Edge Detection using Artificial Bee Colony Algorithm (ABC)

Elif Deniz Yigitbasi and Nurdan Akhan Baykan

***Abstract*—Edge detection methods in the field of image processing are an important application area. Currently, image processing is being exploited in many areas. For this reason, methods used in developing more and more every day and studies which is about computer vision systems are being developed for less errors. Optimization algorithms have been used for better results in so many studies. In this paper, Artificial Bee Colony (ABC) Optimization Algorithm is used for edge detection which is about gray scale images. First, ABC algorithm is explained. Following, edge detection and edge detection with ABC algorithm are clarified. Finally, results are showed. Results show that the proposed method can be applied for edge detection operations.**

***Index Terms*—Image processing, edge detection methods, meta-heuristic methods, artificial bee colony (ABC) optimization.**

I. Introduction

Edge detection is one of the most important tasks of finding the image. Edges within the image are the most important knowledge. The human visual system is based on the recognition of edges directly [1].

Marr and Hildreth (1980), proposed to search the corresponding edges of the zero crossings with using Gaussian's Laplacian operator. The most basic method which is used to locate the edge is the use of the derivative.

Haralick (1984), found that out of the equation applied on the interpolated pixels are found by using the value of the gradient value of the derivative, second derivative has presented a method of searching for a gradient that zero crossings [2].

Canny (1986), proposed a method based on application of the mask operator derivative which is obtained from Gaussian mask [3]. Roberts, Prewitt and Sobel operators which are example to appropriate operators, are the first methods which are used in image processing area [4].

In this paper, a method developed for edge detection without any mask operator or any derivate process. Proposed method is based on optimization algorithm. Pixels which are appurtenant to an edge line, can be distinguish owing to using ABC algorithm.

ABC algorithm which originates from bee's food searching behavior is tested on so many different images. Results are compared with Canny, Sobel and Roberts edge operators' results.

Manuscript received June 12, 2013; revised September 16, 2013.

Elif Deniz Yigitbasi is with Işık University, Department of Computer Engineering, Istanbul, Turkiye (deniz.yigitbasi@isikun.edu.tr).

Nurdan Akhan Baykan is with Selçuk University, Department of Computer Engineering, Konya, Turkiye (nurdan@selcuk.edu.tr).

II. Artificial Bee Colony Algorithm and Edge Detection

A. Artificial Bee Colony Optimization Algorithm

Examination of the processes occurring in nature with intelligent behavior has led researchers to develop new optimization methods.

Honey bees live in colonies and show many features. These features include bee foraging, bee dance, queen bee, task selection, collective decision making, nest site selection, mating, pheromone laying and navigation systems, which can be used as models for intelligent applications. Actually, a lot of researchers have been inspired to develop algorithms by the behaviors of bees [5], [6].

Artificial Bee Colony (Artificial Bee Colony (ABC)) algorithm developed by Karaboga and Basturk [6], [7] is one of the most popular algorithms and modeling the behavior of foraging bees.

In ABC algorithm, an artificial bee colony consists of employed bees, onlookers and scouts.

For every food source, there is only one employed bee. So the number of employed bees is equal to the number of food sources. Employed bees number is equal to the number of onlooker bees. Scout bee case is dependent on food source conditions.

Each employed bee selects a food source randomly within the search space circumstances. These circumstances are performed according to the (1) below.

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

x_i is D-dimensional vector, i=1, 2, 3, …, SN (SN=number of food source), j=1, 2, 3, …, D, $x_j^{\max}$ and $x_j^{\min}$ are the determined maximum and minimum limits. Employed bees positions are determined by this process.

After all employed bees finish their search process, they share the information about the direction and distance to food sources and the nectar amounts with onlookers in the dancing area. According to the waggle dance, each onlooker bee chooses a food source depending on the probability value associated with the food source, and searches the area within its neighborhood to generate a new candidate solution.

Each employed and onlooker bee tries to develop the quality of nectar, these employed bees select different neighbor itself by (2) below.

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

v_i is a candidate source which is randomly selected from neighbors of x_i. The j is a random integer between [1, D] and k is another random integer between [1, SN], k must be different from i value. $\phi_{i,j}$ is a real random number in the range [-1, 1].

