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A Literature Review of Bee Colony Optimization Algorithms.

Rishabh Gulati,
HMR Institute of Technology & Management,
New Delhi, India.
(rishabh.gulati2013@hotmail.com)

Prashant Vats,
HMR Institute of Technology & Management,
New Delhi, India.
(prashantvats12345@gmail.com)

***Abstract*—Bee Colony optimization techniques are inspired by the high level of mutual intelligence shown by the natural bees in the food foraging process. It is a population based natural search algorithm which provides the base to solve metaheuristic computational optimization problems. In this paper we have carried out a literature review of the applications of BCO into various areas of computational problems where they prove their worth in providing optimized solutions. We have further carried out a tabular comparison of the work performed by the various researchers by applying the the BCO as optimization algorithms for solving the Optimization Problems.**

Keywords— *Bee Colony Optimization, Scheduling, Optimization, Foraging behavior.*

I. Introduction

The Bee Colony Optimization (BCO) is a technique based on the high level mutual understanding exhibited by natural bees in food foraging process. It is a population based search algorithm for optimizing numerical problems. Bees are classic example of teamwork experience, coordination and synchronization. They carry out a kind of neighborhood search combined with global search by mimicing the food foraging behavior. The foraging strategy of Bees is used to look for the best solution to an optimization problem. In this process each candidate solution is considered as food source and a population of Bees is used to search solution space. At each and every instant when a Bee visits a source it evaluates its profitability.

It allows meaningful generalization to optimize various problems by recognizing a profitable solution to complex engineering problems. It provides an adequate conceptual framework as well as a mathematical tool to depict the real world problems in an optimized way. It is one of the well known techniques with its successful applications in various domains.

Bee colony optimization technique is recommended above other means of optimizations because it provides clarity and errors in case of optimal solutions. This algorithm can also be analyzed as a path structuring algorithm that structure the path from one source to another tracing the movements of bees as per their journey along the path.

In this paper we have reviewed the work carried out by various researchers on the Bee Colony Optimization techniques and their applications into various domains. In the second section of this paper we have presented a literature review of various applications of Bee Colony Optimization Technique towards providing useful solutions for some critical real time situations. In the third section we have made a comparative analysis for the applications of Bee Colony Optimization Techniques based on certain parameters and with their comparison is presented in a tabular format. In the fourth section we have concluded the usefulness of the BCO in providing solutions to the optimization problems.

II. LITERATURE REVIEW

In this section, we have presented a literature review of applications of bee colony optimization technique in various domains.

D. Jeya Mala, V. Mohan [1] have proposed a test suite optimization approach which is based on non-pheromone-based biological behavior that is inspired by the behavior of biological bees in area of Test Suite Optimization which uses fewer iterations to complete the task with efficient scalability. Its demerit is that the proposed work is needed to be automated for providing near global optimal solution. It is implemented using java.

Jasjeet K., Tajinder K. [2] has proposed their work on evolving a Crossbreed Algorithm for Regression Testing in order to improve the performance of a software system on the basis of faults that are found in the region of Regression Testing. Its advantage is that in this approach BCO in combination with ACO are used to optimize the result & are found useful in overcoming the challenges in Regression Testing. It has been implemented by using Mat lab.

Authors Soma S., M. L. Hari Prasad [3] has proposed a search technique for the automatic generation of Feasible Independent Paths and Software Test Suite Optimization using Artificial Bee Colony (ABC) for generation of independent test paths and test suite optimization. Its advantage is that the propose framework makes the generation of feasible independent paths and software test suite optimization faster. It also provides an independent test path coverage criterion which is issued as objective criteria to achieve the full test coverage with less number of test runs by reducing the number of iterations. Its disadvantage is that it cannot be applicable to generate other test data types like strings.

