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Research Article

A Comparison Study: Image Restoration Based on Two Heuristic Algorithms

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Abstract: In computer science, optimization can be defined as maximizing or minimizing the result. Heuristic algorithms have been developed inspired by nature and to solve different optimization problems. In this study, Artificial Bee Colony (ABC) Algorithm and Firefly Algorithm (FA) have been explained in detail and a comparison between these two algorithms has been implemented. The comparison between these two algorithms is made for image restoration by using a dataset. Image restoration is the process of reducing or eliminating data loss or deterioration that may occur during the creation of an image. The loss of efficiency in the image (reducing the visual appearance of the image) is caused by noise. It is the process of obtaining the original image from the distorted image, given the knowledge of distorting factors. There are many methods applied in the literature for image restoration. In this study, two of the evolutionary algorithms have been used for this purpose and analyzed. The data set used in the study was taken from the Kaggle website. The comparison metrics are PSNR (Peak Signal-to-Noise Ratio) and MSE (Mean Squared Error). This study shows that ABC Algorithm has better results than FA on the selected 20 images dataset used for blurred image restoration. According to the results obtained, it was seen that the ABC algorithm performed % 85 better than FA.

1. Introduction

Optimization can be defined as using the smallest amount of data optimally. The aim of optimization is maximization in some studies and minimization in some studies. For any problem, it is to obtain the best solution among all solutions under the given conditions. This concept has emerged, inspired by the behaviors of living things to survive in their daily lives. For example, the reaction of one of the individuals in the herd to the danger may turn into a joint action by affecting the other individuals. Inspired by creatures living in swarms, scientists developed swarm-based optimization algorithms. With these developed algorithms, real-world problems and computer problems can be solved. It has been seen that creative solutions can be obtained by adapting the survival behaviors of living things to problems [1, 2].

ABC algorithm and FA were used in this study. For image restoration, a comparison was made using a dataset of text photos (book titles and readings) with and without the motion blur effect from the Kaggle website. This dataset was used to analyze the performance difference between the ABC algorithm and FA in blurry image restoration. 20 randomly selected images from the data set were used.

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Some studies in the literature are shown in the literature review section in the form of a table. The data set and evaluation criteria used in the study are mentioned in the material and method section. In the section on algorithms, there is information about the ABC algorithm and FA. In the conclusion part, the findings obtained from the study are presented comparatively.

Literature Review

In this section, several studies with image restoration using the ABC algorithm and FA are introduced. These studies are from 2011 to 2023. The number, authors, purpose, used algorithms, and evaluation metrics of these studies are given in Table 1.

Table 1. The studies on image restoration using the ABC algorithm and FA

Number	Authors	Purpose	Used Algorithms	Evaluation Metrics
[3]	Kumar et al. (2022)	Using the histogram of low contrast images and depth images aimed to increase contrast and remove unwanted noise	FA	PSNR, RMSE, UQI, MAE and MSE
[4]	Banharnsakun (2022)	It is aimed to find the most suitable filter coefficient to remove image noise	ABC	-
[5]	Gao et al. (2023)	In this study, the aim is to develop a hybrid algorithm to optimize BPNN for image restoration	FA and Genetic Algorithm	PSNR and MSE
[6]	Sun et al. (2022)	Aimed to solve problems of poor image quality, loss of detail information, and excessive brightness gain during image enhancement in low-light environments	ABC	Standard Deviation, Average Gradient, Information Entropy
[7]	Yang et al. (2016)	By using ABC algorithm, suggests a new technique for image restoration	ABC	PSNR
[8]	Li & Chan (2011)	A complex-fuzzy approach is used and complex fuzzy sets is proposed to deal with the problem of adaptive image noise cancelling	ABC	PSNR
[9]	Kockanat et al. (2012)	To design 2D FIR digital filters for the noise elimination on the noisy images, the ABC algorithm has been applied	ABC	Mean Value, Standard Deviation and PSNR
[10]	Sánchez-Ferreira et al. (2019)	To forecast the model parameters by using bio-inspired optimization, a restoration algorithm is proposed	ABC and Differential Evolution (DE)	NR-IQA
[11]	Kumar et al. (2020)	Proposes an object restoration approach in which images are affected by the salt & pepper noise modified by a median filter based on fuzzy logic	Modified Firefly Optimization Algorithm (MFOA) and Richardson-Lucy Algorithm	SDME and PSNR
[12]	Savithri & Kousalya (2016)	Aim of the paper is to carry out Bandelet transform with FA on SAR images	FA and Bandlet Transform with Firefly Algorithm (BFA)	MSE, ENL, SSI, SMPI, ESI and PSNR
[13]	Csam et al. (2017)	Offers the distinctive hybrid methods which evacuate the mixed type of noise from the images	FA	Root Mean Squared Error (RMSE) and PSNR
[14]	Sam et al. (2019)	Uses a blend of filters to determine the noise from the images	FA	RMSE, PSNR and SSIM

