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# Medical image enhancement in health care applications using modified sun flower optimization

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ABSTRACT

Image enhancement (IE) is a process which improves the contrast of image by sharpening the edge pixels intensity. This technique has attained much attention in medical field and several enhancement techniques are proposed by researchers. In image processing, the enhancement is regarded as complex optimization issues. This work introduces an efficient model to solve optimization issues using a modified optimization approach. Initially, the input medical images are denoised using Modified median filter (MMF) filter. Then these denoised images are enhanced for the further process. The enhancement is carried out by pixel intensity of image. The parameters like entropy, edge information and intensity are optimized by modified sun flower optimization (MSFO). This optimization is used for increasing the convergence speed. The overall evaluation is carried in Matlab platform. The image quality is analyzed on six performance metrics and compared over several approaches and provided better results. The experimentation is evaluated on five medical images and the Mean square error (MSE) and peak signal noise ratio (PSNR) achieved by the medical image 1 are 0.02 and 43.7 respectively.

## 1. Introduction

Image enhancement (IE) is one of the major images processing approach and used for enhancing the original image quality [1]. Recently, medical imaging is necessary to present the ability of anatomical and physiological features. Hence, medical images are necessary for radiologists in detection various disease [2]. In the last few decades, medical image analysis is emerging due to enhancement of digital image models. The large number of medical images is produced with ever improving quality [3]. Even though, conventional medical image analysis methods have attained limited achievements and they do not deal with large qualities of images. The medical images generated using MR (magnetic resonance imaging), US (Ultrasound) and CT (computed tomography) are caused

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due to noise, illumination and contrast. Some kinds of noises like salt and pepper noise, Rayleigh and Gaussian noises are occurred with the images [4]. Denoising of these images is necessary for the treatment of any kind of diseases. Due to the occurrence of various overlapped objects, these images are complicated in nature. Hence, for best diagnosis artefacts are to be eliminated [5].

The ROI (region of interest) is not identified in less contrast image and understanding these images is complex. Hence, the treatment process becomes complicated which leads to faulty observation [6]. Therefore, the enhancement of images is essential which facilitates the radiologists during segmentation and detecting the type of disease. The major aim of this enhancement is to monitor and provide proper treatment to the people. Several IE approaches is introduced in the literature to enhance the contrast and quality of images [7]. Some of the utilized approaches are HE (histogram equalization) [8], Global HE (GHE) [9] and gamma correction [10]. The algorithms on the basis of HE are extensively utilized for IE due to its effectiveness. However, some noises and artefacts are present in the images. For preserving the brightness and improving contrast, several techniques are used. They are dualistic sub-image HE (DSIHE), adaptive HE (AHE) Contrast limited adaptive histogram equalization (CLAHE) and brightness preserving bi-HE (BBHE) [11, 12]. Recently, the optimization techniques like PSO (particle swarm optimization), KHO (kill herd optimization) and GA (Genetic algorithm) are used for optimizing the parameters in pixel intensity [13–15].

### *1.1. Motivation and contributions*

IE is an extremely complicated problem in medical and several research applications areas. By altering the colours and intensities, IE processes enhances some features. IE approaches are applied to medical imaging and in applications like latent fingerprint, remote sensing and etc. medical images has essential information that radiologists need for diagnosing and making a proper treatment. The manual observation of image is essential for diagnosis process. However, there is a chance of getting error in manual observation which highly affects the life of patients. Therefore, an automatic tool for enhancement of the medical images is essential. This automatic IE enhances the image visual quality and facilitates the radiologist in making correct decision for treatment. The major contributions of the proposed work are:

✓ Introduces an MMF (Modified median filtering) for removing the noise in medical images.
✓ Then, these denoised images are enhanced by pixel intensity. Then the parameters like entropy, edge information and intensity are optimized by modified sun flower optimization (MSFO).
✓ The performance of image enhancement is analyzed on the six different metrics and compared over several image enhancement approaches.

The rest of the article is arranged as: Section 2 is a related work; Section 3 is a proposed image enhancement technique; Section 4 is a brief explanation of results and Section 5 is the conclusion of the entire work.

## 2. Related works

Some of the recent related work related to the image enhancement techniques are listed below:

Pourasad and Cavallaro [16] introduced a model for IE and compression of X-rays. The compression approaches like lossless and lossy were provided for compressing the images. In addition to this, certain enhancing approaches were used to compress image which recover the quality of image. Zhou et al. [17] introduced an improved model of WCO (World Cup Optimization) which was based on chaos theory. The major aim of the work was to enhance the image quality in medical field and to attain the optimal solution for Gamma using WCO. Shao et al. [18] integrated frequency and spatial domain for IE. Then Intravascular ultrasound (IVUS) was used for enhancing defects occurred due to single domain enhancement. This model has addresses plague interference and noise in image. Acharya and Kumar [19] presented PSO based HE model for enhancing the brain images quality. The major aim of this model was to choose the constraint and threshold values automatically. Then, the non-texture region was suppressed for reducing the unnecessary artefacts.

