Volume 8, No. 4, May 2017 (Special Issue)
ISSN No. 0976-5697
International Journal of Advanced Research in Computer Science
REVIEW ARTICLE
Available Online at www.ijarcs.info

A Review study on Swarm Intelligence and their Optimization Techniques

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***Abstract*- Nature is a constant source of inspiration in the development of new approximate algorithms for solving optimization problems. Nature-inspired algorithms have high relevance when solving hard and complex optimization problems by mimicking the behavior arisen in nature in various forms. The main objective of this paper is to focus on swarm intelligence and some of its techniques to increase the performance and robustness. It is an attempt to design algorithms or distributed problem-solving devices inspired by the collective behavior of social insect colonies and other animal societies like colonies of ants, flocks of birds etc.**

***Keywords*- Swarm intelligence, Stigmergy, Ant colony optimization, Bee Colony Optimization, Cuckoo search optimization**

I. INTRODUCTION

Swarm intelligence is the discipline that deals with natural and artificial systems composed of many individuals that coordinate using decentralized control and self-organization [11]. The main focus of swarm intelligence research is on the collective behavior that results from local interactions of individuals with each other and with their environment. It is a revolutionary technique for solving optimization problems that formerly took its inspiration from the biological examples that can be observed in nature, such as ant colonies, flocks of birds, fish schools and bee hives**,** where a number of individuals with limited capabilities are able to come to intelligent solutions for complex problems The social interactions among individual swarms can be either direct or indirect. The direct interaction is done by audio or video. Examples are birds where they interact with each other through sound and bees interact through waggle dance. In the indirect interaction the agents interact with the environment i.e., one agent changes the environment and other agents respond to the change. Example is ants where they communicate through the process called stigmergy in which the pheromone trail lay by the ants during the search of food [9]. Swarm intelligence is a relatively new subfield of artificial intelligence which studies the emergent collective intelligence of groups of simple agents. Computer researchers have tried to develop highly developed methods and systems that make use of the techniques of the swarms to find solutions to complex problems with the help of their success and efficiency. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment.

II. ANT COLONY OPTIMIZATION

Ant Colony Optimization (ACO) was introduced in 1996 via an algorithm called `Ant System' (AS) by Marco Dorigo in 1992 in his PhD thesis [10].The Ant Colony Optimization (ACO) represents the model of the collective foraging behavior of ants. The ants' goal is to find the shortest path between a food source and the nest. Each path constructed by the ants represents a potential solution to the problem which is being solved. When foraging for food, ants lay down a chemical substance called pheromone. Ants can communicate to each other with the help of the pheromone trails deposited in the environment. Some ants choose the short path and reach the food earlier than the other ants choosing the longer one. The ants reaching the destination through the short path returned to the nest before the others on the long path. Thus the amount of pheromone on the smaller path tends to increase faster than the longer path and results an increase in the probability of choosing that path by the foragers. Since ants prefer to follow trails with larger amount of pheromones, which leads to the shorter path followed by ants [5]. In ant colony optimization (ACO), a set of software agents called "artificial ants" search for good solutions to a given optimization problem transformed into the problem of finding the minimum cost path on a weighted graph. The artificial ants incrementally build solutions by moving on the weighted graph [8]. ACO algorithm is used to solve complex problems like optimization problems, sequential ordering problems, scheduling problems, graph coloring, assembly line balancing, vehicle routing problems. Multi objectives areas used are data mining, telecommunication networking and bioinformatics A main concentration while developing of any ACO algorithm is to decide the fitness function based on which the components of a problem‘s construction graph will be rewarded with a large number of pheromones, and to determine how ants will deed these promising components when constructing new solutions.[1] The following is the basic flow of the ant colony optimization-

1. Represent the solution space by a construction graph.
2. Set ACO parameters and initialize pheromone trails.
3. Generate ant solutions from each ant‘s walk on the construction graph mediated by pheromone trails.
4. Update pheromone intensities.
5. Go to step 3, and repeat until convergence or termination conditions are met. [7]

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On 21st April 2017
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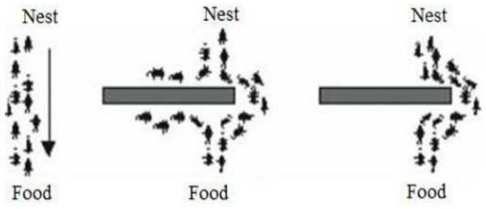

Figure 1: Ant's stigmergic behavior in finding the shortest path between the food and nest

The following equation is used to find the best solution start with choosing the node.

