Denoising Digital Images using Order Statistic Filtering Technique

R.Pushpavalli, G.Sivarajde

Abstract— A new filtering technique is proposed to denoising process on digital images. This filter is a combination of statistics and average. It is very useful for denoising if image is corrupted with impulse noise and gaussian noise. This filtering scheme offers edge and fine detail preservation performance while, at the same time, effectively denoising digital images. Extensive simulation results were realized for the proposed filter and different filters are compared. Results show that the proposed filter is superior performance in terms of image denoising and edges and fine details preservation properties.

Index Terms— Decision based algorithm, Gaussian noise, Impulse noise and Image denoising.

1 INTRODUCTION

Digital images are often contaminated by impulse noise and gaussian noise during image acquisition and/or transmission over communication channel. Majority of the existing filtering methods comprise order statistic filters utilizing the rank order information of an appropriate set of noisy input pixels. These filters are usually developed in the general framework of *rank selection filters*, which are nonlinear operators, constrained to output an order statistic from a set of input samples. The difference between these filters is in the information used to decide which order statistic to output. The *standard median filter* (MF) [1]–[3] is a simple rank selection filter and attempts to remove impulse noise from the center pixel of the analysis window by changing the luminance value of the center pixel with the median of the luminance values of the pixels contained within the window. This approach provides a reasonable noise removal performance with the cost of introducing undesirable blurring effects into image details even at low noise densities [4-27].

In order to address this issue, a new Decision Based Algorithm (DBA) is presented. This filter is a combination of statistics and average. It is very useful for denoising if image is corrupted with impulse noise and gaussian noise. Pixel inside the window is separated as impulse noise and remaining pixels. The remaining pixels (without impulse noise) inside the filtering window are arranged in ascending order and average value is calculated for filtering.

The rest of the paper is organized as follows. Section II explains the structure of the proposed operator and its building blocks. Section III discusses the application of the proposed operator to the test images. Results of the experiments conducted to evaluate the performance of the proposed operator and comparative discussion of these results are also presented in this Section IV, which is the final section, presents the conclusions.

2 PROPOSED OPERATOR

Fig. 1 shows the structure of the proposed impulse noise removal operator. The proposed filtering technique is obtained by appropriately combining nonlinear mean and median filter. The decision based algorithm is discussed in section 2.1. The overall filtering process is discussed in section 2.2.

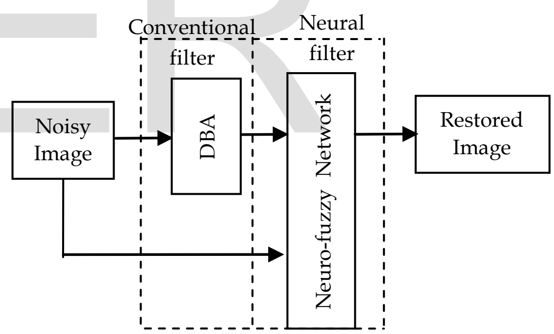

Fig.1 Proposed Hybrid Filter

2.1 Decision Based Algorithm

The filtering technique proposed in this paper employs a decision mechanism to detect the presence of impulse noise and uniform noise on the test image. The pixels inside the sliding window are identified as corrupted or not. If the pixel is corrupted, based on the type of noise, the corrupted central pixel is replaced by either median filter or nonlinear mean filter. Median filter is defined as

$$MF = [med\{F(i,j)\}], (i,j) \in S_{mn} (s,t) \in S_{mn} \qquad (2.1)$$

where, *MF* represents median filter, *F(i,j)* represents processing pixel, S_{mn} represents the filtering window. Mean filter simply computes the average of pixels within the filtering window. So mean filter is defined as

$$MF_{avg} = [mean\{F(i,j)\}], (i,j) \in S_{mn} (s,t) \in S_{mn} \qquad (2.2)$$

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ISSN 2229-5518

where, MF_{avg} represents average filter, $F(i,j)$ represents processing pixel, S_{mn} represents the filtering window. This filter is a combination of statistics and average. It is very useful for denoising if image is corrupted with impulse noise and gaussian noise. Pixel inside the window is separated as impulse noise and remaining pixels. The remaining pixels (without impulse noise) inside the filtering window are arranged in ascending order and average value is calculated for filtering.

Consider an image of size M×N having 8-bit gray scale pixel resolution. The proposed filtering algorithm as applied on noisy image is described in steps as follows:

Step 1) A two-dimensional square filtering window of size 3 x 3 is slid over the noisy image.

Step 2) As the window move over the noisy image, at each point the central pixel inside the window is checked whether the pixel is corrupted by impulse noise or not.

Step 3) If it is corrupted by impulse noise, then the central pixel is replaced by median pixel value.

