Advances in Computer, Signals and Systems (2020) 4: 36-46
Clausius Scientific Press, Canada

DOI: 10.23977/acss.2020.040106
ISSN 2371-8838

Nature Inspired Algorithms multi-objective histogram equalization for Grey image enhancement

Ahmed Naser Ismael [1,a,*], Majida Ali Abd[2] [1,b] and Hamed Ali Abd[3,c]

[1]*Department of Management Information Systems, University of Basrah, Iraq*
[2] *Department of Computer Sciences, University of Tikrit, Iraq*
[3]*Department of Communication, Iraq University Colloge,Iraq*
a. Ahmadnassie84@gmail.com

Keywords: Medical Images, Histogram Equalization, Enhancement Techniques, Nature Inspired Algorithms.

Abstract: Nature is a very rich source of inspiration. Many algorithms have inspired from nature and source of algorithms inspiration development are diverse with different quality. Nature–inspired optimization techniques play an essential role in the field of image processing. It reduces the noise and blurring of images with improves the image enhancement, image segmentation, image pattern recognition. The Image enhancement is a process to make image ready for further uses in certain applications. The image quality is individually related with its contrast by rising the contrast, further disfigurements can be produced. In this paper covers current equalization enhancement technique some nature inspired algorithm for medical images. In addition, proposed an image enhancement method built by using two natures inspired algorithms Particle Swarm Optimization (PSO) and Bat Optimization Algorithms (BOA) combined to produce better enhancement. Here an objective criterion for measuring image enhancement is used which considers the Discrete Entropy (DE), the Structural Similarity Index Matrix (SSIM) and Executing Time (ET). The results showed the Bat Algorithm has produced a batter enhanced images when comparing with Particle Swarm Optimization images and the existing histogram-based equalization methods. The final results showed proposed image enhancement method can not only improve the contrast of the image, but also preserve the details of the image, which has a good visual effect.

1. Introduction

Your paper will be part of the journals therefore we ask that authors follow the guidelines explained Image enhancement technology is a multidisciplinary research topic involving subject areas such as advanced mathematics, computer science, and signal processing technology. Image enhancement has been divided into two categories, a first one is used on the gray level of the image which is called space domain, while the second one is an indirect enhanced algorithm based on the frequency domain [1]. There are many enhancement methods in the industry, such as histogram equalization,

homomorphic filtering, wavelet transform and retinex. Histogram equalization is enhanced based on probability statistics. It is enhanced based on probability statistics.

The histogram provides the gray value distribution, the overall description of the original image and expands the contrast [2} Grayscale transformation is divided into negative transformation, logarithmic transformation, exponential transformation and piecewise linear transformation.

Among them, piecewise linear transformation has contrast stretching, grayscale cutting and bitmap cutting [3]. The more important thing in gray transform is histogram processing, which is divided into histogram equalization and histogram specification. The basic method of the histogram equalization method is calculating the gray histogram for image, and stretch some gray intervals in the histogram to the uniform distribution in the whole gray range. [4].

The strategy of nature inspired algorithm utilized the optimal solution can be approximated faster than the classical optimization algorithm. One of the most excellent usually used algorithms is PSO which was used to test the quality performance in [5]. A proposed a context free image enhancement method based on the multimodal PSO combined with chaotic mechanism. An objective function the expected contrast gain and tone distortion are used [6].

This improves a dynamic range of the pixel gray value, thereby, y is usually used to increase the local contrast and realizing of many images. The method performance was evaluated by Absolute Mean Brightness Errors (AMBE), Mean Squared Errors (MSE), Measure of Enhancement (EME), Structural Similarity Index Matrix (SSIM) and Entropy (En) respectively [7].

The peak signal-to-noise ratio (PSNR) is often worked as a measurement method for signal reconstruction quality in areas such as image compression and Enhancement. Modern heuristic algorithms mainly include: Artificial Fish Swarm Algorithm (AFSA), Ant Colony Algorithm (ACA), list Search Algorithm (ST), Co-Evolution Particle Swarm Optimization (PSO), Evolutionary Strategy (ES), Firefly and Bat Optimization Algorithms (FOA and BOA) applied for enhancement images [8].

2. Histogram Equalization Enhancement Technique (HE)

Histogram equalization (HE) is the very general indirect contrast enhancement method in the field of image processing. The principle for histogram specification: equalize the histograms of the original image and the reference image, transform them into a same normalized uniform histogram, and then use the uniform histogram as the medium to perform the equalization inverse operation on the original image [9]. This method is mainly used to rises the global contrast for images with a small dynamic range of grey values, mainly when the practical data of the image is represented by near contrast values. On the input image, methods an operation (linear or non-linear) are performed on the neighbourhood pixels of coordinate (x,y) and giving an enhanced image $\check{F}$ [10].

