Adaptive Switching based Impulse noise suppression using Wind Driven Optimization

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Abstract **A new Optimization based technique of suppression of Random valued impulse noise from the corrupted image using adaptive Switching Technique is presented in this paper. The algorithm has two stages, i.e. detection of impulses followed by filtering. The impulse detection method is based on the concept of cumulated distances between the processed pixel and its neighbors. The measure of impulsiveness is determined by the sum of distances to only the most similar pixels of the neighborhood. In order to make the detection results more accurate, Optimization techniques has been used for the selection of optimal parameters. Filtering is performed by the simple Adaptive median filter. Experimental result analysis shows that the performances of the proposed techniques achieve high peak signal-to-noise ratio and great image quality by efficiently suppressing impulse noise.**

Keywords* — *Salt and Pepper Noise (SPN), Random Valued Impulse Noise (RVIN), Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Image Quality Index (IQI), Non-Local Means (NLM), Wind Driven Optimization (WDO)

I. INTRODUCTION

Image denoising for impulse noise suppression is one of the widely studied unsolved problems and plays a significant role in the research area of image processing and computer vision. Images are most of the time contaminated by impulse noise during the process of acquisition and transmission due to malfunctioning pixel elements in the camera sensors, channel transmission errors or faulty storage hardware. Therefore any image needs to be passing through a pre-processing stage before used for any application. Noise filtering is one of the important parts of this stage. The objectives of image denoising algorithms are to detect and suppress the presence of noise in the image without harming the fine details of the image.

Impulse noise found in digital images is a spark that affects the contents of digital images. It distorts the pixels of a digital image by replacing the original value either by fixed value or any random value within the available dynamic range. So there are two different form of the impulse noise as per the noise distribution: salt and pepper noise and Random valued impulse noise. Impulse noises can be described by the following model:

$$x(i,j) = \begin{cases} \eta(i,j) & \text{with probability} \quad p \\ y(i,j) & \text{with probability} \quad 1-p \end{cases}$$

Where, $x(i,j)$ indicates a corrupted image pixel, $y(i,j)$ indicates an original noise free image pixel and $\eta(i,j)$ denotes a noisy impulse at the location (i,j). In salt-and-pepper noise, the corrupted pixels take either minimal or maximal values i.e. $\eta(i,j) \in \{L_{min}, L_{max}\}$, and for random-valued impulse noise, noisy pixels take any value within the range minimal to maximal value i.e. $y(i,j) \in [L_{min}, L_{max}]$ where, L_{min}, L_{max} denote the lowest and the highest pixel luminance values within the dynamic range respectively so that it is a little bit difficult to remove random valued impulse noise rather than salt and pepper noise [1],[2],[3].Figure: 1 shows the result of image corrupted by random valued and salt and pepper impulse noise. Most of the schemes work very well under salt and pepper noise (SPN), whereas under random valued impulse noise (RVIN) their performance is quite miserable.

Noise removal from images is a prominent field of research and many researchers have suggested a large number of methods and compared their results [4]. The main thrust on all such methods is to suppress impulsive noise while keeping the image details unaffected. The simple median filter [2] and its modifications [5], [6]were once the most popular nonlinear filter for filtering out impulse noise. But it could not differentiate between noisy and noise free pixels. Due to this limitation all the pixels are take parts in filtering process and results in destroying fine details and producing blotches in the restored images. A solution to this problem is to devise an impulse detector to distinguish between noisy and non-noisy pixels prior to filtering from image so that the identified noisy pixels can only be suppressed. In last few year some better noise removal algorithm with different kinds of noise detectors have been proposed, such as signal-dependent rank order mean (SD-ROM) filter [7],tri-state median (TSM) filter[8],multistate median (MSM) filter [9], adaptive center-weighted median (ACWM) filter [10] and the pixel-wise MAD (PWMAD) filter [11] ,adaptive mad-based threshold (ADMAD)[12],the Alpha Trimmed Median Based filter(ATMBF)[13],Modified switching Weighted