Arvinder K., Shivangi G. [4] has proposed a BCO algorithm for fault coverage based testing to attain maximum fault coverage in minimum number of units, for the execution time of each test case using Average Percentage of Fault Detection (APFD) metrics in Fault Coverage Based Regression Test Suite Prioritization. Its advantage is that it makes a very effective use of the exploration of paths and their exploitation which is a common phenomenon of Scout bees and Forager bees for the effective prioritization of the fault coverage test suite of an altered code by using a cpp compiler. Its disadvantage is that for applying it to larger programs, it is needed to be improved for its automation concept in order to minimize the human interface requirement and also it can't be applicable on larger projects along with large number of test cases and faults.

Plamenka B., Veska G. [5] have proposed their research to investigate & improve the performance of multiple sequence alignment by code optimization, porting of code alignment, scaling of the code and performance evaluation based on BCO for the case study of the influenza virus sequences hybrid parallel

implementation utilizing MPI and Open-MP which provides considerably better performance than the original code using C++. Its advantage is that it allows researchers to perform simulations with very large amounts of data in the field of bioinformatics to conduct their experiments on even more powerful Supercomputers.

Nebojsa B., Milan T. [6] has proposed the analyzing of an Object oriented software system for optimization problems which is based on modification of Karaboga's ABC algorithm. Its advantage is that it is used for solving the combinatorial and numeric optimization problems. In the proposed system use of threads provides better utilization of multicore processors. It has been implemented using C# in Visual Studio 2008.

Sandeep D., Rajender S. C. [7] have proposed an approach for the effective detection of all the flaws by covering all possible paths of the system. In this proposed testing technique (BCO-mGA), it ensures maximum code coverage in a minimum possible time frame by using UML software by execution of the final minimized test suite for the generation of test cases based on BCO by reducing the nodular path options by using a combined application of BCO and a modified genetic algorithm. Its advantage is that it identifies and reduces the test data. But its demerit is that for automatic fault rectification it was not able to develop another algorithm.

Bharti S., Isha M. & Varun S. [8] aimed for generating solutions for optimization problems using computational techniques inspired by the natural evolution like inheritance, mutation process, selection process, and crossover & BCO in Regression Test Suite Reduction which proves to be an optimistic approach by providing optimum results in minimum time. Its advantage is that it provides effective results in the initial iteration of the whole process. But at the same time, it was not able to lead to better solutions in optimum time when applied to large and complex problem.

Prabhu J., N. Malmurugan [9] have proposed an Model-driven approach by considering the expected output and comparing it with actual output in Automated GUI Test Cases Generation, by using effective fault detection with execution time and Fault detection rate. Its advantage is that this Fault detection rate is covered of the test cases for both Forward process and Reverse process. But it cannot be applicable on larger projects by applying large number of test cases and faults. It is implemented in Oracle.

Li-Pei Wong, Malcolm Y., Chin S. C. [10] has projected their research to find a Hamiltonian path with minimum cost in Travelling Salesmen Problem (TSP). The proposed algorithm helps in achieving optimality for TSP. But it was not able to obtain optimal solution for problems with larger dimension. It was implanted In JAVA with NetBeans IDE 5.5.

Chin S. C., Malcolm Y. H. L. [11] have proposed a novel approach for solving the job shop scheduling problem by using the honey bees foraging model which made it relatively easier to treat each bee forager as an agent in the bee colony algorithms since the issue of share state in maintaining a global pheromone table in ant algorithms does not occur. It is implemented in Java on Windows XP platform.

Milos N., Dusan T. [12] have evolved BCO for optimizing numerous numerical test functions in combinatorial optimization problems. The proposed algorithm is able to optimize numerical test functions. But it was not able to generate high-quality solutions within negligible CPU times.

Nasser R. S., Masri A., Graham K. [13] has addressed the educational timetabling problems by considering a new variant of the Honey-bee Mating Optimization Algorithm. It maintains the population diversity by discarding by discarding mated drones and by insertion of the generated broods into the population for the next mating flight. It was implemented using Visual C++.

Vahid A., Ali M [14] have intended to apply BCO for solving the task scheduling problem in which dependencies of each task onto each other is used to obtain the minimum schedule length i.e. make-span in Task Scheduling Problems. The proposed algorithm considers a general memory for all bees, to compare their obtained results with the acceptable results which are obtained previously.