In particular, this technique treats the image globally, thus it is reasonable to adopt adaptive technique for the image local contrast improving. This technique called AHE which it is extension to HE [11]. The steps of calculating image histogram equalization are illustrated in below Figure 1.

3. Nature Inspired Algorithms

Nature plays a main part in different human activities and it is ample source of inspiration. Therefore, algorithms based on nature are called Nature Inspired Algorithms (NIAs) [12]. The purpose of designing NIAs is to obtain an optimal solution of the difficulty with inspiration for search and optimization based on natural. In the last two decades, several algorithms that have been proposed and achieved for solving multimodal and multidimensional optimization problems, such as non-deterministic and deterministic algorithms.

Image enhancement which improves the quality of an image for visual analysis and/or machine understanding. There is no unique image enhancement technique and its measurement criterion which satisfies all the necessity and quantitatively judge the quality of a given image respectively. In order to overcome that problem, researchers formulated the image enhancement as optimization problems and solved using NIAs which starts a new era in image enhancement field. There were few natures inspired algorithms applied for enhancement uses to mimic the flocking behavior of birds and applied also to schooling fish [13]. The Firefly Algorithm (FA) is a nature inspired computing by the flashing behaviour of fireflies. Also, Cuckoo Search (CS) is an algorithm that successfully solves the optimization problem by simulating the parasitic brooding for certain species cuckoos. We used in our paper two nature inspired algorithms (PSA) and Bat Optimization Algorithms (BOA) [14].

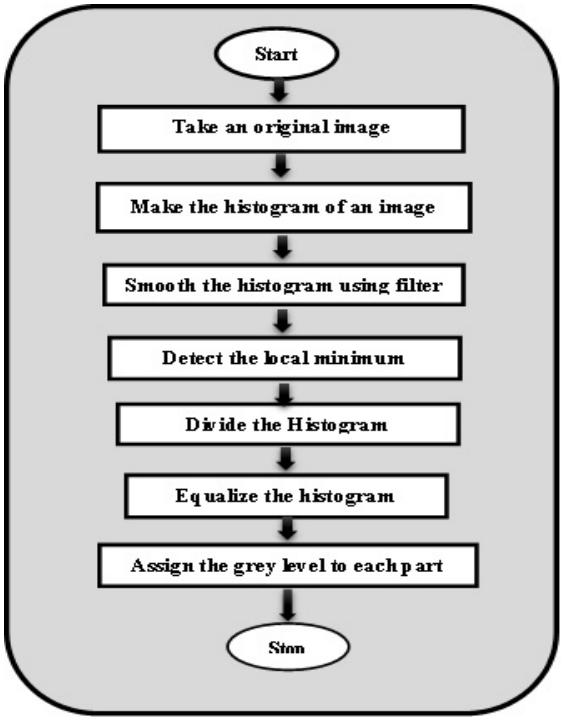

Figure 1: The Histogram equalization steps algorithm

4. Methodology

In this section, the procedures of handling the data followed the suggestions algorithm HEE of the two Nature Inspired based algorithms used here for, namely PSO and BOA algorithms. Details of these algorithms are provided in their respective subsections.

4.1 Particle Swarm Optimization (PSO)

The equations have been accepted for the prescribed specifications of this template. Particle Swarm Optimization (PSO) algorithm is a kind for global and public intelligence based on group intelligence inspired by Kennedy and Eberhart's results from artificial life research. PSO was inspired by observing that the movements of some animals moving in herd while meeting their basic needs, such as finding food, affect other individuals in the herd, and that the flock can achieve its purpose more easily [15].

The aim of PSO is to locate the particle with the best position in the flock with allow other particles to move in that direction. Particles aim to improve their next position based on their past experience and the best position in the flock [16]. PSO is initiated by a set of randomly created results, with the creations are updated to search for an optimal value. In each iteration, each particle is updated according to two “best” values.

The first is the best suitability value a particle has ever found. In addition, this value is stored in memory for later use and is referred to as “pbest”, the best value of the particle [17]. The other best value is the solution with the best fitness value obtained by any particle in the population. This value is the global best value for the population and is called best "gbest . The Basic process of PSO is defined in the following steps (pseudocode of PSO) in Figure 2.

