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# A NOVEL HYBRID EDGE DETECTION TECHNIQUE: ABC-FA

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**Abstract**: Image processing is a vast research field with diversified set of practices utilized in so many application areas such as military, security, medical imaging, machine learning and computer vision based on extracted useful information from any kind of image data. Edges within images are undoubtedly accepted as one of the most significant features providing substantial practical information for various applications working on top of miscellaneous optimization algorithms to achieve better results. Artificial Bee Colony and Firefly algorithms are recently developed optimization algorithms and are used to obtain better results for various problems. In this study, a novel hybrid optimization technique is proposed by combining those algorithms aiming better quality in edge detection on grayscale images. The performance of the proposed algorithm is compared with individual performances of Artificial Bee Colony algorithm and the fundamental edge detection methods. The results are demonstrated that the proposed method is encouraging and also produces meaningful results for similar applications.

***Keywords:*** Image processing, edge detection, meta-heuristic, artificial bee colony (abc), firefly (fa)

## Introduction

Information extraction with image processing has become quite important because of the development of computer vision systems. Objects or events in the images can be estimated with the information obtained. Edge detection is very important area in image processing. For this reason, many methods of edge detection have been developed and are still being studied. Edge information can be used as a result for various image processing problems, such as face recognition, object recognition or segmentation. Kumar and Mohan (2014), proposed a method based on fuzzy logic technique for edge detection in Magnetic Resonance (MR) brain image . The Canny edge detector was used to segmentation of iris image by Shashidhara and Aswath (2014). Singh A., Singh M. and Singh B. (2016), proposed an algorithm using Sobel edge detection for face detection and eyes extraction. X-ray images were used to detect the edges with Sobel, Canny, Roberts, Zero cross and Log operators by Goswami and Misra (2016). Optimization algorithms are also used by researchers for edge detection. Tian, Yu and Xie (2008), proposed an algorithm based on Ant Colony Optimization for image edge detection. Gonzalez, Castro, Melin and Castillo (2015), proposed that optimizing a fuzzy logic system for edge detection based on Sobel algorithm and an Interval Type -2 fuzzy logic system, applying Cuckoo Search Algorithm. Yigitbasi and Baykan (2013), used Artificial Bee Colony Algorithm for edge detection. Dwivedi, Sethi and Rohilla (2016), presented a research of edge detection using Bat Algorithm.

Image processing with optimization algorithms has become a very important area. By using a combination of various optimization algorithms, researchers aim to do the best edge information extraction. Extracting edge information from images was studied with a single optimization algorithm in Tian, Yu and Xie (2008); Gonzalez, Castro, Melin and Castillo (2015); Yigitbasi and Baykan (2013); and Dwivedi, Sethi and Rohilla



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(2016). The proposed algorithm combined two optimization algorithms and improved new hybrid approach for edge detection.

Canny (Shashidhara & Aswath, 2014), Sobel (Singh et al., 2016) and Roberts (Goswami & Misra, 2016) edge detection methods identifies edges with a pre-defined mask operator. Besides while finding edge with these methods, corner pixels are often either ignored or taken as zero. This type of information loss is not experienced with the developed algorithm.

Proposed approach is different from the methods which are based on any mask operator or any derivate process. ABC-FA test images are taken from RADIUS/DARPA-IU Fort Hood object image database. Test performances are compared with Canny, Sobel and Roberts detectors and edge detection approach with Artificial Bee Colony. Results showed that improved method can be used as an alternative.

In this paper, a novel hybrid approach ABC-FA by combining Artificial Bee Colony (ABC) Algorithm (Karaboga, 2005) and Firefly Algorithm (FA) (Yang, 2009).

The paper is organized as follows. The basic concepts of the edge detection, Artificial Bee Colony algorithm and Firefly optimization algorithm are defined in Section 2. In Section 3, proposed hybrid approach by combining Artificial Bee Colony (ABC) Algorithm and Firefly Algorithm (FA) is described in detail. Experimental results are presented in Section 4. Finally, conclusions are presented in Section 5.

