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Impulse Noise Removal from Digital Images- A Computational Hybrid Approach

By M.Jayamanmadharao, M S Ramanaidu & Dr. KVVS Reddy
Andhra University, A.P., India

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IMPULSE NOISE REMOVAL FROM DIGITAL IMAGES- A COMPUTATIONAL HYBRID APPROACH

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Impulse Noise Removal from Digital Images- A Computational Hybrid Approach

M.Jayamanmadharao [α], M S Ramanaidu [σ] & Dr. KVVS Reddy [ρ]

Abstract - In digital Image Processing, removal of noise is a highly demanded area of research. Impulsive noise is common in images which arise at the time of image acquisition and or transmission of images. In this paper, a new hybrid filtering algorithm is presented for the removal of impulse noise from digital images. Here, we replace the impulse noise corrupted pixel by the median of the pixel scanned in four directions. The experimental results of this filter applied on various images corrupted with almost all ratios of impulse noise favor the filter in terms of objectivity than many of the other prominent impulse noise filters.

I. Introduction

Digital images play an important role both in daily life applications such as Satellite television, Magnetic Resonance Imaging, Computer Tomography as well as in areas of research and technology such as geographical information systems and astronomy .Digital images are often corrupted by different types of noise during its acquisition and transmission phase. Such degradation negatively influences the performance of many image processing techniques and a preprocessing module to filter the images is often required [1, 2]. To enhance the quality of images various images enhancement or restoration techniques are use. Efficiency of every method is depending on the quality of input images.

The overall noise characteristics in an image depend on many factors, including the type of sensor, pixel dimensions, temperature, exposure time, and speed. The goal of image denoising is to remove the noise while retaining the important signal features. The denoising of a natural image corrupted by noise is an important problem in image processing. Image denoising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images. This paper discusses the methods of noise reduction of impulse noise image using hybrid approach [3-5].

II. Literature Review

The one of the emerging field of image processing is removal of noise from a contaminated image. Many researchers have suggested a large number of algorithms and compared their results. The main thrust on all such algorithms is to remove impulsive noise while preserving image details. Some schemes utilize detection of impulsive noise followed by filtering where as others filter all the pixels irrespective of corruption. In this section an attempt has been made for a literature review for the filtering of random-valued impulsive noise.

Umesh Ghanekar et.al [6] presents a new filtering scheme based on contrast enhancement within the filtering window for removing the random valued impulse noise. The application of a nonlinear function for increasing the difference between a noise-free and noisy pixels results in efficient detection of noisy pixels. As the performance of a filtering system, in general, depends on the number of iterations used, an effective stopping criterion based on noisy image characteristics to determine the number of iterations is also proposed. Extensive simulation results exhibit that the proposed method significantly outperforms many other well-known techniques. The performance of the proposed scheme has been compared with many existing techniques. The efficacy of the proposed method is demonstrated by extensive simulations. The experimental results exhibit significant improvement in the performance over several other methods. Also, the proposed method requires less iteration in comparison with some recently proposed methods.

Yiqiu Dong et.al [7] proposes an image statistic for detecting random-valued impulse noise. By this statistic, it can identify most of the noisy pixels in the corrupted images. Combining it with an edge-preserving regularization, it obtain a powerful two-stage method for denoising random-valued impulse noise, even for noise levels as high as 60%. Simulation results show that proposed method is significantly better than a number of existing techniques in terms of image restoration and noise detection. The authors say that for the other methods, there are still some noticeable noise unremoved and there exist some loss and discontinuity of the details, such as the hair around the mouth of the baboon and the edges of the bridge. In contrast, the visual qualities of restored images are quite good, even with the abundance of image details and the high noise level present in the images. Simulation results show that proposed method outperforms a number of existing methods both visually and quantitatively.

Author α : Professor, Department of EIE, AITAM, Tekkali, A.P., India.
Author σ : Associate Professor, Department of EIE, AITAM, Tekkali, A.P., India.
Author ρ : Professor, Department of ECE, AU College of Engineering, Andhra University, A.P., India.

