



Ultrasound Image Noise Reduction and Enhancement Model based on Yellow Saddle Goatfish Optimization Algorithm

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Abstract

In the modern-day diagnostics, ultrasound play an important role in different applications such as vascular, gynecological, cardiac, and obstetrical for diagnosis the various diseases. The main benefit of the ultrasound is that it is non-invasive method and inexpensive. However, in the real-scenario, ultrasound images contain speckle noise which negatively impact the image quality in terms of edges, texture information, and boundaries. In order to eliminate noise, various filters are deployed by researchers in the literature. The limitations of their method are that a fixed level of noise is removed using conventional filters in which parameter values of the filters are fixed. However, in the real-time situation, the noise is random and adaptive filters are required which eliminate any level of noise. To achieve this goal, this paper proposes an adaptive filtering model for eliminate speckle noise based on yellow saddle goatfish optimization (YSGO) algorithm. The YSGO algorithm is based on the hunting behaviour of the fishes. In the proposed model, bilateral filter and speckle-reducing anisotropic diffusion filtering methods and enhancement power law method are taken under consideration. Further, the parameter values of the filtering method and enhancement methods are determined using the nature-inspired YSGO algorithm. The YSGO algorithm minimize the noise and enhances the image brightness and edge information based on the objective function. In our model, mean square error (MSE) and entropy is taken as the objective function. Further, the proposed model is applied on the standard ultrasound images. The visual analysis of the images is done based on the subjective analysis whereas various performance metrics are measured for measure the image quality in the objective analysis. The results reveals that the proposed model outperforms over the existing models in terms of PSNR.

Keywords: Edge Preserving; Enhancement; Noise Reduction; Power Law; Speckle Noise; Ultrasound Images; YSGO.

1. Introduction

In the present scenario, medical ultrasonography plays an important role in the clinical diagnosis [1]. The main benefit of ultrasonography procedure is that it is non-invasive in nature, less expensive, and less-time consuming. Further, it is maximum used in the medical field for analyse the internal structure of the body. Thus,

to accomplish this goal, ultrasound systems are used. These systems used extremely high energy of acoustic ways (Higher than 20kHz) and measures the echo patterns are generated from the organ or tissues in the body and plotted in the two-dimensional image. However, in the real-scenario, the images are affected due to various obstructions such as artefacts, shadows, and noises. In the noises, speckle noise is highly visual in the ultrasound images over other. This noise comes under multiplicative noise. Due to this noise, degradation comes in the image textural data. Besides that, fine details in terms lines and edges of the image also negatively impact [2-3]. Further, ultrasound images are used for various applications such as feature extraction and segmentation. Thus, pre-processing of the ultrasound images is required for remove the noise while preserving the edges, brightness of image. To achieve this goal, the main objective of this paper is to design a noise reduction and enhancement model. The paper's key contribution is then briefly outlined.

- An ultrasound image noise reduction and enhancement model based on YSGO algorithm is proposed. As we compared to the previous models, our model is adaptive and according to the ultrasound characteristics remove the noise and enhance the image.
- In our model, in place of fixed parameter values of filtering and enhancement algorithm, optimal parameter values are determined using YSGO algorithm. To achieve this goal, objective functions are designed based on Mean Square Error (MSE) and entropy parameter.
- Our model achieves better PSNR over the existing models.

The remaining paper is classified into five sections. Section 2 shows the related work done for ultrasound image noise reduction and enhancement. Section 3 defines the preliminaries in which filtering, enhancement, and the YSGO algorithm are explained. Section 4 explains the ultrasound image noise reduction and enhancement model using the YSGO algorithm in the Proposed model section. Section 5 shows the results and discussion part, in which subjective, objective, and comparative analysis is shown. Section 6 provides conclusion.

