

Handling Optimization Problem, and the Scope of Varied Artificial Bee Colony (ABC) Algorithms: A contemporary Research

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Abstract— One of the most successful search algorithms of the last decade is Artificial Bee Colony (ABC) algorithm. It was first coined by Dervis Karaboga, 2005. Since then a group of variants of the algorithm have been anticipated to find solutions for the problems of optimization. The motivation for the algorithm is the search process of honey bees for food sources. The present paper aimed to bring out the evolutionary developments of the algorithm that cover numerous versions of the algorithm with the strategic changes to meet the optimization needs of the adopted problem contexts. This survey clearly reviewed the basic types, advancements, application areas, and the relevance of the ABC algorithm addressing various problem contexts. The efforts made by the research community since the last two decades along with the success stories are discussed in detail. The attachment of the optimization process of ABC with data mining is dealt in particular. Finally the opportunities and the scope of the application of the algorithm in large areas of problem domains are highlighted.

Keywords — Swarm Intelligence, ABC Algorithm, Clustering, optimization and Outlier Analysis, particle swarm optimization (PSO).

I. INTRODUCTION

Swarm intelligent algorithms are mainly used in population based algorithms. Swarm intelligence algorithm is naturally evolved from searching dynamics followed by life groups. The main characteristic of swarm intelligence is own safeguarding and management. This new type of natural intelligence is particularly useful to solve non-linear functions. Kennedy and Eberhart are developed particular swarm optimization (PSO) technique using population based algorithm. The PSO algorithm could be the outcome of several studies as well as inspiration from natural living beings like birds, insects, fish, etc. The collective behavior of these natural elements is a good motivation for the development of swarm based algorithms.

One group of artificial bees dances when they observed food source in the neighborhood. This helps the other groups to opt for the best food source in order to gather more food qualitatively in good quantities with less energy.

Optimization is the primary goal of many subjects like machine learning, information science, operations research, engineering design, and many more. Most of the real life problems reduce to optimization problems [17]. Variety of stochastic optimization models are used to solve optimization problems. Many design variants have been in use to solve a lot of searching problems based on natural

intelligence. Some of such optimizations include ant colony optimization (ACO) algorithm, algorithms based on biogeography, algorithms based on swarm intelligence, genetic algorithms, harmony search algorithms, and the ABC. All these nature based algorithms are the actual result of inspiration from nature, division of work of and coordination. [7].

Researchers have been providing versions of ABC that meet the needs of various problem contexts. Inspired by natural procedures of living things to solve the search problems, Dervis Karaboga and his team designed the ABC algorithm in 2005. This natural and nature inspired process resembles in all the way the smart activities of honey bees to search the food. Since then the study is active and adopted many real world application areas with various versions of ABC algorithm.

The research group headed by Dervis Karaboga has undertaken the study of bio-inspired optimization procedures to solve the search problems in various application areas covering engineering, mathematics, machine learning, data mining and more.

The ABC comprises of 3 clusters: Employed bees, Scouts, & Onlookers, and. Swarm intelligence (SI) is an example for bio-inspired computation. As a subset of artificial intelligence (AI) it is popular and has been in use by numerous researchers for a variety of application areas. The nature of swarm groups can be studied based on communication means, search process, pointing nest location ,task sharing information sharing, decision making, and finally the optimization. The perceptive of the swarm behavior helps in design and modification of the basic algorithm according to the necessities of the specific problem. The artificial bee colony (ABC) algorithm helps to achieve desired optimization by iteratively searching and computation. This type of intelligence is a mean for the best-fit solution among a huge number of data and arriving at the solution to many critical problems.

The detailed sketch of the basic ABC algorithm is specified in the subsequent section. The past and current research details with respect to ABC algorithm are discussed in the succeeding section. Various improvements and the application of variants of ABC algorithm are given. The role of the ABC optimization in data mining and the related fields is discussed thoroughly in the next section. The following section presents the opportunities of the ABC variants in future research.

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II. THE BASIC ABC ALGORITHM

The original practice of the algorithm is summarized as follows:

Artificial Bee Colony (ABC) Algorithm:

1. Generate an initial population of SN solutions which is randomly distributed where the size of population denotes by SN. Here the solutions represent genuine food source locations, whereas each solution, x_i denotes a vector of dimension D.
2. The initial solution is subject to modify over $C = 1, 2, 3, \dots$, MCN cycles of the search process by Scouts, On-lookers, and Employed bees.
3. Employed bee computes novel food source fitness value to produce a modification of the current solution in her memory. This information is passed over to the onlooker bees. Based on the information shared with employed bees, on-looker bees do computations to evaluate the nectar information. This evaluation helps the onlooker bees to choose the probability of meeting for food source towards its nectar quantity. Onlooker bees randomly search for a modification in the current solution. The food source may be left out by the search process where the replacement is done the scouts. The probability estimation made by onlooker bee makes use of the following formula: $P_i = \text{Fit}_i / \sum_{i=1}^N \text{Fit}_i$, where Fit_i denotes the value of fitness for solution i .

