

Optimization of Bilateral Filter for DICOM Images

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ABSTRACT: DICOM (Digital Imaging and Communication in Medicine) is the standard for storing, handling, printing and transmitting information in Medical Imaging. DICOM Image files are also known as '.dcm' format files. DICOM Images are prone to noise and get corrupted due to reasons like presence of ambient noise from environment, acquisition and transmission noise from the equipment etc which can considerably affect the diagnosis and treatment. Presence of noise is a major concern which calls for efficient smoothing and filtering of DICOM Images. Bilateral Filter has gained a lot of importance in Medical Imaging as it preserves fine details, edges and textures of an image. In this paper, a technique using Bilateral Filter and Genetic Algorithm is proposed to denoise and to smooth the textures of DICOM Images. The database used is of 20 MRI Images and 20 Ultrasound Images in '.dcm' format. The results are analyzed on the basis of parameters MSE and PSNR. The accuracy of filter is analyzed using Kappa statistic. For the collected DICOM database, implementation has also been done for existing technique which is Lemma distributions based Fast Bilateral Filter and is compared with the proposed technique. The results show that the proposed technique is better in terms of MSE, PSNR and Kappa Coefficient. The proposed technique is found to be very effective in filtering and smoothing the textures of DICOM Images and can be deployed where smoothing and filtering of DICOM Images are required for proper diagnosis and treatment.

KEYWORDS: Bilateral Filter, DICOM, Genetic Algorithm, Image Filtering, Image Smoothing, Medical Images, MSE, Optimization and PSNR.

I. INTRODUCTION

Medical Image Processing has gained a lot of momentum over last two decades and there has been an enormous increase in the use of digital systems in medical field. Medical Images are used in their digital form and play an important role in every modern hospital. These images are produced by various imaging modalities also known as non-invasive modalities [1] such as Ultrasound, CT, and MRI etc. Medical Imaging is a technique which helps to capture images of internal organs of the body which in turn helps tremendously in diagnosis and treatment of patients. In today's world, DICOM (Digital Imaging and Communication in Medicine) protocol has been the international standard for administration of medical image data. A DICOM image file is an outcome of the Digital Imaging and Communication in Medicine standard. Image files that are compliant with the part 10 of the DICOM standard are generally referred to as "DICOM format files" or simply "DICOM files" and are represented as ".dcm" [2]. Its purpose is to standardize the digital medical imaging and data for easy access and sharing. DICOM supports operation in a networked environment using the industry standard networking protocol TCP/IP. DICOM is the standard developed by American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA). ACR and NEMA made a joint committee in 1983. Their first standard, ACR/NEMA 300, was released in 1985. In 1988, the 2nd version was released and it gained more acceptances among vendors but soon it was realized this version needed improvements too. In 1993, 3rd version was released. Its name was then changed to "DICOM". Officially, the latest version of the standard is still 3.0 and has been constantly updated and extended since 1993 [3]. Picture Archiving and Communication System (PACS) receives, saves and transports medical images and other related information through digital ways and assists medical diagnoses efficiently. The DICOM standard has been constituted for the

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implementation of communication between medical image equipments [4]. All equipments that accord with DICOM format can connect with PACS and transport and exchange information with other equipments directly. DICOM Images get corrupted in many ways and are prone to ambient noise from environment, acquisition and transmission noise from the equipment etc which can considerably affect the diagnosis and treatment. A technique using Bilateral Filter and Genetic Algorithm has been proposed to efficiently denoise and to smooth and filter DICOM Images. The rationale of bilateral filtering is that two pixels are close to each other not only if they occupy nearby spatial locations but also if they have some similarity in the photometric range. The Bilateral Filter [5] BF $[I]_p$ is defined by:

$$BF[I]_p = \frac{1}{W_p} \sum_{q \in S} G_{\sigma_s}(\|p - q\|) G_{\sigma_r}(|I_p - I_q|) I_q \quad (1)$$

Where normalization factor W_p makes certain sum of weights of pixels to 1.0:

$$W_p = \sum_{q \in S} G_{\sigma_s}(\|p - q\|) G_{\sigma_r}(|I_p - I_q|) \quad (2)$$

Parameters σ_s and σ_r depict the amount of filtering for the image I . Equation of $BF[I]_p$ is a normalized weighted mean where G_{σ_s} is a spatial Gaussian weighting that diminishes the impact of pixels p that are away, G_{σ_r} is a range Gaussian that diminishes the impact of pixels q when their intensity values differ from I_p . [6]

The rest of the paper is organized as follows: Section II gives brief idea about the related work in the domain of Bilateral Filter and DICOM Images. Section III presents methodology in detail. Section IV shows analysis and results of the proposed method. Section V gives conclusion and References are in Section VI.

II. RELATED WORK

A lot of work has been done in the domain of medical images, Bilateral Filter and DICOM Images.