 DOI : 10.35291/2454-9150.2019.0253

ISSN : 2454-9150 Vol-05, Issue-03, June 2019

median filter(MSWMF) [14]Trilateral filter[15], a directional weighted median (DWM) filter [16] and so on.A universal filter (ROR-NLM) [17] was proposed by combining a complicated impulse detector called the robust Outlyingness ratio (ROR) with the nonlocal means (NLM) method. This method provides poor results for low noise density images. In[18]Ali S.Awad used the optimal direction of a defined window as a measure to distinguish between noise-free and noisy pixel. For detecting the central pixel whether it is corrupted or not, a similarity parameter, i.e. normalized distance in optimal direction (NDOD) is calculated by measuring the normalized distance between the pixels in the optimal direction and the tested pixel,. Then by using a proper threshold, it can decide whether the test pixel is a noisy or an original pixel. More edge pixels can be detected if the accurate or optimal direction of the edge is determined. The pixel that has small deviations with the pixels in the optimal direction is deemed an uncorrupted pixel. GuangyuXu currently proposed a universal noise filter in [19]by combining the robust local image statistics called the extremum compression rank order absolute difference (ECROAD)with the nonlocal means. The filter is capable of effectively suppressing any type of impulse noise by varying some parameters in the algorithm.

Guangyu Xu currently proposed a universal noise filter in [30] by combining the robust local image statistics called the extreme compression rank order absolute difference (ECROAD) with the nonlocal means. The filter is capable of suppressing any type of impulse noise efficiently by varying some parameters discussed in the method. Another filtering technique is the Adaptive rank weighted switching filter RWASF [31], this filter is based on order statistics and uses the weighted cumulative distances between pixels for the detection of corrupted pixel elements. Some techniques using the fuzzy rule for denoising methods for finding out corrupted pixels and uncorrupted pixels more effectively for removal of RVIN have also been\ introduced in the last two years. One of such methods is a new weighted mean filter ANWMF [32] method, the noise detector proposed in this case identifies a noisy pixel by some fuzzy rule that matches the stochastic nature of impulse noise and highly improves the restoring ability. In addition to this, a local image statistic minimum edge pixels difference (MEPD) is used to identify edge pixels from noisy pixel element. Muhammad Habib proposed another fuzzy based method called adaptive fuzzy inference system based directional median filter (AFIDM) [33] method for impulse noise removal. The algorithm uses fuzzy logic to construct a membership function adaptively for robust fuzzy inference based impulse noise detector which can efficiently distinguish between original pixels and noisy pixel element without affecting the edges and detail information present in the image. However, at higher noise densities, it fails to restore fine details due to improper classification of noisy and non-noisy pixel elements. Machine learning decision-based approach namely multiclass SVM based adaptive filter (MSVMAF) [29] has also been proposed, which utilizes variations in the feature vector set for noisy pixel detection and adaptive VMF as a filtering technique. But this has a disadvantage of requiring a prior knowledge base for the filter to operate.

In this paper, we proposed a new two stage noise removal algorithm using optimization techniques for suppression of random valued impulse noise. An easily implemented switching techniques performance is enhanced by choosing the optimal parameter for impulse detection. WDO has been used to choose such parameters best suited for the impulse detection.. Subsequently, the identified noisy pixels are filtered with a simple adaptive median filter.

The overall paper is organized as follows. Section-1 deals with introduction.Section-2 describe the proposed denoising work. The performance measures are discussed in Section-3. Section-4 discusses the simulation and results. Finally, Section-5 provides the concluding remarks.

