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A SYSTEMATIC REVIEW ON ARTIFICIAL BEE COLONY OPTIMIZATION TECHNIQUE

Dishti Agarwal[*] Aakriti Gupta[**] Pradeep Kumar Singh[***]

Abstract: The paper explains how one can solve different optimization problems using the Artificial Bee Colony Algorithm. It is one of the recent and effective optimization a technique belongs to the area of Meta-heuristic. It observes the behavior of bees in the real environment and then applying that behavior on various optimization problems to find desired optimal results. We have searched various repositories to identify the usages of Artificial Bee Colony (ABC) algorithm. We have considered the most recent and relevant papers for our analysis and most of the papers are taken from the year 2005 to 2015. In all the relevant papers found, area and application of the algorithm have been identified. The purpose of the proposed work is to analyze the work done using ABC for optimization in different areas and to find out strengths and drawbacks of the approach along with their applications.

General Terms: Algorithms, Performance, Design, Reliability, Experimentation, Security, Factors, Reliability, Theory, Languages, Legal Aspects, Verification.

Key Words: Artificial Bee Colony Algorithm, Optimization, Particle Swarm Optimization.

1. INTRODUCTION

Artificial Bee Colony is the optimization technique based on how group of bees behave in the real environment. The algorithm has been proposed in the year 2005 by D. Dervis Karaboga in his paper. This approach is like many other swarm intelligence technique like The Bees algorithm, Ant colony Optimization, The Bat Algorithm, Glowworm Particle swarm optimization, Bird flocking, fish schooling. The results of this technique have been found quite impressive in various problems. Moreover, several hybrid techniques have been proposed to enhance the results.

Artificial Bee Colony (ABC): A Brief Review: In the actual Bee colony, there are mainly three kinds of bees i.e. Scout, Worker and Onlooker Bees. The bees associated with the food sources are worker Bees. Each bee searches for the food source, visits that food source, collects the nectar, then come back to their hive and performs the dance. Such an activity indicates the foundation of food source and its particular direction. Onlooker bees sees worker bees dancing and choose the sources of food accordingly to go out searching food sources near to those found by the worker bees. Lastly, the scout bees which are independent of the above two types of bees keep on searching sources on their own (or which we say have been abandoned the food source).

[*] Department of CSE, ASET, Amity University Uttar Pradesh, Noida, India Email: dishti.agarwal@gmail.com
[**] Department of CSE, ASET, Amity University Uttar Pradesh, Noida, India Email: superaakriti1@gmail.com
[***] Department of CSE, Jaypee University of Information Technology (JUIT), Waknaghat, HP, India Email: pradeep84cs@yahoo.com

2. REVIEW PROCEDURE

To analyze the Artificial Bee colony Algorithm, we have downloaded the papers from popular repositories like IEEE Digital Library, ACM, Science Direct and Google Scholar. To identify the most relevant papers we have adopted the approach as considered by Singh et *al.* [51-53]. After removing the duplicate papers, we have read nearly 150 papers and have identified the most relevant papers base on the following steps:

(a) Downloaded the papers based on the search keyword: Artificial Bee Colony Algorithm.

(b) We have read the Abstract, Title and Conclusion of the papers which were specifically related to our topic.

(c) Based on the content of papers we have selected the research papers relevant to our analysis.

(d) Out of the 150 papers 50 most relevant papers were found.

(e) Each paper is thoroughly analyzed and then findings have been reported.

(f) Finally, table was made to categorize the major contribution of the authors to solve certain problems.

