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A Comprehensive Survey on Variants in Artificial Bee Colony (ABC)

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***Abstract*—The artificial bee colony (ABC) algorithm is a popular swarm based technique, which is inspired from the intelligent foraging behaviour of honeybee swarms. In ABC, the neighbourhood search strategy is employed in order to find better solution around the previous one. ABC algorithm is used to solve many real world problems. Number of researchers are interested in ABC algorithm for solving optimization problems Since 2005, several related works have appeared to enhance the performance of the standard ABC in the literature, to meet up with challenges of recent research problems. In this review paper, we provide an overview of Artificial Bee Colony (ABC) algorithm and advances in ABC algorithm.**

***Keywords*— Artificial Bee Colony (ABC) algorithm, Optimization, Swam Intelligence.**

I. INTRODUCTION

Over the past decades, a number of optimization algorithms have been used extensively in structural and manufacturing optimization tasks. These methods may not be used efficiently in finding global optimum solutions. As an alternative to traditional techniques, population-based optimization approaches, such as, genetic algorithm, particle swarm optimization algorithm, artificial immune algorithm, cuckoo search algorithm, differential evolution, ant colony optimization and artificial bee colony algorithm have been developed to solve complex problems in engineering design, finance and for finding the optimum solution or unconstrained maxima or minima of continuous and differentiable functions. These algorithms can be successfully applied to solve many real life problems. The problems to be optimized by swarm intelligence algorithms do not need to be mathematically represented as continuous, convex, and/or differentiable functions; they can be represented in any form.

Artificial bee colony (ABC) algorithm is one of the population based metaheuristic approach developed by Karaboga in 2005 for global numerical function optimization, which simulates the foraging behaviour of honey bee swarm. Within 10 years, ABC algorithm has found to be successful in solving global optimisation problems. Due to its simplicity and ease of application, the ABC has been widely used to solve both continuous and discrete optimization problems (1). However, there are some inherent pitfalls. The convergence speed of ABC is slower than those of the representative population-based stochastic algorithms, such as differential evolution (DE) and particle swarm optimization (PSO). Moreover, ABC suffers from premature convergence while dealing with certain complicated problems. Several ABC variants have been proposed to overcome these pitfalls.

The ABC variants can be generally categorized into three groups:

1. The parameters of configuration tuning
2. Hybridizing with other evolutionary optimization operators to improve performance
3. Designing of new learning strategy by modifying the search equation of the basic ABC algorithm (2).

II. ARTIFICIAL BEE COLONY (ABC) ALGORITHM

Artificial bee colony algorithm (ABC) developed by Karaboga and further developed by Karaboga and Basturk is a nature inspired algorithm based on the intelligent foraging behaviour of honeybee swarm. The ABC algorithm describes the foraging behaviour, learning, memorizing and information sharing characteristics of honeybees.

The colony of artificial bees consists of three groups of bees: employed bees, onlookers bees and scouts bees. The colony of the artificial bees is divided into two groups, first half of the colony consists of the employed artificial bees and the second half includes the onlooker bees. Scout bees are the employed bees whose food source has been abandoned. In ABC algorithm, the position of a food source represents a possible solution to the optimization problem (value of design variables) and the nectar amount of a food source corresponds to the quality of the associated solution (fitness value) (6).

The employed bees randomly search for food-source positions (solutions). Then, by dancing, they share information (communicate) about that food source, such as nectar amounts (solutions qualities), with the onlooker bees waiting in the dance area at the hive. The duration of a dance is proportional to the nectar's content (fitness value) of the food source being exploited by the employed bee. Onlooker bees watch various dances before choosing a food-source position, according to the probability proportional to the quality of that food source. Consequently, a good food-source position attracts more bees than a bad one. Onlookers and scout bees, once they discover a new food source position, may change their status to become employed bees. When the food-source position has been visited (tested) fully, the employed bee associated with it abandons it, and may once more become a scout or onlooker bee. In a robust search process, exploration and exploitation processes must be carried out simultaneously. In the ABC algorithm, onlookers and employed bees perform the exploration process in the search space, while, on the other hand, scouts control the exploration process (7). In the basic ABC algorithm implementation, number of food sources i.e., solutions) is equal to the number of employed bees. An employed bee whose food source is exhausted (i.e. solution has not improved after several attempts) becomes a scout (4).