Schaefer et al. (2006) tried to investigate how DICOM standard in its current form can be used to store and communicate medical infrared images. Most of the medical areas that employ digital imaging have subscribed to DICOM standard as a common standard for storing and retrieving medical images. A conversion program will convert C THERM image to a DICOM file. [7]

Arif et al. (2011) used two popular methods: Bilateral Filter and Anisotropic-Diffusion Filtering to denoise medical images. MSE, PSNR evaluation was done for 23 MRI Images in JPEG format. The proposed method Bilat_Aniso gained PSNR and CR (Compression Ratio) performance when compared with traditional methods by 8%. [8]

Tang et al. (2012) investigated reduction of speckle noise in 3D Ultrasound images using Adaptive 3D Bilateral Filter for cattle follicle segmentation and volume estimation. The quantitative analysis verified the effectiveness of the proposed method. [9]

Sumalatha et al. (2013) proposed a technique which used salt and pepper noise corrupted MRI and Ultrasound images. Experimental results show that the proposed filter outperforms the mean, median and Adaptive median filters in terms of MSE and PSNR. [10]

Mahesh Mohan et al. (2013) proposed contourlet transform as a step which will be executed as a preprocessing step on Bilateral Filtering or on NLM filtering. It utilized CT image of abdomen and MRI image of brain. It is superior approach when it comes to calculating PSNR and perceptual quality in comparison to that of Bilateral Filtering or NLM denoising performed alone. [11]

Kalavathi et al. (2016) proposed Histogram-based Localized wiener filter in order to remove impulse noise from MR brain images and the proposed method gives better results on denoising of impulse noises in medical images compared to other existing methods. [12]

Kaur et al. (2016) used Multifarious denoising filters and proposed a technique which includes Genetic Algorithm to denoise medical images. The results used Ultrasound images and are compared with spatial domain based denoising filtering techniques. Experimental results show that the proposed technique gives enhanced visual clarity for diagnosing the medical images. [13]

Papari et al. (2016) has proposed fast implementation of bilateral filtering by optimal expansion of the filter kernel using Lemma distributions. This method leads to much faster convergence than similar algorithms aimed at improving the speed of bilateral filter and preserves edges while smoothing an image. [14]

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Muthuswamy (2017) proposed a new edge preserving hybrid method which is a blend of two filters (Bilateral Filter and Wiener Filter) to denoise liver CT images and abdominal CT images. The technique was found efficient in removing noise from liver CT images. [15]

III. METHODOLOGY

The proposed work has been motivated by the fact that Bilateral Filter is very efficient at smoothing the textures of an image while preserving edges and fine details. In this paper, the performance of Bilateral Filter has been improved for DICOM Images. The algorithm used for optimization is Genetic Algorithm. The first and foremost step is converting '.dcm' format files to '.bmp' format files for visualization and processing for experimental purpose. After that, pre-processing of noise present in images is done using 'imfilter function' in MATLAB. Now, instead of processing complete image, an image is segmented into various segments i.e. sets of pixels to make the processing easy and this is done using Trigonometric Polynomials approximation. Then, Quantization is performed and the quantized values are then given as population to Genetic Algorithm. Genetic Algorithm with the help of its genetic operators performs selection, crossover and mutation using fitness function and yields optimized values as filtered image pixels. The output optimized values provided by Genetic Algorithm are then fed to Kernel which will help in the reconstruction of an image and a smoothed and filtered output image is obtained as result. The Block Diagram of the Proposed Method is shown in Fig. 1.