Sudarshan N., Partha P. S. [15] has proposed a training method by using a back-propagation neural Network training method for an improved and effective convergence rate of the hybrid neural network learning method based on BCO for the effective optimization of the back-propagation neural network training. In the proposed method the involvement of a scout bee in each iteration of back-propagation optimization phase is decided in accordance with the average performance of solutions and thus results in the maintenance of the process of exploitation.

Fanchao Z., James D.[16] have used an Autonomous Bee Colony Optimization (A-BCO) algorithm for solving multi-objective numerical problems for optimizing the balance between exploration and exploitation during the search process for solving the multi-objective numerical problems. Its advantage is that the self-organized and collective behavior exhibited by the colony insects enables them to solve multi-objective problems which cannot be addressed by single insects by acting independently.

S. Talatahari, M. Nouri [17] have proposed their research to optimize different skeletal structures using Artificial BCO technique for minimization of the weights of the structures while satisfying all the design requirements which are imposed by design codes for solving the structural optimization problems containing truss and frame structures using MATLAB.

Alexey O., Sergey S. [18] have used a clustering method which is based on BCO for estimating the number of cluster in a given dataset where there is no previous knowledge of number of clusters is available in clustering of datasets. It is implemented using Matlab 7.0.

Iona M. S., Roberto S.[19] have presented a new event classification system based on the ability of the BCO algorithm for finding the best centroid positions which correctly identifies an accident in a PWR nuclear power plant, thus maximizing the number of correct and effective classification of the transients for the diagnosis of accidents that may occur in a PWR nuclear power plant. Its advantage is that it can be used in complex high dimensional multimodal search spaces but it might not contribute to the production of trial solutions.

Gaowei Y., Chuangqin L.[20] have solved the accuracy problem of global optimal value by applying Chaotic Local Search based on Artificial Bee Colony optimization (CABC) method in Peripheral interface devices (PID) control parameters optimization for PID control parameters optimization. The proposed CABC algorithm has a great adaptability to the actual control system also it has a higher accuracy.

Sana A., K. R. K. Mahmud [21] have proposed their framework for multi objective bee colony optimization for scheduling of batch jobs for the available resources where the number of jobs is greater than the available resources by integrating Pareto analysis and k-means analysis along with BCO for effective scheduling of Grid jobs. This framework allows multiple objectives to be set in an order for optimizing the performance of job scheduling in grid environments and fulfill the requirements of concerned users.

Mohammad S., Gholamhasan S. [21] has proposed a Artificial BCO for MRI Fuzzy Segmentation of the Brain Tissues. It uses a noise probability factor for each pixel that is used within the image of MRI. The proposed algorithm is based on Modified Intensity matrix using ABC and is efficient in terms of performance efficiency, accuracy speed and the avoidance trapping in local

minima points. It was implemented using MATLAB R2008a in windows vista OS platform.

Miao M., Jianhui L., Min G. [22] have presented a fast segmentation method for SAR Images which regards threshold estimation as a search process and employs ABC algorithm to optimize it in SAR image segmentation. This method is superior to Genetic Algorithm based or AFS based methods with respect to accuracy for the segmentation, the segmentation time and the convergence speed for fast segmentation but it requires paying more attention to multiple thresholds and other new fitness functions.

Prabhat K. S., Bhavya V. S. [23] has proposed the usage of ABC for an effective optimal fusion of the multi-temporal images and have studied the effects of variations in the source area in an image fusion. The output images fused are based on ABC in VC++ 6.0. Its advantage is that it is having more information content (higher Entropy value) and it also looks more effective on higher Spatial Frequency values than the images which are used by arithmetic operation, but it was not able to find an optimized source area that is a defined window size for the fusion of images using ABC.