Detailed Pseudocode of the ABC Algorithm is given below:

1. Initialize the population of solutions $x_{i,j}$
2. Evaluate the population
3. cycle=1
   repeat
4. Produce new solutions (food source positions) $\upsilon_{i,j}$ in the neighbourhood of $x_{i,j}$ for the employed bees using the formula
   $\upsilon_{i,j} = x_{i,j} + \Phi_{ij}(x_{i,j} - x_{k,j})$ (k is a solution in the neighbourhood of i, Φ is a random number in the range [-1,1]) and evaluate them
5. Apply the greedy selection process between x_i and υ_i
6. Calculate the probability values P_i for the solutions x_i by means of their fitness values using the equation (1)
   $$p_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i}$$
   (1)
7. In order to calculate the fitness values of solutions we employed the following equation (eq. 2):
   $$fit_i = \begin{cases} \frac{1}{1+f_i} & \text{if } f_i \geq 0 \\ 1+abs(f_1) & \text{if } f_i < 0 \end{cases}$$
   (2)
8. Normalize P_i values into [0,1]
9. Produce the new solutions (new positions) υ_i for the onlookers from the solutions x_i, selected depending on P_i, and evaluate them
10. Apply the greedy selection process for the onlookers between x_i and υ_i
11. Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution x_i for the scout using the equation (3)
    $x_{ij} = min_j + rand(0,1) * (max_j - min_j)$
12. Memorize the best food source position (solution) achieved so far
13. cycle=cycle+1
14. until cycle= Maximum Cycle Number (MCN)

The ABC algorithm has been applied to many real world applications, for example, function optimization, real parameter optimization, digital filter design, clustering, and neural network training.(3)

A. Advantages of ABC algorithm

The major advantages which ABC holds over other optimization algorithms are (9)(5):

- Simplicity, flexibility and robustness
- Use of fewer control parameters compared with many other search techniques
- Ease of hybridization with other optimization algorithms
- Ability to handle the objective cost with stochastic nature
- Ease of implementation with basic mathematical and logical operations
- Finding global optimization solution.

III. Variants of ABC Algorithm

Since its first introduction in 2005, ABC continues to attract the interest of investigators from diverse disciplines across the globe. This has resulted into a variety of modifications to the basic ABC. Originally, ABC optimization was proposed for solving numerical problems. Karaboga and Basturk (2007) extended ABC algorithm for solving constrained optimization problems and applied it to a set of constrained problems. D. Karaboga and B. Basturk (2007) compared the performance of ABC algorithm with that of differential evolution (DE), particle swarm optimization (PSO) and evolutionary algorithm (EA) for multi-dimensional numeric problems and can be efficiently employed to solve engineering problems with high dimensionality. Dervis Karaboga et al. (2007) tested ABC algorithm on training on artificial neural networks which are widely used in signal processing applications and the performance of the algorithm has been compared to differential evolution and particle swarm optimization algorithms which are also population-based algorithms.

Karaboga (2008) described new method based on ABC algorithm for designing digital IIR filters and its performance is compared with that of a conventional optimization algorithm (LSQ-nonlin) and particle swarm optimization (PSO) algorithm. R. Srinivasa Rao et al. (2008) proposed a new method which applies an artificial bee colony algorithm (ABC) for determining the sectionalizing switch to be operated in order to solve the distribution system loss minimization problem. Tsai et al. (2009) introduced an enhanced ABC algorithm, which is called the interactive ABC, for numerical problems. F. S. Abu-Mouti et al (2009) presented a modification in the neighbouring search of the artificial bee colony (ABC) algorithm for optimal distributed generation sizing and allocation in distribution systems.

Brajevic et al. (2010) presented an improved version of ABC for constrained optimization problems, which has been implemented and tested on several engineering benchmarks which contain discrete and continuous variables. Mezura-Montes and Velez-Koeppel (2010) introduced a novel algorithm based on the ABC to solve constrained real-parameter optimization problems, in which a dynamic tolerance control mechanism for equality constraints was added to the algorithm in order to facilitate the approach to the feasible region of the search space. Aderhold et al. (2010) studied on the influence of the population size on the optimization behaviour of ABC and also proposed two variants of ABC which use the new methods for the position update of the artificial bees.

Dervis Karaboga et al (2011) described a modified ABC algorithm for constrained optimization problems and compared the performance of the modified ABC algorithm against those of state-of-the-art algorithms for a set of constrained test problems. For constraint handling, ABC algorithm uses Deb's rules consisting of three simple heuristic rules and a probabilistic selection scheme for feasible solutions based on their fitness values and infeasible solutions based on their violation values. Bahriye Akay et al (2011) introduced modified versions of the Artificial Bee Colony algorithm and applied for efficiently solving real-parameter optimization problems. Anandha kumar et al.(2011) introduced Modified Artificial Bee Colony (MABC) algorithm is applied to solve the GMS optimization problem efficiently. The MABC algorithm is proposed in order to handle the system constraints effectively and obtain the better maintenance schedules.

