A Detailed Study about Foraging Behavior of Artificial Bee Colony (ABC) and its Extensions

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Abstract- Swam intelligence is an emerging field in Artificial Intelligence. The living nature and life style of animals, birds and other living organisms can be inherited and applied to solve many real world problems. ABC is a recently developed swam intelligence algorithm developed by Dervis Karaboga in the year 2005.In ABC, foraging is one of the behavior of honey bees to search, collect food from its food resources. Many research works has undergone about foraging behavior and it is applied to solve variety of optimization problems. This paper discusses the detailed study of different types of extensions of foraging behavior of honey bees.

Keywords: ***Artificial Intelligence, swarm Intelligence, foraging behavior, Bee colony, ABC, swarm optimization***.

I. INTRODUCTION

Nature has the solution for everything. Although computer field is far away from the nature, it is strongly connected to the human intelligence. For certain problems, there is a need to get a solution strategy from the social behavior or an individual, even which is not connected to the problem domain. One can derive the better solving mechanism for any problem from that. Swam intelligence is one of the emerging field which enables to apply the behavior and life style of insects such as honey bees in the world. It is a field of AI which gives the optimum solutions to computer related problems. In this paper we discussed the foraging behavior of ABC and its extensions. This work is categorized based on the foraging features of honey bees such as food collection, optimization, and performance.

II. BEE COLONY AND ITS NATURE

The *Apis mellifera (Bee)* is one of the fascinated social insects which lives together as a family. All the members in the family are engaged with complex tasks. Each bee in a colony has an individual and collective (social) behavior which is very useful for communication, construction and responsibility. A bee colony consists of three types of bees' namely drones, workers and queen. There are thousands of worker bees in a colony to collect food from various resources. The different size and physical appearances of honey bees are

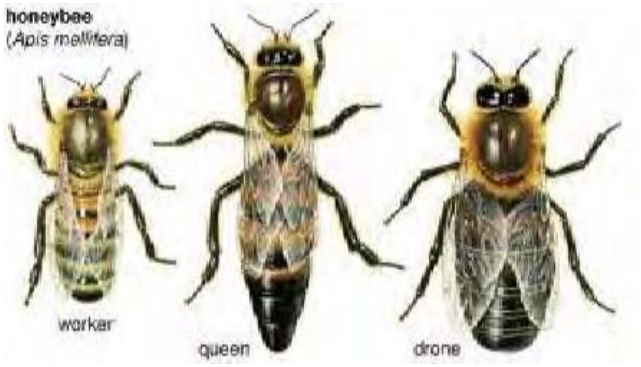

Figure1. Types of Honey Bees

The drone bees are called male bees which does not have any responsibilities. The role of drone is to maintain the considerable population of colony. The queen is unique nature as well as head of the colony. The primary role of queen is to lay high rate of eggs depends on the, population rate of the colony.

A. Foraging behavior of honey bees

Generally insects like bees, their food search or forage of food supply consists of nectar and pollen from various plants within certain range. Forage is also significant for pollination management with other bee species. Nectar contains sugars that are the primary source of energy for the bees' wing muscles and for heat for honey bee colonies for winter. Approximately the foraging area ranges up to two miles, although bees have been observed foraging twice and three times this distance from the hive. Foraging at extreme distances wears out the wings of individual bees, reduces the life expectancy of foraging bees and therefore the efficiency of the colony.

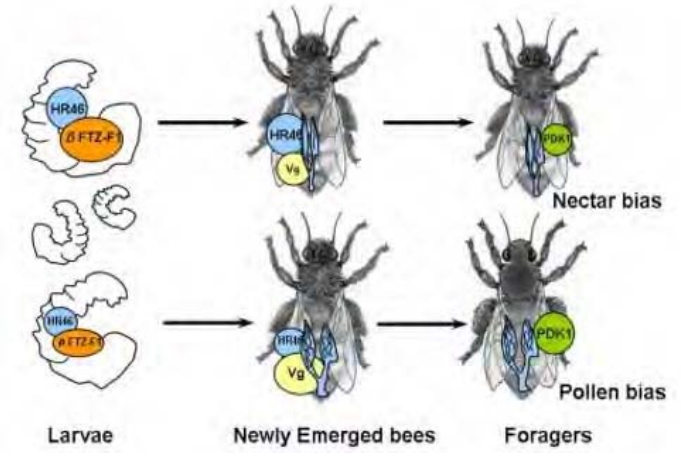

Figure .2 Origination of foraging behavior

B. Observation from foraging behavior of Natural Honey Bee

From the nature of honey bee we observed that

1) The size of the colony is inversely proportional to the food source of the colony.
2) The efficiency of the colony is based on the number its foragers
3) The efficiency of a forager is depends on the distance between nectar and food source as well as number of times travelled
4) The optimum food collection can be possible only when the communication between the bees is comfortable.

Based on the above collective behaviour, the Artificial Bee Colony is developed. The general types of bees are categorised with different roles based on its nature. The artificial bee has a limitation of data searching area like natural bee. When foraging behaviour is considered, the inter communication between the artificial bees, nearest resource sharing, repeated updation of resources, distance measures in between nectar and resources are the factors have to be considered. Most of the ABC extensions are based on the alteration of above mentioned factors. Here we took some important extensions of ABC algorithm based on the optimisation of the foraging behaviour.