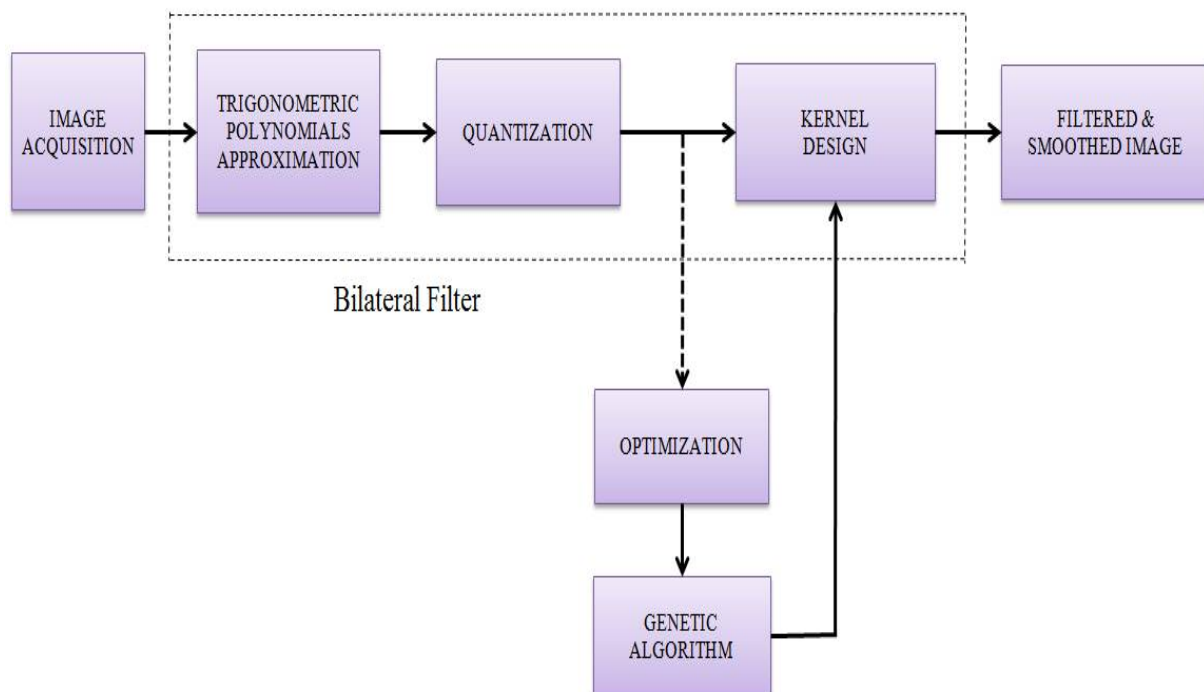


Figure 1: Block diagram of the proposed method

The steps involved in the implementation are:

1) Image Acquisition

The term implies processing, storage and display of collected images. The pre-processing steps chosen are conversion from '.dcm' format images to '.bmp' format images for visualization and pre-processing of noise in

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images using 'imfilter function' in MATLAB. The acquired images are then used as input images for simulation purpose.

2) Trigonometric Polynomials

Bilateral Filter comprises three parts: Trigonometric Polynomials approximation, Quantization and Kernel Design. The parameters for Bilateral Filter are shown in Table 1.

Table 1: Parameters of Bilateral Filter

Symbol	Parameter	Value
w	Window size	9
σ_s	Spatial domain standard deviation	1
σ_r	Intensity domain standard deviation	20

Segmentation is basically done to divide an image into different parts for better analysis. Cluster based segmentation approach is followed using trigonometric polynomials. A Trigonometric Polynomial is a finite linear combination of functions $\sin(kx)$ and $\cos(kx)$ i.e.

$$F(x) = \cos(kx) \text{ and } \sin(kx) \quad \text{for } k=0, \dots, n.$$

The pixels in each row and column are processed by means of trigonometric polynomials of type as defined by $T(x)$. $T(x)$ stands for a Trigonometric Polynomial function of degree n.

$$T(x) = a_0 + \sum_{k=1}^n (a_k \cos kx + b_k \sin kx) \quad (3)$$

Where $x \in R$, $a_k \neq 0$ or $b_k \neq 0$.

k= total number of pixels

a= total number of rows

b= total number of columns.

3) Quantization

The result obtained by Trigonometric Polynomials Approximation is then used for quantization to produce Quantized values. These Quantized values then act as Population for Genetic Algorithm. Quantization is achieved by compressing a range of values to a single quantum value. It has a relation with the number of gray levels as it determines the number of gray levels that an image can have. Quantization used is expressed as below:

$$H(z) = (1 + e_0 z^{-1} + e_1 z^{-2} + e_2 z^{-3} + e_3 z^{-4})^{-1} \quad (4)$$

Where z= Total Polynomials and e= error.

The supposed values are:

$$\begin{aligned} e_0 &= (3.6)^{-1} & e_2 &= (2.916)^{-1} \\ e_1 &= (4.80)^{-1} & e_3 &= (0.6561)^{-1} \end{aligned}$$

4) Genetic Algorithm

Optimization is the process of making something better. It means adjusting the input values to find minimum or maximum output or result. The optimization technique used is Genetic Algorithm. Genetic Algorithms (GA's) is a soft-computing approach. The basic principles of GA were first proposed by Holland [16]. Genetic Algorithms follow the principle of Charles Darwin's Theory of "Survival of the fittest". Optimization is done through natural exchange of genetic material between parents and an Offspring is formed from parent genes. Fitness of an offspring is evaluated and only the fittest individuals are allowed to breed. In computer world, genetic material is replaced by the strings of bits and natural selection replaced by fitness function. Mating of parents is represented by genetic operators such as crossover and mutation. Fig. 2 represents flowchart of simple Genetic Algorithm showing all the steps involved in the implementation of algorithm.