2. Related Work

In the literature, numerous speckle noise filtering methods are designed by researchers for ultrasound images. Singh et al. [4], hybridized the three filters (such as guided, bilateral, and rotation invariant bilateral nonlocal mean filter) for eliminate the speckle noise. The simulation evaluation is performed on the synthetic and real-time images. The result shows that their method is able to remove noise, preserve the edge and small characteristics of the image. Mstafa et al. [5], designed ultrasound speckle noise filtering and enhancement method to eliminate noise and preserve the features of the image using the noise filtering and edge detection methods. In their work, the filtering methods are taken under consideration are "homogeneous mask area filtering", "median filtering", "geometric filtering", "anisotropic diffusion filtering", "wavelet filtering", and "total variation denoising". On the other hand, canny, sobel, Prewitt, Robert, and Laplacian in the edge detection method. Initially, in their work, they applied all filters on the ultrasound image and determine the three best filter based on the performance metrics. After that, on the best filters, applied the edge detection methods. Their evaluation result shows that with sobel filter gives superior results over others. In [6], used the SRAD, DWT, WGIF, and GDGIF filtering methods to remove speckle noise. Further, in their work, standard and real-time images are taken under consideration for validate the model and various performance metrics are measured. In [7], combined the bilateral, median modified wiener filter, with dual tree complex wavelet transform to remove the speckle noise and fused the filtered images. The simulation evaluation is done on the open-source database images and determined two performance metrics PSNR, SSIM for validation purposes. Kadah et al. [8], initially, used the five stacked filters (wavelet, relaxed median filtering, SRAD, local statics-based filtering). After that, determined the weight values of stacked filters using the PCA algorithm. The evaluation is performed on the real-time images.

From the literature, we found that in the existing methods, a fixed noise is added. Further, the window size and number of parameter values of the filtering methods are fixed. However, in the real-scenario, the noise is random. Therefore, adaptive filtering methods are required which remove the any level of noise. To achieve this goal, in place of fixed parameter values of filtering methods, optimal parameter values required for it. However, in the real-scenario, it is difficult task to determine the optimal parameter value from the desired range value of the parameter. To accomplish this, optimization algorithms are played an important role. In the literature, numerous optimization algorithms are available. Out of these, nature-inspired algorithms are gained popularity in the image processing methods to search the optimal parameter values. These algorithms are based on the living organisms which performs various operations for their searching their food for survival purposes. In the literature, nature-inspired algorithm is classified into evolutionary and swarm intelligence algorithms and differentiated from each other based on the searching process principle. In this paper, nature-inspired yellow saddle goatfish optimization (YSGO) algorithm is deployed for determine the optimal parameter value of the filtering methods. Further, in order to enhance the quality of the image, in the final stage of the proposed model,

power law method is applied. Also, parameter value of power law method is determined using YSGO algorithm based on the objective function.

3. Preliminaries

In the proposed ultrasound image noise reduction and enhancement model, three methods (such as bilateral filter, speckle filter, and power law method) and one nature-inspired optimization YSGO algorithm is taken under consideration. This section gives a detailed description of these methods and algorithm to understand the proposed model.

A. Bilateral Filter: The bilateral filter is used to preserve the edges of the images in an efficient way. To achieve this goal, bilateral filter uses the gaussian bilateral method [9]. In the proposed method, we have used the inbuilt function of bilateral filter (*imbilatfilt*). The syntax of this function is shown below.

$$j = \text{imbilatfilt}(I, \text{degree of smoothing}, \text{spatial sigma}) \quad (1)$$

In Eq. (1), the I denotes the input image, degree of smoothing, and spatial sigma are variable parameter in it and its optimal values are determined using the YSGO algorithm in the proposed method.

B. Speckle Filter: In order to remove the speckle noise, speckle filter is used. The speckle filter uses the “speckle-reducing anisotropic diffusion” (SRAD) algorithm to reduce the speckle noise in an image [10]. In the proposed method, we have used the inbuilt function of speckle filter (*specklefilt*). The syntax of this function is shown below.

$$j = \text{specklefilt}(I_{\text{noise}}, \text{degree of smoothing}, \text{number of iterations}) \quad (2)$$

In Eq. (2), the I_{noise} denotes the input image. On the other hand, the *degree of smoothing* parameter value varies in between [0-1] and higher value of it denoises the image to a greater degree. In the last, number of iterations should be a positive integer and higher value of denoise the image in an efficient manner. In the proposed method, the optimal parameter values of degree of smoothing and number of iterations are determined using the YSGO algorithm.

