Development of an Improved Adaptive Switching Approach for Impulse Noise Reduction in Magnetic Resonance (MR) Images

Aayushi Shrimali, Navneet Agrawal

Abstract— Controlling the density of the impulse noise in an image is an upcoming area on which number of researchers are working in medical imaging applications. In this paper, region of interest (ROI) in an image is examined for extreme intensity to classify the image as noisy or noiseless. The filtration process is applied to the pixels which are noisy in nature only and this is further made efficient and optimized by means of swarm intelligence approach. The window size of the adaptive filter depends on the projected noise concentration. The proposed approach is tested on the medical as well as normal images at varying noise density from 10% to 60%. This paper comprises of Discrete Cosine Transform (DCT) and median filter in collaboration with optimization. The simulation work has been carried out in MATLAB 2016b environment. The proposed approach is able to achieve high performance in terms of the mean square error (MSE) rate and peak signal to noise ratio (PSNR). The outcome of this research will help doctors in the medical science for the analysis of diseases in more accurate manner.

Index Terms— Cosine Transform, Filtration, Impulse Noise, Medical Image Processing, MR Images, Optimization, Structural Similarity Index Measurement.

1 Introduction

Digital image description may be unnatural with impulse noise throughout acquisition or conduction process [1]. Impulse noise attained by faulty pixels in camera devices, defective memory places in hardware or broadcasting in noisy network. There are two types of impulse noise which are termed as fixed and random valued noises. The fixed valued impulse noise swaps a pixels by the highest and the lowest possible strength value in active gray scale appearances. The random impulse noise substitutes the values of the pixels within a variety about the extreme opinions in active gray scale choice. Impulse noise can affect the excellence of appearance by deteriorating its spatial resolution and loss of appearance facts. Such impurity may reduce the appropriateness of digital imageries for computer vision presentation, surveillance methods, image solidity. Consequently, it is indispensable to re-establish this imageries before further handling [2],[3].

Numerous linear and non linear filters are already proposed and applied to repress impulse noise in digital images. The linear filter causes blurring Median Filters effects in digital images. Thus, non linear filters using improved filtering presentation have been extensively employed. Amongst them, increasing the pixel intensities and replaces the focus pixel with the average of the window. It is operative in impulse noise destruction at a low noise concentration, but compromises with image specifics and results in image distortions when noise solidity becomes extra ordinary. Consequently, various with few alterations have been presented by researchers like Weighted Median and Center Weighted Median filter[4].

Subsequently, Adaptive Median Filter has been presented in [5] which increase the window size using local noise concentration. This filter stretches better consequences to 40% noise concentration. As the noise concentration upsurges the size of the frame increases subsequent image blurring step and also upsurges the computation period [6]. The conservative median filters apply the median process to every pixel of ruined image without examining whether it deals with the noisy pixel or not. The image particulars added from noiseless scenario are also scrubbed and the image quality may further decline. So it is essential to notice noisy values in the appearance before filtering procedures. In this method only pixels which are recognized as noisy one would experience a filtering approach, whereas those recognized as noiseless would be intact always [7],[8]. By presenting such noise discovery appliance in the median filtering methods, the median filters evolved into Switching Median Filters. These types of filters have exposed significant performance development over conservative MF. But for the discovery of noisy values, a threshold rate is desirable in SMF and it is problematic situation to describe a vigorous threshold value [9] ,[10].

Impulse noise is primary type of noise produced in medical image instruments such as MRI, CT-scan, ultrasound, X-ray, etc. It produces visual artifacts of the interior of human organs. The process of diagnosis is affected due to the presence of these artifacts and it

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misleads the experts. So, the removal of the impulse noise from medical images is an essential step for further prognosis [11].

In this paper, a new algorithm is designed for removal of random valued impulse noise in MR images as well as for various gray scale and color images by using DCT, Median Filter and optimization technique. This proposed technique shows better results in terms of PSNR, MSE and SSIM in comparison to most of the existing techniques.

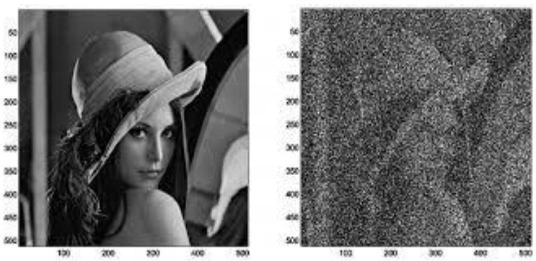


Fig. 1. Original vs. Noisy Image

2. Proposed Approach

The process flow chart for improved and optimized adaptive switching approach for reduction of impulse noise in MR images is shown in Fig.2.