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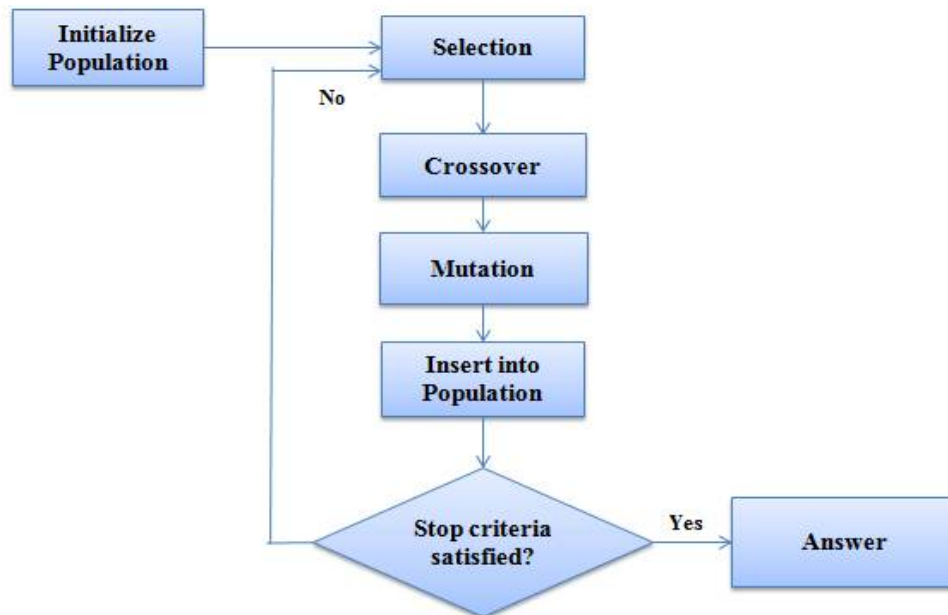


Figure 2: Flowchart of simple Genetic Algorithm

The steps involved are:

i) Initialization of Population

For the Algorithm to run, population is required. From the population, Parents are selected and then crossover and mutation takes place [17]. After terminating condition has been satisfied, the algorithm comes out of the loop and gives the result. Here, the quantized values obtained after Quantization step act as population to GA. With the initialization of the algorithm, the first generation starts and the algorithm runs till the maximum number of generations defined.

ii) Evaluation of Population

In this step, every pixel value is taken under consideration. The loop runs as shown below:

```

for i= 1 to N do
  for j= 1 to L do
    Evaluate P[i] and P[j].
  
```

Where N shows the pixel values are evaluated row wise, L shows the pixel values are evaluated column wise. P[i] and P[j] represent the pixel values being taken under consideration.

iii) Selection

The selection operator is based on two functions: Fitness function and Roulette function. Parents are selected according to their fitness and using Roulette wheel selection function.

Fitness function is an objective function which describes how close a solution to the problem can be achieved according to the set aims.

The fitness function is described as:

$$\begin{aligned} &\text{If } (x \geq \text{roulette function value}) \text{ or} \\ &\text{If } (x > 0) \\ &f(x) = \left\lceil \left(\frac{1}{\text{sum}(x)} \right) * 0.9 \right\rceil^T \end{aligned} \quad (5)$$

$$\begin{aligned} &\text{Else} \\ &f(x) = 0 \\ &\text{return.} \end{aligned} \quad (6)$$

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Where $x = [\text{length of chromosome, blocks, pixel value, roulette function value}]$

Length of chromosome = 5, number of pixels taken under consideration at a time = 10, block size = 2×5 .

Roulette-wheel selection is the most common used selection mechanism for the selection of Parents to produce Offspring. [17]

Roulette wheel model selects Parents according to their fitness. Roulette-wheel Parent selection follows the steps as shown below:

- Sum the fitness of all the population members
- Generate a random number (n) between 0 and total fitness value of all the population members.
- Return the first population member whose fitness added to the fitness of the preceding population members is greater than or equal to n.

Using these two functions, Selection operator selects the Parents and the loop that runs for this operator in Algorithm is

```
for i= 1 to N do
for j= 1 to L do
Parent[i] = fitness (P[i], roulette function)
Parent[j] = fitness (P[j], roulette function)
```

The two Parent matrices selected in this step are then subjected to crossover to produce an offspring matrix.

iv) Crossover

Crossover indicates exchange of genetic material between two Parent matrices and the resultant matrix is termed as Offspring. Crossover occurs according to the user-definable Crossover Probability [18]. The steps for uniform crossover to take place are:

```
for i= 1 to N step2 do
for j= 1 to L do
If (j ≤ crossover_point)
Offspring [i] [j] = Parents [i] [j]
Offspring [i+1] [j] = Parents [i+1] [j]
Else
Offspring [i] [j] = Parents [i+1] [j]
Offspring [i+1] [j] = Parents [i] [j].
```

v) Mutation

Mutation is a genetic operator that alters some gene values in Offspring from its initial state. Mutation occurs according to the user-definable Mutation Probability [18]. This probability should be set low. If it is too high, the search will turn into primitive random search. The steps for mutation to take place are:

```
for i= 1 to N do
for j= 1 to L do
If (random_number < mutation rate)
Offspring [i][j] = random (cell(i,j))
Else
Offspring [i][j] = Offspring [j][i]
```

vi) Reinsertion into Population

The resultant Offspring after mutation is again inserted into population and there is a start of new generation. Again, there will be selection of fittest individuals to be Parents. In the new generation, again Parents undergo crossover to produce Offspring. The process continues till the termination condition has been satisfied.

vii) Termination Condition

The terminating condition says if current generation is less than maximum number of generations defined for the process, algorithm runs and jumps to selection step again. Otherwise it comes out of the loop and gives the result.

