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Analysis of Denoising Framework and Novel Approach for Removing Impulse Noise

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***Abstract*—Random variation of illuminations and color quantity causes noise in an image. This variation doesn't carry any meaningful information and becomes the reason to degrade the image quality. This influences a lot when the image size is small and recorded in a low contrast area. In order to understand the information through an image, the image quality has to be upgraded and hence denoising framework is proposed. Several researchers have already proposed different approaches for denoising the image. In this paper, different denoising techniques are critically analyzed with respect to PSNR, MAE, MSSIM, and ROAD. Subsequently, a novel approach is proposed. The outcome of the proposed technique and previously proposed techniques are analyzed which justifies the suitability of the proposed approach.**

***Index Terms*— Impulse Noise, PSNR, ROAD, MAE, MSSIM.**

I. INTRODUCTION

The images are corrupted due to different noises added to an image in different circumstances. These noise components are nothing but random variations in the pixel attribute with respect to the neighbouring pixels. The noise may corrupt an image possibly at the time of shoot, during processing or at the time of transmission. At the time of image capturing, due to switching elements, shake, sensor influence and many other reasons, the image gets noisy. During image processing, changing the ISO factors may add noise in an image and channel interference and environmental conditions may add the noise at the time of transmission from one point to the other. In this situation, in order to reproduce an image, equivalent to an original image, denoising frameworks are described. These frameworks are deployed for restoring the corrupted images.

The impulse noise is added in the image and becomes visible like the bright and dark spots appearing in the different areas of the image. Through the present research work, an extensive survey is carried out to understand the previously reported technology and a new technology is proposed for denoising an image infected with salt and pepper noise, in Non-linear mode. For implementing the said approach, Lena, Mandrill and Bridge images are used. For performance analysis, different factors like PSNR, MAE and MSSIM are used in the result and discussion section. The rest of the paper is organized into five different sections as literature review, understanding image and impulse noise, proposed methodology, results and conclusion.

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II. LITERATURE REVIEW

The process of removing the noise from the images is also called as restoring or denoising or image enhancement. The quality of image enhancement depends on multiple factors like quality of the original image, noise density and the filter which is used for denoising. From the studies, it is evident that there exist variety of noises such as Impulse Noise, Gaussian Noise, Speckle Noise and many others. These noises directly infect the pixels of the image causing image degradation. In this collection of noises, the impulse noise creates white spots in dark areas and dark spots in bright areas whereas the gaussian noise either increases or decreases the brightness in the image. Sometimes, it also causes blurring. The impulse noise and gaussian noise are distributed uniformly over the image. Speckle noise creates patches in the images and it is non-uniformly distributed.

Considering the diversity of the image processing domain, impactful noise handling techniques are cited and categorised the denoising techniques into linear and non-linear. Depending upon the type of noise infecting the image, either some of the pixels or all of the pixels are infected. In the process of denoising the image, either, only infected pixels are identified and treated separately or complete image is treated, without identifying the infected pixels. The first technique is called as non-linear technique and the later one is called as linear technique.

A. Denoising using Linear Technique

In linear technique of denoising the image, all of the image pixels are treated, this damages the pixels since infected and original pixels are treated using same approach. Average, Mean and Median filters are the examples of the line denoising technique.

