

Relative Study of CGS with ACO and BCO Swarm Intelligence Techniques

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Abstract

Swarm intelligence is the collective-level, problem-solving behavior of groups of relatively simple agents. Local interactions among agents, either direct or indirect through the environment, are fundamental for the emergence of swarm intelligence. Ant Colony Optimization (ACO) is a swarm based meta-heuristic method that is inspired by the behavior of real ant colonies. Bee Colony Optimization (BCO) meta-heuristic belongs to the group of Swarm Intelligence techniques. Consultant Guided Search (CGS) is a new hybrid meta heuristic, which combines new ideas with concepts found in Ant colony Optimization (ACO), Bee Colony Optimization (BCO) technique. This paper presents comparative study of CGS, ACO, BCO techniques and the flexibility of CGS.

Keywords: Swarm intelligence (SI), Ant Colony Optimization (ACO), Bee Colony Optimization (BCO), Consultant Guided Search (CGS).

1. Introduction

Swarm Intelligence employs the collective behaviors in the animal societies. It designs algorithms for distributed problem-solving devices by using behavior of insects. (Ants, Termites, Bees). It is first and foremost characterized by autonomy, distributed functioning and self-organizing. It is the area of Artificial Intelligence that is based on learning of actions of individuals in various decentralized systems.

Ant Colony Optimization (ACO) is a swarm based meta-heuristic method that is inspired by the behavior of real ant colonies. It is one of the most recent techniques for approximate optimization. More specifically, ACO is inspired by the ants' foraging behavior. At the core of this behavior is the indirect communication between the ants by means of chemical pheromone trails, which enables them to find short paths between their nest and food sources.

Bee Colony Optimization (BCO) meta-heuristic belongs to the group of Swarm Intelligence techniques. 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. The BCO uses a similarity among the way in which bees in nature look for a food, and the way in which

optimization algorithms search for an optimum in combinatorial optimization problems.

Consultant-Guided Search (CGS) is recent swarm intelligence meta heuristic for solving combinatorial optimization problems. CGS takes inspiration from the way real people make decisions based on advice received from consultants. Human behavior is complex, but Consultant-Guided Search uses virtual people that follow only simple rules.

2. Swarm Intelligence Techniques

Swarm Intelligence (SI) is the collective behavior of decentralized, self organized systems, natural or artificial. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of "intelligent" global behavior, unknown to the individual agents. Some of the significant swarm intelligence techniques as follow:

- ✓ Ant Colony Optimization (ACO)
- ✓ Bee Colony Optimization (BCO)
- ✓ Consultant-Guided Search (CGS)

Ant Colony Optimization

Ant colony optimization (ACO) was introduced by M. Dorigo and colleagues as a novel nature-inspired metaheuristic for the solution of hard combinatorial optimization (CO) problems. ACO belongs to the class of metaheuristics, which are approximate algorithms used to obtain good enough solutions to hard CO problems in a reasonable amount of computation time. The inspiring source of ACO is the foraging behavior of real ants. When searching for food, ants initially explore the area surrounding their nest in a random manner. As soon as an ant finds a food source, it evaluates the quantity and the quality of the food and carries some of it back to the nest. During the return trip, the ant deposits a chemical pheromone trail on the ground. The quantity of pheromone deposited, which may depend on the quantity and quality of the food, will guide other ants to the food source. The indirect communication between the ants via pheromone trails enables them to find shortest paths between their nest and food sources. This characteristic of real ant colonies is exploited in artificial ant colonies in order to solve CO problems[10].

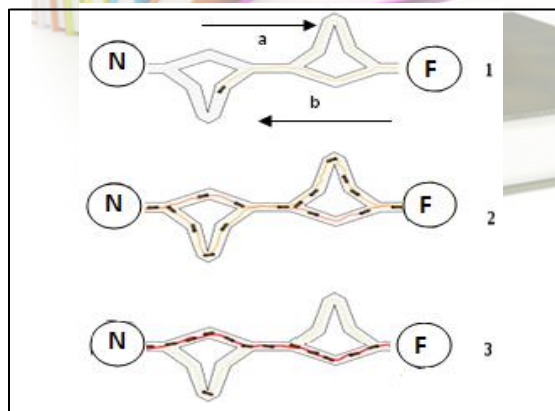


Fig1: Ant colony Optimization

1. The first ant finds the food source (F), via any way (a), then returns to the nest (N), leaving behind a trail pheromone (b)
2. Ants indiscriminately follow four possible ways, but the strengthening of the runway makes it more attractive as the shortest route.
3. Ants take the shortest route; long portions of other ways lose their trail pheromones.