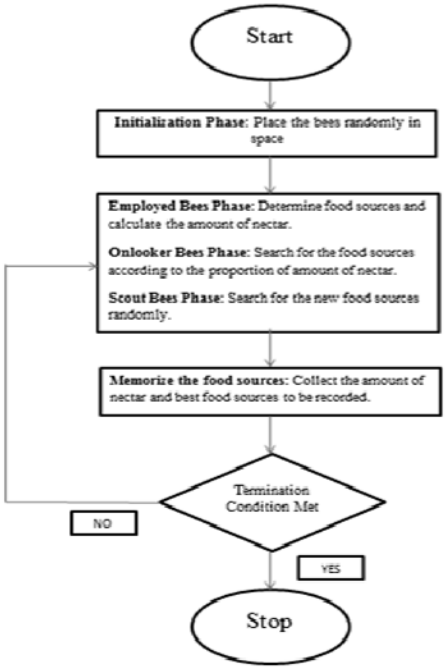

Figure 1. Flowchart of the ABC Algorithm

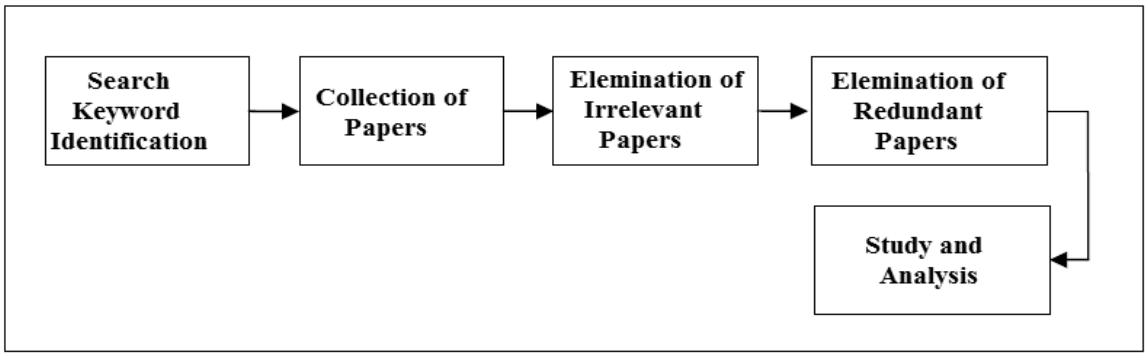

Figure 2. Review Procedure

We have decided following research goals to do the analysis on Artificial Bee Colony optimization:

Research Questions:

RQ1: To find out the applications where ABC has been applied?

RQ2: To analyze the technique and find out if the results are found to be impressive?

RQ3: To identify the strengths and limitations of the technique?

RQ4: To study the future scope of the technique?

Figure 3. Research Questions

3. LITERATURE SURVEY

In this section, we have reviewed the most relevant paper based on our decided research objectives. In this section total fifty papers have been taken into account for systematic analysis. Farooq *et al.* [1] proposed a routing algorithm named as Bee AdHoc which is inspired by ABC algorithm and uses scouts and to perform the routing.. The proposed algorithm is a good algorithm than other routing algorithms like AODV, DSR, and AODV without compromising parameters like delay and throughput as it utilizes lesser control packets in the routing process.

Wong *et al*. [2] solved the Job Shop Scheduling problem by proposing a very improved Bee Colony Optimization algorithm. The results were good and hence show the effectiveness of the algorithm.

Tsai *et al.* [3] discussed an enhanced optimization algorithm for the problems of numerical optimization. The onlooker bee straightway moves to coordinate which was being pointed to by the bee which has been employed. Then a fitness value has been evaluated near to it for reducing the complexity. The universal Gravitation concept has been introduced by the modified algorithm by observing the bonding between onlooker and employed bees.

Benala *et al.* [4] suggests that ABC algorithm can be used in image enhancement techniques as it can be easily adapted in image processing, enhancement, segmentation, classification and feature extraction. In their work, the edge enhancement is done using the algorithm and the results were analyzed with the GA. Different images were considered and all the results were found after applying the algorithm on the images.

El- Abd *et al.* [5] proposed the algorithm which was noise-free i.e. BBOB 2010. The results depicted a better performance in the weak structured function.

