DOI: 10.21917/ijivp.2025.0534

AN EFFICIENT QUARTILE-DRIVEN MORPHOLOGICAL FRAMEWORK FOR IDENTIFYING FIXED VALUE SALT AND PEPPER NOISE IN STRUCTURED MRI BRAIN DATA

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Abstract

Digital images are often corrupted by impulse noise during acquisition or transmission due to the camera sensors, faulty memory locations or environment. The efficiency of noise reduction techniques in digital images strongly depends upon the successful detection of the noisy pixels. The pixels corrupted with salt and pepper noise (SPN) have the value of 0 or 255 in the grey scale digital image that cannot always be true because some non noisy pixels with the value of 0 or 255 may contain important information of the image hence requires the distinction of such precious pixels and noisy pixels. There are numerous filters available in the literature those presume pixels noisy having intensity minimum or maximum, and behave poorly with the increase in levels of noise. A novel quartile based method for the convolution matrix of 3x3 or 5x5 is proposed to label pixels noisy or noiseless having the pixel value of 0 or 255 successfully and have been found efficient subjectively and objectively when compared to standard techniques available in the literature on the basis of parameter for evaluation like PSNR, MSE, SSIM while preserves the sensitive information of the digital image. The proposed framework demarcates pixels based on the local morphology of neighboring immediate quartile pixels. The proposed method only processes noisy pixel while leaves non noisy pixels unchanged.

Keywords:

Salt and Pepper Noise, Linear Cellular Automata, Mean Filter, Median Filter, SPN Identification

1. INTRODUCTION

Digital images find application in medical science, geography, geology, mining, manufacturing industry, medical imaging and video animation etc. Digital images in the health care medical reports plays vital role in identification of Region of Interest (ROI) that carries sensitive information for early and accurate diagnosis by medical experts to save the precious human lives by detecting diseases in the early stages. The quality of the image plays an important role and requires image restoration that is removal of unwanted elements [1] which were introduced when the image was taken either due to the circuitry or the environment. SPN is very common in natural images and requires removal for safeguarding the important details of the images which is added at the time of image acquisition or storage, due to fault in camera sensors and wrong locations in memory [2]. The image can be binary that take the value of 0 or 1 for all the pixels, grayscale that takes eight bit value (0-255) or color images that takes eight bit value for RGB of each pixel [3]. A matrix with size m x n can be utilized to represent a 2D digital image where the element in Ith row and Jth column can be represented as A (i,j), within the matrix of size m x n. The intensity is the value given to the element that is pixel corresponding to the luminosity information for the same [4]. Each cell of the cellular automaton can be seen as a pixel in the digital image.

The ability of linear and non-linear filter for noise reduction in grey scale digital images proposed in the literature between 1990 to 2015 tend to perform poorly when the noise levels go above 30 db as most of the filters randomly apply procedure to all the pixels irrespectively that removes the fine details particularly the edge details of an image, hence identification of noisy pixels becomes necessary and application of proposed method is restricted to noisy pixels only to improve the performance of noise filtration. The application of Cellular Automata for noise filtration plays important role in identifying the noisy pixels as has been proved with the development of various CA based models. There is strong correlation between pixels adjacent in row, diagonal and column orientations as illustrated in [5] [6] [7].

Average filter is one of the linear filters that removes noise from corrupted digital images but also removes sensitive information present in the image [8] that has been affirmed ineffective as per the simulation results [9]. Median filter (MF) is one of the non linear filter that performs better in removing SPN compared to various linear filters like average filters and maintains the sensitive information of the digital image[8], that pawed way for the development of various variants of the median filter like Adaptive median filters [AMF] [10] progressive switching median filter [11], noise adaptive soft-switching median filter [12], multi-state median filter [13], improved median filter [14], fast and efficient median filter [15], that takes care of noisy and noiseless pixels which is otherwise in median filter, and weighted median filters [optimal weighted median filters under structural constraints]. The size of the window is restricted to avoid median value lying away from the pixel under consideration under modified AMF [16] and some are processed without limit put to the window size, processing time is reduced in classified MF [17] with noise presence less than 50 db.

