A hybrid bat-genetic algorithm for improving the visual quality of medical images

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ABSTRACT

Efficient repression of noise in a medical image is a very significant issue. This paper proposed a method to denoise medical images by the use of a hybrid adaptive algorithm based on the bat algorithm (BA) and genetic algorithm (GA). Medical images can be often affected by different kinds of noise that decrease the precision of any automatic system for analysis. Therefore, the noise reduction methods are always utilized for increasing the Peak signal-to-noise ratio (PSNR) and the structural similarity index measure (SSIM) of images to optimize the originality. Gaussian noise and salt and pepper noise corrupted the used medical data, separately. The noise level to medical images was added noise variance from 0.1 to 0.5 to compare the performance of the de-noising techniques. In the analytical study, we apply different kinds of noise like Gaussian noise and salt-and-pepper noise to medical images for making these images noisy. The hybrid BA-GA model was applied on medical noisy images to eliminate noise and the performances have been determined by the statistical analyses such as PSNR, values are gotten 63.04 dB and 59.75 dB for CT and MRI images.

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1. INTRODUCTION

The researches in the field of medical image processing are one of the most challenging and promising fields in recent years, this is due to the increased spread of diseases[1]. Medical imaging is the method and procedure of creating visual representations of the internal of a body without opening up the body surgically, for diagnosis, illness monitoring, and medical intervention [2]. Medical images contribute considerably in providing an accurate diagnosis of patients, those images contain information about human tissues. Enhanced medical images are useful for physicians to provide accurate documentation and the images are frequently associated in the clinic–related fields, therefore, it is recommended to employ image enhancement in medical imaging [3], [4]. Through using numerous techniques, medical images can be produced i.e. magnetic resonance imaging (MRI), ultrasound, computerized tomography (CT), and X-Ray. Different ways of thinking based on knowledge have different abilities to analyze the same image, especially the medical image with noise [5], [6]. To solve this problem, it is very important to use computer technology to enhance medical images. To denoise images and obtain better images, image enhancement can be utilized due to its importance and tractability [7]. The objectives of this study focus on the set filters chosen by hybrid BA-GA for denoising and increasing visual quality and saving medical image edge and building the adaptive model related to the different kinds of medical images. A comparison is made to the advanced algorithms/methods performance with the existing ones regarding peak signal-to-noise ratio (PSNR), structural similarity index measure (SSIM), and mean square error (MSE). The remainder of the paper is structured as follows: The second portion featured a review of the related work, as well as a brief discussion of noise.Then the work methodology, the bat algorithm, and the genetic algorithm.and discuss the results and conclusion were presented in the remaining sections.

2. RELATED WORK

We present some researchers working denoising image field, Saraiva *et al*. [8], 2019 introduced the development of a combined technique by using genetic algorithm technique, through this method, optimal filtration can be obtained and artifacts can be reduced. The algorithm structure functions in two basic methods, the first method: is to filter with 3d medium filter, BM4D filter and ellipsoid filter. The second step is conducted by applying mutation operators in images that are recovered previously using intensity-change methods, medium filter, and Gaussian filter, and provide a competence of the model adopted as a filter is exposed with good application results. Yousefi *et al*. [9] 2020 applied different types of noise like Gaussian noise and salt-and-pepper noise to medical images to making these images noisy. Moreover, there are nine filters used in the study, to denoise medical images as Digital Imaging, the filters used are as follows: i) sigma filter, ii) log filter, iii) Wiener filter, iv) unsharp filter, v) average filter, vi) Gaussian filter, vii) min filter, viii) max filter, and ix) median filter. The denoising algorithm proposed has shown a significant increase in images' visual quality the statistical evaluation, the values of PSNR values are gotten between 59 to 63 and 63 to 65 for CT and MRI images. Asokan *et al*. [10] 2020 present optimized contrast stretching by the use of non-linear transformation to enhance images. selecting control parameters appropriately for sample images will affect the non-linear transformation because of the tediousness of the manual adjustment of individual images. A comparison is made to the optimization algorithm's performance with other metaheuristic algorithms such as Ant colony optimization and particle swarm optimization. The contrast enhancement that depends on the bat algorithm is outperforming the other types of optimization methods regarding metrics like absolute mean brightness error (AMBE), mean square error, PSNR, and entropy. Rasheed [11] presented a method to estimate noise, called adaptive tuning noise estimation (ATNE) which applies convolution Laplacian for estimating noise. The proposed method is based on subtraction of Gabor Wavelet-based edge detection of images and includes the element-based relation on the input image parameters [12].

