A NEW CONCEPT TO DENOISE THE HIGHLY CORRUPTED GREY SCALE IMAGES FROM MIXED NOISE

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ABSTRACT

In this paper, a new concept to denoise the highly corrupted grey scale images from mixed noise (i.e. mixture of Gaussian and salt & pepper noise of various noise densities) is proposed. This filter first detect the presence of salt & pepper noise with the help of ROAD (Rank Order Absolute Difference) statistics, if salt & pepper noise is present in the selected window, then it employs the impulse denoising filter on the selected window, otherwise only Gaussian filtering part of the proposed filter works on the selected window to suppress the Gaussian noise. The experimental results show that filtering performance of the proposed filter is better than other standard filters like Median, Wiener, Bilateral and Trilateral filters.

Keywords: Bilateral, Gaussian noise, Median, ROAD, Salt & Pepper noise, Trilateral filter, Wiener.

I. INTRODUCTION

Image processing has a wide variety of applications in Machine Vision, Multimedia Communication, and Television Broadcasting etc. that demands very good quality of images [1]. The quality of an image degrades due to introduction of noise during acquisition, transmission/ reception and storage / retrieval processes. It is very essential to suppress the noise in an image and to preserve the edges and fine details as far as possible [2].
During image acquisition (digitization), performance of imaging sensors is affected by a variety of factors, such as environment conditions and the quality of the sensing elements themselves. For instance, in acquiring images with the CCD camera, light levels and sensor temperature are major factors affecting the amount of noise in the resulting image. Images are corrupted during transmission, principally due to interference in the channel used for transmission e.g. an image transmitted using a wireless network might be corrupted as a result of lightning or other atmospheric disturbance. The most common noises that affect the quality of image are Gaussian noise and salt & pepper noise. These two noises are dominating noise. In this paper, a novel approach is presented to denoise the images from a mixture of Gaussian and salt & pepper noise of various noise densities. This paper also contains the detailed theory of Gaussian noise and Impulse noise.

II. GAUSSIAN NOISE

This noise comes into notice due to poor quality image acquisition, images observed in a noisy environment or noise inherent in communication channels [3]. Noise is modeled as Additive White Gaussian Noise (AWGN), where all the image pixels deviate from their original values following the Gaussian curve. That is, for each image pixel with intensity value O_{ij} ($1 \leq i \leq M$, $1 \leq j \leq N$ for an $M \times N$ image), the corresponding pixel of the noisy image X_{ij} is given by,

$$X_{ij} = O_{ij} + G_{ij} \quad (1)$$

Where, each noise value G_{ij} is drawn from a zero-mean Gaussian distribution. Gaussian noise is used as an approximation in cases such as imaging sensors operating at low light levels. Its PDF is given as:

(2)

Where z is the pixel intensity, μ is mean and σ is the standard deviation which decides shape of Gaussian function. The standard deviation squared value σ^2 is called the variance of z. A plot of Gaussian function is shown in fig.1. When z is described by Eqn. (2), approximately 70% of its values will be in range [(μ-σ),(μ+σ)] and about 90% will be in the range [(μ-2σ), (μ+2σ)].

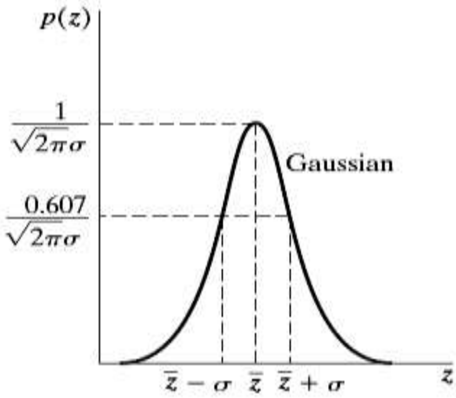


Fig. 1: Probability density function of Gaussian noise

III. SALT & PEPPER NOISE

Impulse noise is characterized by replacing a portion of an image's pixel with noise values; this noise affects image pixel by pixel and not the whole area of an image. Such noise is introduced due to transmission errors. Impulse noise can be of two types:

- Random Values Impulse Noise (RVIN)
- Salt & Pepper noise

The Salt and Pepper (SP) noise is also called as fixed valued impulse noise, it will take a gray level value either minimal (0) or maximal (255) (for 8-bit monochrome image) in the dynamic range (0-255). It is generated with the equal probability. In the case of salt and pepper noise, the image pixels are randomly corrupted by either 0 or 255. That pixel is replaced by either white value (255) or black value (0) that's why it is called as salt & pepper noise.