And then, the greedy criterion is applied again just as it works in the employed bees. If a position cannot be improved after a predetermined number of cycles, the position should be abandoned; meanwhile, the corresponding employed bee becomes a scout. The abandoned position will be replaced with a new randomly generated food source [7], [8].

The main steps can be described as follows [9]:

1) Initialize the bee colony X = { x_i | i = 1, 2, …, n}, where n denotes the population size, x_i is the i'th bee.
2) According to the fitness function, calculate the fitness f_i of each employed bee x_i, and record the maximum nectar amount as well as the corresponding food source.
3) Each employed bee produces a new solution v_i in the neighborhood of the solution in its memory by v_i where k is an integer near to i, $k \neq i$, and ϕ is a random real number in [−1, 1].
4) Use the greedy criterion to update x_i. Compute the fitness of v_i. If v_i is superior to x_i, x_i is replaced with v_i; otherwise x_i is remained.
5) According to the fitness f_i of x_i, get the probability value P_i by 3) and 4) below.

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

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

6) Depending on the probability P_i, onlookers choose food sources, search the neighborhood to generate candidate solutions, and calculate their fitness.
7) Use the greedy criteria to update the food sources.
8) Memorize the best food source and nectar amount achieved.
9) Check whether there are some abandoned solutions or not. If true, replace them with some new randomly-generated solutions by 1), where ϕ is a random real number in [-1, 1], min and max stand for lower and upper bounds of possible solutions respectively.
10) Repeat steps 3)–9), until the maximum number of iterations is reached or stop conditions are satisfied.

The fitness function is a key component of ABC algorithm. Besides, some control parameters, such as the number of employ bees or onlooker bees, the limit times for abandonment, the maximum number of iterations or stop conditions, must be defined. They have a direct influence on the speed and stability of convergence.

B. Edge Detection

Edges characterize the boundaries and they are obtained by sudden changes in pixel of current image. If the concept of a physical edge, fold the objects, used to define the colors of the changing places. Finding the edges of an image protects important structural features of image. Even the human visual system is based on finding edges of views.

Edge detection is one of the most important tasks of finding the image. Edges within the image are the most important information. The human visual system is based on the recognition of edges directly [10].

Most of edge detection algorithms are based on derivate system and masking system. Gradient method uses the first order derivative and Laplacian method uses the second order derivative on target image. Sobel, Canny, Roberts and Prewitt methods are some of methods which use masking system.

In this paper, a new different method is developed by ABC optimization algorithm.

III. The Proposed Algorithm

A method which is based on optimization algorithm is developed for edge detection problems on images. Generally, edges are found with masks, and dependence of masks can be removed by this improved method.

The first image is taken from the process of finding the edge with ABC, first (initial image) is determined. Dimensions of the image, the size of the colony and the colony size than the experiments formulated and calculated by equation (5).

$$K = \sqrt{N \times M} \tag{5}$$

where K is the total number of sources, N rows of the image, M is the number of columns [11].

After determining the size of the colony on the image, the source is located in the employed bees. Located source number is equal to half of the total number of source (6). At the same time employed bee number becomes equal to located source number.

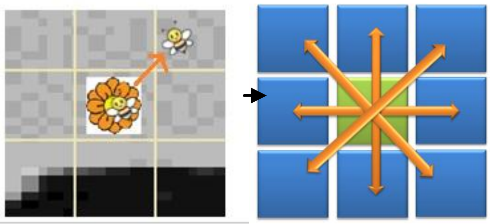
$$LocatedSourceNumber = \frac{K}{2} \tag{6}$$

By the number of the source, employed bees are randomly distributed on the image (initial image).

The coordinate data of the navigated sources, the gray level values, fitness value, failure counter, probability, the source is banned or not data are held. If a better source adjacent to the navigated source could not be found, failure counter increased. The total probability of all the resources of the current resource availability value is the ratio of fitness value. Banned resource is the source which is synchronized with the failure counter and limit value of the source. Exploration and exploitation operations continue on resources which are permitted. If navigated source is allowed source, the source's neighbors' data are held as the navigated source.

