Универзитет Привредна академија у Новом Саду
University Business Academy in Novi Sad

Факултет за примењени менаџмент, економију и финансије Београд
Faculty of Applied Management, Economics and Finance Belgrade

ФАКУЛТЕТ ЗА ПРИМЕЊЕНИ МЕНАЏМЕНТ ЕКОНОМИЈУ И ФИНАНСИЈЕ МЕФ

MEFKON20

International Scientific & Professional Conference

МЕЂУНАРОДНА НАУЧНО-СТРУЧНА КОНФЕРЕНЦИЈА

INNOVATION AS AN INITIATOR OF THE DEVELOPMENT

ИНОВАЦИЈЕ КАО ПОКРЕТАЧ РАЗВОЈА

INNOVATIONS AS THE KEY TO BUSINESS SUCCESS
ИНОВАЦИЈАМА ДО ПОСЛОВНОГ УСПЕХА

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INNOVATIONS

December 3rd
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„Иновацијама до пословног успеха“

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ПРЕДГОВОР

И ове године, као и пет претходних, иновације су наш покретач развоја и повод да дамо нови допринос овој неисцрпној и изазовној теми. Неговање традиције императивно обавезује да за сваку нову конференцију будемо бољи и по квалитету радова, њиховој бројности и ширини. Истовремено, измењене животне околности намећу актуелност тренутка. Иновације и означавају и генеришу будућност, али почињу у садашњости која мора бити осветљена, анализирана и разматрана. Факултет за примењени менаџмент, економију и финансије у циљу друштвено одговорног пословања и бриге за здравље због пандемије је организовао ове године конференцију само на основу пристиглих радова, без физичког присуства учесника. Међутим, аутори су показали заинтересованост и поред отежане ситуације и ширења вируса *Covid 19*, а и број пристиглих радова је потврда тога. Управо су утицај и последице ширења вируса елаборирани и истраживани у више радова и то из различитих углова: туризма, дигиталне трансформације рада и радног окружења, пољопривреде, иновативног сектора, затим са медицинског аспекта који је иманентан епидемији. Поред тога, анализиране су социо-економске последице вируса, утицај на менаџмент, али и на трговински биланс у Европској унији, као и комуникацију у малопродаји. Овај списак у тематском смислу допуњују и луксузна индустрија и технологија индустрије 4.0. Овако свеобухватан тематски аспект је доказ да се иде у корак са временом. То даље имплицира да су иновације свуда око нас.

Та парадигма разноликости коју иновација носи, намеће и потенцира даљи тематски спектар који је присутан међу радовима. Дакле, није само утицај и последице корона вируса заокупљао пажњу учесника, већ су их инспирисали и други аспекти и проблематика.

Примерено теми „Иновације као покретач развоја“ и циљу научног скупа установљене су две сесије: I сесија: Иновације у функцији развоја (Тематски зборник) и II сесија: Иновацијама до пословног успеха (Зборник радова са међународног скупа). Избор теме скупа и свеприсутност иновација, као и понуђени већи број тематских области утицао је да су у овим публикацијама радови многих угледних универзитетских професора, истакнутих истраживача, експерата и научних радника, како из Србије, тако и из иностранства.

Зборници радова са међународног скупа, као резултат конференције, су у форми дигиталне едиције и биће доступни широј научној јавности. Публиковани радови у овим зборницима значајно доприносе утврђивању нераскидиве везе између иновација и развоја. Истовремено смо тиме показали да подручје иновација дефинитивно више није везано само за техничко – технолошки прогрес. У складу са тим, радови могу бити корисни како научној, тако и стручној јавности и свим заинтересованим за утицај иновација на развој.