For each image pixel at location (i,j) with intensity value O(i,j), the corresponding pixel of the noisy image will be X(i,j), in which the probability density function of X(i,j) is

$$p(x) = \begin{Bmatrix} \frac{p}{2} & for\ x = 0 \\ 1 - p & for\ x = o_{i,j} \\ \frac{p}{2} & for\ x = 255 \end{Bmatrix} \quad (3)$$

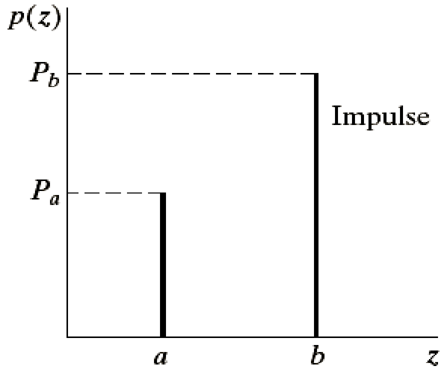


Fig. 2: Probability density function of impulse noise

IV. PROPOSED FILTER

After studying and analyzing the performance of the existing standard filters (i.e. Median, Wiener, Bilateral and Trilateral filters), it is observed that most of these filters blur the image and smooth the edges that cause non-preservation of image detail. It is also observed that these filters are either good for Gaussian noise or for salt & pepper noise but not for a mixture of Gaussian and salt & pepper noise. So by keeping in mind the shortcomings of existing standard filters, a new algorithm has been developed to denoise the noisy grey scale images from mixed noise. To speed up the filtering process, ROAD (Rank Ordered Absolute Difference) statistics has been introduced in proposed algorithm to inspect the presence or absence of salt & pepper noise in the acquired image.

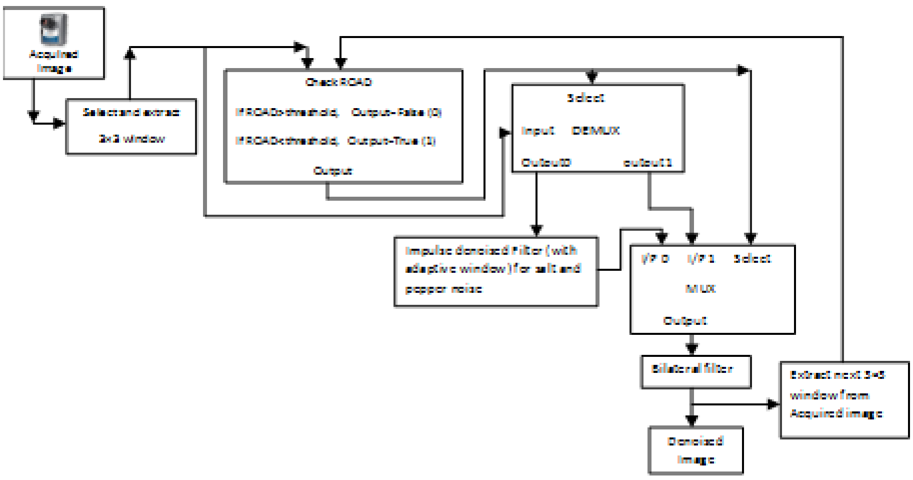


Fig. 3: General Architecture of Proposed Hybrid Filter

The ROAD statistic provides a measure of how close a pixel value is to its four most similar neighbours. The logic underlying the statistic is that unwanted impulses will vary greatly in intensity from most or all of their neighbouring pixels, whereas most pixels composing the actual image should have at least half of their neighbouring pixels of similar intensity, even pixels on an edge. The detailed architecture of proposed filter is shown in fig.3. The proposed filter is combination of two filters i.e Gaussian Filter and Impulse filter. ROAD value of a particular window decide that the central pixel is corrupted or not with salt & pepper noise. If pixel is corrupted i.e. ROAD of the selected window is greater than threshold, then impulse denoising filter will work on that window otherwise only Gaussian filter will work to suppress the Gaussian noise.