Muhammad Marwan M. F. [24] proposed a new distance metric ABCSG, which is when applied to strings it has given better results in spite of the difference in the complexities by using set operations

Bhagat S. P., Laxmi S. [25] indented their research for solving the multi-objectives Reactive Power Optimization (RPO) problems by using ABC algorithm. In Multi-Objective Reactive Power Optimization which is effective to solve the multi-objective RPO problem. Its advantage is that it is robust and effective to solve the multi-objective RPO problem. It was implemented using IEEE-30 bus test system.

Asaju L.B., Ahamad T. K., Mohammed A. A. [26] presented their research on the adaption of the Artificial Bee Colony algorithm for solving timetabling problems that focus on the curriculum-based course timetabling in Curriculum-Based Course Timetabling Problem in Microsoft Visual C++ 6.0 under Windows Vista. The algorithm is capable of solving timetabling problems but the results produced by the algorithm in this study are presently not comparatively better than those already reported in the literature.

Kunthavai A. and Vasantharathna S.[27] have aimed there research on a small domain of sequences have been selected from the DNA database and experimentally proved that fine-tuned enhanced suffix array reduces space complexity by five times and time complexity is also reduced with the help of developed Hash Index function in pair wise Sequence Alignment. It is useful for identifying sequence similarity, producing phylo-genetic trees or evolutionary tree which is a branching diagram or "tree" showing evolutionary relationships among various biological species or other entities. It is implemented in java.

Rabindra K. J. [28] has proposed a methodology for placements of nodes in a wireless sensor network using the ABC based multi-objective methodology in wireless sensor networks (WSN). It allows use of less control parameters to get the most competitive performance in WSN & also the results in an optimal design scheme that specify operation mode for each sensor.

O. Kesemen, Y. Yeginoglu[29] have evolved their research on Panoramic Image Mosaicing to take wide- angle photography based on multi objective ABC optimization in accordance with a set of photographs taken piece by piece . The proposed algorithm determines that which image is positioned in which order and which location by considering multi objective function of ABC optimization method.

Nurhan K., Mehmet B. C. [30] have proposed their research in ABC algorithm for adaptive FIR and IIR filter design was described for the purpose of noise cancellation in adaptive filtering which can successfully be used for designing adaptive FIR and IIR filters for noise cancellation. It is implemented using mathematical tools Matlab.

Sana A., K.R. K. Mahmud [31] has proposed a framework for multi objective BCO for scheduling of batch jobs to the available resources where the numbers of jobs are greater than the available number of resources by integrating Pareto analysis and k-means analysis along with BCO. It is used for Grid Job Scheduling. Its advantage is that it allows in setting of multiple objectives for optimizing the performance of the effective job scheduling in various grid environments and also to fulfill the requirements of the concerned users.

III. A COMPARATIVE ANALYSIS OF BEE COCLONY OPTIMIZATION FOR ITS APPLICATIONS IN VARIOUS DOMAINS

In this section we have reviewed and analyzed the bee colony optimization techniques and their applications in various domains. The comparative analysis is presented in tabular format in Table 1.

IV. CONCLUSIONS

In this paper, we have carried out a survey on the Bee Colony Optimization Algorithms and its applications into various domains. Further, we have also carried out a comparative analysis of the survey and thus can conclude that BCO is recommended above other means of optimizations because it provides clarity and errors in case of optimal solutions. BCO algorithms have proven their worth into various real time applications by providing useful results.

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TABLE. 1 A COMPARATIVE ANALYSIS OF APPLICATIONS OF BCO INTO VARIOUS APPLICATION DOMAINS.