The Parameters of GA taken under consideration are: Maximum population size = 100, Crossover probability = 0.6, Mutation probability = 0.2 and Maximum number of generations = 200.

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5) Kernel Design

Reconstruction of image is the last task done by Bilateral Filter and is done with the use of Kernel. Kernel helps in the reconstruction of image using the result provided by GA. It helps in parallel processing. The kernel designed is:

$$V = v_{ij} = \left\lfloor \frac{\sum_{i=1}^N (\sum_{j=1}^M f_{ij} d_{ij})}{F} \right\rfloor \quad (7)$$

Where

f_{ij} Represent the coefficient of convolution values for kernel at position in the kernel (i,j).

d_{ij} Represent the data value of the pixel that corresponds to f_{ij}

F= either the sum of the coefficients of the kernel or, 1 if the sum of the coefficients is equal to zero.

v_{ij} represent the output pixel value. In case it is less than zero, it is clipped to zero.

V= the output image.

A smoothed and filtered Image is produced as output.

IV. EXPERIMENTAL RESULTS

Database of 20 MRI and 20 Ultrasound images has been collected from UCI Machine Learning Repository. Images of collected database have been resized to 256*256 dimensions for further processing in MATLAB. The performance analysis has been done on the basis of parameters MSE and PSNR. The accuracy of the filter is analyzed using kappa coefficient.

i) Mean Square Error (MSE): It represents the cumulative squared error that occurs between denoised and original form of the image. Its mathematical representation is:

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2 \quad (8)$$

Where m represents number of rows in an image, n represents number of columns in an image. $I(i,j)$ Is noisy image and $K(i,j)$ is the denoised image.

ii) Peak signal-to-noise Ratio (PSNR): It computes Peak signal-to-noise Ratio between images. It is mathematically expressed as:

$$PSNR = 10 \cdot \log_{10} \left(\frac{MAX_I^2}{MSE} \right) \quad (9)$$

Where, MAX_I is the maximum possible pixel value of the image or is also known as maximum fluctuation in the input image data type. When the pixels are represented using 8 bits per sample, this is 255 and if the input image has a double-precision floating-point data type, $MAX_I = 1$. The PSNR value approaches infinity as the MSE approaches zero. Higher value of PSNR of denoised and original image implies that the performance of the denoising filter method and visual quality of the denoised image is good [19].

iii) Kappa Coefficient: Kappa coefficient is used to measure the agreement between two processes. Here, the filter accuracy has been measured using kappa coefficient for both existing and proposed technique. It is defined as:

$$\text{kappa's coefficient} = \left| \frac{\text{True acceptance rate} - \text{True rejection rate}}{\text{Total dataset}} \right| \quad (10)$$

20 MRI images were used for the work and the filtered output image corresponding to two sample input MRI images by proposed method is shown in Fig. 3.

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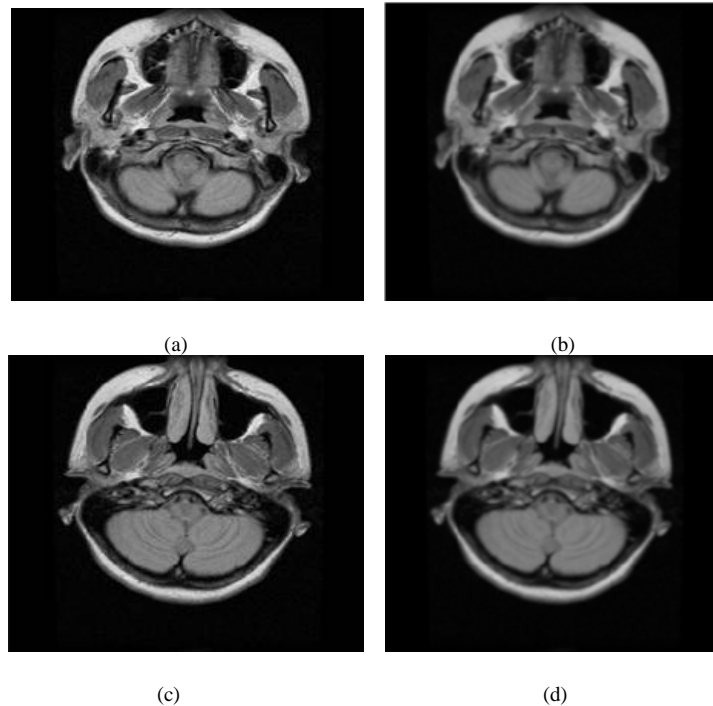
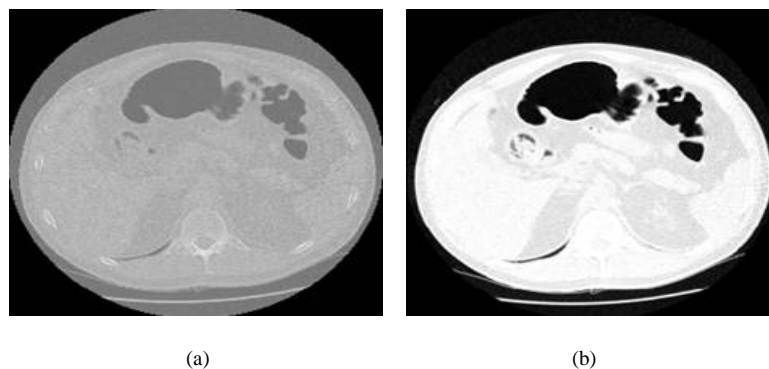