## Materials and Methods

Edge information is so important for recognizing objects and segmentation. Edges characterize the boundaries and they are obtained by sudden changes in pixel of current image (Yigitbasi & Baykan, 2013). For this reason, edges contain meaningful features about current image.

The human visual system is based on the recognition of edges directly (Marr & Hildreth, 1980). Extracting edge data is widely used in computer vision systems. There are many edge detectors which require a pre-defined mask or use derivative systems for finding edge pixels such as Canny, Sobel or Roberts.

Many methods of finding edges of images have been improved and are still being studied. In this paper, a new different method is developed by combining Artificial Bee Colony (ABC) Algorithm (Karaboga, 2005) and Firefly Algorithm (FA) (Yang, 2009) and used for edge detection which is about gray scale images. In gray scale image each pixel is represented by 8 bit, hence gray level values vary from 0 to 255, where 0 value stands for black color and 255 value stand for white color (Gonzalez & Woods, 2007).

### Artificial Bee Colony Optimization Algorithm

Artificial Bee Colony (ABC) algorithm was developed by Karaboga (2005) is an optimization algorithm which is modeling the behavior of foraging bees.

In ABC algorithm, an artificial bee colony contains three type of bee. These are employed, onlooker and scout bees. Algorithm has three control parameters which are the number of food sources (SN), the maximum cycle number and the value of limit. The food sources are produced according to following equation (1) in a certain minimum and maximum range.

$$x_{i,j} = x_j^{\min} + rand(0,1)(x_j^{\max} - x_j^{\min}) \tag{1}$$

$x_i$ is D-dimensional vector, SN=number of food source, i=1,2,3,…,SN, j=1,2,3,…,D, $x_j^{\max}$ and $x_j^{\min}$ are the determined maximum and minimum limit values. Each employed and onlooker bee tries to find the new better source, these employed bees search neighbor itself by (2) below.

$$v_{i,j} = x_{i,j} + \phi_{i,j}(x_{i,j} - x_{k,j}) \tag{2}$$

$v_i$ is a new source which is neighbors of $x_i$. The j is a random value between [1, D] and k is another random value between [1, SN]. Also, k and i value must be different. $\phi_{i,j}$ is random number between [-1, 1]. After these steps, the greedy criterion is applied in the process of understanding which sources are better. If current position cannot be improved after a predetermined number of cycles, this position should be abandoned by employed bee.

The corresponding employed bee becomes a scout bee. The abandoned position will be replaced with better neighbor source.

The main steps can be described as follows (Karaboga & Akay, 2009):

Initially all the parameters are initialized;
**while** Until the stopping is reached **do**
  Employed bee stage is applied to produce new food positions;
  Onlooker bees stage is implemented on the food positions on basis of strength;
  Scout bee stage is implemented to avoid the stagnation situation;
  The current best solution is selected;
**end while**
Display the most accurate solution is the swarm.

Figure 1. Pseudo code of artificial bee colony algorithm

According to the fitness which is symbolized $f_i$ of $x_i$, get the probability value $P_i$ by (3) and (4) below.

$$P_i = \frac{fit_i}{\sum_{i=1}^{n} fit_i} \tag{3}$$

$$fit_i = \begin{Bmatrix} \frac{1}{1+f_i}, & f_i \geq 0 \\ 1+abs(f_i), & f_i < 0 \end{Bmatrix} \tag{4}$$

Onlookers choose food sources depending on the probability $P_i$.

**Firefly Optimization Algorithm**

Yang developed Firefly optimization algorithm (FA) (Yang, 2009) which is inspired by the brightness and movement directions of fireflies.