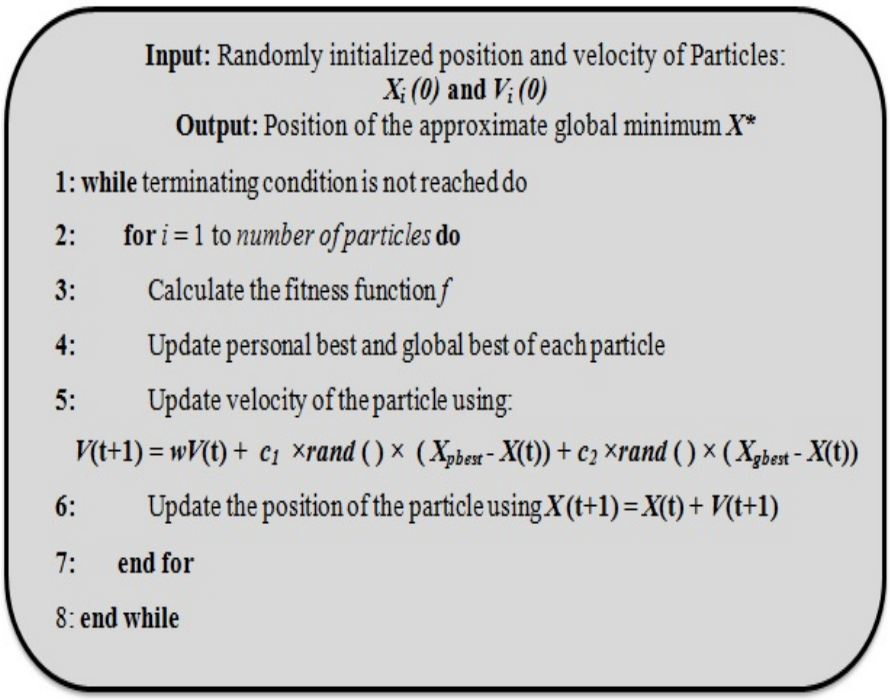

Figure 2: Particle Swarm Optimization steps algorithm

4.2 Bat Optimization Algorithm (BOA)

The Bat Optimization Algorithm (BOA) is an intuitive algorithm which was proposed by [18]. The BOA is based on the determining characteristics that bats often make use of during hunting.

- All bats determine the location of their prey by echolocation size.
- Each bat flies randomly with velocity, frequency and position, looking for prey by changing wavelength and audio output values.
- Bats can adjust wavelengths and sound outputs for different situations. Location update according to the echolocation system is performed with the following equations. The bat algorithm pseudocode is illustrated in Figure3 below.

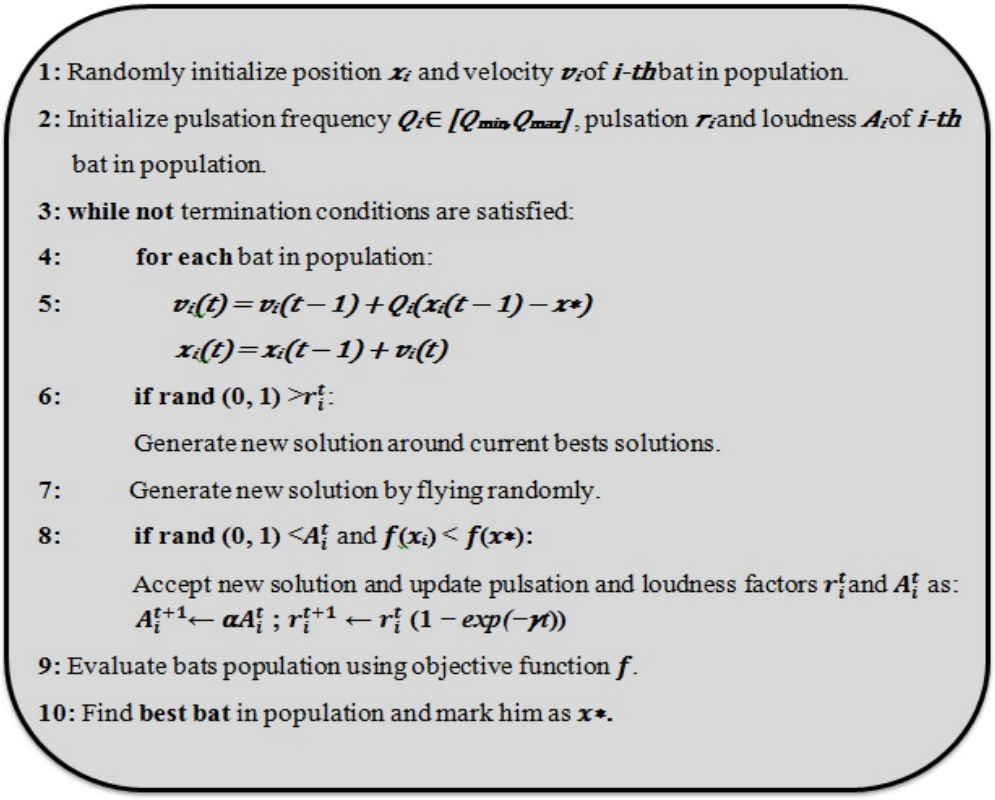

Figure 3: Bat algorithm steps algorithm

4.3 Bat the Proposed Optimized (HEE) Technique

The gray histogram of the image is a relationship between the gray values of each level for digital image with its frequency of occurrence. If the gray level range of a digital image is [0, L-1], the gray histogram of the image can be defined as, h(rk)=nk, r= 0, 1, 2, …, L-1, where rk denotes the kth gray level, and h(rk) and nk denote the quantity for pixels whose gray value is rk in the image [19]. The histogram can only describe the quantity for pixels in each gray level of image, and cannot represent every image in the image.

