Removal of Salt and Pepper Noise from highly Corrupted Images using Mean Deviation statistical parameter

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***Abstract*—** A novel idea of using median deviation parameter in estimating the noise in the images is proposed and successfully applied to both gray level as well as color images. The median filter which is very popular in removing the salt and pepper noise from the images ,has undergone many changes in recent past. To this modified median filter the concept of median deviation is added and used in estimating and removing the noise. The proposed method is implemented by developing a Graphical User Interface in MATLAB and also implemented using the Spartan 3E Filed Programmable Device. The results are found to be better than earlier methods and also robust in terms of preserving the contrast and fine details of the image even at high noise densities.

Keywords - *Median filter; Median deviation; Salt and Pepper noise; MATLAB; Image processing*

I. INTRODUCTION

During the last few years there have been innumerable number of research papers published in various journals on the application of median filters for removal of salt and pepper noise from the images, by various authors[1,2,3]. The success of median filters can be attributed to two intrinsic properties : edge preservation and efficient noise attenuation with robustness against impulsive type noise. Edge preservation is essential in image processing due to the nature of visual perception. Edges also occur in biomedical signals when the “system” moves from one state to another .The fact that some signals are invariant to median filtering offers interesting possibilities. In noise filtering, the basic adea is how to preserve some desired signal features while attenuating the noise. An optimal situation would arise if the filter could be designed **so** that the desired features were invariant to the filtering operation and only noise would be affected. As the superposition principle can not be applied to non-linear filters , this can never be fully achieved . However, when a signal consists of constant areas and stepwise changes between these areas, a similar effect is achieved. Noise will be attenuated, but stepwise changes will remain [1]. In spite of this, the median filter is far from being a perfect filtering method since it may remove fine details, sharp corners and thin lines. The main reason is that the ordering process destroys any structural and spatial neighborhood information .To overcome such problems many modifications were applied to median filters which resulted various new filters. For example, An adaptive median filter eliminated the above drawback, but owing to its increasing window size lead to blurring of images [2]. Switched median filters [3,4] were proposed. But these filters do not have a strong decision or does not consider the local statistics. To elude the flaw, Decision based filter [5] was proposed. This filter identifies the processed pixel as noisy, if the pixel value is either 0 or 255 ; else it is considered as noiseless pixel. Under High noisy environment the DBA filter replaces the noisy pixel with neighborhood pixel. In spite of repeated replacement of neighborhood pixel results in streaks in restored image. To avoid streaks in images an improved DBA (DBUTMF) [6] is proposed with replacement of median of unsymmetrical trimmed output, but under high noise densities all the pixel inside the current would take all 0’s or all 255’s or combination of both 0 and 255. Replacement of trimmed median did not fare well for the above case. So, the modified decision based un-symmetric trimmed median filter (MDBUTMF) was proposed [7] . This algorithm processes the corrupted images by first detecting the impulse noise. 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 MDBUTMF. If the selected window contains salt/pepper noise as processing pixel (i.e., 255/0 pixel value) and neighboring pixel values are either 0 or 255 ,then the median of the centre pixel will be either 0 or 255.So,to solve this problem the authors have taken the mean of the selected window and the centre pixel is replaced by the mean. But ,it is our observation that a better alternative can be thought of by considering certain statistical parameters which will be a robust solution even at high salt and pepper noises. .Also, some authors [8] proposed an idea that ,when the median of the selected window is either 0 or 255 ,the centre pixel must be replaced by the top neighbor pixel value. But , here there is no convincing reason for this argument. So,to address this problem ,the authors have used the statistics of the window elements. Instead of considering the mean an attempt is made to compute the mean deviation of the widow and the central pixel is replaced by this.

Therest of the paper is organized as follows : Section II discusses the development details of proposed image processing algorithms , section III gives the illustration of the proposed algorithm , section IV gives the implementation of the proposed algorithms using the MATLAB GUI and FPGA and section V summarizes the results and conclusions.

II. PROPOSED ALGORITHM

In many practical cases of image processing, only a noisy image is available. This circumstance is known as the blind condition. Many denoising methods usually require the exact value of the noise distribution as an essential filter parameter. So, the noise estimation methods in the spatial domain, use the variance or standard deviation to estimate the actual added noise distribution. But it is found that the mean deviation provides better results than the variance or standard deviation to estimate the noise distribution. The advantage of this approach is that the mean deviation is actually more efficient than the standard deviation in practical situations [9].The standard deviation emphasizes a larger deviation; squaring the values makes each unit of distance from the mean exponentially (rather than additively) larger [10]. The larger deviation will cause overestimation or underestimation of the noise. So, we assume that use of the mean deviation may contribute to more accurate noise estimation. Keeping these points in view ,the authors have used the mean deviation parameter in deciding the noise pixel and replaced the central pixel by its mean deviation instead of its mean. The steps in the proposed algorithm are given below.