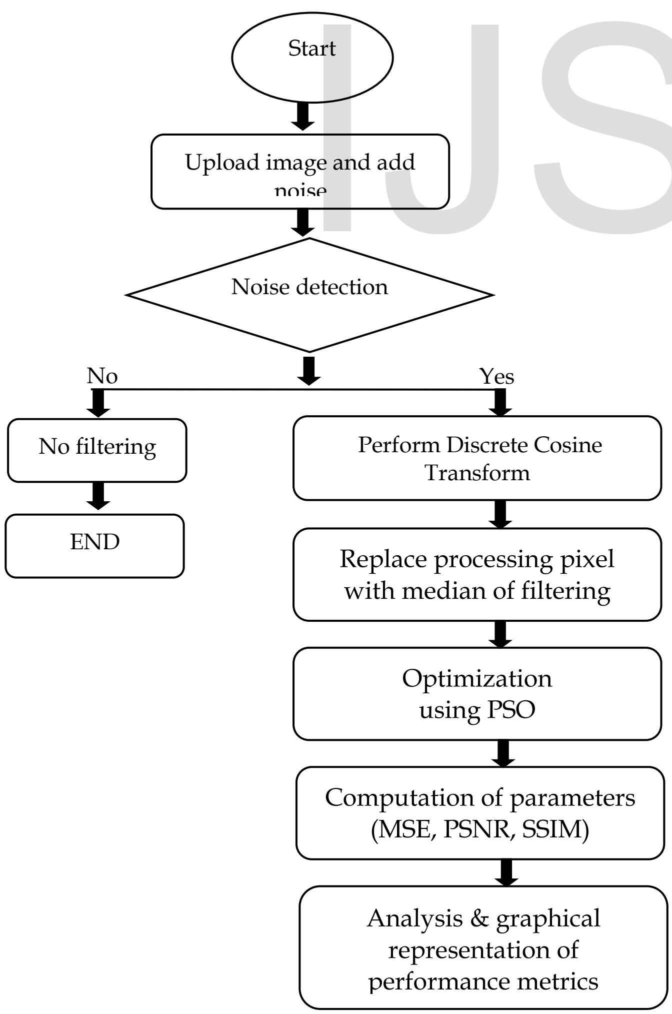


Fig.2. Flow Chart of Proposed Algorithm

2.1 Noise Detection Stage

The digital (color and gray scale) and MRI medical images are tested on wide range of noise density ranges from 10% to 60%.

The first stage of proposed filter is to detect the noisy pixels in image. The corrupted noisy pixel are appeared as significantly brighter or darker than their neighborhood pixels. The pixels darker than their neighborhood pixels are intensity minima points and pixel brighter than their neighborhood pixel are intensity maxima points. A square window of size3x3 is used in this stage . If the pixel value in the intensity extrema map is greater than 6 than the pixels are considered as noisy pixel because it is possible that there are more than one noisy pixel in the locality of processing pixel. The pixel intensity matrix and the test image I(x,y) is shown in fig 3.3 and the mechanism of locating intensity extrema points for the processing pixel in the test image I(x, y) using square window of size 3x3 is shown in Fig .3 and Fig. 4.

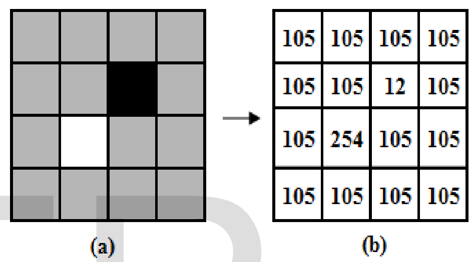


Fig. 3. Segmented Image Matrix

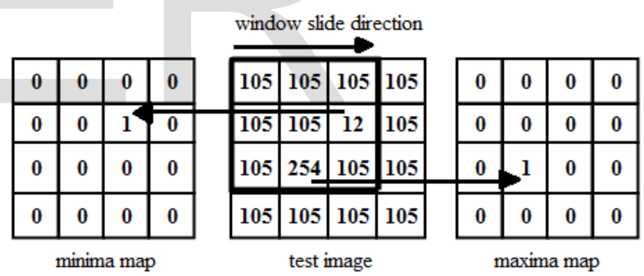


Fig. 4. Process to build intensity minima and maxima map using window size 3x3

- If no noisy pixel is detected then no further processing is performed on images.
- If the noise is detected in images than the following methods are performed on images [12].