$$P_i = \frac{\text{Fit}_i}{\sum_{i=1}^N \text{Fit}_i}$$

Where Fit_i ($i = 1, 2, 3, \dots, N$) is the fitness (probability) value of the i^{th} solution. The fitness value can be denoted by the equation

$$\text{Fit}_i = \begin{cases} \frac{1}{1 + f_i}, & \text{if } f_i \geq 0 \\ \frac{1}{1 + |f_i|}, & \text{if } f_i < 0 \end{cases}$$

Where f_i represents the value of objective function for the set of N-solution ($i = 1, 2, 3, \dots, N$) that is particular to optimize the issue. The novel food source locations treated based on their superiority in terms of the fitness value and the necessary replacement is done. If a new solution has a superior quality than the former, then the replacement will be taken place by the new one. If it is not the case, then the former one is recalled that is similar to employed bees phases.

To generate a new candidate food position from old one ABC uses the following formula: $v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj})$. Here k takes indices in $\{1, 2, \dots, SN\}$, and j takes indices in $\{1, 2, \dots, D\}$ which are the randomly chosen indexes. The index, k , is determined randomly, which is a different index from i . Here ϕ_{ij} is a random number between $[-1, 1]$.

III. RELATED WORK

Now a day's bio-inspired computing approaches are evolving as principle means of techniques in big data analytics. There are numerous kinds of popular bio-inspired computing techniques. The examples include but not limited

to ABC algorithm, NN algorithm, ACO algorithm, the principle of bacterial foraging, firefly method, particle swarm procedure, Cuckoo search, and artificial plant optimization technique and flower pollination method. This technique is efficient for its convergence speed with clever selection criteria and neighbor identification. This algorithm meets optimization at global level. The capability of this algorithm in attaining the desired outcome with less number of runs attracted the research community.

Many studies lead to the development of search optimization techniques with different variants.

A. Various Improvements To ABC Algorithm

The ABC algorithm can also be applied in many real time situations such as collective decision-making for dealing with multi-criteria selection problems. ABC algorithm is used in both constrained and unconstrained optimization problems. ABC algorithm evolved with, its usage and application in diversified domains. The interesting application areas of ABC algorithm cover customer segmentation and analysis in e-business environment, outlier detection and in expert systems for agriculture [2].

The original ABC algorithm has the challenge of low convergence speed at the search process. To speed up the process with better convergence performance of ABC algorithm, Yunfeng Xu et al, 2012 [23] modified the basic version and proposed a novel process named novel ABC (NABC) algorithm by enhanced search procedure of both the onlooker & employed bees. The novel procedure is built upon the search process named by a special and differential evolution (DE). Two mutation schemes of DE named DE/best/1 & DE/rand/1 were applied in combination in the solution search process. The new process tried to store and uses some of the best solutions and use the stored solutions set for dynamic selection of new useful solution pools. This dynamic separation improves the search process significantly. The modifications of the current solutions are done on fly. Novel candidate solutions were produced through searching the area of potential solutions from the pool of solutions. The authors stated about the superiority of the proposed process.

The ABC algorithm initially suggested to unconfined optimization issues and proved to be superior method to solve the optimization issues. The work [9], presented an extended variant of the ABC to resolve the optimization issues with constraints. To do this they adopted Deb's confined handling model [8]. Deb's model utilized a tournament chosen operator that enforces the criterion that: **1)** A solution is better when it is superior to another in terms of feasibility, **2)** The strength of an objective function is the next level measure to decide the superiority, **3)** Less number of constraints is a strength. This approach made changes to the process of scout production where the process allows new and probably infeasible individuals to be in the population. For determining novel food sources arbitrarily it is planned to produce artificial scouts at a cycle period of predetermined number in the random discovery of a new food sources.



Weifeng Gao *et al* [22] proposed a new iterative based dynamic search process that is very similar to the basic ABC algorithm. In general the actual search process followed by each of the bee concentrates to improve the current position in each iteration. This explores the chances over the iterations. New way of systems with different learning methods were tried to get better convergence results. Originally conducted actual experiments have justified the actual performance of the proposed variant of the ABC technique in solving many complex numerical optimization problems. To initialize the solution set a novel way is followed using sinusoidal iterative process, with the relation $ch_{k+1} = \sin(\pi ch_k)$, $ch_k \in (0, 1)$, $k = 0, 1, 2, \dots, k$, note that here k is the actual iterative count. This proposal gave the comments about the application capabilities of the approach in the areas that include design, communication networks optimization & data mining and more.