Karaboga *et al.* [6] discussed a new approach for the clustering with the aim of minimizing the energy consumption. The idea is to find the optimal clusters using the algorithm. Hence depicted by the simulation outputs that WSNCABC (Wireless Sensor Network Clustering using Artificial Bee Algorithm) algorithm gave better results than the direct transmission and LEACH (Low Energy Adaptive Clustering Hierarchy) algorithm.

Banharnsakun *et al.* [7] proposed the distributed version of the algorithm which was base on manager-worker model to support the large problem size. In this method, communication and synchronization of processes is achieved through message passing interface.

Accuracy and Efficiency were the two modes on which the proposed algorithm has been evaluated. Near linear speedup with almost full efficiency in case of large problem size has been achieved.

Shi *et al.* [8] developed a new hybridized algorithm after combining the swarm algorithm with the ABC. The author suggested to observe how the information is been exchanged between two set of algorithms that is bee colony and swarms .The flowchart has been designed by combining the

both individual processes. The suggested algorithm is been tested on the 5 problems and al three algorithms was compared in form of experimental results. The results show that the combined algorithm preformed best among all the 3 algorithms.

Zhang *et al.* [9] introduced a classifier to distinguish between abnormal & normal MRIs of brain. Results which were found suggested a better performance.

Zhang et *al.* [10] for image segmentation proposed a thresholding method. The traditional method used the histogram of the gray level thereby using the Shannon Entropy.

Prasad Babu *et al.* [11] discussed the usage of machine learning algorithms and rule based techniques (PSO and ABC) for the creation of sheep and goat disease database. The expert systems are developed with the application of these techniques on the database to find the diseases which affected goat and sheep animals. The user enters symptoms, so that the system may diagnose the diseases.

Rashedi *et al.* [12] focused solving the dynamic Routing and wavelength assignment problem. The performance of proposed algorithm based dynamic routing was compared and the result was found to be better.

Zou *et al*. [13] presented a Pareto dominance algorithm which was then used to determine the bee's direction. The standard test problems have been used to validate the algorithm and results found suggested that the modified proposed algorithm is effective and is able to solve various problems.

Mohammad El-Abd [14] presented that opposition based learning can improve the performance of the algorithm. It has been introduced in the two following steps: opposition based initialization and the generation jumping. The results found suggested that the modified proposed algorithm is effective and performs much better than ABC.

Peng *et al.* [15] suggested a modified algorithm which includes best individual of the current iteration with the details of global and food sources which are available at the best position. The results showed modified GABCS algorithm gives better results in the experiments, especially in case of multi-model benchmark functions.

Junaedi *et al.* [16] compared his proposal with that of one proposed by Asaju et *al.* The algorithm which has been suggested consists of four phases. The initialization phase deals with placing subjects in the available space. The employee bee and Onlooker bee phase deals with searching rooms and slots near the subjects keeping in mind the minimization of constraint violations.

Wu *et al.* [17] presented a clustering based algorithm using the bee’s behavior. The author implemented the bee's behavior to predict function of unknown protein in Protein- Protein Interaction network by proposing an improved clustering algorithm. The improved algorithm was stimulated in Matlab 7.7 and then results were analyzed using the MIPS dataset. The results were stimulated and the improved algorithm was compared with others methods.

Zhang *et al.* [18] solved the travelling salesman issue using the novel and enhanced artificial bee colony algorithm by combing the ABC and TSP together. The travelling salesman problem is an important problem to find the minimum distances while touring among the different cities. The ABC method is a newest technique on how honey bees find and locate their food and it can be used to explain the TSP. The modified algorithm has been tested on various benchmarks problems and has been coded in Visual C++. The new proposed algorithm can provide better optimum solution after the results were described and analyzed.

Tien *et al.* [19] presented a new algorithm by mixing clonal algorithm (CLONALG) and bee colony algorithm. It has been named as HCABC which enhances CLONALG performance. The results found suggested that the modified proposed hybrid algorithm is effective and performs much better than ABC. The best fuzzy controller structure has been achieved by the HCABC and the advantages of ABC enhance the performance of HCABC.

