Comparison and Analysis of Cuckoo Search and Firefly Algorithm for Image Enhancement

Sapna Katiyar(✉), Rachit Patel, and Khushboo Arora

ABES-Institute of Technology, Ghaziabad, UP, India
sapna_katiyar@yahoo.com, rachit05081gece@gmail.com,
arora.khushi19@gmail.com

Abstract. Image enhancement is the process of highlighting some characteristics and carrying out certain features in original image for any problem oriented applications. Two domains in which image enhancement can be done is either in spatial domain and frequency domain with good SNR and keeping original colors of image intact. Metaheuristic approach provides a very effective search and optimization approach which gives good results in comparison to traditional approaches. In this paper author improve number of pixels, so that more details of image can be visualized easily and accurately. Two Metaheuristic algorithms, cuckoo search and firefly algorithms are applied here to find out optimal solution which gives peak performance. Experimental results of both the algorithms are tabulated and compared, which shows that firefly algorithm gives better performance as compared to cuckoo search algorithm in terms of robustness, fitness function and convergence rate. Some hybridization of metaheuristic algorithms can also be applied to improve performance.

Keywords: Image enhancement · Image processing · Metaheuristic · Fitness function · Peak signal to noise ratio (PSNR) · Firefly algorithm (FA) · Cuckoo search (CS)

1 Introduction

Main purpose of image enhancement to increase subjective quality parameters of image. This process is very simple and used to recover the image which is more appropriate than original one and gives better information about image for any explicit application. Its applications are in various areas like medical imaging, remote sensing, satellite image processing, airborne imaging, fingerprint matching, IRIS matching, digital camera applications etc. [1].

For every different type of image, optimizing the parameters and approach is a very meticulous job therefore image enhancement becomes a complex optimization problem. This paper describes the various metaheuristic algorithms. Every optimization algorithms have its own characteristics and limitations. Its objective is to take up the advantages of respective search algorithm while avoiding and ignoring limitations.

A. Unal et al. (Eds.): SmartCom 2016, CCIS 628, pp. 62–68, 2016.
DOI: 10.1007/978-981-10-3433-6_8

In literature, various metaheuristic algorithms have been proposed like Genetic Algorithms, Differential Evolution, Ant Colony Optimization Algorithm, Cuckoo Search, Honey Bee Algorithm, Particle Swarm Optimization etc. these algorithms are capable to obtain low error rate with high computation time [2]. Here a comparison between traditional technique and metaheuristic technique for image enhancement is done.

2 Techniques Used for Image Enhancement

The process of image enhancement is heuristic in nature and basically there are two major categories of image enhancement:

- Frequency domain: It actually works with Fourier transform of an image.
- Spatial domain: It is a procedure, which works directly on pixels of an image.

For an image, frequency domain based techniques can be directly applied on an image via Fourier Transform, Discrete Wavelet Transform (DWT), and Discrete Cosine Transform (DCT). Its advantage is less computation complexity, easy to manipulate the frequency component of an image etc. [3, 4]. The main drawback is that, it can not enhance all parts of image all together. Here new image is obtained by the convolution of an image through linear position invariant operator, and is given by:

$$n(x, y) = h(x, y) * m(x, y) \tag{1}$$

Where,
$m(x, y)$: Input image
$n(x, y)$: New image
$h(x, y)$: Linear position invariant operator

The main advantage of spatial domain based technique is- it is very simple in nature and can be easily applied to a number of real time applications. Its limitation is that generally it enhances the whole image in uniform manner which is actually not desirable in many cases. The process of spatial domain is written as [4, 5]:

$$n(u, v) = T[m(u, v)] \tag{2}$$

Here,
$m(u, v)$: Input Image
$n(u, v)$: Processed Image
T: An operator on m, which is defined for some neighborhood of (u, v)

There are various type of image enhancement techniques used in spatial domain, few of them are: histogram equalization, grey scale manipulation, contrast stretching, image negative, compression of dynamic range, improving quality parameters using logical and arithmetic operations [6].

Image Quality Metrics. Always it is required to quantify the features of any image; therefore metrics are used to compute the image quality. It is divided into two categories:

- Objective fidelity criteria: they provide equations which are used to quantify errors and characterize quality of image.
- Subjective fidelity criteria: they are not based on any metrics.

MSE- Difference between estimator and estimated value.

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left[I(i,j) - (k(i,j)) \right]^2 \tag{3}$$

PSNR- Ratio of possible power (max.) of a signal to power of corrupting noise.

SNR- Ratio of power of a significant signal to power of surroundings noise or unwanted signal.

$$SNR = \frac{P_{signal}}{P_{noise}} \tag{4}$$

Where,

P: average power.

