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AUTOMATED IMAGE ENHANCEMENT USING GREY-WOLF OPTIMIZER ALGORITHM

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ABSTRACT

Application of Grey-wolf optimizer algorithm for image enhancement is the objective of this paper. Here Image enhancement is considered to be an optimization problem and it is solved using Grey-wolf optimizer algorithm. The process is automated by using entropy and edge information of the image. The superiority of the proposed technique is established by statistically analyzing the results of 50 independent trails of the algorithm. Additionally, PSNR are used to evaluate the performance of the algorithm. The results are compared with classical Histogram Equalization (HE) and evolutionary Particle Swarm Optimization (PSO) algorithm.

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INTRODUCTION

Digital image processing is of great relevance to researches both in academia and in the industry as it involves many practical projects leading to various applications. Being an indispensable field, Vision and image processing techniques have become a part of our daily lives. One of the most critical and crucial parts of image processing is image enhancement. It is one of the important pre-processing techniques. According to Gonzalez et al, enhancement techniques may be branched into four groups: a) Point operation; b) Spatial operation; c) Transformation and d) Pseudo-coloring; [1]. This paper is based on spatial operation.

Automation of image enhancement is notoriously a difficult task in image processing [2]. However, these automation algorithms find many application is various fields such as automation engineering, medical imaging [3,4] etc; They help to enhance the image in a incomplex manner, by reducing the cumbersome job. The aim of this paper is to enhance images without intervention of humans. It could possibly pave way to artificial vision, machine learning & classification etc.[5] in the near future. Recently some of the image quality metrics such as edge intensity, sum of the edges, entropy etc., have been used for image enhancement.

One of the classical methods for image enhancement is Histogram equalization [HE][1]. Being one of the simplest methods, it creates a uniform distribution of cumulative density function of input image [6]. The major drawback of HE is that the mean- brightness of the HE image is considered as the middle gray-level and the mean of the image is not considered . So it is important to consider alternatives for image enhancement. One such alternative is metaheuristic algorithms, which is simple and time efficient. Some of the metaheuristic algorithms reported for image enhancement are Genetic Algorithm (GA) [7,8], Artificial Bee colony Algorithm(ABC)[9], Particle Swarm Optimization (PSO) [10,11], Black hole algorithm [12] etc.

The better performance of the above algorithms motivated me to apply "Grey-wolf optimizer" (GWO) algorithm [13] on image enhancement problem. The results are compared with HE and PSO for validation of IE. The reminder of the paper is organized as follows; Section II provides the problem formulation for IE; In section III,

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Grey-wolf optimizer algorithm is described. The results along with the discussion are given in section IV. The conclusion is drawn in section V.

PROBLEM FORMULATION

In this paper, image is mapped to an objective value. The objective value is determined by parameters such as entropy and edge information. In order to increase the value of this objective function, value of each and every pixel of the image is altered. They are altered in such a way that the image does not lose its information, while enhanced [9,12]. To evaluate the image, an objective function is created.

Local Information

For a local user defined window $n \, X \, n$, the local mean $m(i,j)$ is defined as,

$$m(i, j) = \frac{1}{n \times n} \sum_{p=i-(n-1)/2}^{i+(n-1)/2} \sum_{q=j-(n-2)/2}^{j+(n-2)/2} f(p,q) \tag{1}$$

Global Information

The Global mean of the image is defined as

$$D = \frac{1}{M \times N} \sum \sum f(x, y) \tag{2}$$

The Global variance of the image is given by

$$\sigma(i, j) = \sqrt{\frac{1}{n \times n} \sum \sum (f(x, y) - m(x, y))^2} \tag{3}$$

Therefore the total global information would be extracted as given in eqn. (4). With the above equation the total transformation function can be summarized as the following

$$K(i, j) = \frac{k\,D}{\sigma(i, j) + b} \tag{4}$$

$$g(i, j) = K(i, j)[f(i, j) - c \times m(i, j)] + m(i, j)^a \tag{5}$$

In eqn (5)., there are four constants "a, b, c and k", that are varied for altering the values of the pixels. They produce large variations to create $g(i,j)$, from which the best image is taken as the 'enhanced' image.

Objective function:

In order to automate the image enhancement process, we need to create objective function that will be used for determining the quality of the image. According to [9], an image is said to be enhanced if a) the number of edges are high; b) It is uniformly distributed; It is known that when an image is uniformly distributed, the entropy of the image is high [10]. So, to determine the objective function or the evaluation criterion, we take parameters such as entropy, number of edges and sum of edge intensity into consideration [8].