The idea of adaptive thresholding in wavelet domain using generalized Gaussian distribution in sub-band coefficient estimation [D. Gnanadurai and V. Saddasivam 2008] has been suggested [1].They used standard deviation, arithmetic mean and geometrical mean parameters for sub-band estimation. Non-local means denoising approach needs calculation of weighting terms for pairs of the pixels, a computationally expensive process. [Jeff Orchard *et al.* 2008] proposed SVD technique which eliminates the dissimilar pixel pairs [2]. To overcome the setbacks of NLM, researchers proposed to nullify the small weights with soft thresholding [3] in order to optimize the accumulation [Lu Lu *et al.* 2015]. To nullify the effect of the mixed noise on the image, new technique is reported [Yanchum Wang *et al.* 2006] for overcoming image corruption using Gaussian noise and impulse noise using averaging filter and unidirectional median filter [4]. A new image filtering technique LS-WVM, combining features of wavelet transformation and support vector machine is proposed [Guoping Zeng and Ruizhen Zhao 2007], which performs better than existing SVM with G-RBF and P-RBF [5]. An adaptive denoising technique is proposed through [V. Nivitha Varghees *et al.* 2012] for overcoming Rician noise effect from MRI images, based on total variation minimization and local noise estimation modelling [6]. In order to accelerate the process of denoising using NL Means, denoising filters are proposed [M. Mahmoudi and G. Sapiro, 2005] which eliminate unrelated neighbourhood pixels from the weighted average [7]. Speckle reducing anisotropic diffusion (SRAD) [Dr. G. Padmavathi *et al.*2010] are found to be the real quick filter for pre-processing of the underwater images [8]. Patched-based evolved local adaptive filter is proposed [Ruomei Yan *et al.*2014] which deals with the noisy image using patch clustering and genetic programming fundamentals [9]. Neural network-based image denoising technique is proposed in wavelet transform domain [S. Zhang and E. Salari 2005]; in this approach, sub-bands are created and then through trained neural network noise is removed and wavelet coefficients are generated [10].

B. Denoising using Non-Linear Technique

In this technique of denoising, the image pixels are bifurcated into noisy pixels and original pixels and the denoising algorithm is applied to the noisy pixels only. Multi-Method Fusion (MMF), Centre-Weighted Median Filter (CWMF), Adaptive Median Filter (AMF), Progressive Switching Median Filter (PSMF), Triplet Markov Field (TMF) and Decision Based Algorithm (DBA) are the different approaches used in Non-Linear technique.

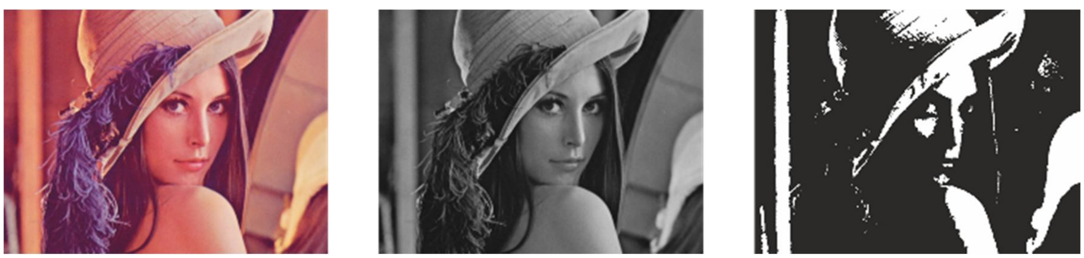
Two stage method [Hossein Hosseini *et al.* 2015] for denoising high density impulse noise is proposed [11], in which the impulse detector is used for identification of the infected pixels and novel weighted average filter is employed in the second stage for removing the impulses. A discrete wavelet and fast Fourier transform based scheme is proposed [Shiny Gopinathan et. al. 2015] for removing the Gaussian noise from the image; In this approach, sub-bands are identified and sum of low sub-bands are filtered out and in the lateral approach, the low frequency and high frequency components are identified and filtered out using PWL and soft thresholding [12]. The novel approach for image denoising, without blurring the image [T. K. Thivakaran and Dr. R.M. Chandrasekaran 2010], using adaptive median filter is proposed [13]. As per the disclosure [Zhiwu Liao *et* *al.*2010], it is possible to estimate the neighbouring pixels automatically for denoising using nonlinear time series analysis [14]. Possibility of decision-based approach [Suman Shrestha 2014] for image denoising using median filter is proposed [15]. Denoising of hyperspectral images is disclosed [Hemant Kumar Aggarwal and Angshul Majumdar 2015]. In this technique, denoising is achieved by considering noise as synthesis optimization problem which uses spectral correlation present in hyperspectral images. Split-Bregman based approach has been used to solve resulting optimization issues. Denoised hyperspectral image is claimed to be superior than previously reported techniques [16]. Diffusion based denoising method to deal with impulse noise is proposed [Hakran Kim, Seongjai Kim 2015] in which a novel impulse mowing anisotropic diffusion filter is designed which regulates the impulses and max and mins without disturbing neighboring pixel amplitudes. [17]. Adaptive median filtering technique is suggested [Nasar Iqbal *et al.* 2017] to denoise an image in which the infected pixel is replaced by median value of 3x3 window. Technically, the noisy neighbor pixel is replaced by the median value calculated by using clean pixels. Outcomes are claimed to give optimized Mean Square Error, Universal Quality Index and Peak Signal to Noise Ratio [18]. Universal denoising framework based on non local means filtering [Bo Xiong and Zhouping Yin 2012] is discussed in which denoising is pursued in detection and filtering stages. For detection of the impulse infected pixel, outlyingness ratio is used which is followed by dividing all pixels into four clusters depending on outlyingness ration value. Subsequently, to precisely detect the infected pixels from coarse to fine strategy and iterative framework are used. To filter the impulses, NL means are extended by introducing the reference image. Finally, universal denoising framework, designed by combining outlyngness ratio and NL means, is used for image restoration. The proposed technique claimed to achieve high peak SNR and improved image quality by efficiently removing impulse, Gaussian and mixed noise. [19].