In this study, fitness function of ABC algorithm is gray level value of resources. First, fitness functions are computed and then probability values are computed based on fitness values. Navigated source's probability and one of its neighbor's which is selected randomly, probability are compared. Thus, randomly navigated resource has been improved. If the neighbor's probability is higher than located resource's probability, failure value increased 1 and they are checked for is equal or not. If these values are equal, the located source becomes banned and scout bee number is increased. Afterwards bees don't locate on these banned sources. In this study, we set limit value as 5.

TABLE I: LOCATED SOURCE AND CONTROLLING NEIGHBOR SOURCE WHICH IS RANDOM SELECTED



There are three different cases about comparing probabilities (Table I). First, if located source's probability is less than probability boundary value, located source's failure counter increased. Second, if located source's probability is higher than probability boundary value, still a neighbor pixel is selected randomly in center pixel's neighborhood. If neighbor's probability is less than probability boundary value or located source's probability value, located source's failure counter increased. Third, if located source's probability is higher than probability boundary value, a neighbor pixel is selected randomly in center pixel's neighborhood. If neighbor's probability is higher than probability boundary value and located source's probability value, located source is abandoned and neighbor pixel becomes new resource and abandoned source's failure counter value resets.

After all computes, located sources are determined and then we can analyze these sources (pixels) for belonging to any edge line. For this reason pixels are examined for directional aspects (left, right, top, bottom and diagonally).

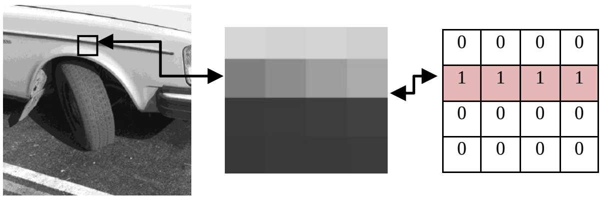


Fig. 1. Detecting edge from pixels on 207.pgm.

If the calculated gray level difference is higher than the specified value what its mean is boundary value for thresholding, the located source is determined as edge pixel and that pixel's coordinate on the result image are set 1. Here, the threshold for each image, depending on the standard deviation of the image gray levels. The formula is below (7).

$$\text{threshold value} = \text{fix}(\text{std2}(\text{image})) \times 1.5 \qquad (7)$$

IV. EXPERIMENTAL RESULTS

In our study, we use ABC optimization algorithm to modify edge detection. For this reason improved method was used on five gray scale images. Each image size is different from other ones. Population size was taken according to images sizes as formula (6) and the maximum number of iterations is 2500. The control parameter limit is equal to 5 because of 8-neighborhood. For all tested images we are computed boundary for threshold and probability.

Test images was get from a web site [12] which is about comparison of edge detection algorithms and used by K. Bowyer [13]. In this work, the best edge image for each algorithm can be viewed. The best edge images were determined in two different ways; by finding the best parameters to use for the set of images (fixed parameters) and by adapting the parameters to each individual image (adapted parameters). We chose 5 test images the best adaptive images for our experiment.

Canny, Roberts and Sobel edge detection methods were also applied to comparing these methods' result images with ABC method's result images. Test images and their results are given below. Fig. 2 shows test images and experimental results are given in Fig. 3-Fig. 7.