C. Power Law Method: The power law method is used to enhance the gamma value of the images [11]. It is calculated using Eq. (3).

$$I_{\text{out}} = 255 \left(\frac{I_{\text{in}}}{255} \right)^{\gamma} \quad (3)$$

In Eq. (3), I_{in} and I_{out} denotes the input and output image whereas gamma is an application dependent constant. The appropriate value of γ plays a significant role in the enhancing the image naturalness. $\gamma > 1$ will make the image darker whereas $\gamma < 1$ will make the image brighter. In the proposed method, according to the image contrast, the optimal parameter value of γ is determined using the YSGO algorithm.

D. Yellow Saddle Goatfish Optimization Algorithm: The yellow saddle goatfish lives in the live in the group to increase the chances of foraging and reproduction rate. In these groups, these fishes are self-organized and adopt different behaviour (such as catcher and blocker fishes) to hurt the prey. The main role of the catches fishes to find the prey in a certain area whereas blocker fishes try to control the escape of the prey. Besides that, these fishes change their behaviour while hurting the behaviour due to self-organized nature. This behaviour was studied and analysed by Zaldivar et al. [12-13] and proposed a nature inspired yellow saddle goatfish optimization algorithm. There are five stages in the YSGO algorithm is shown in Figure 1. The detailed description of these stages is given below.

- **Primary Stage:** In the primary stage of the YSGO algorithm, the input parameters of the algorithm is defined such as total number of goatfishes, total number of groups in terms of clusters, total iterations, objective function, and lower and upper limits of the parameters which need to find.
- **Chaser Fishes:** In each cluster, a chaser fish is chosen based on how much it is near to the prey. In the YSGO algorithm, the fitness evaluation of the goatfish is done based on the objective function and which fish has the best fitness is selected as chaser fish while searching the optimal solution.
- **Blocker Fishes:** The fishes are remained after selecting the chaser fish works as blocker fishes in the groups. These fishes follow the chaser fishes and tries to control the escape of the prey.
- **Interchange of Roles:** During the hurting process of the prey, the prey tries to escape from the cluster of fishes. Therefore, the position of the prey is random with respect to time. Therefore, the fishes perform one other attractive principle known as interchanging of their roles in the group. In the YSGO algorithm, the chaser and blocker fishes interchange their position according to which fish near to prey.
- **Changes of the Zones:** In this stage, the fishes are moved to other sector after searching the whole area of prey in the group.

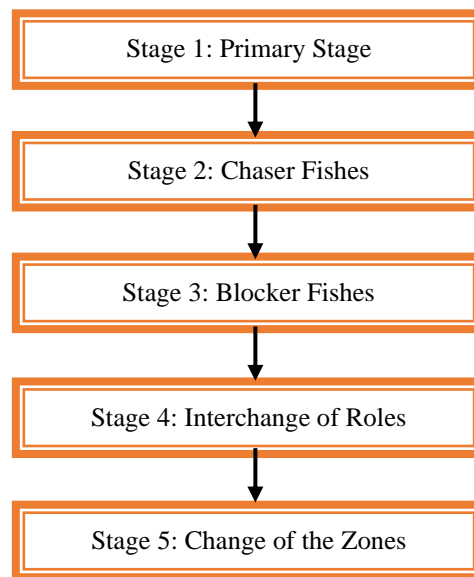


Figure 1: Stages of the YSGO Algorithm [12-13]

4. Proposed Model

Figure 2 shows the ultrasound image noise reduction and enhancement model based on the YSGO algorithm. The proposed model has four steps, data collection, filtering, enhancement, and performance analysis. In the filtering and enhancement steps, YSGO algorithm is used to determine the optimal parameter values of the filters (Bilateral and Speckle filter) and enhancement method (power law method). The detailed description of these steps is given below.

A. Data Collection Step: In the proposed model, synthetic data is taken under consideration which is publicly available on the Kaggle website (<https://www.kaggle.com/datasets/aryashah2k/breast-ultrasound-images-dataset>) [14]. The resolution of the images is 500×500 and format is *.png*. Further, the database contains 780 images of 600 female patients.