III. Understanding the Image and Impulse Noise

A. Image Representation

Theoretically, the image may be represented as $f(x,y)$. This indicates that any image is function of image intensity I at any location in an image, which can be located by (x,y).The pixel value through which any image is developed, defines the type of an image. Accordingly the image can have three colour formats, colour image, gray scale image and black and white image.

The Lena image in above three colour formats may look like as given in Fig. 1.



(a) (b) (c)

Fig. 1. Lena Image in (a) Colour, (b) Gray scale and (c) Black and White Format

B. Impulse Noise Representation

Since noise is a random variation in the pixel value with respect to the neighbouring pixels, it can be defined as

$$NI(x,y) = I(x,y) + N(x,y) \qquad (1)$$

The impulse noise is an abrupt variation of the brightness. This variation is random and it contaminates some of the pixels in the image. Because of such appearance it is also called as salt and pepper noise. Since, few of the pixels are infected with the noise signal unlike Gaussian noise, mathematically, it can be represented as:

$$NI(x,y) = \begin{cases} 0\,/\,255 \; with\ probability\ p \\ I(x,y)\ with\ probability\ 1-p \end{cases} \qquad (2)$$

As disclosed in the Equation2, the noisy pixel in the image can take either 0 or 255 value, representing either dark spot or bright spot, with total probability of p. If the pixel in the image remained uncompromised, it is called original pixel and it will appear with probability of $(1-p)$.Through the subsequent sections, a novel approach for removing impulse noise from the image is presented.

IV. PROPOSED METHODOLOGY

The proposed technique for denoising the impulsive corrupted image is evident through steps outlined in the flowchart as shown in the Fig. 2.

To begin with, the pure image is fed to the system. This image can be either colour image or gray scale image or it can be black and white image. We carried out the demonstration using colour image of Lena, Mandrill and Bridge in .jpg format. In the second stage, the impulse noise is added in to the image. This noise addition is in step of 10% and is carried out up to 60%. Due to such addition of noise in steps, it is possible to clearly observe the effect of noising and denoising on the image. Due to the impulse noise, all pixels in the image are not infected, as it happens in case of Gaussian noise. So, it is obvious to find the infected pixels in the image. To identify the infected pixels in the image, Rank Order Absolute Difference (ROAD) is calculated in the next stage of the process, ROAD is calculated using the formula

$$ROAD_m(x) = \sum_{i=1}^{m} r_i(x) \qquad (3)$$

TABLE I. TERMINOLOGY

Notation	Description	Notation	Description
$ROAD_m(x)$	Rank Order Absolute Difference	*255, max*	White pixel
$x=(x1,x2)$	Location of pixel under consideration	$R(x,y)$	Amount of red colour at x,y location
m	Number of most similar neighbours	$Y(x,y)$	Amount of yellow colour at x,y location
$w_I(x)$	Impulsive weight	$B(x,y)$	Amount of blue colour at x,y location
σ_I, σ_J	Initial threshold value	$NI(x,y)$	Function of noisy image
$\omega(x,y)$	Resulting weight of y with respect to x	$I(x,y)$	Function of original image
ω_S	Spatial Weight	$N(x,y)$	Function of external noise
ω_R	Radiometric Weight	$J(x,y)$	Joint impulsivity
ω_I	Impulsive Weight	r_i	Intensity difference of neighbouring pixels
0, min	Black pixel		