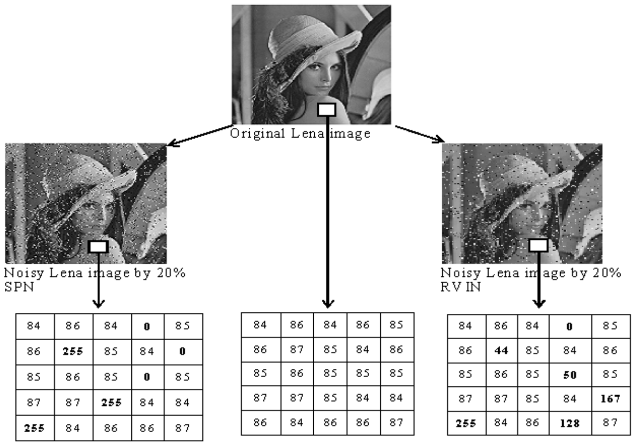


Figure 1: Original and noisy Lena image with SPN and RVIN

II. PROPOSED TECHNIQUE

Review There are two stages present in proposed technique, the first one is the adaptive switching trimmed technique [34] for impulse noise suppression. The second one is the simple adaptive median filter. A nature inspired optimization technique called Wind driven optimization is used to provide the optimal values i.e Window size, Threshold value and number of pixels after trimming in the window for distance measure. The distance measure is compared with the optimal threshold to decide whether a test pixel is noisy or not. Once the detection stage is over, with the help of generated binary map a simple adaptive median filter is used to restores the value of the noisy pixels by its non-noisy neighbors keeping the value of non-noisy pixels unaltered.

A. Adaptive Switching trimmed technique(AST) for noise detection

Adaptive Switching trimmed technique (AST) calculates a trimmed sum of distances for every pixel of the window W and the difference between weighted distances assigned to the center pixel and the minimum value of the weighted distances of the filtering window is used to detect the impulse. The steps to calculate AST are given below

Step 1: Let's consider a window 'W'of size (N×N) and find out the distance between each pixel in the window from other pixels i.e.

$$d_{mn} = x_m - x_n \qquad (1)$$

 DOI : 10.35291/2454-9150.2019.0253

ISSN : 2454-9150 Vol-05, Issue-03, June 2019

Where m =1.2.3…..N2and n = 1, 2 … (N2 -1)

Step 2: Arrange the distance matrix in ascending order

$$d_{m1}, d_{m2}, d_{m3} \ldots\ldots d_{mn},$$
$$\rightarrow d_{m(1)}, \leq d_{m(2)}, \ldots \ldots . d_{m(n)},$$

Step 3: Calculate the trimmed sum of distance for each and every pixel of the window W as given by the equation be

$$\hat{d}_m = \sum_{n=1}^{k} d_{m(n)} \quad (2)$$

Step 4: Find out the difference between trimmed sum distances of the center pixel to the minimum trimmed sum distance of the window as

$$D_{ij} = \frac{(\hat{d}_1 - \hat{d}_{(1)})}{k} \quad (3)$$

Where $\hat{d}_1$ is the trimmed sum distance w.r.t center pixel and $\hat{d}_{(1)}$ is the minimum trimmed sum distance of the window. 'k' denotes the number of nearest pixels taken for the calculation of the trimmed sum of distances

Step 5: Construct the binary map as given below by representing the impulse as '1' and a '0' denotes a noise free pixel at coordinate (i,j)

$$F(i,j) = \begin{cases} 1, & D_{ij} \geq T \\ 0, & D_{ij} < T \end{cases} \quad (4)$$

Where 'T' is a pre define threshold,

B. Noise Filtering:

The identified noisy pixel from the detection stage with the help of Binary map is now going through the filtering process. The filtering process used here is the simple adaptive median filtering technique as discussed below.

Step 1. Select a 3 × 3 filtering window 'w' from the Image 'I' and corresponding 3 × 3 window from generated binary map F.

Step 2. Collect the number of identified noise free pixels in the current filtering window from the corresponding binary map window.

Step 3. If the available noise free pixels is below three in the filtering window, the size of the filtering window need to be increased outwards by one pixel and go to step-2 otherwise proceed to next step

Step 4. Determine median of the identified noise free pixels and replace the center pixel with this value

C. Parameter selection:

To make the algorithm more efficient, optimal value of 'W', 'T' and 'k' is required. In order to determine the correct values of the parameters above parameters, an optimization technique known as Wind Driven optimization[34] is used. WDO search for optimal values of the above parameters by maximizing the objective function. WDO is applied on a different types of image with a noise density varies from 20% to 40%.