Acharya and Kumar [20] demonstrated a model for MRI images enhancement on the basis of GA optimization. Threshold was selected automatically and the approach was more adaptive. This model provided less information loss and better image quality. Siddiqi and Alsirhani [21] used ensemble model for IE. Initially this model utilized Laplacian filter for highlighting the intensity changes in areas and improved the features. Then, averaging filter was used for the better enhancement. Kandhway et al. [22] used the optimization KH for enhancement of sharp edges and contrast of medical images. The plateau limit (PL) was provided for clipping the histogram and relocation process was carried out. The fitness function has entropy, GLCM (gray level co-occurrence matrix) and edges. Bhandari et al. [23] introduced SSA (Salp swarm optimization) for the IE problems and the major role of the algorithm was to obtain brightness and preservation of features. Initially, the histogram was split into two sub type. Then three PLs were calculated for every sub type and PLs were optimized using SSA. This model enhances the low contrast and doesn't disturb the images naturalness. Even though, these images achieved better quality of images, PSNR, SSIM and error values obtained by these approaches are low. Further, the optimizations utilized in these approaches were suffered due to convergence speed. Hence there is a need of IE technique in medical field.

## 3. Proposed methodology

The proposed model uses Modified median filter (MMF) filter for denoising and optimized image enhancement model using MSFO.

PSNR, MSE, Structural Similarity Index (SSIM), weighted PSNR (WPSNR), homogeneity and contrast are computed for proposed IE. The overall working methodology is explained in Fig. 1.

### 3.1. Denoising using MMF

Initially, the input medical image is denoised using MMF (Modified median filtering). Denoising process undergo two stages (detection of noise and denoising).

Detection of noise is given as:

$$\Im\left(a,b\right) = \begin{cases} 1 & when \quad \delta(a,b) \;\; noisy \\ 0 & when \quad \delta(a,b) \;\; not \;\; noisy \end{cases} \tag{1}$$

where $\delta(a,b)$is a input medical image and $\Im(a,b)$is detected image. In detection of noise phase, the maximum value of intensity (255) is a salt noise and maximum value of intensity (0) is a pepper noise. Other range of intensity is non-noise pixel.

*Denoising phase:* In this phase, initial size of window is set as [3 × 3]. Then the chosen pixel is analyzed whether it has noise or not. When the pixel in not associated with noise, then the pixel is considered for the further process. Otherwise, the values of pixels ($M$) are sorted and provided in $E$. The neighbouring pixel is verified and split into groups. When size of $E$is odd number, then consider the median of $E$. Repeat the process until the pixel becomes noise free. The size of window is varied by 5, 7, 9,11and finally, obtained image is a denoised image.

### 3.2. Image enhancement (IE)

The major goal of this research is to use transformation function ($P$) to enhance the image contrast quality. This function is the spatial domain which maps the input image's brightness. Hence, for achieving the medical image with better quality from the denoised image it is necessary to map intensity on the basis of optimization transformation. This function is calculated as:

$$h(l,m) = P(g(l,m)) \tag{2}$$

where $g(l,m)$, and $h(l,m)$ are input image grey value and improved image. $P$is given as:

$$h(l,m) = K(l,m)[g(l,m) - e \times f(l,m)] + f(l,m)^a \tag{3}$$

where $e$ and $f$ are the parameters and their values are to be optimized. $K(l,m)$and $f(l,m)$ are enhancement term and local mean. $f(l,m)$ is given as:

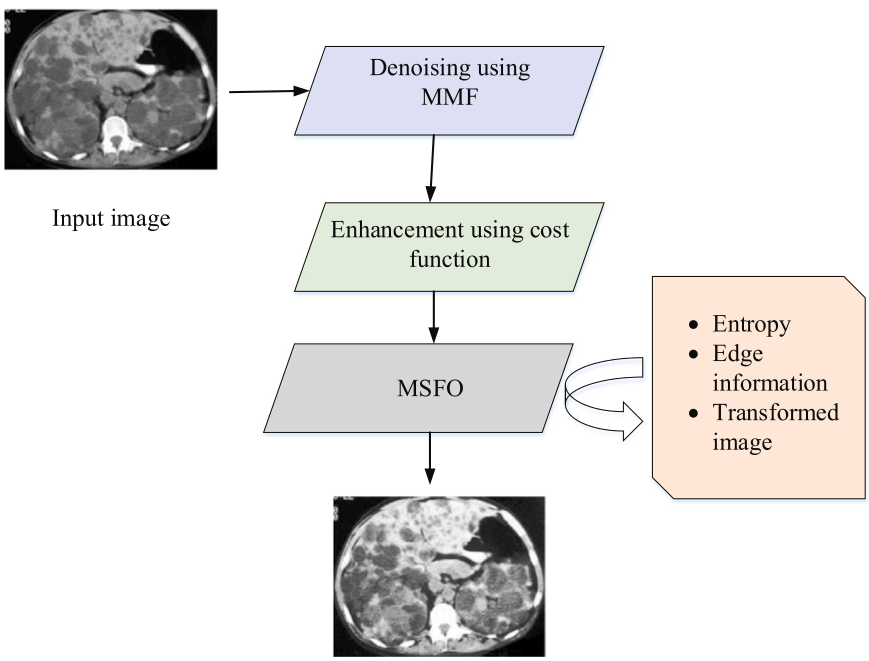


**Fig. 1.** Framework of the proposed IE.

$$f\left(l,m\right) = \frac{1}{l\times l}\sum_{a=0}^{l-1}\sum_{b=0}^{l-1}g(a,b) \tag{4}$$

$K(l,m)$is stated as:

$$K\left(l,m\right) = \frac{k.C}{\sigma(l,m)+d} \tag{5}$$

where $k$and $d$are the parameters, $\sigma(l,m)$is LSD (local standard deviation) and $C$is a global mean and it is represented as:

$$C = \frac{1}{S\times T}\sum_{a=0}^{Sl-1}\sum_{b=0}^{T-1}g(a,b) \tag{6}$$

where $S$ and $T$are the total of pixels in directions like horizontal and vertical. LSD is stated as:

$$\sigma\left(l,m\right) = \sqrt{\frac{1}{l\times l}\sum_{a=0}^{l}\sum_{b=0}^{l}g\left(a,b\right) - f(a,b)^2} \tag{7}$$

Finally, $P$ is stated as:

$$h\left(l,m\right) = \frac{k.C}{\sigma(l,m)+d}\left[g\left(l,m\right) - e\times f\left(l,m\right)\right] + f(l,m)^a \tag{8}$$

Using this Eq. (8), the image contrast is increased by local mean to the enhancement centre. $f(l,m)^a$ has effect of smooth and bright, hence used to smooth the enhanced image further, it smoothes the parameters like $k_, d_, a_,$ and $e$. The small changes in these values of parameters, generates a huge change in a processed image. Hence these values should be chosen carefully.

***Evaluation of enhancement criterion:*** There are various cost function are developed for the medical IE process. In this, an integrated cost function is developed on the basis of entropy, edge information and transformed image for the IE optimization. The values of these measures are small and the multiplicative operator makes their outcome into low value. Hence, the further tasks becomes complex. Hence, in cost function GM (geometric mean) is utilized. Even though, the global operators SD and entropy minimizes the complexity of system, utilizing local operators as cost function ensures better outcomes. The edge detector is used to determine the number of edges. When the detected edges are more, then the better IE will obtain. Hence, in this work edge detector is regarded as one segment of cost function. Then, canny operator is used for extracting the edge information. Finally, the cost function is written as:

$$D(f) = \sqrt[3]{\sigma_s \log\left(\log\left(A(h)\right) \times \frac{B(h)\times D_e}{S\times T}\right.} \tag{9}$$

where

$$\sigma_{s(l,m)} = \sqrt{\frac{1}{S\times T}\sum_{l=1}^{S}\sum_{m=1}^{T}\left(h_{l,m} - f_{s(l,m)}\right)^2} \tag{10}$$

$$f_{s(l,m)} = \frac{1}{S\times T}\sum_{l=1}^{S}\sum_{m=1}^{T}\left(h_{l,m}\right) \tag{11}$$

where $A(h)$is a range of pixel for an edge detected image $h$. $B$is entire pixel quantity in $h$. In this work, the parameters entropy, edge information and transformed image are optimized using MSFO. This optimization is used for enhancing the contrast of image. MSFO (Modified Sunflower optimization algorithm) [24] is an optimization algorithm which portrays the process of pollination among the neighbouring sunflowers while moving towards sun. The major stages are explained below:

*Natural characteristics:* Sunflower moving to sun and process of pollination among the neighbouring sunflowers are $Z_j$and $Z_{j+1}$. The quantity of heat obtained $(H_j)$for every sunflower from sun is denoted as:

$$H_j = \frac{P}{4\pi b^2} \tag{12}$$

where $P$is power and $b$is distance among sun (best solution).