In the process, new weight is computed using the values of the ROAD obtained in the previous step. The new weight can be calculated using

$$W_I(x) = e^{\frac{ROAD(x)^2}{2\sigma_I{}^2}} \qquad (4)$$

In this case, the optimal value of control parameter to calculate the weight is decided by carrying out multiple iterations. The joint impulsivity of the pixel under consideration and the neighbouring pixel is calculated in the next stage as

$$J(x,y) = 1 - e^{-\left(\frac{ROAD(x)+ROAD(y)}{2}\right)^2/2\sigma_J^2} \qquad (5)$$

It necessary to decide whether the pixel under consideration is impulsive or not. If the pixel is impulsive it means it is infected and vice versa. The pixel can be impulsive if $JI(x,y) \sim 1$. After estimating the infected pixels in the image, the final weight is calculated using spatial, radiometric and impulsive weights.

$$\omega(x,y) = \omega_S(x,y)\omega_R(x,y)^{1-J(x,y)}\omega_I(y)^{J(x,y)} \qquad (6)$$

These weights are applied on each pixel in the image. This process mitigates the effect of the impulse noise on the pixels in the image. Hence the output image is the denoised image.

The steps carried out for denoising the image are elaborated in flowchart as shown in figure 2.

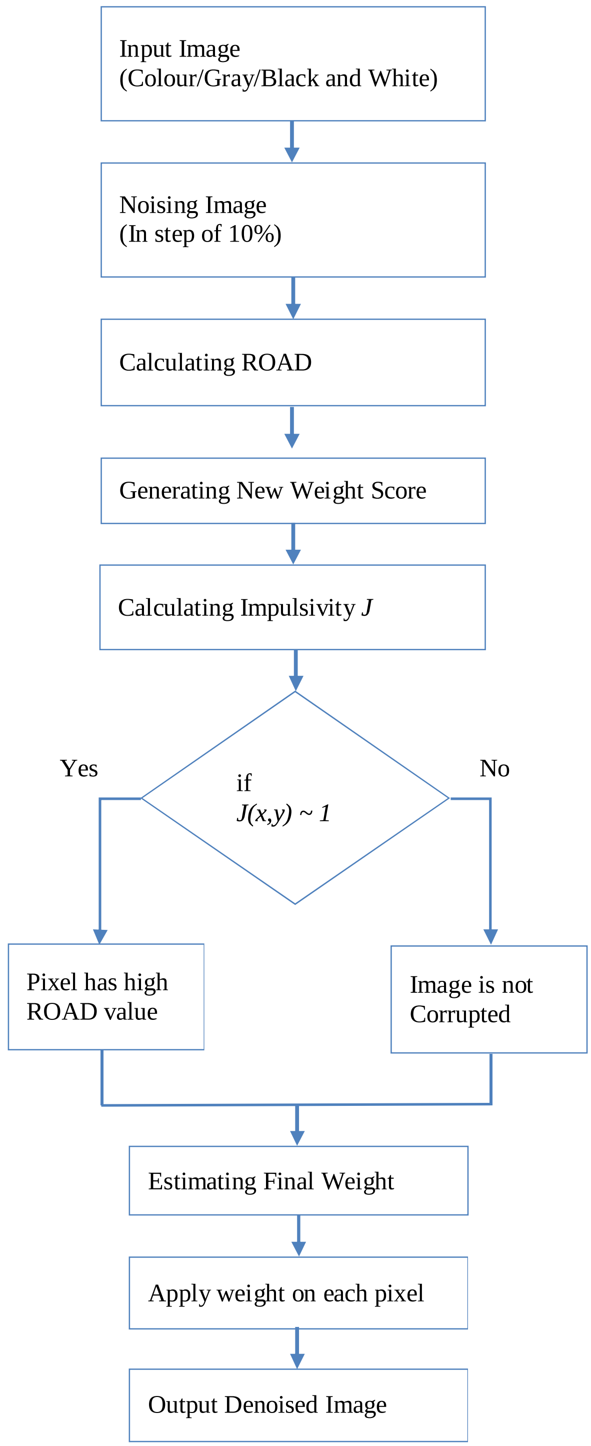


Fig 2. Flowchart for denoising impulse effect in image

V. RESULT AND DISCUSSION

A. Noise Density Vs PSNR

The ratio of the strength of corrupted pixels in the image to the strength of the uncorrupted pixels in the image is called as Peak Signal to Noise Ratio (PSNR). This value affects the fidelity of the image representation. PSNR is used as a measure of quality of reconstruction of corrupted image. Higher the value of PSNR, the better will be the reconstruction of the noisy image.

From the Fig. 3, it is evident that, for 10dB impulse noisy image, the adaptive median filter performs better, but, as the noise level increases gradually from 10 dB to 60 dB the performance of the adaptive median filter linearly decreases. At this stage the proposed filter seems to perform better than rest of the filter and significant PSNR of 33.8988 dB is observed.

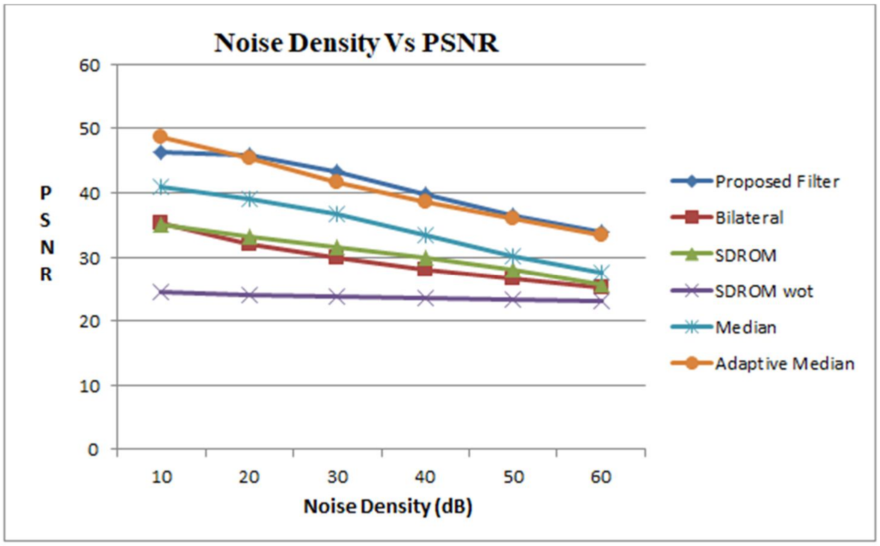


Fig 3. Noise Density Vs PSNR

B. Noise Density Vs MAE

Mean Absolute Error (MAE) is the means for comparing errors between the paired observations.

