IMPULSE NOISE REMOVAL USING FUZZY SWITCHING MEDIAN FILTER

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Abstract: ***Elimination of noise is a necessary and challengeable operation in image processing. Before performing any operation, images have to be first restored. Images are corrupted by noise during image acquirement and transmission. Noise and blurring effects always corrupts any recorded image. To reduce the impulse noise level in digital images a novel algorithm FSM(Fuzzy Switching Median) filter is proposed in this paper .In this algorithm first phase is used to detect the impulse noise using clustered based approach, which works as impulse noise detector. And the second phase which is also called as filtering phase replaces the detected noise pixel, which also includes fuzzy reasoning to deal with uncertainties present in local information FSM, is capable of filtering all types of impulse noise.***

Keywords: Random valued impulse noise Impulse noise reduction, FSM, Fuzzy switching median, Peak signal noise ratio (PSNR), Mean square error (MSE).

I. INTRODUCTION

In image processing, Impulse noise reduction is an active area of research. With the usage of multimedia material becoming more common from day to day, visual data from high value digital images performances plays a significant role in numerous daily- life submissions. Unfortunately, digital images came by through numerous consumer electrical devices products are commonly subjected to the infectivity of impulse disturbance. Some With low computational complexity, a high-quality noise filter is required to satisfy two criteria namely, preserving the noise and suppressing the useful information in the signal. Reasons for impulse noise disturbance are malfunctioning pixel sensors, defective recollection flats, imperfections encountered in medium during transmission, external disturbances in a thunderous natural environment, electromagnetic interferences, and timing mistakes in analog-to-digital alteration.

De-noising the corrupted image is performed in the early channel of image processing before subsequent likeness processing procedures are conveyed out. Preprocessing is very important because following procedures (e.g., Image segmentation, enhancement, classification, parameter estimation, etc) are mostly influenced by the value of the filtered image. As more image sensors per unit locality are packed on a portion, image apprehending device has become more perceptive to the exposure of impulse noise. To this end, digital camera manufacturers mainly rely on image de-noising algorithms to improve the quality of image came by camera.

The goal of image de-noising is to estimate the original image from the noisy image. De-noising and pre-processing are the important task in digital image processing. For impulse noise reduction there are many median filters are available although these methods have been improved many times, but the quality of de-noising image is still not providing satisfactory results.

As a result, a various number of methods have been suggested for the removal of impulse disturbance expressly for the exclusion of impulse disturbance, nonlinear filters can be well thought-out as the state-of-the-art methods granted their remarkable performances. For example, the median filter is one of the best choice to get rid from impulse disturbance. It works in simply and tried to finds all the noise and noise free pixels identically. But due to this method, Some fine details and image borders are tainted, the median filter often leaves attractive minutia at best blur and at worst missing. This difficulty has given up the reason for the development of different categories of filters such as the median-based filters adaptive filters and filters employing supple-computing and or rank- ordered statistics especially, the performances of these filters proceed on higher side but at the cost of advanced complexity is very high.

With the advancement in likeness acquisition technologies, density of impulse disturbance corruption in digital images has fallen consistently over the years. Newly various methods have been proposed, for demonstration on the filtering of very strongly corrupted images by a specific impulse disturbance model. By very strongly corrupted we signify the corruption of more than 30% to 90% pixels. Furthermore, decrease of likeness minutia and flattening of borders are widespread when the similarity is only contaminated with low noise density. These characteristics will not fit for the ever more requiring requirements by consumer electrical devices goods such as digital cameras.

In this paper, we have deep focus on developing a robust filter that caters for any type of impulse noise models. We propose a new recursive robust filter, which is called as Fuzzy Switching Median (FSM), for detail preserving and restoration of information. The FSM filter operates at a wide range of impulse noise densities without falling in a situation in which there is a danger of loss, harm, or failure of image fine details and textures. We have also channeled our attention to develop a fast, efficient and automated algorithm. The proposed filter does not require any time consuming training of parameters as well. In addition, simulation results show us that the FSM filter outperforms other state-of-the art impulse noise filters in terms of subjective and objective qualities in the filtered images when applied recursively and iteratively. Furthermore, the proposed FSM filter consistently shows us excellent and satisfactory restoration results in de-noising digital images.