It is necessary that both signal and noise power must be calculated at the same points in any system. It is also required that it should be within the same system bandwidth.

3 Cuckoo Search

Yang and De, in the year 2009 have given thought of CS. Similar to other metaheuristic techniques, this one also kind of population based optimization approach. Cuckoo species have a tendency of putting their eggs in nest to other swarm birds. Cuckoos have a special characteristic, known as Egg Laying Space, is used by research scholars in many daily life applications. These birds either destroy the eggs or they leave their nest within specified space [7, 8].

The procedure of CS is a three step:

- For a particular time a cuckoo lays 1 egg and haphazardly dump its egg into any other chosen nest.
- For consequently generation, finest nest having best quality of eggs will take over.
- When total number of present host nest is fixed then egg laid by a cuckoo is exposed by host birth with likelihood.

Start
Objective Function, M(U),U= (U_1, U_2,……..U_d)^T
Create Initial Population of k host nest U_i(i = 1, 2, 3,……,k)
While (t<maximum generation) or (stop criterion)
Randomly select a cuckoo
Calculate its fitness value
Randomly select a value of nest among k (let us say, j)
If (F_i>F_j)
Then replace the selected value of j by new solution
End
Poorer nest will be discarded and new one will built
Update the best solution
Rank the resultant solutions and obtaining current best value
End while
Post processing of results and then visualization
Stop

Pseudo code of applied CS

4 Firefly Algorithm (FA)

Xin-She Yang in year 2010 given idea about FA for encouraging metaheuristic algorithm. FA is actually based on the characteristics of firefly. Firefly is a category of insect which is produced by the process of bioluminescence. They are capable for producing short and rhythmic flashes. Firefly moves because of the light intensity, and this behavior is used to solve worldwide optimization problem. FA gives better performance as compared to other metaheuristic algorithms due to of its automatic subdivision and the capability of dealing with multimodality. Generally Firefly algorithm follows three rules [9]:

- Since these are unisex, so they will be attracted towards others irrespective of their sex.
- Basically a flashing firefly is fascinated toward other firefly if other is brighter but if both fireflies have same brightness then other will move haphazardly. Attractiveness varies according to light intensity.
- Using background of function, brightness can be determined.

Variation of light intensity with distance is defined by following formula:

$$I(r) = I_0 e^{-\gamma r^2} \tag{5}$$

Where,
I- Intensity of intensity
I_0- Original intensity of light
γ- Absorption coefficient of light
r- Distance of one firefly from other firefly
β represents attractiveness. And given by

$$\beta = \beta_0 e^{-\gamma r^2} \tag{6}$$

Where,

β_0- Attractiveness known at distance r = 0

Distance between any two fireflies is calculated by helping Cartesian distance:

$$r_{ij} = \left| x_i - x_j \right| = \sqrt{\sum_{k=1}^{d} (x_{i,k} - x_{j,k})^2} \tag{7}$$

If brightness of *j* is greater than *i*, then *i* will be attracted toward firefly *j*. This type of movement is defined be the following expression:

$$\Delta x_i = \beta^{0e^{-\gamma r^2 ij}\left(x_j^t - x_i^t\right)^2} + \alpha\varepsilon_i, \quad x_i^{t+1} + \Delta x_i \tag{8}$$

In above equation, the first term explains attraction, γ is the limiting factor (either value approaching to zero or it is too large). If γ is very small and approaches to zero ($\gamma \to 0$), then the attractiveness and brightness will be constant, $\beta = \beta_0$ but if γ s too large the attractiveness decreases and firefly moves randomly.

```
Start
  Objective Function: M(U), U= (U1, U2,……..Ud) ;
Create an initial population of fireflies Ui(i = 1, 2, 3… k)
Originate I and γ
While (t < maximum generation)
for i =  1:k
for j = 1:k
If (Ij ˃ I i)

then I move towards j;
    Calculate the new value and update I;
End
Grade fireflies and determine best value;
End while
Post-processing of results and then visualization;
Stop
  Post-processing of results and then visualization;
Stop
```

Pseudo code of applied FA

5 Results and Discussion

The results of image enhancement using cuckoo search algorithm and firefly algorithms have been presented for two images of bird and leaf. Here the objective is to increase the overall intensity of edge of image, therefore maximizing the number of pixels in edge. The mentioned algorithms are compared in terms of computation time to run

algorithm, fitness value, computational time for image enhancement, SNR and PSNR. Figure 1 shows the original image as well as images obtained after applying cuckoo search and firefly algorithm.