Sr. No.	Authors	Issues Addressed	Area of application	Complexity Involved	Merits	Demerits	Tools Used.
1.	D. Jeya Mala, V. Mohan [1] (2009)	To propose a non pheromone-based test suite optimization approach inspired by the behavior of biological bees.	In Test Suite Optimization	O(n2)	The proposed approach uses less iteration to complete the task + is more scalable.	Needs to be automated for providing near global optimal solution generation	Java.
2.	Jasjeet Kaur, Tajinder Kaur [2] (2013)	To propose a Crossbreed Algorithm for Regression Testing to improve the performance of the system on the basis of faults found in the region.	In Regression Testing.	O (N log N)	In this approach BCO in combination with ACO to optimize the result & is useful in overcoming the challenges faced by Regression Testing.	NA	Matlab.
3.	Soma S., M. L. Hari Prasad [3] (2012)	To propose a novel search technique for automatic generation of Feasible Independent Paths and Software Test Suite Optimization using Artificial Bee Colony (ABC)	For generation of independent test paths and test suite optimization	NA	It makes generation of feasible independent paths and software test suite optimization faster + independent test path coverage criterion is used as objective criteria to achieve the all test coverage with less number of test runs by reducing number of iterations	It cannot applicable to be generating other test data types like strings.	NA
4.	Arvinder K., Shivangi G. [4] (2011)	To propose a BCO algorithm for fault coverage to attain maximum fault coverage in minimal units of execution time of each test case using Average Percentage of Fault Detection (APFD) metrics	In Fault Coverage Based Regression Test Suite Prioritization	{O}(n^3)	It makes effective use of the path exploration and path exploitation phenomenon of Scout bees and Forager bees for the prioritization of the fault coverage test suite of the modified code.	For applying it to larger programs, there is a need to improve its automation concept to minimize the human interface requirement + can't be applicable on larger projects with large number of test cases and faults.	CPP compiler
5.	Plamenka B., Veska G. [5] (2013)	To investigate & improve the performance of multiple sequence alignment by code optimization, porting, scaling and performance evaluation based on BCO.	For the case study of the influenza virus sequences	O (N log N)	Hybrid parallel implementation utilizing MPI and Open-MP provides considerably better performance than the original code + It allows researchers to perform simulations with very large amounts of data in the field of bioinformatics to conduct their experiments on even more powerful supercomputers	NA	C++
6.	Nebojsa B., Milan T. [6] (2010)	To propose & analyze a Object oriented software system for optimization problems based on a modification of Karaboga's ABC algorithm.	For solving combinatorial & numeric optimization problems	O(N) in Worst case	In the proposed system use of threads provides better utilization of multi-core processors.	NA	Using C# in Visual Studio 2008.
7	Sandeep Dalal, Rajender Singh Chhillar [7] (2013)	To Propose an approach that effectively detects all the flaws by covering all possible paths of the system. The proposed software testing technique (BCO-mGA) ensures maximum coverage in minimum possible time	For Generation of Test Cases Based on Bee Colony Optimization	O(n^2 log n)	It reduces the nodular path options by a combined application of bee colony optimization and modified genetic algorithm +identifies and reduces the test data	It was not able to develop another algorithm for automatic fault rectification	Using uml software (state diagram)