This paper outline is as follow; section II is about the study of previous work which is done impulse noise reduction, Section III is about what is the problem in previous surveys, Section IV is about proposed methodology. Section V is about Noise model and design. Section VI is about Simulation result, Section VII is about conclusion.

II. LITERATURE SURVEY

In [1] they proposed a novel method, which contained two stages, in the first stage, Noisy pixels detect based on an Adaptive Neuro-Fuzzy Inference System (ANFIS), then in the final stage, the new changes apply on these pixels using the Fuzzy Wavelet Shrinkage (FWS). To illustrate the proposed method, some experiments had been performed on several standard gray level test images, also based quantitative and qualitative criteria they were compared with popular methods. A hybrid method with two stages is proposed. In the first stage using ANFIS, noisy pixel is identified and then in the next stage only this pixel using FWSM was changed. Their proposed method had to reduce impulse noise in digital images was presented and useful. In this paper various experiments done to be able to evaluate reasonably. To review of experimental results can be seen that the proposed method has acceptable and appropriate performance statistically and visually than fuzzy based and median based methods. Comparison results also show the proposed method is superior. So it seems that this method had reduced the computational complexity of other methods. Because most of these methods required calculation of distribution functions that increase computational complexity and the proposed method sounds by using fuzzy rules to reduce computing and execution time more less than statistical methods.

In [2] they proposed a new technique for detects and removes impulse noise in gray scale digital images. Proposed method work in two steps, in first step they detect noisy pixels using fuzzy reasoning with uncertainty, and in second step they replace noisy pixels with a heuristic median filter, their heuristic median's filter is combined with human knowledge for select best replacement. They analyzed this method with PSNR (Pick Signal Noise Ratio) metric and visual comparison, the results show this method is very good for noise reduction and image restoration in high level noisy images. And they know, if PSNR of first method is higher than other then means first method is better than other methods. They presented result of this method in different state.

In [3] they present a novel method for the removal of impulse noise from digital images. Their proposed filter, called the Cluster-based Adaptive Fuzzy Switching Median (CAFSM), is composed of a cascaded easy-to-implement impulse detector and a detail preserving noise filter. Initially, the impulse detector classifies any possible impulsive noise pixels. Subsequently, the filtering phase replaces the detected noise pixels. In addition, the filtering phase employs fuzzy reasoning to deal with uncertainties present in local information. Contrary to many existing filters that only focus on a particular impulse noise model, the CAFSM filter is capable of filtering all kinds of impulse noise – the random-valued and/or fixed-valued impulse noise models. In this paper, they present a novel method for the removal of impulse noise from digital images. Their proposed filter, called the Cluster-based Adaptive Fuzzy Switching Median (CAFSM), is composed of a cascaded easy-to-implement impulse detector and a detail preserving noise filter. Initially, the impulse detector classifies any possible impulsive noise pixels. Subsequently, the filtering phase replaces the detected noise pixels. In addition, the filtering phase employs fuzzy reasoning to deal with uncertainties present in local information. According to their analysis many existing filters that only focus on a particular impulse noise model, the CAFSM filter is capable of filtering all kinds of impulse noise – the random-valued and/or fixed-valued impulse noise models.

In [4], they introduce a Pixel Correlation based Impulse Noise Reduction. The proposed algorithm consists of two main steps, detection and correction. In the first step, noise detection is performed using a scalable detection mask and morphological operation. In the second step, a corrupted pixel is corrected using the correlation .The uncorrupted pixels in the mask. The experimental results showed that the proposed method can reduce more impulse noise and preserve more edge information. They proposed a Pixel Correlation based Impulse Noise Reduction. Proposed algorithm is composed of a detection step using the characteristics of impulse noise and a correction step considering the correlation with the neighboring pixels in a given mask. The experimental results showed that the proposed algorithm outperformed the existing median-based filters in terms of the PSNR. In particular, proposed algorithm improves the weakness of median-based filtering through a noise correction step after considering the correlation of the neighboring pixels.