The ACO algorithm is essentially the interplay of three procedures:

- ✓ ConstructAntsSolutions
- ✓ UpdatePheromones
- ✓ DeamonActions

ConstructAntsSolutions is the process by which artificial ants construct walks on the construction graph incrementally and stochastically. UpdatePheromones is the process by which pheromone is modified on arcs. Pheromone may be both increased and decreased. Pheromone is modified (decreased) by each ant on each arc as soon as it is added to a partial walk on the construction graph; this operation is called local update. Moreover, pheromone is further modified (increased) on selected good solutions to more strongly bias the search in future iterations, and this operation is called global update. Decreasing pheromone on selected arcs is important, in order to avoid too rapid convergence of the algorithm to suboptimal solutions. Interestingly, pheromone decreases also in the biological environment, due to evaporation. DeamonActions are centralized operations, such as comparing solution values among ants in order to find the best solution, or running a local search procedure.

Bee Colony Optimization

The Bee Colony Optimization (BCO) is inspired by bees' behavior in the nature. The idea behind the BCO is to create the multi agent system (colony of artificial bees) capable to successfully solve difficult combinatorial Optimization problems. The artificial bee colony behaves partially alike, and partially differently from bee colonies in nature. Honey bee comb build-up and management is a classic example of teamwork, experience, co-ordination and synchronization [7]. In a natural honey bee hive there are a variety of bees with specific role(s) to perform. There are three types of bees:

Queen Bee (one)

It is responsible to lay eggs which are used to build new colonies.

Male Drone Bees (many)

These are responsible for mating with the queen bee.

Worker Bees (thousands)

These bees perform all the maintenance and management jobs in the hive. There are two types of worker bees, namely

- ✓ Scout bees
- ✓ Forager bees

The Scout Action

In the scout behavior there are following steps:

- i. The scout bees start from the hive in search of food source randomly.
- ii. They keep on this exploration process until they are out of energy/tired and return back to the hive.
- iii. When they return back to the hive, they share their experience and knowledge with the forager bees by performing the mechanism called “waggle dance”. (Wagging is a form of dance in circular direction in the shape of digit 8. It is repeated again and again by a bee. Its intensity and direction gives the idea of food source quality and food source location respectively to other bees).

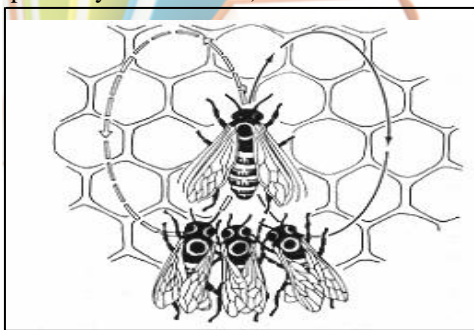


Fig2: Bees Waggle Dance

iv. It is the means by which the bees communicate. It is used to convey the parameters like foods Source Quality, distance of food source from hive, Location of food source, to guide the path to the available forager bees.

v. These steps of the scout bees constitute the first step of the BCO process called the “Path Construction”.

The Forager Action

In the Forager behavior, the forger bees do the following:

- i. The Forager bees observe and learn the steps done by the scout bees while wagging so as to ease their journey.

ii. Then these forager bees go to the food sources as guided by the scout bees to exploit them

iii. These forms the second step of the BCO process called the “Path Restructuring”.

Consultant-Guided Search

Consultant-Guided Search (CGS) is a new metaheuristic algorithm for solving combinatorial optimization problems. CGS takes inspiration from the way people make decisions based on suggestion received from consultants. In CGS Virtual persons represent as agents, which collaboratively solve complex combinatorial optimization problems. It is a population-based method. An individual of the CGS population is a virtual person, which can simultaneously act both as a client and as a consultant[1].

At the beginning of each iteration, a client chooses a consultant based on its personal preference and on the consultant's reputation. The reputation of a consultant increases with the number of successes achieved by its clients. A client achieves a success, if it constructs a solution better than all solutions found until that point by any client guided by the same consultant. Each time a client achieves a success, the consultant adjusts its strategy in order to reflect the sequence of decisions taken by the client. The exact details of how reputation and personal preference are used in order to select a consultant are specific to each application of CGS to a particular class of problems. Because the reputation fades over time, a consultant needs that its clients constantly achieve successes, in order to keep its reputation. If the consultant's reputation sinks below a minimum value, it will take a sabbatical leave, during which it will stop offering advice to clients and it will instead start searching for a new strategy to use in the future.

