Noisy Image Segmentation Based On Genetic Artificial Bee Colony Algorithm

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Abstract— Segmentation of images is a very challenging problem due to the presence of noise in the images and its widespread usage and applications. In this paper we proposed the GABC-Genetic Artificial Bee Colony Algorithm which is a hybrid concept of Artificial Bee Colony and Genetic Algorithm used for solving segmentation problem. Here we add Genetic Algorithm with ABC Algorithm which improves the solution space. In GABC, threshold estimation is regarded as search procedure which finds an appropriate value in a continuous grey scale interval. In our proposed methodology, optimal threshold is searched with the help of ABC algorithm and the GA updates the solution space. For finding efficient fitness function for ABC algorithm the original image is decomposed using discrete wavelet transform after the definition of grey number in the Grey theory. Now the approximation image and gradient image is reconstructed with low frequency coefficients and high frequency coefficients respectively. Then a filtered image is produced with noise reduction to the approximation image. Therefore a co-occurrence matrix is constructed based on filtered image and gradient image. Then we define improved two-dimensional grey entropy which serves as the fitness function for GABC. And finally optimal threshold is rapidly discovered by the behavior of ABC operators in honey bee colony. Here the two operators of ABC, employed bees and onlooker bees are extended with genetic processes, crossover and mutation. Initially set of schedules are generated by the GABC algorithm which has to be evaluated against constraints and infeasible solutions has been resolved to feasible ones. And finally the algorithm iteratively improves the initial schedules until the termination condition is met. Artificial Bee Colony algorithm is used for global search strategy and the Genetic algorithm is used for local search strategy. The hybrid approach of GABC model can improve the result of ABC. The experimental result reveals that our GABC model can give a near to approximation and improved result and reach a broader domain in search space. It also improves both the computation time and precision and better than GA, ABC, PSO and AFS.

Keywords- ABC, Artificial Bee Colony, GA, Genetic Algorithm, PSO, Particle Swarm Optimization, AFS, Artificial Fish Swarm.

I. INTRODUCTION

Image segmentation has a very big role for noisy images. Noisy image segmentation is still a bit complicated task because of presence of noise in the images. There can be many types of noises like noise due to bad quality of camera, noise due to whether, noise due to unclear picture, noise due to blurriness and many more. Noise in the images produce a random variation of brightness, sharpness, contrast or any color information in images and is usually an aspect of electronic noise. Noise in the image can also be called as an undesirable by-product. In image segmentation, we classify or cluster an image into parts or regions. It is useful in many aspects. Segmentation is the operation between low-level image processing and image analysis. It is known that which pixel belongs to which object after segmentation. The image is parted into regions and the discontinuities are known as the boundaries between the regions. The different types of segmentations are pixel based segmentation, edge based segmentation and region based segmentation. Image segmentation is helpful in identifying the region of interest in a scene or annotates the data. A number of segmentation techniques have been developed and reported in the literature but there does not exist any algorithm that can perform the segmentation of all types of images in an excellent manner. Algorithms like Artificial Bee Colony Algorithm(ABC)[1], Particle Swarm Optimization(PSO)[2], Quantum Evolutionary Algorithm(QEA)[3], Genetic Algorithm(GA)[4], Fish Swarm Algorithm[5] etc. can be used for segmentation. These algorithms also provide good results for segmentation of noisy images but to improve the performance of algorithm we presented a hybrid approach of Genetic algorithm with ABC. Here we used the approach of segmentation based on grey levels which divides an image into several regions by some threshold and thus this issue is the case of threshold estimation problem [6]. Artificial Bee Colony Algorithm is usually adopted to increase the global search capacity as well as randomness of population. In our proposed algorithm, Genetic Algorithm is applied with ABC to increase the performance and adopt the local search strategy. This hybrid approach provides global optimization to the Artificial Bee Colony Algorithm.