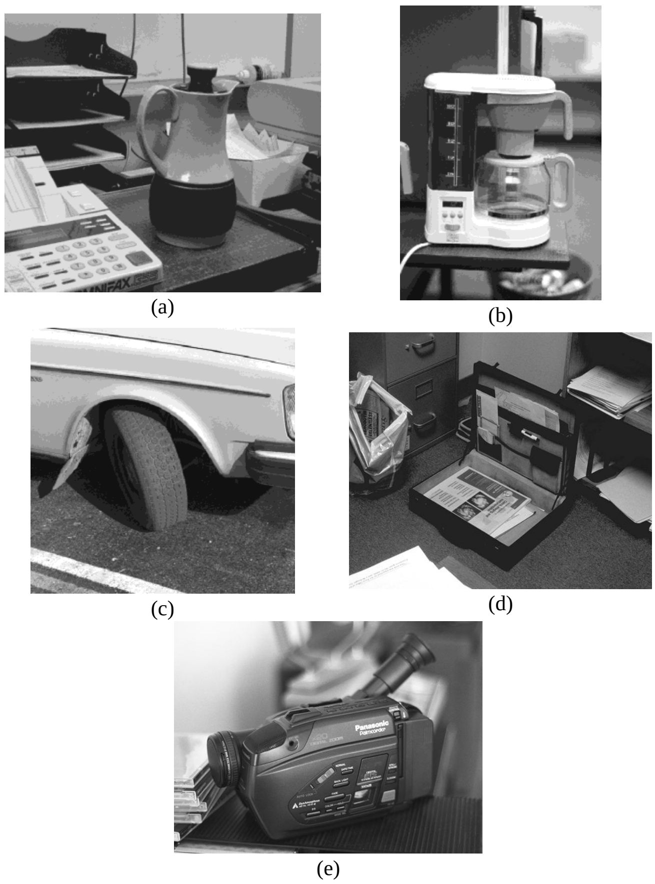
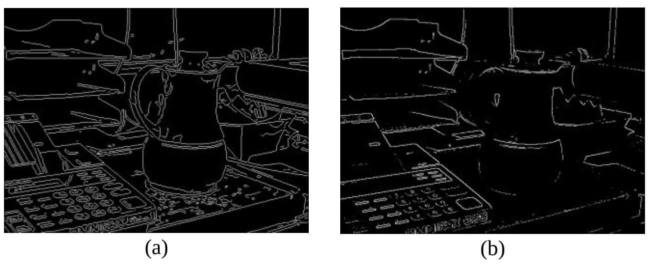
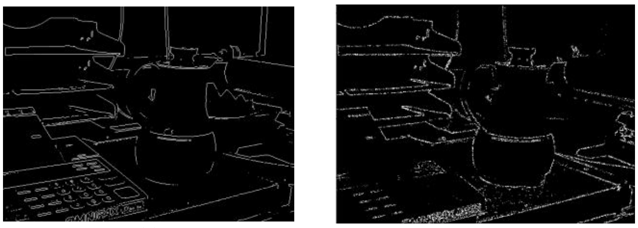


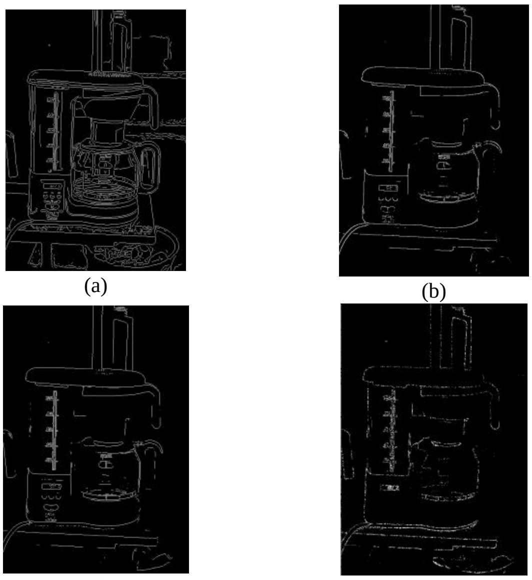
Fig. 2. Test Images (a) 46.pgm; (b) 115.pgm; (c) 207.pgm; (d) 36.pgm;(e)106.pgm.





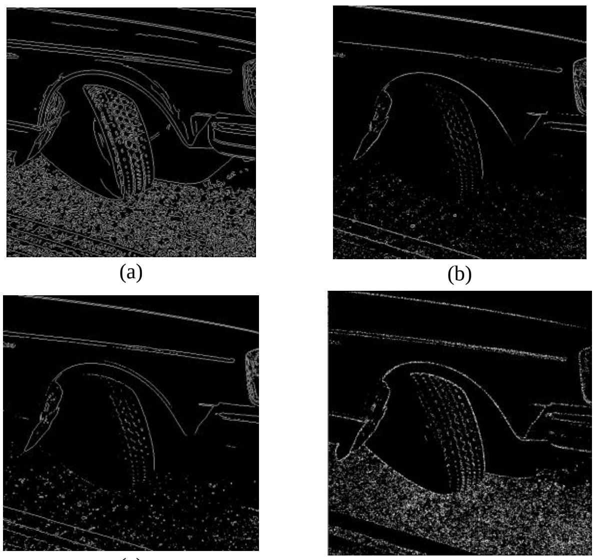
(c) (d)

Fig. 3. Result images of 46.pgm (a) Canny; (b) Roberts; (c) Sobel; (d) Our method.