Stefan Schulte et.al [8] presented a new impulse noise reduction method for color images. Color images that are corrupted with impulse noise are generally filtered by applying a grayscale algorithm on each color component separately or using a vector-based approach where each pixel is considered as a single vector. It discuss an alternative technique which gives a good noise reduction performance while much less artefacts are introduced. The main difference between the proposed method and other classical noise reduction methods is that the color information is taken into account to develop a better impulse noise detection method and a noise reduction method that filters only the corrupted pixels while preserving the color and the edge sharpness.

Abdul Majid et.al [9] proposes a novel impulse noise removal scheme that emphasizes on few noise-free pixels and small neighborhood. The proposed scheme searches noise-free pixels within a small neighborhood. This scheme has provided better performance as compared to existing approaches. Moreover, this scheme is capable to restore the corrupted images while preserving edges and fine details. Experimental results show that the proposed scheme is capable of removing impulse noise effectively while preserving the fine image details. Especially, this approach has shown effectiveness against high impulse noise density

Leah Bar et.al [10] presents a unified variational approach to image deblurring and impulse noise removal. The objective functional consists of a fidelity term and a regularizer. Data fidelity is quantified using the robust modified L1 norm, and elements from the Mumford-Shah functional are used for regularization. It shows that the Mumford-Shah regularizer can be viewed as an extended line process. It reflects spatial organization properties of the image edges that do not appear in the common line process or anisotropic diffusion. This allows distinguishing outliers from edges and leads to superior experimental results.

Zayed M. Ramadan [11] proposes a two-stage adaptive method for restoration of images corrupted with impulse noise. In the first stage, the pixels which are most likely contaminated by noise are detected based on their intensity values. In the second stage, an efficient average filtering algorithm is used to remove those noisy pixels from the image. Only pixels which are determined to be noisy in the first stage are processed in the second stage. The remaining pixels of the first stage are not processed further and are just copied to their corresponding locations in the restored image. The experimental results for the proposed method demonstrate that it is faster and simpler than even median filtering, and it is very efficient for images corrupted with a wide range of impulse noise densities varying from 10% to 90%. Because of its simplicity, high speed, and low computational complexity, the proposed method can be used in realtime digital image applications, e.g., in consumer electronic products such as digital televisions and cameras.

Jian-Feng Cai et.al [12] proposes a two-phase approach to restore images corrupted by blur and impulse noise. In the first phase, It identify the outlier candidates—the pixels that are likely to be corrupted by impulse noise. It considers that the remaining data pixels are essentially free of outliers. Then in the second phase, the image is deblurred and denoised simultaneously by a variational method by using the essentially outlier-free data. In general the two-phase method for salt-and-pepper noise performs better than for random-valued noise: it can handle salt-and-pepper noise as high as 90% but random-valued noise for about 55%. The main reason is that the former is easier to detect than the latter in the first phase. In fact, AMF is a very good detector for salt-and-pepper noise, and almost all the noise positions can be detected even when the noise ratio is very high. In addition, with salt-and-pepper noise, most of the noisy pixels are much more dissimilar to regular pixels, hence are easier to detect. However, there is no good detector for random-valued noise when the noise ratio is high. The performance for random-valued noise can be improved if a better noise detector can be found in the first phase.

R K Kulkarni et.al [13] proposes a simple yet effective algorithm for effectively denoising the extremely corrupted image by impulse noise. The proposed method first classifies the pixels into two classes, which are "noise free pixel" and "noisy pixel" based on the intensity values. The corrupted pixels are replaced by "alpha trim- mean" value of uncorrupted pixels in the filtering window. The method adaptively changes the size of filtering window based on the number of "noise free pixels". Because of this, the proposed method removes the noise much more effectively even at noise density as high as 90% and preserves the good image quality. Experimental results show that this method always produces good output, even when tested for high level of noise. The details inside the image are preserved. This method is simple and relatively a fast method and suitable for consumer electronic products such as digital camera.

