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A CONCISE OVERVIEW OF ANT COLONY OPTIMIZATION

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***Abstract*— Ant colony optimization is a population and probabilistic based meta- heuristic technique which is used to evaluate the nearer optimal solution for the combinatorial problems. As combinatorial optimization problems are very challenging; they are very simple to state but difficult to solve; we are not able to find their optimal solution in polynomial bounded time with the direct methods. So as to solve these problems Ant colony optimization (ACO) is finest algorithm, which is inspired from the behavior of ants in which ant colonies help in establishing shortest path to food source. Ants always search food in the group or we can say in colonies they do not work individually. While moving on the path they deposit chemical like substance called pheromones from nest to food so as to get the shortest path to the food source from the nest. The aim of this paper is to give the general idea of ACO.**

Keywords— **Ant colony optimization (ACO), Pheromones, Ant System, combinatorial Problems, Metaheuristic, Probabilistic**

I. INTRODUCTION

ACO is metaheuristic probabilistic approach which is based on the behavior of ants. It is used to discover the optimized solution for the computational problems which are not able to compute by direct methods. This can find the shortest path between their colonies and food. While moving from colonies to food ants deposits chemical like substances known as pheromones. Pheromones intensity increases with the number of ants passing through the path and drops due to evaporation of pheromones. This way smaller path has more pheromones trail and this pheromone trail helps to find the shortest distance path. This algorithm was originally proposed by Marco Dorigo in 1992 in his PhD Thesis and originally proposed as Ant System. In order to be familiar with the ant colony optimization it is necessitate to completely understand the behavior of ants colonies refers to the social insects societies; ants works in colonies they does not work individually. They work as a distributed system that grants a highly structured social organization which is capable enough to accomplish complex tasks[3].

The paper is organized as follows: Section II introduces the Background of ACO, Section III explain the Ant's Communication, Section IV describe the Pheromones Evaporation, Section V covers the Double bridge experiment, Section VI deals with the problems in looping, Important characteristics of real ants are presented in Section VII, Section VIII explain the ACO metaheuristic, Section IX covers the application of ACO, Section X presented the advantages and disadvantages of ACO. And Section XI finally concludes the paper.

II. BACKGROUND

Initially ACO was proposed by Marco Dorigo in 1992 in his PhD thesis and proposed an algorithm Ant System; the intention of this algorithm was to search for an optimal path in a graph, based on the behavior of ants looking for a path between their colony and a source of food[4]. The original idea has since diversified to figure out a wider class of numerical problems, and as a result, several problems have emerged, drawing on various aspects of the behavior of ants. In 1959, Pierre-Paul Grassé invented the theory of stigmergy to enlighten the behavior of nest building in termites. Stigmergy indicates the mechanism of indirect coordination between agents. The principle is that the trace left in the environment by an action stimulates the performance of a next action, by the same or a different agent. Deneubourg and his colleagues studied the collective behavior of ants in 1983 and the work of collective behavior of ants gives the inspiration of ant colony optimization which was executed by Goss, Aron, Deneubourg and Pasteels in 1989.Then in 1991 Macro Dorigo proposed the idea of ACO which was published in 1992. As the first ant colony optimization algorithm is known as Ant System. Ant System is the result of a research on computational intelligence approaches to combinatorial optimization that Dorigo conducted at Politecnico di Milano in collaboration with Alberto Colorni and Vittorio Maniezzo. It was initially applied to the travelling salesman problem, and to the quadratic assignment problem[5].

In 1996, Hoos and Stützle invent the max-min ant system. This algorithm is the enhancement to the original Ant System Algorithm. It assures that only the best ant updates the

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pheromone trails and the value of the pheromone is bound. In 1997 Dorigo and Gambardella publish the ant colony system. They introduce the local pheromone update in an addition to pheromone performed at the end of the construction process also called offline pheromone update. Local pheromone update is optional. This step is performed by all the ants after each construction step. Dorigo, Gambardella and Stützle have also proposed new hybrid versions of ant colony optimization with local search. In 1997, Schoonderwoerd and his colleagues developed the first application to telecommunication networks**.** In 1999, Dorigo, Di Caro and Gambardella defined the Ant colony optimization metaheuristic[5].