III. EVOLUTION OF FORAGING BEHAVIOR

The foraging behavior is derived from the field of ecology. The primary concern of foraging behavior is to get the maximum food for each instance. [1] In 1966 MacArthur and Pianka are two American ecologists who proposed a technique for foraging behavior called Optimal Storage Foraging (OFT) theory. This theory focused the general foraging nature of animals, plants and insects.

A. Optimal Storage Foraging (OFT) Theory

This represents the food handling capability of a living being. It is habitual functionality of each species in the world. The basic variable in OFT are

E = the volume of intake of food

h = the time required to consume the food

Therefore E/h shows the profitability. The important representation by MacArthur and Pianka is the search time prediction of food. This shows that the foraging is the primary concern of population based systems. The total size (members) of the family, such as in the case of bee colony, the colony size and its food resourcing members

of that family are inversely proposed. This approach has given the broad idea about the foraging behaviour . The instance and maximum possibilities of food collection are represented as

The maximised tries are calculated = $\frac{E}{h + s}$, *where* s *is the search time.*

The average time of intake rate is = $\frac{E_{average}}{h_{average} + s_{average}}$. *Hence*

$E_{average}$ = *the average energy level*

$h_{average}$ = *the average handling time*

$s_{average}$ = *the average search time.*

[2]. In 1967 K.Von Frisch proposed an approach for solving problems using swarm intelligence. [3].In 1992 Macro Dorigo a mathematician developed ACO (Ant Colony Optimization) Algorithm. He implemented ACO as a mathematical model to find the shortest path for a graph. Based on the foraging behavior of ants, the shortest path of a graph is determined. This invention coined that the foraging behavior can be used as solution strategy for engineering problems.

B Evolution of Foraging Behavior in ABC

In the year 2005[4] valley Tereshkova and Andreas Loengarov were proposed a foraging behavior model for behavior of honey bee colony. They classified the proposed basic behavior of honeybees called employed and unemployed (called as dynamic states) of honey bees. When a honey bee is active then it is said to employed otherwise called inactive and vice versa. Therefore foraging behavior can be calculated as

The Foraging behaviour

$$F = Y + X \rightarrow 2X > 2Y$$

Where X represents employed bee and Y represents the unemployed bee. An employed forager abandons an unrewarding food source at a rate inversely proportional to that source's quality:

$$X \xrightarrow{1/F} Y$$

The basic idea of this approach is

- To improve the collective behavior of the employed bee by changing the role of unemployed forager becomes employed, while the employed forager goes to dissuasion state.
- This approach encourages improving the communication between the nectar and the foraging bees.
- This technique is derived from the bee colony system and proposed to implement for machine learning applications such as Robotics, Fault tolerance and collective Intelligence.
- It is the first approach to apply bee's behavior to knowledge based system.
- When resources are greater than the foragers then additional forager should be assigned to achieve optimization.
- The optimization can be attained, When a food source is represented as E

  Hence, E must be greater than FS (E > FS)

  Where E is an employed forager and FS is a food source then the additional employed foragers are assigned from the nectar who are in unemployed state.

In the year 2005[5] based on the foraging model, Dervis karaboga proposed a Artificial Bee colony algorithm based on the intelligent behavior of honey bee swarms. Based on karaboga, there are three types of bees namely employee bees, onlooker bees and scout bees. He is one of the important contributor of Bee colony optimization research. The basic phenomenon of an artificial bee is structured by karaboga. The research work on ABC by karaboga represented that foraging behavior of honey bee gives better results for many computer related problems than other swarm intelligence algorithms. According to his view the structure of ABC and its members has three different roles.

