Artificial Bee Colony Algorithm: A Survey and Recent Applications

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Abstract—Swarm intelligence has provided solution to classical mathematical techniques which can’t be dealt easily. An intelligent foraging behavior of honey bees falls into category of swarm intelligence. Deception of honey bee foraging behavior of Artificial Bee Colony (ABC) was established in 2005. Due to its origination, researches had been made on ABC and applied it on different types of problems. In this article, a brief review is presenting about ABC and its progress, implementation, comparative completion and future scrutinizing perspectives. We focused and presented on recent works by ABC and its applications.

Index Terms—artificial, optimization, bee colony

1 INTRODUCTION

Collective behavior of individuals which is a natural phenomena inspired for development of population-based optimization algorithms by researchers. Which helps to work on better fitness areas of search space. Near-optimal solutions to the difficult optimization problems is carried out by this algorithm. There are two important types of population-based algorithms are Evolution based and Swarm Intelligence-based algorithms [1]. Most of popular evolutionary algorithms are Genetic algorithm (GA), Genetic programming (GP), Evolutionary strategy (ES) and Evolutionary programming (EP) [2]. In recent invention of evolutionary algorithms who only focused on social insects defined swarm intelligence as “any attempt to design algorithms or distributed problem solving devices inspired by the collective behavior of social insect colonies and other animal societies”. With small in built intelligence appearance of swarm intelligence from group work, trial, error behavior of insects where member of swarms are assigned to be influential effectual and most communicative. Where in previous research showed potential in the field of numerical optimization by these algorithms. Algorithms which appeared in recently include Particle Swarm Optimization (PSO) [3], Ant Colony Optimization (ACO) [4], Bacteria Foraging Optimization (BFO) [5].

Main concerns for designing vigorous search process are Exploration and Exploitation. An optimal solution is been searched in exploration, exploitation bias the search depending on existing knowledge.

Artificial Bee Colony Algorithm is one of the approaches to fine the desirable solution for numerical optimization problems, which is infused by behavior of honey bees in soliciting quality good food source. It is population based stochastic search technique really simple and fast.

2 BACKGROUND

Here we are discussing about the action of honey bees in the nature which discusses about different actions that are been performed by the honeys at different stages. ABC is innovation from foraging behavior of honey bees. Honey bee is one of the swarm existing in nature which collects the food based on collective intelligent manner, this honey bee swarms can transmit information, can retain the environment, stores and shares information and decides depending on it. This performance of bees is been discussed in Evolution of yellow royal jelly [6], Swarm can update, assigns tasks actively, moves on by socializing (learning and teaching) by itself. Action of honey bee can be outlined by food sources, employed bees, unemployed bees, foraging behavior and dances [7].

2.1 Sources for food

While exploring the food, bees specifically choose a flower (so called food source) for herself, where in it collects information about amount of nectar, ease of extraction, farness and direction from the nest. Where in bee stores this total information as a single unit(called as total profitability for a specific food source) for purpose of benefit and non complexity.

2.1.1 Bees which are employed

Group of bees exploits the available food sources, where in they are called as employed bees and keeps profitability (quality, direction, distance from hive) of related food source.
Bees which are unemployed

Information between employed bees and other group of bees (so called unemployed bees) of a definite probability. That group of bees are accountable to summarize data of food and to select a food source for exploiting. Further on these bees are divided into two categories onlooker bees and scout bees. Onlooker bees: onlooker bees collect data from employed bees from hive, then on they establish a food source for themselves by analyzing the data collected, where in scout bees are accountable for gaining new food sources around hive. While few being food sources exhaust, these bees are busy finding other food source parallel to existing one. There are 50% of employed bees, 50% of unemployed bees and 5% to 10% of scout bees in a swarm.

Foraging behaviour

One of the most important characteristic of swarm where bees leave the hive and starts searching new food foraging process takes place. When bee finds food source collects the nectar and stores in its stomach. It extracts nectar for 30-120 minutes according to situation such as wealth and space between food source and hive. Accordingly by production of enzymes in its stomach making of honey process starts where it excretes the nectar in empty cells of hive on reaching. Last that bee shares data to preceding bees in various forms of dance (given in next section).