Београд, Уредници

Децембар, 2020. Др Дарјан Карабашевић

Др Светлана Вукотић

Др Габријела Поповић

FOREWORD

This year, as well as the previous five, innovations are our driver of development and an occasion to make a new contribution to this inexhaustible and challenging topic. Nurturing tradition imperatively obliges us to be better for each new conference in terms of the quality of papers, their number, and breadth. At the same time, changed life circumstances impose the topicality of the moment. Innovations both mark and generate the future, but they begin in the present that must be illuminated, analyzed, and considered. Faculty of Applied Management, Economics and Finance, for the purpose of socially responsible business and health care due to the pandemic, organized a conference this year only on the basis of the submitted papers, without the physical presence of the participants. However, the authors showed interest despite the difficult situation and the spread of the Covid 19 virus, and the number of papers received is a confirmation of that. The impact and consequences of the spread of the virus have been elaborated and researched in several papers from different angles: tourism, the digital transformation of work and work environment, agriculture, innovation sector, then from the medical aspect that is immanent to the epidemic. In addition, the socio-economic consequences of the virus, the impact on management, but also on the trade balance in the European Union, as well as retail communication, were analyzed. This list is thematically complemented by the luxury industry and Industry 4.0 technology. Such a comprehensive thematic aspect is proof that we are keeping up with the times. This further implies that innovation is all around us.

This paradigm of diversity that innovation carries, imposes, and emphasizes the further thematic spectrum that is present among the articles. Thus, not only did the impact and consequences of the coronavirus capture the attention of the participants, but they were also inspired by other aspects and issues.

Appropriate to the topic "Innovation as the initiator of development" and the goal of the scientific conference, two sessions were established: Session I: Innovations in the function of development (Thematic Proceedings – Thematic Monograph) and Session II: Innovations as the key to business success (International conference proceedings). The choice of the topic of the meeting and the ubiquity of innovations, as well as the offered number of thematic areas, influenced the works of many eminent university professors, prominent researchers, experts, and scientists, both from Serbia and abroad.

Proceedings of the international conference, as a result of the conference, are in the form of a digital edition and will be available to the general scientific public. The papers published in these collections significantly contribute to establishing the unbreakable link between innovation and development. At the same time, we have shown that the field of innovation is definitely no longer related only to technical - technological progress. Accordingly, the papers can be useful to both the scientific and professional public and all those interested in the impact of innovation on development.

Belgrade, Editors

December, 2020 Darjan Karabašević, PhD

Svetlana Vukotić, PhD

Gabrijela Popović, PhD

САДРЖАЈ / CONTENT:

РАДОВИ СА КОНФЕРЕНЦИЈЕ

CONFERENCE PAPERS

РАДОВИ СА КОНФЕРЕНЦИЈЕ

CONFERENCE PAPERS

Modified artificial bee colony algorithm applied to multilevel image thresholding

Ivona Brajević[1], Miodrag Brzaković[2], Dušan Rajčević[3]

[1] *Faculty of Applied Management, Economics and Finance, Business Academy University, Jevrejska 24, 11000 Belgrade, Serbia, ivona.brajevic@mef.edu.rs*
[2] *Faculty of Applied Management, Economics and Finance, Business Academy University, Jevrejska 24, 11000 Belgrade, Serbia, miodrag.brzakovic@mef.edu.rs*
[3] *Faculty of Applied Management, Economics and Finance, Business Academy University, Jevrejska 24, 11000 Belgrade, Serbia, dusan@mef.edu.rs*

Abstract: Multilevel image thresholding is a widely used image segmentation technique. High computational cost of an exhaustive search for the optimal thresholds leads to the use of metaheuristic optimization algorithms to set the optimal thresholds. In this paper a new multilevel thresholding method based on a modified artificial bee colony (MABC) algorithm is proposed. The optimal thresholds are found by maximizing Kapur's thresholding function. Artificial bee colony (ABC) algorithm is also implemented and compared to our proposed method. Both algorithms have been tested on standard benchmark images. The experimental results obtained by our proposed MABC method have been found to be better than those obtained by ABC algorithm.