X D Jiang [14] proposed a new nonlinear filter for attenuating impulsive noise while preserving image details. The filter truncates the grey value of a pixel to the maximal or minimal value of its enclosed surrounding band. Impulsive noise inside the band is thus attenuated while image details are preserved as long as they stretch to the band. The recursive form of the proposed filter leads to a simple architecture for fast implementation. Theoretical analysis and experimental results demonstrate the effectiveness of this new filter for both noise attenuation and detail preservation. According to simulation results the proposed filter outperforms the standards median filter, the centre-weighted median filter and the unidirectional multistage median filter in terms of mean absolute error and filtering speed.

J.Harikiran et.al [15] introduces the concept of image fusion of filtered noisy images for impulse noise reduction. Image fusion is the process of combining two or more images into a single image while retaining the important features of each image. Multiple image fusion is an important technique used in military, remote sensing and medical applications. Five different filtering algorithms are used individually for filtering the image captured from the sensor. The filtered images are fused to obtain a high quality image compared to individually denoised images. The performance of filters was evaluated by computing the mean square error (MSE) between the original image and filtered image. Experimental results show that this method is capable of producing better results compared to individually denoised images.

III. Proposed Method

The main challenge in impulse noise removal is to suppress the noise as well as to preserve the details (edges). This paper presents a simple & effective way to remove the impulse and random noises from the digital image. The first step is to detect the impulse and random noise from the image as shown in Fig 1. In this stage, based on the only intensity value, the pixels are roughly divided into two classes, which are "noise-free pixel" and "noise-pixel". Then the second stage is to eliminate the impulse and the random noise from the image.

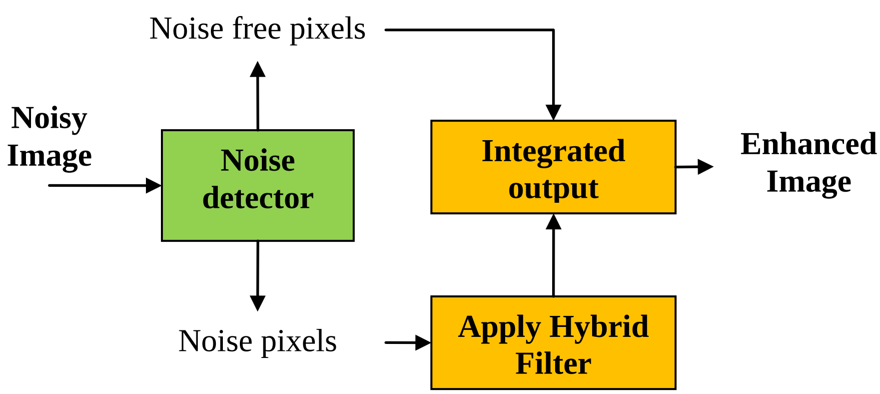


Fig. 1 : System Structure

The proposed filter operates on impulse noise densities without jeopardizing image fine details and textures. Fast and automated algorithm is focused. The proposed filter does not require any tedious tuning or time consuming training of parameters as well. No priori threshold is to be given. Instead, the threshold is computed locally from image pixels intensity values in a sliding window using weighted statistics. More precisely, the weighted mean value and the weighted standard deviation are estimated in the current window. The weights are the inverse of the distance between the weighted mean value of pixels in a given window and the considered pixel. A result is that impulse noise does not corrupt the determination of these statistics from which the Threshold is derived. Noise-free pixels are relatively easy to be selected by utilizing the binary decision. A limit for window is set to contain a minimum number of pixels avoid loss of image details .In filtering mechanism, the proposed filter adopts fuzzy reasoning to deal with uncertainties present in the local information. These uncertainties, e.g. thin lines or pixels at edges being mistaken as noise-pixels, are caused by the nonlinear nature of impulse noise. The fuzzy set is processed by calculating local information to produce a suitable fuzzy membership value.

a) Proposed Algorithm

In an image contaminated by random-valued impulse noise, the detection of noisy pixel is more difficult in comparison with fixed valued impulse noise, as the gray value of noisy pixel may not be substantially larger or smaller than those of its neighbors. Due to this reason, the conventional median-based impulse detection methods do not perform well in case of random valued impulse noise. The numerical Threshold value is defined a priori or chosen after many data dependant tests. The literature shows that an optimal threshold in the sense of the mean square error can be obtained for most real data. However, Threshold suitable for a particular image is not necessarily adapted to another one. To overcome this problem, the following algorithm is proposed.