Milan Tuba et al. (2012) proposed a modified algorithm which integrates artificial bee colony (ABC) algorithm with adaptive guidance adjusted for constrained engineering optimization problems. Yan-Jun Shi (2012) presented heuristic algorithm (ABC-T) to deal with vehicle routing problems with time windows. Dervis Karaboga(2012) proposed novel energy efficient clustering mechanism for wireless sensor network, based on artificial bee colony algorithm, is presented to prolong the network life-time. Manish Gupta et al. (2012) proposed An Efficient Modified Artificial Bee Colony Algorithm for solving the job scheduling problem with the criterion to decrease the maximum completion time. Salima Ouadfel Dr. et al. (2012) proposed a new fuzzy clustering algorithm based on a modified Artificial Bees Colony algorithm, in which a new mutation strategy inspired from the Differential Evolution is introduced in order to improve the exploitation process. R. Murugan et al.(2012) proposed Modified Artificial Bee Colony (ABC) algorithm for Economic Dispatch (ED) problem. B. Babayigit (2012) presented a new modified ABC algorithm for numerical optimization problems to improve the exploitation capability of the ABC algorithm. A different probability function and a new searching mechanism are proposed. Tarun Kumar Sharma et al. (2012) proposed a ABC variant called B-ABC to improve the capability of local search. Nishida et al. (2012) modified ABC algorithm for adaptation to time-varying functions. To adjust the change in the function, the procedure for reevaluating the bee at each time is introduced. Bahriye Akay, Dervis Karaboga (2012) the ABC algorithm is used to solve large scale optimization problems, and it is applied to engineering design problems by extending the basic ABC algorithm simply by adding a constraint handling technique into the selection step of the ABC algorithm

Ahmet Ozkis et al.(2013) proposed Accelerated ABC (A-ABC) Algorithm for Continuous Optimization Problems. In A-ABC, two modifications are used on the Artificial Bee Colony (ABC) algorithm to progress its local search ability and convergence speed. Sandeep Kumar et al. (2013) introduced Crossover based ABC (CbABC) which integrates crossover operation from Genetic Algorithm (GA) with original ABC algorithm. The CbABC strengthens the exploitation phase of ABC as crossover enhances exploration of search space. Xiangyu Yu et al.(2013) introduced a sensor deployment algorithm based on modified ABC algorithm called FNF, (forgetting and neighbor factor)-BL (backward learning) ABC algorithm is proposed. In order to have a better coverage and a faster convergence speed, the onlooker bee phase and the scout bee phase of the ABC algorithm have been modified. Takeshi Nishida (2013) modified the ABC algorithm for adaptation to time-varying functions. To adjust to the change in the function, a procedure for re-evaluating the bees at each time is introduced. Dharmender Kumar et al. (2013) proposed a variant of ABC algorithm based on rectangular topology structure, namely rectangular topology based Artificial Bee Colony algorithm (RABC). RABC significantly improves the original ABC in solving high dimensional optimization problems. Alina Rakhi Ajayan et al. (2013) proposed an improved ABC algorithm to match the different characteristics of wireless sensor network deployment process, which will be optimum for real time dynamic network functioning. Muhammad shahrizan shahrudin et al (2013) presented a modified ABC algorithm to fine optimum value for optimum functions. The Hybrid ABC algorithm are applied searching mechanisms and probability functions. Ivona Brajevic et al. (2013) introduced an upgraded artificial bee colony (UABC) algorithm for constrained optimization problems. UABC algorithm enhances fine-tuning characteristics of the modification rate parameter and employs modified scout bee phase of the ABC algorithm.

Dervis Karaboga et al. (2014) introduced Quick artificial bee colony (qABC) is a new version of ABC algorithm which models the behaviour of onlooker bees more accurately and improves the performance of standard ABC in terms of local search ability. Wei-Der Chang et al.(2014) developed an improved version of artificial bee colony (ABC) algorithm for solving the numerical optimization problem. Zhen-an He et al. (2014) proposed SDABC which provides high quality of initial solutions and to improve population diversity. Vani Maheshwari et al. (2014) proposed an efficient modified version of ABC algorithm , where two additional operator crossover and mutation operator is used in the standard artificial bee colony algorithm. S. Shanthi et al. (2014) introduced modified artificial bee colony based feature selection (MABCFS) technique to select the predominant feature set in classification of breast lesion in mammogram images. Mustafa Servet Kiran et al. (2014) proposed iABC a selection mechanism for neighborhood of the candidate solutions in the onlooker bee phase. Soudeh Babaeizadeh et al. (2014) proposed a Modified artificial bee colony (mcABC) algorithm for constrained optimization problems. mcABC proposed where three new solution search equations are introduced respectively to employed bee, onlooker bee and scout bee phases. Noorazliza Sulaiman et al. (2014) introduced a two new modified ABC algorithms referred to as JA-ABC3, JA-ABC4 with the objectives to diligently avoid premature convergence and enhance convergence speed for reactive power optimization. Wei Gao et al. (2014) improved ABC algorithm and proposed improved artificial bee colony algorithm based gravity matching navigation method. Bai Li et al. (2014) proposed a novel artificial bee colony (ABC) algorithm by a balance-evolution strategy (BES) is applied for optimization. AlkJn Yurtkuran and Erdal Emel (2014) introduced a modified ABC algorithm that benefits from a variety of search strategies to balance exploration and exploitation. Xiu Zhang et al. (2014) modified Artificial Bee Colony Algorithm is to promote the convergence rate of ABC which is applied to loudspeaker design problem. Noorazliza Sulaiman et al. (2014) proposed a new ABC variant referred as JA-ABC2 to enhance convergence rate and to avoid local optima trapping. Zhenyue Zhang et al. (2014) modified ABC that improves local search mechanism and applied to face recognition and sparse representation. Sandeep Kumar et al. (2014) introduces a local search mechanism in ABC called Enhanced local search in ABC (EnABC) that increases exploration capability of ABC and avoids the dilemma of stagnation. Shimpi Singh jadon et al. (2014) proposed an Expidited Artificial Bee Colony(EABC) to improve ABC algorithm by balancing its exploration and exploitation capabilities.