Dongli *et al.* [20] suggested that bee colony is the algorithm of swarm intelligence depicting the behavior of bees. The paper depicted the behavior of honey bees in the real environment where the bees look for best optimal solution to search food in their neighbor. The author suggested the exchange of the neighborhood during the search for food. It resulted in more efficient and speed has also been improved.

Zhang *et al.* [21] for the purpose of solving the QoS based route optimization problem the author introduced an ABC technique based multi-objective. The traditional bee behavior had been differentiated with the proposed Genetic algorithm. Results have been found impressive in terms of solution and performance.

Sharma *et al.* [22] presented a variant of bee with a purpose of easily solving numerical problems dealing with optimization having bound constraint. The technique employs colony size reduction during evolutionary stage and then modification for controlling perturbation frequency. Moreover the usage of rank selection method has been included to improve population diversity and for controlling premature convergence. And thus, it has been found out to be better than usual ABC in performance.

Zhang *et al.* [23] presented a co evaluation model combining the multi-hive properties of honey bees with the swarm intelligence. The experiment was simulated on the 5 benchmark problems to analyze the performances of both the algorithms.

Rajasekhar *et al.* [24] presented a novel modification of the algorithm named as μABC i.e., micro artificial colony algorithm in which the bees are ranked according to fitness keeping the Best bee same and reinitializing other bees based upon food source extracted by the best bee. On comparison with methods such as CCPSO2, EPSPSO and further, phenomenal results were recorded in the proposed strategy even with greater dimensions.

Ponsich *et al.* [25] compared the discrete algorithm, on a real life instance of Mexican Electoral institute database the algorithm have been applied. On evaluating the performance of both the techniques in terms of resulting approximation of the Pareto front and convergence, it is found that DABC gives better results within lower running times.

Rekaby *et al.* [26] suggested that the algorithm is the modern intelligence algorithm and he proposed “Adaptive Artificial Bee Colony” (AABC). The standard bee colony and the proposed adaptive bee algorithm have been compared through traveling salesman problem. He further suggested that it is one of the most common problems in the searching techniques evaluation, so the paper considers it as an experimental case for the algorithms' performance discrimination.

Shi *et al.* [27] suggested a hybrid for TSP. The author suggested a coding method which was discrete for the position of the food source. The new proposed algorithm can provide better optimum solution after the results were described and analyzed.

Johan *et al.* [28] presented a performance which was based upon multi-objective. On the standard IEEE bus system the proposed algorithm has been tested and the new proposed algorithm can provide better optimum solution after the results were described and analyzed.

Liang *et al.* [29] discussed the ABC algorithm as an advanced and novel optimization algorithm and uses it to solve many sorts of problems related to combinatorial as well as numerical function

optimization. The author states that ABC algorithm and its other variants are still lacking the capacity for the optimization of high dimensional problems without taking into consideration the interactions within each dimensional variable.

Yu *et al.* [30] proposed a two step greedy position update technique for the ABC algorithm. It is one of the iterative methods where among the top solutions the best solutions were selected and then those selected solutions were used for searching the food sources by the onlooker bees. In every iteration a new parameter has been adjusted. On various set of problems this greedy strategy has been applied and evaluated. The experimental results suggested improving the performance.

Bin *et al.* [31] implemented the ABC algorithm on vehicle routing problem. This paper studies a new problem of vehicle routing i.e. 2L-CVRP to solve the issue ABC algorithm have been developed with three loading heuristics. The proposed algorithm has been coded in visual C++ and tested on 10 instances of the benchmark problems. The ABC algorithm can provide better optimum solution to find the best possible route, after the algorithm was applied on the problem.