Looking at the studies in the literature, it is seen that the ABC algorithm and FA are used. However, no performance comparison has been made by using these two algorithms together in any study. So, it is not known which algorithm is more performant for image restoration. For this reason, in this study, it was investigated which one was more effective for image restoration using the ABC algorithm and FA.

3. Material and Method

Swarm intelligence is decentralized control, the collective behavior of natural or artificial self-organizing systems. Especially, it is focused on the collective behavior and environments of animals or beings. Animals do not have any control mechanism by themselves but, interestingly, they can find foods easily, feel environmental attacks, and they can respond to foes. They have simple communication and this time they spend less cost they create a flexible and robust swarm structure and they act intelligently to solve their problems when they encounter any problems. Some scientists and engineers are interested in interesting techniques of animals because in many areas these kinds of swarm intelligence algorithms are used to resolve difficult problems [15].

All of the experimental work was implemented in MATLAB® R2015a and performed on an Intel(R) Core™ i7-10870H CPU @ 4.80 GHz, 32 GB RAM and an x64 based processor.

3.1. Data set

In this study, the dataset which is photos of text (book titles and readings) with and without the motion blur effect is selected from Kaggle to present the performance differences between ABC Algorithm and FA. This dataset provides motion blur-affected and unaffected images. This dataset includes 184 images of various book titles and texts both motion-blurred and normal. For this study, 20 blurred images are selected from these 184 images [16].

3.2. Image quality

In digital imaging, the image is captured by the camera and converted into digital signals. This image may not be the same as the original image, subject to various distortions when shown to the user. These distortions are caused by different factors such as Gaussian noise, compression, and transmission disturbances. Control of the image quality is important for the digital imaging system to evaluate the image quality optimally.

The image can be checked with metrics of image quality. Quality of image metrics can be used to compare algorithms such as compression, restoration, and restoration techniques in images. Full reference quality metrics can be used to directly compare the target image and the reference image [17].

In this study, MSE and PSNR are used to make a comparison between ABC Algorithm and FA by using the blurred image dataset.

3.2.1 Mean squared error (MSE)

The MSE measures the average square difference between real and ideal pixel values. The calculation of this metric is basic but it does not correspond to human quality perception. The smaller the mean square error, the closer it is to the original. It can be calculated by using Eq. 1 [18].

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2 \tag{1}$$

Where Y_i is the actual values, $\hat{Y}_i$ is the predicted values, and n is the number of data.

3.2.2 Peak signal to noise ratio (PSNR)

PSNR is a metric that indicates the rate of the maximum possible power of a signal to the power of noise on the signal. The signal represents the original data and the noise represents the compression-related error. When comparing compression codes, PSNR can be considered an approach to human quality perception. PSNR value can be calculated by using Eq. 2 [19].

$$PSNR = 10.log_{10}\left(\frac{MAX_i^2}{MSE}\right) \tag{2}$$

Where, MAX_i is the maximum possible pixel value of the image. MSE is mean squared error.