Step 1:	Read the input image and add Random Valued Impulse Noise to the image.
Step 2:	Compute the weighted mean value of the window. $$\mathrm{M(i,j)} = \frac{\sum_{m,n} w_{m,n}\, x_{i+m,j+n}}{\sum_{m,n} w_{m,n}} \quad (1)$$
Step 3:	Weighted standard deviation is calculated using the weighted mean value.

$$\sigma(i,j) = \frac{\sum_{m,n} w_{m,n} (X_{i+m,j+n} - M(i,j))^2}{\sum_{m,n} w_{m,n}} \quad (2)$$

Step 4: Threshold is obtained from the above statistical parameters which is given by A$x\boldsymbol{\sigma}$(i,j), α=1

Step 5: Noisy pixel is found when difference between centre pixel and weighted mean exceeds threshold.

Step 6: Binary flag represents as follows:
1- Noisy pixel
0- Noise free pixel.

Step 7: Compute the median value for noise free pixels

Step 8: Determine absolute difference.
D(i,j)=max{d(m,n)}-------(3)
Where d(m,n)=$\frac{|x(m,n)-x(i,j)|}{255}$ $x(n,m) \in_{\omega} (x)_{(i,j)}$
X(i,j) is the centre pixel in window.

Step 9: Compute the fuzzy membership value F(i,j)
F(i,j)=0 if D(i,j)<T_1
F(i,j)=1 if D(i,j)> or equal to T_2

Step 10: Compute the restoration term y(i,j)

IV. Performance Evaluation

There are two main methodologies are used to estimate the quality of images. They are subjective evaluation and objective evaluation.

a) Subjective Evaluation

To obtain reliable quality rating, subjective viewing tests carried on post processed images. The rating for given image is given as excellent, good, average, bad etc. but the result of given rating depends on the following factors.

- The experience and motivation of the subject.
- The range of the picture used,
- The conditions under which the pictures are viewed

b) Objective quality measures

The simplest and still most commonly used objective measures are Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR). The mathematical formulae for the two are

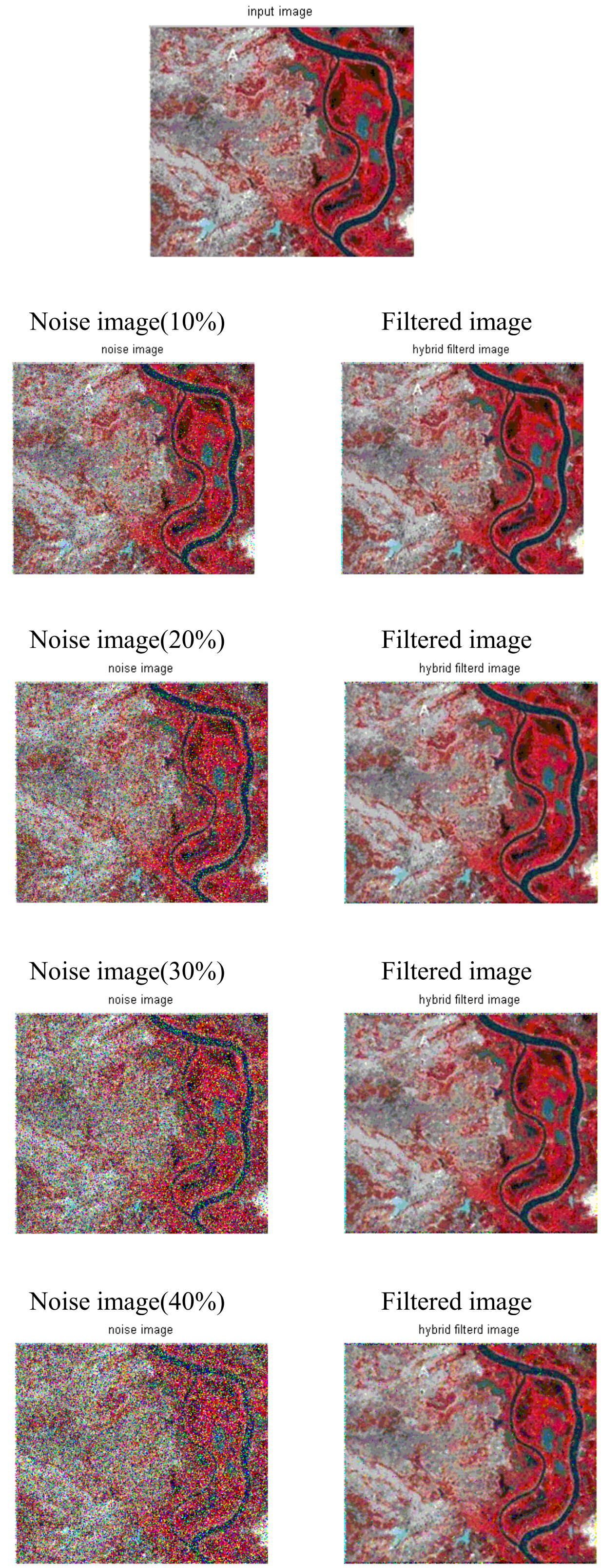
$$\text{MSE} = \frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}\left[I(x,y) - I^1(x,y)\right]^2$$