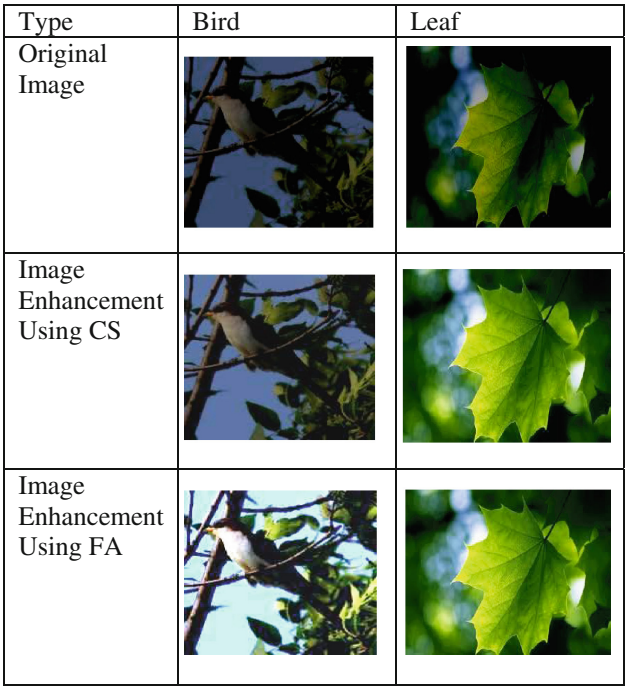

Fig. 1. Original image and enhanced images using CS and FA

After comparing all results author observed here, performance of Firefly Algorithm (FA) is much better in comparison Cuckoo Search (CS) because in case results obtained using Firefly algorithm, brightness and contrast level is appearing more visible with good PSNR. Image having higher number of pixels is viewed as more detailed content. Table 1 shows the various parameters obtained from both metaheuristic techniques and Table 2 shows the data obtained from both algorithms.

Table 1. Comparison of various parameters

Image	Fitness value		No. of edges detected		
	CS	FA	Original	CS	FA
Bird	102.320	121.911	2961	3099	3301
Leaf	119.712	126.048	1978	2203	2290

Table 2. Comparison of PSNR Value

Image	CS	FA
Bird	15.764	18.138
Leaf	16.387	18.751

Both the algorithms have been executed for 100 runs of times and below mentioned the values obtained for the simulation time for CS and FA:

CS: 169.78 s

FA: 150.49 s

Therefore after comparing all the data, it can be stated that FA gives better performance because it takes less simulation time as compared to CS.

6 Conclusion and Future Work

Author worked on performance of metaheuristic techniques like cuckoo search and firefly algorithms has been tabulated and compared for image enhancement. Two types of images have been taken for comparison and analysis. Result shows that firefly algorithms give much better results in comparison to cuckoo search; various parameters are evaluated and mentioned in table.

This approach can be extended to hybrid algorithms, which may consist of more than two search methodologies. Fine tuning of various parameters can also be done in terms of reducing maximum number of iterations. In future, optimization can also be accomplished with help of hyper heuristic.

REFERENCES

1. Hong, J.H., Cho, S.B., Cho, U.K.: A novel evolutionary approach to image enhancement filter design: method and applications. IEEE Trans. Syst. Man Cybern. **39**(6), 1446–1457 (2009)
2. Blum, C., Aguilera, M.J.B., Roli, A., Sampels, M. (eds.): Hybrid Metaheuristics: An Emerging Approach to Optimization. Studies in Computational Intelligence, vol. 114. Springer, Heidelberg (2008)
3. Yang, Q.: An adaptive image contrast enhancement based on differential evolution. In: 3rd International Congress on Image and Signal Processing, CISP (2010)
4. Agaian, S.S., Blair, S., Panetta, K.A.: Transform coefficient histogram-based image enhancement algorithms using contrast entropy. IEEE Trans. Image Process. **16**(3), 741–758 (2007)
5. Yang, F., Wu, J.: An improved image contrast enhancement in multiple peak image based on histogram equalization. In: IEEE ICCDA, vol. 1, pp. 346–349 (2010)
6. Rajavel, P.: Image dependent brightness preserving histogram equalization. IEEE Trans. Consum. Electron. **56**, 756–763 (2010)
7. Yang, X.S., Deb, S.: Cuckoo search via levy flights. In: IEEE (2009). ISBN 978-1-4244-5612-3
8. Rajabioun, R.: Cuckoo optimization algorithm. Appl. Soft Comput. **11**, 5508–5518 (2011)
9. Fister Jr., I., Yang, X.S., Fister, I., Brest, J.: Memetic firefly algorithm for combinatorial optimisation. In: Bio Inspired Optimisation Methods and Their Applications (BIOMA 2012), 24–25 May 2012, Bohinj, Slovenia, pp. 75–86 (2012)