Firefly algorithm is applied based on three principles. First, fireflies are considered as unisex and can affect each other without discrimination. Second, the attractiveness of fireflies is proportional to their brightness and the brightest fireflies attract them to the less bright ones. Last principle is that brightness is determined by the value which produces from the functions to be optimized. Based on these three rules, the basic steps of the firefly algorithm (FA) can be summarized as the pseudo code shown in Fig.2 (Yang, 2009):

Objective function f(x), x=$(x_{1,} ..., x_d)^T$
Generate initial population of fireflies $x_i$
Light intensity $I_i$ at $x_i$ is determined by f( $x_i$ )
Define light absorption coefficient ɣ
**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-dimension;
    **end if**
    Attractiveness varies with distance r via exp[-ɣr]
    Evaluate new solutions and update light intensity
**end for** j
**end for** i
Rank the fireflies and find the current best
**end while**
Process results and visualization

Figure 2. Pseudo code of firefly algorithm

$x_i$ is solution of $i$'th firefly. The brightness of the firefly is represented by *I* as shown in equation (5).

$$I = I_0 \, e^{-\gamma r} \tag{5}$$

$I_0$ is initial and original light intensity. $\gamma$ is absorption coefficient. Attractiveness which is symbolized with β, varies with brightness and distance as shown in equation(6). $\beta_0$ is a value between [0,1].

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

The distance between any two fireflies is calculated by the Cartesian distance (Marr & Hildreth, 1980). According to β value, fireflies which are less bright fly to more bright ones in r distance. This movement is calculated with equation (7).

$$x_i^{t+1} = x_i + \beta_0 \, e^{-\gamma r_{ij}^2} \left( x_j - x_i \right) + \alpha \varepsilon_i^t \tag{7}$$

The new location of $i$'th firefly is $\boldsymbol{x_i^{t+1}}$ and randomization parameters are symbolized with α and ε.

**Proposed Hybrid ABC-FA Edge Detection Approach**

Proposed method is using two types of meta-heuristic optimization algorithm which are based on solutions of swarm intelligence.

The artificial bee colony algorithm is population based search algorithm which is simulates foraging behaviors of real bee colonies. It has ability to explore local solutions, simplicity, flexibility and robustness, but it may lose some relevant or better solutions in some cases.

The firefly algorithm can deal multi-modal optimization problems efficiently by using swarm intelligence. It doesn't require a good initial value to start process. Firefly algorithm is superior to existing meta-heuristic algorithms (Yang, 2009).

In this consideration of characteristics of the two algorithms, this paper introduces the improved hybrid ABC-FA edge detection algorithm which is combining Artificial Bee Colony (ABC) algorithm (Karaboga, 2005) and Firefly optimization algorithm (FA) (Yang, 2009) is mentioned in this section.

To improve search efficiency, artificial bee colony algorithm's probability adapted to brightness which is used by firefly algorithm.

Proposed method can find edge pixels according to optimization techniques without any mask or derivate calculations. The steps of the improved hybrid ABC-FA technique for edge detection are shown in Figure 3.

In FA part of improved algorithm, probabilities of each source are taken as brightness for adapting FA algorithm. Comparison of the brightness and flying to more bright ones in r distance takes place at this stage.

Checking that whether the probabilities are less than the boundary value and whether the failure count values exceed the limit value are handled in ABC part. According to these control part's result, a pixel is defined as an edge in a final output image.

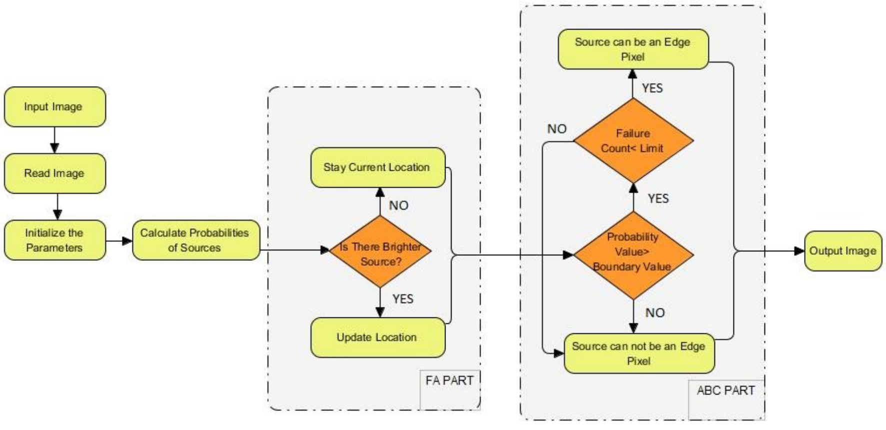



Figure 3. Edge detection with ABC-FA technique

In ABC-FA, colony size which is defined by K and varies with N rows and M columns of image is equal with the total number of sources.