B. Filtering Step: In this step, initially, optimal parameter values of the bilateral and SRAD filter is determined using the YSGO algorithm. After determination of the optimal parameter values, bilateral and SRAD filter is applied on the input image. In the proposed model, mean square error is taken as the objective function. MSE parameter determines the mean square error between the input ultrasound image and output image is generated after filtering step. It is determined using Eq. (4).

$$MSE = \frac{\sum_{x=1}^M \sum_{y=1}^N (IUI_{xy} - OUI_{xy})^2}{MN} \quad (4)$$

where IUI, OUI denotes the input and output ultrasound image, respectively. MN denotes the resolution of the underwater images.

C. Enhancement Step: In this step, initially, YSGO algorithm is applied for determine the optimal parameter value of the power law method. After that, power law method is applied on the filtered image based on the optimal parameter values to enhance the images. In the proposed model, entropy is taken as the objective function and it is determined using Eq. (5)

$$E = \sum_{k=0}^{L-1} p(k) \log_2 p(k) \quad (5)$$

D. Performance Analysis: The performance analysis of the proposed model is done based on the subjective and objective performance metrics. In the subjective analysis, the visual quality of the ultrasound image at different steps of the proposed model is shown. In the objective analysis, the input image and output images are compared based on the various performance metrics. The performance metrics are taken under consideration in this work is explained below [15].

- **Root Mean Square Error (RMSE):** This parameter determines the square root of mean square error using Eq. (6).

$$RMSE = \sqrt{MSE} \quad (6)$$

- **Peak Signal to Noise Ratio (PSNR):** It is measured using Eq. (7).

$$PSNR = 10 \log_{10} \frac{P^2}{MSE} \quad (7)$$

where P denotes the maximum value of the signal presented in the input/output ultrasound image. In the ultrasound grey scale images, its value 255 is taken because each pixel is represented in 8-bit.

- **Signal to Noise Ratio:** SNR measures how well the processed signal suppresses noise. Better-processed images have greater SNR values.

$$SNR = 10 \log \frac{\sum_{x=1}^M \sum_{y=1}^N (I_{I_{xy}})^2}{\sum_{x=1}^M \sum_{y=1}^N (I_{I_{xy}} - O_{I_{xy}})^2} \quad (8)$$

- **Sobel Count:** This performance metrics determines the total number of edges in the image. It is calculated using Eq. (9).

$$SC = \frac{\sum_{x=1}^M \sum_{y=1}^N e_{xy}}{MN} \quad (9)$$

where e denotes the total number of edges in the image.

- **Time Complexity:** This performance metric is determined the total time is spent for filter and enhance the ultrasound image using the proposed model. This performance metrics is highly dependent on the image resolution, YSGO algorithm parameters (such as population and iterations), and system configurations. In our work, we have used MATLAB software (MATLAB 2018) and run it on a system with its configuration are Intel Core I-i7-7500U CPU @ 2.70GHz, 64-bit operating system, and 1TB hard disk.

5. Result and Discussion

This section shows the simulation results are performed for the proposed ultrasound image filtering and enhancement model for check its validity over the existing models. The ultrasound images are taken under consideration for simulation purposes are shown in Figure 2.

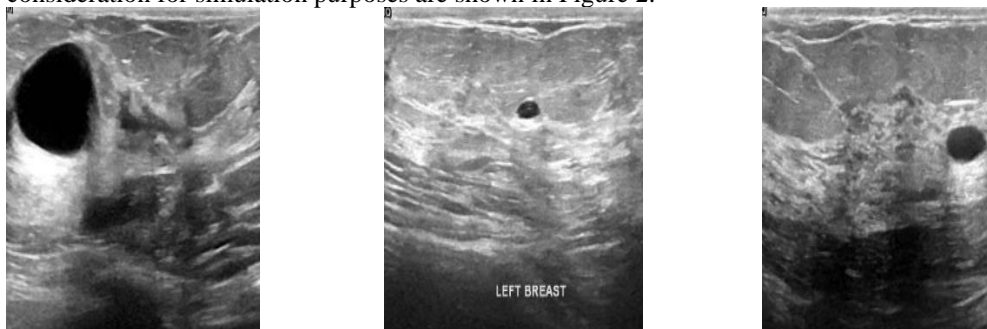


Figure 2: Ultrasound Images [14]

Table 1 shows the setup value of the YSGO algorithm is done for determine the optimal parameter values of the filtering and enhancement method.