Keywords: maximum entropy thresholding, image thresholding, artificial bee colony algorithm, nature inspired metaheuristics

1. INTRODUCTION

Image segmentation is the process of partitioning an image into non-overlapping, homogenous regions containing similar objects. The goal of segmentation is to simplify the representation of an image into something that is more meaningful and easier to analyse. The problem of digital image segmentation is an important research field and some practical applications include: computer vision (Heikkonen & Mantynen, 1996), recognition tasks (Zhang et. al., 2008), medical imaging (Li et. al., 2017) etc. Thresholding is one of the most widely used approaches for performing image segmentation. It tries to identify and extract a target from its background based on the distribution of grey levels or texture in image objects. If the image is split into two classes, such as the background and the object of interest, it is called bi-level thresholding. Bi-level thresholding is extended to multilevel thresholding to get more than two classes.

The global thresholding methods select thresholds by maximizing or minimizing some criterion functions defined from images. Among the enormous amount of image thresholding techniques, entropy-based approaches have interested many researchers. Computational inefficiency of the traditional exhaustive methods leads to the use of metaheuristic algorithms to set the optimal thresholds. In (Yin, 2007) a new method that adopts the particle swarm optimization (PSO) algorithm to select the thresholds based on the minimum cross-entropy is proposed. Horng employed the honey bee mating optimization (HBMO) (Horng, 2009) and the firefly algorithm to search for the thresholds using the maximum entropy criterion (Horng & Jiang, 2010). The efficiency of the artificial bee colony (ABC) algorithm in solving multilevel thresholding problem was investigated in (Akay, 2013). The experimental results obtained on standard test images showed that the ABC can produce comparable or better performance with respect to PSO algorithm.

In this paper, the modified artificial bee colony (MABC) algorithm recently proposed with the aim to enhance the performance of the ABC for integer programming problems (Brajević & Brzaković, 2018) is adopted and applied to solve multilevel thresholding problem. The MABC employs two different modified ABC search equations in employed and onlooker phases, with the aim to enhance the exploitation ability of both phases. This paper employs the MABC algorithm to search for the multilevel thresholds using the maximum entropy criterion. The basic ABC algorithm is implemented for purposes of comparison. In addition, the exhaustive search method is conducted for deriving the optimal solutions for comparison with the results generated from ABC and MABC methods.

The rest of the paper is organized as follows. Section 2 introduces the ABC algorithm. Section 3 presents the multilevel thresholding using MABC algorithm. Comparative results of the implemented ABC and MABC algorithms are presented in Section 4.

2. A BRIEF INTRODUCTION OF ABC ALGORITHM

The ABC algorithm is a metaheuristic technique based on the foraging behavior of honeybees for numerical optimization problems (Karaboga, 2005). A swarm of artificial bees include employed bees, onlooker bees and scouts. Employed bees are all bees that are currently exploiting a food source, meanwhile they share their information about food sources with the onlooker bees. Onlookers select good food sources from those found by the employed bees and further search the foods around the selected food sources. Employed bees that leave their food sources to search for new ones become scout bees. In the ABC algorithm usually one half of the population of artificial bees consists of the employed bees, while the other half include the onlookers and scouts. The framework of the ABC algorithm is given as follows:

Initialization Phase
REPEAT
  Employed Phase
  Onlooker Phase
  Scout Phase
  Memorize the best solution achieved so far
UNTIL (Cycle = Maximum Cycle Number (*MCN*))

In the ABC algorithm there are three control parameters: the maximum cycle number (*MCN*), the size of the population which is equal to the sum of numbers of employed and onlookers (*SP*), the *limit* which represents the number of trials for releasing food source. In the initialization phase of the ABC, the population of solutions is generated randomly in the search space.