3. NOISE SOURCES AND MATHEMATICAL REPRESENTATION OF NOISE

In the operations of acquisition, transmission, storage, and retrieval, the noise corrupts image signal. In many engineering-related applications, typically, acquisition noise is low-contrast, and the basic cause is attributed to sensors' high quality [13]. Furthermore, in certain applications, acquisition noise might be enough, such as biomedical devices, and remote sensing devices. The main clarification of that method is the system of image acquisition is composed of a transmitting tube. Salt-and-pepper noise and additive white Gaussian noise, and mathematical formula are described below GN correspondingly distributed over signal, i.e. each pixel in the noisy image is representing actual values of pixel sum and random noise value with a given distribution is given by (1) [14].

$$F_{awgn} = f(x,y) + \eta_G(x,y) \tag{1}$$

Where η_{G^a} represent a variable at random having Gaussian probability distribution and a bell-shaped function of a probability distribution that is given in (2).

$$\mathrm{F(g)} = \frac{1}{\sqrt{2\pi\sigma^2}}\,\mathrm{e}^{-\frac{(\mathrm{g}-\mathrm{m})^2}{2\sigma^2}} \tag{2}$$

Where g refers to the grayscale, m refers to the mean value of g, and σ refers to standard deviation of the noise.

4. PROPOSED ALGORITHM

This work applies the bat-genetic algorithm (BGA) as a denoising technique of medical images for many types of noise and this technique is compared with Gaussian filter, median filter, bat algorithm, wiener filter, bilateral filter. In work proposes BGA to denoise the medical image achieved by the first step generation of the initial random population by applying various filters having different characteristics. calculation the fitness value (PSNR) for each particle from the population to measure the quality of the solution and choose the local best and global best of participation. Then update the population using the bat algorithm equations. The genetic algorithm is used to modify the existing population, then the local best and global best of participation are selected, then the population is updated based on BGA and updating the local and global best enhancement image, see Algorithm 1 and Figure 1.

Algorithm (1) of the bat-genetic algorithm of denoising of medical image explained in the following steps:

Input: Noisy image
Output: Denoised image
- The parameter PSNR is specified as the fitness function
- Initialize population by apply a number of filters with various parameters on the input image
- The parameter of bat frequency is specified and create zeros velocity of every particle
- Calculate the fitness of each particle affording to PSNR performance
- Define the best local image and global best of the image where the best image a realize a high PSNR value
- For itr= 1 to max iteration
    For $i = 1$ to size the population
    - velocity computing
      $Velocity\{i+1\} = Velocity\{i\} + best\ global\ image\ - current\ image\ * frequency$
    - normalizing the velocity{i+1} value between (-2 and 2) for controlling the changing of pixel
    - Updating the practical
      $new\ image\ =\ existing\ image\ +\ velocity\ \{i+1\}$
    - End for
    Computing each image's fitness
    From the current population, the two-maximum fitness of image is selected
    Crossover the two image-based on single-point crossover
    Replacing image's two minimum fitness by the two new images
    Computing the best local of the new population
    Updating the best global
     if the fitness of best global image< fitness of the best local image
     $best\ global\ image\ =\ best\ local\ image$
    End for
- Returning the best global image

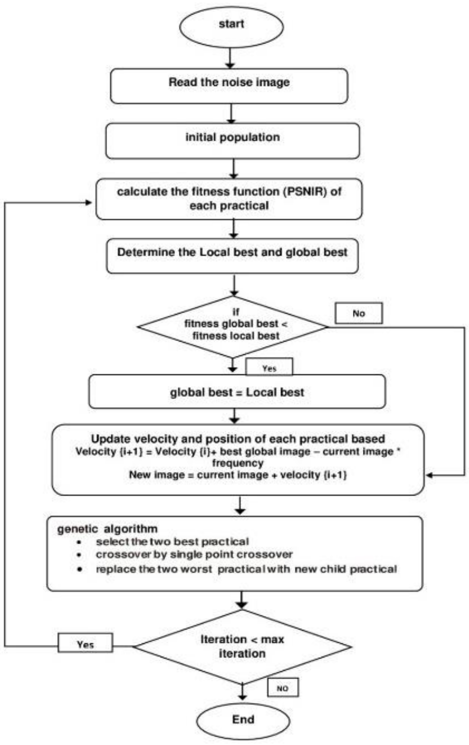

Figure 1. The flowchart of denoise of the proposed method (bat-genetic algorithm)

4.1. Bat algorithm

The bat algorithm is a metaheuristic algorithm inspired by nature commonly utilized to tackle real-world global optimization problems. This technique is based on the way bats look for food using echolocation The majority of bats can make use of their sophisticated hearing ability [11], [15]. That is, the bat uses sound to locate items instead than sight. Bats utilize echolocation to locate food and evade colliding with trees at night. Echolocation is a technique that includes producing a sound and analyzing its echoes to determine what things are nearby [4], [16], [17]. Three rules govern the implementation of the bat: first and foremost, all bats utilize echolocation to determine the distance to a particular spot. Second, bats fly in a random pattern with a predetermined frequency and at a certain velocity toward the designated spot. The loudness and wavelength, on the other hand, can change. Thus, bats modify their wavelengths automatically in response to their goal. Thirdly, the author reasoned that loudness is diverse by varying it from maximum to lowest instead than by varying it in any other method, as shown in (3), (4), and (5) [18].