*Adjusting sunflower intention:* This stage for every sunflower is computed by:

$$\overrightarrow{S_j} = \frac{Z^* - Z_j}{\left|\left|Z^* - Z_j\right|\right|} j = 1,2.N \tag{13}$$

where $N$is a size of population, $Z^*$and $Z_j$ are the best solution and solutions.

*Sunflower step size to the sun*: The step size for every sunflower to sun is measured as:

$$d_j = \gamma \times P_j||Z_j + Z_{j-1}|| \times ||Z_j + Z_{j-1}|| \quad (14)$$

where $\gamma$is inertial displacement of sunflower, $P_j||Z_j + Z_{j-1}||$ is a pollination probability between $Z_j$and $Z_{j+1}$.

Fertilization: The solution (sunflower) is fertilizing over the sun for generating new individuals and this process is represented as:

$$Z_{j+1} = Z_j + d_j \times \overrightarrow{S_j} \quad (15)$$

However, this SFO algorithm suffers from slow convergence and being trapped by local optima. Hence, in this work, levy operator which is random walk model is included to enhance the SFO. This function enhances the convergence speed and consumption time. These advantages can increase diversity in population and overcome from local optima. In Eq. (14) levy flight is included and it is represented in Eq. (16).

$$d_j = \gamma \times P_j||Z_j + Z_{j-1}|| \times ||Z_j + Z_{j-1}|| \times levy\ (u) \times \gamma \quad (16)$$

where $\gamma$ is adjusting parameter and $levy\ (u)$is a levy flight distributor. The parameters are optimized by MSFO and this $\gamma$and $levy\ (u)$ are used for enhancing the process. Further, it improves the speed of convergence. Algorithm of MSFO is given in Fig. 2. In this, initially, the initial parameters are assigned. Then the fitness is computed using Eq. (8). Then the best solution is assigned. The solution adjust their intention to sun is computed by (13). Then to obtain best convergence speed, levy flight with adjusting parameters are included and updated based on Eq. (16). The process continues until the best solution is obtained.

## 4. Results and discussion

This section provides the results and discussion of IE model. The overall analysis is processed with Intel Core i5 CPU and 8 GB RAM. The experimental analysis is demonstrated on Matlab. There are four medical images are considered for the qualitative analysis and it is given in Fig. 3.

### 4.1. Performance measures

The performances of IE approaches are measured using PSNR, MSE, SSIM, WPSNR, homogeneity and contrast. The formulae used