In the employed phase, every solution i, i =1, 2,…,*SP* is updated by:

$$v_{ij} = x_{ij} + \varphi_i\left(x_{ij} - x_{kj}\right), \quad (1)$$

where x_{ij} denotes the jth parameter of x_i, j is a random index, φ_i is a uniform random number in range (-1,1), x_k represents the other solution selected randomly from the population. The update process is ended when the greedy selection is applied between x_i and v_i.

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In the onlooker phase, the solutions which will be subjected to the update process are chosen according to the fitness proportionate selection. The update process in this phase is the same as in the employed phase. In the scout phase, a solution that does not change over a certain number of trials is again randomly generated in the search space.

Nowadays the ABC algorithm represents one of the most prominent metaheuristic algorithms due to its successful performance. There are numerous ABC variants for solving numerical optimization problems, as well as the extended ABC versions also have been described for the discrete and combinatorial types of problems (Karaboga et al., 2014; Brajević and Ignjatović, 2019; Brajević et al., 2020).

In this paper, the recently proposed modified artificial bee colony (MABC) for integer programming problems is adopted to solve multilevel image thresholding problem (Brajević & Brzaković, 2018).

The MABC introduces additional control parameter called modification rate *MR* and uses modified search strategies in employed and onlooker phases. The search equation used in the employed bee phase of the MABC is given as follows:

$$v_{ij} = \begin{cases} x_{ij} + \varphi_i (x_{ij} - x_{kj}), & \text{if} \quad R_j \leq MR \\ x_{ij}, & \text{otherwise} \end{cases} \tag{2}$$

where φ_i is a uniform random number in range (-1, 1), x_k represents the other solution selected randomly from the population, R_{ij} is a randomly chosen real number in range (0,1), and $j = 1,2...D$. The introduced control parameter *MR* controls possible modifications of optimization parameters and it can take value between 0 and 1.

The search equation used in the onlooker bee phase of the MABC is inspired by the variant of the ABC proposed to solve numerical optimization which is presented in (Zhu G. & Kwong S., 2010). It is given as follows:

$$v_{ij} = \begin{cases} x_{ij} + \varphi_{ij} (x_{ij} - x_{kj}) + \omega_{ij} (y_j - x_{kj}), & \text{if} \quad R_j \leq MR \\ x_{ij}, & \text{otherwise} \end{cases} \tag{3}$$

where φ_{ij} is a uniform random number in range (-1, 1), w_{ij} is a uniform random numbers in range (0, 1.5), x_k represents the other solution selected randomly from the population, y_j is the *j*th element of the global best solution, R_{ij} is a randomly chosen real number in range (0,1), and $j = 1,2...D$.

3. PROPOSED APPROACH

The proposed algorithm has two phases. The first phase implies generating the objective function based on image entropy. The second phase introduces the MABC algorithm for multilevel image thresholding.

3.1. Entropy criterion method

The multilevel thresholding problem can be defined as a k-dimensional optimization problem, for determination of k optimal thresholds $[t_1, t_2, ..., t_k]$ which optimize an objective function. Entropy criterion method is proposed to perform bi-level thresholding (Kapur et al., 1985). This method considers the image foreground and background as two different signal sources. The image is optimally thresholded when the sum of the two class entropies reaches its maximum. Therefore, the goal is to find the optimal threshold yielding the maximum entropy. Kapur has proposed the algorithm for bi-level thresholding, which can also extend to solve multilevel thresholding problems. It can be presented as follows.

Let there be L gray levels in an image I which has M pixels and these gray levels are in the range $\{0,1, \ldots L-1\}$. The Kapur's objective function is determined from the histogram of the image, denoted by $h(i)$, $i = 0,1 \ldots L-1$, where $h(i)$ represents the number of pixels having the gray level i. The normalized probability at level i is defined by the ratio $P_i = h(i)/M$. The goal is to maximize the objective function:

$$f([t_1, t_2, \ldots, t_k]) = H_0 + H_1 + H_2 \ldots + H_k, \tag{4}$$

where

$$H_0 = -\sum_{i=0}^{t_1 - 1} \frac{P_i}{w_0} ln \frac{P_i}{w_0}, w_0 = \sum_{i=0}^{t_1 - 1} P_i,$$

