

Gray level image enhancement using Particle Swarm Optimization with Lévy Flight: An Eagle Strategy Approach

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ABSTRACT: An application to enhance low contrast images using Eagle Strategy (ES) has been attempted in this paper. This is not an algorithm; it is a strategy because it is a well combination of global search and efficient local search algorithms. In this strategy the optimized solution is achieved by an intensive local search around the global solution achieved in global search part. Here Particle swarm optimization (PSO) taken as a global search algorithm and levy flight used as an efficient local search method. It is proved in this paper that by using levy flight as local optimizer efficiency of PSO is increased. In this paper image enhancement is considered as an optimization problem and ES is used to solve it. Image enhancement is mainly done by maximizing the information content of the enhanced image with intensity transformation function. In this paper a parameterized transformation function is used. Here an objective criterion for measuring image enhancement is used which considers entropy and edge information of the image. Objective of the proposed ES is to maximize an objective fitness criterion in order to enhance the contrast and detail in an image by adapting the parameters of a novel extension to a local enhancement technique. At last entropy, numbers of edge pixels (edgels), sum of the intensity of all edge pixels are compute to prove the effectiveness of the proposed Algorithm. A comparison with images generated via Genetic Algorithm (GA), particle swarm optimization (PSO), Cuckoo search (CS) is made. The obtained results indicate that the proposed ES yields better results than PSO, GA and CS in terms of both the maximization of the number of pixels in the edges and the entropy.

KEYWORDS: Image enhancement, Eagle strategy, Particle swarm optimization, Cuckoo search, Genetic Algorithm.

I. INTRODUCTION

The goal of Image enhancement is to process an image using some transformation function such that the resultant image is more suitable than the original one for some specific applications [1]. Enhancement is taken as a pre-processing step in image processing field because many images, such as remote sensing images, medical images and also our real-life images suffer from poor contrast or the image is darker. Actually enhancements of images are classified into main four classes; (I) contrast enhancement, (II) noise reductions, (III) edge enhancement, (IV) edge restorations. In this paper, contrast enhancement of gray level dark images taken into consideration. Not only gray level, color images can be also enhanced. Color images can be enhanced by separating the image into the chromaticity and intensity components [2, 3]. Histogram transformation is considered as one of the fundamental processes for contrast enhancement of gray level images [4]. Histogram equalization (HE) is a mechanism that has no control over the rate of enhancement. The enhanced image always follows the uniform distribution. But the controlled enhancement is done by putting constraints on the probability density function with the bin underflow (BU) and bin overflow (BO) [5]. An automatic power law transformation used for image enhancement where do not require to choose the gamma constant [6]. Although based on histogram information different techniques are proposed in literature but enhancement of dark

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and low contrast images in a controlled fashion is still a big problem. For this reason there is steady rise of soft computing oriented approaches. Recently nature inspired population based metaheuristics have been devised to solve optimization problems [7]. So, they can also apply in image processing field where some problems like image enhancement, segmentation etc has been considered as an optimization problems [8, 9, 10, 11]. Evolutionary Algorithms like Differential Evolution (DE) and Genetic Algorithm (GA) are stochastic and robust metaheuristics in the field of evolutionary computation and also used in image processing field to solve optimization problems [10,11, 12]. Mutation factor and crossover rate have been modified by chaotic sequence of traditional DE algorithm and experimental result shows that modified DE is far better than traditional DE in image enhancement field with fast convergence rate and maintain also a good diversity property [12]. Swarm optimization algorithms like PSO based on social behavior of organisms such as bird flocking and fish schooling are have been widely applied in image enhancement field where parameterized transformation functions have been used [2, 3, 13, 14]. PSO outperforms the GA in image enhancement field [2, 3]. PSO not only used for gray scale image enhancement also used as a color image enhancement [3]. Newly developed another metaheuristic named ant colony optimization (ACO) is also applied in image enhancement technique and it gives better results than PSO and GA [15]. In this paper image enhancement has been taken as a non-linear optimization problem. In this context, this paper introduces an image enhancement technique which is a well combination of traditional PSO and levy flight. PSO is a good global optimizer and levy flight has been taken to create a local search around the global solutions. So, this is a well combination of global search and local search, called Eagle strategy [16]. It is not an algorithm; it is a hybrid technique to enhance the capability of one algorithm. Here, levy flight has been used to enhance the capability of PSO algorithm. The original PSO algorithm was inspired by the social behaviour of biological organisms [13]. PSO is a population based or multi-agent swarm based stochastic algorithm like genetic algorithm and has a good capability to solve non-linear optimization algorithm [2, 17]. Levy flight is a random walk and helps in diversification to find global best solution [7, 17].