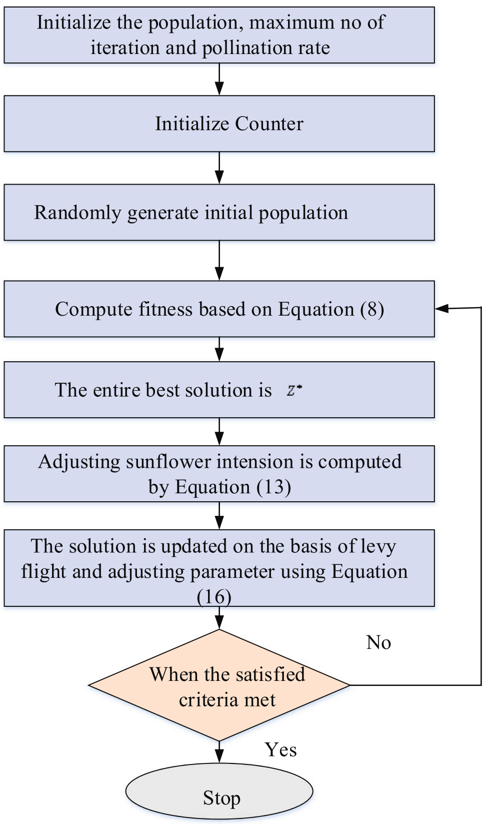


**Fig. 2.** Flowchart of IE using MSFO.

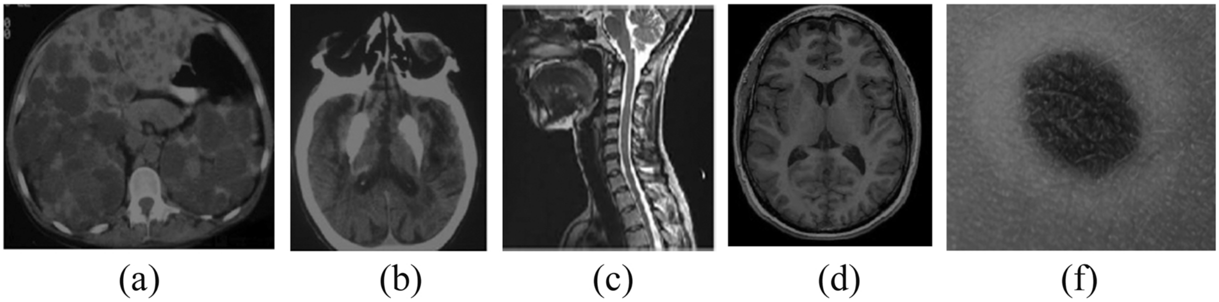


**Fig. 3.** Input images of (a) medical image 1, (b) medical image 2, (c) medical image 3 (d) medical image 4 (e) medical image 5.

to computing these measures are listed below:

***MSE:*** this metric is used to compute the difference among the original and enhanced images and it is represented as:

$$MSE = \frac{1}{w_l h_l} \sum_{a=1}^{w_l} \sum_{b=1}^{h_l} (D_{ab} - S_{ab})^2 \tag{17}$$

where $D_{ab}$and $S_{ab}$ are the grey values of pixel$(a, b)$ of original image and enhanced image. Enhanced image's width and height are $w_l$and $h_l$.

***Contrast:*** It defines the statistical features that ensure the variance among intensity and the original image.

$$C_o = \sum_a \sum_b (a - b)^2 C_A \left( a, b \right) \tag{18}$$

where$C_A(a, b)$is a total of co-appearance for levels of intensity $a$and $b$.

***PSNR:*** It is exploited to evaluate variance among the original and enhanced images and it is represented as:

$$PSNR = 10 \log_{10} \left[ \frac{255^2}{MSE} \right] \left( dB \right) \tag{19}$$

***WPSNR:*** It is an enhanced metric of PSNR and uses one more parameter called NVF (Noise Visibility Function).

$$WPSNR = 10 \log_{10} \left[ \frac{255^2}{MSE \times NVF} \right] \left( dB \right) \tag{20}$$

***Homogeneity:*** This metric provides the image intensity similarity. That means large value for homogeneity provides the large quality of image. It is expressed as:

$$H_o = \sum_a \sum_b \frac{C_A(a, b)}{1 + |a - b|} \tag{19}$$

***SSIM:*** It is the necessary image quality measure. The SSIM among the original and enhanced images is given as:

$$SSIM = \frac{(2\sigma f \sigma g + c_1)(2\alpha fg + c_2)}{\left( \sigma_f^2 + \sigma_g^2 + c_1 \right) \left( \alpha_f^2 + \alpha_g^2 + c_2 \right)} \tag{20}$$

where $\sigma f$ and $\sigma g$ are the average of $f$ and $g$.$\alpha fg$ is the covariance and $\alpha_f^2$ and $\alpha_g^2$ are variance.

### 4.2. Qualitative analysis

This section illustrates the qualitative analysis of three medical images and the respective histograms are presented. These analyses are on the basis of visual quality or the image's appearance. The visual analysis includes artefacts, unnatural enhancement and over enhancement.

Fig. 4 represents the image enhancement of AHE, BBHE and proposed enhancement model. The image qualities presented by the two approaches are low when compared to proposed enhancement model. Furthermore, certain artefacts are found on these images. Then in medical analysis, one object will be overlapped with another, hence the complexity will be more. Therefore, the information will be lost in these images and also they have low contrast. Hence, these two methods are not suitable for the medical field, since they make the further process to more complex. Further, the histogram image of the proposed enhancement model is better and other two images did not produce clear histogram images. This is achieved due to the parameter optimization using MSFO.