2.2. Discrete Cosine Transform

Discrete Cosine Transform is used for the decomposition of the image pixels. The cosine transform is generally linked to structure of the image. It computes the sinosoids sum of varying scales and rate of recurrence in the image.

It converts an image into its equivalent frequency domain by partioning image pixel matrix into size of blocks N*N, where N depends upon the type of image. If we use a black & white image of 8 bit then all shading of black & white color can be expressed into 8 bit .Similarly, for color image of N=24 is used as block size. But using N=24 may increases time complexity. So for color image DCT operates on individual color component. Color image consist of 8 bit red + 8 bit green + 8 bit blue[13]. The flow chart of process is shown in Fig. 5.

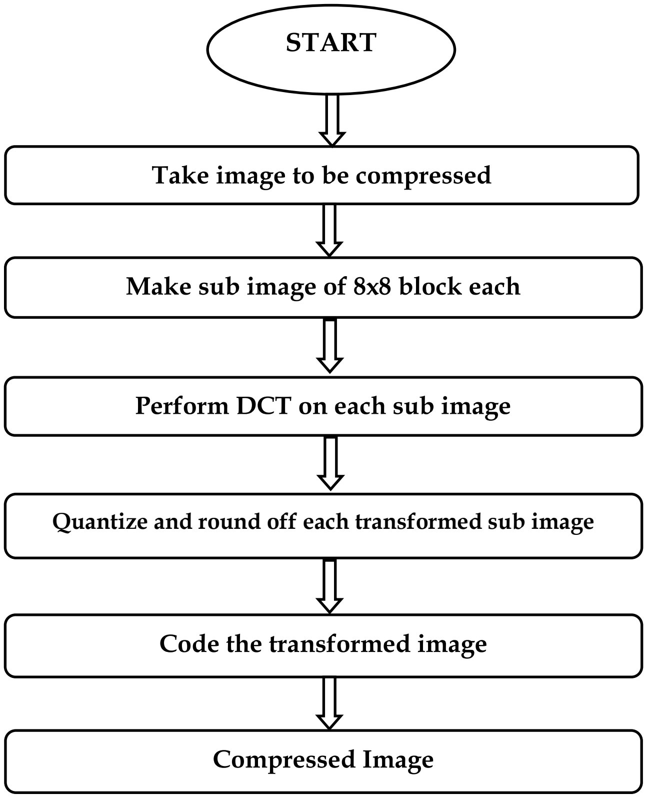


Fig. 5. Flow chart for image compression using DCT

Step 1. The image is segmented into N*N blocks of pixel. Here N may be 4, 8, 16, etc.
Step 2. Working from top to bottom, left to right, the DCT is applied to each block.
Step 3. Through quantization each block's element are compressed which means dividing by some specific value. So the large value become small and it need small size of space. This is a lossy step.
Step 4. The array of compressed blocks that compose the image is stored in a drastically reduced amount of space [14].

2.3 Median Filter

The obtained cosine output image is fed to the median filtration which in turn gives the resultant image which is having high intensities. Median Filtration is a part of a non linear filtering method which is normally used to eliminate distortions from the imageries. Such noise reducing process is to improve the outcomes of processing of the pixels. It is widely used in image processing using various certain conditions and also conserves boundaries while eliminating noise.

Standard median filter is used to remove impulse noise due to its effective noise suppression capability and its simplicity. These filter is implemented uniformly across the image and modifies both noisy and non- noisy pixels . In this method the size of square window is taken as 2k+1 , where k goes from 1 to N is used to filter the centre pixel. All the pixels in the square window are first sorted and the center pixel is change to the median value of the sorted sequence [15].