In this paper, specially dark and low contrast images are enhanced using an algorithm that based on the principal of high- boost filter and contrast stretching technique described in section II. In this paper efficiency of PSO algorithm is enhanced by using levy flight as a local search around the global solutions that is achieved by PSO. Actually Eagle strategy is not an algorithm it is a strategy that is a good combination of global search algorithm with an efficient local search algorithm or technique [16] and cuckoo search is optimization algorithm that is based on the brood parasitic behaviour of certain species of the cuckoo bird [18] described in section III. Both are compared with PSO and GA and simulation result in section IV proved that ES is better than CS, PSO and GA.

II. IMAGE ENHANCEMENT ALGORITHM AND OBJECTIVE FUNCTION

Image enhancement technology improve the contrast and sharpen the features, which actually facilitate further image processing application such as segmentation or enforcing the capability of human or machine recognition system to interpret the useful information in the image [1].

A. PROPOSED ALGORITHM

Actually this paper enhances the dark and low contrast images, so the algorithm much depends on the method of high-boost algorithm because the principal of high-boost filter is used when the input image is darker than desired. By varying the boost coefficient, it generally is possible to obtain an overall increase in average gray level of thee image, thus helping to brighten the final result [1]. The proposed algorithm is as follows:

Let Maximum generation (MG) is 5.

Step 1: Compute

$$\phi_1 = \alpha_1 + \left[\alpha_2 \times \frac{(MG - t)}{MG^2} \right]$$

Step 2: For all pixel find the average or mean ($m(i,j)$) of its neighbourhood pixels using $[3 \times 3]$ window.

Step 3: Modify all the pixels by

$$x_1(i,j) = \phi_1 \times f(i,j) + (f(i,j) - m(i,j)) \times \phi_2$$

Step 4: IF ($f(i,j) \leq \phi_3$) then make $f(i,j) = 0$

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Step 5: while($t \leq MG$), do step 1 to step 4

From the algorithm it is clear that pixel modifier function used in step 3 is nothing more than a high-boost filter. Functionality of step 4 in this algorithm is to help to maintain a good contrast. In this algorithm there are mainly four parameters, namely $\alpha_1, \alpha_2, \phi_2, \phi_3$.

B. ENHANCEMENT CRITERION:

The necessity of Objective function of optimization algorithms that used for image enhancement is to select a criterion that is associated to a fitness function which will say all about the image feature. In this paper three performance measurement parameters taken into account. These are Entropy, sum of the edge intensity and the number of edge pixels or edgels. It can be sure that good contrast enhanced image has more edgels and higher intensity of the edges [2]. If the allotment of the intensities is homogeneous, then histogram is equalized and the entropy of the image will be more. The objective function proposed in this paper is:

$$F(z) = \log_e^{(E(I_e))} \times (n_{edgels(I_e)} / (M \times N)) \times H(z) \quad (1)$$

$F(z)$ is the fitness value of enhanced image, $E(I_e)$ is the sum of pixel intensities of Sobel edge image I_e .

$n_{edgels(I_e)}$ is the number of edge-pixels whose intensity value is above a threshold in the Sobel edge image. Based on the histogram, entropy value $H(z)$ is calculated on the enhanced image z . M, N is the number of row and column of the image respectively.