Sharma *et al*. [32] suggested that improvising the food sources and their tracking behavior can remove certain limitations of the ABC algorithm hence making algorithm more efficient. Certain modifications were done to improvise the algorithm. Out of various benchmark problems, 6 were selected and testing was performed on them. The results can be further analyzed in several engineering disciplines.

Yi *et al.* [33] stated on the basis of behavior of honey bees a new population evolutionary method. As compared to other optimization algorithms the ABC show better results. There are certain limitations also in ABC. The author identified all the limitations like speed. Hence, proposed a new algorithm for handling such insufficiencies to find the best possible solution in the search of food.

Wijayanto *et al.* [34] discussed the design for the improving the limitations in fuzzy geo-demographic clustering algorithm by suggesting the integration of ABC based optimization and Fuzzy Geographically Weighted Clustering (FGWC) algorithm to reach a better level of geo-demographic clustering accuracy. The proposed method gives better clustering quality than the original FGWC.

Mollinetti *et al.* [35] reported a hybridization of the ABC Algorithm based upon the strategies which were discovered in the Particle Swarm Optimization. The author aimed to extend the normal ABC which includes the strategies that were discovered in PSO along with the simplicity of ABC.

Kumar *et al.* [36] proposed a multi-target tracking system for Mobile sensor Networks. The author uses ABC algorithm to find the current position of the food source and to predict the next positions of the available food source... A hybrid sensor network consisting of both mobile (used for optimizing target tracking) and static nodes (used for ensuring total network coverage) has been used. Each sensor is given a position based on this algorithm according to high fitness value. The proposed method was studied under different benchmarks and the results were found to be quite efficient. Standard deviation, mean and cycle errors were used to evaluate the performance. It gives even better results when compared with single target tracking methods.

Zeighami *et al.* [37] suggested a Multi Level Artificial Bee Colony (MLABC) which includes the use of two species. In first case, entire solution vector is optimized by n colonies where cooperation takes place through a Leader colony consisting of elite bees. Whereas in second case, the solution vector is subdivided in k sub-vectors and then each colony optimizes a sub-vector finally combining all solutions to form complete solution vector. Lastly, information is exchanged between two species to achieve cooperation. The tests showed that MLBAC gives quite efficient solution.

Saxena *et al.* [38] proposed a strategy where group of bees has been divided into smaller subgroups and the search has been carried out by these independent groups of bees. It utilizes the current solution and the best solution to give optimized solution. The given algorithm has been found to perform better.

Kothari *et al.* [39] reported advancement in ABC algorithm which lessens the variations in executions. The proposed algorithm has been found efficient when compared with the ABC algorithm. The co-relation between algorithm efficiency and solution persistence has been indicated. Moreover the results conclude by proving genetic methods, a right leap forward.

Ning *et al.* [41] proposed a strategy for training fuzzy neural network using ABC algorithm. Such a trained FNN has been applied to speech recognition system and then performance has been compared to Back Propagation and Particle swarm optimization algorithm. The results have showed better convergence speed and recognition results when compared with back propagation while results were found quite similar on comparison with PSO.

Chen et *al.* [42] suggested a blind source separation method. In many fields such as voice processing, wireless communications, image processing the BSS technique have been used. The method aims to extract the signal from the chaotic signal. The author defined the BSS method and how artificial bee colony algorithm can help to extract the source sign*al.* The simulation has been carried out in Matlab 7.0 and the results of the simulation suggested that within little iteration the chaotic signals were separated.

Tan *et al.* [43] suggested EABC which is improved ABC algorithm for the clustering. Clustering is used to cluster the similar items together by making groups of items having similar properties. Four algorithms were applied on 5 different data sets i.e. Wine, Iris, Glass, Dermatology and WDBC and the result has been compared. The results suggested that the performance was better than other 3 algorithms. During the enhancement a new parameter has been explored called Initialization Reference Proportion (IRP).