	10	5	20		
	14	70	11		
	8	2	23		

2, 5, 8, 10, 11, 14, 20, 23, 70

↑

Median (Central value 70 is replaced by 11)

Fig.6. Method of Median Filtering

1) Assume a 3x3 empty mask.
2) At the left hand corner place the empty mask.
3) Arrange the 9 pixels in descending or ascending order.
4) Chose the median from these nine values.
5) Place this median at the center.
6) Move the mask throughout the image.

Thus, in median filtering, the grey level of the centre pixel is replaced by the median value of the neighborhood pixels.

2.4 Particle Swarm Optimization

The particle swarm optimizations applied for the detection of the optimize pattern in the image.PSO is a method of parameter optimization developed by Kennedy and Eberhart in 1995. The idea of PSO was inspired by social behavior of fish schooling , bird flocking as well as swarming theory. The concept of PSO is that each particle is flown in searched space or hyperspace to find its best solution (fitness) called pbest. Then, the overall best value (global value) which is called gbest achieved by any particle in the population with its position is identified.

In PSO, the solution is associated to the position of the bird. The position is called as "particle". In order for the particle to move in the search space, it has its own flying velocity and space position. Each particle has the ability to track and memorize the current best particle (pbest) in a swarm. The particle then flies to better position (gbest) based on its neighbors best experience and own best experience [16].

Algorithm for PSO is as follows:

1) Firstly, create a population of particles or agents or pixel value to build a swarm , evenly distributed over the space X.
2) Estimate the position of each pixel value according to objective function.
3) If a particle's current position is better than its initial position , then upgrade it.
4) Determine the best particle according to particles's previous best position.
5) Update the particle's velocity value.

$$V_i^{t+1} = V_i^t + c_1U_1^t(pb_i^t - p_i^t) + c_2U_2^t(gb^t - p_i^t) \quad (1)$$

Where,
pb_i= particles's best position
gb_i= swram' s best position

C_1= cognitive learning constant

C_2= social learning constant

v_i= velocity of the particle

$c_1U_1^t(pb_i^t-p_i^t)$ = it represents personal influence

$c_2U_2^t(gb^t-p_i^t)$= it represents social influence

6) Particles are move to new position.

$$\mathbf{P_i^{t+1} = P_i^t + V_i^{t+1}} \quad (2)$$

7) Go to step 2, until target is reached.

8) Find the performance parameter.

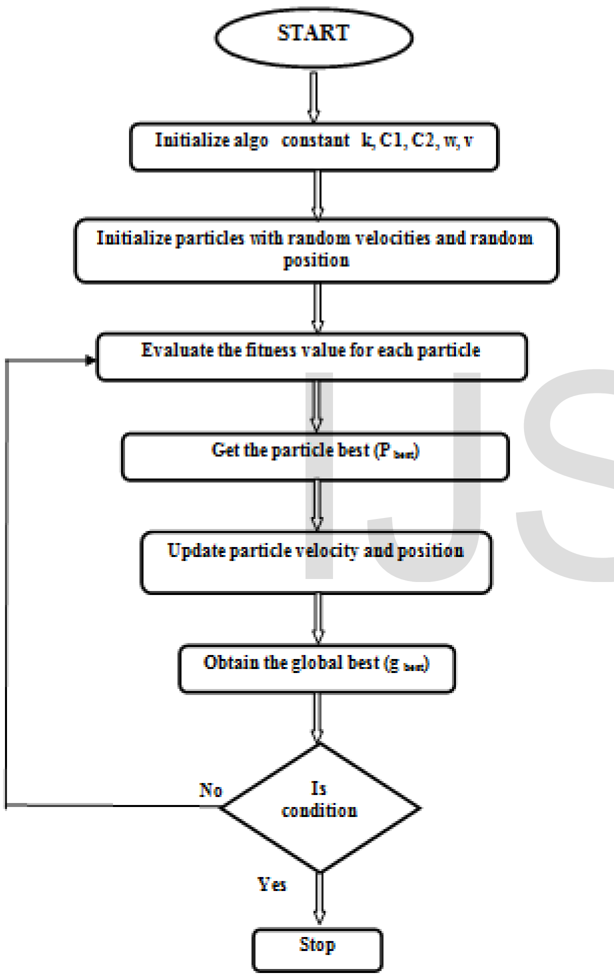


Fig. 7. Block Diagram of Particle Swarm Optimization

3. Results and Discussion

This section deals with the result and discussions of the proposed developed approach for the removing of the impulse noise. The simulation results are obtained in the MATLAB environment. The proposed filter is compared and evaluated with the existing filter. Experiments are conducted on the different types of standard gray scale , color , medical MRI images , including Cameraman , Lena , Baboon, Barbara and sample medical images. The noise density is changes from 10 % to 60 %. Comparison of proposed approach with existing approaches on the basis of values of performance metrics such as PSNR , MSE and SSIM.