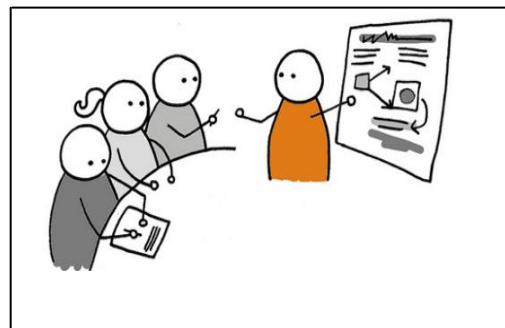


Fig3: Virtual Persons Discussion

3. Review of Literature

Serban Iordache 2010 introduced Consultant-Guided Search (CGS), a new metaheuristic for combinatorial optimization problems, based on the direct exchange of information between individuals in a population. It exemplifies the application of this metaheuristic to a specific class of problems by introducing the CGS-TSP algorithm, an instantiation of Consultant-Guided Search for the Traveling Salesman Problem (TSP). To determine direct communication approach can compete with stigmergy-based methods, by comparing the performance of CGS-TSP with that of Ant Colony Optimization algorithms. Its experimental results proved that the solution quality obtained by CGS-TSP is comparable with or better than that obtained by Ant Colony System and MAX-MIN Ant System [3].

Serban Iordache 2010 discussed how Consultant-Guided Search (CGS) relates to other metaheuristics for combinatorial optimization, argue that CGS is a hybrid metaheuristic, by identifying a series of concepts borrowed from other optimization techniques and they applied Consultant-Guided Search a novel metaheuristic for the Quadratic Assignment Problem (QAP), which hybridizes CGS with a local search procedure. In those experiments they used MAX-MIN Ant System (MMAS) as a yardstick to compare the performance of the proposed CGS-QAP algorithm, which hybridizes CGS with Local search procedure. Its experimental results confirmed that the solution quality obtained by CGS-QAP is comparable with or better than that obtained by MAX-MIN Ant System (MMAS)[2].

Shigeyoshi Tsutsui 2008 proposed several types of parallel Ant Colony Optimization algorithms with symmetric multi processing for solving the quadratic assignment problem (QAP). These models include the master-slave models and the island models. They evaluated each parallel algorithm with a condition that the run time for each parallel algorithm and the base sequential algorithm are the same. Their results suggested that using the master-slave model with increased iteration of ACO algorithms gave promising in solving QAPs [4].

Christian Blum 2005 presented the Ant Colony Optimization algorithm introduction and its recent trends. In this paper, they explained how ant behavior exploited to searching the approximate solutions for discrete optimization problem, Continuous Optimization problem and to important problem in telecommunication, such as routing & load balancing problems. They also provided examples of an interesting recent research direction[5].

Karaboga D. 2005 analyzed the foraging behavior of honey bee swarm and proposed a new algorithm simulating this behavior for solving multi-dimensional and multi-modal optimization problems, called Artificial Bee Colony. In the algorithm, an artificial bee colony consists of three groups of bees: employed bees, onlookers and scouts. In the ABC algorithm the first half of the colony consists of the employed bees and the second half includes the onlookers. The algorithm is tested on three well known test functions. From the simulation results, it is concluded that the proposed algorithm can be used for solving uni-modal and multimodal numerical optimization problems [6].

Lucic and Teodorovic 2001, 2002, and 2003 tested the Bee Colony Optimization approach in the case of Travelling Salesman Problem (TSP). The well-known TSP was defined in the following way: Given n nodes, find the shortest itinerary that starts in a specific node, goes through all other nodes exactly once and finishes in the starting node. They considered symmetric TSP when the distance from node i to node j is the same as the distance from node j to node i [7,8,9].

4. Comparative Study of CGS with other techniques.

CGS is a new population-based method, it introduces a novel metaphor, and however it is not obvious whether it represents a novel metaheuristic or relatively a reformulation of a well-known method, using novel names for existing concepts. Table 1 represents that CGS is hybrid metaheuristic, which combines new ideas with concepts found in Ant colony Optimization (ACO), Bee Colony Optimization (BCO) technique.