$$ft = fmin + (fmax - fmin) \times \beta \quad (3)$$

$$v_i^{(t+1)} = v_i^t + (x_i^t - x_{Gbest})ft \quad (4)$$

$$x_i^{(t+1)} = x_i^t + v_i^{t+1} \quad (5)$$

Where $\beta \in [0, 1]$ is a random number follows the uniform distribution, f represents the frequency of all bat, $xGbest$ here is the current globally best location, xi indicates the current bat position at, vi denote the velocity by using (4) and (5), the position and velocity updates of ith bat can be calculated. Based upon the prey's bulk and location, the wavelength, and loudness A differ. xi and vi can be initialized through the use of certain initial random values. The particles' position coordinates were utilized for calculating the function of fitness. The best fitness value in all bats is indicated to as $xGbestbat$. A positive value represents differences between $xi(t)$ and $xGbestbat$, meaning $xGbestbat$ bat can process more properties than i_{th} bat. This variation is summed up by the preceding velocity to accelerate the motion of ith bat towards the $xGbestbat$ [19]–[21].

4.2. Genetic algorithm

A genetic algorithm is a randomized search technique, which can search each part of the solution space using a different type of solution or subset characteristics for finding the optimum answer for every iteration. In this algorithm, the process of searching is simply needed for determining the value of the objective function value in various points, and also, extra information is not required such as differentiating any function. The most important operator in the genetic algorithm is the crossover operator, which can produce a new population through a combination of chromosomes relying upon their selection. The selected parents for crossover, transmit their genes jointly for creating new offspring. Crossover can eliminate genetic variation in the population. Moreover, another operator in the genetic algorithm is the mutation operator that can produce multiple optimal solutions [22]. In mutation, it is possible to remove a single from the subset or produce a new one that is added to the population [23], [24].

5. SIMULINK RESULT AND DISCUSSION

In this work, used the several filters and implemented by (MATLAB R2020a) and two kinds of noise are tested: Gaussian noise and salt and pepper noise. The denoising from the image using bat- genetic algorithm, Gaussian filter, bilateral filter, median filter, bat algorithm, and wiener filter. The work test on several medical images digital of different kinds like CT, MRI, in various formats ('.png', '.jpg', '.bmp'). The results of our proposed technique which use the bat-genetic algorithm for image de-noising has been compared with other noise reduction methods such as bat algorithm, median filter, bilateral filter, Gaussian filter, and Wiener filter with various kinds of noise, see Figure 2, Figure 3.

This section explains the result achieved when this proposed technique is used, verifies, and presents a comparison to the denoising process of the proposed technique with other conventional filters. The experimental results were applied on MRI images and CT images. This section uses statistical parameters metrics such as (MSE, SSIM, and PSNR) for demonstrating the proposed method's comparison with several filters with different kinds of noise.

The experiment follows these steps: first, medical images are selected from the database Kaggle, then Gaussian noise and salt and pepper noise are added to the image. The noise variance level ranging from 0.1 to 0.5 is added to the CT and MRI image. The medical image in which Gaussian noise (GN), salt and pepper noise (SPN) was used to corrupt it with noise variance from 0.1 to 0.5 where denoised by utilizing the proposed technique (bat-genetic). Then, filtering the same noise corrupted image by applying Gaussian filter, a median filter, bat algorithm, bilateral filter, and wiener filter to give a comparison. and to evaluating the proposed method performance using PSNR, MSE, and SSIM values are specified as a quality metric. Table 1, shows the PSNR, MSE, and SSIM values for removing GN.

Removing (SPN) by the use of the technique of bat -genetic algorithm would provide optimum result at higher noise variance. Table 2 tabulated the PSNR value, MES value, and SSIM value which are gotten for denoised and noised medical images that SPN corrupt. For each method that is tested, the results showed that this method produces the highest PSNR, MSE, and SSIM values when comparing to other filtering methods at several noise levels. Tables 1 and 2 contain the tabulation to the results related to denoising medical images, the result concluded that this proposed technique presents optimum results in each aspect when removed Gaussian noise and salt and pepper noise. Table 3 showed the results related to the comparison based on SSIM value and PSNR value.