The authors utilized the concept of absolute luminance difference (ALD) [18] between the pixel under examination and pixels in the neighborhood to differentiate between noisy and noiseless pixels having the value of 0 or 255 which were otherwise assumed as noisy but they might carry some important information despite of having the value of 0 or 255 but could not succeed because the pixels in neighborhood having the value of 255 in the opposite direction ruin the results. The solution to this is provided by categorizing pixels as uncorrupted, lightly corrupted and heavily corrupted [19]. A methods presumes that all pixels with value 0 or 255 are not treated as noisy if their exists in the neighborhood pixels with the values of < 10 and > 245 meaning threshold of 10 is utilized that may change for higher noise densities [20]. The noisy pixels are decided on the basis of threshold that is based on the lower and higher membership values [21]

The identification of fixed value impulsive noisy pixel in a digital image is easy to discover as we have to find the values of 0 or 255 but the identification of random valued impulsive noisy pixel is difficult to obtain as the noisy pixel may take values other that 0 or 255 that may or may not be potentially lower or higher than its neighbors as suggested in [22]. The conventional median based filters fail as the detection module performs miserably.

An eight bit integer represents the intensity of a given pixel in a grey scale digital image that possibly produces 256 values in the interval of (0 – 255). The SPN in a digital image takes just two values 0 and 255 that are the minimum (pepper) and maximum (salt) of the intensities possible in the levels of 8 bit grey scale image. The salt noise appears as positive impulse that takes the value for intensity as 255 which is white and pepper noise appears as negative impulse and takes the value for intensity as 0 which is black [23]. The filters that consider 0 or 255 intensity values in the grey scale digital image as corrupted by S&P are [24], [25], [26], [27], [28], [29].

An efficient method for removal of high density impulsive noise [30] takes the values of 0 or 255 to find a pixel is noisy or not then the method for noise removal is applied.

A simplest of the methods but highly effective model in [31] for impulse noise filtration utilizes the basic properties of SPN for identification of noisy pixels among the array or pixels formulating the digital image in the grey scale are 0 (minimum, pepper) and 255 (maximum, salt). The pixels with the value of 0 or 255 are filtered for the restoration of the degraded grey scale digital image by utilizing local cells when the level of noise is less while non local neighboring pixels are utilized when the level of noise is above 30 db.

The Fuzzy Switching Median Filter (FSMF) identifies the corrupted pixel for correction or restoration by a particular method in the grey scale digital image by identifying two peaks in the histogram [32] of the digital image, one peak from left and another from right of the histogram as the same is proposed by [33]. L (lower) is evaluated while travelling from left side of the histogram towards right is the lower end local maximum- which is negative first peak and Lupper is evaluated while travelling from right side of the histogram towards left is the upper-end-local-maximum- which is positive first peak. The authors in [34] presented a method for impulse noise filtration by utilizing histogram for identification of the noisy pixel based on FSMF, since the proposed method utilizes grey scale digital images where intensity of every pixel is represented by eight bit integer in the interval of 0-255 (256) hence the value for Llower = 0 and Lupper = 255.

Neural network classifiers are utilized in CNN for achieving classification in accuracies when the reference images and noisy image are supplied to the principal component analyzer where in, dimensionality reduction is utilized to reduce the space complexity with the help of convolution filter and spatial size is reduced with the help of pooling layer [35] [36]. CA based filters that considers 0 or 255 intensity values in the grey scale digital image as corrupted by S&P are utilized in [24], [25], [26], [27] , [28] , [29].