The problem of global optimization arises in almost every field of science, business and engineering. Many algorithms have been developed to solve these problems [7] like GA, ACO, DE and PSO. A new kind of powerful optimization algorithm have been developed by Karaboga known as Artificial Bee Colony Algorithm [1, 8] used for optimization which simulates the foraging behavior of honey bee swarm. ABC has advantage that it employs fewer control parameters and can be applied to complex function optimization, robot path planning, parameter identification, job shop scheduling etc. Because ABC is quite simple it can also be applied to solve several real world problems like travelling salesman problem[9], clustering problem[10], inverse analysis problem[11], flow shop scheduling[12], minimum spanning tree problem[13] and so on. ABC usually seems to be a well effective and accomplished algorithm for the purpose of noisy image segmentation and estimate global threshold for image segmentation. In this approach we also combine the discrete wavelet transform with Grey theory to obtain improved two-dimensional grey entropy which is the fitness function for the ABC algorithm and acquire a reasonable foraging guide for the bee colony. However there are still some inefficiencies like slower convergence speed for some unimodal problems. It also certainly get trapped in local optima for some complex multi modal problems [14].

As we know that search method of ABC is good at exploration but poor at exploitation. Both the exploration and exploitation abilities must be involved for population based algorithm. These two are the contradicting abilities which should be well balanced to achieve good performance. To overcome these issues, we proposed the Genetic Artificial Bee Colony Algorithm (GABC), a new hybrid approach of Genetic and Artificial Bee Colony algorithm. In our proposed methodology we extend genetic algorithm with basic operators of ABC, the employed bees and the onlooker bees. We used here a hybrid approach because success of hybrid methods has roots in the fact that they have utilization capability of both algorithms. It also provides us the ability to use the advantage to relieve from the drawbacks of both algorithms. Several other hybrid methods are ANGEL [15], ACOSS [16], Neurogenetic [17], GA-Hybrid [18], etc.

The remainder of this paper is organized as follows: The next section introduces the basic Artificial Bee Colony Algorithm and its work mechanism. Section 3 introduces the Genetic Algorithm. Section 4 gives the definition of grey number in Grey theory and introduces improved two-dimensional grey entropy for threshold estimation. Then in section 5 our proposed Genetic Artificial Bee Colony Algorithm (GABC) is explained. In section 6 experiments and discussions are given and in section 7 conclusions are given. And lastly in section 8 references are given.

II. ARTIFICIAL BEE COLONY ALGORITHM

Artificial Bee Colony Algorithm based on swarm intelligence based optimization algorithm proposed by Karaboga in 2005[19] which simulates the foraging behavior of honeybee colony [20]. The ABC algorithm consists of the following steps:

Initialization

Repeat

Stage 1: place employed bees on their food sources in the memory.

Stage 2: place the onlooker bees on their food source depending on their nectar amount.

Stage 3: send the scouts to the search area for discovering new food sources.

Stage 4: memorize the best food source found so far above.

Until (requirements are met)

In Artificial Bee Colony algorithm, the colony consists of 3 kinds of bees: employed bees, onlooker bees and scout bees. Employed bees explore the food source and gather information about the food source and its quality then sends this information to the onlooker bees. The onlooker bee chooses food source to exploit and decide which food source is better. This bee also perform global search. Scout bee which is one of the employed bees whose food source are abandoned carry random search for food and discover new area which are uncovered by employed bees to find new food source. In ABC the position of food source represents the possible solution to the optimization problem and nectar amount of food source corresponds to the quality of solution.

Let SN food source position (solution) is generated. Here SN also denotes the size of employed bees or onlooker bees. The position of i^{th} food source can be represented as x_i (i=1,2,…..SN) which is a D- dimensional vector. Here D is the number of optimization parameter. Depending on the probability values associated with food source, the onlooker bees chooses a food source as,

$$P_i=\frac{\text{fitness i}}{\sum_{i=1}^{SN}\text{fitness i}} \quad (1)$$

where fitness i is the fitness of i^{th} food source. The ABC algorithm defines i_{th} fitness value $fitness_i$ as,

$$fitness_i=\begin{cases}\frac{1}{1+fi}\\ 1+abs(fi)\end{cases} \quad (2)$$

Candidate food source position from old one in memory can be generated as,

$$v_{ij}=x_{ij}+\Phi_{ij}(x_{ij}+x_{kj}) \quad (3)$$

where k={1,2,……,SN} and $j\epsilon\{1,2,\ldots,D\}$ are randomly chosen indexes. $\Phi_{ij}\epsilon$ [-1, 1] is a random number. The comparison between v_i and x_i positions is done and the remaining one is a better solution. If the food source is abandoned by bees, the old food source is replaced with a new food source by the scout bees which exploit it with the new one as,

$$x_{ij}=x_j^{min}+rand(0,1)(x_j^{max}-x_j^{min}) \quad (4)$$

where x_i is abandoned source, $j\epsilon\{1,2,\ldots,D\}$, x_j^{min} and x_j^{max} are the lower and upper bounds of j^{th} dimension of problem space.