PSNR = 20 * log10 (255 / sqrt(MSE))

Where I(x,y) is the original image, I'(x,y) is the approximated version and M,N are the dimensions of the images. These measures give simple mathematical deviation between original image and reconstructed image. They operate solely on pixel by pixel basis.

V. Results

The designed filter was tested with impulse noise in remote sensing images under several noise conditions, it shown in Fig 2.



Noise image(50%) Filtered image

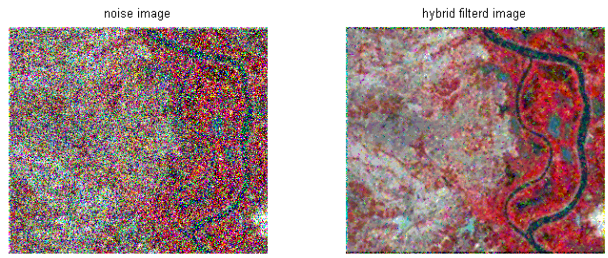


Figure 2 : Original, noise and filtered images of hybrid method

Table 1 : Noise ratio, MSE and PSNR

Noise (%)	MSE	PSNR
10	392.7394	44.379
20	589.0978	40.857
30	818.9550	37.996
04	1.1439e+00	35.094
50	1.5667e+00	32.362

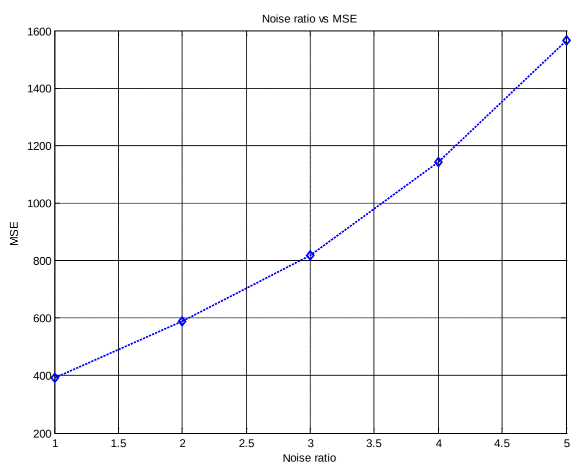


Figure 3 : Shows the Noise ratio vs MSE

These results are shown in Table 1. The original image is corrupted by mixed noise. Based on the result data we construct the graphs for MSE, PSNR under different noise ratios, which are shown in Fig 3, 4. From these figures we said that Image with lower MSE and a high PSNR, it means the image is a better one.