III. Ant's Communication

Human beings communicate via visual and hearing aid. But ants are essentially blind and deaf so they communicate via pheromone which is a chemical like substance excreted by the ants; Ants allure towards the pheromones. Whenever an ant moves from its colony to the food source it excretes the pheromones in its path upon finding the food returns to their colony. When other ants come across the pheromones, they are likely to follow the path with a certain probability. If they do, then they populate the path with their own pheromones as they bring the food back. As more ants find the path, it gets stronger until there are a couple streams of ants traveling to various food sources near the colony[2].

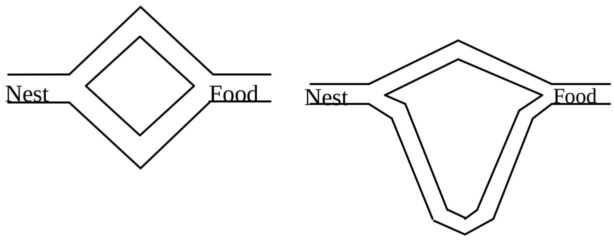
IV. Pheromones Evaporation

It has been examined that the ant colonies are capable enough to find the shortest path to the food source. As the ant moves and searches for food it deposit pheromones on the path and during this process of searching food an interesting concept is used which is known as pheromone evaporation. Pheromone trail thus starts evaporate over the time, thus falling its attractive strength. The more time it takes for an ant to travel down the path and back again, more the pheromones evaporate. In this way shorter path must have the higher density of pheromones so most probably the ant will choose the shorter path as compare to the longer path. Therefore pheromones evaporation is deemed as an advantage for choosing the shorter path.

V. Double Bridge Experiment

As the direct communication between ant and food source is based on the pheromones deposit on the ground by the ants while walking from the colony to the food source and vice versa. Ants can odor those pheromones and most probably they have a tendency to select the path having higher intensity of pheromone trails. So as to proof this Deneubourg and his colleagues designed and run a superb experiment named as Double Bridge Experiment. In this experiment they use two different bridges of varied lengths. This experiment proceed by varying the ratio l_s/l_s between the lengths of two branches of the double bridge where l_s is length of smaller branch and l_l is the length of the longer branch.

In the first experiment (see figure 1a) the bridge contain two branches of identical length. Initially all the ants are free to move from nest to the food. The percentage of the ant prefers one or the other path can be determined by the time passed. While considering both the figures resultant is that although in the starting phase the ants move casual in any branch because when the trail begin there is no pheromones in any of the branch. So, the ants do not have any preference and they select any of the branches with the same probability. Yet, because of some random fluctuations some ant randomly choose other branch with the same probability; as the ants deposits pheromone on the path and creates a pheromone trails. Larger the number of ants in the path will deposits large amount of pheromones; this large amount of pheromone attracts more ants to choose the same path.



(a) (b)

Figure 1: Double bridge experiment. (a) Branches with equal length. (b) Branches with different length.

In the second experiment, the ratio between the length of two branches is r = 2. i.e. the length of the larger branch is twice the length of the smaller branch. Initially ants choose the path randomly. Those ants who are choosing the short branch are the first to reach the food and to start and return to their nest. But when they make a decision between the short and long branch the higher level of pheromone on the short branch will bias their choice in its favor. Consequently pheromone starts to accumulate faster on the short branch[2].

VI. Problem In Looping

ACO is precious for diminishing the cost we just need to compose such algorithms which can figure out the minimum cost of the graph. Consider a graph G (N, A) where N is the number of nodes and A are the edges.