III. SOFT-COMPUTING APPROACH

A. LÉVY FLIGHT:

Lévy Flight has been used to generate random walk which plays a great role in metaheuristic algorithms. A random walk is a mathematical method of representing a series of consecutive random steps. It has wide applications in the fields of computer science, physics, statistics, economics and engineering [7, 17]. It can be expressed by the formula

$$S_N = \sum_{i=1}^N X_i \quad (2)$$

Where, X_i is a random step size drawn from a random distribution and S_N is the sum of each of these consecutive random steps. Lévy Flight is a random walk whose step length is determined from the lévy distribution. It is capable of exploring large amount of search space. Lévy Flight is also found in nature as certain species of birds and insects exhibit this type of motion while gathering food [17]. Even physical phenomena such as diffusion of gas molecules have been seen to follow Lévy Flight behavior under the right conditions. Lévy Flight can be produced using different algorithms which include Rejection algorithm, McCulloch's algorithm, Mantegna's algorithm etc [19]. In this study Mantegna's algorithm has been used. It produces random numbers according to a symmetric Lévy stable distribution as described below—

$$\sigma = [\Gamma(1 + \alpha) \sin(\pi\alpha/2) / \Gamma((1 + \alpha)/2) 2^{\alpha/2} \alpha^{(1-\alpha)/2}]^{1/\alpha} \quad (3)$$

Where, Γ is the gamma function [17], $0 < \alpha \leq 2$ [17], in this study it is taken as 1.5 which is same as [18]. σ is the standard deviation.

As per Mantegna's algorithm the step length v can be calculated as,

$$v = \frac{x}{|y|^{1/\alpha}} \quad (4)$$

Here, x and y are taken from normal distribution and $\sigma_x = \sigma, \sigma_y = 1$ [17]. Where σ is the standard deviation. The resulting distribution has the same behavior of Lévy distribution for large values of the random variables [17]. Lévy Flight is used for the diversification as well as intensification in stochastic optimization algorithm [7, 17]. For the case of diversification the step length has been taken larger than in the case of intensification. The repetition of the same position in its space by Lévy Flight is less than the Brownian motion [7, 17].

B. EAGLE STRATEGY:

Eagle strategy is a two stage hybrid optimization strategy developed by Xin-She Yang and Suash Deb in 2010 [16]. Actually in eagle strategy, at first global search is done via any global optimizer, then around the global best solution a

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intensive local optimizer is used to find a promising solution that is far better than global best solution. In this paper PSO is used as a global optimizer and levy flight is used as an intensive local optimizer. The advantages of such combination are to use a balanced tradeoff between global search which is often slow and a fast local search. In this strategy global optimizer like PSO explore the search space diversely and then local optimizer (here levy flight) do an intensive local exploitation around the global best and find a local optimal solution quickly [16].

The proposed eagle strategy is as follows:

1. Objective function has been taken as described in section 2.
2. Initially take a number of initial population.
3. At first find the global best solution ($gbest$) using particle swarm optimization (PSO) [1].
4. According to fitness fit_i of each enhanced image X_i probability value p_i is
$$p_i = fit_i / \sum fit_i$$
5. Select a number of best solutions (b_i) which are derived using PSO algorithm depend upon the probability value p_i .
6. Assign a random number (r_i) to every best solution.
7. Then generate a random number $rand_i$ for every b_i .
8. If ($rand_i < b_i$), then create a local search by levy flight around the best solution.
Let it S_i , So $S_i = x_i + \alpha * Lévy(\lambda)$
9. If ($fitness(S_i) > fitness(gbest)$),
then, $gbest = S_i$
10. Take $gbest$ is the optimized solution.
11. Repeat step 3 to 9 until the maximum generation.

From the above procedure it is clear that PSO is used as a global search algorithm which is a very good global optimizer and it is already proved in literature, and then levy flight is used for local optimizer. Actually levy flight used for global exploration because it has heavy tailed distribution means it takes value in any range. We can transform it to a efficient local optimizer by using it only around the Global best solutions. it can find the local solution around the global solution that is achieved by global search algorithm like Particle Swarm Optimization (PSO). In the above algorithm number of iteration is taken less than pure PSO algorithm.

C. THEORY OF CUCKOO SEARCH ALGORITHM:

The aforementioned parasitic behaviour among cuckoo birds refers to the aggressive and highly successful reproduction strategy of certain species of cuckoo birds based on an evolutionary predisposition to lay their eggs in the nests of other birds [18]. This behavior aided in the propagation of their species. This natural observation is applied in the computational field by treating the host bird eggs as the initial solutions and the cuckoo eggs as the alternative solutions with the aim of reaching a near-optimal solution by successful iterations involving the replacement of weaker solutions with better ones.