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

Step 2: If this pixel value lies between 0 and 255 , 0< Pij < 255 , this is considered as an uncorrupted pixel. So, no processing is required and its value is left unchanged.

Step 3: If Pij = 0 or 255 , it indicates that the pixel is corrupted by salt and pepper noise .Here two cases are considered

Case i: The selected window contains few 0 or 255 elements and other elements lie between 0 and 255.Then

the 0 and 255 elements are discarded and the median of the remaining elements is found.The Pij pixel is replaced with this median value.

Case ii: Suppose the window under consideration has all the elements either 0 or 255 .Then median of these

elements may also be either 0 or 255 which is again a noisy element. Now , find the mean deviation or absolute mean deviation of the window which can never be 0 or 255.Replace the pixel Pij with this mean deviation value

Step 4: Apply the steps 1 to 3 for all the pixels in the image for complete processing.

III. ILLUSTRATION OF THE PROPOSED ALGORITHM

This section explains the proposed algorithm with a flow chart and numerical examples.In the processing methodology the entire image must be checked for the presence of noise.The flow chart of the algorithm is shown in Fig.1.Let us first consider the Case ii. The 3x3 window under consideration has all the elements between 0 and 255 as shown blow.

$$\begin{bmatrix} 76 & 48 & 125 \\ 69 & \mathbf{86} & 49 \\ 98 & 77 & 55 \end{bmatrix}$$

Here the central pixel Pij is 86 which is a noise free pixel .So,no further processing is required for this pixel.

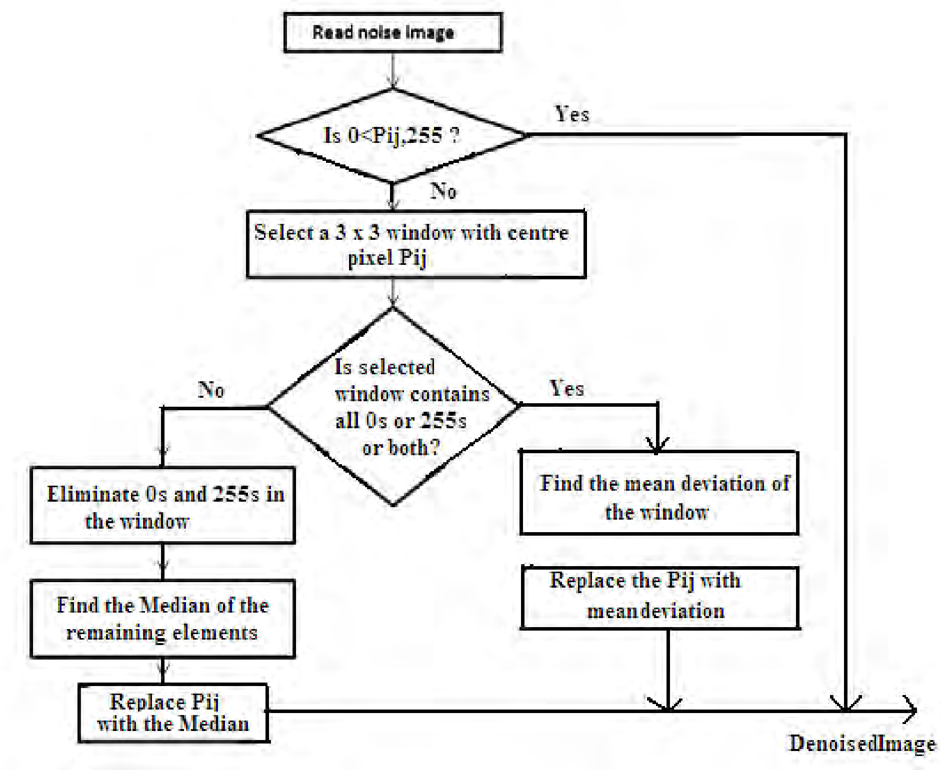

Figure 1. Flow chart of the proposed algorithm

Next, let us consider a 3x3 window which contain both 0 and 255 elements along with other elements as shown below.

$$\begin{bmatrix} 76 & 48 & 125 \\ 69 & \mathbf{255} & 49 \\ 0 & 77 & 255 \end{bmatrix}$$

Here the Pij is 255.To process this pixel, eliminate all the 0 and 255 elements and arrange the remaining elements in the ascending order. The ascending order after elimination is

[48 49 69 76 77]

The median of the window now is 69.So, the central pixel 255 is replaced by 69.