If we want to set up a minimum cost path between the source and destination nodes (see figure 2) on the graph G using artificial ants, the ants may generate while building a solution. But it may generate the problem of looping. Results into the updating of forward pheromone trail, loops turn out to be more attractive and trap the ants.

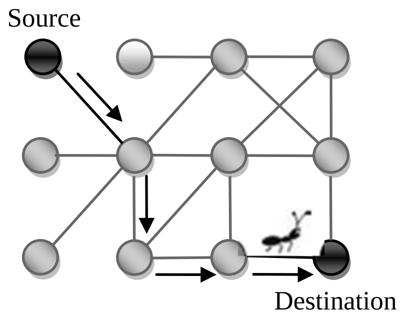


Figure 2: Path build by ant from source to destination

Even though the ant can get rid of such loops yet the shortest path phenomenon of ant does not work any longer. As the problem is arises because of forward pheromone trail updating; so it needs to be removed. In this way ants would rely only on backward updating. But it is not the solution we need to extend the capabilities of the artificial ants; while retaining the crucial characteristics of real ants, permit them to solve it on generic graphs[2].

VII. BEAHAVIOUR OF REAL ANTS

Limited memory is given to the artificial ants to store the partial paths as well as the cost of the links they traversed. This memory is very advantageous; through this ants can implement a variety of useful behaviors that let them build solutions to the minimum cost problem.

Probabilistic forward ants and solution construction: Ants have basically two working modes: forward and backward. Forward mode is that when they move from nest to food and backward mode is reverse of this. After reaching the destination via forward mode, ant switches to the backward mode and starts travel back to the source. Forward ants build a solution by selecting probabilistically the next node to travel among the other neighbor nodes of the graph. The preference is depend upon the pheromone trails prior deposited on the graph by other ants. Forward ants do not leave any pheromone. This along with deterministic backward ants will assist in eliminating the formation of loops.

Deterministic backward ants and pheromone update: As the memory stores the path which ants already traced some time back. This permits an ant to retrace the path; moreover, Simple-ACO ants improve the performance by implementing loop elimination. Before going backward on the path they remember by exploring the destination node, loops will be eliminated. While traveling backward, Ants leave pheromone.

***Pheromone updates based on solution quality*:** Because of the memory ants can evaluate the cost of the solutions they produce and by using this they modulate pheromone that they deposit while in backward mode. Pheromone updates based on solution quality help in directing the future ants more strongly towards the better solution. By letting ants deposit a higher amount of pheromone on the short path, the ants path searching is more quickly biased toward the best solutions.

VIII. THE ACO METAHEURISTIC

Now days, researchers are paying much attention towards the superior methods which can find the good quality solutions of these combinatorial optimization problems which is known as Metaheuristic. Metaheuristic techniques contains set of algorithm which are independent of the problems, this concept of new class of algorithms has increased the quality and efficiency of solutions of the problems. Among various metaheuristic techniques Ant Colony Optimization is very popular.

ACO can be used for static as well as dynamic combinatorial optimization problems; where static problems are those in which the characteristics of the problem are given once and for all when the problem is defined and do not change till the problem is being solved; such as TSP in which the location of cities and their relative distances do not change at run time. On the other hand, dynamic problems are those functions whose value changes at the run time and the optimization algorithm must be capable of adapting online to the changing environment such as work routing problems in which the data traffic and network topology can vary in time.

Informally, an ACO algorithm consists of three phases: Construct And Solutions, Update Pheromones and Daemon Actions.

Construct And Solutions: In this number of solutions are constructed by the ants. It manages a colony of ants that concurrently and asynchronously visit adjacent states of the considered problem by moving neighbor nodes of the problem's construction graph.

Update Pheromones: It the process by which the pheromone trails are updated or modified. The trails value can either increase, as ants deposit pheromone on the components or it may decrease due to the process of pheromone evaporation.