F. Mollinetti *et al.* [43] based upon the evolutionary techniques explored the Evolutionary Particle Swarm Optimization (EPSO) and the author presented a hybrid ABC algorithm. The main aim was to combine the ABC algorithm with the evolutionary strategies. The algorithm was tested on the two problems of engineering design and the results were compared to various techniques. The results suggested that the performance of hybrid algorithm was much better and can be implemented further on other problems.

Habbi *et al.* [44] proposed a method to develop automatically and learn Takagi-sugeno (TS) fuzzy systems using ABC algorithm from the numeric data thereby simultaneously generating complete structure, parameters along with the number of rules, rule consequent parameters and rule premise within the search space and that too with minimum performance index. The results through this method were found to be efficient and effective than various other methods like GA, PSO, CRPSO, DE etc.

Banitalebi *et al.* [45] proposed an algorithm for the optimization problems that deals with hardware limitations of cost and space. Algorithm employs Probability density functions to calculate virtual population. The use of two probability density functions improve the probabilistic

feature of the algorithm and help the EcABC due to introduction of some uncertainty to search direction. The algorithm has been found to outperform several other memory saving algorithms.

Zhang *et al.* [46] presented two modified versions of ABC to improve the exploitation capability of algorithm inspired by Grenade Explosion Method (GEM) named as GABC1 and GABC2. In GABC1, GEM is being combined with worker bee in GABC2, it is being combined with the onlooker bee phase. On comparing the two versions, it was found that GABC1 had better performance but GABC2 is more effective and robust than many competing algorithms.

Santos *et al.* [47] presented a modified version of ABC algorithm in case of cache memory hierarchy exploration problems for the purpose of increasing performance in embedded system processes and to lessen the consumption of energy. The exploration of architecture is based upon adjustments of cache parameters which have been inserted on memory hierarchies. On applying the proposed algorithm to six of the applications from MiBench and MediaBenchII suites and on comparison with EDDM, SPEA2, and NSGAII optimization methods, which were actually used for similar problems, it is found that proposed algorithm worked better in case of two indicators namely hyper volume and generational distance in several cases(about 66.66%). Moreover the method found quite impressive solutions by just exploring 1.80% of the solution space.

Miri et *al.* [48] proposed a strategy to overcome problems of finding the minimum frequency value of data item sets due to difficulty in finding association rules of fuzzy values and the problem of increase in operational time of item sets. The paper deals with eliminating those data items which hold no importance in finding association rules thereby reducing operational data and proving out to be acceptable when mining association rules from large data sets are applied.

Xiang *et al.* [49] introduced the simple strategy of Elitism to improve ABC algorithm. The solutions which were not dominated and discovered during the process of search were store using a fixed archive. The elites from the archive are chosen which are used to produce new food sources in worker and onlooker bee phases in every cycle. When overflow occurs in the archive, the member from the most crowded place is removed. The suggested algorithm produced comparable and even much better results.

Kiran *et al.* [50] integrated multiple solution update rules with ABC where counters and five search strategies have been used for the updating of solutions. To initialize, every update rule is assigned to a constant counter content and the rule which is chosen by the bees is determined by these counters during searching. Depending upon the features of the numeric function, one or more strategies are used in this approach which help the artificial agents in learning which update rule is better suited which can lead to even better results. The proposed strategy is found to be outperforming usual ABC and several other variants of ABC.