For evaluating the performance of the proposed algorithm following parameters are used.

(a) Mean Square Error(MSE):

The MSE is the cumulative squared error between the original and restored image.

$$MSE = \frac{\sum_i \sum_j \left(Y(i,j) - X(i,j) \right)^2}{M * N} \quad (3)$$

Where , M*N represents the size of the image
X denotes the restored image
Y denotes the original image.

(b) Peak Signal to Noise Ratio (PSNR):

It shows the resemblance between the reconstructed image and an original image.

Mathematically , it can be expressed as :

$$(PSNR)db=10\log10\left(\frac{MAX^2}{MSE}\right) \quad (4)$$

Where, MSE is mean square error

MAX is maximum possible pixel value of image

(c) Structural Similarity Index (SSIM):

SSIM is used for measuring the similarity between two images. The Structural Similarity (SSIM) Index quality assessment index is based on the computation of three terms, namely the contrast term, luminance term and the structural term. The overall index is a multiplicative combination of the three terms.

$$SSIM(x, y)=[l(x, y)]\alpha\cdot[c(x, y)]\beta\cdot[s(x, y)]\gamma \quad (5)$$

Where,

$$l(x,y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^2\mu_y^2 C_1} \quad (6)$$

$$c(x,y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^2\sigma_y^2 C_2} \quad (7)$$

$$s(x,y) = \frac{\sigma_{xy} + C_3}{\sigma_x\sigma_y + C_3}, \quad (8)$$

Where μx, μy, σx ,σy, and σxy are the local means, standard deviations, and cross-covariancefor images *x, y*. If α = β = γ = 1 (the default for Exponents), and C3 = C2/2 (default selection of C3) the index simplifies to:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_3)}{(\mu_x^2 + \mu_y^2 + C_1)(\sigma_x^2 + \sigma_y^2 + C_2)} \quad (9)$$

Table 1 Comparison of MSE of different filters for Cameraman image at different noise density

Noise density (η) in %	MSE			
	MF	DBA	MDBUTMF	Proposed Filter
10	298.37	25.44	20.11	0.010
20	382.27	60.07	42.03	0.017
30	473.99	108.97	72.15	0.028
40	592.81	161.84	113.10	0.038
50	873.57	247.54	165.63	0.040
60	1537.50	350.50	276.36	0.043

Table 2 Comparison of PSNR of different filters for Cameraman image at different noise density

Noise density (η) in %	PSNR(dB)			
	MF	DBA	MDBUTMF	Proposed Filter
10	23.42	34.11	35.13	42.53
20	22.34	30.38	31.93	42.67
30	21.41	27.79	29.58	40.74
40	20.44	26.07	27.63	39.57
50	18.75	24.23	25.97	39.27
60	16.30	22.72	23.75	39.04

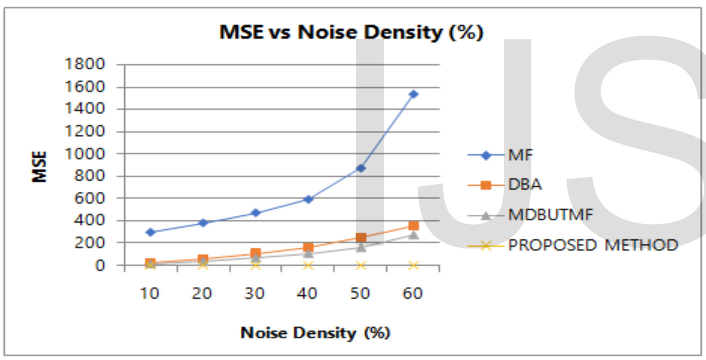


Fig.8. Graphical comparison of MSE of different filters for Cameraman image at different noise density