The hybrid algorithm with validation set of test medical images is applied in this section. We are always looking for better ways which improving the performance for algorithm by parameters selection. However, a proposed Optimized HEE transformed the color image to gray scale image using four parameters namely a, b, c and d. Here, we evaluate the performance of enhancement technique using three quality metrics are (DE) is the Discrete Entropy, (ET) is the Executing Time, and Structural Similarity Index Matrix (SSIM) [18]. The proposed algorithm steps are showed in figure.4 below.

Optimized Histogram Equalization Algorithm

1. **Input** ***I [M, N]***: image, ***L***: Maximum gray level.
   Output ***He[M, N]***: histogram equalized image
2. Initialize particles ***a***; ***b***; ***c*** and ***d*** for a population size.
3. Calculate the values of Objective functions: Minimize ***TDE= DE(OI) - DE(HI)***, Minimize ***TET= ET(OI) - ET(HI)*** and Maximize ***TSSIM= SSIM (OI) - SSIM(HI)***;
   Where:
   T is the total, ***DE*** is the discrete entropy, ***ET*** is the Executing Time, ***SSIM*** is the Structural Similarity Index Matrix, ***OI*** and ***HI*** are the original and enhanced images, respectively.
4. Objective function ***OF= TDE+TET+TSSIM***
5. For each particle a, b, c, generate (n) random values, $a_1 \dots a_n$, $b_1 \dots b_n$, $c_1 \dots c_n$ and $d_1 \dots d_n$.
6. Run optimization algorithms to get the optimal parameters ***a, b, c*** and ***d*** using ***OF***.

Figure 4: Optimized histogram equalization algorithm

4.4 Discrete Entropy

The entropy of an image is a statistical form of features. It represents the aggregate characteristics of the grey allocation for the image [20]. However, it cannot invert the spatial characteristics of the grey allocation for the image. Based on the one-dimensional entropy, feature quantities which can invert the spatial characteristics of grey allocation are introduced for two-dimensional entropy of the image. Then, the one-dimensional discrete entropy (DE) for grayscale image is defined as [21]:

$$DE = -\sum_{i=0}^{L-1} P(i)\, log_2(P(i)) \qquad (1)$$

Where P is the possibility which a grey scale seems in the image and can be obtained from the grey histogram.

4.5 Structural Similarity Index Matrix (SSIM)

The structural similarity index matrix has been widely used in image and video processing related applications in recent years. The main idea of structural similarity is that natural images are extremely structured. That is, there is a robust correlation between adjacent pixels in natural images, and this correlation transports the structural information of objects in the scene. The structural similarity between the two images can be regarded as an image quality measurement index of the distorted image. The SSIM is defined as [22]:

$$SIM(X,Y) = \frac{(2\mu_X\mu_Y+C_1)(2\sigma_{XY}+C_2)}{(\mu_X^2+\mu_Y^2+C_1)(\sigma_X^2+\sigma_Y^2+C_2)} \qquad (2)$$

Where:

X: Reference.

Y: The output image.
μ_X : The respective mean of X.
μ_Y : The respective mean of Y.
σ_X and σ_Y are the standard aberration of X and Y respectively.
σ_{XY} : A square root for covariance of X and Y.
C1 and C2: constants.

The standard histogram equalization algorithm has a easy base and suitable good real-time performance to generate an enhanced image for different image sizes [23]. We propose here an Optimized HEE Technique procedure for measuring the performance of enhancement images. The procedure is given in Figure 4.