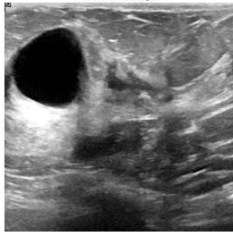
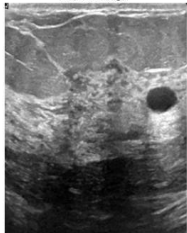
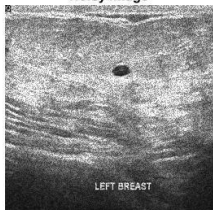

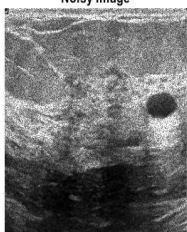
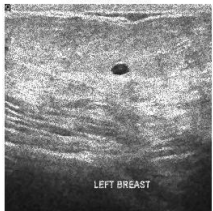
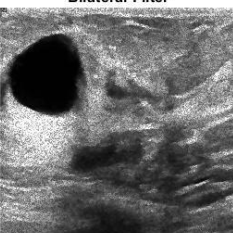
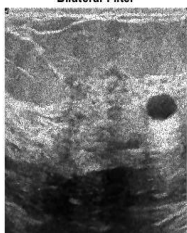
Table 1: Setup Value of the YSGO Algorithm

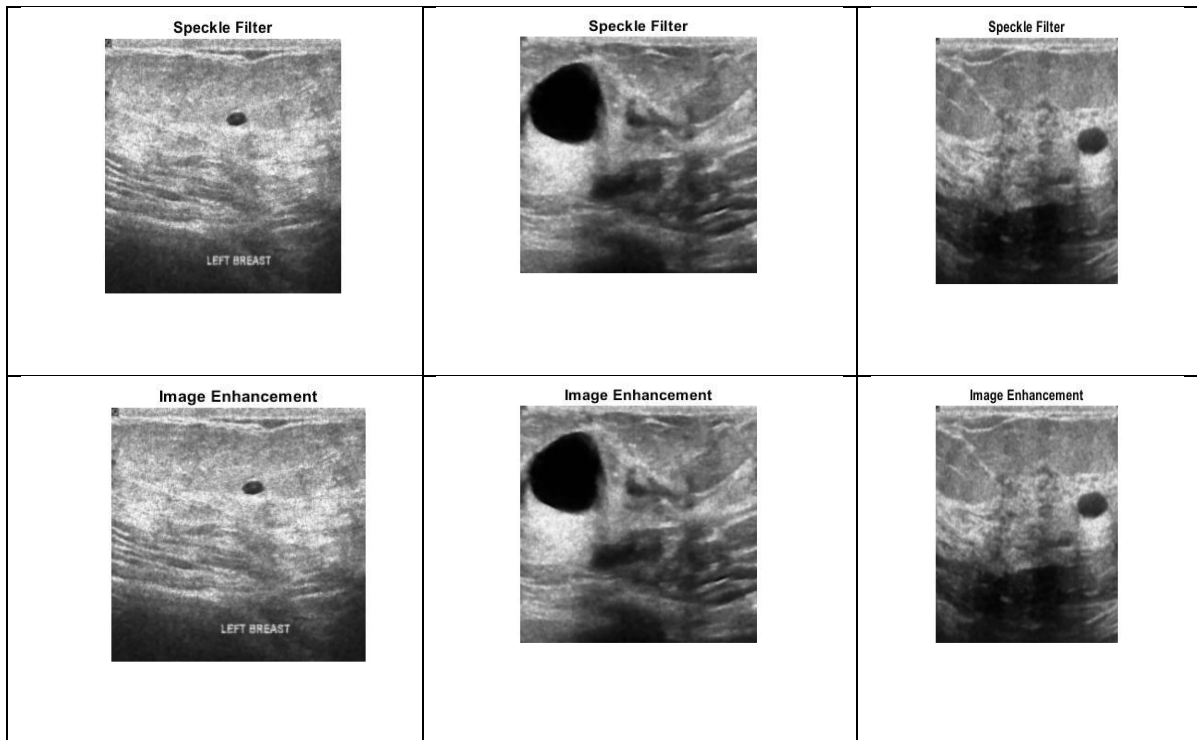
Parameter	Value
Total Population	4
Total Iterations	50
Objective Function for Image Enhancement	Entropy