2.3.1: Wind driven Optimization (WDO):

WDO is a nature inspired population based heuristic global optimization algorithm. The main source of inspiration is the motion of wind on the earth surface. Wind, which is considered here as the group of air parcels moves horizontally on the earth surface to balance the air pressure. The population of air parcel are taken randomly within the bound [-1 1] in the search space. The velocity and the position of air parcels are updated in every iteration to obtain the optimum position by maximizing or minimizing the objective function. The velocity and the position update expression is given below

$$vel_{new} = (1-\alpha)vel_{cur} - gx_{cur} + \left(RT\left|\frac{1}{i} - 1\right|(x_{best} - x_{cur})\right) + \frac{cu_{cur}^{other\ dim}}{i} \quad (5)$$

$$x_{new} = x_{cur} + vel_{new} \quad (6)$$

Where vel_{new} and x_{new} represents the velocity and position for next iteration. The first term of (5) represents that the air parcels will begin its current path with a defined velocity proportionally with frictional force α is the friction coefficient. Second term denotes that the gravitation force draws the air parcel persistently from its current location and is proportional to the gravitational constant, g. It prevents any air parcel from sticking at the boundaries in the search space. The third term in (5) indicates the diminish the repercussions of pressure gradient, location closer to the optimum position; xbest. A rank based approach is included to rank (i) the air parcels in descending order depending on their pressure values. RT involved in the term denotes the universal gas constant and temperature. The last term in (5) allows the velocity direction to be adjusted by other dimensions with a greater impact on higher ranked air parcels which is the influence of Coriolis force.

In the algorithm the position represents the Threshold (T) and the number of neighboring pixels (k) for calculation of trimmed sum distance. The objective function is taken as the PSNR value which is depending upon 'k' and 'T'. In the experiment the population size is taken 50 and the number of iteration is 100.

III. PERFORMANCE MEASURES

One of the issues of denoising is the measure of the reconstruction error. The metrics used for performance comparison of different filters (existent and proposed) are Peak Signal to Noise Ratio (PSNR)[2, 26]:

In statistics, the mean squared error or MSE of an estimator is one of many ways to quantify the amount by which an estimator differs from the true value of the quantity being estimated. The mean square error (MSE) is commonly used and given that original image X of size $(M \times N)$ pixels and as reconstructed image $\hat{X}$, the MSE is defined as:

 DOI : 10.35291/2454-9150.2019.0253

$$MSE = \frac{1}{M \times N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (X_{i,j} - \hat{X}_{i,j})^2 \qquad (7)$$

MSE represents the power of noise or the difference between original and tested images.

It estimates the quality of a reconstructed image with respect to an original image. Reconstructed images with higher PSNR are judged better. PSNR is the ratio between the maximum possible power of a signal and the power of noise. Given that original image X of size $(M \times N)$ pixels and as reconstructed image $\hat{X}$, the PSNR (dB) is defined as:

$$PSNR(dB) = 10 \log_{10} \left(\frac{255^2}{MSE} \right) \qquad (8)$$

Where, 255 is the maximum possible amplitude for an 8-bit image.

An improvement in the PSNR magnitude will increase the visual appearance of the image. PSNR is typically expressed in decibels (dB). For comparison with the noisy image, the greater the ratio, the easier it is to identify and subsequently isolate and eliminate the source of noise.

IV. SIMULATIONS AND RESULTS

The proposed method uses Adaptive switching trimmed technique in the noise detection stage. In order to obtain the optimal parameters the WDO is applied to different types of image and the optimal value of the Threshold found between 30 to 40 and the number of neighboring pixel(k) in an 5x5 window found between 10 to 12. Figure 2 shows the convergence curve of the optimization technique. It can be observe from the graph that WDO takes very less iteration to provide the optimal values of the Threshold and number of neighbor pixels.