3.2.3. Image restoration

Image restoration is a basic method of obtaining the original state of a blurred image. To be able to find the optimal solution $u \in R^m$ based on the following model:

$$f = Au + \varepsilon \tag{3}$$

where $A \in R^{m \times m}$ is a blurring operator, $\varepsilon \in R^m$ is an unknown Gaussian white noise with variance σ^2, f and u denote the indicate degraded image and the original image, respectively [20].

4. Algorithms

Detailed information about the ABC algorithm and FA are included in this section under subsections.

4.1. Artificial Bee Colony (ABC) Algorithm

ABC algorithm is the algorithm developed by the modeling foraging attitude of bees. In a natural bee colony, there is task sharing between bees according to the work to be done and bees do this work by themselves without a central unit. Job sharing and self-organization are the two important features of swarm intelligence. Bees go to food sources to find honey, pollen, or nectar. The factors such as proximity of the food resource to the nest, type, density of nectar, and facilitate of extracting the nectar determine the value of the food source. Addressing a single factor rather than simultaneously evaluating many such factors may simplify the situation in problem-solving. It is the responsibility of the worker bee to bring the nectar from the previously discovered sources to the hive. They also share information about the quality and location of the resource they visit with other bees in the hive. Non-tasked worker bees are looking for new food sources where nectar can be collected. There are two types of bee groups that are ambiguous; the first one is explorer bees, who seek indiscriminate resources with the help of instinct or external factors. The second one is the lookout bee group. These are bees waiting in the hive and watching the bees in charge and using the information shared by these bees, they turn to a new source. Information sharing is an important factor among bees. The location and quality of the food source are shared with other bees thanks to the dancing ability of the bees. The bee, who is familiar with the food source, starts to dance, and the other bees touch it and get information about the food source. ABC algorithm tries to find the place of the food resource with the most nectar and tries to find the solution that gives the minimum or maximum of the problem in space solutions [21].

Algorithm 1. Pseudocode of ABC Algorithm [22]

1. By using x_i, initialize the population of solutions
2. Appraise the population
3. period=1
4. Repetition
5. For the working bees by evaluating solutions, Generate new solutions v_i.
6. Implement the greedy choosing process between x_i and v_i
7. If the fitness value of v_i is worse than x_i $failure_i$=$failure_{i+1}$, if the solution is improved $failure_i$=0
8. For the solutions x_i compute the probability values P_i
9. Generate the new solutions v_i for the onlookers from the solutions x_i chosen depending on P_i and appreciate them.
10. Between x_i and v_i, implement the greedy choosing process
11. Define the abandoned solution for the rover bee, if it exists, and modify it with a new randomly produced solution x_i
12. Memorize the best solution reached so far
13. period=period+1
14. Until period=maximum period number of $failure_i$ =limit

4.2. Firefly Algorithm (FA)

Fireflies are small winged insects that can produce cold and flashing lights to attract other insects of their kind. Female fireflies try to attract men by mimicking the light signals of different species. Their energies emerge in the form of light and repeat in a cyclic manner [23]. The FA is one of the optimizing swarm intelligence approaches developed by Yang. It is inspired by the attenuation of light relative to distance and the attractiveness of insects. Three assumptions are adopted in the FA.

1. All fireflies are considered sexless. So all fireflies can affect the rest of the other fireflies.

2. The firefly with less light moves towards the firefly with bright light. The brightness changes depending on the distance. If the brightness level is equal, random motion occurs.

3. The fitness function determines the brightness. According to the result of this function, the best one is the brightest [24].