Figure 3: (a) Input MRI image 1. (b) Filtered MRI image 1. (c) Input MRI image 2. (d) Filtered MRI image 2.

20 Ultrasound images were used for the work and the filtered output image corresponding to two sample input Ultrasound images by proposed method is shown in Fig. 4.



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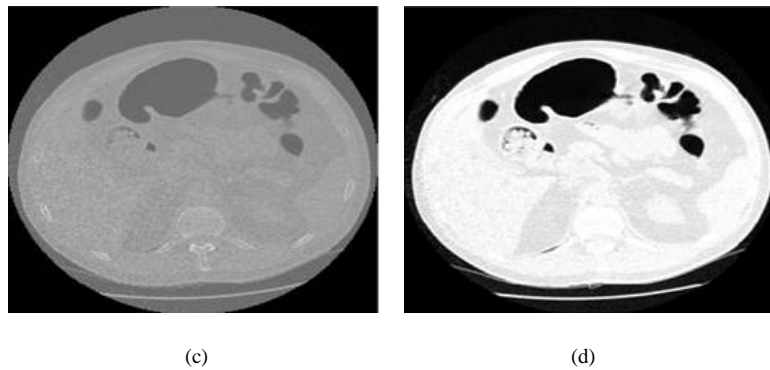


Figure 4: a) Input Ultrasound image 1. (b) Filtered Ultrasound image 1. (c) Input Ultrasound image 2. (d) Filtered Ultrasound image 2.

PSNR and MSE parameters depict the visual quality of an image. Fig. 5 shows PSNR and MSE plot for MRI Dataset (20 images) and Fig. 6 shows PSNR and MSE plot for Ultrasound Dataset (20 images).

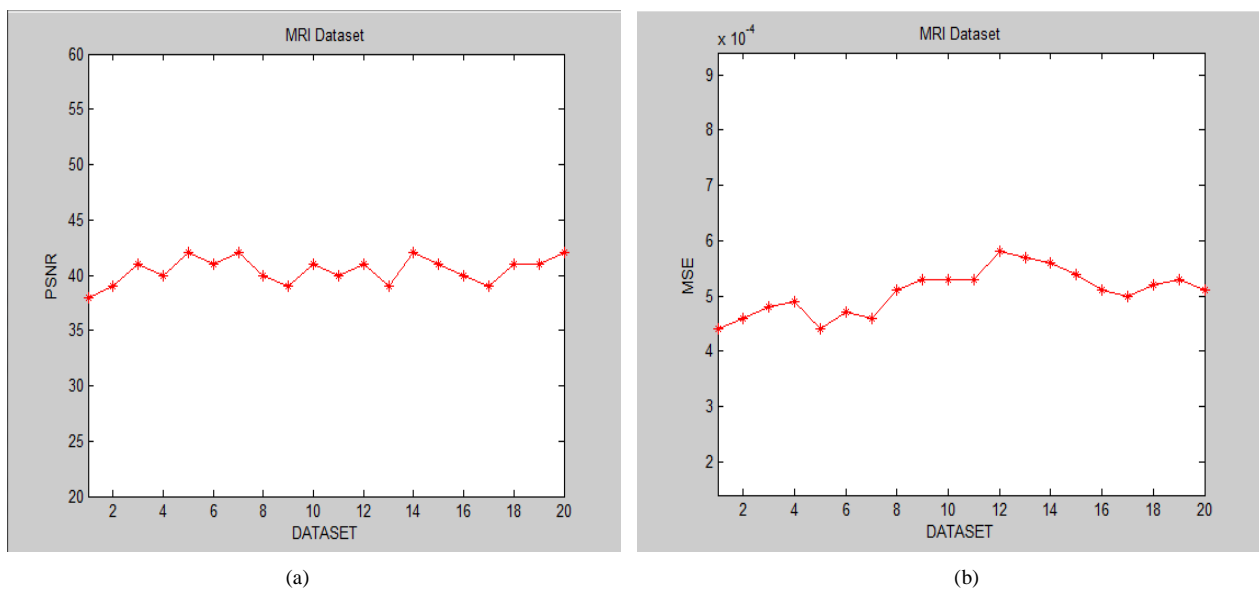


Figure 5: (a) PSNR plot for MRI dataset. (b) MSE plot for MRI dataset.