As a last illustration let us consider the Case ii: Let us consider the 3x3 window shown below which contains all the 0 or 255 elements.

$$\begin{bmatrix} 255 & 0 & 255 \\ 0 & \mathbf{255} & 0 \\ 255 & 0 & 255 \end{bmatrix}$$

For this window the central pixel Pij is equal to 255.The median of the window is either 0 or 255.Replacing the Pij with this value is of no use.So,find the mean deviation of the window. The mean deviation of the window is

$$\frac{\sum |x - \bar{x}|}{n}$$

Where x is the element of the window, $\bar{x}$ is the mean of the window elements and n is the total number of elements. So,for the above window the mean deviation is 126.So,the central pixel 255 is replaced with the value 126.

IV. IMPLEMENTATION OF THE PROPOSED ALGORITHM

The proposed algorithm is implemented by developing a Graphical User Interface (GUI) .The GUI is developed using MATLAB version 7.10.0.499(R2010a). This GUI is run on adual core processor of frequency 2.80 G.Hz. The same algorithm is also implemented on Spartan 3E FPGA device. Here Xc3s 500e-4ft256 FPGA device with Xilinx ISE10.1 webpack and XILIX 10.1 EDK software is used.. Using this GUI the efficiency of the various algorithms like Standard median filter (SMF), Adaptive median filter(AMF), Progressive switching median filter(PSMF) , Decision based median algorithm(DBMF), Modified Decision Based Unsymmetrical Trimmed Median Filter (MDBUT) along with the proposed filter (PF).The GUI has the option to select the type of the filter and the noise level. It displays the original image , noisy image and output image along with the metrics evaluated for each filter.The snap shot of the GUI at 20% noise is shown in Fig.2.Similarly the Fig.3. displays the GUI snapshot for cameraman image at 30% noise level.The performance of the proposd algorithm is verified by varying the noise density from 10% to 90%. To analyze the quantitative performance the metrics like peak signal noise ratio(PSNR) ,mean square error(MSE) and Image enhancement factor(IEF) are evaluated for each noise level for every algorithm .Table 1 shows the comparison of PSNR values estimated using different algorithms at different noise levels for LENA gray scale image(256 x256).The relations used to estimate the corresponding metrics are given below .

$$\text{PSNR in dB} = 10 \log_{10}\left(\frac{255}{MSE}\right)^2 \qquad (1)$$

$$\text{MSE} = \frac{\sum\sum(Y(i,j) - Y'(i,j))^2}{MXN} \qquad (2)$$

$$\text{IEF} = \frac{\sum\sum(\eta(i,j) - Y(i,j))^2}{\sum_i\sum_j(Y'(i,j) - Y(i,j))^2} \qquad (3)$$

In the above relations M X N is the size of the image, Y denotes the original image ,Y**’** denotes the denoised image **and** η is the noisy image.

The qualitative analysis of the proposed algorithm at different noise levels for Lena (256x256 gray sacle),Cameraman (256x256 gray scale) and Baboon(256x256 gray scale) images is studied. Table 4.shows these results for 70% salt and pepper noise