2. CELLULAR AUTOMATA

Cellular Automata (CA) are time and space discrete mathematical models described in late 1990‘s by John Von Neumann [23]. CA is considered as one of the most pronounced parallel computational tools in the recent era of nature and bio-inspired computing [SPN filtering using cellular automata]. The space in CA is divided into discrete units in the form of cells that contains different states at different points in time. The next state of the cell at time t+1 is obtained by the application of predefined transition function that is based on the combination of linear or non-linear neighboring cells in totalistic CA (TCA) or outer TCA (OTCA) [5]. There are many neighborhood approaches available in the literature but most commonly applied methods are Van Neumann (Nvn) that includes top, bottom, left and right pixels and Moore Neighborhood Nm that includes all the 8 adjacent neighbors.

3. PROPOSED MODEL

In this paper, a novel method is proposed for identifying pixel $A(i,j)$ with value 0 or 255 in the gray scale digital image to be noisy or noiseless by taking into consideration pixels in four different quartile of convolution matrix. The framework is proposed on the principle that there is good correlation between neighboring pixels [5]. The correlation between pixels of the digital image in row, column and diagonal orientations has been made known to be extremely high [6] [37]. We are taking into consideration four neighborhood quartiles for labeling a pixel with intensity of 0 or 255 as noisy or noise less as shown in Fig.1and Fig.2.

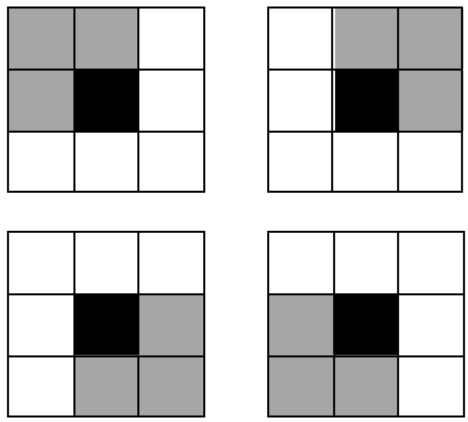

Fig.1. Quartiles (w1, w2, w3, w4) for noise densities up to 45% db

We utilized 3 x 3 Moore neighborhoods up to the noise levels of 45% and 5 x 5 Moore neighborhoods beyond the noise densities of 45%. The pixel having intensity value of 255 with all the neighboring pixels in the convolution matrix of 3 x 3 or 5 x 5 in any of the proposed quartile to be same (255), the pixel will be labeled as noise less similarly for the pixel with intensity value of 0 with all the neighboring pixels in the convolution matrix of 3 x 3 or 5 x 5 in any of the proposed quartiles to be same (0) the pixel is treated as noiseless.

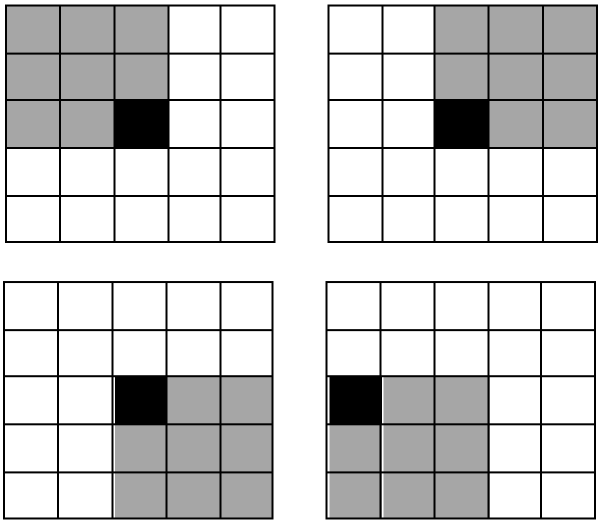

Fig.2. Quartiles (w1, w2. w3. w4) for noise densities beyond 45% db.

In Fig.1 and Fig.2, black cell is cell under consideration and grey cells are grouped in quartiles (3x3, 5x5) that help in identifying the pixel 0 or 255 as noisy or noiseless.

Algorithm for the proposed method

Read input image I

Convert image A into gray scale image.