		frame by executing the final minimized test suite					
8.	Bharti Suri, Isha Mangal [8] (2011)	To generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover based on BCO.	In Regression Test Suite Reduction	NA	It proves to be optimistic approach which provides optimum results in minimum time + It provides better results in the initial iteration of the whole process	It was not able to lead to better solutions in optimum time when applied to large and complex problem.	NA
9	Prabhu.J, N.Malmuruga n, [9] (2013)	To propose an Model-driven approach considering the expected output and its comparison with the actual output	In Automated GUI Test Cases Generation	NA	It makes effective use of the Fault detection with Execution time and Fault detection rate covered of Forward process and Reverse process for the test cases.	It cannot be analyzed on larger projects with large number of test cases and faults.	Oracle
10.	Li-Pei Wong, Malcolm Yoke H. L. [10] (2008)	To find a Hamiltonian path with minimum cost in travelling salesmen problem	In Traveling Salesman Problem	O(n!)	It helps in achieving optimality for TSP	It was not able to obtain optimal solution for problems with larger dimension.	In JAVA with NetBeans IDE 5.5
11.	Chin Soon Chong, Malcolm Yoke H. L. [11] (2006)	To propose a novel approach that uses the honey bees foraging model to solve the job shop scheduling problem	For Job Shop Scheduling	O(n2)	It made it relatively easier to treat each bee forager as an agent in the bee colony algorithms since the issue of share state in maintaining a global pheromone table in ant algorithms does not occur	NA	IN Java on Windows XP platform
12.	Miloš Nikolic´ , Dušan T. ´[12] (2013)	TO PROPOSE BCO FOR optimizing numerous numerical test functions	In combinatorial optimization problems	NA	It was able to optimize numerical test functions.	It was not able to generate high-quality solutions within negligible CPU times.	Mathematica l tools
13.	Nasser R. Sabar, Masri Ayob1. [13] (2012)	To propose a variant of the Honey-bee Mating Optimization Algorithm for solving educational time tabling problems	In Educational Timetabling Problems	O(n^2 log n)	The proposed HBMO-ETP maintains the population diversity by discarding mated drones and inserting the generated broods into the population for the next mating flight.	NA	Visual C++ 6.0
14.	Vahid A., Ali M. [14] (2011)	To apply BCO in order to solve the task scheduling problem which tasks have dependency with each other, to obtain in the minimum schedule length i.e. make-span.	In Task Scheduling Problems.	O(n2)	The proposed algorithm considers a general memory for all bees, to compare their obtained results with the acceptable results which are obtained previously.	NA	NA
15.	Sudarshan N., Partha P. S. [15] (2012)	To propose a training method using back propagation neural network training method for fast and improved convergence rate of the hybrid neural network learning method based on BCO. .	To optimize the back-propagation neural network training.	NA	In the proposed method involvement of scout bee in each iteration of back-propagation optimization phase are decided according to the average performance of solutions and thus the process of exploitation is maintained.	NA	UCI machine learning library is used for test data sets.
16.	Fanchao Z., James D. [16] (2010)	To propose an Autonomous Bee Colony Optimization (A-BCO) algorithm for solving multi-objective numerical problems is proposed in order to optimize the balance between exploration and exploitation during the search process.	For solving multi-objective numerical problems	(−5,(2k+1)π)	The self-organized and collective behavior of colony insects enables them to solve multi-objective problems which cannot be addressed by single insects acting independently.	NA	NA
17.	S. Talatahari, M. Nouri [17] (2012)	To optimize different skeletal structures using ABCO in order to minimize the weight of structures while satisfying all design requirements imposed by design codes.	To solve structural optimization problems containing truss and frame structures.	O(n^2*2*n)	The ABC algorithm provides results as good as or better than other algorithms and can be used effectively for solving such problems.	NA	Matlab.
18.	Alexey O., Sergey S. [18] (2010)	To propose a method of clustering based on the bee colony optimization to estimation of the number of cluster in a given dataset where no previous knowledge of number of clusters is available.	In clustering of datasets.	O(n*k*d*i)	In the proposed method a priori information about shape of clusters is not necessary and definition of cluster numbers is not needed.	NA	Matlab 7.0.
19.	Iona M. S., Roberto S. [19] (2009)	To presents a new event classification system based on the ability of the algorithm to find the best centroid positions that correctly identifies an accident in a PWR nuclear power plant, thus maximizing the number of correct classification of transients.	For the accident diagnosis in a PWR nuclear power plant.	NA	It can be used in high dimension and complex multimodal search spaces,	It might not contribute to the production of trial solutions.	Matlab.
20.	Gaowei Y., Chuangqin L. [20] (2011)	To solve the accuracy problem of global optimal value by applying Chaotic Local Search based on	For PID control parameters optimization	NA	The proposed The CABC algorithm has a great adaptability to the actual control system +CABC algorithm has a higher accuracy + PID control	NA	NA