In [5] they proposed a new method that overcomes the thickness of Median filter. It works in this way: firstly, use fuzzy gradient values and fuzzy logic theory to detect impulse noise, then a noise label matrix is generated; secondly, scans the noise label matrix: if the pixel is a signal point, then its gray value is outputted directly, otherwise, the size of filtering window is adaptively adjusted to the density of noise points in the window. Afterward, generates a difference matrix which is defined as the absolute difference of the gray value of the pixels and the mean of the signal point's intensity in the filtering window, and adaptively assigns a right value to the pixels of the difference matrix. Lastly, returns the location of the minimum pixel of the heighted difference matrix through linear comparison, then replaces the intensity of the noise point with the gray value in the location. Experimental results have demonstrated that the proposed filter outperforms many had accepted switching median-based filters in terms of both noise suppression and detail preservation. A new filter, whose original intention is to reduce the time complexity, is proposed. This filter is especially developed for removing salt and pepper noise. Its main feature is that it leaves the pixels which are noise-free unchanged. Experimental results show that the feasibility of our proposed filter. They use the objective measure PSNR to show convincing results for grayscale images.

In [6] they proposed a filter based on fuzzy logic is proposed to reduce impulse noise from 2D electrical resistivity imaging data. Common types of noise in electrical resistivity data are coherent noise, due to near surface in homogeneities or electrode effects, random or impulsive noise, resulting from telluric currents, electrode polarization or measurements with low signal-to-noise ratio. This noise detection is based on computing difference between a central sample and its neighborhood. The detected noisy sample is then removed by a fuzzy based filtering process. Experimental results show the effectiveness of our filter in reducing both coherent and impulsive noise compared to popular median filter. The comparison of the results is based on the Mean-square-error in the inversion process. The impulse noise has been shown to be the major source of error when performing electrical resistivity inversion. In [6] a filter based on fuzzy logic was addressed to filter noisy ERI data. Results obtained by applying their filter to ERI data have demonstrated that the proposed filter achieves good noise removal and outperforms the popular median filter. The performance of the fuzzy based filter was analyzed according to the RMSE value.

In [7], they propose a new detection mechanism for universal noise and a universal noise filtering framework based on the non local means(NL-means). The operation is carried out in two strategies i.e. detection follow they by filtering. For detection, first they propose the robust outlying ness ratio (ROR) for measuring how impulse like each pixel is, and the null the pixels are divided into four clusters according to the ROR values.

In [8], they proposed an effective method proposed for detects and removal of impulse noise from digital images. Their method consists of two stages: in first stage they detect noisy pixel based on intensity values. In the second stage they replace noisy pixel with average estimated from noise-free pixels with in a small neighborhood. The method adaptively changes the size of the noise-free pixel in the neighborhood. The results showed in this method had been good for noise reduction and image restoration especially in high level noisy images.

In [9], they had proposed a genetic based method to remove impulse noise. This method proposes a composite filter which is a combination of several standard filters to reduce the noise effect. Their experimental results showed the proposed method could efficiently restore degraded image while it is approximately stable to noise ratio increment. In [9] they had proposed a method to remove impulse noise by genetic algorithm that was simple and efficient. When the observed the experimental the results, it was obvious that proposed method could efficiently restore degraded images while it is proportional stable to noise ratio increment. Their proposed algorithm may be extended and improved by placing more standard filters into the filter pool or tuning genetic algorithm parameters in future.

In [10], they had proposed an efficient method for noise reduction. This method applies fuzzy logic for removing the impulse noise. Given results from the proposed method was compared to those of median filter and mean filter. Experimental result validated the robustness of the proposed method in term of impulse noise reduction especially in high levels of noise.

In [11], they had discusses the impulse noise and presented a brief literature review of techniques and architecture that was used for the implementation of the impulse noise filtration using FPGA and CPLD. They presented the causes and effects of the impulsive noise and the basic working of the median filter for removing it respectively. The fourth section of [11] discussed the recently proposed different techniques and architectures of the impulsive noise filter with their unique techniques to improve the performance in terms of time and resource requirements.