Resize the input image to [256,256].

Add artificial S&P noise to the output image of step 3 in Matlab environment.

For I ←2 to n-1 and J←2 to m-1

If A(i,j) == 0

Evaluate w1,w2,w3,w4

If w1/3 = 0 or w2/3 = 0 or w3/3 = 0 or w4/3 = 0 for (3x3)

Classify pixel as non noisy

Else

Evaluate pixel correction value for noisy pixel.

We used mean and median.

End

If A(i,j) == 255

Evaluate w1,w2,w3,w4

If w1/3 = 255 or w2/3 = 255 or w3/3 = 255 or w4/3 = 255 for (3x3)

Classify pixel as non noisy

Else

Evaluate pixel correction value for noisy pixel.

We used mean and median.

End

Evaluate the pixels at boundaries

Print the output image B.

The fundamental proposed in the algorithm is that if any of the neighborhood quartiles are 0's 0r 255's for any 0 0r 255, the pixel is classified as non noisy.

4. EXPERIMENTAL RESULTS

The experimentation for proposed algorithm is carried out in Matlab 2016a (9.0.0.341360), 64 bit (win64) on a system having 11th Gen Intel(R) Core(TM) i5-1135G7 @ 2.40GHz 2.42 GHz for image (braintumor.jpg) randomly chosen from the brain tumor image segmentation dataset (https://www.kaggle.com/datasets/masoudnickparvar/brain-tumor-mri-dataset).

The Table.1 displays the mean square values (MSE) of braintumor.jpg image for noise densities of 5% to 55% for median filter and proposed method with median filter.

Table.1. MSE values of input image across noise densities with median filter and proposed identification method with median filter.

Noise	**5%**	**15%**	**25%**	**35%**	**45%**	**55%**
Median Filter	30.4	111.9	267.9	605.3	1369.2	2878.9
Proposed with Median	6.3	27.1	132.8	458.5	1138.5	2775.3

Table.2. PSNR values of input image across noise densities with median filter and proposed identification method with median filter.

Noise	**5%**	**15%**	**25%**	**35%**	**45%**	**55%**
Median Filter	33.30	27.6	23.8	20.3	16.8	13.5
Proposed with Median	40.1	33.8	26.9	21.6	17.6	13.9

Table.3. SSIM values of input image across noise densities for median filter and proposed identification method with median filter.

Noise	5%	15%	25%	35%	45%	55%
Median Filter	0.98	0.94	0.87	0.73	0.53	0.29
Proposed with Median	0.99	0.98	0.92	0.76	0.54	0.29

The Table.2 displays the Peak Signal to Noise Ratio (PSNR) values of braintumor.jpg image for noise densities of 5% to 55% for median filter and proposed method with median filter. The Table.3 displays the Similarity structure Index (SSIM) values of braintumor.jpg image for noise densities of 5% to 55% for median filter and proposed method with median filter. The Table.4 displays the mean square values (MSE) of input image for noise densities of 5% to 55% for mean filter and proposed method with mean filter. The Table.5 displays the Peak Signal to Noise Ratio (PSNR) values of input image for noise densities of 5% to 55% for mean filter and proposed method with mean filter. The Table.6 displays the Similarity structure Index (SSIM) values of input image for noise densities of 5% to 55% for mean filter and proposed method with mean filter.

Table.4. MSE value of input image across noise densities for mean filter and proposed identification method with mean filter

Noise	**5%**	**15%**	**25%**	**35%**	**45%**	**55%**
Mean Filter	221.6	633.6	1270.3	1996.6	2966.7	3962.0
Proposed with mean	41.3	189.9	494.4	934.3	1634.6	2660.8

Table.5. PSNR value of input image across noise densities for mean filter and proposed identification method with mean filter.

Noise	5%	15%	25%	35%	45%	55%
Mean Filter	24.7	20.1	17.1	15.2	13.4	12.2
Proposed with mean	31.9	25.3	21.2	18.4	15.9	13.9

Table.6. SSIM value of input image across noise densities for mean filter and proposed identification method with mean filter.