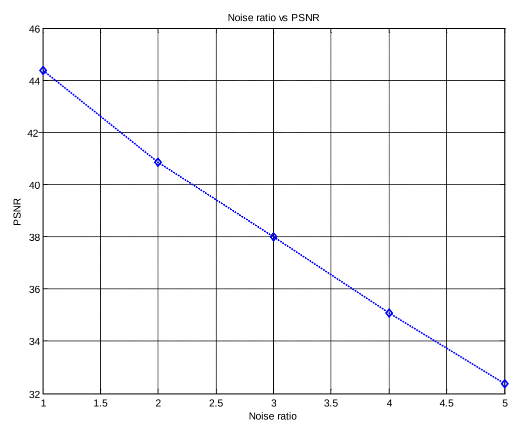


Figure 4 : Noise ratio vs PSNR

Table 2 shows the MSE, PSNR values of the proposed method which is compared with the other methods. Based on this data we constrcut the graph as shown in Fig 5, from this graph we clearly observe that the proposed method performs better in the form of high MSE with low PSNR.

Table 2 : Performance evaluation with different filtered images at same noise level for Remote sensing image

	Noise level 10%		Noise level 20%		Noise level 30%		Noise level 40%		Noise level 50%	
Filter	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR	MSE	PSNR
Vector median filter(VMF)	47.984	31.23	86.9	28.6	146	26.6	333.88	24	696	19.6
Rank conditioned VMF	48.368	31.4	83.4	29.2	142	26.9	312	23.4	683	19.7
Rank conditioned & threshold VMF	68.7	30.6	99.6	30.12	184	23	411	20.3	918	18.6
Center weighted VMF	173.42	26.1	273	22.9	482	21	944	18	2014	14.9
Absolute deviation VMF	19.58	34.2	28.27	31.8	77.9	29	211	22	346.0	22.8
Spatial Median Filter Image	12.88	37.032	16.86	35.86	30.64	33.26	75.816	29.369	174	25.724
Modified Spatial Median Filter	13.99	38.86	14.76	36.78	27.44	36.321	72.89	31.789	162	22.346
Proposed filter(Hybrid)	392.7394	44.3795	589.0978	40.8579	818.9550	37.9964	1.1439e+003	35.0940	1.5667e+003	32.3621

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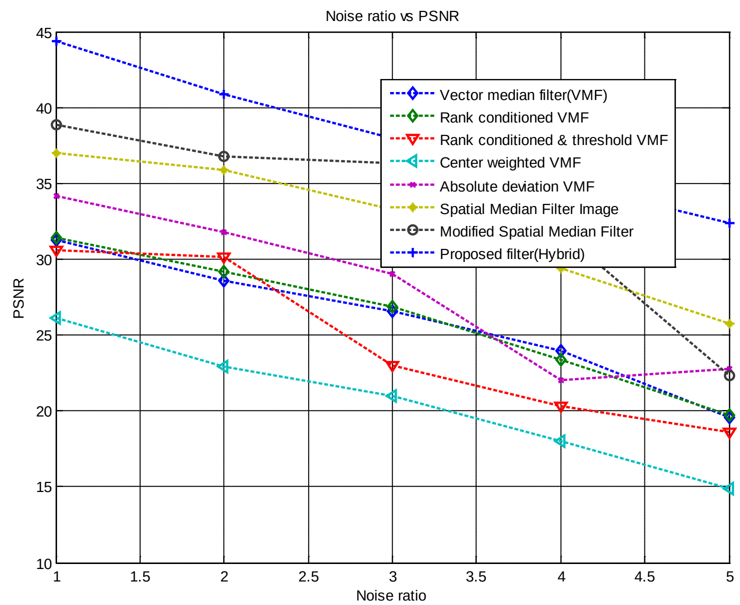

Figure 5 : Shows the comparison among the filters

VI. Conclusions

A novel hybrid filtering operator for removing mixed noise from digital images is presented. The fundamental superiority of the proposed operator over most other operators is that it efficiently removes impulse noise from digital images while preserving thin lines and edges in the original image. Extensive simulation results verify its excellent impulse detection and detail preservation abilities by attaining the highest PSNR and lowest MAE values across a wide range of noise densities. Thus rampant loss of image is reduced without jeopardizing image fine details.

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