Step 3) If the central processing pixel within the moving window is detected as an uncorrupted pixel, the pixels within the filtering window are sorted out excluding impulse noise and then nonlinear mean filter is performed on sorted pixels within the moving window.

Then the window is moved to form a new set of values, with the next pixel to be processed at the centre of the window. This process is repeated until the last image pixel is processed. It may be noted that the filtering is performed by either taking the median or the mean value of the pixels of the filtering window. Moreover, the mean filtering on the remaining pixels (without impulse noise) sample is performed only on processing pixels. As a result, the pixels in the filtered image do not cause any noticeable visual degradation. The performance of the proposed filter is superior to other existing filters in terms of eliminating multiple noise and preserving edges and features of images.

2.2 Filtering of the Noisy Image

The noisy input image is processed by sliding the 3x3 filtering window on the image. This filtering window is also the moving window for both median and nonlinear mean. The window is started from the upper-left corner of the noisy input image, and moved rightwards and progressively downwards in a *raster scanning* fashion. For each filtering window, the nine pixels contained within the window are first fed to the median filter and the nonlinear mean in the structure. Finally, the restored luminance value for the center pixel of the filtering window is obtained by decision mechanism.

3 Results and Discussion

The proposed hybrid impulse noise removal operator discussed in the previous section is implemented. The performance of the operator is tested under various noise conditions and on four popular test images from the literature including *Baboon, Lena, Pepper and Rice images*. All test images are 8-bit gray level images. The experimental images used in the simulations are generated by contaminating the original images by impulse noise with an appropriate noise density depending on the experiment. Several experiments are performed on Lena test image to measure and compare the noise suppression and detail preservation performances of all operators. The performances of all operators are evaluated by using the *peak signal-to-noise ratio* (PSNR) criterion, which is defined as

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{3.1}$$

where *MSE is the mean squared error* and is defined as

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left|(x(i,j)-y(i,j)\right|^2 \tag{3.2}$$

Here, M and N represents the number of rows and columns of the image. $x(i,j)$ and $y(i,j)$ represents the original and the restored versions of a corrupted test image, respectively. The averages of these values are then taken as the representative PSNR value for that experiment. The experimental procedure to evaluate the performance of a given operator is as follows: For each noise density step, the four test images are corrupted by Noise density with 0.1 of impulse noise and gaussian noise of zero mean and σ=200. Finally, the overall experimental procedure is individually repeated for each operator. Since all experiments are related with noise and noise is a random process, every realization of the same experiment yields different results even if the experimental conditions are the same. Therefore, each individual filtering experiment presented in this paper is repeated for different PSNR values for the same value.

TABLE I

PSNR Values Obtained Using Different Filtering Technique on Lena Image Corrupted with Various Densities of Impulse Noise

Noise		Median filter	Mean filter	DBA
Gaussian noise	Impulse noise			
100	10%	19.45	16.23	28.92
200	10%	18.95	16.80	28.52
300	10%	18.23	16.23	28.28
400	10%	18.09	15.84	28.03
500	10%	17.67	14. 27	27.91
600	10%	17.93	14.56	27.64
700	10%	17.43	14.37	27.42

For comparison, the corrupted experimental images are also restored by using several conventional and state-of-the-art impulse noise removal operators including are subjectively evaluated on Lena test image in Fig.2 and graphically illustrated in Fig.3. These filters are representative implementations of different approaches to the impulse noise filtering problem. Fig.4 illustrates the performance of proposed filter and compares with that of the different filtering algorithm in terms of PSNR when applied on Lena image contaminated with noise densities. The new nonlinear filter outperforms the improved decision making algorithm.

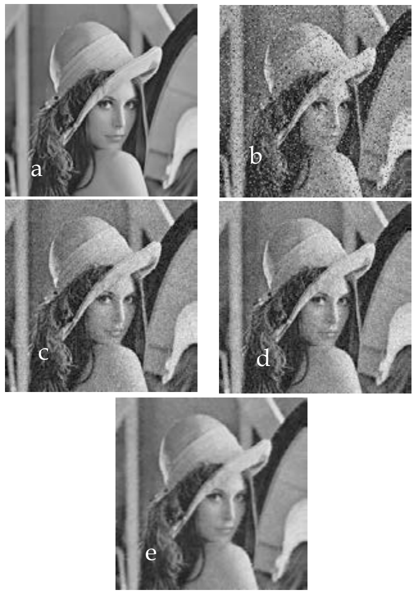

Fig.2 Subjective performance illustration of the proposed filtering technique compared with existing technique: (a) Original Lena image, (b) Lena image Corrupted by 10% impulse noise and gaussian noise with zero mean and σ2=200, (c) Restored by median filter (d) Restored by mean filter (e) Restored by the proposed DBA

In order to prove the effectiveness of this filter, existing filtering techniques are experimented and compared with the proposed filter for visual perception and subjective evaluation on Lena image including the proposed filter in Fig.2.