Thus, the "Objective function" which also called as fitness function is formulated as

$$Max.F(I_e) = \log(\log(E(I_s))) \times \frac{n_{edgels}}{MXN} \times H(I_e) \tag{6}$$

Where,

E(I_s) is the edge intensity of image after Sobel operator is used as edge detector [1].
n_edgels is the number edges above threshold in sobel operation.
H(I_e) is the entropy of the transformed image[1].

IMPLEMENTAION OF GREY-WOLF OPTIMIZER ALGORITHM

The Grey-Wolf Optimizer (GWO) algorithm is a nature inspired algorithm introduced by Mirjalili et al.[13]. It mimics the leadership hierarchy and hunting mechanism of the Canis lupus (i.e Grey-wolves). The effectiveness of the algorithm makes it to have a wide variety of applications in the fields of Economic dispatch [14,15], neural networks in training multi-trainer perceptron's [16], harmonic elimination in inverters [18], Software reliability growth modelling [19] etc. The Particle Swarm Optimization (PSO) algorithm is implemented as given in [17]. The mathematical model by which the Grey-wolf optimizer algorithm works is briefed below.

Grey-Wolf Optimizer - Algorithm

The best position of the swarm or search agents is called alpha wolf or the leader wolf [13]. The next two best solutions are considered as Beta (β) and delta (δ) respectively. These three α, β and δ wolves play a crucial role in determining the optimal or near-optimal solution. All the other solution are assumed as omega solution (ω), which are made to change with reference to the above three solutions.

The position of the omega solutions are updated by the following equations

$$\vec{D} = \left| \vec{C}.\vec{X}_p(t) - \vec{X}(t) \right| \tag{7}$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A}\vec{D} \tag{8}$$

Here, 't' indicates the current iteration,

$\vec{X}_p$ denotes the position of the prey/ solution

$\vec{X}$ denotes the position of grey-wolf.

The vectors $\vec{A}$ and $\vec{D}$ are given by

$$\vec{A} = 2.\vec{a}.\vec{r}_1 - \vec{a};$$
$$\vec{C} = 2.\vec{r}_2 \tag{9 \& 10}$$

Where $\vec{a}$ is linearly decreased from '2' to a very small value near zero.

The position of α, β and δ wolves are updated as follows

$$\vec{D}_\alpha = \left| \vec{C}_1.\vec{X}_\alpha - \vec{X} \right| \tag{11}$$

$$\vec{D}_\beta = \left| \vec{C}_2.\vec{X}_\beta - \vec{X} \right| \tag{12}$$

$$\vec{D}_\delta = \left| \vec{C}_3.\vec{X}_\delta - \vec{X} \right| \tag{13}$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1.(\vec{D}_\alpha) \tag{14}$$

$$\vec{X}_2 = \vec{X}_\beta - \vec{A}_2.(\vec{D}_\beta) \tag{15}$$

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$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3.(\vec{D}_\delta) \tag{16}$$

$$\vec{X}(t+1) = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \tag{17}$$

Where, $\vec{D}$ gives the distance;

$\vec{X}$ is the position;

While, $\vec{X}(t+1)$, gives the updated position using eqn.(17).

Pseudocode for implementation

Initialize the grey-wolf population
Initialize a, A and C
Calculate the fitness of each search agent / grey-wolf
For each iteration
Use best search agent as 'X$_\alpha$';
Use the second best search agent as 'X$_\beta$ ';
Use the third best search agent as 'X$_\delta$ ';
While(t<Max no. of iterations)
If search agent = ω
Use eqn.(7) and (8) for position updation
If search agent = $\alpha/\beta/\delta$
Use eqn.(11)-(16) for position updation
t=t+1;
end while;
return;