Form the above study, it shows that ABC is a well-suited and well-performed algorithm for various optimization problems and also for segmentation of images, there are still some limitations. For some problems, convergent speed of ABC is quite slower. It is also not well suited for some complex multimodal problems as it get slowly trapped in local optima. To overcome this limitation issues, a hybrid approach of Genetic ABC is proposed in 5^{th} section.

III. GENETIC ALGORITHM

Genetic Algorithms are invented by John Holand in 1960's [21] and were developed by Holland and his students and colleagues at the University of Michigan in 1960's and 1970's [21]. Genetic Algorithm is a method for moving from one population of chromosomes (e.g. strings of one's or zeros, or "bits") to a new population by a kind of natural selection together with the genetics inspired operators of crossover, mutation and inversion. Genetic Algorithms are robust heuristic search algorithm which postulates the evolutionary ideas of natural selection and genetic. Genetic Algorithm has its use in various engineering fields and has verified optimization performance in the literature [22].

The simplest form of Genetic Algorithm involves three types of operators: selection, crossover and mutation. The selection operator selects chromosomes in the population for reproduction. It is an artificial version of natural selection. The crossover operator is used for production of two offspring. It randomly chooses a spot and exchanges the subsequences before and after that spot between the two chromosomes. The task of mutation operator is to flip randomly some of the bits in chromosomes.

There are many kinds of crossover operators like simple crossover [23], multi crossover, arithmetical crossover [24], BLX-CY crossover [25] and modified simple crossover [26]. Mutation is the unary operator having capability to change genes in a chromosome. Various kind of mutation operators are uniform mutation [24], real number creep mutation [27], dynamic mutation [28] and Miihlenbein mutation etc.

IV. IMPROVED TWO-DIMENSIONAL GREY ENTROPY

A. GREY NUMBER IN GREY THEORY

An effective mathematical method for solving problems like uncertainty and indetermination developed by Deng in 1982 called as Grey theory [29]. It's a multidisciplinary and generic theory that is designed to deal with systems containing poor information. Grey theory, the random process is treated as grey process within certain range and a random variable is regarded as a grey number.

Definition : A grey number can be defined as an unknown value in an interval with known lower and upper bounds of x, where x denote a closed and bounded set of real numbers.

$$\overline{\otimes}x \ \epsilon \ [\underline{\otimes}x, \overline{\otimes}x]$$

where $\underline{\otimes}x$ and $\overline{\otimes}x$ are lower and upper bounds of x respectively.

B. IMPROVED TWO DIMENSIONAL GREY ENTROPY

According to the above definition, segmentation threshold is a number is a grey number x whose exact value is unknown but the range of value is known. Concerning 256 grey level images, lower bound and upper bound are 0 and 255 respectively. So the grey number for segmentation threshold can be expressed as:

$$x=[0,255]=[x'|0\leq x'\leq 255]$$

The segmentation threshold is regarded as "grey number" and segmentation process as "grey process". Now after transforming the original image into the wavelet domain using an orthogonal periodic wavelet transform, two types of image are reconstructed. The first one is an approximation image reconstructed with low frequency coefficient containing approximation information and the second one is the gradient image reconstructed with high frequency coefficients at the highest level containing edge and texture information. These two images form a co-occurrence matrix based on which two-dimensional grey entropy is established. The grey entropy unlike traditional entropies [30] is able to suppress noise disturbance to some extent.