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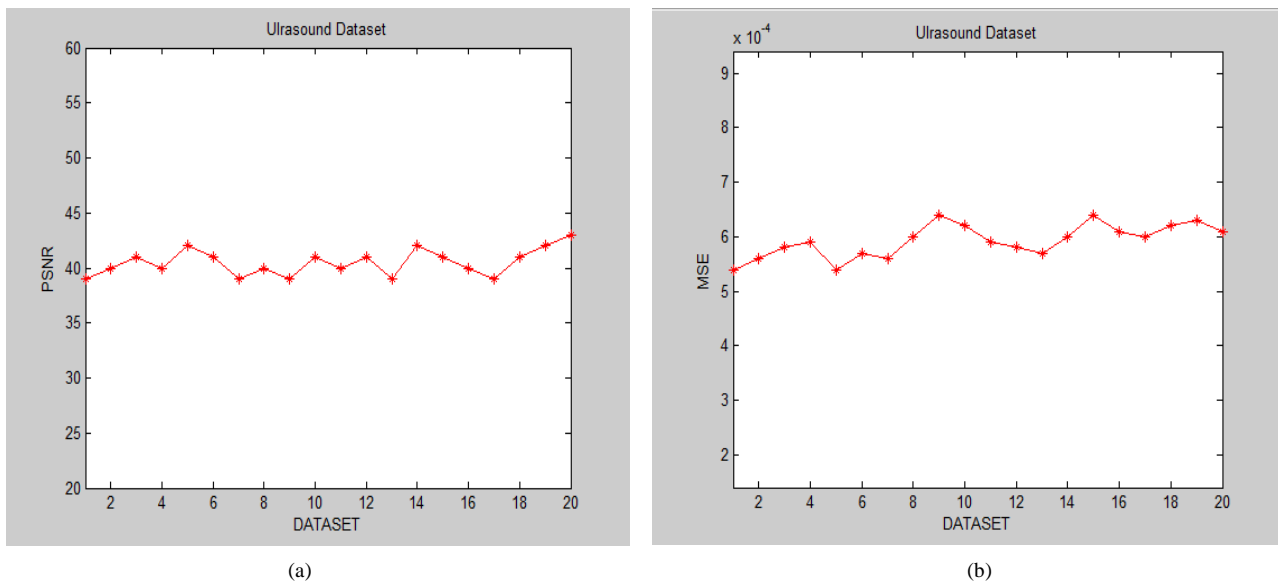


Figure 6: (a) PSNR plot for Ultrasound dataset. (b) MSE plot for Ultrasound dataset.

The comparison of existing technique [14] and proposed technique has been done on the basis of parameters Mean Square Error, Peak Signal-to-noise Ratio, and Kappa coefficient. Fig. 7 shows MSE plot and PSNR plot for comparative analysis done on MRI dataset. Fig. 8 shows MSE plot and PSNR plot for comparative analysis done on Ultrasound dataset.

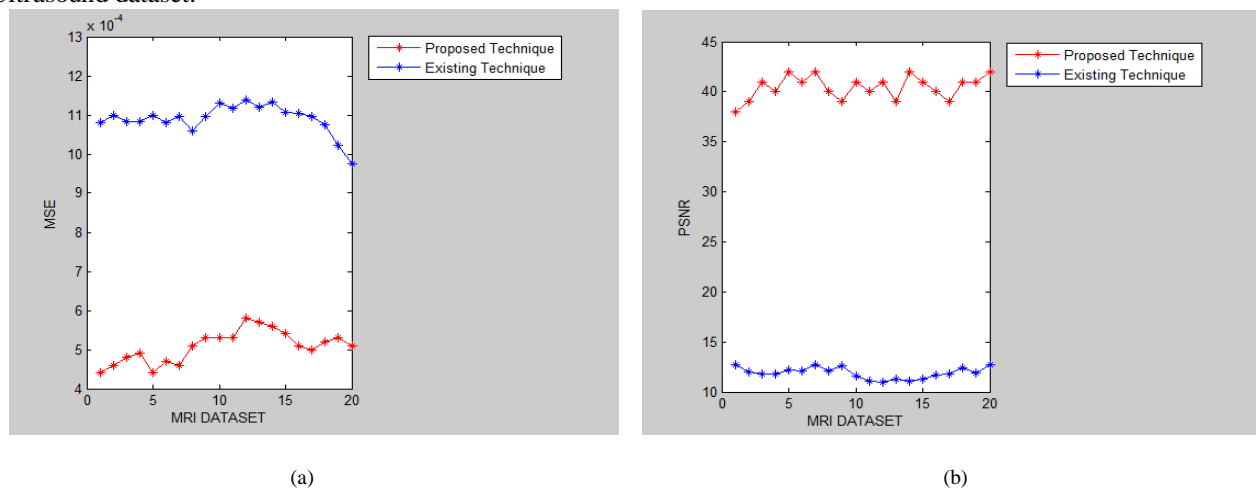


Figure 7: (a) MSE plot for comparative analysis on MRI dataset. (b) PSNR plot for comparative analysis on MRI dataset.

