The Applications Survey : Bee Colony

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***Abstract*—Swarm Intelligence has emerged as a promising research area in the field of optimization. Several researchers have studied the behavior of various members of the swarm of animals and insects such as ants, bees, birds, fishes, etc and developed various algorithms. In 2005 Bee Colony Optimization based on the Bee swarm has been introduced and has been applied to solve optimization problems in various areas within a time of almost a decade. Different original studies have been described here and have been classified along with their applications, comparisons against other approaches and results. The intelligent behavior of bee swarm has been summarized here to describe the areas of applicability and explore possible areas of applicability for the same. We then summarize a review of their derived algorithms and research efforts.**

Keywords-Swarm Inteeligence (SI); Bee Colony Optimization (BCO); Artificail Bee Colony (ABC).

I. INTRODUCTION

Nature Inspired algorithms have been increasingly attracting the computational researchers from the last two decades as a paradigm to model combinatorial as well as non-combinatorial problems. The immensely increasing popularity of these biology inspired groups is due to their ability to solve the problems effectively and efficiently and in an adaptive and modifiable nature of conduct. Such believes gave birth to the population based meta-heuristics such as Ant Colony Optimization, Evolutionary Algorithms, Particle Swarm Optimization, Genetic Algorithms, Bee Colonys etc.

Swarm behavior is one of the key characteristic features of the social insects such as Ants, Bees, termites, fishes, cockroaches etc. SI is an area of Artificial Intelligence that is based on the behavior of an individual in the maintenance process of the development of the group. It was first found in [1] to characterize the behavior of an individual in a decentralized system. SI has been regarded as one of the most intelligent optimization tools used to solve computational and complex problems. Among all the SI systems honey bees' behavior have been found to be the most well studied social insect systems. [2]

In this paper a survey on the areas of applicability of bee colony system have been presented. In this survey work around 15 papers on the ground of bee algorithm used to solve the problem, the type of bee behavior used to solve the problem, the analysis work done by the researcher, the implementation language used, the type of tests performed and the other algorithms with which the proposed technique has been compared to prove the effectiveness as well as to identify the further areas of applicability of the bee system.

The organization of this paper is as follows. In section 2 a brief on the bee's life in nature has been presented so that its mapping to the artificial scenario can be well understood. In Section 3 the areas of applicability of the bee system has been explored. In the next section the tabular representation of the discussed areas of applicability has been presented. And finally in section 5 we conclude the work presented here and all the used references have been listed.

II. THE BEE COLONY

A. The system of the nature

BCO is the SI system where the low level agent to the system is the bee. BCO is the name given to the collective food foraging behavior of honey bee. The bee system is a standard example of organized team work, well coordinated interaction, coordination, labor division, simultaneous task performance, specialized individuals, and well-knit communication.[3]
In a typical bee colony there are different types of bees. There is a queen bee, many male drone bees and thousands of worker bees.

B. Types of bees:[3]

1. The Queen's responsibility is of laying eggs so that new colonies can be formed.
2. The Drones are males of the hive and are responsible to mate with the Queen. This is their sole role in the hive. They are discarded from the colony during their down fall.
3. The worker bees are the females of the hive. They are the main building blocks of the hive. They build the honey bee comb, clean it, maintain it, guard it, and feed the queen and drones. Apart these side responsibilities the main job of a worker bee is to search and collect rich food. There are two types of worker bees namely scout bees and forager bees. Both of them are collectively responsible for the collection of food but they play different roles.

C. What does Scout do?[3]

1. The Scout bees fly around and search for food sources available randomly.
2. They return back to the hive after they exhaust their energy and distance limits.
3. Upon returning to the hive they share their exploration experience and a lot of important information with the forager bees.
4. The scouts tell the foragers about the location of rich food sources which comprises of the direction (angle) of the food source from the hive w.r.t. sun and distance from hive. This is

done using a dance called "waggle dance" which is in the figure of digit "8". It also indicates the quality of food.

D. What does Forager do?[3]

1. The forager bees closely observe the scout bee in order to learn the directions and information given by scout. It then goes to collect food.

Artificial Bee Colony (ABC) was introduced by Karabora in 2005. It was developed to solve real parameter optimization problem. In ABC the BCO's foraging behavior is simulated.