To avoid the influence of speckle noise in image segmentation, we replace the approximation image with filtered image to get a new version of grey entropy which can be obtained using the following steps:

1) Original image is decomposed into several sub bands using three levels Discrete Wavelet Transform (DWT). Then at the third level, reconstruct the approximation and gradient image with low frequency and high frequency coefficients respectively. The approximation image and gradient image reflects the approximation and edge and texture information respectively. Most of the noise is greatly suppressed in the two reconstructed images.
2) Obtain a filtered image by dealing the approximation image by a low pass filter. Again noise reduces in the filtered image.
3) Normalizing the filtered image I and gradient image G to [0,255] by

$$I(m,n)=round(abs(\frac{I(m,n)}{\max(I(m,n))}x(L-1))) \quad (5)$$

$$G(m,n)=round(abs(\frac{G(m,n)}{\max(G(m,n))}\ x\ (L^{'}-1))) \quad (6)$$

where round() is an operator to get integer format, abs() is an operator to get absolute value, max(I(m,n)) and max(G(m,n)) corresponds to the maximum value in I and G respectively. $L=L^{'}=256$ stands for the number of the grey scales in the two normalized images.

4) Now construct a co-occurrence matrix $C=[c_{ij}]_{LxL^{'}}$, where c_{ij} stands for the number of pixel pairs satisfying I(m,n)=i *and* G(m,n)=j. So, p_{ij} that denotes the probability of c_{ij} in the matrix can be computed by :

$$P_{ij}=\frac{c_{ij}}{\sum_{i=0}^{L-1}\sum_{j=0}^{L^{'}-1}c_{ij}} \quad (7)$$

5) Let (s,t) be the pair of threshold where s is a threshold of I and t is a threshold of G, then (s,t) will divide the matrix C into four quadrants, i.e., Q_1, Q_2, Q_3 and Q_4 as shown in figure 1.

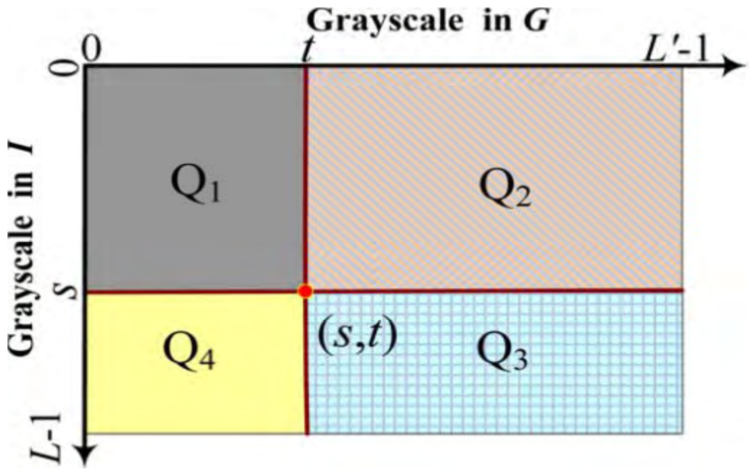

Figure 1. Filtered-Gradient co-occurrence matrix showing position of (s,t)

Now let us suppose that Q_1 and Q_4 denote objects and backgrounds respectively, or we can also say that there are some dark objects in bright surroundings. The grey scale values of most pixels are even similar or mostly the same either in Q_1 or Q_4, while their gradient values are very small. On the other hand, Q_2 and Q_3 stand for the edge and texture in object regions and background regions. Their conditional entropies can be computed as [31]:

$$H(E|O)= -\sum_{i=0}^{s}\sum_{j=t+1}^{L^{'}-1}p_{ij}^{Q_2}\log_2 p_{ij}^{Q_2} \quad (8)$$

$$H(E|B)= -\sum_{i=s+1}^{L-1}\sum_{j=t+1}^{L^{'}-1}p_{ij}^{Q_3}\log_2 p_{ij}^{Q_3} \quad (9)$$

According to the two-dimensional conditional entropy, we found (s,t) is the best position to segment I and G, when the difference between objects and backgrounds reaches the biggest value. As their values are unknown and bounds are specified as [0,255], both s and t are the grey numbers. And thus the improved two-dimensional grey entropy can be given as [31]:

$$H_{grey}(s,t) = \frac{1}{2}(H(E|O) + H(E|B)) = \frac{1}{2}\left[\left(-\sum_{i=0}^{s}\sum_{j=t+1}^{L'-1} p_{ij}^{Q_2}\log_2 p_{ij}^{Q_2}\right) + \left(-\sum_{i=s+1}^{L-1}\sum_{j=t+1}^{L'-1} p_{ij}^{Q_3}\log_2 p_{ij}^{Q_3}\right)\right] \quad (10)$$

where

$$p_{ij}^{Q_2} = \frac{c_{ij}}{\sum_{i=0}^{s}\sum_{j=t+1}^{L'-1} c_{ij}},$$

$$p_{ij}^{Q_3} = \frac{c_{ij}}{\sum_{i=s+1}^{L-1}\sum_{j=t+1}^{L'-1} c_{ij}},$$

L=L'=256.