In [12], they had presented the study and comparison of filtering techniques for the detection and filtering of impulse noise from the gray scale images. Performance of Non fuzzy filters i.e. classical filters and the fuzzy filters are analyzed based on various image quality assessment parameters. In this paper different impulse noise reduction methods are studied and compared. This paper gives the review of filtering techniques which are used to reduce or remove impulse noise from the image. The standard median filter removes both the noise and the fine details such as thin lines, sharp corners, textures since it can't tell the difference between the two. If the image is affected only by low level noise, weighted median filter preserve edges. Adaptive median filter works well for suppressing impulse noise with noise density from 5 to 60 % while preserving image details. In adaptive weighted median filter, the noise suppression capability is enhanced but with much image detail (e.g. image of edge, corner and fine lines) lost, which causes image blur. The adaptive center weighted median filter can reduce more additive noise and impulsive noise. The CWM and ACWM filters had been useful for detail preserving smoothers but the computation time required increases as noise density increases which are quite acceptable for the result. The increase in computation time might be explained by fact that at higher noise densities the filter is applied again and again till the noise detector is unable to detect any noise in images. The performance of the filters depends on how well it can suppress undesired parts of the signal and, equally important, how well desired information is retained. There is no general numerical measure to combine these two properties and thus evaluate the performance of the filter. From the comparison, the conclusion is the fuzzy filter is superior to a number of well-accepted median-based filters in the literature. Fuzzy techniques are powerful tools for knowledge representation and processing. Fuzzy techniques can manage the vagueness and ambiguity efficiently. Fuzzy filters are capable of removing the noise sufficiently without distorting the edges and hence keeping the details of the image intact. The main advantage of the fuzzy filtering technique over the other filtering techniques is its marvelous noise removal as well as detail preserving capability.

In [13] they presented the study and comparison of various salt & pepper noise reduction techniques for the gray scale images. They had discussed various linear and non-linear filters. They studied all algorithms and compared them to determine better detail preserving algorithm. There survey provides help to researchers for selecting the best algorithm with detail preserving for the removal of salt & pepper noise from the gray scale image.

III. PROBLEM STATEMENT

There are different approach of image filtering that contains impulse noise has been proposed. There are certain problems that are identified in cited papers. The problems are as follows:

1. There are many different methods of image processing. Different filter based approach is used to remove impulse noise in the given input image but it will not work efficiently when the noise rate is high. Some of the other filters are also come into picture that actually works on preserving, smoothing and sharp edges.
2. The common drawback of all the previously being developed filter are either work on low noise rate or high. There is no filter according to user choice whether to eliminate high noise from the noisy image or to eliminate low noise.

3. In all other traditional methods of image processing, they either work on black and white image or color image.
4. In all the previously being developed filter like GFIF, SD-ROM, NASM, CWM, FIF etc., can take input image of specified size.
5. Some filters is used to remove impulse noise but work on either random valued impulse noise or fixed value impulse noise.
6. Some filters like median filter is used to remove impulse noise but not to preserve edge detail and smoothing of edge are rampant.

IV. PROPOSED METHOD

The Fuzzy Switching Median (FSM) is composed of a cascaded easy-to-implement impulse noise detector and a detail preserving noise filter. Initially, the impulse detector classifies impulsive noise pixels. Subsequently, the filtering phase replaces the detected noise pixels with the computed mean value of un-noisy pixels. In addition, the filtering phase employs fuzzy reasoning to deal with uncertainties present in local information. Contrary to many existing filters that only focus on a particular impulse noise model, the FSM filter is capable of filtering random-valued and/or fixed-valued impulse noise. Extensive simulations conducted on several gray images under a wide range of noise densities show that the FSM filter substantially outperforms other state-of-the-art impulse noise filters. Furthermore, the relatively fast processing time suggests the FSM filter's applicability in consumer electronic products such as digital cameras.

V. NOISE MODEL

The model for impulse noise with probability ρ is defined as follows:

$$x(i,j)=\begin{cases} o(i,j) : with\ probability\ 1-\rho \\ f(i,j) : with\ probability\ \rho \end{cases} \quad (1)$$

Where $x(i,j)$ represents the pixel in the location (i,j) and $o(i,j)$ and $f(i,j)$ represents the original and noisy image respectively.