		Artificial Bee Colony optimization (CABC) method in Peripheral interface devices (PID) control parameters optimization.			systems adopt optimal parameters can obtain the quantity that low rise time, overshoot as well as quickly achieve steady state.		
21.	Mohammad S., Gholamhasan S. [21] (2011)	To propose a Artificial Bee Colony Optimization for MRI Fuzzy Segmentation of Brain Tissue by using a noise probability for each pixel within the image.	For MRI Fuzzy Segmentation of Brain Tissue	NA	The proposed algorithm is based on Modified Intensity matrix using ABC and is efficient in terms of performance, speed and avoidance trapping in local minima points.	These algorithms do not guarantee high accuracy especially for noisy or abnormal images.	MATLAB R200- 8a + windows vista OS.
22.	Miao Maa B., Jianhui Lianga, M. G. [22] (2011)	To propose a fast segmentation method for SAR Images which regards threshold estimation as a search process and employs ABC algorithm to optimize it.	In SAR image segmentation	NA	This method is superior to GA based or AFS based methods with respect to segmentation accuracy, segmentation time, and convergence speed for fast segmentation	It requires to pay more attention to multiple thresholds and other new fitness functions	NA
23.	Prabhat K. S., Bhavya V S, [23] (2012)	To propose the usage of ABC for optimal fusion of multi-temporal images and studied the effect of variation in the source area.	In image fusion	NA	The output images fused based on ABC has more information content (higher Entropy value) and also looks better (higher Spatial Frequency values) than the images fused by arithmetic operation	It was not able to find an optimized source area (window size) for fusion of images using ABC	VC++ 6.0
24.	Mhd. M. Mhd. F. [24] (2012)	To propose a a new distance metric; ABCSG, which is applied to strings	In string application.	O(NlogN)	ABC-SG gave better results in most cases, despite the difference in complexity	N.A	Using set operations
25.	Bhagat S. P., Laxmi S. [25] (2012)	To solve the multi-objective Reactive Power Optimization (RPO) problem using ABC algorithm	In Multi-Objective Reactive Power Optimization	NA	It is robust and effective to solve the multi-objective Reactive Power Optimization (RPO) problem	N.A	Using IEEE-30 bus test system
26.	Asaju L. B., Ahamad T. K. [26] (2011)	To present the adaption of the Artificial Bee Colony algorithm for solving time tabling problems, focusing on the curriculum-based course timetabling	In Curriculum-Based Course Time tabling Problem	{O}(n^3)	The algorithm is capable of solving timetabling problems	NA	Microsoft Visual C++ 6.0 under Windows Vista
27.	Kunthavai A., Vasantharathn a S. [27] (2013)	To select a small domain of sequences from the DNA database for fine-tuned enhanced suffix array using Hash Index function based on ABCO	In Pair wise Sequence Alignment	NA	It is useful for identifying sequence similarity, producing phylogenetic trees or evolutionary tree which is a branching diagram or "tree" showing evolutionary relationships among various biological species or other entities	NA	Implemented in java
28.	Rabindra K J. [28] (2013)	To demonstrate the node placement methodology for wireless sensor network using ABCMO based multi-objective methodology	In wireless sensor networks (WSN)	NA	It allows use of less control parameters to get the most competitive performance in wsn+ results in an optimal design scheme, which specifies the operation mode for each sensor	NA	NA
29.	O. Kesemen, Y. Yegino G. [29] (2012)	To propose Panoramic Image Mosaicing to take wide- angle photography based on multi objective ABC optimization in accordance with a set of photographs taken piece by piece	In Panoramic Image Mosaicing	NA	The proposed algorithm determines that which image is positioned in which order and which location by considering multi-objective function of ABC optimization method.	NA	NA
30.	Nurhan K., Mehmet B.C., [30] (2011)	To describe ABC algorithm for adaptive FIR and IIR filter design was described for the purpose of noise cancellation	In adaptive filtering	NA	This approach can successfully be used for designing adaptive FIR and IIR filters for noise cancellation	NA	Mathematica l tools
31.	Sana A., K.R. K. Mahmud [31] (2013)	To propose a framework for multi objective bee colony optimization to schedule batch jobs to available resources where the number of jobs is greater than the number of resources by integrating Pareto analysis and k-means analysis along with BCO.	For Grid Job Scheduling	NA	This framework allows multiple objectives to be set in order to optimize the performance of job scheduling in grid environments and fulfill the requirements of users.	NA	NA