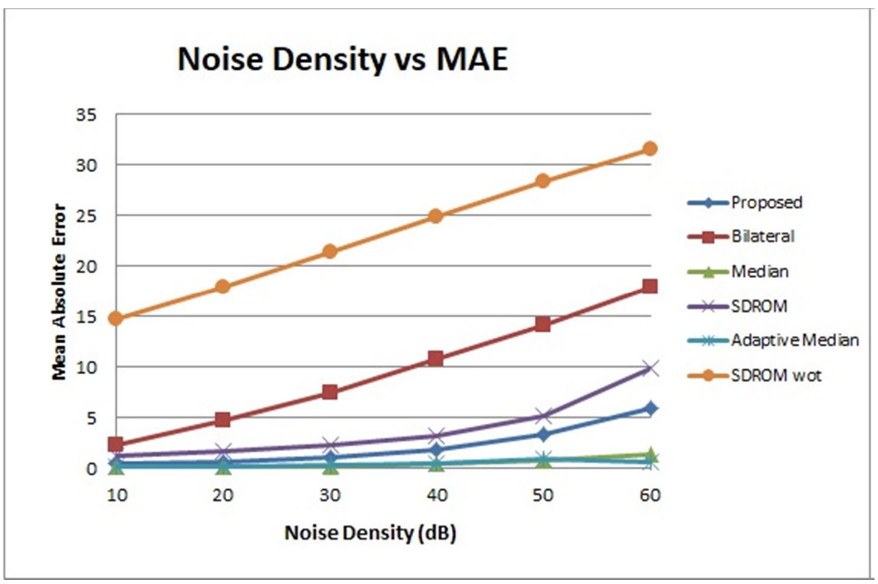


Fig 4. Noise Density Vs MAE

From the Fig. 4, it is obvious that, performance of the proposed denoising approach is comparable with the outcome observed with adaptive median filter. As the noise density increases to 30 dB, the MAE starts increasing gradually and it is reported as 5.95002 at 60 db. Such gradual increase in the MAE is almost not noticed by humans.

C. Noise Density Vs MSSIM

MSSIM is a measure of similarity between two images. Here this component indicates, how much the reconstructed image is similar to the original image. In other words, it indicates how much better reconstruction takes place using a particular filter. As shown in the Fig.6 below, the proposed filter performs extremely well at 10 dB noise level. Even at the highest level of noise addition, at 60 dB, the quality of reconstruction is deteriorated but still it is at 0.266289, which is still better than the rest of the filters.

The exact visual effects can be seen through the subsequent collection of input images, noisy images with 10 db to 60 db noise and respective recovered images.

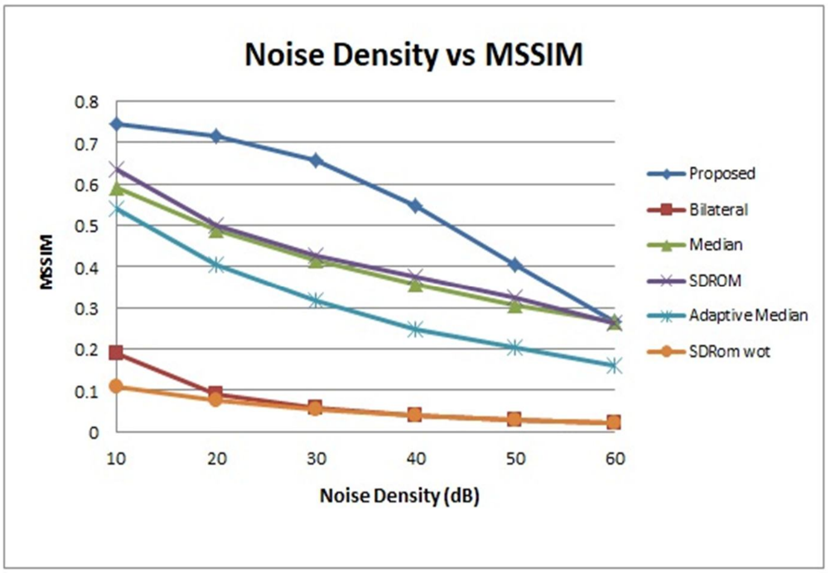
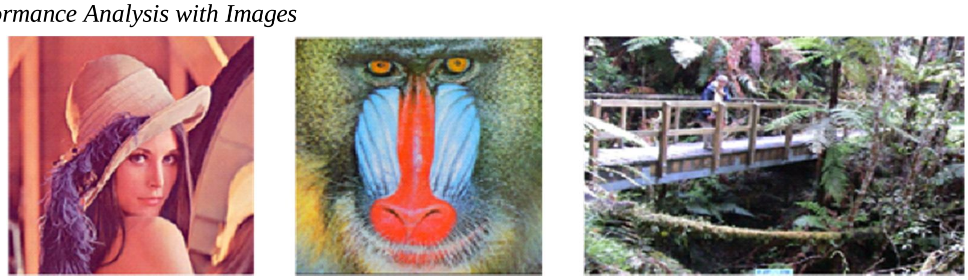