Implementation of Algorithm

The GWO, implanted for image enhancement were initialized with 20 search agents. The values of 'a', which is linearly decreasing from '2' to '0' is initialized. The maximum number of iterations is fixed as 20. After first iteration, the best solution as given by eqn.(6) is taken as "α-wolf", while next two best solutions are taken as "β" and "δ" wolves respectively. The other solutions become ώ wolves. Using (7) and (8)., positions of all the wolves are updated.
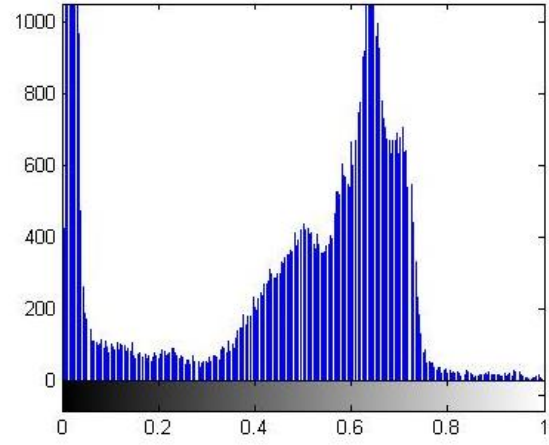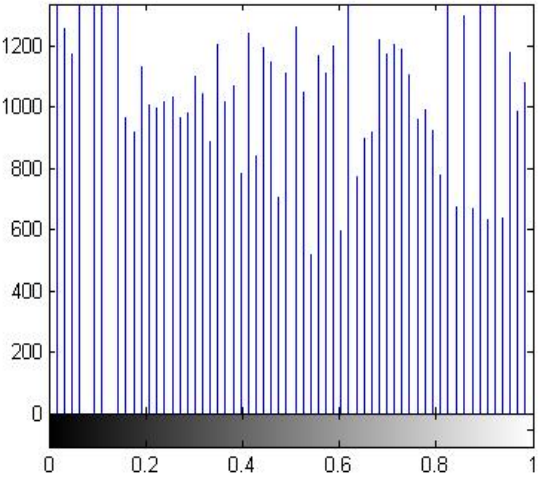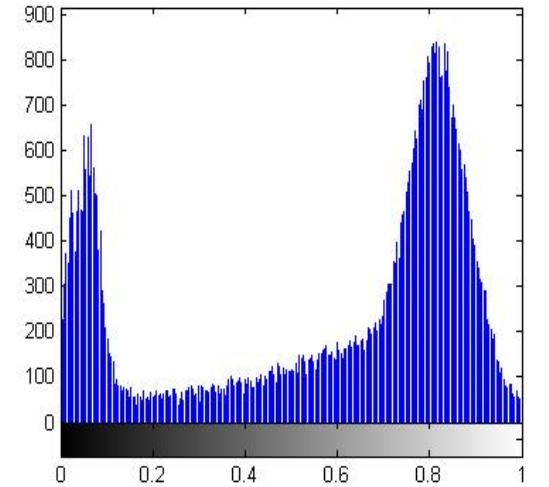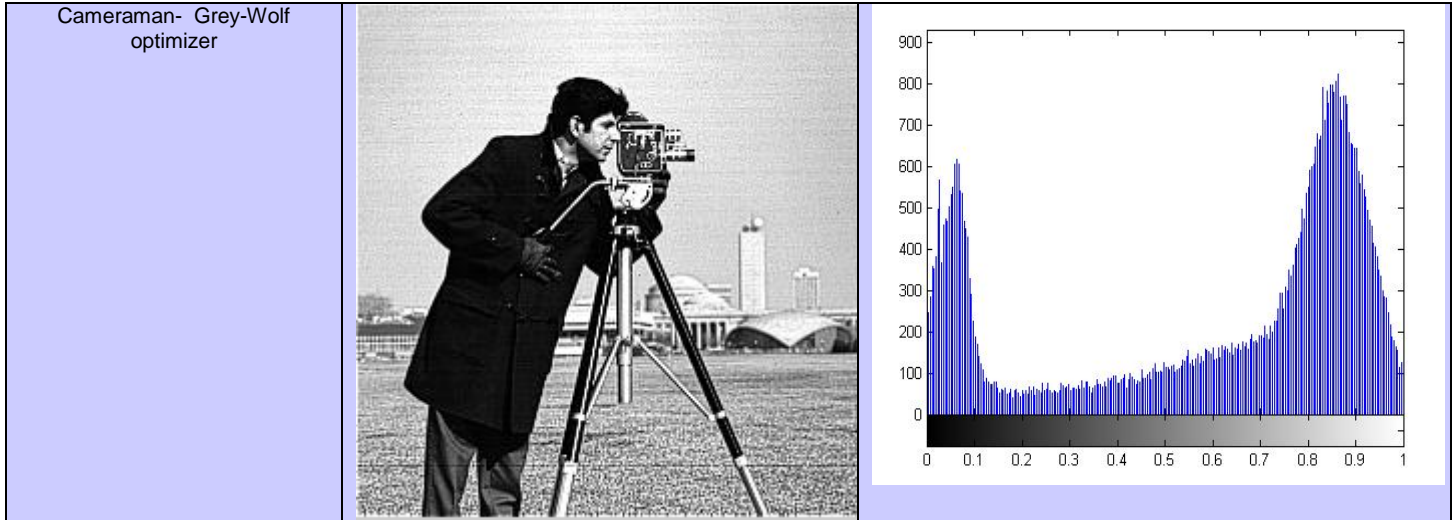
RESULTS AND DISCUSSIONS

The above proposed method is evaluated with many gray-level images. However, due to space limitations, results of four benchmark images and two medical images are shown. The four decision variables $a\epsilon(0,1.5)$; $b\epsilon(0,Total\ mean/2)$; $c\epsilon(0,1)$ and $k\epsilon(0.5,1.5)$ are initialized in their limits [10]. The four decision variables are then used by eqn. (5) to transform the image. Then the objective or fitness value is calculated according to eqn. (8).