Dance

Employed bees perform specific type of steps in the hive area called dance in order to give information to other bees present in the hive regarding the food source. Dance language of bees was decoded and sorted that supervision of data of bee dance specifies position of food source comparative to son and distance of food source as it performs various types of dances proclaimed floral odors on the foragers being primary cues enables employed bees to locate food sources. To fulfill the foraging behavior of the bees either dance language or floral odor is required. Bee will be performing dance steps in mean to show the direction of food source to other bees while this process the other bees touch their antennas in order to taste the nectar collected from the food source. Dance forms performed by the bees are: i). Round dance, ii). Waggle dance and iii). Tremble dance [8].

3 ARTIFICIAL BEE COLONY ALGORITHM

Finding solution from collaborative trail and error method. Swarm based algorithms mainly follow behavior of social colonies with peer to peer learning where ABC is recent add on, which contains population of potential solutions having ability of solutions for food sources. Presence of three various bees in the hive which uses knowledge gathered from employed bees and decides the food source whose food source is consumed then becomes scout bee and starts searching the new food source [9].

Like other algorithms which are based on swarm, ABC is an repetitive process. Fundamental processes which acquire evolution of ABC population are variation process and selection process. Where in variation process furnishes authorizing distinct surfaces of search space and selection process protects exploitation of before experiences. Even though population has not converged to a local degree possible in ABC which may occasionally halt progressing for global optimum [10]. Algorithm processing cycle involves four steps: Fist as initialization, second is employed bees, third is onlooker bees and finally scout bee as fourth step. The detailed steps are discussed as follows:

3.1 Initialization of population

Firstly, ABC creates a uniformly distributed population of SN solutions in which each solution xi(t = 1, 2, 3, ..., SN) is a dimension vector. In which D is variable number for optimization problem and xi represents ith food source in population. Food source is represented as

\[ X^i_j = X^i_{min} + rand(0, 1)(X^i_{max} - X^i_{min}), \forall j = 1, 2, \ldots, D \]

where \( X^i_{min} \) and \( X^i_{max} \) are bounds of \( X^i \) in jth direction.

3.2 Phase of employed bees

Bees revamp their present solution dependent on knowledge of one and each experiences and appropriate values of new solution. Where in appropriate value of recent nectar is greater then the old food source then it is further replaced by new one. Then equation changes to

\[ V^i_{ij} = X^i_{ij} + \phi^{ij}(X^i_{ij} - X^j_{kj}) \]

where \( \phi^{ij} \) is random number between \[ 1, 1 \]. Here \( X^i \) represents current position and illuminated box indicates randomly chosen direction \( j \). \( X^i_k \) is randomly chosen bee, indication \( j \) of a random bee \( k \neq i \) is removed from similar path of \( i \)th bee then that difference is multiplied by random number \( \phi^{ij} \). This equation is merged to jth dimension of \( X^i \), to get jth dimension of recent food position \( V^i_{ij} \). This \( V^i_{ij} \) represents vertical vector in figure all distinct measurements are same as of \( X^i \) and is procured by neighborhood of \( X^i \). Considering only 2D search space then optimal positions for this new food source \( V^i_{ij} \).
3.3 Phase of onlooker bees

After employed bees phase this phase is started, where in employed bees shares the information of new solutions (food sources) and position of it with onlooker bees in the hive. These bees analyzes the information shared and selects a probability pi solution regarding to its strength. Pi can be calculated using the below expression

\[ p_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i} \]  

(3)

Where fit_i shows fitness value of jth solution. In case of employed bees, onlooker bees changes its position in memory and checks fitness of candidate source, if it is found with more fitness than the older one it replaces the bees memories and forgets the old one.

3.4 Phase of scout bees

This phase is started when a food source is not updated for predetermined number of cycles where it is abandoned where that food source is updated by randomly chosen food source within search space. In ABC, crucial control parameter is number of cycles called as limit for abandonment. Assuming xi as abandoned bee replaced by new Xj food source as follows

\[ X_j^i = X_{\min}^i + \text{rand}[0, 1](X_{\max}^i - X_{\min}^i), \forall i = 1, 2, \ldots, D \]  

(4)

Xmin and Xmax represents bounds of Xi in jth direction.