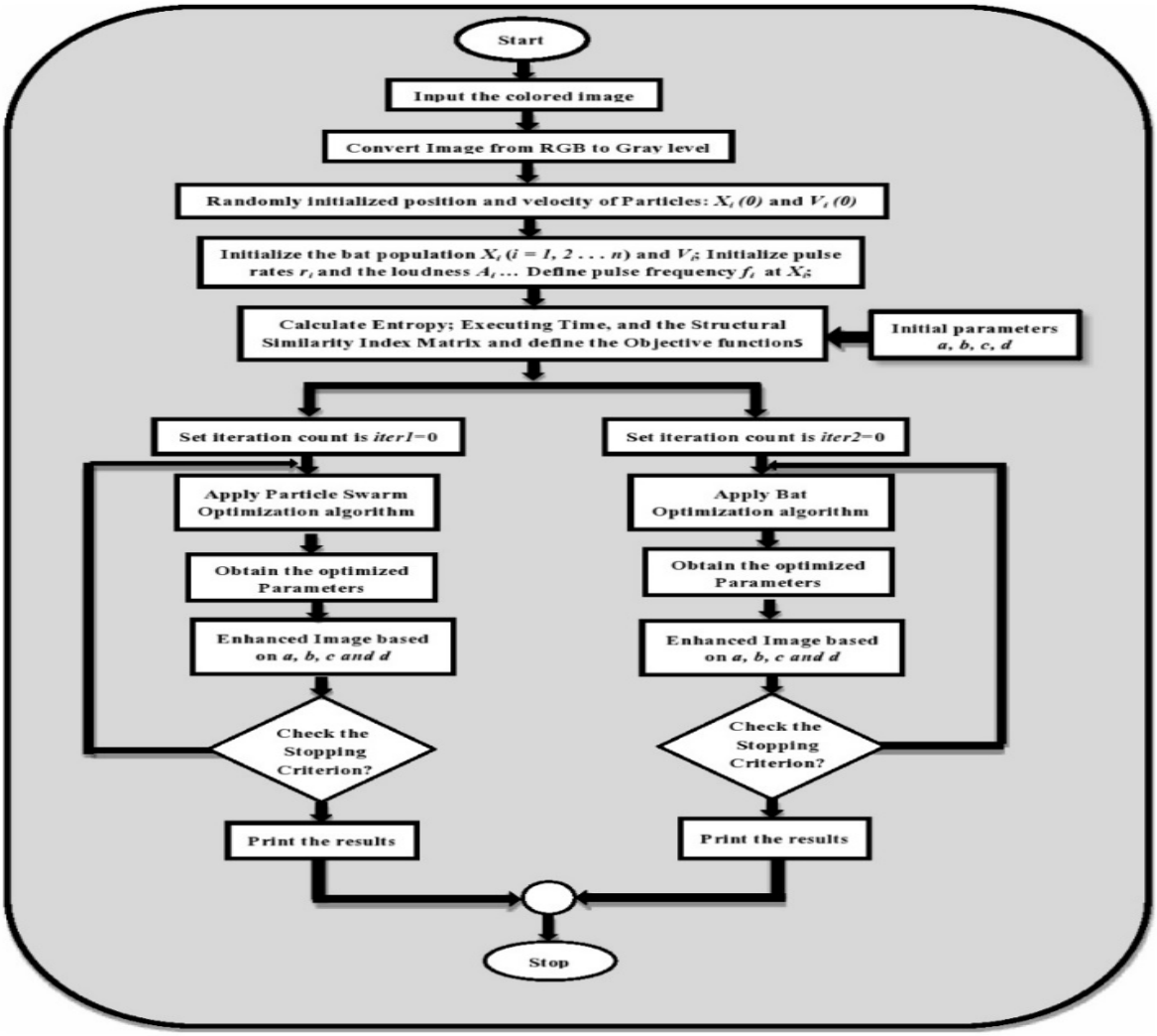

Figure 5: Proposed Optimized Technique Procedure Algorithm

5. Experimental Results

Image enhancement is a purposeful emphasis on the overall or local characteristics of an image, such as improving the colour, brightness, and contrast of an image. In recent years, some nature inspired algorithms have made great breakthroughs in many low-level computer vision tasks,

including image super-resolution, de-blurring, and defogging and image enhancement. In the current work it is wise to enhance a contrast for the image by using hybrid nature inspired algorithms; PSO and BA. However, even better results are achieved when using our proposed algorithms.

This section summarizes the findings and contributions made. Medical images have been taken as dataset for apply the techniques. The images captured by digital camera and stored as JPEG format with dimensions 520*520 pixels. Totally, there are two set of test medical images in the dataset. The comparison between all enhanced images achieved using MATLAB R2017a software. The fig.5 showed samples of dataset images.