To validate the efficacy of the proposed algorithm, extensive simulations were carried out using standard test images having distinctly different features. The results for Goldhill and pepper image of size 512×512 are only presented here to evaluate the image restoration performance. The images are corrupted by random valued impulse noise and the proposed scheme along with the well performing schemes DWM, SDOOD, ROR-NLM, ENLM, AFIDM, ANWMF, RWASF, & MSVMF are applied to the noisy images. The noise density of the noisy images is varied from 20% to 60%.Subjective as well as objective evaluations have been made for each restored images.

The PSNR values of the proposed algorithm are compared against the existing well known algorithms by varying the noise density from 20% to 60% and are shown in Table 1 and Table 2. It may is clearly observed that the performance of the proposed algorithm is better than all the existing techniques at all noise level. In order to give a visual impression about the performances of the filters included in the comparison, the results for the Peppers image corrupted with 40 % and 60% random value impulse noise are given in Figure 3.

Table 1: Comparative analysis of PSNR(dB) for various

Methods /Noise	% of RVIN				
	Goldhill Image				
	20%	30%`	40%	50%	60%
DWM	34.99	32.13	30.33	28.54	25.30
SDOOD	35.21	31.22	29.12	26.21	22.31
ROR-NLM	35.55	31.61	30.41	28.32	27.64
ENLM	36.02	31.05	28.92	27.30	24.65
AFIDM	34.77	30.50	29.11	27.81	26.78
ANWMF	27.02	25.44	25.02	24.97	23.77
RWASF	36.44	33.22	30.72	26.79	22.65
MSVMF	36.71	33.31	30.69	28.82	26.77
Proposed	37.02	34.02	31.11	29.54	26.85

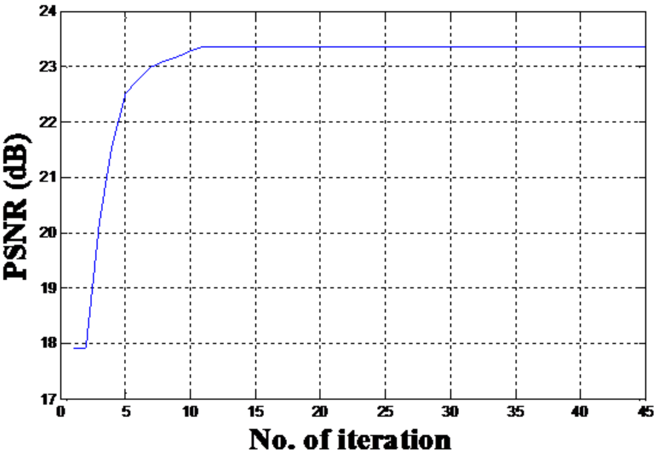
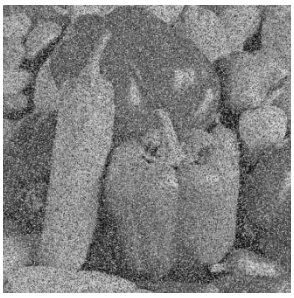


Figure-2: Convergence Curve

 DOI : 10.35291/2454-9150.2019.0253

International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-03, June 2019

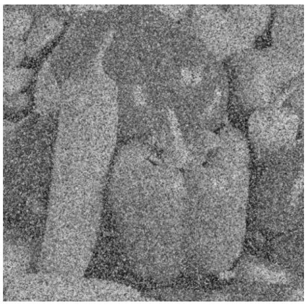
Original Image



Noisy image(40%)

Restored Image

Original Image



Noisy Image (60%)

Restored Image

Figure-3: Results of proposed algorithm on Peppers image

V. Conclusion

In this paper a new innovative restoration method is proposed to recovers images corrupted with RVIN effectively. The method used an optimization technique to produce the optimal value of threshold and number of desired pixels to identify the impulses in the image. In most of the algorithm threshold values are calculated experimentally which may not work for all types of image. As most of the switching techniques depend on a threshold value for detection of impulses, the uses of optimal threshold will enhance their performance. The used of adaptive median filter makes the filtering techniques more convenient and faster The comparative performance analysis in general shows that the proposed scheme outperforms the existing schemes both in terms of noise reduction and retention of images details

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