$$H_1 = -\sum_{i=t_1}^{t_2 - 1} \frac{P_i}{w_1} ln \frac{P_i}{w_1}, \ w_1 = \sum_{i=t_1}^{t_2 - 1} P_i,$$

$$H_2 = -\sum_{i=t_2}^{t_3-1} \frac{P_i}{w_2} ln \frac{P_i}{w_2}, w_2 = \sum_{i=t_2}^{t_3-1} P_i, \ldots$$

$$H_k = -\sum_{i=t_k}^{L-1} \frac{P_i}{w_k} ln \frac{P_i}{w_k}, w_K = \sum_{i=t_k}^{L-1} P_i$$

3.2. Image thresholding based on MABC

Our proposed MABC algorithm based on maximum entropy criterion aims to provide this optimum *k*-dimensional vector $[t_1, t_2, ..., t_k]$ which can maximize Eq.(3). The objective function is also used as the fitness function for the proposed approach. The details of the developed algorithm are introduced as follows.

Step 1. (Create the initial population of solutions)

The MABC algorithm creates a randomly distributed initial population of *SP* solutions x_i $(i = 1, 2, ..., SP)$ with *k* dimensions denoted by matrix *X*,

$$X = [x_1, x_2, \ldots x_N] \text{ and } x_i = (x_{i,1}, x_{i,2}, \ldots x_{i,K}), \quad (5)$$

where x_{ij} is the *j*th component value that is restricted into [0,…,*L*-1] and the $x_{ij} < x_{ij+1}$ for all *j*. The fitness values of all solutions x_i are evaluated, the parameter *cycle* is set to 1 and the *trail* number of each solution is set to 0.

Step 2. (Employed phase)

In this step, each employed bee produces a new solution v_i by using Eq. (2). Then the new solution is evaluated. If the objective function value of the new candidate solution is higher than that of the previous one x_i, memorize the new solution and forget the old one. Otherwise the old solution is kept.

Step 3. (Onlooker phase)

In this step, we first calculate the the probability values pv_i for solutions x_i $(i = 1, 2, ..., SP)$ by using the following equation:

$$pv_i = 0.1 + 0.9(fit_i/maxfit) \quad (6)$$

where *maxfit* is the best fitness value of the population and fit_i is the fitness value of the *i*th solution in the population. Then, we generate new solutions v_i for the onlooker bees from the solutions x_i selected depending on pv_i by using the Eq. (3), evaluate them and apply the greedy selection process.

Step 4. (Scout phase)

If the solution x_i is not enhanced through Steps 2 and 3, the *trail* value of solution x_i will be increased by 1. In this phase, the solution with the highest *trail* value that exceeds predetermined *limit* value (if such solution exists) is replaced with a new randomly generated solution.

Step 5. (Record the best solution)

Memorize the best solution so far, i.e. the solution vector with the highest objective function value.

Step 6. (Check the termination criterion)

If the *cycle* is equal to the maximum cycle number *MCN* then finish the algorithm, else go to Step 2.

4. EXPERIMENTAL STUDY

In this study the proposed MABC algorithm was compared against the basic ABC metaheuristic method. The tests were done on four standard images where the optimal multilevel threshold values were searched for. The exhaustive search method was conducted first to derive the optimal solutions for comparison with the results generated by the ABC and MABC algorithms.