Table 1.
Contribution of Relevant Papers in Various Sources

S. No.	*Sources*	*No. of identified papers*
1.	IEEE	26
2.	ACM	15
3.	SCIENCE DIRECT	5
4.	OTHER JOURNAL	4

Table 2.
Various applications of ABC algorithm in various areas

S. No.	*Area*	*Application*	*Author*	*Publication Year & Source*	*Ref.*
1.	Networking	Designing a routing algorithm named as BeeAdHoc	Farooq et *al.*	2005, ACM	[1]
		Studies a new problem of vehicle routing.	Bin et *al.*	2013, IEEE	[31]
		Proposed a multi-target tracking system for Mobile sensor Networks.	Kumar et *al.*	2014, IEEE	[36]
		Solving the dynamic Routing problem.	Rashedi at *al.*	2011, IEEE	[12]
		For solving routing based problems.	Zhang et *al.*	2012, IEEE	[21]
2.	Scheduling	To Solve the Job Shop Scheduling problem	Wong et *al.*	2008, IEEE	[2]
		Solving problems of Curriculum-Based Course Timetabling	Junaedi et *al.*	2011, IEEE	[16]
3.	Image Processing	Edge Enhancement using ABC algorithm	Benala et *al.*	2009, IEEE	[4]
		Introducing a method for image segmentation	Zhang et *al.*	2011, Entropy	[10]
4.	Numerical Analysis	Benchmarks the algorithm by using noise free BBOB 2010.	El- Abd et *al.*	2010, ACM	[5]
		Enhancing performance of ABC by introducing opposition-based learning	Mohammad El-Abd	2011, ACM	[14]
		Comparison of Discrete ABC and simulated annealing on Redistricting Problem	Ponsich et *al.*	2012, ACM	[25]
5.	Clustering	Minimizing energy consumption through novel hierarchical clustering approach	Karaboga et *al.*	2010, IEEE	[6]
		predicting the function of unknown protein in Protein-Protein Interaction network	Wu et *al.*	2011, IEEE	[17]
		suggests EABC which is improved ABC algorithm for the clustering	Tan et al	2014, ACM	[42]
6.	Distributed Systems	distributed version of ABC algorithm based upon manager-worker model for large problem size	Banharnsakun et *al.*	2010, IEEE	[7]
7.	Classification	Introduced a new classifier for distinguishing normal and abnormal MRIs of the brain.	Zhang et *al.*	2011, ACM	[9]

Table 2 Contd…

8.	Machine Learning	Creating sheep and goat disease database	Prasad Babu et *al.*	2011, IEEE	[11]
9.	Artificial Intelligence	Determining flight direction of a bee by using the concept of Pareto dominance	Zou et *al.*	2011, ACM	[13]
10.	Metaheuristics	Solving travelling salesman problem using the novel ABC	Zhang et *al.*	2011, IEEE	[18]
		Solving numerical problems of optimization having bound constraint by colony size reduction	Sharma et *al.*	2012, IEEE	[22]
		Multi objective optimization through Multi-Hive ABC	Zhang et *al.*	2012, IEEE	[23]
11.	Fuzzy Logic	Optimizing the structure and parameter of the PID-like fuzzy controller.	Tien et *al.*	2012, ACM	[19]
		The improvement in the limitations of fuzzy geo-demographic clustering algorithm	Wijayanto et *al.*	2014, IEEE	[34]
		Proposes a method to develop automatically and learn Takagi-sugeno (TS) fuzzy systems	Habbi et *al.*	2015, Science Direct	[44]
		Proposes a strategy to overcome problems of finding the minimum frequency value	Miri et *al.*	2015, ACM	[48]
		Proposes a strategy for training fuzzy neural network using ABC algorithm	Ning et *al.*	2011, IEEE	[40]
12.	Greedy Problems	proposes a two step greedy position update technique for the ABC algorithm	Yu et *al.*	2013, ACM	[30]
13.	Enhancement of ABC	Numerical optimization by Enhanced ABC i.e., Interactive ABC	Tsai et *al.*	2009, IJICIC	[3]
		Based upon the behavior of honey bees.	Yi et *al.*	2014, IEEE	[33]
		Presents a hybridization of the ABC Algorithm.	Mollinetti et *al.*	2014, ACM	[35]
		Hybridization of ABC and PSO to propose an novel ABC algorithm	Shi et *al.*	2010, IEEE	[8]
		explores the Evolutionary Particle Swarm Optimization (EPSO)	Mollinetti et *al.*	2014, ACM	[43]