$$K = \sqrt{NxM} \tag{8}$$

Employed bee number is equal to located source number. Located source number is calculated with equation (9).

$$LocatedSourceNumber = \frac{K}{2} \tag{9}$$

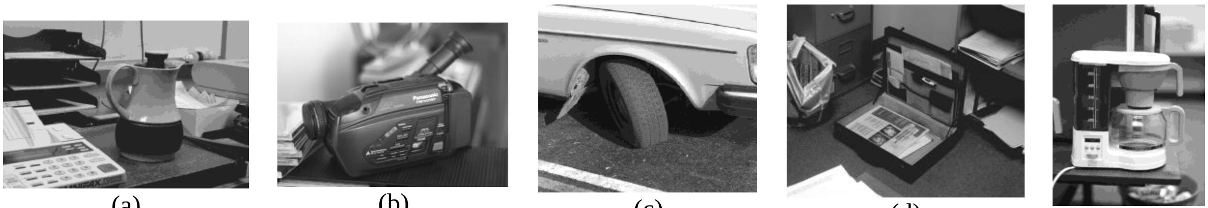
The coordinates of located pixels and neighbor pixels, the gray level values, fitness values, failure counters, probabilities, the sources are banned or not data are held as in edge detection study with ABC (Yigitbasi & Baykan, 2013). If the difference between an existing pixel and its neighbors is greater than the threshold value, then that pixel can be included by an edge. Threshold value varies according to deviation which is calculated for each different image.

**Experimental Results**

In this section, developed ABC-FA method is performed with test images. Then obtained result images are compared with the other specified edge detection techniques. These test images are selected from RADIUS/DARPA-IU Fort Hood object image database (Bowyer et al., 1999).

In ABC-FA approach, colony size changes depending on each image sizes. Maximum iteration number is 5000 and the control parameters are specified as limit value is 5 because of 8-neighborhood, alpha value 0.5, gamma value is 1 and minimum beta value is 0.2.

We compared ABC-FA test results with Canny, Sobel and Sobel techniques' result images. Additionally, the performance of the proposed algorithm is compared with edge detection approach with Artificial Bee Colony (Yigitbasi & Baykan, 2013). ABC-FA algorithm is tested with 5 gray scale images that are shown in Figure 4. Each test image has an object for extracting edge information. Dimensions of test images are different from each other.



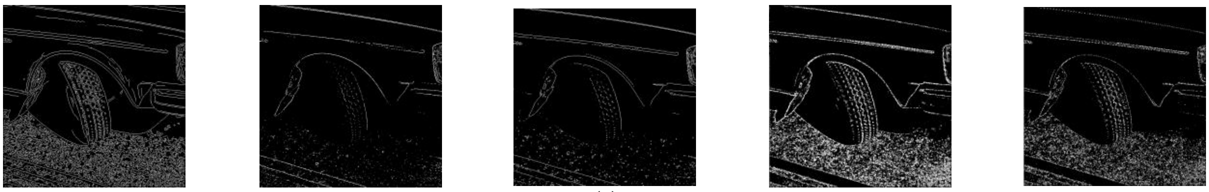
(a) (b) (c) (d) (e)

Figure 4. Test Images: (a)46.pgm; (b)106.pgm; (c)207.pgm; (d)36.pgm; (e)115.pgm

Experimental results of each edge detection technique are given in Figure 5 for 46.pgm, Figure 6 for 207.pgm, Figure 7 for 36.pgm, Figure 8 106.pgm and Figure 9 for 115.pgm. Results contains Canny, Sobel, Roberts, ABC and ABC edge detection method's output images which have extracted edge information.