Figure 1. *Test images: (a) Barbara, (b) Living room, (c) Boats, (d) Goldhill.*

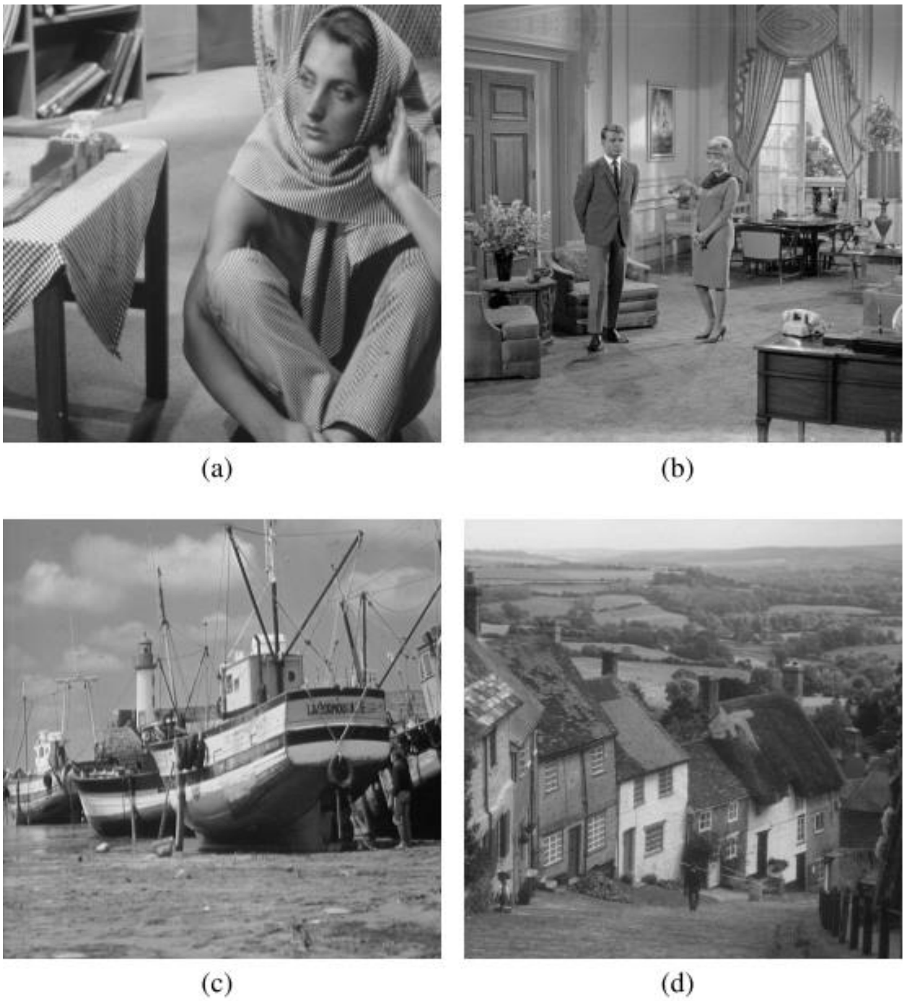
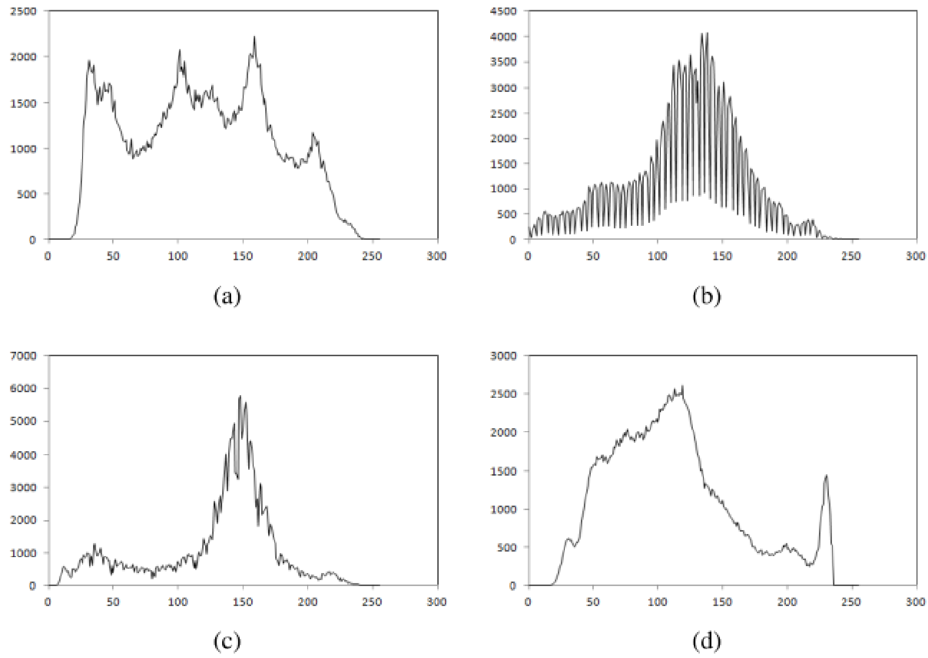