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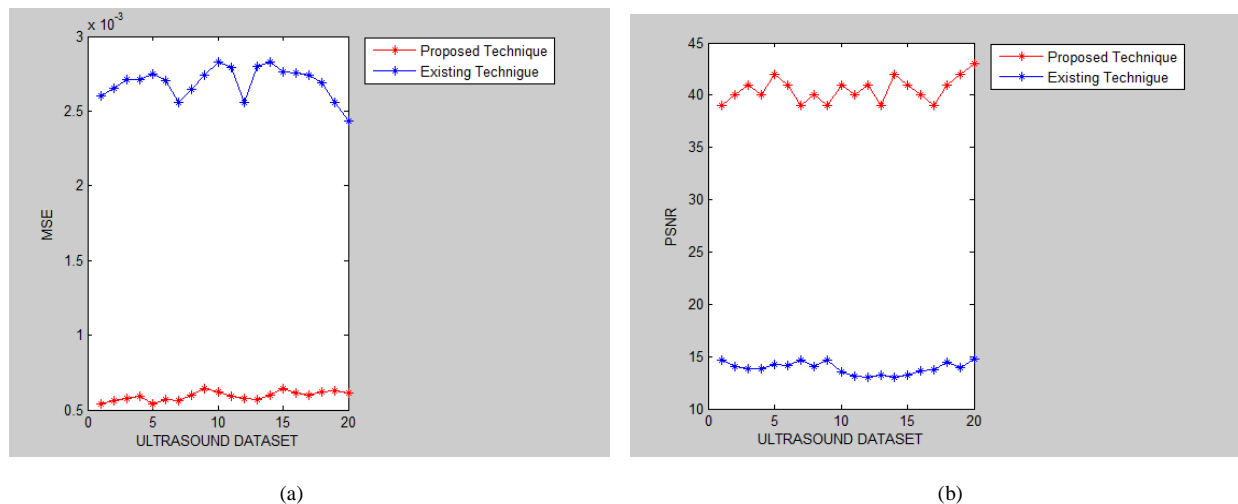


Figure 8: (a) MSE plot for comparative analysis on Ultrasound dataset. (b) PSNR plot for comparative analysis on Ultrasound dataset.

Another parameter used for comparative analysis is Kappa's Coefficient. The value of kappa coefficient can be at the most equal to 1 or can be described in percentage. On MRI dataset, Kappa's value for existing technique is 78.9 (%) and for proposed technique is 89.1. On Ultrasound dataset, Kappa's value for existing technique is 80.9 and for proposed technique is 91.1.

From the performance analysis and comparative analysis done on both the datasets, it can be said that the proposed technique is efficient in smoothing and filtering DICOM Images as it yields higher PSNR values and lower MSE values for both datasets (MRI and Ultrasound) used for experimental purpose.

V. CONCLUSION

Medical Imaging is one of the most important techniques which play a major role in diagnosis of diseases present in body. There has been an enormous increase in the use of digital systems in medical field over last two decades. DICOM (Digital Imaging and Communications in Medicine) is a standard for handling, storing, printing and transmitting information in Medical Imaging. DICOM Images are vulnerable to noise and efficient filtering technique is required for these images. In this paper, a technique using Bilateral Filter and Genetic Algorithm has been proposed to smooth and filter DICOM Images. The implementation of Genetic Algorithm was done in MATLAB. Bilateral Filter has three main aspects: Trigonometric Polynomials approximation, Quantization and Reconstruction of image using Kernel. Quantized values are fed as population to GA and GA gives optimized values as output. Kernel designed helps in reconstruction of images to give smooth and filtered images as output. The database used is of 20 MRI Images and 20 Ultrasound Images. For the database collected, implementation was also done for existing technique which is Lemma distributions based Fast Bilateral Filter. The analysis done on database is based on the parameters MSE and PSNR. The filter accuracy is analyzed using Kappa statistic. Results show proposed technique gives lower MSE and higher PSNR values and is very efficient in smoothing the textures of DICOM Images and hence can be employed where smoothing and filtering of DICOM Images are required.

An effort can be made to further improve this technique in terms of simulation time and accuracy. The simulation time can be improved by utilizing testing processes. Testing processes include validation and training with the use of Support Vector Machine (SVM) or Neural Networks. Accuracy can be improved with respect to precision and recall rate on the basis of data mining.

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