Form the above, we found that once the value of formula (10) is maximum one, its corresponding (s,t) value will be the best pair of thresholds. Now to increase the speed of the whitening process of grey numbers (s,t), we adopt the hybrid optimization algorithm, namely, GABC in the next section.

V. GENETIC ARTIFICIAL BEE COLONY ALGORITHM FOR IMAGE SEGMENTATION

The details of our proposed hybrid GABC algorithm are presented in this section. Here we extend ABC with GA to include the effect of hybridization in the problem space and called it as GENETIC ARTIFICIAL BEE COLONY ALGORITHM. The Genetic Artificial Bee Colony Algorithm for noisy image segmentation can be diagrammatized in figure 2.

In the proposed algorithm, initially the algorithm concerns the global threshold estimation as a search procedure. Hence it chooses ABC for finding optimal threshold and gives a hybridization of GA with ABC to get a better updated solutions or thresholds. At the beginning ABC generates some random schedules, and then evaluates them. But solutions are feasible and infeasible, so initial solutions have to be improved iteratively. This can be done by hybridization of Artificial Bee Colony Algorithm and Genetic Algorithm. Genetic Algorithm updates the schedules produced by the ABC. The ABC acts as a global search while GA acts as a local search.

Algorithm: GABC algorithm

1. The original image is decomposed with a three-level DWT. Now an approximation image and a gradient image are reconstructed.
2. Now a filtered image I is obtained by passing the approximation image to a low pass filter (a circular averaging filter).
3. Normalizing the gradient image and filtered image to [0,255] using (5) and (6) to construct a 256x256 filtered gradient co-occurrence matrix C which gives the improved two-dimensional grey entropy.
4. Now this two-dimensional grey entropy can be treated as the fitness function for the ABC algorithm.
5. Set control parameters for the algorithm including population size, maximum number of iterations, limit times for abandonment etc.
6. Initialize the food source (thresholds) randomly with m solutions in an n-dimensional vector space, n represents the activities to be scheduled.

   $x_i = (x_{i1}, x_{i2}, \ldots, x_{in})$ where $0 <= x_{ij} <= 1$

   $\& \; j \in (1, 2, \ldots, n)$
7. Start ABC phase with set of feasible and infeasible schedules.
   a. ABC phase use feasible solution to compute feasible boundaries of activities.
   b. Search for a new food source for employed bees, i.e. , send employed bees and find the fitness values according to (1).
   c. Send onlookers bees for updating the solution and calculating the quality of food according to (3).
   d. Start boundary checking module to maintain the priorities of activities in feasible range.
   e. Send the scout bees, stagnant solutions are determined and new random solutions (populations) are produced.
   f. Call constraint handling module so infeasible solutions are resolved to the feasible ones.

8. Resulting schedules are passed to GA phase.
   a. Start GA phase which updates the output of ABC phase using operators, crossover and mutation.
   b. Initially defined percentages of schedules are selected as parents to perform crossover operation.
   c. Children generated by crossover are compared against their parents. If performance of children is better than their parents, then children replaces their parents by removing them adding themselves to the population.
   d. Crossover succeeds mutation.
9. Updated solutions by GA phase are returned back to the ABC phase and iterated cycle by cycle until complete termination condition is met.
10. Now the best solution or whitened grey numbers (s,t) are returned.
11. Finally segmenting the filtered image with s and getting a segmented image.