Table 1 Comparative study between ACO, BCO, and CGS

<i>Features</i>	<i>ACO</i>	<i>BCO</i>	<i>CGS</i>
<i>Inspiration</i>	ACO takes inspiration from the behavior of real ant colonies.	BCO takes inspiration from behavior of real bee colonies	CGS takes inspiration from the real way people make decisions based on advice received from consultant.
<i>Population</i>	ACO is a population-based method. It use ant as population.	BCO is also population-based method. It use bee as population.	CGS is a recent population-based method. It use virtual person as population.
<i>Communication method</i>	ACO technique use Stigmergic (Indirect) Communication to exchange information.	BCO use Non-Stigmergic (Direct) Communication to exchange information between bees.	CGS use Non-Stigmergic (Direct) Communication to exchange information.
<i>Desirability Function</i>	Desirability is given by the amount of Pheromone on the edge connecting the last component included & the candidate component.	A real bee uses waggle dance to recruit other nest mates to discover food source. Thus BCO technique uses the solution quality for recruitment Procedure.	Desirability function can be expressed in terms of two elements: the Reputations and the Strategies of the consultants.
<i>Extensions</i>	Elitist ant system, Max-Min ant system, Ant Programming, Ant colony system and Rank based ant system.	Bee algorithm, Artificial Bee Colony Algorithm, Bee Swarm, Virtual bee Algorithm , Bee Hive, Honey bee algorithm.	New Metaheuristic. No extensions in CGS.
<i>Maintenance of Information's</i>	ACO maintains a list of high quality solutions	In BCO, the experienced forage type bee Maintain the solution quality.	CGS keeps information about promising solutions, by means of consultant strategies.
<i>Advantages</i>	The pheromone evaporation of this algorithm has the advantage of avoiding convergence to locally optimal solution.	BCO technique avoids locally optimal solution. It searches for the best solution obtains by the entire bee colony. It is adaptive to changes in the environment.	CGS uses virtual person that follow only simple rules. There is no centralized control structure in CGS, and the group behavior self-organizes.
<i>Disadvantages</i>	Difficult to analyze it theoretically, since it is based on sequence of random decisions that are usually not independent and its probability changes from iteration to iteration.	In BCO, it is difficult to examine it hypothetically and its probability changes from iteration to iteration.	CGS also difficult to analyze it theoretically and its probability distribution changes from iteration to iteration.
<i>Applications</i>	Scheduling problems, Assignment problems, vehicle routing, etc.,	Job shop Scheduling problems, Flow Shop Scheduling problems, Open shop Scheduling Problems,etc.,	Quadratic Assignment Problems, Travelling Salesman Problems etc.,

5. Flexibility of CGS

CGS is a new swarm intelligence technique based on the direct exchange of information between individuals in a population. An individual of the CGS population is a virtual person, which can simultaneously act both as a client and as a consultant. As a client, a virtual person constructs at each iteration a solution to the problem. As a consultant, a virtual person provides suggestion to clients, in order to assist them to construct a solution.

The strategy of a consultant in CGS can be seen as a region of the search space that is advertised by this consultant. Because consultants with a superior reputation are more possible to be chosen by clients, it is significant to make sure that the reputation of a consultant is in state with the probability to find best-quality solutions in the region of the search space that it advertises.

The strategy of a consultant approaches a local or global optimum, the rate of achieving new successes decreases. This leads to reduce in the consultant's reputation. CGS maintains a ranking of the consultants. This ranking is not based on reputation, but on the best result obtained until then by any client guided by the considered consultant. It is likely that the global optimum lies in one of the regions advertised by consultants appearing at the top of the ranking. Preventing the reputations of these consultants to sink below a particular level guarantees that the search will continue in the regions that most possible contain the global optimum.

CGS maintains stability between the exploration of new regions in the search space and the exploitation of promising regions already found. In CGS, the sabbatical leave allows to abandon regions of the search space that are no longer promising and to start exploring new regions. During the sabbatical mode, at each iteration a new region of the search space is visited. At the end, the best region found is chosen to be advertised as the consultant's strategy. Because this region had not been exploited before, it is expected that its corresponding results are initially rather modest. If clients would choose consultants based on their results, a consultant that has just finished its sabbatical leave would have only a little chance to be chosen. Fortunately, consultants are chosen based on their reputation and the reputation of a consultant is reset at the end of the sabbatical. The

reset rate should be low enough to prevent the overexploitation of a region whose potential is still unknown, but high enough to allow a few clients to exploit this region. If the region selected during the sabbatical leave really has possible, a huge number of successes will be achieved in the next period for this region, leading to a rapid increase in the consultant's reputation. This way, the consultant is possible to rise to the top of the ranking, thus ensuring that its reputation will not fade below a specified level and therefore, that the region of the search space it advertises will be further exploited by clients. In order to apply CGS to a particular group of problems, one have to define the different concepts used by this metaheuristic (e.g., strategy, result, personal preference) in the context of the given class of problems. Then, one can decide how to implement the actions left unspecified by the CGS metaheuristic. (e.g., *constructStrategy*, *constructSolution*, *chooseConsultant*) and any other efficient strategy can be chosen [1].

In CGS, a too high rate leads to the premature termination of the exploitation of promising regions of the search space, thus preventing the convergence of the algorithm or a too low rate leads to stagnation, because it keeps reputations at high values for a long time, thus preventing consultants from taking a sabbatical leave in order to explore new regions of the search space.

6. Conclusion

Ant Colony Optimization (ACO), Bee Colony Optimization (BCO), Consultant Guided Search (CGS) meta-heuristics belongs to the group of Swarm Intelligence techniques. CGS is a new hybrid Meta heuristic, which combines new ideas with concepts found in ACO, BCO technique. This paper mainly addresses the relative study between ACO, BCO, and CGS and flexibility of CGS.

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Publications