In image processing there are two types of impulse noise, First one is the fixed valued impulse noise, moreover referred as Salt and Pepper (SNP) impulse noise and the second is the random valued impulse noise, moreover called Uniform noise (UNIF). The salt and pepper impulse noise takes the value of lowest and maximal intensities,i.e., $f^{snp}(i,j)$ ϵ (L min, L max). Whereas the uniform impulse noise takes any value within the dynamic range, i.e., $f^{unif}(i,j)$ ϵ [L min, L max]. The impulsive noises which have random amplitudes, which results from interference of noise signals. Consequently, the amplitude of the impulse noise could lie within the image dynamic range or out of it. When the amplitude of impulse noise lies within the dynamic range it appears as salt and pepper noise and when it lies out of the dynamic range it is said to be uniform noise.

The general purpose impulse noise model is defined as.

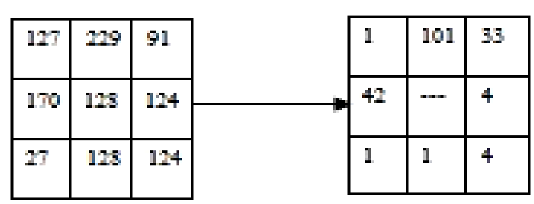
$$x(i,j)=\begin{cases} o(i,j) \quad : with\ probability\ 1-\rho \\ f^{unif}(i,j) : with\ probability\ \frac{\rho}{2} \\ f^{snp}(i,j) : with\ probability\ \frac{\rho}{2} \end{cases} \quad (2)$$

FSM ALGORITHM FIRST PHASE

The impulse detection is carried out by analyzing the local image statistics within a window patch whose size is bounded by the filter. A local window

With $W_d(i,j)$ odd $(2L_d+1)\times(2L_d-1)$ is defined as:

$$W_d(i,j)=x(i+k,j+1)\forall K,I\in[-L_d,L_d]$$



Sorted first order absolute differences, which is denotes as $D_s(m)$ and the indexed pixels as $x^I(m)$

$D_s(m)$ = {0, 1, 1, 4, 4, 37, 42, 101}

$x^I(m)$ = {128, 127, 127, 124, 124, 91, 170, 229}

No. of cluster, n, on the basis of Second-order absolute differences, $D^2(m')$

n=1 n=2 n=3

$D^2(m')$ = {1, 0, 3 0,|33, 5,| 59}

$D^2(m') < T_d(t)$ Cluster elements, C (n)

C (1) = {128, 127, 127, 124, 124}

C (2) = {91,170}

C (3) = {229}

As shown above there are three cluster are formed C (1), C (2), C (3). And we have chosen the larger cluster for evaluation of noisy pixels.

Largest Cluster, $C_L(n)$ = C (1) with mean $\mu_C(1)$ = 125 and standard deviation $\sigma_C(1)$ = 1

Local noise free pixels boundaries (LB and HB) r

$C_L(n)$ = {123, 126, 126, 127, 127}

LI = 123 HI = 127

Where LI is lowest density and HI is highest density

LB = LI - $\sigma_C(1)$ = 123 HB = HI + $\sigma_C(1)$) = 128

Where LB is lower boundary and HB is higher boundary

[LB<x (i,j) = 127<HB] AND []

Thus, the center Pixel is a NOISE FREE pixel.

At the end of the detection stage, a two-dimensional binary decision map $b^{(t)}(i,j)$ is formed based on

$$b^{(t)}(i,j) = \begin{cases} 1 \ :\left[LB \le x(i,j) \le HB\right] \\ \quad \cap\left[x(i,j) \ne L_{SALT} \cap L_{PEPPER}\right] \\ 0 \ :otherwise \end{cases} \quad (3)$$

Where logic 1s, indicate the positions of noise-free pixels and logic 0s, for those noisy ones.

FSM ALGORITHM SECOND PHASE

1. Determine the number of noise-free pixels G(i,j) by computing the number of '1s' in B(t)(i,j)

$$G(i,j) = \sum_{p,q\in\{-L_f, L_f\}} B^{(t)}(i+p, j+q) \quad (4)$$

2. Expand $W_f(i,j)$ by one pixel at each of its four sides (i.e., $L_f \leftarrow L_f + 1$) if G (i,j) < 1. Repeat Steps 1 and 2 until the criterion G (i,j) ≤ 1 is satisfied.