N firefly flock is used in the FA. C_i refers to the solution of the ith firefly. $f(C_i)$ indicates the cost of the solution, ie the distance to the best. For all fireflies, C_i has as many elements as the problem size and is initialized with random values. Each candidate solution to be optimized represents the glow/light intensity (I) of the firefly (Eq. 4).

$$I = I_0 e^{-\gamma r} \tag{4}$$

I_0: Starting light density
γ: Light absorption coefficient
r: Distance between two fireflies

Algorithm 2. Pseudocode of Firefly Algorithm [25]

Objective function $f(c)$, $c = (c_1, \ldots, c_d)^T$
Create an initial population of fireflies c_i (i=1, 2, …, n)
Light density I_i *at* c_i *is decided by* $f(c_i)$
Define light absorption coefficient γ
while (t<$MaxGeneration$)
  for i=1:n *all n fireflies*
    for j=1:n *all n fireflies*
      if (I_j> I_i), *Move firefly i towards j in d-dimensions;*
      end if Attractiveness varies with distance r via exp [$-\gamma r$]
    Appraise new solutions and update light density
    end for j
  end for i
Sort the fireflies and find the current best
end while
Postprocess results and visualization

The attraction of the firefly depends on its brightness and distance (Eq. 5)

$$\beta = \beta_0 e^{-\gamma r^2} \tag{5}$$

β: Firefly attractiveness.
β_0: The attraction value when r is 0, indicating the distance between two fireflies (It can take values between 0 and 1).

Depending on the value in β expression, the *i*th firefly, which is less attractive, moves towards the *j*th firefly, which is more attractive than itself. This movement is determined by Eq. 6.

$$x_i^{t+1} = x_i + \beta_0 e^{-\gamma r_{ij}^2}\left(x_j - x_i\right) + \alpha \varepsilon_i^t \tag{6}$$

x_i: Applicant solution of *i*th firefly
x_j: Applicant solution of *j*th firefly
ε_i: It is determined by the Gaussian distribution

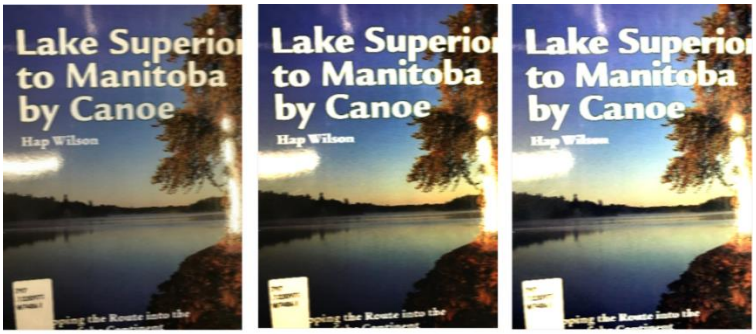
The distance between the two fireflies is examined by the Cartesian distance formula (Eq. 7) [26].

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

5. Results

PSNR and MSE values were used to compare the performance of the ABC Algorithm and FA in image restoration. A high PSNR value indicates high image quality and low noise level. There is an inversely proportional relationship between PSNR and MSE. Therefore, a lower MSE value means fewer errors and higher image quality [18, 19].

The dataset consists of 20 images. As an example, some of these images are shown in Figure 1, Figure 2, and Figure 3. Here, a) shows the original image, b) shows a state after the ABC algorithm application, and c) shows a state after the FA application.

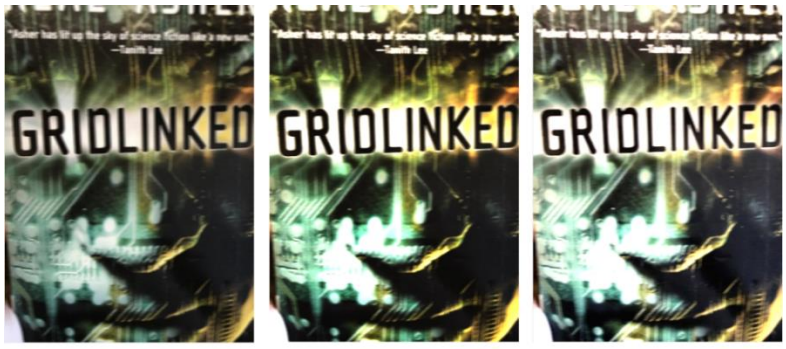


(a) (b) (c)