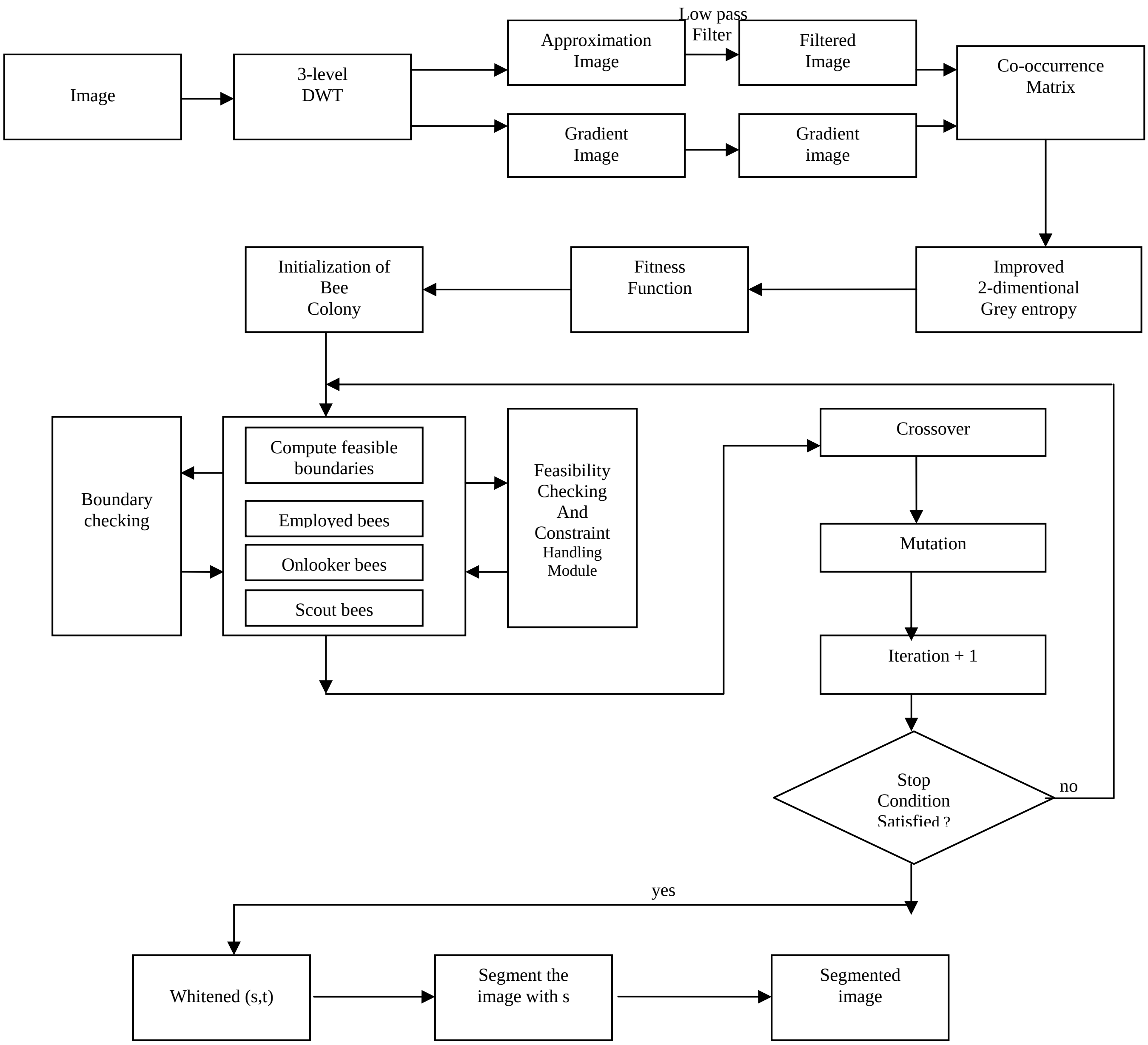

Figure 2. Image Segmentation Method Based on GABC

VI. EXPERIMENTS AND DISCUSSIONS

Our proposed algorithm, the GABC is good agreement utilizing the performance of both ABC and Genetic Algorithm. A set of experiments has been conducted which defines the performance of genetic artificial bee colony (GABC) hybridization algorithm and also gives a comparisons with ABC algorithm used for segmentation. In general, ABC method has good performance on various optimization problems and opted as a good segmentation method for various types of images. ABC has the ability to integrate with various algorithms such as GA, PSO, DE, etc. In our proposed work, ABC is integrated with GA and a new method called as GABC is emerged in order to provide more efficiency in solving hard segmentation problems. This method utilizes the efficiency of both GA and ABC algorithm so as to provide better output compared to ABC and other bee algorithm. Here the basic objective is to study the effect of Genetic Algorithm over ABC algorithm. For this purpose a set experiments has been conducted to evaluate the performance of our proposed algorithm over ABC algorithm.