The ABC differs from a real BCO since in ABC we use only scouts and foragers in equal proportion as initial population. The main steps of ABC are:

1. Initialization of food sources.
2. Scouts perform exploration of available food sources randomly until stopping criteria is met.
3. Each Forager exploits the respective scout's food sources until stopping criteria is met.
4. Forager chooses the best food source as per quality.

III. AREAS OF APPLICABILITY

A. Generalized Assignment Problem (GAP)

An ABC framework has been designed in [4] to solve the GAP. They have proposed the general ABC algorithm and the GRAH algorithm [5] to solve the GAP. The proposed algorithm has been implemented in C# and has been tested on a set of problems ranging from 5 agents-15 agents to 10 agents-60 agents. The proposed ABC algorithm have proved to be efficient for solving small to medium sized GAPs.

B. Complex Transportation Problem

A BCO Algorithm to solve complex transportation problems has been developed in [6]. This algorithm proposed in this research conforms to both the deterministic combinatorial problems as well as combinatorial problems characterizes by uncertainty. It has been designed to solve Ride-matching problems. This paper proposes the Fuzzy Bee System to impart decision making ability while searching the optimal/ best solution. The fuzzy system has been designed to describe distance. The proposed algorithm has been applied on 97 traveler's data with 6 foraging paths.

C. Code Coverage Test Suite Prioritization Problem

A BCO Algorithm for Regression Test suite prioritization for code coverage has been proposed in [7]. The proposed BCO algorithm used the scout bee behavior and forager bee behavior for the selection and prioritization of test cases. The proposed algorithm's effectiveness has been illustrated using Average Percentage of Code Coverage (APCC) [8] metric. The values of BCO order has been found comparable to the Optimal order value.

D. Job Shop Scheduling (JSS)Problem

A Honey Bee Colony Algorithm for JSS has been proposed in [9]. The proposed algorithm is the combination of forage and waggle dance algorithms which runs for a specific N_{max} number of times. The proposed algorithm has been implemented in Java on Windows-XP platform. The performance of the proposed Honey bee colony algorithm has been compared with Ant Colony and Tabu search algorithms.

E. Numerical Optimization Problem

An ABC Algorithm inspired by the simulating behavior of real honey bees has been described in [10] for solving multidimensional and multimodal optimization problems. The proposed algorithm was tested on a limited set of test problems.

F. Travelling Salesman Problem (TSP)

A BCO Algorithm with local search for TSP has been proposed in [11]. The proposed BCO has been constructed algorithmically based on the collective intelligence shown by bee's foraging behavior. The proposed algorithm has been integrated with 2-opt heuristics. The proposed BCO algorithm has been implemented using Java with Netbeans IDE 5.5.

G. Automated Red Teaming (ART)

A Multi-Objective BCO (MOBCO) algorithm for ART has been proposed in [12]. The proposed MOBCO uses waggle dance selection of crowding distance, observation and adoption. The proposed MOBCO algorithm has been compared to other well known Multi-objective optimization algorithm called NSGAII and the proposed MOBCO presents promising results.

H. Image Classification

An ABC optimization algorithm for image classification has been presented in [13]. The proposed ABC uses color and texture feature similarity fusion for image fusion. The proposed algorithm has been designed to retrieve image based on multi features. The proposed ABC has been tested on Intel Core 2 Duo using MATLAB R2000b. The test was conducted on a set of 800 images from COREL DB library.

I. Power System Stabilization

An ABC algorithm has been designed for a novel power system stabilization and significance convergence in [14]. The proposed ABC has been used for better stability of power system. The ABC uses the food foraging function as the function to be used by the processing engine. The proposed ABC has been compared to Genetic Algorithm (GA) and Non Dominated Ranked Genetic Algorithm (NRGA) and the proposed ABC demonstrated promising results.

J. Image Registration

An ABC algorithm has been designed for rigid image registration in [15]. The proposed algorithm uses the global optimization method instead of traditional cross correlation. The proposed ABC has been on MATLAB 2000b global optimization toolbox. The proposed ABC was compared to GA and Particle Swarm Optimization (PSO) by running the algorithm 30 times to eliminate randomness and ABC proved to be the most robust of all.