3.4.1 Important steps of ABCA

In this search space process exploitation is processed by employed and onlooker bees and exploration is processed by scout bees. Algorithm 1 shows the pseudo-code of ABCA [10]

3.5 Parameters to be controlled in ABC

Three of main control parameters for algorithm are:

1. Number of food sources limit and \( \phi_{ij} \) (random number in range \([-1, 1]\) uniformly distributed) [11] stated ABC execution is too delicate to decide \( \phi_{ij} \) and limit. Few scenarios of control parameters:
   - \( \phi_{ij} = \text{rand}[-1,1] \) (random number in range [-1,1])
   - Limit should be (colony-size/2) * D
   - 50-100 bees is the colony size

Probability \( p_i \) which is generated by probability calculations for probabilistic selection is an important parameter which is function for fitness values of present population members. Basic roulette selection approach applied where size of fitness is proportional to slices of roulette wheel.

Distinguishing between present food source and randomly selected food source’s weight is \( \phi_{ij} \) which is accountable to sustain proper diversity mechanism in search procedure of ABC usually distributed uniformly random number in range [-1,1].

To explore new areas of search space limit is another parameter in ABCA, where in it checks whether there is any food source exhausted after onlooker and employed bees phase. If there is presence of any exhausted food source it is unrestrained and replaced by random food source identified by scout, this task copies negative feedback mechanism and fluctuation property of self organization. In ABC depletion of only one bee at a time is possible, where combination of both onlooker and employed bees are equal and scout bee is the one whose food source is exhausted. As the colony size increases it can produce the best results where in after a enough value in the colony size won’t be allowing to increase value of ABCA. According to researches done by Karaboga and Basturk [7] suggested colony size 50-100 produces acceptable convergence.

4 MODIFICATIONS IN ABC

From the establishment of ABC a lot of research works have been taken place for removing all the drawbacks present in basic version and improved it in many ways. Potentials of ABC are broadly classified into four categories:

1) Tuning existing parameters by introducing new strategies.
2) New control parameters are introduced.
3) Using population based probabilistic and deterministic algorithms
4) Assorted
Brief review for every category is mentioned in following sections.

4.1 Tuning existing parameters by introducing new strategies

For any stochastic optimization algorithm this is a necessary field which directly effects the performance of algorithm to get advisable results under time constraint, values should be tuned. Value of $ij$ in range $[-1,1]$ is the best value. Quality of limit should be $SN$ * $D$, where in $SN$ represents total number of potentials and $D$ is problems dimension. Where Karaboga and Basturk [7] proposed colony size being 50 100 yields the best acceptable convergence.

New strategy for initialization scheme in ABC was introduced by Haijun and Qingxian(2008) making initial groups symmetrical. For improving convergence ability in ABCA instead of roulette wheel selection Boltzmann selection is used.

Tsai et al. [12] implied interactive artificial bee colony (IABC) for maximizing utilization capacity of onlooker stage. Onlookers phase was introduced by Newtonian law of universal gravitation in which onlookers are selected based on roulette wheel. Four modifications was proposed to modify ABC behavior for constrained search space related to search mechanism, scout bee operator and equality and boundary constraints [13]. Tournamenet selection is performed instead of fitnes proportional selection to utilize employed bee food sources by the onlooker bees. Secondly employed dynamic tolerance for impartial constraints by making partial consistants as partial constraints, tolerance helps to slightly extend region of search space for constraints corresponding which is defined as

$$
\epsilon(t + 1) = \epsilon(t)/dec
$$

Where $t$ represents iteration counter and $dec$ represents decreasing value of every iteration ($dec > 1$) where it begins from huge feasible portion and by iteration it reduces. Thirdly the smart flight operator is scout bee phase, in which unrestrained food source is not randomly initialized in search space, where generated food is replaced, $Xij$ used as a base to create search direction given by best solution $y$ in present position and randomly chosen solution $Xj$ as given below

$$
V_{ij} = X_{ij} + \phi_{ij}(X_{kj} - X_{ij}) + (1 - \phi_{ij})(Y_{i} - X_{ij}) \quad (5)
$$