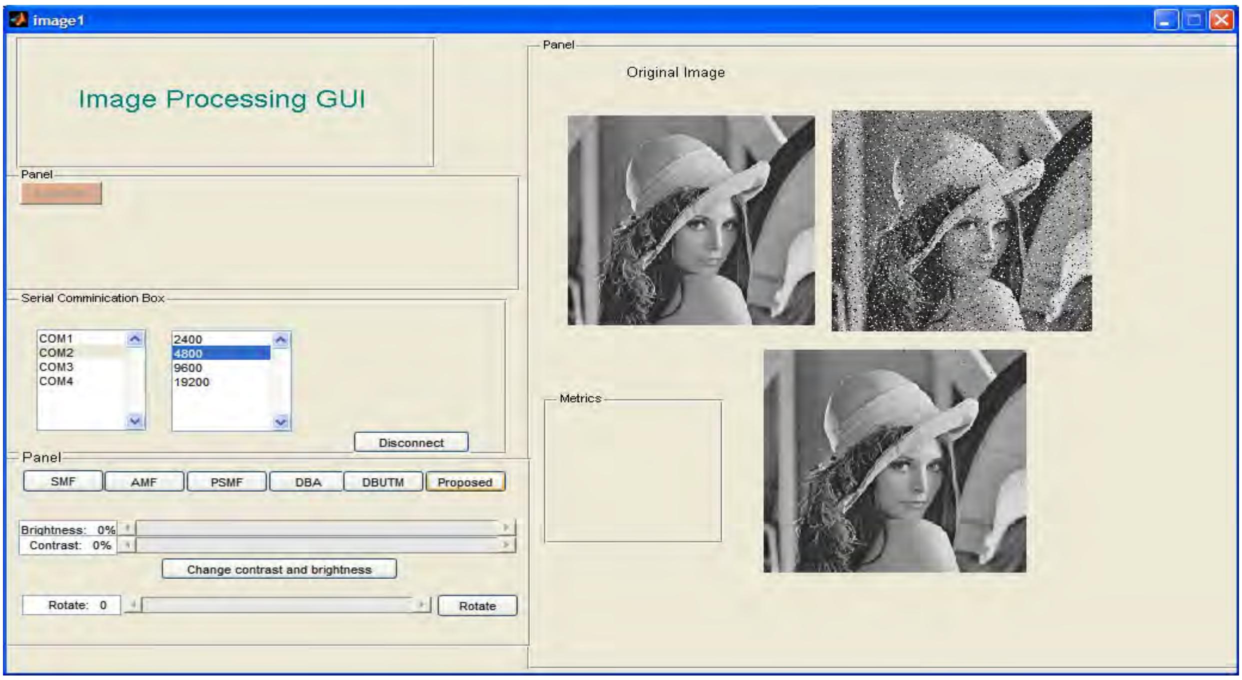

Figure 2.The snap shot of the GUI for Lena image at20% noise level.

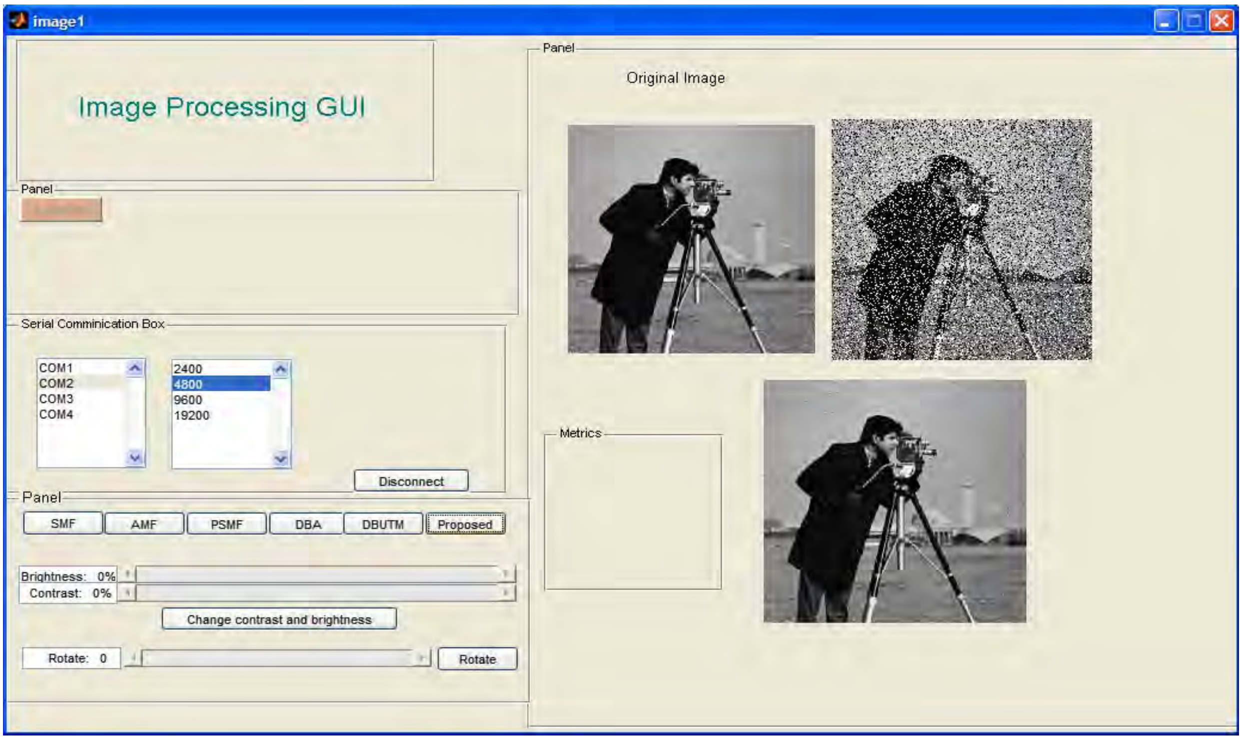

Figure 3.The snap shot of the GUI for Cameraman image at 30% noise level

Figure 4.shows the utilization summary of the hardware implementation of the proposed algorithm.