Baris Kocer [4] proposed a modified method for swarm optimization using some statistical methods. The new procedure first finds 10 best fitness value solutions. In the 2nd stage the values of standard deviation (SD) for every parameter are computed from former better fitness solutions. This provides best parameter. These two steps merged with normal ABC become the new way of statistically guided ABC algorithm.

Alkin Yurtkuran and Erdal Emel[1] tried to improve the ABC algorithm solution quality by utilizing probabilistic multi search. The main contributions of the proposed study include i) Probabilistic multi search with predetermined probability values and ii) a new way of candidate solution acceptance, where a worse solution also have some probability to be accepted. The new proposal showed good performance at early stages of solution search. The suggested algorithm is effective in terms better exploration approaches. The experimental studies showed that ABC-SA performs better than competitor algorithms in most of test cases.

Dongli Z. *et. al.* 2011 [10] presented a modified ABC algorithm (MABC) through improved initial population arrangement, clustering of population, & regeneration of population for ABC. Here the initial solution and the corresponding reverse initial solution t are generated. Currently 2 types of the solutions are arranged for attaining the best fitness solution in the form of initial population. This initialization type could assist in enhancing the effectiveness and quality of ABC. New grouping criteria named h-type subpopulation grouping is introduced in which the difference among the groups will be reduced. An exponential function could be utilized in this manuscript for updating the length of step. The experimental results revealed that MABC is superior to ABC, NABC, and DEABC.

Rajasekhar A. *et al*, 2011 [20] gave an improved version of the algorithm which made use of the Levy Probability Distributions. This distribution can improve the search process by generating an offspring through mutations guided by the internal parameter α . In order to apply Levy mutation Rechenberg's 1/5 rule was used. The search process of L-ABC is similar to the search process of ABC except the added application of Levy mutation. The mutation nature provides optimum solutions towards the issues than that of

traditional models. The Levy mutation integrated ABC provides better efficiency without effecting rate of the convergence.

Kashan MH. *et. Al.* 2011[16] made modifications to ABC algorithm to optimize binary structured problems. The new approach named DisABC introduces a new differential expression. The proposed approach differentiates two binary vectors based on the dissimilarity measure that quantify how far one binary vector is different from the rest. This novel approach was applied on various benchmark or standard test problem instances of the un-capacitated facility location problem (UFLP). The comparison is made on binary optimization algorithms like binDE and PSO. The new approach proved its ability with respect to efficiency and competency.

Since its introduction ABC algorithm has undergone into quite a good number of variants. All this evolution has taken place within the short span of just a decade. Among a large list of versions some of the milestone improvements of ABC include Interactive ABC (IABC) devised for solving numerical optimization issues, the rank selection schemes ABC (RABC), TABC (Tournament Selection ABC) & DABC (Disruptive Selection ABC) [3], [5]. Complete these are possessing common objective that contain (a) for upsurge the general population diversity & (b) for evading the previous convergence.

B. Various ABC Algorithm implementations

As ABC algorithm is applied on various problem contexts with appropriate modifications. The mostly observed application area is neural networks and artificial neural networks [13] Kurban and Besdok, 2009[18] made the comparative study on the RBF neural network training algorithms. Other useful contributions were observed in the literature in the sub field of training of neural networks [12] [19].

Another interesting area of interest for the application of ABC is data mining. The functionalities of data mining like clustering, outlier detection, feature selection and rule discovery have been in practice by many researchers. Karaboga and Ozturk, 2011[15] modified ABC algorithm to facilitate data clustering. The proposal has undergone for testing against thirteen popular data sets sourced available online from e-data sources. Zhang *et al.*, 2010[24] proposed ABC clustering algorithm for optimal grouping of n objects into the k clusters. Here, ABC performance, was tested by Karaboga and Ozturk, 2010[14] for fuzzy clustering with successful outcomes. A clustering approach based on hierarchies embedded with ABC intelligence was proposed by Karaboga in 2010 for the management of wireless sensor networks.

The contributions in similar area were made by different authors providing varieties of the basic algorithm with suitable additions [6]. The applications of the ABC Algorithm with different variations are identified through this review. The main categories of applications include but not limited to

- ✓ Assignment problems
- ✓ Task allocation problems
- ✓ The problems of Multi-level thresholding
- ✓ Networks and routing problems
- ✓ Data clustering
- ✓ Social network analysis
- ✓ Fraud detection
- ✓ Optimization problems.

Amal M. Abunasar and Sausan Alshattnawi [2] proposed a new algorithm for clustering social networks using artificial bee colony optimization approach. This algorithm is particularly based on swarm based Meta heuristic algorithm. The main goal of the proposed clustering method is to maximize the modularity. Modularity is a measure of representing the quality of network partitioning. Authors cluster the existing social network with ABC algorithm. Experimental results are compared with many existing approaches and they have observed that the quality of the clustering results with the proposed method is superior to the results of the existing methods.