Fourthly modified employe for boundary constraint handling. Assuming any of the solution which is generated outside range it is between upper and lower limit of that variable of problem shown as

$$
V_{ij} = \begin{cases} 
2 * X_{\text{min}} - V_{ij}, & \text{if } V_{ij} < X_{\text{min}} \\
2 * X_{\text{max}} - V_{ij}, & \text{if } V_{ij} > X_{\text{max}} \\
V_{ij}, & \text{otherwise}
\end{cases}
$$

Karaboga and Akay [10] redesigned probability calculation method for onlooker bees to solve the constrained optimization problems. Probability values are calculated by onlooker bees where they receives the information regarding nectar information and position of food source. Where non achievable solutions are allowed to populate in colony modifications are made for the probability values of non achievable as well as achievable values. For calculating the probability values of onlooker bees used as:

$$
p_i = \begin{cases} 
0.5 + \left( \frac{\text{fitness}}{\sum_{i=1}^{SN} \text{fitness}} \times 0.5 \right), & \text{if } X_i \text{ is feasible} \\
1 - \left( \frac{\text{violation}}{\sum_{i=1}^{SN} \text{violation}} \times 0.5 \right), & \text{if } X_i \text{ is infeasible}
\end{cases}
$$

Solution $X_i$ has penalty value as $\text{violation}$, fitness value as $\text{fitness}$, proportional to nectar value of food source. Probability values of non achievable solutions ranges between 0 and 0.5 and achievable values ranges between 0.5 and 1. Solutions are selected probabilistically proportional to violation values in state of non achievable solutions. In order to calculate performance of modified ABCA used for efficiently solving optimization constrained problems.

Pan et al. [14] brought up discrete artificial bee colony (DABC) algorithm and applications in lot-streaming flow shop scheduling problem. This algorithm guarantees starting of population with possible quality and diversity, where in a section of food is produced using priority groups and instead of roulette wheel selection used to figure out a new food source for an employed or onlooker bees. When a new food source is successfully updated with the present one then this enters into a winning neighboring list(WNL).Once NL is vacated 75% is filled up with random selection from current approaches, if WNL is vacated again latest NL is used. Process is repeated until termination criteria is found, this allows to learn proper neighboring approach by algorithm itself to adapt particular problem and even a search phase process.

Gao and Liu [15] introduced an advanced solution search equation in ABC explains improvement of exploitation by bees where they search the best solution of previous iteration. Introduced two main changes in basis ABC first one is that to generate initial population following novel initialization approach which helps to employs opposition-based learning method and chaotic systems with sinusoidal iterator.

$$
X_{ij} = X_{\text{min}} + ch_{kj}(X_{\text{max}} - X_{\text{min}})
$$
where $c_{k+1} = \sin(\pi c_k)$, $c_k \in (0, 1)$ and $k$ is iteration counter. Variables in equation are distributed in search space with zero probability, non recursive, irregularity and randomness.

Second modification in ABC is developed obtaining inspiration from DE variant DE/best/1, proposed strategy ABC/best/1 drives new candidate solution around best solution of previous iteration. Exploitation can be increased by proposed solution equation given below:

\[
ABC/best/1: \ V_{ij} = X_{bestij} + \phi_{ij}(x_{r1j} - x_{r2j})
\]

From equation indices $r1$ and $r2$ are randomly and mutually exclusive integers chosen from set \{1, 2, ..., SN\} and different from base index $i$, in current population $X_{bestij}$ is the best individual vector with best fitness, $j \in 1, 2, ..., D$ are random chosen indices, random number $\phi_{ij}$ in range [-1,1].

A Gaussian ABCA was introduced by Coelho and Aletto [16] and it was applied on Loney’s Spheroid problem. Where Gaussian distribution was applied by authors for producing candidate food positions rather than uniform distribution for two of employed and onlooker bee phases. Following novel alternative helps to improve the performance

\[
X_{\text{new}ij} = \begin{cases} 
X_{ij}^{old} + \phi_{ij}(X_{ij} - X_{kj})\beta\alpha, & \text{if } r1 > p \\
X_{ij}^{old} + \phi_{ij}(X_{ij} - X_{kj})2\alpha, & \text{if } r1 \leq p 
\end{cases}
\]