V. EXPERIMENTAL RESULTS

To examine the filtering performance of proposed filter and various standard filters, three tests are conducted with these filters and outputs of the filters are evaluated in terms of PSNR and MAE for quantitative analysis. For subjective evaluation, MOS and Visual results of all filters are compared.

5.1 Experimental Test Procedure

The following three test samples of mixed noise were added in original Lena image to get the different test images. Each test sample of mixed noise contains different quantity of Gaussian and impulse noise (salt & pepper noise). Various performance measures like PSNR and MAE are evaluated from experiments conducted with test images.

Test Sample –I: This test sample of mixed noise was a mixture of Gaussian noise with standard deviation σ_g= 0.15 and salt & pepper noise with variance σ_I =0.20**.**

Test Sample –II: This test sample of mixed noise was a mixture of Gaussian noise with variance σ_g= 0.30 and salt & pepper noise with σ_I =0.20**.**

Test Sample–III: This test sample of mixed noise is a mixture of Gaussian noise with variance σ_g= 0.30 and salt & pepper noise with variance σ_I =0.40**.**

5.2 Results Analysis

The PSNR (dB) values of the different filters for various test images are given in table-I. The highest (best) PSNR (dB) value for a particular Test-sample of mixed noise is highlighted to show the best performance. As from table-1, it is observed that PSNR (dB) value of proposed filter is better than other filters in all experiments. It shows that the proposed filter outperforms at higher noise densities of Gaussian noise and salt & pepper noise. Bilateral filter is next after PF which having better performance in terms of PSNR (dB).

It is also observed from table-II that MAE value of proposed filter is lower for all three samples, so output image of proposed filter is much similar to original image as compared to output images of other filters. For test-sample-I, Median filter has lower MAE value than other filters except proposed filter. But for sample-II and III, performance of Bilateral filter in terms of MAE is better than Median filter and other filters except proposed filter.

From table-III, it is observed that MOS of proposed filter is 3.54 which is 2nd highest amongst the all filters for Test-sample-I of mixed noise. For Test-sample-II,III of mixed noise, proposed filter leads than other filters including Median Filter. This shows that overall performance of proposed filter to filter the mixed noise is better than well-known standard filters.

TABLE.I: FILTERING PERFORMANCE OF VARIOUS FILTERS AND PROPOSED FILTER, IN TERMS OF PSNR (DB), OPERATED ON 'LENA IMAGE' UNDER VARIOUS NOISE CONDITIONS OF MIXED NOISE.

S.No.	IMAGE DENOISING FILTERS	DENSITY OF MIXED NOISE σ_g=Density of Gaussian Noise , σ_I=Density of Salt & Pepper Noise		
		TEST-I (σ_g=15%, σ_I=20%)	TEST-II (σ_g=30%, σ_I=20%)	TEST-III (σ_g=30%, σ_I=40%)
		Peak -Signal to Noise Ratio, PSNR(dB)		
1	MEDIAN	27.4092	19.8708	18.8528
2	WIENER	26.435	20.828	21.2084
3	BILATERAL	27.1518	21.323	21.6538
4	TRILATERAL	25.5966	20.8422	20.567
5	PROPOSED FILTER	**29.2204**	**24.0394**	**22.7548**

TABLE II: FILTERING PERFORMANCE OF VARIOUS FILTERS AND PROPOSED FILTER, IN TERMS OF MAE, OPERATED ON 'LENA IMAGE' UNDER VARIOUS NOISE CONDITIONS OF MIXED NOISE.