3. Compute the median pixel $M(i,j)$ using all noise-free pixels in the current $W_f(i,j)$. The median pixel $M(i,j)$) is given as:

$$M(i,j) = median\left\{x(i+p, j+q)\right\} \forall p,q \quad (5)$$
$$with\, B^{(t)}(i+p, j+q) = 1$$

4. Extract the local information $D_I(i,j)$ from $W_f(i,j)$ according to

$$D_I(i,j) = \max\left\{D^1(m)\right\} = D_S\left(\left(2L_d+1\right)^2 - 1\right) \quad (6)$$

5. Compute the fuzzy membership value $F(i,j)$ based on the local information $D_I(i,j)$

$$F(i,j=)\begin{cases} 0 & :D_1(i,j) < T_1 \\ \dfrac{D_1(i,j) - T_1}{T_2 - T_1} & :T_1 \le D_1(i,j) < T_2 \\ 1.O & :D_1(i,j) \ge T_2 \end{cases} \quad (7)$$

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6. Compute the restoration term y(i, j) as follows:

$$y(i,j) = F(i,j).M(i,j) + [1 - F(i,j)] \cdot x(i,j) \qquad (8)$$

Even though noise-free pixels are easy to be identified by using the binary decision map $B^{(t)}(i,j)$, the number of noise-free pixels is used as elements for restoration posed as a problem. This is especially true for median-based filters because the median pixel selected from only noise-free pixels of a large window is very likely belonged to a nonlocal neighbor. Restoring a noise pixel with a nonlocal noise-free pixel could guide to loss of image details. Consequently, the restored image is blurred and jittering appears at objects' edges. Additionally, a large number of noise-free pixels in a sample will consume a high computational time. Therefore, we set a limit for $W_f(i,j)$ to contain a minimum number of pixels and we choose the minimum number of pixel as one in Step2 before $W_f(i,j)$ stops enlarging its window size.

Step4, the proposed filter has the uniqueness to removes the local information from the noisy image using the MAX-operator in. The local information plays a vital role to get essential information such as image fine details, edges, thin lines, and textures even after the image has been tainted with noise.

As part of the proposed filtering mechanism, the proposed filter adopts a fuzzy reasoning in Step5 to deal with uncertainties present in the local information. These uncertainties, like, thin lines or pixels at edges being mistaken as noise-pixels, are caused by the nonlinear nature of impulse noise. Therefore, the fuzzy set in processes the local information DI(i,j) by producing a suitable fuzzy membership value . Subsequently, is used to assist the restoration of a noise pixel by approximating an accurate restoration term . Instead of replacing the noise pixel with the median pixel as practiced by median-based filters, lends a weight on whether more of or will be restored in . As a result, image details are very well preserved after filtering A simulation result for the noisy cameraman image using various filters is given below.