$r1 \in [0, 1]$ is from a uniform distribution extracted randomly, $p \in [0, 1]$ parameter value effects numerical results and

\[
\beta = |s|, \alpha = 0.5 - 0.25(\text{iter}/\text{maxiter})
\]

$s$ is set of random numbers abstracted from a normal Gaussian distribution, iter and maxiter represents present iteration and maximum iteration number, balance between Gaussian and uniform distribution are balanced by $p$, when iteration proceeds search radius decreases automatically. Integrating information of global best solution into solution search to improve exploitation was discussed in ABCA called gbest-guided artificial bee colony (GABC) algorithm which was introduced by Zhu and Kwong [17]. This algorithm is conveyed by PSO where in to enhance the exploitation this gets the favour of data of global best solution for guiding the search by candidate solutions.

Improved version of ABCA called I-ABC in which parameter $C$ plays a vital role. Sharma et al. [18] produced a variant of ABC namely group socializing in ABC by modifying structure of swarm.

### 4.2 Introduction of new control parameters in ABC

For fundamental functions essential translation of ABCA is too productive for multimodal and multi-dimensional, while occupying with constrained problems, composite functions and some non-separable functions convergence rate of algorithm is deficient [10]. For productive convergence rate [19] studied effects of perturbation which controls frequency of parameter change, scaling factor (step size) determines magnitude of change in parameters while making parameter “limit” on performance and neighboring solution of ABCA, introduced modified version to solve efficient real-parameter optimization problems. In perturbation process modifications in ABCA are made to reduce frequency of perturbation. In basic version of ABC frequency is fixed, produces new solution $V_{ij}$ changes only one parameter of parent solution $X_i$ resulting slow convergence rate. Where in the newly proposed ABCA a new reduce parameter, modification rate (MR) are produced, parameter $X_{ij}$ is modified if random number is less than MR shown in equation

\[
V_{ij} = \begin{cases} 
X_{ij} + \phi_{ij}(X_{ij} - X_{kj}), & \text{if } R_{ij} < \text{MR} \\
X_{ij}, & \text{otherwise}
\end{cases}
\]

MR is modification rate seeks value between 0 and 1, $k \in \{1, 2, ..., SN\}$ randomly selected index which has to differ from $i$. In the population value which is lower of MR cause solutions to be improved slowly while higher one may produce high diversity in solution, ratio of variance operators is also altered. In order to produce a new solution eliminates getting stuck at local minima and added present solution. Random perturbation is difference of solutions ($X_i$ and $X_k$) and weighted by random real number $\phi_{ij}$, which vary in range [-1,1] for basic ABC while in changed ABCA [-SF, SF]. Control parameter called scaling factor (SF) is used to control magnitude of perturbation. While causing slow convergence of SF permits search to fine tune process in small steps for lower values, larger value speeds up value of SF search reducing exploitation and convergence speed. Automatic tuning of SF is regulated by Rechenberg’s 1/5 mutation rule stating ratio of successful mutations for all should be 1/5 [11].

Improved version of ABCA called I-ABC in which best-so-far solution, inertia weight and acceleration coefficients were proposed by Li et al. [20], where neighborhood solution $V_{ij}$ is given by

\[
V_{ij} = X_{ij} + \phi_{ij}(y_{ij} - X_{kj})\alpha + \phi_{ij}(y_{ij} - X_{kj})\beta + \phi_{ij}(y_{ij} - X_{kj})\gamma
\]
where $w_{ij}$ is inertia weight controlling impact of previous solution $x_{ij}, y_j$ is jth dimension of best-so-far solution, $i$ and $j$ are random numbers between $[0,1]$, 1 and 2 defined as fitness functions in search process of ABC where $w_{ij}$ and 1 are given equal values as

$$W_{ij} = \omega_1 = \frac{1}{1 + \exp(-fit_i/ap)}$$  \hspace{1cm} (9)

for maintaining balance between exploitation and exploration, 2 of set 1 is employed bee and in onlooker bee phase it is set to 1,

$$\phi_2 = \frac{1}{1 + \exp(-fit_i/ap)}$$  \hspace{1cm} (10)

A new accomplishment called prediction and selection in artificial bee colony (PS-ABC) where in neighborhood solution $v_{ij}$ is calculated using three accomplishments according to equations (2) (13) (15), in original ABC, in I-ABC and in GABC respectively prediction phase of algorithm and in selection phase it considers solution which has better fitness among these three and also the previous ones.