S.No.	IMAGE DENOISING FILTERS	DENSITY OF MIXED NOISE σ_g=Density of Gaussian Noise , σ_I=Density of Salt & Pepper Noise		
		TEST-I (σ_g=15%, σ_I=20%)	TEST-II (σ_g=30%, σ_I=20%)	TEST-III (σ_g=30%, σ_I=40%)
		Mean-Absolute-Error(MAE)		
1	MEDIAN	38.8432	74.2797	76.6874
2	WIENER	41.5011	69.1099	63.4918
3	BILATERAL	38.9706	65.0027	60.115
4	TRILATERAL	44.8627	67.2581	64.851
5	PROPOSED FILTER	**37.0196**	**62.2902**	**56.4387**

TABLE.III: MOS OF VARIOUS EXPERIMENTS, WHERE INPUT IMAGES ARE CORRUPTED BY THREE SAMPLES OF MIXED NOISE.

S.No.	IMAGE DENOISING FILTERS	MOS of Test-I	MOS of Test-II	MOS of Test-III
1	MEAN	1.95	2.41	1.82
2	MEDIAN	**3.73**	**3.27**	**3.27**
3	WIENER	2.32	2.77	2.18
4	ADAPTIVE MEDIAN	2.14	1.77	2.27
5	BILATERAL	2.14	2.32	2.00
6	TRILATERAL	2.27	2.91	2.05
7	DOUBLE BILATERAL	1.91	2.27	1.81
8	PROPOSED FILTER	**3.54**	**3.36**	**3.32**

Visual results of Test-I and Test-II are shown in fig.4 to fig.5.Visual results shows that proposed filter is the best in filtering and smoothing the complex regions with quite little distortion and giving the best visual quality amongst all other filters compared here.

(a)Original Lena Image

(b)Corrupted Image (Gaussian Noise-30%, Salt & Pepper Noise-20%) (c) (d)

(e)

(f)

(g)

(h)

(i)

(j)

Fig.4: Performance of Various Filters for Lena Image corrupted with Test sample-IV of mixed noise (a) Original image (b) Noisy image (c) – (j): Results of various filtering schemes (c) Output of Mean Filter (d) Output of Median Filter (e) Output of Wiener Filter (f) Output of Adaptive Median Filter (g) Output of Bilateral Filter (h) Output of Double Bilateral Filter (i) Output of Trilateral Filter (j) Output of Proposed Filter.

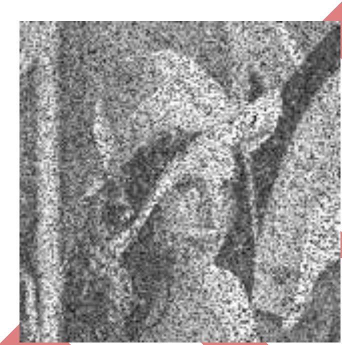
(a)Original Lena Image

(b)Corrupted Image (Gaussian Noise-30%, Salt & Pepper Noise-40%)

(c)

(d)

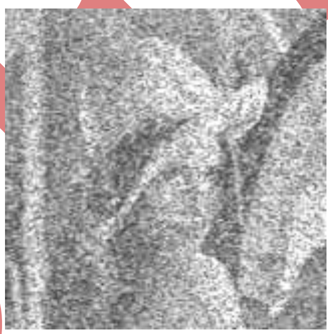
(e)



(f)

(g)

(h)



(i)

(j)

Fig.5: Performance of Various Filters for Lena Image corrupted with Test sample-V of mixed noise (a) Original image (b) Noisy image (c) – (j): Results of various filtering schemes (c) Output of Mean Filter (d) Output of Median Filter (e) Output of Wiener Filter (f) Output of Adaptive Median Filter (g) Output of Bilateral Filter (h) Output of Double Bilateral Filter (i) Output of Trilateral Filter (j) Output of Proposed Filter.

VI. CONCLUSION

A novel approach to denoise the noisy grey scale images from mixed noise is proposed in this paper. To examine and demonstrate the filtering ability of various filters, three samples of mixed noise containing different amount of Gaussian and SP noise were added in Lena image to get the test image. It is observed from experimental results of all tests that capability of proposed filter to suppress the mixture of Gaussian and salt &

pepper noise is more than other filters. Visual results of three tests show that proposed filter can preserve image detail more with little distortion as compared to other filters for highly corrupted images.

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