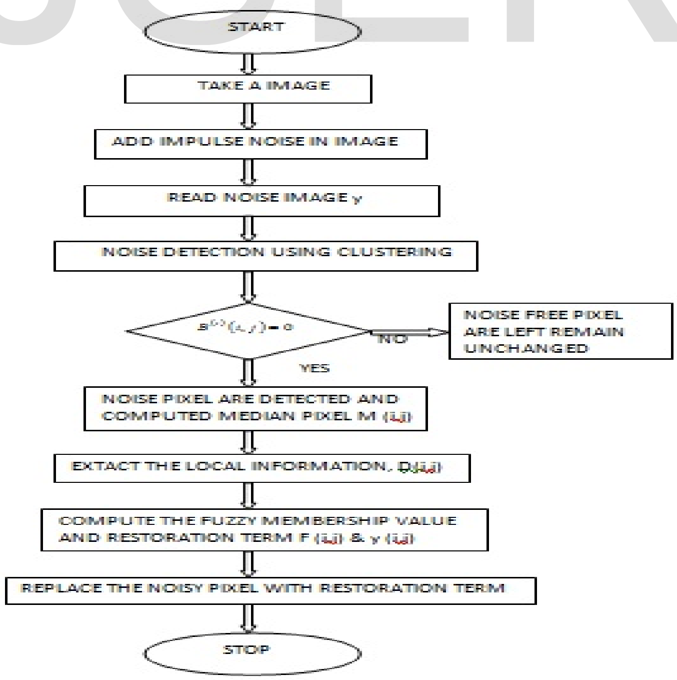

Fig 1Flow chart for proposed method

Method name	Noise Density %								
	10	20	30	40	50	60	70	80	90
FIRE[]	34.43	31.13	28.51	26.43	24.39	23.25	21.12	21.01	20.05
BDND[]	23.07	19.95	18.10	16.54	15.38	14.73	13.36	11.05	10.54
DMW[]	34.20	30.66	28.83	26.42	24.95	22.76	21.98	19.32	18.64
LUO[]	30.02	24.68	21.36	19.00	17.15	16.22	15.14	14.59	14.08
FMEN[]	31.90	27.52	23.32	20.57	17.71	17.54	14.32	14.11	13.87
PROPOSED FILTER	42.28	40.59	39.46	38.60	37.54	36.90	36.19	35.05	33.94

Table 1 Comparison Of PSNR Values Of Different Algorithms For Cameraman Image At Different Noise Densities

VI. SIMULATION RESULTS

A simulation result for the noisy cameraman image using various filters is depreciated in table 1.

Comparison in image restoration

The performances of all filters implemented are compared qualitatively through visual inspection and quantitatively by using the peak signal-to-noise ratio (PSNR), which is defined as:

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

$$MSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left\{Y(i,j) - \hat{Y}(i,j)\right\}^2}{mxn} \qquad (9)$$

The PSNR (or MSE) estimation is aimed at measuring the differences or similarities between the restored and original images [7]. As such, essential information such as image fine details cannot be measured because different combinations of image deformation and residual noise can balance the effect of one another [9].