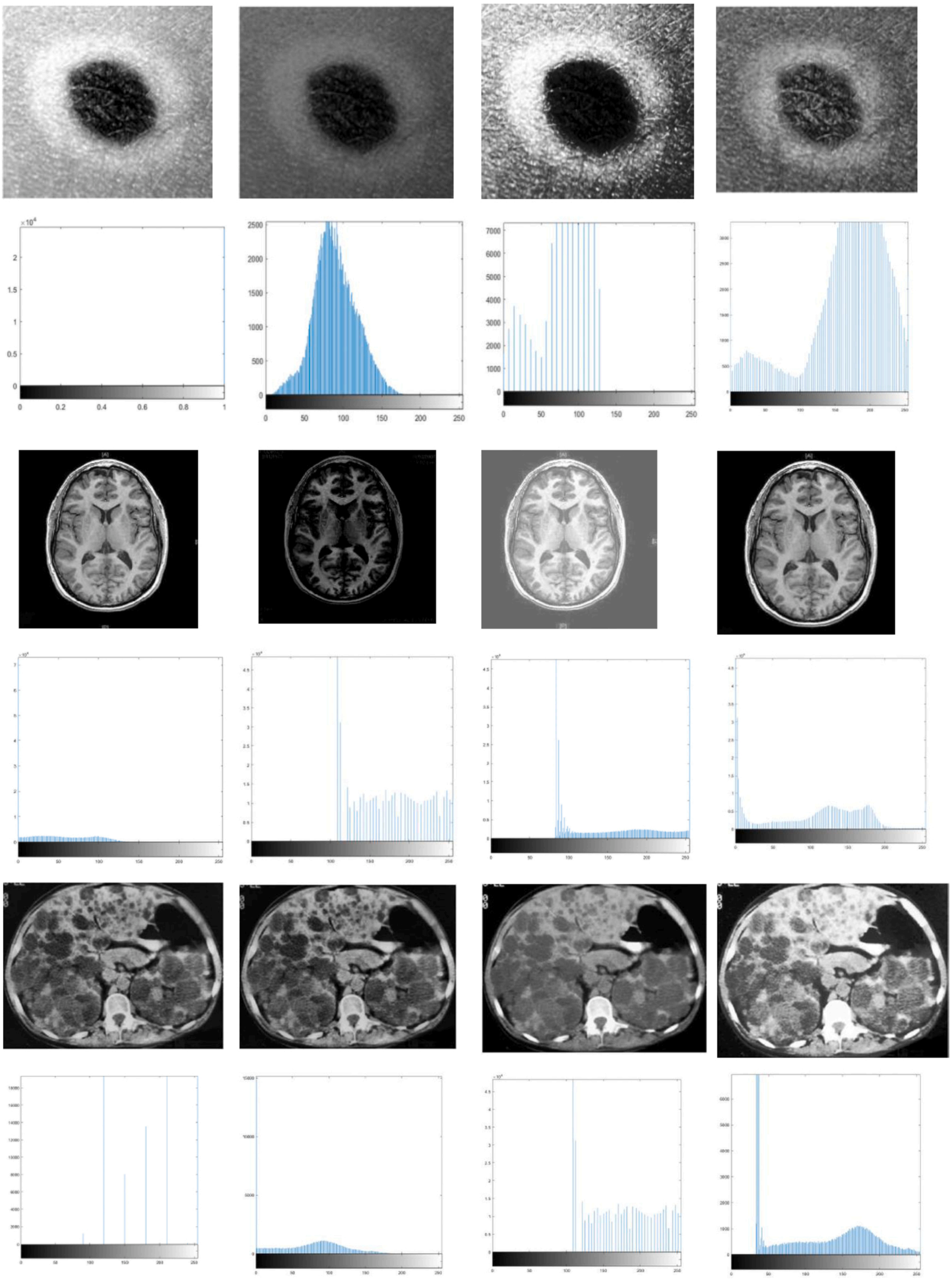

**Fig. 4.** Image enhancement of (a) AHE (b) BBHE (c) CLAHE (d) proposed.

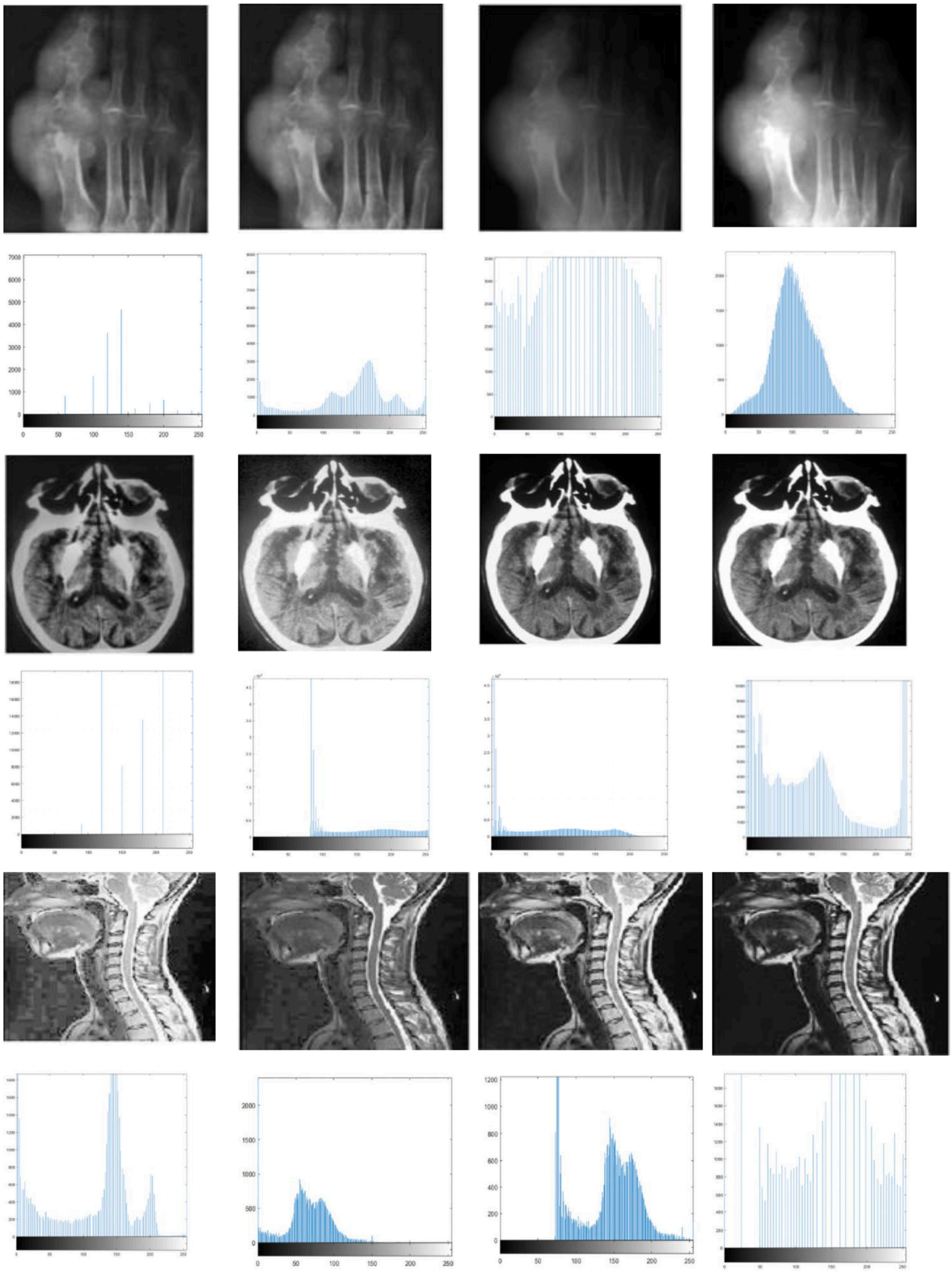

**Fig. 4.** (*continued*).

### 4.3. Quantitative analysis

The quality analysis of IE is not an easy process. For measuring the quantitative performance, some of the metrics used are SSIM, PSNR, MSE, WPSNR, homogeneity and contrast. These metrics play a vital part on the treatment process.

Table 1 presents the quantitative performance comparison of AHE, BBHE, CLAHE and proposed models. From the table it is observed that, the PSNR value attained by proposed IE technique is higher than other two models. For the better quality image, SSIM value is almost equal to one. For all the five cases, the SSIM value of the proposed IE technique is nearly close to 1. When the homogeneity, WPSNR and contrast are higher, it provides the better quality image. Further, the error measure value is very less for the proposed model when compared to AHE, CLAHE and BBHE.

Table 2 represents the Execution time (seconds) of various approaches. The time of processing is on the basis of four times of evaluation. Form the table it is seen than, the proposed IE has less time of execution.

### 4.4. Convergence analysis

Convergence analysis is used to measure the convergence performance. When the population size is increased, the convergence speed also increases. In this experimentation, 100 populations are selected.

The convergence of MSFO is compared with the optimization techniques like SFO [24], GWO [25] and GA [26] in Fig. 5. From the graph, it is observed that, when the iteration is increased, the fitness value is also increased. It is seen that MSFO has better convergence speed when compared to other algorithms.

## 5. Conclusion

Medical imaging is a major challenge in medical field and these images are generally in low contrast. This makes the treatment as complex process. To address these issues, several approaches were introduced in the existing works. In this work, AAF was used to denoise the image and MSFO was used for IE. By increasing the fitness function, the parameters like entropy, edge information and intensity are improved. Further, the fitness function was compared over the optimization techniques like SFO, GWO and GA. When comparing to other two algorithms, MSFO attained better convergence speed. The experimental analysis was carried out three medical images and their qualitative and qualitative analyses were presented. The achieved outcomes were visually good and noise free. This technique will surely facilitate medical experts by providing better quality images.