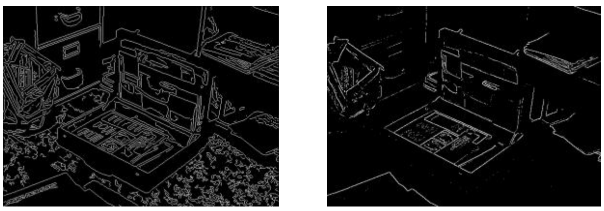
(a) (b) (c) (d)

Fig. 4. Result images of 115.pgm (a) Canny; (b) Roberts; (c) Sobel; (d) Our method.

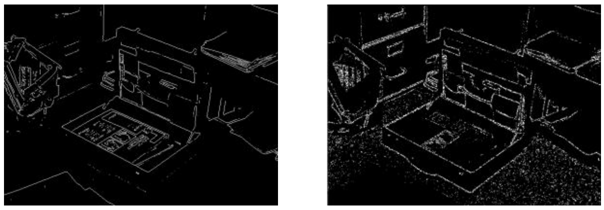


(a) (b) (c) (d)

Fig. 5. Result images of 207.pgm (a) Canny; (b) Roberts; (c) Sobel; (d) Our method.

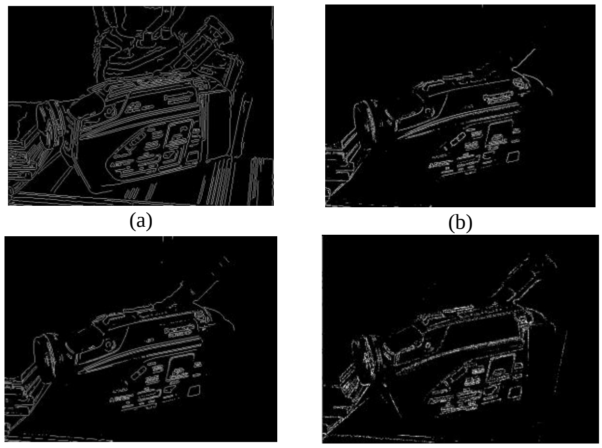


(a) (b)



(c) (d)

Fig. 6. Result images of 36.pgm (a) Canny; (b) Roberts; (c) Sobel; (d) Our method.



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

Fig. 7. Result images of 106.pgm (a) Canny; (b) Roberts; (c) Sobel; (d) Our method.

We used Hamming Distance for analyzing of results.

Hamming Distance (HD) measures the bits which are the same between two images. This method makes comparison of bits in the input images and then it decides that these images are the same or not.

In this method, output value varies between 0-1. If this value converges to 0, similarity percentage increases. So if same images are compared by this method, result is calculated 0. X and Y input images are compared with HD is performed with the equation (8). N is the number of bits in the image videlicet N is size of the feature vector. XOR is logical operator. X_j and Y_j are the input images which are examined.

$$HD = \frac{1}{N}\sum_{j=1}^{N} X_j (XOR) Y_j \tag{8}$$

Results shows that improved method is can be used as an alternative method. Analyzing of results is given in Table II.

V. Conclusion

In this study, the overall positioning of the source ABC optimization algorithm was carried out on a random pixel in the input image.

In basic ABC, new source is determined by the formula, but in the study 8-neighboring pixels of the first destination resource identified new resources. Gray level values are used as the knowledge of nectar.

Colony sizes vary depends on the pictures size, maximum number of cycles is 2500 and the limit value is set as 5. Threshold value, depending on the standard deviation of each image was determined by a formula.