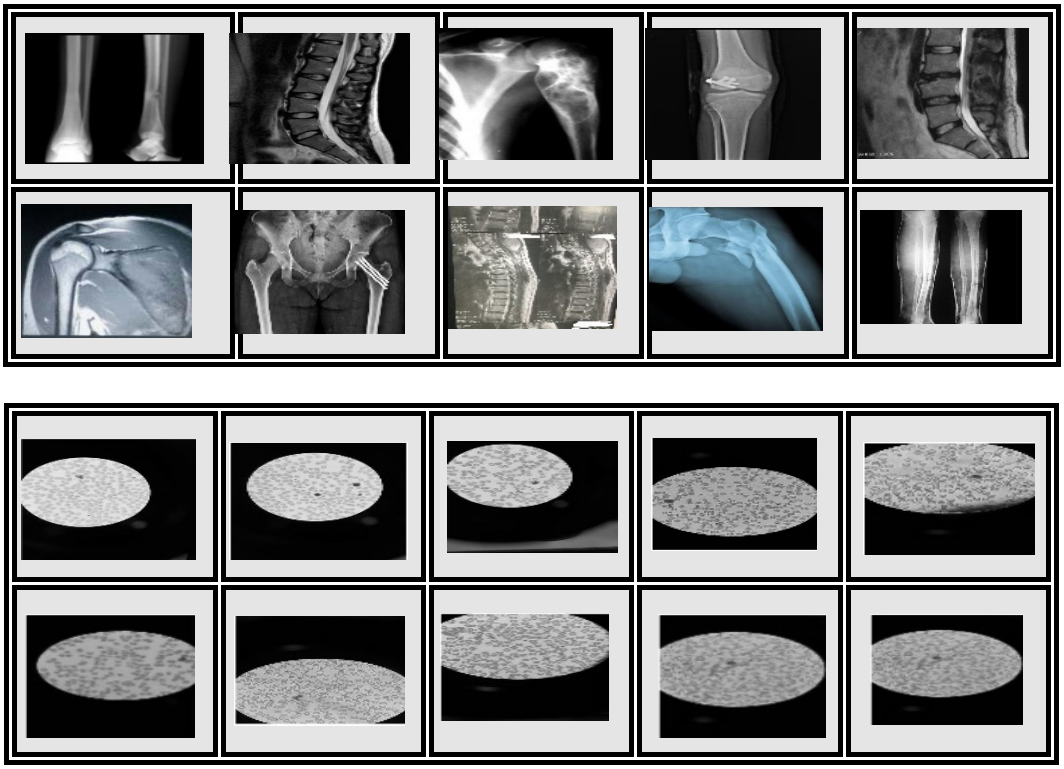

Figure 6: Some Samples Dataset

We describe the obtained results of the existing and proposed techniques in figure (6a to c) by applying the Discrete Entropy, the Structural Similarity Index Matrix (SSIM) and the Executing Time techniques.

The major content for image enhancement processing is to focus the portions for significance for images, weakening with removing unwanted information. This enhances suitable information, resulting in a further applied image or alteration to an image which is extra proper for machine analysis and human. There are many indicators for measuring the results of image quality utilizing the specified method; calculate the values of objective functions such as Minimize Total DE, Maximize Total SSIM and Minimize Total ET taken to move towards to the optimal weights. These comparisons quantitatively prove the merits of Optimized HEE Technique for being a superior technique for image enhancement as shown in Figure.7a to c.

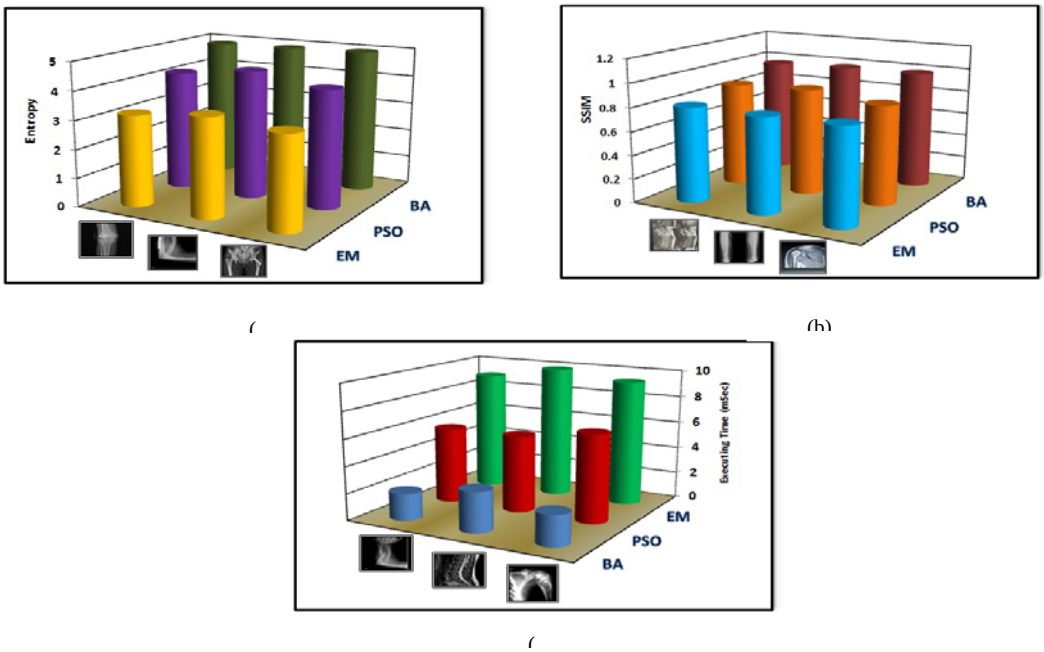

Figure 7: Comparisons between Hybrid optimized (PSO), (BA) and exciting method (EM) for Some Samples Dataset images, (a) Discrete Entropy (DE), (b) Structural Similarity Index Matrix (SSIM), and (c) Executing Time (ET).