Objective Function for Image Filtering Methods	MSE
Lower and Upper Limits for Enhancement Method	[1-4]
Lower and Upper Limits for Bilateral Filter Method	Degree of Smoothing: [0-1] Spatial Sigma=Positive Integer
Lower and Upper Limits for Speckle Filter Method	Degree of sharpening: [0-1] No. of iterations: Positive Integer

Table 2 shows the subjective analysis of the different images are taken under consideration for the proposed model for validate its performance. In this analysis, input image, noisy image, image after bilateral filter, speckle filter, and enhancement methods are shown.

Table 2: Subjective Analysis of the Ultrasound Image Noise Reduction and Enhancement Model

Image1	Image2	Image3
<p>Input Image</p> 	<p>Input Image</p> 	<p>Input Image</p> 
<p>Noisy Image</p> 	<p>Noisy Image</p> 	<p>Noisy Image</p> 
<p>Bilateral Filter</p> 	<p>Bilateral Filter</p> 	<p>Bilateral Filter</p> 



Further, Figure 3 (a-c) shows the convergence rate graph of the proposed model to search the optimal parameter values. The result shows that optimization algorithm searches the optimal values in the 5th, 13th, and 3rd iteration for image 1-3.

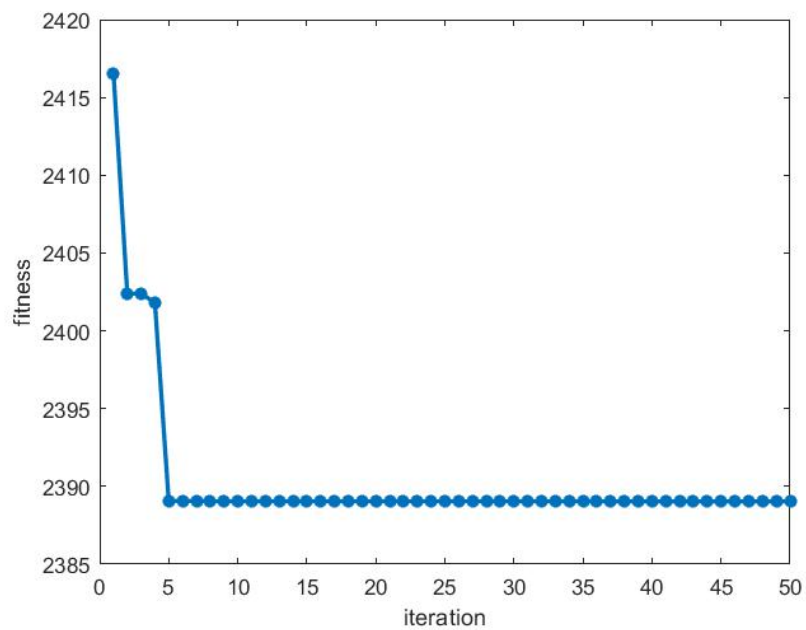


Figure 3 (a): Convergence Rate Graph for the Proposed Model (for Image1)