TABLE II: HAMMING DISTANCES FOR RESULT IMAGES

		Canny	Roberts	Sobel	ABC
46.pgm	Canny	0	0.2591	0.2318	0.280
	Roberts	0.2591	0	0.1554	0.2105
	Sobel	0.2318	0.1554	0	0.2074
	ABC	0.2800	0.2105	0.2074	1
207.pgm	Canny	0	0.3170	0.3078	0.3104
	Roberts	0.3170	0	0.1680	0.2679
	Sobel	0.3078	0.1680	0	0.2658
	ABC	0.3104	0.2679	0.2658	0
36.pgm	Canny	0	0.3237	0.3069	0.3406
	Roberts	0.3237	0	0.1393	0.2861
	Sobel	0.3069	0.1393	0	0.2853
	ABC	0.3406	0.2861	0.2853	0
106.pgm	Canny	0	0.2743	0.2635	0.2806
	Roberts	0.2743	0	0.1058	0.1412
	Sobel	0.2635	0.1058	0	0.1439
	ABC	0.2806	0.1412	0.1439	0
115.pgm	Canny	0	0.2301	0.2145	0.2493
	Roberts	0.2301	0	0.0905	0.1284
	Sobel	0.2145	0.0905	0	0.1272
	ABC	0.2493	0.1284	0.1272	0

Images of our study results, the methods used extensively and known that Sobel, Canny, Roberts edge detection methods are compared with the results. Results showed that improved method can be used as an alternative. Also these edge detection operators require a pre-defined mask for edge detection process. Besides while using these masks, corner pixels and pixels of frame around the image are often either ignored or taken as zero. Without this kind of loss of information, the edge information extraction was carried out with the ABC algorithm and the dependence on the mask has been removed.

REFERENCES

[1] D. Karaboğa, "Yapay Zeka Optimizasyon Algoritmaları," *Nobel Akademik Yayıncılık*, 2011 , pp. 201-225.

[2] R. M. Haralick, "Digital step edges from zero crossing of second directional derivatives," *IEEE Trans. Pattern Anal. Mach. Intell*, pp. 58–68, 1984.

[3] J F. Canny, "A Computational Approach to Edge Detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, pp. 679-698, 1986.

[4] A. Bovik, *Handbook of Image and Video Processing*, Academic Press, 2010.

[5] D. Karaboga and B. Akay, "A survey: algorithms simulating bee swarm intelligence," *Artificial Intelligence Review*, 2009, pp. 61–85.

[6] D. Karaboga and B. Basturk, "A powerful and efficient algorithm for numerical function optimization: artificial bee colony (ABC) algorithm," *Journal of Global Optimization*, pp. 459–471, 2007.

[7] D. Karaboga, "An Idea Based on Bee Swarm for Numerical Optimization," *Technical Report-TR06*, October 2005.

[8] D. Karaboga, and B. Basturk, "On the performance of artificial bee colony (ABC) algorithm," *Applied Soft Computing*, 2008, pp. 687–697.

[9] M. Miao, Jianhui, L. Guo, Y. Fan, and Y. Yin, "SAR image segmentation based on Artificial Bee Colony algorithm," *Applied Soft Computing*, pp. 5205–5214, 2011.

[10] D. Marr and E. Hildreth, "Theory of edge detection," in *Proc. R. Soc. Lond. A, Math. Phys. Sci*., vol. B, no. 207, pp. 187–217, 1980.

[11] H. Nezamabadi-Pour, S. Saryazdi, and E. Rashedi, "Edge detection using ant algorithms ," *Soft Compute 10*, pp. 623–62, 2006.

[12] Marathon. [Online]. Available: http://marathon.csee.usf.edu/edge/

[13] M. Heath, S. Sarkar, T. Sanocki, and K.W. Bowyer, "A Robust Visual Method for Assessing the Relative Performance of Edge-Detection Algorithms," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 19, no. 12, pp. 1338-1359, December 1997.

Elif Deniz Yigitbasi was born in Turkey on June 11, 1988. She graduated from Department of Computer Engineering at Selcuk University in 2011. She is studying on M.E. at Department of Computer Engineering at Selcuk University. Also she is a research assistant in Department of Computer Engineering at FMV Isik University. Her interest areas include image processing, optimization algorithms, meta-heuristic methods, swarm intelligence.

Nurdan Akhan Baykan was born in Turkey on June 10, 1979. She graduated from Department of Computer Engineering at Selcuk University in 2001. She received MSc and PhD degrees in computer engineering from the Selcuk University in 2004 and 2010, respectively. She is currently Assoc. Assist. Prof. at the Department of Computer Engineering in Selcuk University. Her research interests include image processing, artificial intelligence and mathematics.