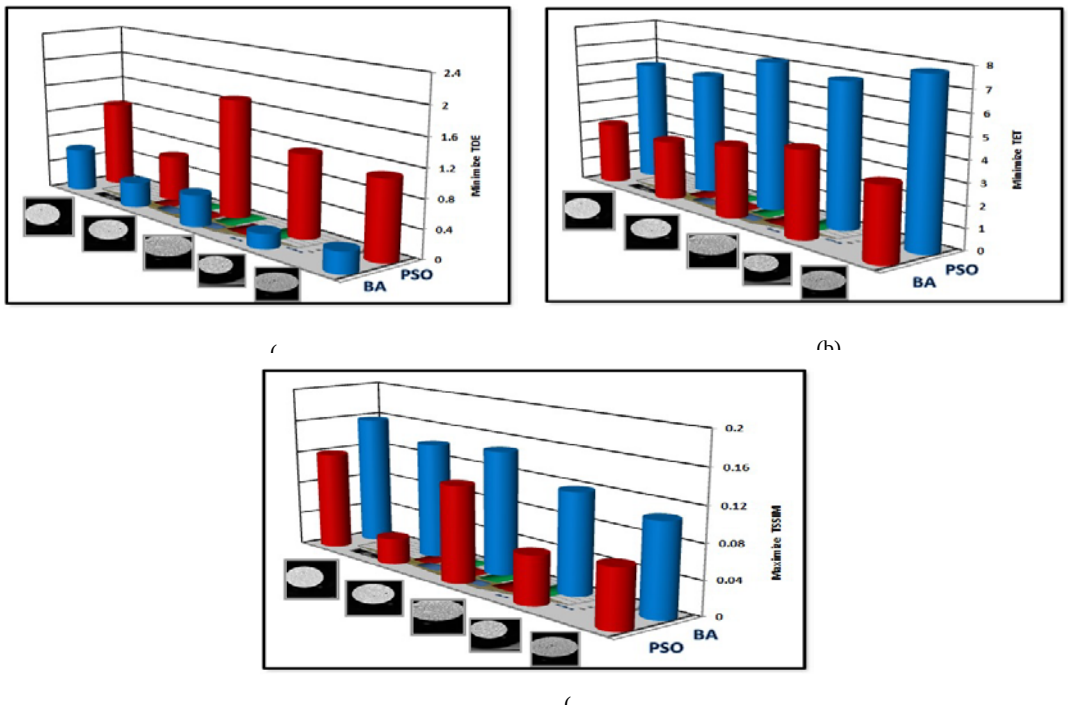

Figure8: Comparisons between optimized PSO and BA for Some Samples Dataset images, (a) Minimize Total DE, (b) Maximize Total SSIM, and (c) and Minimize Total ET.

6. Conclusion

The optimization steps are always used to solve problems for image processing and enhancement. This paper has conducted in-depth research on new hybrid algorithm based histogram equalization

enhancement technique with two nature inspired algorithms which are PSO and BOA. The work focuses on enhancing two set of medical images. The proposed algorithm HEE is evaluated by objective criterion measuring image enhancement which are DE, SSIM and ET. The qualitative experiments have appeared that optimized method is excellent when compared with other recent and traditional algorithms. It has showed and achieved better enhancement impact in different conditions. The work may be further extended for a comparative analysis and enhance colourful images of medical image or another type of images with enhancement techniques.

References

[1] A. Moraglio, C. Di Chio, J. Togelius, R. Poli, 2008, "Geometric particle swarm optimization", Journal of Artificial Evolution and Applications.

[2] Pooja, Jyoti Rani ,2015," Contrast Enhancement Based on BAT Algorithm ", International Journal of Engineering Research and General Science Volume 3, Issue 4, Part-2, ISSN 2091-2730.

[3] D. Nirmala,2015," Medical image contrast enhancement techniques "Journal of Chemical and Pharmaceutical Research, 7(7):1-8, ISSN: 0975-7384.

[4] R. Seetha and S. Santhosh Baboo, ," Analysis of Enhancement Techniques for Medical Images", IJCTA, 9(40), pp. 141-147, 2016.

[5] Raihan Firoz, Md. Shahjahan Ali, M. Nasir Uddin Khan1, Md. Khalid Hossain, Md. Khairul Islam, Md. Shahinuzzaman1 ," Medical Image Enhancement Using Morphological Transformation "Journal of Data Analysis and Information Processing, 4, 1-12, 2016.