(a) (b) (c) (d) (e)

Figure 5. Results of 46.pgm: (a) Canny; (b)Roberts; (c)Sobel; (d)ABC; (e)ABC-FA

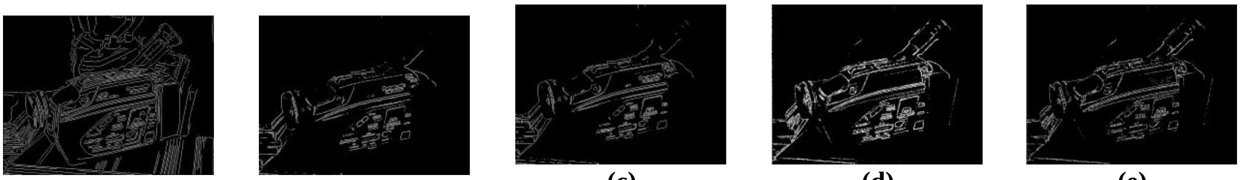


(a) (b) (c) (d) (e)

Figure 6. Results of 207.pgm: (a) Canny; (b)Roberts; (c) Sobel; (d) ABC; (e) ABC-FA

(a) (b) (c) (d) (e)

Figure 7. Results of 36.pgm: (a) Canny; (b)Roberts; (c) Sobel; (d) ABC; (e) ABC-FA



**(a)** **(b)** **(c)** **(d)** **(e)**

Figure 8. Result of 106.pgm: (a) Canny; (b)Roberts; (c) Sobel; (d) ABC; (e) ABC-FA

**(a)** **(b)** **(c)** **(d)** **(e)**

Figure 9. Results of 115.pgm : (a)Canny; (b)Roberts; (c) Sobel; (d) ABC; (e) ABC-FA

Hamming distance (HD) calculations were used between the result images for the analysis (Yigitbasi & Baykan, 2013). If HD value converges to 0, similarity percentage increases. HD values are between edge detection techniques as in Table 1.

Table 1. Hamming distances for result ımages

| | | Canny | Roberts | Sobel | *ABC* | **ABCFA** |
|---|---|---|---|---|---|---|
| 46.pgm | Canny | 0 | 0.2591 | 0.2318 | 0.2775 | **0.2738** |
| | Roberts | 0.2591 | 0 | 0.1554 | 0.2256 | **0.2145** |
| | Sobel | 0.2318 | 0.1554 | 0 | 0.2191 | **0.2092** |
| | *ABC* | 0.2775 | 0.2256 | 0.2191 | 0 | **0.1668** |
| | **ABCFA** | **0.2738** | **0.2145** | **0.2092** | **0.1668** | **0** |
| 207.pgm | Canny | 0 | 0.3170 | 0.3078 | 0.3040 | **0.3061** |
| | Roberts | 0.3170 | 0 | 0.1680 | 0.2788 | **0.2616** |
| | Sobel | 0.3078 | 0.1680 | 0 | 0.2767 | **0.2612** |
| | *ABC* | 0.3040 | 0.2788 | 0.2767 | 0 | **0.2178** |
| | **ABCFA** | **0.3061** | **0.2616** | **0.2612** | **0.2178** | **0** |
| 36.pgm | Canny | 0 | 0.3237 | 0.3069 | 0.3385 | **0.3373** |
| | Roberts | 0.3237 | 0 | 0.1393 | 0.3101 | **0.2834** |
| | Sobel | 0.3069 | 0.1393 | 0 | 0.3065 | **0.2801** |
| | *ABC* | 0.3385 | 0.3101 | 0.3065 | 0 | **0.2527** |
| | **ABCFA** | **0.3373** | **0.2834** | **0.2801** | **0.2527** | **0** |
| 106.pgm | Canny | 0 | 0.2743 | 0.2635 | 0.2810 | **0.2812** |
| | Roberts | 0.2743 | 0 | 0.1058 | 0.1493 | **0.1392** |
| | Sobel | 0.2635 | 0.1058 | 0 | 0.1480 | **0.1381** |
| | *ABC* | 0.2810 | 0.1493 | 0.1480 | 0 | **0.1195** |
| | **ABCFA** | **0.2812** | **0.1392** | **0.1381** | **0.1195** | **0** |
| 115.pgm | Canny | 0 | 0.2301 | 0.2145 | 0.2467 | **0.2454** |
| | Roberts | 0.2301 | 0 | 0.0905 | 0.1399 | **0.1330** |
| | Sobel | 0.2145 | 0.0905 | 0 | 0.1356 | **0.1299** |
| | *ABC* | 0.2467 | 0.1399 | 0.1356 | 0 | **0.1084** |
| | **ABCFA** | **0.2454** | **0.1330** | **0.1299** | **0.1084** | **0** |