Noise	5%	15%	25%	35%	45%	55%
Mean Filter	0.5854	0.3371	0.2451	0.1934	0.1463	0.1199
Proposed with mean	0.8354	0.5828	0.4285	0.3366	0.2537	0.1902

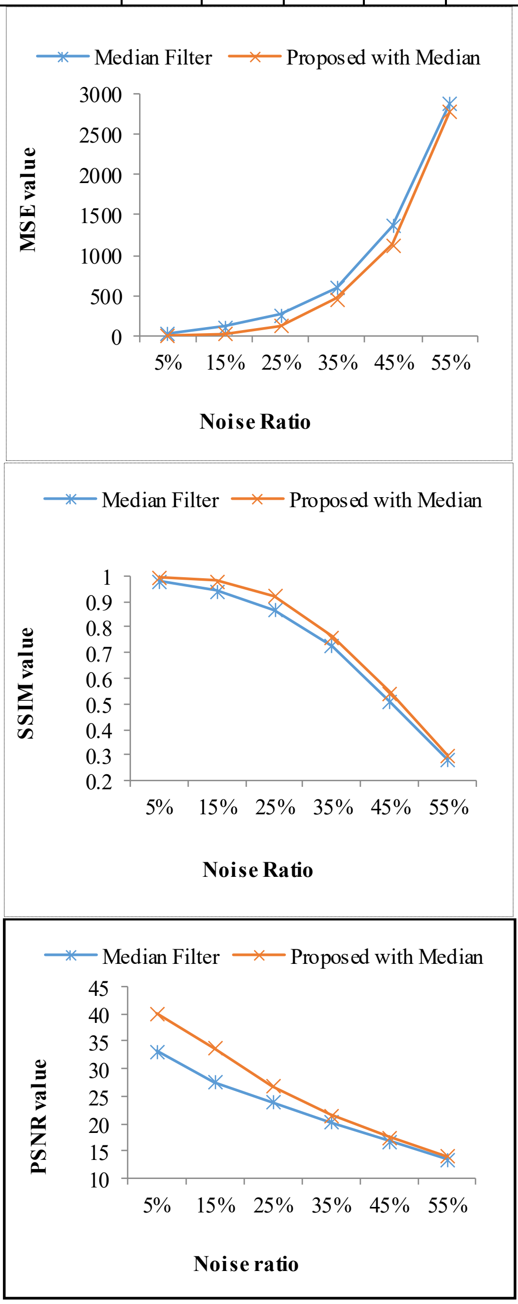

Fig.3. Graph displaying a) MSE values b) SSIM values (c) PSNR values for median filter and proposed method with median filter