Hardiansyah et al. (2015) proposed to solve combined economic emission dispatch (CEED) problem in power systems using modified artificial bee colony (MABC) algorithm considering the power limits. S. Uma et al. (2015) enhanced ABC algorithm using Partial Least Square (PLS) mechanism in order to extract frequent interaction among patterns. Khalid A. Eldrandaly et al. (2015) proposed modified Artificial Bee Colony (ABC) algorithm for solving least-cost path problem in a raster-based GIS. Noorazliza Sulaiman et al.(2015) introduced a new modified ABC algorithm named JA-ABC5 to enhance convergence speed and improve the ability to reach the global optimum by balancing exploration and exploitation processes. JA-ABC5 used optimize the reactive power optimization problem. Ashay Shrivastava et al. (2015) proposed enhanced ABC algorithm with SPV for travelling salesman problem is used. Jun-Hao Liang et al. (2015) introduced a modified artificial bee colony algorithm (MABC) for solving function optimization problems and control of mobile robot system. Vineet Singh Bhadoriya et al. (2015) introduced a modified ABC algorithm to optimize the association rules from a huge dataset. Hai Shan et al. (2015) proposed an improved hybrid ABC algorithm to improve the convergence performance and search speed of finding the best solution in real parameter numerical optimization problems. Tarun Kumar Sharma et al (2015) modified version called Dichotomous ABC (DABC), the idea is to move dichotomously in both directions to generate a new trial point for solving global optimization problems over continuous space. Mutasem K et al. (2015) proposed a new automatic and intelligent clustering for the segmentation of brain tumor using hybridization of Fuzzy C-mean and Artificial Bee Colony (FCABC), in order to enhance the ability of the FCM to segment the MRI brain image, extract the appropriate number of cluster centres and the number of abnormal cells in each cluster using automatic and dynamic way. Ding Zhenghao et al. (2015) , modified the ABC algorithm by choosing the tournament selection instead of roulette, and chaotic search mechanism is applied to improve algorithm's global search capability for damage detection. Celal Ozturk et al. (2015) proposed a novel binary version of the artificial bee colony algorithm based on genetic operators (GB-ABC) such as crossover and swap to solve binary optimization problems.

D. Karaboga et al. (2016) introduced a discrete artificial bee colony (ABC) algorithm, which is inspired by the intelligent foraging behaviour of real honey bees, for the detection of highly conserved residue patterns or motifs within sequences in the bioinformatics. Ting-Cheng Feng et al. (2016) apply the mechanism of symbiosis to create a hybrid modified DNA-ABC algorithm for hierarchical fuzzy classification applications. Enrico Ampellio et al. (2016) improved the Artificial Bee Colony (ABC) algorithm, called the Artificial super-Bee enhanced Colony (AsBeC) to provide fast convergence speed, high solution accuracy and robust performance over a wide range of problems. Fuli Zhong et al. (2016) modified ABC algorithm based on improved-global-best-guided approach and adaptive-limit strategy for global optimization problems called IGAL-ABC algorithm is proposed. An improved-global-best-guided term with a nonlinear adjusting factor is employed in the update equation.

IV. Conclusions

In the current paper, possible number of articles were reviewed for providing literature. There may be some articles missed from this review. But from the considered articles it is clear that Artificial Bee Colony (ABC) is an algorithm which is used for solving many real world problems. It is also observed that many researchers are concentrating on the modifications to the ABC algorithm. Hence, ABC became an interesting algorithm for solving constraint and unconstraint optimization problems and can be applicable to different applications.

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