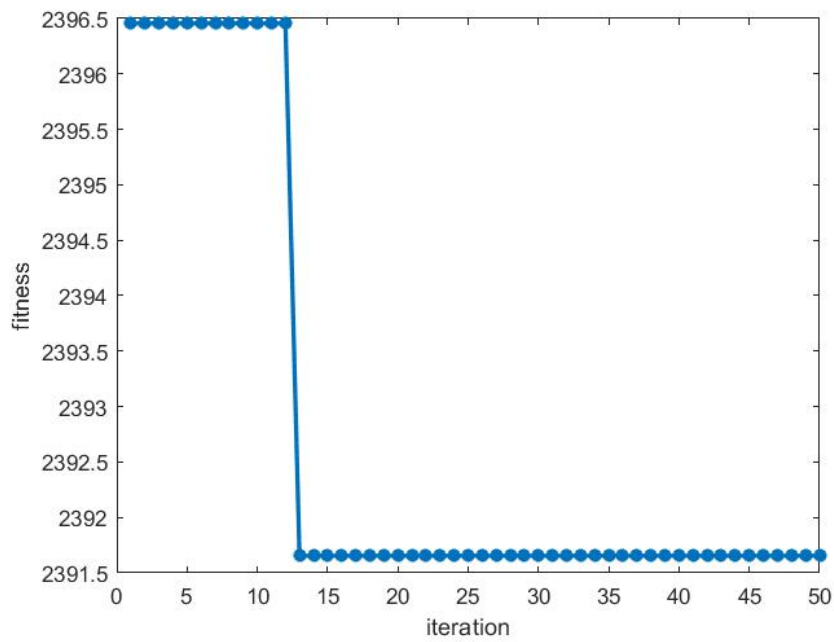


Figure 3 (b): Convergence Rate Graph for the Proposed Model (for Image3)

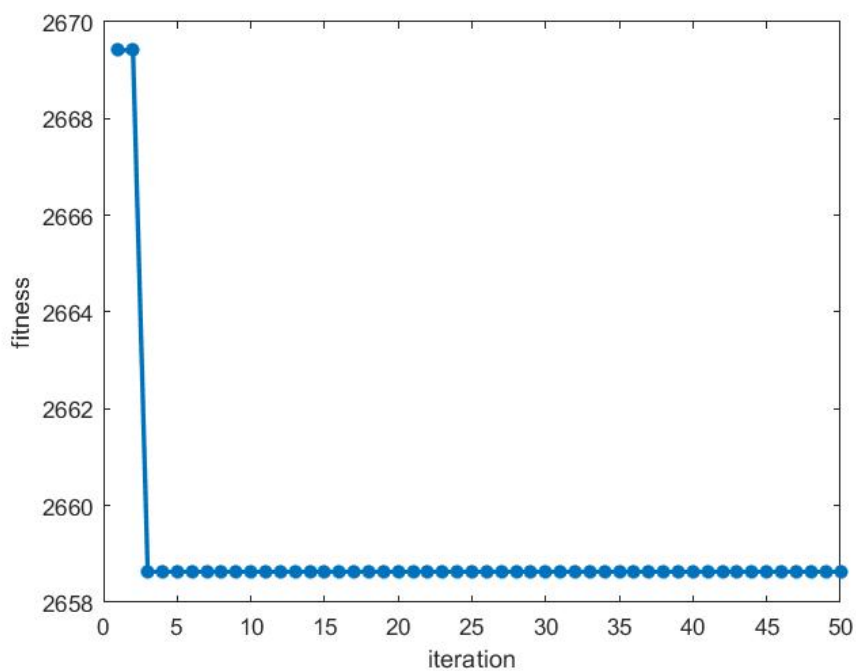


Figure 3 (c): Convergence Rate Graph for the Proposed Model (for Image3)

Table 3 shows the objective analysis based on the MSE, RMSE, PSNR, SNR, Sobel Count, and time complexity. From the results, we have found that overall entropy (7.60678) is reduced due to noise factor. Further, on average, the proposed model achieves 120.7144 MSE, 10.8585 RMSE, 27.5096dB PSNR, 20.9026 SNR, 1809.6 Sobel count, and 108.8021 seconds.