Figure 2. *Gray-level histograms of test images: (a) Barbara, (b) Living room, (c) Boats, (d) Goldhill.*



Both algorithms have been implemented in Java programming language on a PC with Intel(R) Core(TM) i7-3770K 4.2GHz processor with 16GB of RAM and Windows OS. Well-known images, namely Barbara, Living room, Boats and Goldhill with 256 gray levels are used as the test images. All the images are of size (512 x 512). These original images and their histograms are shown in Fig 1 and Fig 2.

The number of thresholds *k* explored in the experiments were 2−5 and each experiment were repeated 50 times for each image and for each *k* value. The run of each algorithm was stopped when the fitness value of the best solution $f(t*)$ reached the optimal value of the known objective function (f_{opt}), i.e. $|f(t*) - f_{opt}| \leq \varepsilon = 10^{-9}$, where ε is a threshold value which fixes the accuracy of the measurement. Therefore, the stopping criteria for the ABC and MABC is based on the value of the fitness and not of the maximum iteration number. In all experiments these algorithms use the same size of population of 40 and the maximum iteration number of 100. In addition, in the ABC and MABC the value of parameter *limit* was set to 50 and the value of parameter *MR* was set to 0.8.

Thresholds, objective function values and time processing provided by the exhaustive search is presented in Table 1. To analyze the solution quality of the ABC and MABC algorithms, the mean and standard deviations for 50 runs have been calculated and these results are presented in Table 2. Obtained mean values can be compared to the optimal values of the corresponding objective functions found by an exhaustive search. In addition, computational times for the algorithms have been analyzed. Table 3 presents the mean number of iterations and the average of the CPU time taken by each algorithm to satisfy the stopping condition.

Table 1. *Thresholds, objective function values and time processing provided by the exhaustive search for Kapur's method*

Image	k	Kapur		
		Threshold values	Objective function	Time (ms)
Barbara	2	96, 168	12.668336540	28
	3	76, 127, 178	15.747087798	1812
	4	60, 99, 141, 185	18.556786861	122087
	5	58, 95, 133, 172, 210	21.245645311	5647294
Living room	2	94, 175	12.405985592	40
	3	47, 103, 175	15.552622213	1949
	4	47, 98, 149, 197	18.471055578	135259
	5	42, 85, 124, 162, 197	21.150302316	5875781
Boats	2	107, 176	12.574798244	32
	3	64, 119, 176	15.820902860	2063
	4	48, 88, 128, 181	18.655733570	126690
	5	48, 88, 128, 174, 202	21.401608305	5840989
Goldhill	2	90, 157	12.546393623	23
	3	78, 131, 177	15.607747002	2097
	4	65, 105, 147, 189	18.414213765	110650
	5	59, 95, 131, 165, 199	21.099138996	5064697

From Table 2 it can be noticed that MABC algorithm performs equal or better than ABC algorithm both in terms of accuracy (mean fitness) and robustness (small standard deviation). The only exception is the case of image Living room for *k* = 2, where the ABC obtained better mean result and standard deviation value. The mean values obtained by MABC algorithm are close to optimal values provided by the exhaustive search and obtained standard deviations are low in all cases.