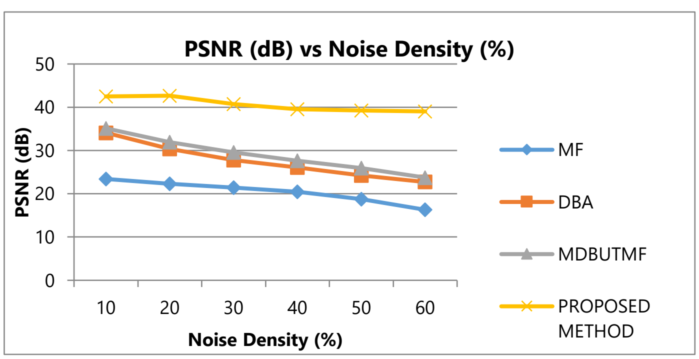


Fig. 9. Graphical Comparison of PSNR of different filters for Cameraman image at different noise density

Table 1 and Table 2 shows the comparison of PSNR and MSE of the proposed approach with the existing filters such as MF , DBA and MDBUTMF by changing the noise density from 10% to 60% . It is observed from Table 1 and Table 2 that the proposed method outperforms other ones at high and low noise densities in terms of MSE and PSNR.

Graphical representation of MSE and PSNR against noise density for cameraman image are shown in Fig. 8 and Fig.9 respectively.

Fig. 10. (a) Standard Cameraman image (b) Image corrupted by 60% noise density (c) Output of proposed filter

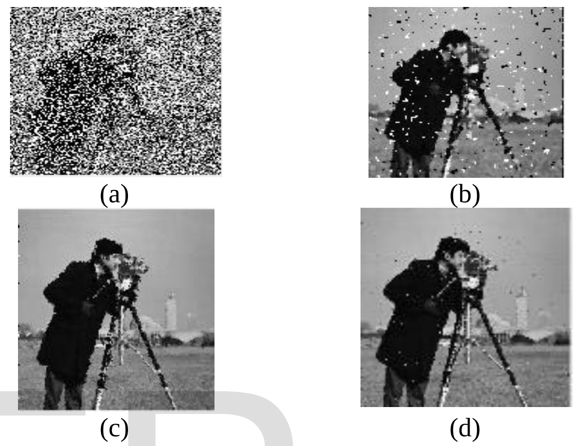


Fig.11.Results for different filters for gray scale cameraman image at 60% noise density (a) Noise corrupted image (b) Output of MF (c) Output of DBA (d) Output of MBUTMF.

Fig. 10 shows the output of standard cameraman image when corrupted with 60 % noise density. Fig. 11 shows the qualitative analysis of the proposed approach with existing approach at 60 % noise density for the gray scale cameraman image. From this figures it is noticed that output image of proposed approach is better than existing approach.

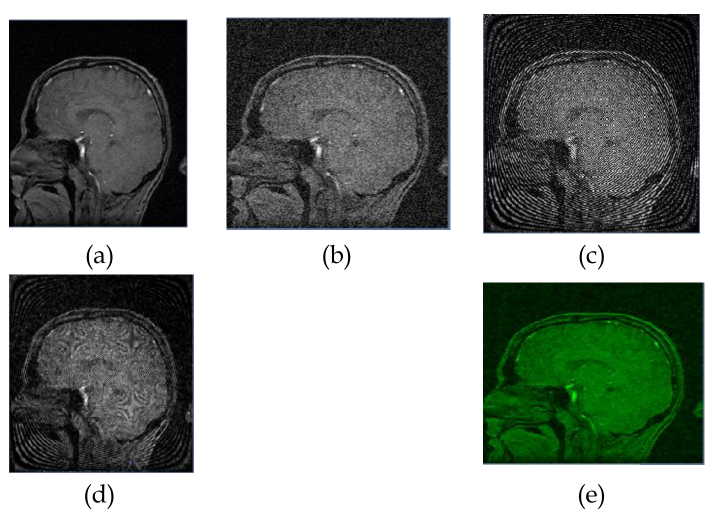
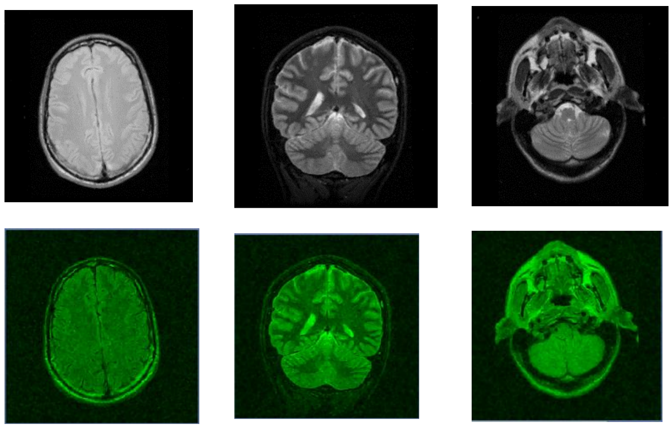