Table 3: Objective Analysis of the Ultrasound Image Noise Reduction and Enhancement Model

Images	Input Entropy	Output Entropy	MSE	RMSE	PSNR (in dB)	SNR	Sobel Count	Execution Time (in Seconds)
1	7.7124	7.6346	197.29	14.046	25.18	20.247	2079	145.52
2	7.6555	7.6339	107	10.344	27.837	21.18	1547	102.7022
3	7.6709	7.5889	116.84	10.809	27.455	20.757	1929	98.212
4	7.6054	7.5755	85.788	9.2622	28.797	21.134	1724	105.44
5	7.687	7.601	96.654	9.8313	28.279	21.195	1769	92.1364
Average	7.66624	7.60678	120.7144	10.8585	27.5096	20.9026	1809.6	108.8021

Finally, based on the PSNR parameter, the proposed model is compared with the existing model for different images. The result reflects that the proposed model achieves better PSNR for different images, as shown in Figure 4.

Table 4: Comparative Analysis

Methods	Proposed Method (Without Optimal Parameter Value)	Proposed Method (with Optimal Parameter Value)
Image1	20.579	25.18
Image2	22.539	27.837
Image3	22.533	27.455
Image4	23.543	28.797
Image5	22.925	28.279

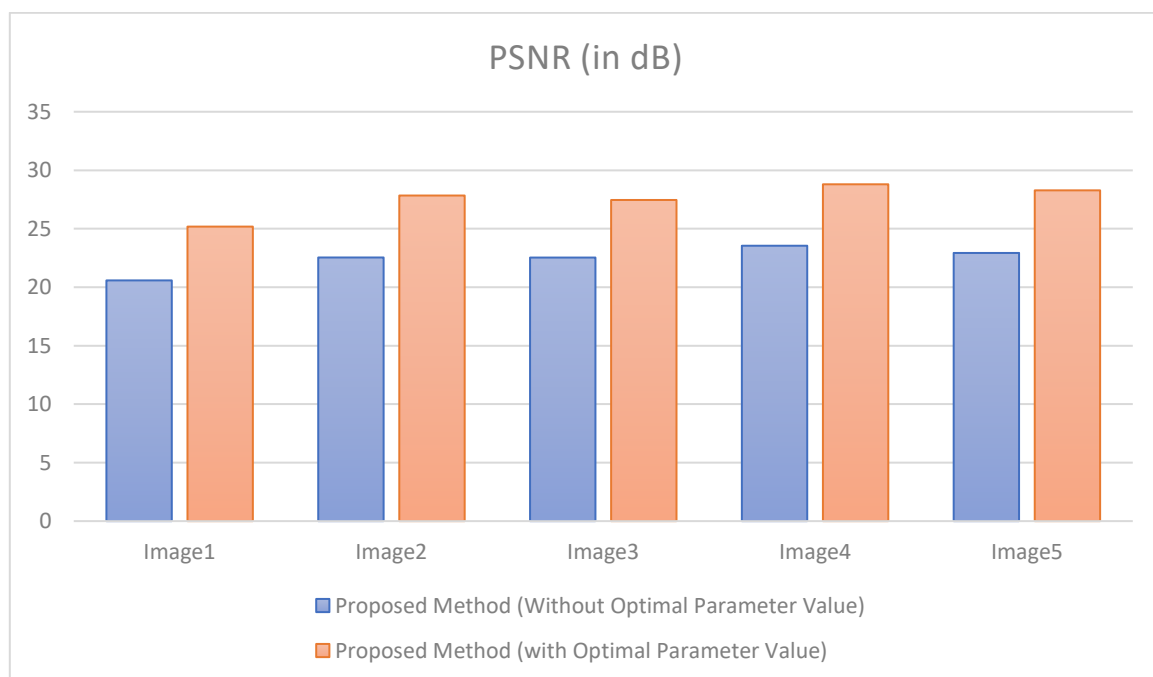


Figure 5: Comparative Analysis based on PSNR Parameter

6. Conclusion

In this paper, YSGO algorithm-based ultrasound image filtering and enhancement model is presented. In our model, YSGO algorithm determines the optimal parameter values of the filtering and enhancement model based on the objective function. The main benefit of the proposed model is that it is adaptive model in place of traditional model it means it removes any level of noise effectively. The simulation evaluation is performed on the publicly available synthetic database. Further, visual, and various parameters are measured for the output

image in the subjective and objective analysis. The result reveals that the proposed model remove the noise, preserve the information of the image in terms of edges, contrast. Finally, comparative study defines that the proposed model achieves better PSNR parameter.

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