A. EXPERIMENTAL SETUP

There are some control parameters for every algorithm used for its efficient working. So there are also some control parameters for our Genetic Artificial Bee Colony Algorithm. A set of literature survey has been carried out and the standard values of control parameters are used in this experiment which is suitable for the experiment. The list of control parameters are shown below in table 1.

PARAMETER	**VALUES**
No. of bees	10,20,etc.
Dimension	2
Iteration	100,90,……etc
Probability	0.5
Runs	2,1

The value of control parameters can vary depending on the experiment taken. Here we can change the value of no. of bees. The parameter dimension will always remain 2 because the threshold value of the algorithm is in 2-dimention (s,t). Iterations can also be changed for getting different set of values or threshold. The probability value of 0.5 is used as an standard value but we can also change it as per the convenience of the experiment. We get different values of threshold and a comparative performance between GABC and ABC algorithm by changing parameter values and analyzing them.

B. EXPERIMENTAL RESULTS

In this section the results of our experiment is analyzed. Here we test the efficiency of our GABC algorithm by comparing the results of our algorithm with Artificial Bee Colony Algorithm. We can give a comparison between our experiment which preprocesses the noisy image to a grey image using the concept of 2-dimensional grey entropy. The figure 3 gives a comparison on segmentation performance by method and ABC algorithm by looking over the figure 3 and 4. In our study to test the efficiency of our method experiments are conducted by changing the values of parameter no. of iteration and applied to both the ABC and our method of segmentation.

(a) (b) (c)

Figure 3.Comparison on segmentation performances. (a) Original image. (b) Segmented grey image of (a) by our method. (c) Segmented image of (a) by ABC algorithm.

Here in this experiment, we found that every time we apply segmentation on the image a grey segmented image is produced. It is clear from fig 4 that every time during segmentation our method gives more efficient performance than the ABC. Also form table 2 we find that our method takes less elapsed time to reach to the threshold value than ABC algorithm.