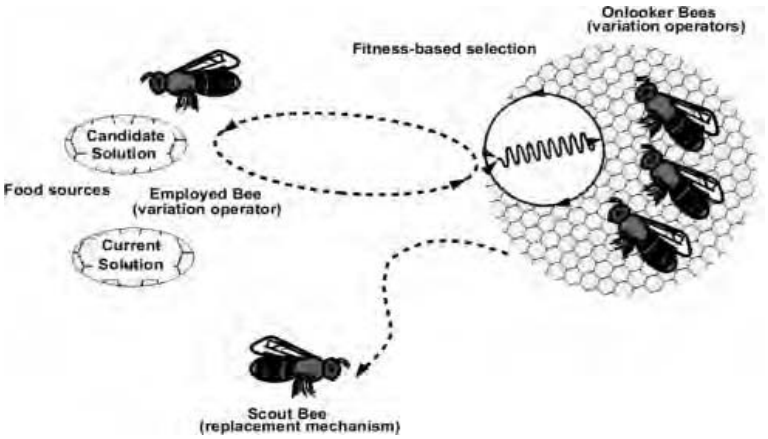

Figure3. Artificial Bee and its responsibilities

The Employee Bee is a kind of female bee who stays in the resource and shares the food information with its neighbours. The Onlooker Bee acts like a follower of employee bee while gets the source of information from employee bee in the hive and selects the best food source together. The third one is Scout Bee which is responsible to find the new food source and nectar. Later on the research, based on foraging approach in ABC with agents, the karaboga and Basturk developed a extension of ABC algorithm to solve numeric problems. The major drawback of ABC algorithm is its local optimal complexity. The boundary of onlooker bees is very limited which leads poor results. Suppose the number of food sources visited is greater than the number of food collected then it results worst case.In the year 2008[6] Li-pei Wong and his team proposed the combination of Bee colony algorithm with big valley landscape structure. This hybrid approach achieves local maximum of Bee colony algorithm, which focuses the Job scheduling process for semi conductor industry. In the year 2008[7] Nyree lemmers Steven de Jong, Karl Tuyls, and AnnNow´e experimented the foraging behavior of bees. The work suggested three functions to improve food collection behavior of bees. First, Manage bees activity is considered as a first function which contains six different states of the bee. These phenomenons enable to maintain the different activities of bees by assigning single agent for single activity. Second the calculate vector function used to compute the distance and direction of agents. Third the Distance and direction of bees are computed. This phenomenon is calculated using

$$b = \sqrt{a^2 + c^2 - 2ac \times cos\beta}$$

Where a= distance travelled
c= old homing Distance
B = old homing angle
b = new homing distance
I.e. homing angle is determined by using cosine rule.

$$\alpha = \arccos\left(\frac{a^2 - b^2 - c^2}{-2bc}\right)$$

The drawback of this approach is agent communication. The number of agents is proportional to the size of colony. If sufficient agents are not available, it results poor performance. In the year 2012[8] Yiming yan, Yezhang and Fengjiao Gao developed a multi parameter optimization algorithm of ABC. This modified approach overcomes the dimensionality problem in traditional ABC. They proposed the methodologies called parameter initialization before optimization. The approach suggested that the colony size must be initialized earlier.Similarly, based on the colony size, the fitness value is calculated. The initial value of colony size and the member selection for assigning task is based on its fitness value. Here local optimization is achieved by Employee Bee (EB) and global optimization is achieved by Onlooker Bee (OB).

$$x_i^{(j)} = LB^{(j)} + \phi_i^{(j)}\left(UB^{(j)} - LB^{(j)}\right)$$
$$\text{where } i = 1, 2, \ldots, PN/2 \quad j = 1, 2, \ldots, D$$

For multi parameter initialization they used SVM (Support Vector Machine) Classifier. For mixed parameters intialisation there are limitations assigned. It is divided as lower bound and upper bound respectively. The local optima and global optimum can be dynamically reached based on the fitness value. The estimated fitness and recurring probability is calculated as

$$\begin{cases} \text{Fitness(i)} = \dfrac{1}{1+f(\vec{x}_i)} \\ \text{prob(i)} = \dfrac{\text{Fitness(i)}}{\sum_{i=1}^{PN/2} \text{Fitness(i)}} \end{cases}$$

The only drawback in this approach is its ambiguity and frequent selection of bees based on its dynamic fitness value.

IV. DISCUSSION AND CONCLUSION

The research contributions studied in this approach is based on the foraging behavior of ABC and its extensions. Foraging is one of approach in swarm optimization, but it is an active research area since 1970. The consistent development and its modifications based on the problem solving mechanism shows that it plays an vital role analysis. It reveals that the multiple features of foraging behavior have the capability to implement it in wide are of applications. We consolidated the contributions and achievements based on the year and modifications made in the traditional Bee colony algorithm.

YEAR	CONTRIBUTORS	TECHNIQUES USED WITH ABC	MODIFICATIONS
1966	MacArthur & Pianka	OSF (Optimal Storage Foraging)	Collective Behavior Prediction
1967	K.Von Frisch	Bee Language	Swarm Intelligence
1992	Macro Dorigo developed ACO (Ant colony optimisation)	ACO (Foraging Behavior)	Mathematical Model, Graph generation
2005	Valley Tereshkova and Andreas Loengarov	Foraging Behavior Model	ABC optimization
2005	Dervis karaboga	Foraging Model	Optimization in Numerical problems
2008	Nyree lemmers Steven de Jong, Karl Tuyls, and AnnNow´e	Multi Agent System	Lower Bound, upper bound
2012	Yiming yan, Yezhang and Fengjiao Gao	SVM(Parameter optimization)	ABC with Dynamic Parameter initialization

Table1. Different Approaches of foraging behavior in ABC

This fascinating bees' life cycle can be implemented as a model for many population based operations. To achieve optimum solution with minimum time and cost, the ABC is one of the best algorithms among other optimization approaches. The inherent feature of foraging behavior initiates communication sharing, dynamic multi parameter support, and dimensionality modifications. Although many modified ABC approaches are based on foraging behavior were developed, still it is an active area of research and need to be explored more. There are some drawbacks and limitations in the existing developments and it is discussed in this paper. Although one algorithm cannot used as solution technique for all problems, but the study shows that foraging approach in ABC can be used as a optimal solution technique for most of the problem domains.

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