Three idealize rules are:

- 1) Each cuckoo lays one egg at a time, and dump its egg in randomly chosen nest;

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- 2) The best nests with high quality of eggs will carry over to the next generations;
- 3) The number of available host nests is fixed and the egg laid by a cuckoo is discovered by the host bird with a probability $p \in [0, 1]$. In this case, the host bird can either throw the egg away or abandon the nest, and build a completely new nest. [18]

D. CS VIA LÉVY FLIGHT ALGORITHM:

1. An objective function has been taken described as in section II.
2. Initialize population $X = \{x_i | i=1,2,3,\dots,n\}$, where n is the number of solutions or population size, and x_i is the i^{th} cuckoo.
3. Get a random cuckoo solution by modifying the four enhancement parameters using lévyflight.
The parameters are modified as:
$$X_i^{t+1} = X_i^t + \alpha \times \text{Lévy}(\lambda)$$
Where, X_i^{t+1} is the value of the parameter at (t+1) iteration, α is constant, $\text{Lévy}(\lambda)$ = value determined by levy flight
3. Evaluate its quality or fitness value (F_i)
4. Choose a nest with another solution among n randomly and say this solution is j .
5. Compare the two fitness values.
6. If the fitness value of the cuckoo egg is greater than that of the random nest, then replace the host egg (solution) with the cuckoo egg, otherwise do nothing.
7. According to fitness fit_i of each enhanced image X_i probability value p_i is
$$p_i = fit_i / \sum fit_i$$
8. Post each iteration, a fraction of the worst nests which has the probability value less than some threshold do not contribute better solutions are abandoned and the ones yielding the best solutions are carried over to the next generation.
9. Rank the solutions and find the current best.

10. Processes 1-9 is repeated until the amount of iterations needed reaches the optimal maximum generation criteria.

D. PARAMETER SELECTION

The EA and CS are applied over have been applied over 100 images with initial population number being varied from 10 to 50 and maximum generations up to 150. In this study, numbers of initial populations have been put to 30, maximum generation for EA is 55, CS is 75, PSO is 90 and GA is 120. The result of EA, CS, PSO, GA are very much parameter dependent. From the experiment value of the parameters are $\alpha_1 \in [1, 2.5]$, $\alpha_2 \in [0.2, 2]$, $\phi_2 \in [0.05, 1]$ and $\phi_3 \in [5, 20]$.

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IV. EXPERIMENTAL RESULT

The EA and CS are applied over have been applied over 100 images but three of them given below:

	Original Image	Result of EA	Result of CS	Result of PSO	Result of GA
Img1					
Img2					
Img3					
Img4					

Table 1: The number of edgels as detected with Sobel automatic edge detector

	Original Image	ES based	CS based	GA based	PSO based
Img1	2501	2905	2896	2472	2802
Img2	2463	2810	2828	1801	2497
Img3	1782	2202	1922	1625	1922
Img4	1324	1918	1911	1491	1653

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Table 2: Sum of the edge intensity pixels

	Original Image	ES based	CS based	GA based	PSO based
Img1	993.051	1489.9	1530.9	1457.50	1541.70
Img2	570.267	1451.6	1409.5	964.95	1456.5
Img3	632.526	1349.5	1047.5	1040.9	1047.5
Img4	505.829	1310.5	840.039	934.39	900.17

Table 2: Fitness value of the images

	Original Image	ES based	CS based	GA based	PSO based
Img1	1.8879	2.4535	2.4146	1.9936	2.3384
Img2	1.7434	2.5001	2.4246	1.4499	2.1415
Img3	1.2356	1.8256	1.5718	1.2799	1.5718
Img4	0.8829	1.9776	1.5289	1.2189	1.3401

V. CONCLUSION

This paper introduces a procedure for enhancing low contrast images using Eagle Strategy. From the result part it is clear that Eagle strategy that is build by PSO and levy flight gives a better result than pure PSO. So it increases the efficiency of PSO algorithm, so a good trade-off between global search and local search is obtained by this Eagle strategy. In literature PSO gives worse result than Cuckoo search, but here Eagle strategy that is a good combination of PSO and levy flight gives promising result than pure PSO, Cuckoo search and Genetic Algorithm that has been proved in this paper in terms of some criterion. ES also takes less number of maximum iteration than pure PSO to give this type of result, so Eagle strategy is a good strategy to optimize the image enhancement parameters.

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