Figure 1. a) Original image b) After applying ABC algorithm c) After applying FA

(a) (b) (c)

Figure 2. a) Original image b) After applying ABC algorithm c) After applying FA



(a) (b) (c)

Figure 3. a) Original image b) After applying ABC algorithm c) After applying FA

PSNR and MSE values of the images are given in Table 1. It is desired to obtain images with high PSNR value and low MSE value. According to Table 1, when PSNR and MSE values of the first 17 images are examined, it is seen that ABC algorithm gives better results than FA. In 17 of the 20 images, the ABC algorithm prevailed over FA. In other words, it is 85% more successful in comparison with FA. In addition, the arithmetic mean of PSNR and MSE values obtained by these two algorithms for 20 images is given in the last column of Table 1. The average PSNR of the ABC algorithm is 27.74, while that of the FA is 26.14. In other words, the PSNR value of the ABC algorithm is higher. The average MSE of the ABC algorithm is 114.89. The average MSE of the FA is 162.07. On the other hand,

the MSE value of the ABC algorithm is lower. As a result, it was seen that it would better result to use the ABC algorithm instead of FA in image restoration studies.

Table 1. PSNR and MSE values of images with ABC algorithm and FA

Original Image	PSNR		MSE	
	Value of PSNR (ABC)	Value of PSNR (FA)	Value of MSE (ABC)	Value of MSE (FA)
Image 1	28.16	26.77	99.10	136.67
Image 2	26.30	25.80	152.29	170.99
Image 3	28.92	24.74	83.24	218.23
Image 4	27.37	25.97	118.88	164.26
Image 5	27.50	25.48	115.45	183.99
Image 6	29.56	25.84	71.88	169.26
Image 7	30.52	25.90	57.62	166.87
Image 8	25.99	25.34	163.40	189.75
Image 9	27.97	24.88	103.54	211.21
Image 10	30.02	27.26	64.57	122.08
Image 11	29.07	24.92	80.47	209.18
Image 12	27.02	26.06	129.03	160.83
Image 13	29.53	25.27	72.38	193.21
Image 14	26.00	25.43	163.30	185.95
Image 15	27.76	27.47	108.79	116.42
Image 16	25.78	25.61	171.51	178.29
Image 17	27.61	27.51	112.59	115.20
Image 18	26.19	26.64	156.06	140.92
Image 19	27.12	27.34	125.94	119.73
Image 20	26.42	28.66	147.95	88.49
Arithmetic Mean	27.74	26.14	114.89	162.07

6. Conclusions

This study, it is aimed to compare the performances of the ABC algorithm and FA for image restoration. First of all, a summary of the existing studies in the literature is given. Then, information about the ABC algorithm and FA used in the study is given. The experimental study is shown in the conclusion section. The performance of the algorithms was compared according to PSNR and MSE values. A dataset (book titles and readings) from Kaggle's text photos with and without the motion blur effect was used. 20 random images with motion blur effects were taken from this dataset. The application was made in MATLAB R2015a. As a result of the study, it was seen that the ABC algorithm performed better than FA. The ABC algorithm outperformed 17 of 20 images. This performance is also seen when the average PSNR and MSE values are examined. As a result, it is recommended to use the ABC algorithm in image restoration studies. The ABC algorithm had higher PSNR and lower MSE values on 17 of 20 images compared to FA. The average PSNR of the ABC algorithm for 20 images is 6.12% higher than that of FA. The average MSE value of the ABC algorithm is 29.11% lower than that of FA. As a result, the use of the ABC algorithm in image restoration studies gives better results than FA.

Conflict of Interest

The authors confirm that there is no known conflict of interest or common interest with any institution/organization or person.

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