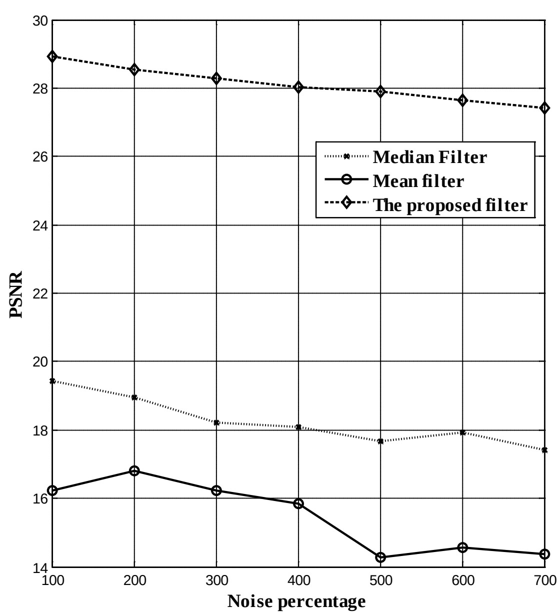

Fig.3 Performance of PSNR for proposed filter compared with different filtering technique on Lena image

Table II lists the variations of the PSNR values of the operators as a function of noise density for proposed filter on different test images. The proposed operator shows the best filtering performance of all. Its PSNR values are extensively higher than those of the other filters for all noise densities. Fig.4 detects the subjective performance of proposed filter on different test images. The proposed filter can be seen to have eliminated the impulse noise completely. Further, it can be observed that the proposed filter is better in preserving the edges and fine details than the other existing filtering algorithm. The experiments are especially designed to reveal the performances of the operators for different image properties and noise conditions.

Table II

Performance of PSNR for proposed hybrid neuro-fuzzy filter for different images corrupted with various noise densities

PSNR					
Gaussian noise	Impulse noise	Baboon	Lena	Pepper	Rice
100	10%	23.95	28.92	32.75	30.93
200		23.32	28.52	32.38	30.62
300		22.96	28.28	32.17	30.42
400		22.47	28.03	32.04	30.12
500		21.85	27.91	31.87	29.96
600		21.27	27.64	31.59	29.74
700		20.25	27.42	31.24	29.32

Fig.4 Performance of test images: ($a_{1,2 \text{ and } 4}$) original images,($b_{1,2 \text{ and } 4}$) images corrupted with 10% of impulse noise and gaussian noise with σ=200 and ($d_{1,\ 2 \text{ and } 4}$) images enhanced by proposed filter

ISSN 2229-5518

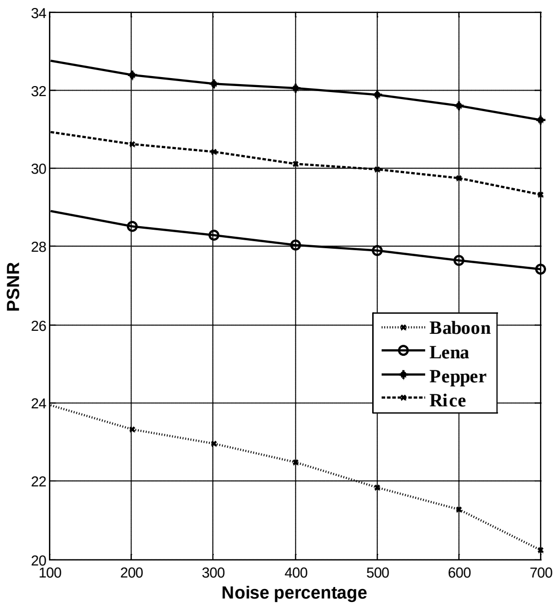

Fig.5 Performance of PSNR for the proposed filter on different test images

Fig.5 presents the noise-free, noisy, and filtered images for objective evaluation. Four different test images corrupted with 10% impulse noise and gaussian noise with σ=200 are used to illustrate the efficacy of the proposed filter. HNF filter is found to have eliminated the impulse noise completely while preserving the image features quite satisfactorily. It can be seen that this filtered images are more pleasant for visual perception.

4 Conclusion

A decision based filtering algorithm is described in this paper. The proposed filter is seen to be quite effective in eliminating the gaussian noise and impulse noise; in addition, the proposed filter preserves the image boundaries and fine details satisfactorily. The efficacy of the proposed filter is illustrated by applying the filter on various test images contaminated by different levels of noise. This filter outperforms the existing median based filter in terms of qualitative and quantitative measures. In addition, the hybrid filtered images are found to be pleasant for visual perception, since the filter is robust against the impulse noise and gaussian noise while preserving the image features intact.

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