Target Device:	xc3s500e-4ft256	• **Warnings:**	97 Warnings (0 filtered)
Product Version:	ISE 10.1 - WebPACK	• **Routing Results:**	All Signals Completely Routed
Design Goal:	Balanced	• **Timing Constraints:**	All Constraints Met
Design Strategy:	Xilinx Default (unlocked)	• **Final Timing Score:**	0 (Timing Report)

firkai-hi Partition Summary	[-]
No partition information was found.	

Device Utilization Summary				[-]
Logic Utilization	**Used**	**Available**	**Utilization**	**Note(s)**
Number of Slice Flip Flops	849	9,312	9%	
Number of 4 input LUTs	4,435	9,312	47%	
Logic Distribution				
Number of occupied Slices	2,900	4,656	62%	
Number of Slices containing only related logic	2,900	2,900	100%	
Number of Slices containing unrelated logic	0	2,900	0%	
Total Number of 4 input LUTs	4,867	9,312	52%	
Number used as logic	4,435			
Number used as a route-thru	432			
Number of bonded IOBs	52	190	27%	
Number of BUFGMUXs	1	24	4%	
Number of MULT18X18SIOs	20	20	100%	

Figure 4.Device utilization summary.

TABLE 1. ESTIMATED VALUES OF PSNR FROM DIFFERENT FILTERS FOR LENA IMAGE

PSNR in dB						
Noise level %	**SMF**	**AMF**	**PSMF**	**DBMF**	**MDBUTMF**	**PROPOSED**
10	28.49	36.30	30.86	36.98	36.67	36.32
20	25.75	29.20	28.28	33.22	32.65	32.94
30	21.85	23.72	25.26	30.38	30.19	30.42
40	18.41	18.60	22.36	28.23	28.32	28.28
50	14.73	15.33	19.18	26.49	26.62	26.59
60	12.23	12.20	12.15	24.72	24.73	24.78
70	9.98	9.95	9.76	22.66	22.38	22.28
80	8.02	8.26	8.09	20.42	20.07	20.13
90	6.58	6.65	6.62	17.23	17.39	17.46

TABLE II. COMPARISON OF ESTIMATED VALUES OF PSNR OF DIFFERENT IMAGES AT A NOISE LEVEL OF 80%

PSNR in dB						
Test Image (256 x256)	**SMF**	**AMF**	**PSMF**	**DBMA**	**MDBUTMF**	**PROPOSED**
Camaraman	7.74	7.79	7.73	21.93	20.22	21.33
Lena	8.02	8.26	8.09	20.42	20.07	20.13
Baboon	7.73	12.05	7.86	22.49	22.90	22.96

V. CONCLUSION

The proposed algorithm is tested using the MATLAB and FPGA hardware. From the observation of Table 1 and Table 2 ,one can come to the conclusion that the present method is showing reasonably good performance at high noise density levels. Also it is clear that the fine details of the image and the contrast levels are much better in the case of the proposed algorithm .Especially the results shown in the Table 2 speaks of this fact. This confirms the validity of the proposed algorithm for denoising the high density salt and pepper noise from the images.

In fact every image processing algorithm can not be implemented effectively in hardware. Most of the image processing algorithms are inherently computationally intensive and may require vast computing power if strict time-constraints are posed. The spreading of parallel image processing techniques and systems has been driven not only by the afore-mentioned need, but the inherent parallel nature of many image processing algorithms has also eased this evolution. The execution characteristics of a certain parallel algorithm on a given architecture heavily depends on the `mutual conformance' of the mentioned algorithm and the architecture pair. Two algorithms with similar sequential performance may behave very differently in a parallel environment. In sequential algorithms the complexity is expressed in terms of operations and storage. In parallel environments these terms are not adequate for characterizing the computing efficiency - fewer operations does not directly mean shorter execution time since there is a definite overhead involved due to availability of resources and communication between processors[11].

Coming to hardware implementation, the Resource utilization for all implementations exceed the resources available on Spartan 3E.So,all the algorithms occupied more than 150% of the available slices on Spartan.As the number of BRAMS in Spartan 3E is only 20 ,smaller images were considered for implementation.Also the Spartan 3E device runs at 50 Hz clock speed. Hence the device can not generate the results at a faster rate. This will be the major limitation in real time image processing. To overcome these limitations Virtex devices are preferred. This is left for future development of our work.

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