IV. THE ROLE OF VARIANTS OF ABC IN DATA MINING, CLUSTERING, AND OUTLIER ANALYSIS & RESULTS

The popularity of ABC technique attracted many researchers for clustering and outlier analysis. Many researchers used the technique as an optimization component in the respective process. Data mining has functionalities like classification through clustering supervised learning & ARM by unsupervised learning. Outlier detection is also one of the popular functionalities of data mining. All the functionalities of data mining have sub procedures connected with searching and optimization. When dealing with large amounts of data, the length of iterative process and recursive procedures are a bottleneck. The variants of ABC algorithm assist a lot in this context. ABC can lessen the count of iterations or recursive procedure length by embedding suitable intelligent functions. This integrated approach will make the processes able to get earlier convergence. To get this convergence facility the length of the intelligent process based on ABC optimization is less in lines of code and great in needed optimization and time saving.

The work [14] presents that on the fuzzy algorithm, the ABC algorithm is tested. They classified different datasets which are bench mark sources from UCI relating to Heart, Diabetes, & Cancer. They stated that ABC showed good outcomes related to robustness & classification error.

Dr. Anil Kumar, 2015[11] proposed an outlier detection approach using ABC with Fuzzy clustering. They performed ABC-FCM clustering approach and identify the small clusters that failed to get the threshold average membership value and treated them as outliers.

Reema Aswani et al., 2016 [21] proposed a hybrid model using meta heuristics for efficiently detecting data anomalies. A distance based optimization algorithm with k-nearest neighbor approach is designed. The process is designed to work with supervised datasets. The minority class is treated as outlier. The authors suggested the extension of the same process to unsupervised datasets using k-means clustering.

V. THE OPPORTUNITIES OF ABC VARIANTS IN FUTURE RESEARCH

The ABC algorithm is better than its alternate algorithms related to robustness, simplicity & flexibility. This algorithm needs fewer overheads compared with other search techniques. These algorithms can be easily merged with other process optimization techniques. The implementation is easy with basic mathematical functionalities. The process can be extended to get global optimization. Majority of the problem and data contexts today needs optimization techniques. ABC and its version like variants could be mould for solving real-time optimization issues.

There is a scope to apply ABC approach in various fields that include searching problems, assignment problems, networking, data mining, multi-level thresholding, routing problem, decision making, and other optimization problems. It can deal with both unconstrained optimization and constrained optimization domains. Artificial bee colony algorithm has a broad scope of innovative applications in customer behavior analysis particularly in e-commerce environment. The algorithm can be efficiently applied for outlier detection in marketing, finance, agriculture, medicine and more.

Now a day's one of the popular communications means to interact among the people is social media such as twitter and face book facilitated all over the world. There is a rapid growth in digital marketing growing expanding and becoming cheaper and cheaper with the tremendous growth of internet. Worldwide web (www) is the most important means of source for development of digital marketing with suitable communication and interaction features. Social media are growing at the exponential rate and their impact is appearing in many real time applications such as e-business, marketing, health care, banking, e-governance, and research and so on.

Huge amount of data is piling as a result of user-generated content in communication over the web continuously. Therefore there is a need to analyze and mine such data in multiple ways for obtaining useful knowledge about data. Social media are the primary means and ways to transfer such viral information to the majority of the people with faster pace. Content buzz is a domain that uses different types of buzz monitoring techniques and is a popular mean for user generated content sharing over the web. This data is available in the web in variety of forms that include numeric, graphic, text, images, audio, video, preferences, ratings and emotions and so on. Data analytics based techniques are needed to deal with content buzz on the web for effective and efficient decision making after mining large amount of data. This data may be very huge with large number of dimensions, multiple data types, with multi-objective. Therefore grouping such data provides primary analysis report. Data mining techniques such as classification and clustering are the suitable choices for primary data analysis. These techniques need polished searching techniques to deal with the size and kinds of data. ABC optimization is one of the vital and desirable choices for searching.

VI. CONCLUSION

The most well-known meta-heuristic algorithms is ABC algorithm. Since its inception the algorithm is implemented successfully in several applications with strategic modifications. This algorithm is easy to apply, requires lesser control variables than its competitors, mostly suitable to solve optimization problems. This paper extensively reviewed various versioned developments of the ABC algorithms. Efforts are made to bring out the application areas that are most suitable to incorporate the variants of the algorithm. This review clearly explained about the changes that came over the algorithm to deal with the evolving problem contexts. From the review it is understood that the ABC algorithm has a broad scope in future to work with many application areas particularly in of data mining for data grouping and outlier analysis. These two related data mining functionalities can provide vital directions by through the analysis of the new age data contexts like e-commerce, social media, banking, and medicine. This review certainly motivates the researchers to undertake ABC related approaches to solve many optimization problems.

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