[6] Shweta Dalwani, Anuradha Agarwal, "Review On Classification of Nature Inspired Approach", International Journal of Computer & Mathematical Sciences, IJCMS, ISSN 2347 – 8527, Vol. 7, Issue 2, 2018.

[7] Yechuang Wang, Penghong Wang, Jiangjiang Zhang, Zhihua Cui, Xingjuan Cai, Wensheng Zhang and Jinjun Chen, "A Novel Bat Algorithm with Multiple Strategies Coupling for Numerical Optimization", Mathematics, 7, 135, 2019.

[8] Sha-Sha Guo, Jie-Sheng Wang and Xiao-Xu Ma, "Improved Bat Algorithm Based on Multipopulation Strategy of Island Model for Solving Global Function Optimization Problem", Computational Intelligence and Neuroscience Vol. 2019, 6068743, 2019.

[9] Majida Ali Abed, Ahmed Naser Ismael, " Comparison of Three Evolutionary Algorithms: PSOA, ACOA and BCOA on Recognition Arabic Characters Problem", Journal of Artificial Intelligence Practice 2: 1-12 Clausius Scientific Press, Canada, 2016.

[10] Hamid Ali Abed Al-Asadi, Majida Ali Al-Asadi , Nada Ali Noori ," Optimization noise figure of fiber Raman amplifier based on bat algorithm in optical communication network", International Journal of Engineering & Technology, 7 (2), 874-879, 2018.

[11] Dhal, K.G., Ray, S., Das, A. et al. A Survey on Nature-Inspired Optimization Algorithms and Their Application in Image Enhancement Domain. Springer, 26, 1607–1638 ,2019. https://doi.org/10.1007/s11831-018-9289-9

[12] Alain Horé , Djemel Ziou "Image quality metrics: PSNR vs. SSIM," International Conference on Pattern Recognition . August, 2010.

[13] Bejinariu, H. Costin, S. Member, F. Rotaru, and R. Luca, "Image Enhancement using Chaotic Maps and Bio-inspired Multi-objective Optimization," International Symposium on Signals, Circuits and Systems (ISSCS), 2019,

[14] S. Bejinariu, H. Costin, S. Member, F. Rotaru, and R. Luca, "Nature Inspired Optimization Techniques for Image Processing— A Short Review," in Intelligent Systems Reference Library ·, no. 1, Researchgate, pp. 1–33, 2019.

[15] S. Mirjalili, J. S. Dong, and A. L. Editors, Nature-inspired Optimizers. Brisbane Australia: Springer, 2018.

[16] A. L. B. Canlin Li 1, Jinhua Liu1, Anyi Liu 2, and Qinge Wu3, "Global and Adaptive Contrast Enhancement for Low Illumination Gray Images," IEEE Access, vol. 11, pp. 1–17, 2019.

[17] A. B. K., P. S. and Subbian2, "Detection of Hard Exudates Using Evolutionary Feature Selection in Retinal Fundus Images," Journal of Medical System., pp. 1–12, 2019.

[18] S. V. Leonardo Rundo1;2;3;4, Carmelo Militello4 and M. C. G. Giorgio Russo4, Evis Sala1;2, "A Survey on Nature-Inspired Medical Image Analysis: A Step Further in Biomedical Data Integration," Fundam. Informaticae, vol. 1, no. 21, pp. 1–34, 2019.

[19] P. K. • A. K. Bhandari, "Spatial context-based optimal multilevel energy curve thresholding for image segmentation using soft computing techniques," Neural Comput. Appl., vol. 7, no. 20, pp. 1–37, 2019.

[20] S.-I. Bejinariu, H. Costin, F. Rotaru, R. Luca, C,. Nita, „Automatic multithreshold image segmentation using metaheuristic algorithms", Signals, Circuits and Systems (ISSCS), 2015 International Symposium on, Iasi,2015, pp. 1 – 4;

[21] S. Bejinariu, H. Costin, S. Member, F. Rotaru, and R. Luca, "Image Enhancement using Chaotic Maps and Bio-inspired Multi-objective Optimization," 2019, December.

[22] S.-I. Bejinariu, H. Costin, F. Rotaru, R. Luca, C. Niţă, D. Costin, „Image enhancement by multiobjective optimization and bio-inspired heuristics",Proc. of 2017 E-Health and Bioengineering Conference (EHB), Sinaia,România, 22-24 June, 2017, pp. 442-445.

[23] X. Xu, H. Rong, M. Trovati, M. Liptrott, N. Bessis, "CS-PSO: chaotic particle swarm optimization algorithm for solving combinatorial optimization problems", Soft Computing, 22, 2018, pp. 783–795.