Fig. 12. (a) Original brain image (b) Noisy image (c) Discrete Cosine image (d) Filtered image (e) Output of proposed filter



(i) (ii) (iii)

Fig.13. Visual quality comparison MRI samples of proposed method with ref [11].

Fig. 12 (a) shows the brain medical image and is applied as the input on which various processing is performed. Fig. 12(b) shows the noisy image corrupted by impulse noise . Fig. 12(c) shows the DCT output, it deals with the fourier transform which converts the image from time domain to frequency domain. The operation of DCT involves computing principles of 8x8 window convolution mask. Fig. 12(d) and 12(e) shows the filtered and optimized image respectively. The particle swarm optimization is used to optimize the pattern of the image which also increases the image intensity and reduces the distortions from the image. In Fig. 13 comparison of proposed method with ref [11] are shown.

The comparative analysis of PSNR between existing and proposed approach of MRI image at different noise density is shown in table 3. It can be observed from the table that proposed approach achieves better PSNR values than existing approach. We have also concluded MSE and SSIM of samples [17] of MRI images at varying noise densities respectively. As the MSE is low PSNR will be high and will get high optimized pattern image. With the evaluation of SSIM the similarity matched is done between the original and resultant image. So high SSIM values indicates less loss of the pixels values or distortions.

4. Conclusions

In this proposed research a low density noise removal scheme for MR imageries is implemented. This technique is proved to be appropriate for software application. Such application can be recycled as a fragment of the medical appearance capturing tools for enhancement and division of MR descriptions before and throughout of medical operation in medical health sciences. The stated method limited two phases of detection and renewal. The achieved aim was the improvement of the accurateness in each stage distinctly. High precision of noisy-pixel discovery in the first phase, and their elimination in the next phase, deals with better renewal of noisy imageries. So the proposed approach is able to achieve high performance and low error rate probabilities for high removal of distortions in the medical image.

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Table 3 : Comparative Analysis of Performance Parameter of MRI Images

		Noise Density (%)											
	Parameters	10		20		30		40		50		60	
		Ref[11]	Prop.	Ref[11]	Prop.	Ref [11]	Prop.	Ref[11]	Prop.	Ref [11]	Prop.	Ref[11]	Prop.
Sample 1	PSNR dB)	36.75	43.83	34.27	42.16	31.12	40.41	30.30	39.19	28.04	39.02	26.73	38.52
	MSE	NA	0.0107	NA	0.0159	NA	0.0250	NA	0.0341	NA	0.0374	NA	0.0403
	SSIM	NA	0.071	NA	0.0675	NA	0.610	NA	0.535	NA	0.505	NA	0.477
Sample 2	PSNR (dB)	31.0	43.30	23.67	42.06	25.65	40.51	25.78	39.46	24.25	39.03	21.03	39.77
	MSE	NA	0.0121	NA	0.0164	NA	0.0250	NA	0.0341	NA	0.0373	NA	0.0407
	SSIM	NA	0.588	NA	0.520	NA	0.418	NA	0.338	NA	0.313	NA	0.289
Sample 3	PSNR dB)	32.14	43.13	33.56	42.29	23.66	40.67	28.27	39.92	26.59	39.13	25.31	38.87
	MSE	NA	0.0122	NA	0.0164	NA	0.0250	NA	0.0341	NA	0.0373	NA	0.0373
	SSIM	NA	0.593	NA	0.519	NA	0.410	NA	0.326	NA	0.300	NA	0.277
Sample 4	PSNR dB)	26.66	43.41	20.67	42.09	17.66	40.39	15.38	39.15	15.14	38.74	14.85	38.44
	MSE	NA	0.0118	NA	0.0163	NA	0.0249	NA	0.0341	NA	0.0373	NA	0.0402
	SSIM	NA	0.543	NA	0.501	NA	0.446	NA	0.390	NA	0.369	NA	0.346