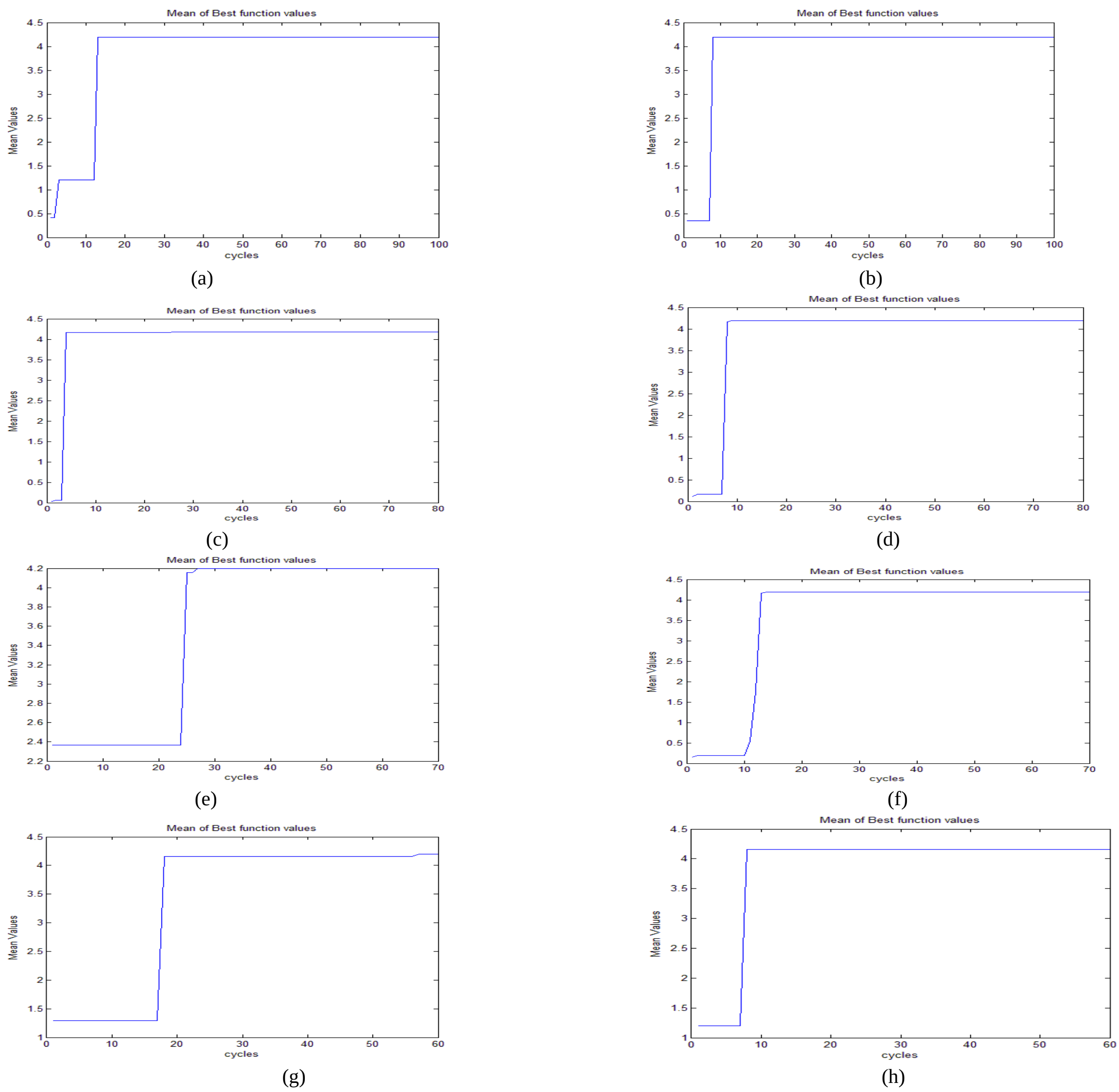

Figure 4.Comparison of mean of best values (threshold value) for GABC and ABC algorithms. (a) Mean value for ABC algorithm with 100 iterations. (b) Mean value for our algorithm (GABC) with 100 iterations. (c) Mean value for ABC algorithm with 80 iterations. (d) Mean value for GABC algorithm with 80 iterations. (e) Mean value for ABC algorithm with 70 iterations. (f) Mean value for GABC algorithm with 70 iterations. (g) Mean value for ABC algorithm with 60 iterations. (h) Mean value for GABC algorithm with 60 iterations.

VII. CONCLUSION

A new method called as Genetic Artificial Bee Colony Algorithm for segmentation of noisy images has been proposed in the present work. This method utilizes the potential capability of both GA and ABC algorithm by hybridizing both the methods. The method has the capability to initially update the arrangements using an adaptive search technique or decision making capability. The GABC method iteratively updates initial arrangements of activities using integration of both GA and ABC in two phases for each cycle. Our GABC algorithm will possess superior performance in terms of speed, stability, accuracy and robustness as compared to ABC. It is also an effective and adequate algorithm as it employs the use of improved two-dimensional grey entropy. We can use our GABC algorithm for many other problems like travelling salesman problem [26], global numerical optimization, complex real world problems, resource constraint project scheduling problems and many more. As seen from fig 4 and table 2 we can also conclude that our method will also perform segmentation in less elapsed time than ABC with better threshold and standard deviation.

Table 2. Comparison on elapsed time and threshold based on fig 4.

No of iterations	Method	Mean of best values	Threshold value (s,t)	Elapsed time(in seconds)
100	GABC	4.19313	(165,1)	13.39801
100	ABC	4.19066	(153,1)	13.75454
80	GABC	4.18842	(157,1)	8.858617
80	ABC	4.18771	(155,1)	10.391827
70	GABC	4.18368	(148,1)	7.904142
70	ABC	4.17612	(161,1)	9.818184
60	GABC	4.19815	(16O,1)	6.907508
60	ABC	4.19183	(166,1)	9.075529

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