K. Big valley Job Shop Scheduling Problem

A BCO has been designed for job shop scheduling problem for big valley landscape exploitation in [16]. The dance accumulation strategy has been used for effective clustering of entire landscape. The effectiveness of the algorithm has been compared with shifting bottleneck heuristic, the Tabu search algorithm and parameter-free genetic algorithm on the Taillerd JSSP benchmark and the ABC showed promising results.

L. Financial Classification Problem

A Discrete ABC optimization algorithm has been designed for financial classification problem in [17]. The proposed ABC is based on the foraging behavior of bees. The ABC uses discrete version of ABC for feature selection step and nearest neighbor classifiers are used in the classification step. The proposed algorithm has been compared with datasets from UCI Machine Learning Repository.

M. Knapsack Problem

A BCO Algorithm for the multi-dimensional Knapsack problem has been designed in [18]. The proposed algorithm has been developed as a combination of 5 algorithms for executing each step of the real BCO process. The proposed algorithm has been applied to benchmark datasets on multi-dimensional Knapsack problem from OR-library and the results has been compared to two ACO algorithms of [19] and [20] and a Genetic Algorithm of [21].

N. Frequency based Travelling Saleman Problem

A efficient BCO Algorithm for Travelling Salesman Problem using frequency based pruning has been developed by [22]. The bee's food foraging behavior along with the frequency based pruning strategy and fixed radius near neighbor has been used to solve the TSP more efficiently. The proposed algorithm has been implemented using Java with Netbeans IDE 5.5. The proposed algorithm has been tested on 20 problem instances from TSPLIB.

O. Fault based Regrassion Test Suite Prioritization Problem

A BCO Algorithm to solve the fault based regression test suite prioritization problem has been developed in [23]. The forager bee and scout bee food foraging behavior has been used to prioritize the regression. The proposed algorithm has been implemented and analyzed in [24]. The proposed algorithm has been implemented in Java using Netbeans and has been tested on 5 standard problems. The proposed algorithm's effective has been proved by computing its APFD [25] values which are comparable to the optimal orderings.

IV. SUMMARY OF APPLICATIONS

S. No	Application	Type of Bee Algorithm Developed	Implementation Of Algorithm?	Tested	compared to other similar algorithms
1	*Generalized Assignment Problem (GAP)*	ABC	C#	5 agents-15 agents to 10-agents-60 agents	
2	*Complex Transportation Problem*	Fuzzy BCO	no	97 traveler's data with 6 foraging path	
3	*Code Coverage Test Suite Prioritization Problem*	BCO	no	2 examples	
4	*Job Shop Scheduling (JSS)Problem*	Honey BCO	Java on windows XP		Ant colony and Tabu Search
5	*Numerical Optimization Problem*	ABC		limited set of test problems	
6	*Travelling Salesman Problem (TSP)*	BCO	Java with Netbeans IDE 5.5		
7	*Automated Red Teaming (ART)*	MOBCO			NSGA II
8	*Image Classification*	ABC		Intel Core 2 Duo usin	800 images from COREL Data

				g Matlab R2000b	Base
9	*Power System Stabilization*	ABC			GA, NRGA
10	*Image Registration*	ABC		Matlab R2000b Global optimization toolbox	GA, PSO
11	*Big valley Job Shop Scheduling Problem*	BCO			Shifting bottleneck heuristic, tabu search, parameter free genetic algo
12	*Financial Classification Problem*	Discrete BCO			UCI machine learning Repository
13	*Knapsack*	MOBCO		Benchm	2 ACO algos,
14	*Frequency based Travelling Saleman Problem*	ABC	Java with Netbeans IDE 5.5	TSP LIB	
15	*Fault based Regrassion Test Suite Prioritization Problem*	BCO	Java with Netbeans IDE	5 standard problems	

V. Conclusion

In this paper, a literature survey on the research activities on the bee colony has been presented. The bee researches have been unified here to identify their possible areas of applicability, similarity in applicability and type of technique used. The studies related to this have been described briefly and been summarized into a summary table. Definitions, explanations, applications, implementations, comparisons and results of the proposed algorithm have been presented. I suggest to group these activities into two categories namely the food foraging activities and communication activities.

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