$$p^{k}_{(i,j)}(t) = \frac{([\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta})}{(\sum_{k \in J_k} [\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta})}$$

p is the probability of going from node i to node j. J are the nodes that the ant is allowed to travel to from node i. η contributes to the visibility between node i and node j. τ(t) represents the amount of un evaporated pheromone between node i and node j at time t. α and β in the equation control the influence of $\tau_{ij}(t)$ and η_{ij}, where if alfa is higher, the searching behavior of ant is more depending on pheromone and if beta is higher, the searching behavior of ant is depending on its visibility or knowledge.[12]

III. BEE COLONY OPTIMIZATION

Bee colony optimization has been introduced by Lucic and Teodorovic as a new direction in the field of swarm intelligence [3]. Honey bees are another examples of swarm. Honey bee swarms are dynamic and intelligent and capable of dividing various tasks among other bees. The activities performed by bees are foraging, retrieving, storing and distributing honey, collecting pollen, communication and adapting themselves to the changes in the environment in the collective manner without any central control. Bees organized their colonies without hibernating and live together in them. Bees produce honey by collecting the pollen and nectar from the flowers and store it in the honey combs. There are two types of worker bees which are named as scouts and foragers. Firstly the scout bees are sent out in search for food source by moving randomly from one flower patch to another and keep exploring the flower patches in order to find the best food source until they are tired. Secondly, the scout bees which have found a flower patch whose quality is best, deposit their nectar or pollen and then they perform a dance to communicate the information regarding the flower patch to the other bees. The nature of the dance performed by a scout bee represents the quality and the proximity of the food source. This dance performed by the scout bees named as waggle dance conveys three pieces of information to the hive which direction of the patch, distance of the patch from the hive and the quality rating. The forager bees are sent to the various patches by the colony while receiving this information by scout bees. The number of forager bees sent to a patch is directly proportional to the quality of the patch. i.e. higher quality of the food source leads to more number of foragers sent to it. With this strategy the bee colony is able to gather good quality food quickly and efficiently. In the BCO there are many agents which work collectively to solve the problem in the optimization method. Yonezava and Kikuchi were the first to describe the collective intelligence of bees[3][13]. Lucic and Teodorovic used the principles of the collective intelligence to solve the optimization problem.

The following is the basic flow of bee colony optimization.

1. Population of the bees is initialized.
2. Population fitness has to be calculated.
3. While (condition (stopping criteria) not met)
4. Select certain spots to search.
5. Select more bees for the new spot and calculate the fitness.
6. Determine the fittest bees.
7. Other bees have to be assigned randomly for the search.
8. End While [2].

The following equation is the ideal solution to the problem

$$L_p = \left[\sum_{i=1}^{K} w_i^p \left| \frac{f_i(\vec{x}) - f_i^o}{f_{i\,\max} - f_i^o} \right|^p \right]^{1/p}$$

Where

- fi(x) –i^{th} objective function value that is a result of implementing decision ~x;
- f_i^0 - the optimum value of the i-th objective function
- $f_{i\ max}$ - the worst value obtainable for the i-th objective function;
- K - total number of objective functions;
- w_i^p - i-th objective function's weight;
- p - the value that shows distance type: for p = 1, all deviations from optimal solutions are in direct proportion to their size, while $2 \leq p \leq 1$, bigger deviation carry larger weight in L_p metric [14].

IV. CUCKOO SEARCH OPTIMIZATON

The Cuckoo Search Algorithm (CSA) is one of the latest approaches introduced by Yang and Deb in 2009 inspired by the strategy lays their eggs in the nest of another host bird nest. Each nest has one egg of cuckoo in which each nest will have multiple eggs represents a set of solutions. Cuckoo Search is successfully used to solve scheduling problems and design optimization problems in structural engineering, speech reorganization, job scheduling, global optimization [4]. The following is the representation of cuckoo search-

1. Each egg in a nest represents a solution, and a cuckoo egg represents a new solution.
2. The aim is to use the new and potentially better solutions (cuckoos) to replace a not-so-good solution in the nests.
3. The algorithm can be extended to more complicated cases in which each nest has multiple eggs representing a set of solutions [4] [15].

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The three basic rules followed by cuckoo search-

1. Each cuckoo lays one egg at a time and dumps it in a randomly chosen nest.
2. The best nests with the high quality of eggs will carry to the next generations.
3. The number of available host nest is fixed and if a host bird identifies the cuckoo egg with the probability of pa= 0,1 then the host bird can either throw them away or abandon them and build a new nest[4][15][6].

V. CONCLUSION

This paper contains a brief survey of some of the optimization techniques which are used to enhance the performance of the algorithms with the help of the foraging habits of ants, bees and cuckoos. Ant colony optimization is generally used for searching an optimal path in the construction graph. Bee colony optimization represents the collective behavior to achieve the goals more efficiently than to achieve individually. Cuckoos search optimization will be very useful to carry out large-scale real-world applications in engineering and industry with the high accuracy.

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