### 4.3 Hybridizing ABC with further population based probabilistic or deterministic algorithms

Generalized assignment problem was assigned by incorporation of ABCA by shifting neighborhood searches and greedy randomized adaptive search heuristic [21].

The figure below shows ABC has simulated foraging behavior of bees. In each phase half of the bees are foraged and other communicate centered information to other bees staying back in hive by performing the dance steps. Food source of which bee is exhausted it becomes scout bee and goes for a new one in random search.

Improvements in Global Swarm Optimization (GSO) by hybridizing it with ABC and PSO [22] used new solution only when it was well than previous one which uses neighborhood solution scheme. For construction site layout optimization blends ABC and PSO algorithm and introduced Particle Bee Algorithm (PBA) [23], Yan et al [24] introducing crossover operator of GA to ABC in information exchange phase between bees for data clustering proposed a hybrid artificial bee colony (HABC).

For dimensionality reduction, developed an independent rough set approach hybrid with ABCA, in which effects of perturbation rate, scaling factor (step size), and limit were inquired on real parameter optimization. Hybridization of ABC with forward neural network (FNN) was proposed [25]. To improve the convergence rate eliminative rule and new search strategy was introduced into iteration of ABC. DE simulates evolution and all individuals are counted into account in each generation to maintain population diversity.

Scout bees in the hybrid algorithm are divided into two parts for balancing exploration and exploitation capability of algorithm. Where in scout bees in one part perform random search in predefined region and scout bee select one non-dominated solution from Pareto archive set in another part randomly. For accurate numerical optimization united Rosenbrocks rational directed method with ABC, where in there are two alternative phases present in Rosenbrock ABC: exploration phase realized by ABC and exploitation phase completed by rational direction method [26]. Hybridization of DABC with variant of iteration greedy algorithm helps to find permutation which produces smallest total flow-time which was developed [27], where iterated greedy algorithms contain local search procedures dependent on insertion and swapping neighborhood structures.

Proposal of a hybrid bee(s) algorithm which solves container loading problems was introduced by Dereli and Das (2011) where a bees algorithm was hybridized by heuristic filling procedure for solution of container loading problems. A new bee optimization algorithm with idle-time-based filtering scheme and its application for open shop scheduling [28], categorized foraging behavior of bees into two terms forward pass and backward pass. Where forward pass expresses process of forager bee leaving bee hive and flying towards the food source and backward pass expresses process of a forager bee returning back to hive and sharing information to other forager bees. Hybridization of GA and ABC was done [29], [30]. Main purpose of this approach is to gain parallel computation merit of GA speed and self improvement merits of ABC which shares knowledge between Ga population and ABC population. Adoption of ABC to increase local search capacity and randomness of populations with quantum evolutionary algorithm (QEA) [31].

### 5 ABC APPLICATIONS

In recent years, cause of ABCs robustness and ease to apply it has become very popular where many researchers successfully applied to many problems from different application areas. Here, we demonstrate...
some of popular areas in Pie chart and presented all published statistics in Bar graph.

The Fig. 2 shows number of publications published yearly, in which first part shows publication of journal pages, second shows conference papers and third one shows books edited. From graph we can observe that period of 2012-17 usage of Artificial Bee Colony has been used in wide range.

From the Fig. 3 we can see the usage of ABC in different fields such as CS-Computer Science, ENG-Engineering, MT-Mathematics, DS-Decision, BGM-biochemistry genetics and molecular biology, PA-physics and astronomy, ER-energy, ABS-agricultural and biological sciences, MUL-multidisciplinary, ES-environmental science, MS-material science, CHEM-chemistry and NR-neuroscience.

6 CONCLUSION

This paper is presented a survey based artificial bee colony algorithm studied deeply and described different kinds of applications for gaining the best optimized solution which works efficiently and effectively. It describes about working of the bee in the detail. Also explained regarding the different phases present in the algorithm explained tuning parameters, invention of parameters and hybridization process. Different kinds of usages are also been explained in detail.

REFERENCES


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