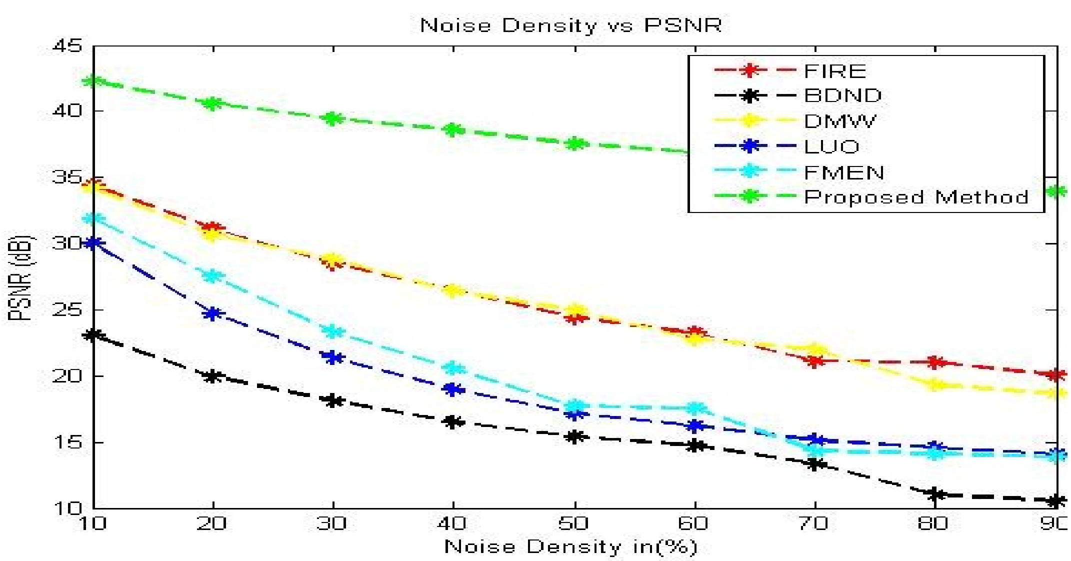

Fig. 2 Graphical representation of PSNR of Cameraman Image

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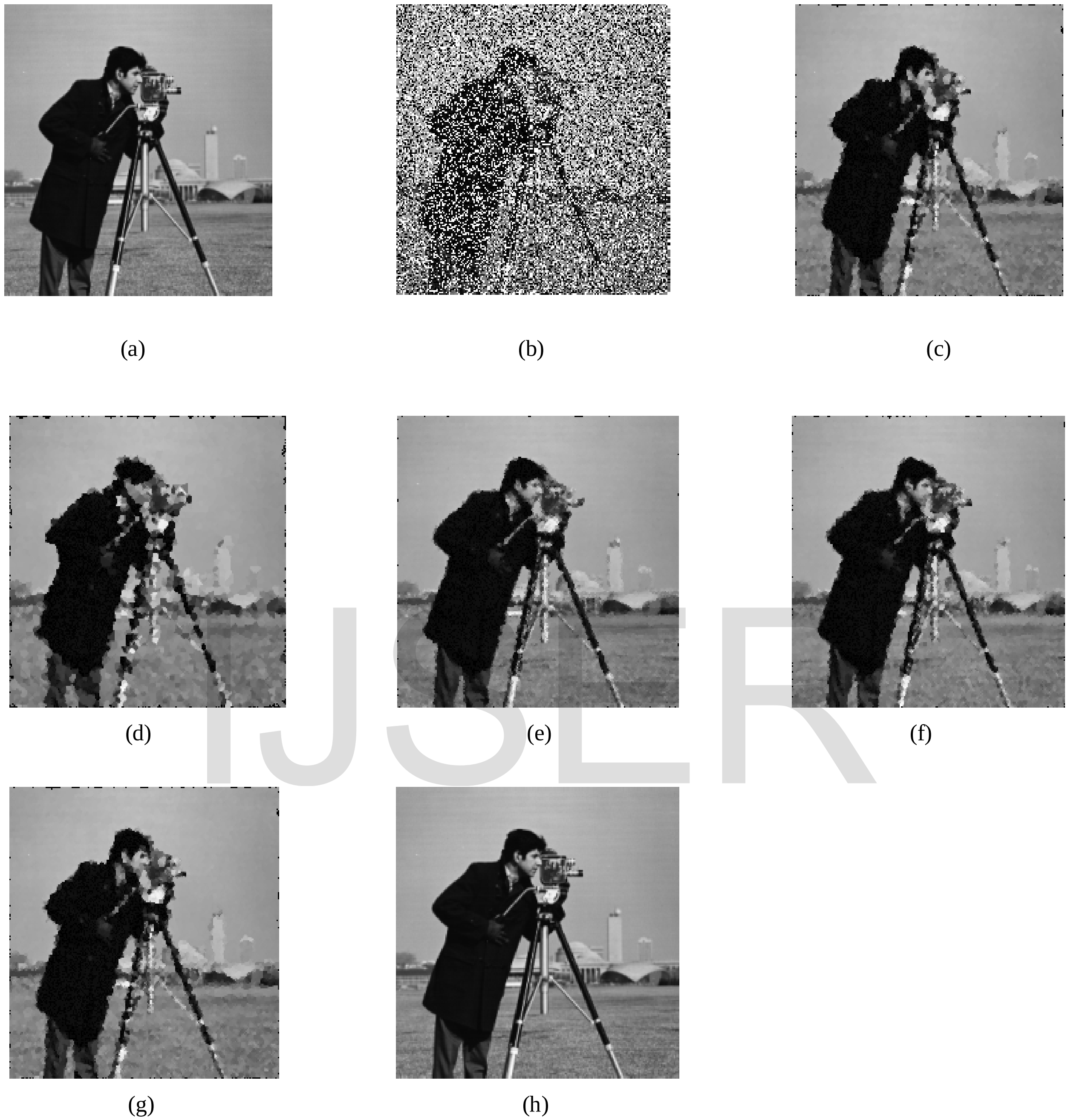

Fig.3 Result for 90% noise corrupted cameraman image (a) Original image (b) Noisy image (c) FIRE (d) BDND (e) DMW (f) LUO (g) FMEN (h)PROPOSED.

VII. CONCLUSION

FSM filter algorithm for effective removal of impulse noise is presented in this paper. This filter is able to suppress high density of impulse noise, at the same time preserving fine details, textures and edges. 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. In addition, the relatively fast runtime and simplicity in implementation, both for monochrome and color images de-noising, as compared to other state-of-the-art filters demonstrate the tremendous importance of the proposed FSM filter towards image applications in consumer electronic products.

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