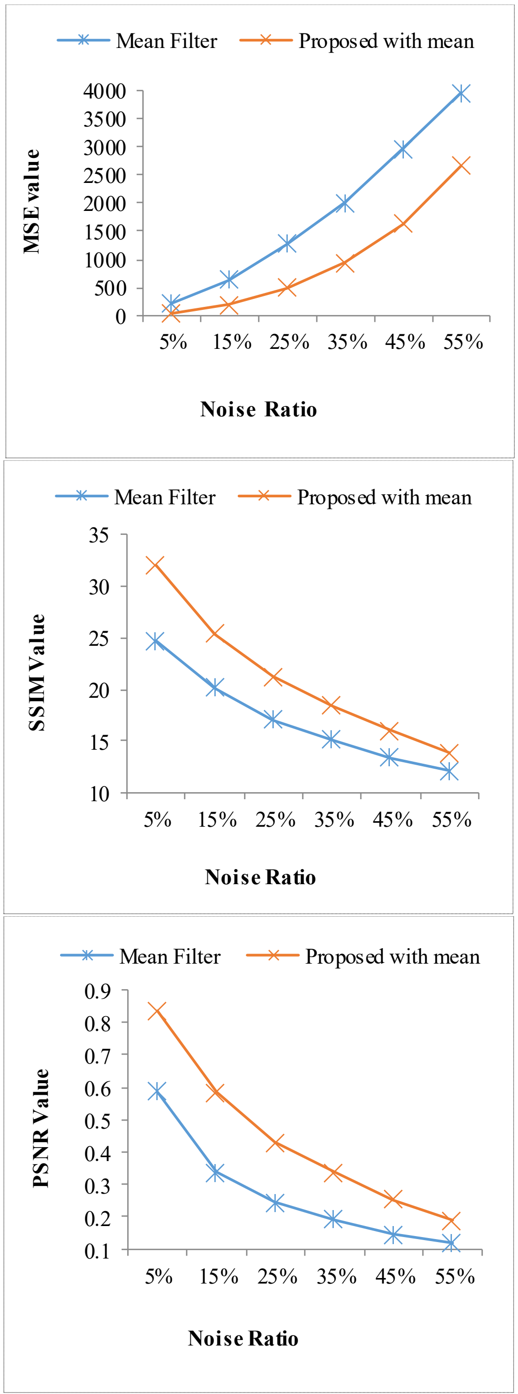

Fig.4. Graph displaying a) MSE values b) PSNR values (c) SSIM values for mean filter and proposed method with mean filter.

The Fig.3(a) exhibits the relationship between noise ratio and MSE value for the input image using median filter and proposed identification method with median filter, Fig.3(b) displays relationship between noise ratio and PSNR value for the input image and Fig.3(c) displays the relationship between noise ration and SSIM value for the input image. The Fig.4(a) exhibits the relationship between noise ratio and MSE value for the input image used for mean filter and proposed identification method with mean filter, Fig.4(b) displays relationship between noise ratio and PSNR value for the input image and Fig.4(c) displays the relationship between noise ratio and SSIM value for the input image. Table.1–Table.3 and Fig.3 and Fig.4 exhibit the superiority of proposed identification method objectively.

The Fig.5(a-e) shows the original input image corrupted by noise from 5 to 35% with noise density intervals of 10%. The Fig.5(f-j) represents the corresponding images filtered by median filter while Fig.5(k-o) represents the corresponding images processed by proposed identification module with median filter.

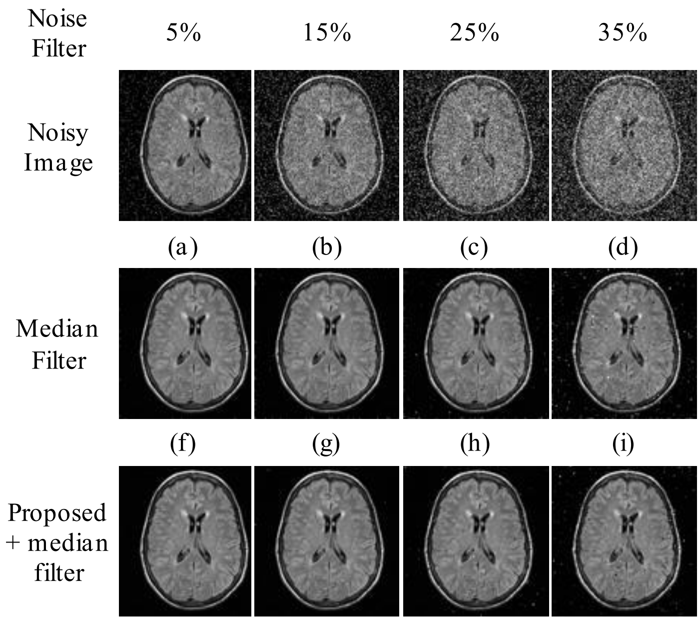

Fig.5. Graphical demonstration for median filters and proposed with median filter across densities.