The proposed technique can be an alternative method to other traditional edge detection methods according to similarity results in Table 1.

Figure 10 shows more clearly that the best resemblance percentage was occurred with ABC technique and developed ABC-FA algorithm. Similarities which were Roberts-ABCFA and Sobel-ABCFA have been achieved almost at the same rate. The best results were obtained in 115.pgm image.

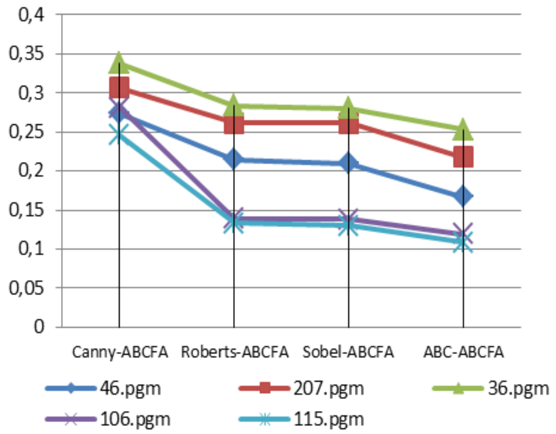



Figure 10. Hamming distances of result images for each test image

The number of pixels defined as edge pixels in ABC end ABC-FA results for each test image is as in Figure 11.

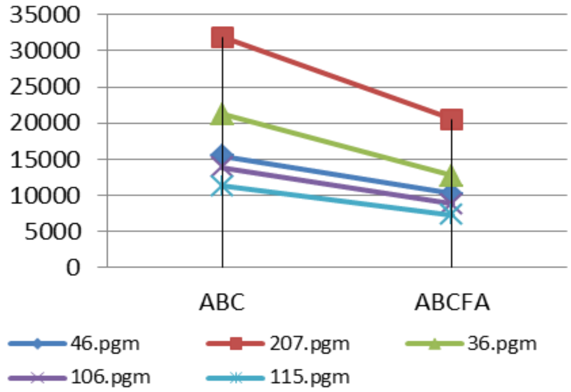



Figure 11. The number of pixels defined as edge pixels ın result ımages.

Figure 11 shows that in ABC method, many non-edge pixels were defined as an edge pixel. These pixels located around the edges. For this reason, edges couldn't be shown as an edge line in the output image. These types of pixels are removed from the result images with developed hybrid method ABC-FA.

## Conclusion

In this paper, a new hybrid approach ABC-FA technique for image edge detection has been proposed. Developed algorithm was performed with 5 gray scale test images which were taken from RADIUS/DARPA-IU Fort Hood object image database. Output images were compared with traditional edge detectors' results. Additionally, ABC-FA's and ABC's result images (Yigitbasi & Baykan, 2013). were compared with the result images. Hamming distance calculation was used for analyze similarity percentages.

Analyzing of results showed that hybrid ABC-FA technique can be an alternative method to other traditional edge detection methods such as Canny, Sobel and Roberts. Developed method doesn't require a mask operator to finding edge pixels. In edge detection methods which use pre-defined mask operator, some pixels are ignored or accepted as zero. Our proposed algorithm finds edge pixels without this kind of loss. Also ABC-FA technique was more effective in finding edge pixels than ABC technique. As shown in Figure 11, non-edge pixels in ABC method were removed from the result images.

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