Fig 5. Noise Density Vs MSSIM

D. Performance Analysis with Images



(a)Lena (b) Mandril (c) Bridge

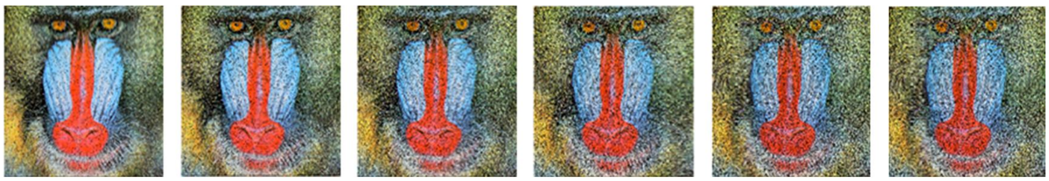
Fig 6. Input Images

(a) (b) (c) (d) (e) (f)

Fig 7. Lena image noising from 10dB (a) to 60 dB (f)

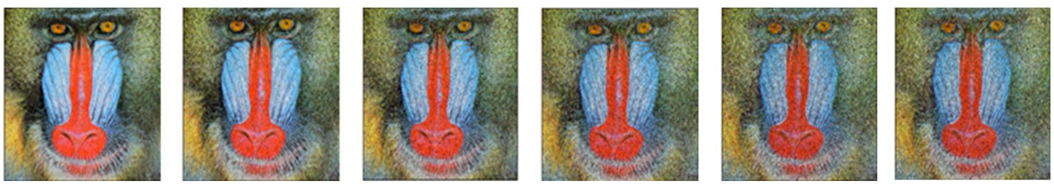
(a) (b) (c) (d) (e) (f)

Fig 8. Lena image denoising for 10dB (a) to 60 dB (f)



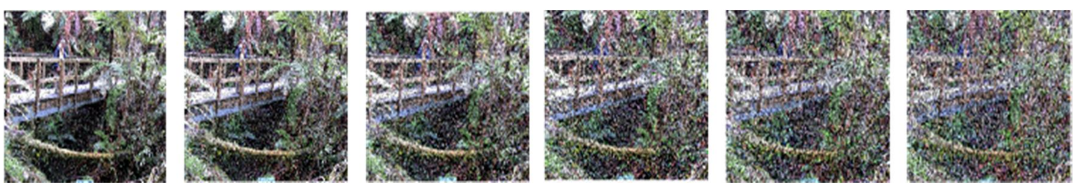
(a) (b) (c) (d) (e) (f)

Fig 9. Mandrill image noising from 10dB (a) to 60 dB (f)



(a) (b) (c) (d) (e) (f)

Fig 10. Mandrill image denoising from 10dB (a) to 60 dB (f)



(a) (b) (c) (d) (e) (f)

Fig 11. Bridge image noising from 10dB (a) to 60 dB (f)

(a) (b) (c) (d) (e) (f)

Fig 12. Bridge image denoising from 10dB (a) to 60 dB (f)

VI. Conclusion

In this paper, an effective algorithm is proposed for removing random valued impulse noise from the colour images. For demonstration of the effectiveness of the proposed algorithm, three different images of Lena, Mandrill and Bridge are considered in jpg file format. Impulse noise is added in all three images from 10 dB to 60 dB. In the process of restoring the noisy image, first of all ROAD is calculated for identification of the infected pixels and the final correcting weight is calculated using spatial, radiometric and impulsive weights. From the Figure 3 to 5 it is evident that, the proposed denoising approach performed well on Lena image with 33.8988 dB PSNR, 5.95002 MAE and 0.266289 MSSIM at a noise level of 60 dB. Similarly for Mandrill image the performance parameters are observed as 31.219 dB PSNR, 8.10262 MAE and 0.23199 MSSIM and for Bridge image the performance parameters are noticed as 29.0542 dB PSNR, 9.0102MAE and 0.23963 MSSIM.

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