Table 2 Contd…

modifying Artificial bee colony algorithm	Peng et *al.*	2011, IEEE	[15]
Modified version called "Adaptive Artificial Bee Colony" (AABC)	Rekaby et *al.*	2013, IEEE	[26]
Proposing modified ABC algorithm based upon the multi-exchange neighborhood	Dongli et *al.*	2012, IEEE	[20]
Proposing novel ABC where bees are ranked as per fitness	Rajasekhar et *al.*	2012, ACM	[24]

According to above Table, we can have a look at the areas where artificial bee colony algorithm has been applied like artificial intelligence, machine learning, software engineering and electronics and so on.

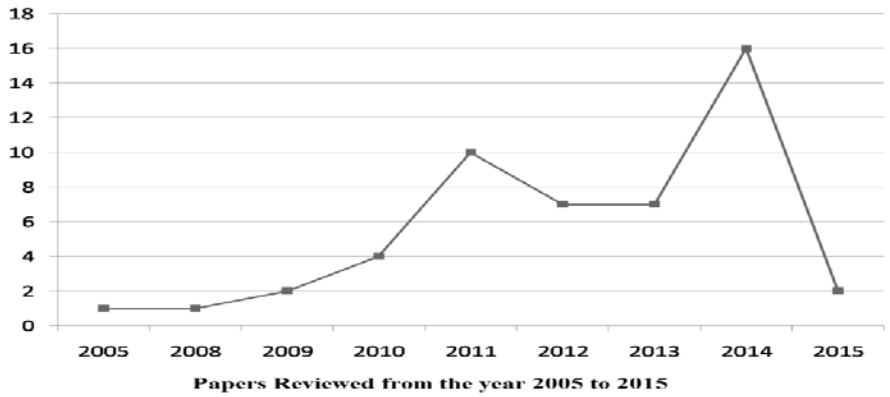

Figure 4. The Line Chart shows the publication papers from the year 2005 to 2015

Table 3.
Areas Where ABC Algorithm Been Applied

1. It has been used in Travelling Salesman Problem.
2. It has been applied for the structural optimization.
3. Applied for multi-level thresholding.
4. Applied for MR brain image classification.
5. Applied for Face pose estimation.
6. Nano electronic based phase-locked loop optimization to speed up the physical design optimization
7. It has been used in IP Routing in mobile networks...
8. A model of honey bees has been developed to solve allocation of resources.
9. To solve the numerical issue a virtual bee algorithm has been developed.
10. The Bees Algorithm has been proposed which performed a neighborhood search of food combined with random search
11. It has been applied to the solution of clustering problems.
12. It has been applied to the neural network training.
13. The bee colony algorithm can be used in image processing, image enhancement, classification, segmentation and feature extraction in digital image processing.
14. It can be extended to the optimization of hybrid functions.
15. It can be applied to fuzzy neural network.
16. A new hybrid algorithm has been developed after combining the swarm algorithm and artificial bee colony algorithm for more efficiency.

4. CONCLUSIONS & FUTURE SCOPE

In this paper from Table 2, our research questions RQ1 and RQ2 have been identified and explained. The main objective of this systematic review is to identify various problems where artificial bee colony algorithm has been applied till now. Various hybrid approaches have also been proposed combining along with techniques like particle swarm optimization and evolutionary strategies. The results suggested that the performance of hybrid algorithm was much better and can be implemented further on other problems. As compared to other algorithms it shows very effective results However, there are still several limitations in ABC algorithm, as it is very bad at exploitation but very good at exploration. Moreover its processing speed in searching of the food in neighborhood is also an issue in several cases. It has also been identified that there are less research work done in software engineering field. Hence there is scope where the algorithm can be modified for better performance results. Based on this particular analysis research can be extended further to identify certain problem where this technique can be applied so that its optimization results can be observed.

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