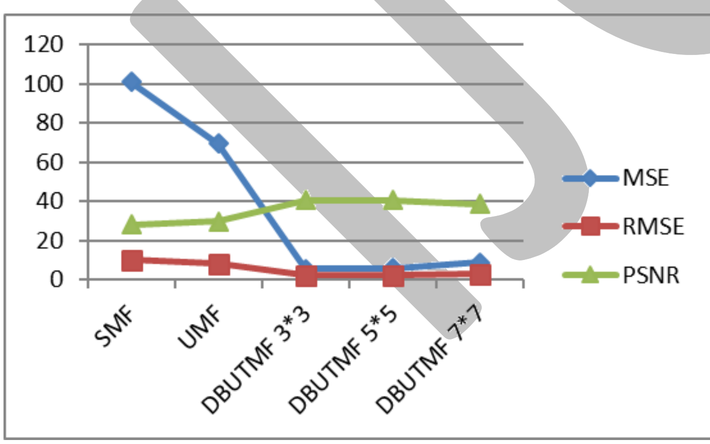

Figure 4 Line graph of PSNR, MSE and RMSE of Lena image with 80% noise intensity

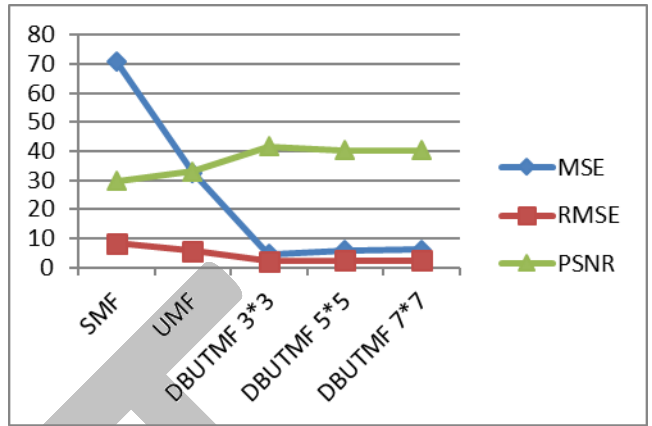

Figure 5 Line graph of PSNR, MSE and RMSE of Water drop image with 80% noise intensity

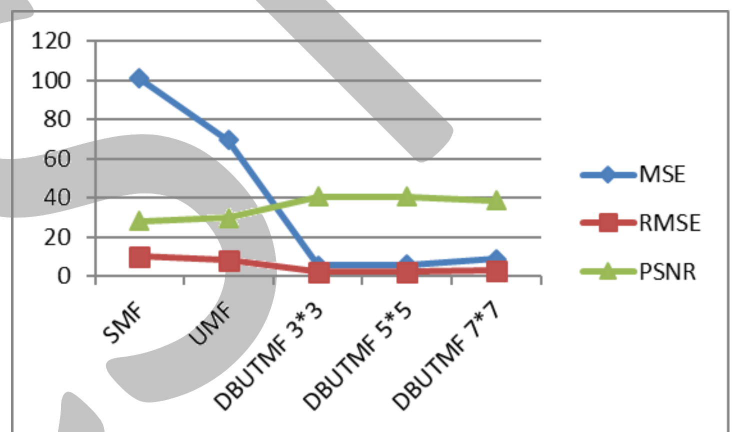

Figure 6 Line graph of PSNR, MSE and RMSE of Lena image with 90% noise intensity

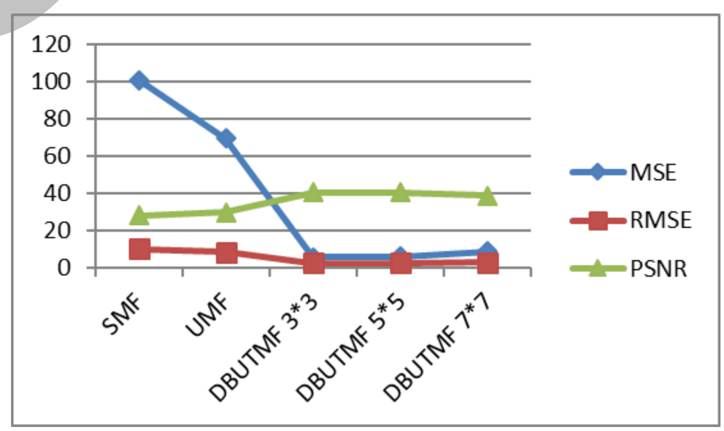

Figure 7 Line graph of PSNR, MSE and RMSE of Water drop image with 90% noise intensity

The proposed IDBUTMF (Improved Decision Based Unsymmetrical Trimmed Median Filter) outperforms the entire earlier used algorithms with highest PSNR value at high level noise density of 90%. It also has lowest MSE value So, if the size of window is varied, the 3x3 IDBUTMF gives the best performance at higher noise densities.

V. CONCLUSION

Denoising performance of proposed work has been evaluated on the basis of quantitative measures like PSNR, MSE and RMSE. Better performance of Improved DBUTMF is proved with the help of graphs. IDBUTMF (Improved Decision Based Unsymmetrical Trimmed Median Filter) was introduced to remove the drawback of Decision Based Algorithms (DBA) by giving better PSNR value. IDBUTMF algorithm operates in two phases; first phase is a noisy pixel detection stage and the second phase is a filtering stage. Decision-based approach allows to process filtering action on noisy pixels only, reducing unnecessary distortion and loss of image details caused due to filtering action on noise-free pixels. However, at a higher noise density, the probability of the event that the entire pixels (in the local window) are noisy is high. Therefore, this replacement produces dark patch-like surface in the restored image. This is the short coming of proposed work that can be eliminated in future by proposing some enhancement on this work.

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