From the Table 1 it can be noticed that the computation time of exhaustive search method is exponential and for threshold number 4 it is not acceptable. The results from Table 3 indicate that for the ABC and MABC also the number of iterations and the run time increase with the threshold number, but not in the same manner.

Table 2. *Comparison of the mean values and standard deviations obtained from the ABC and MABC based on Kapur's entropy criterion for four test images over 50 runs*

Image	k	ABC		MABC	
		Mean value	St. Dev.	Mean value	St. Dev.
Barbara	2	**12.668337**	**5.32E-15**	**12.668337**	**5.32E-15**
	3	**15.747088**	**1.42E-14**	**15.747088**	**1.42E-14**
	4	18.556507	6.63E-4	**18.556783**	**1.39E-5**
	5	21.245036	1.08E-3	**21.245645**	**1.42E-14**
Living room	2	**12.405985**	**5.32E-15**	12.405952	9.97E-5
	3	**15.552622**	**1.06E-14**	**15.552622**	**1.06E-14**
	4	18.470996	3.01E-4	**18.471056**	**2.48E-14**
	5	21.144698	5.12E-3	**21.149825**	**1.18E-3**
Boats	2	**12.574798**	**1.42E-14**	**12.574798**	**1.42E-14**
	3	**15.820903**	**8.88E-15**	**15.820903**	**8.88E-15**
	4	18.655641	2.92E-4	**18.655729**	**3.42E-5**
	5	21.400693	2.21E-3	**21.401589**	**6.63E-5**
Goldhill	2	**12.546394**	7.11E-15	**12.546394**	**0**
	3	**15.607747**	1.42E-14	**15.607747**	0
	4	18.413758	5.73E-4	**18.414214**	**0**
	5	21.098357	8.34E-4	**21.099139**	**0**

Table 3. *Mean of the CPU times (in milliseconds) and mean of the iteration numbers obtained from the ABC and MABC based on Kapur's entropy criterion for four test images over 50 runs*

Image	k	ABC		MABC	
		Time (ms)	Iteration number	Time (ms)	Iteration number
Barbara	2	5.26	10.74	**4.02**	**5.7**
	3	11.18	38.9	**7.74**	**11.02**
	4	**15.28**	76.4	17.28	**37.3**
	5	**16.88**	90.64	18.78	**33.04**
Living room	2	**5.02**	15.08	10.54	28.96
	3	10.02	27.74	**7.44**	**12.96**
	4	13.92	57.44	**12.86**	**19.86**
	5	**22.08**	96.46	31.08	**48.72**
Boats	2	5.54	11.2	**3.4**	**6.72**
	3	6.16	27.02	**5.16**	**11.92**
	4	**15.84**	65.52	18.16	**36.46**
	5	**18.56**	81.08	22.82	**35.26**
Goldhill	2	5.74	12.04	**2.8**	**6.0**
	3	8.96	36.98	**6.2**	**11.6**
	4	17.5	86.16	**9.6**	**19.0**
	5	20.08	92.68	**15.6**	**25.4**

The computation times of the ABC and MABC are faster than those of the exhaustive search. By comparing the computational times for the MABC with respect to the ABC, it can be noticed that the computational times of these algorithms are not significantly different. From Table 3 it can be also observed that the MABC converges in less iterations compared to the ABC.

CONCLUSION

In this paper the modified artificial bee colony algorithm (MABC) for multilevel thresholds selection using the maximum entropy criterion is proposed. Compared to the basic ABC, the segmentation results show that the MABC algorithm performs better with respect to the solution quality and robustness. Experiments on the running times of the ABC and MABC show that both methods are suitably efficient and practical in terms of time complexity for high-dimensional problems. The segmentation results of the MABC are advantageous and encourage further research for applying it on complex image segmentation and recognition problems.

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