## Declaration of Competing Interest

This manuscript was prepared by me and my co-authors. The authors don't have any conflict of Interest.

**Table 1**
Quantitative performance comparison of AHE, BBHE and proposed models.

| Medical image 1 | | | | | | |
|---|---|---|---|---|---|---|
| Techniques | contrast | PSNR | W PSNR | homogeneity | MSE | SSIM |
| AHE | 0.731 | 34.5 | 15.54 | 0.854 | 0.08 | 0.832 |
| BBHE | 0.864 | 37.9 | 16.76 | 0.887 | 0.05 | 0.753 |
| CLAHE | 0.882 | 41.4 | 17.1 | 0.854 | 0.05 | 0.893 |
| proposed | 0.901 | 43.7 | 17.89 | 0.923 | 0.02 | 0.937 |
| **Medical image 2** | | | | | | |
| **Techniques** | **contrast** | **PSNR** | **W PSNR** | **homogeneity** | **MSE** | **SSIM** |
| AHE | 0.874 | 38.9 | 23.67 | 0.851 | 0.234 | 0.531 |
| BBHE | 0.914 | 42.6 | 27.89 | 0.923 | 0.310 | 0.579 |
| CLAHE | 0.893 | 39.1 | 28.9 | 0.918 | 0.348 | 0.781 |
| proposed | 0.943 | 49.2 | 32.51 | 0.942 | 0.114 | 0.924 |
| **Medical image 3** | | | | | | |
| **Techniques** | **contrast** | **PSNR** | **W PSNR** | **homogeneity** | **MSE** | **SSIM** |
| AHE | 0.787 | 38.8 | 34.5 | 0.743 | 0.65 | 0.745 |
| BBHE | 0.753 | 45.7 | 35.1 | 0.815 | 0.51 | 0.833 |
| CLAHE | 0.721 | 41.4 | 37.5 | 0.821 | 0.34 | 0.904 |
| proposed | 0.834 | 45.9 | 39.4 | 0.843 | 0.26 | 0.912 |
| **Medical image 4** | | | | | | |
| **Techniques** | **contrast** | **PSNR** | **W PSNR** | **homogeneity** | **MSE** | **SSIM** |
| AHE | 0.824 | 65.22 | 45.6 | 0.782 | 0.51 | 0.881 |
| BBHE | 0.852 | 68.34 | 38.43 | 0.814 | 0.25 | 0.954 |
| CLAHE | 0.895 | 70.45 | 42.53 | 0.863 | 0.34 | 0.975 |
| proposed | 0.899 | 73.18 | 48.77 | 0.874 | 0.02 | 0.981 |
| **Medical image 5** | | | | | | |
| **Techniques** | **contrast** | **PSNR** | **W PSNR** | **homogeneity** | **MSE** | **SSIM** |
| AHE | 0.831 | 59.81 | 51.9 | 0.791 | 0.21 | 0.963 |
| BBHE | 0.847 | 62.13 | 49.7 | 0.823 | 0.09 | 0.971 |
| CLAHE | 0.886 | 63.71 | 52.4 | 0.922 | 0.14 | 0.945 |
| proposed | 0.935 | 67.89 | 51.7 | 0.945 | 0.02 | 0.986 |

**Table 2**
Execution time (seconds) of various approaches.

| Images | GWO | SFO | GA | proposed |
|---|---|---|---|---|
| Medical image 1 | 0.89 | 1.24 | 1.45 | 0.93 |
| Medical image 2 | 2.3 | 0.95 | 1.78 | 0.84 |
| Medical image 3 | 1.1 | 2.56 | 2.67 | 1.0 |
| Medical image 4 | 1.4 | 1.8 | 2.3 | 0.96 |
| Medical image 5 | 2.82 | 2.56 | 1.6 | 1.9 |

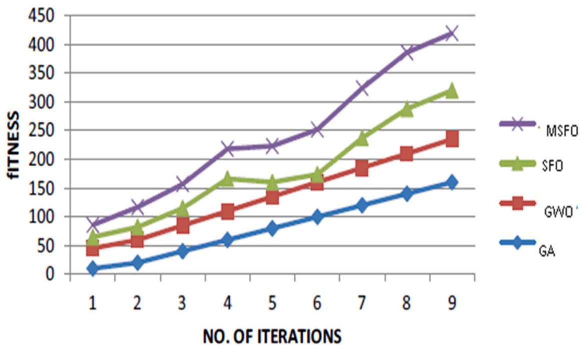


**Fig. 5.** Convergence analysis.

## Data Availability

No data was used for the research described in the article.

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