Table: 1. **Results from various methods**

S.No	Image	Size	Fitness	HE	PSO	Proposed method (Grey-wolf)
1	Tire	205 X 232	0.2707	0.4776	0.8178	**0.8192**
2	Cameraman	256 X 256	0.2677	0.4501	0.8257	**0.8282**
3	Rice	256 X 256	0.5303	0.6169	1.2993	**1.3003**
4	Plane	512 X 512	0.2288	0.4338	0.6912	**0.6930**
5	Medical image 1 – X-Ray	224 X 253	0.2850	0.2192	0.4343	**0.4362**
6	Medical image 2 - Mammogram	558 X 563	0.2832	0.2187	0.3545	**0.3639**

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Table: 2. Visual analysis of *'Cameraman'* image and its histograms

Image /Algorithm	Image	Histogram
Cameraman- Original Image		
Cameraman- HE		
Cameraman- PSO		

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Cameraman- Grey-Wolf optimizer		

The visual results with the respective histograms are given in **Table– 2**. From the table it can be visually concluded that PSO and Grey-wolf optimizer algorithms give better results than HE. In order to evaluate the effectiveness of the algorithm, each algorithm was made to run for 50 independent trail runs and statistical data is presented. From **Table– 3** and **4**, it can be seen that, entropy and number of edges of Grey-wolf optimizer algorithm are slightly higher than PSO. The standard deviation of GWO is less than that of PSO showcasing the consistency of GWO algorithms. This clearly indicates that GWO algorithm can be treated at par or even better when compared to PSO.

Table: 3. Comparison of statistical results of Entropy of *'Cameraman'* Image

Cameraman/ Entropy	Mean	Best	Worst	Standard deviation
Original Image	NA	7.0097	NA	NA
HE	NA	5.9106	NA	NA
PSO	7.3215	7.4159	6.9125	0.2485
GWO	**7.3521**	**7.4032**	**7.0102**	**0.2252**

Table: 4. Comparison of statistical results of number of edges of *'Cameraman'* Image

Cameraman/ No. of edges	Mean	Best	Worst	Standard deviation
Original Image	NA	2503	NA	NA
HE	NA	2430	NA	NA
PSO	3442	3482	3352	142
GWO	**3452**	**3484**	**3395**	**95**

Table: 5. Comparison **of results of fitness and PSNR of *'Plane'* Image with that of GA**[7][8]

Plane	GA[7]	GA[8]	PSO	GWO
Fitness value	NA	0.5702	0.6912	**0.6930**
PSNR	17.92	17.89	20.68	**21.35**

Table 5 presents the comparison of fitness and PSNR of *'Plane'* image with that of other state-of-art algorithms such GA[7]and [8] with that of PSO and GWO. From the table, the superiority of GWO can be clearly seen. In addition, the visual results of all other images are presented in **Table –6**.

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Table: 6. Visual Results of Images enhanced

Image Name	Original Image	HE	PSO	GWO
Tire				
Rice				
Plane				
Medical image 1 – X -ray				
Medical image 2 - Mammogram				

The statistical analysis of all the images 1-6 also reiterates that GWO and PSO are superior to classical HE technique. The images when visually inspected also prove the same. It can also be seen from the above tabulations that GWO is comparable and superior to PSO both in terms of solution quality and computational time. It should also be noted that GWO has relatively less steps when compared to PSO, reducing the computational time.

The exploration of search space of GWO is because of the fact that all solutions are based on alpha, beta and delta positions. This is mathematically modelled in eqn.(9)., where, the A is random with values, greater than +1 or less than -1, causing exploration in the search space. In addition, eqn.(10), randomly generates the value of C, in the range of [2,0], which makes the algorithm more stochastic, thereby increasing its exploitation ability. It also decreases the chance of local convergence. The use of *'a'* in the range of [2,0], by linearly decreasing them paves way for exploitation, i.e. local search. This eventually increases the chance of convergence, when A is in the range of [-1,1].

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CONCLUSION AND FUTURE WORK

In this paper, we have used Grey-wolf optimizer for deducing a technique for automated image enhancement, an optimization problem. The output images and the corresponding metrics of the images produced by classical HE and PSO algorithm are used for comparison. The visual and mathematical results prove the superiority of GWO and PSO over HE. The statistical analysis of 50 independent trail runs of PSO and GWO algorithms shows that GWO is at par comparable or superior to that of PSO, for image enhancement problem. In future, hybridization of the grey-wolf algorithm is to be done to improve its performance. The algorithm will also be extended foe enhancement of colour images.

CONFLICT OF INTERESTS

There are no conflicts of interests.

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