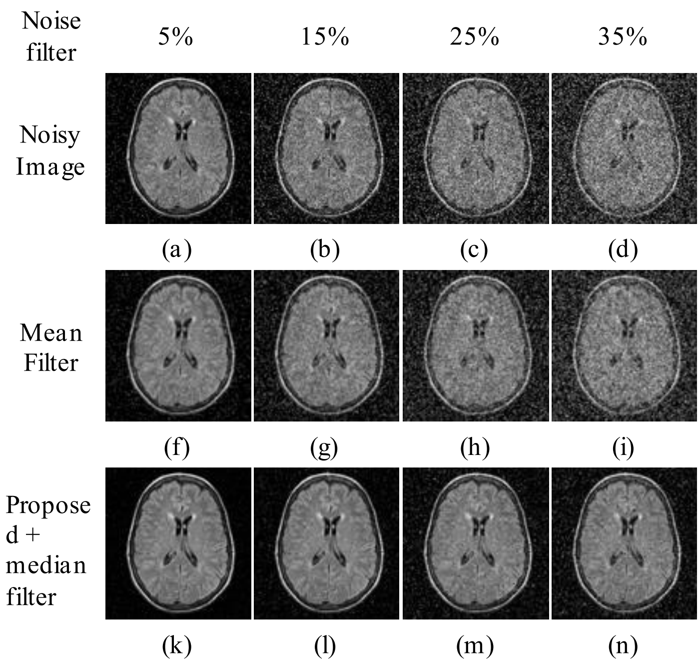

Fig.6. graphical demonstration for mean filter and proposed with mean filter across densities.

The Fig.6(a-e) shows the original input image corrupted by noise from 5 to 35% with noise density intervals of 10%. The Fig.5(f-j) represents the corresponding images filtered by mean filter while Fig.6(k-o) represents the corresponding images processed by proposed identification module with mean filter. The proposed noise identification module for MRI brains using median and mean filters demonstrates better performance subjectively and objectively compared to the conventional median and mean approaches under identical conditions on a set of similar input images. We have performed experimentation on variety and image dataset and the proposed framework demonstrated better performances.

The authors in [38] suggest that extensive training of large datasets sometimes makes algorithms time consuming and expensive. Some methods should be developed that use local image details along with global image details for improving the correlation among pixels in the image. Table 7 displays SSIM values for the image set using [39] based on CA and proposed identification module with [39]. The results demonstrate that proposed identification module perform better subjectively as well as objectively on the evaluation parameters of MSE, PSNR and SSIM when compared with linear, non-linear and state of the art filters in the literature.

Table.7. SSIM value of input image across noise densities for [39] and proposed identification method with [39].

Noise	**5%**	**15%**	**25%**	**35%**	**45%**	**55%**
[39]	0.88	0.73	0.54	0.39	0.15	0.12
Proposed with [39]	0.89	0.78	0.57	0.39	0.25	0.19

5. CONCLUSION

The proposed method successfully distinguishes between the noisy and noiseless pixels of fixed value impulsive noise having the intensity value of 0 or 255 in the grey scale digital images. The identification of noisy pixels is based on the morphology of quartiles of neighboring pixels in the convolution matrix of 3x3 or 5x5 depending upon the density of noise in the image. The proposed identification module considers immediate neighborhood pixels in four quartiles to label pixels with the intensity of 0 or 255 as noisy or noiseless. The proposed method performs better compared to standard and widely accepted filters (mean, median & CA) available in the literature while preserving important information of the digital image in the grayscale on the basis of MSE, PSNR, and SSIM. The proposed method performs better subjectively as well as objectively as depicted by the simulation results. The denoising algorithms contain two modules detection and correction; the proposed method focuses on detection module and requires some efficient module for the noise removal that is kept for future. The efficiency of detection module strongly tells upon the efficiency of overall denoising process and the results of proposed method have shown better performance for the detection module. The proposed identification module will serve as bedrock for design and development of new and improved filters for fixed value SPN filtration.

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