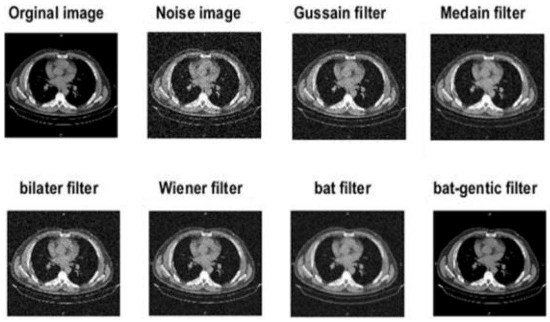

Figure 2. Shows denoising Gaussian noise from CT image

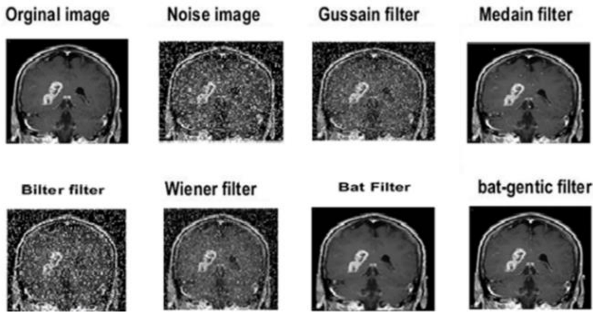

Figure 3. Shows denoising salt and pepper noise from the MRI image

Table 1. Denoising results for Gaussian noise removal

	Level noise 0.1			Level noise 0.3			Level noise 0.5		
Filter	PSNR	MES	SSIM	PSNR	MES	SSIM	PSNR	MES	SSIM
Gaussfilt	26.5709	31.733	0.37956	22.64	71.348	0.32152	20.60786	143.73	0.26613
Bilatfilt	26.3461	36.542	0.35974	21.58	73.881	0.30667	19.58351	144.87	0.25758
Wiener	27.2117	23.754	0.47690	23.74	66.573	0.38544	15.64438	112.51	0.30322
Bat	61.8321	9.2718	0.99905	60.82	11.1836	0.99866	42.21294	15.258	0.99566
Bat-gentic	63.0456	3.997	0.99946	62.66	4.0962	0.99926	59.09695	5.964	0.99941
Medfilt	27.1606	23.829	0.44853	23.68	68.256	0.36692	16.58210	144.85	0.29043

Table 2. Denoising results for removing SPN

	Level noise 0.1			Level noise 0.3			Level noise 0.5		
Filter	PSNR	MES	SSIM	PSNR	MES	SSIM	PSNR	MES	SSIM
Gaussfilt	28.568	26.48	0.37967	20.64	30.488	0.3221	20.608	65.27	0.2667
Bilatfilt	26.348	22.27	0.36037	22.58	29.362	0.3072	19.584	47.12	0.2571
Wiener	29.210	20.07	0.47705	21.74	23.329	0.3855	20.644	35.65	0.3023
Bat	52.006	7.154	0.85612	47.95	8.172	0.7995	46.495	18.31	0.6986
Bat-gentic	59.755	5.3207	0.9976	53.25	7.103	0.9884	50.753	8.905	0.9015
Medfilt	38.605	16.917	0.44931	23.69	19.53	0.36754	21.5834	27.46	0.3199

Table 3. Comparison of results between proposed hybrid method and other works as PSNR and SSIM values

Proposed work	PSNR		SSIM	
	MRI	CT	MRI	CT
Saraiva *et al.* [8]	-	35.76	-	0.90
Anoop *et al.* [25]	30.50	-	0.89	-
Rai and Chatterjee [26]	27.78	-	0.7621	-
Elhoseny and Shankar [27]	47.52	-	0.98	-
Miri *et al.* [28].	-	36.45	-	0.9932
Akar [29]	30.1328	-	0.8833	-
Aravindan *et al.* [30]	-	58.21	-	0.98
Our Proposed Method	59.755	63.0456	0.9976	0.99946

6. CONCLUSION

This paper provided an overview of the quantitative and statistical measures as well as image visual quality are used to measure the proposed denoising algorithms' performance. In this paper, we presented an excellent method through the application of a hybrid of two algorithms (genetic algorithm) and (bat algorithms) as denoising the medical image. In this study, salt and pepper noise and Gaussian noise are used to corrupt the medical images with the noise variances of 0.1, 0.3, and 0.5 then the proposed method was used to denoise these images. A comparison is made to the result with Wiener filter, Gaussian filter, bat filter, median filter, bilateral filter. Finally, the results of the proposed algorithm are best results, when compared with the other conventional filters that were used to denoise medical images. The output from the proposed method contains a higher SSIM value higher PSNR value comparing to the other techniques that were used. The results of the simulation also revealed that the bat-genetic algorithm presented optimum results at a higher level of noise variance Moreover, this method proves that it is better best to maintain the medical images' structure. The PSNR values were obtained at 63.04 dB and 59.75 dB for CT and MRI images. In the future, this Expansion the dataset to comprise the other types of medical images such as ultrasound and x-ray images. also, expand to using other types of noise, and developing the proposed algorithm to enhancement the 3D medical images.

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