Daemon Actions: This phase is optional and used to implement centralized actions which cannot be performed individually. It also refers as Local Search. The daemon can observe the path found by each ant in the colony and select one or a few ants which are then allowed to deposit additional pheromone on the components they used.

```
procedure ACOMetaheuristic
    ScheduleActivities
        ConstuctAntsSolutions
        UpdatePheromones
        DaemonActions  (optional)
    end-ScheduleActivities
end-procedure
```

Figure 3: Pseudo-code of Metaheuristic

The ScheduleActivities construct does not specify how these activities are scheduled and synchronized. So it does not say whether they should be executed in a completely parallel and independent way so the designer is completely free to specify the way these phases should interact[1].

IX. APPLICATIONS OF ACO

Being an emerging technique ACO has numerous applications in various areas. Other than TSP it is applied in scheduling problem, assignment problem, routing problem or graph coloring etc. Specially the biomedical and bioinformatics shows a great interest in ACO. Moreover ACO algorithm is proposed to solve the problems like the sequential ordering, the open shop scheduling, the resource constraint project scheduling problems etc[3].

Table -1 Applications of ACO

Problem Type	Problem Name	Authors
Routing	Traveling Salesman	Dorigo ET AL (1991, 1996) Dorigo (1992) Gambardella & Dorigo (1997) Stutzle & Hoos (1997,2000)
	Vehicle Routing	Gambardella ET AL (1999) Reimann ET AL (2004)
	Sequential Ordering	Gambardella &Dorigo(2000)
Assignment	Quadratic Assignment	Stutzle & Hoos (2000) Maniezzo (1999)
	Course Timetabling	SOCHA ET AL(2002,2003)
	Graph Coloring	Costa & Hertz (1997)
Scheduling	Project Scheduling	Merkle ET AL (2002)
	Total Weighted Tardiness	Den Besten ET AL(2000) Markle &Middendorf (2000)
	Open Shop	Blum (2005)
Subset	Set Covering	Lessing ET AL (2004)
	Cardinality Trees	Blum & Blesa(2005)
	Multiple Knapsack	Leguizamon&Michalewicz(1999)
	Maximum Clique	Fenet & Solnon (2003)
Other	Constraint Satisfaction	Solnon (2000,2002)
	Classification Rules	Parpinelli ET AL (2002) Martens ET AL (2006)
	Bayesian Networks	Campos ET AL (2002)
	Protein Folding	Shmugelska & Hoos (2005)
	Protein Ligand Docking	Korb ET AL (2006)

X. ADVANTAGES AND DISADVANTAGES OF ACO

Nothing is ideal in this world. There are some pros and cons of everything. There must be some negative points that will not make it perfect. ACO has also some positive as well as negative points.

Advantages

- It can be used in static as well as in dynamic applications.
- Its positive feedback results into quick discovery of better solution.
- It has limited memory which cans maintain memory of the entire colony.
- It performs better than other techniques[6].

Disadvantages

- ACO ensure Convergence, however time to convergence is uncertain.
- Coding is a bit complicated not simple[6].

XI. CONCLUSION

It is concluded that the ACO is very effective and popular approach for finding nearer optimal solution of problems like NP-hard. This paper is attempted to give the concise overview of ACO. Nowadays, so many researchers are working on ACO for solving NP hard combinatorial problems. ACO shows a great performance with the applications like scheduling, Networking, Routing, Load balancing, telecommunications etc.

XII. REFERENCE

[1] Marco Dorigo,Mauro Birattari and Thomas Stiitzle, "*Ant colony optimization Artificial ants as a computational intellignence Technique*",IEEE Computational Magazine 2006, pp.28-39.

[2] Marco Dorigo and Thomas Stützle, "*Ant colony optimization*", 2004.

[3] Christian Blum "Ant colony optimization: Introduction and recent trends", ELSIVER, pp. 353-357, oct 11,2015.

[4] "*About ACO*" http://www.aco-metaheuristic.org/about.html

[5] "*Ant Colony Optimization algorithms"* https://en.wikipedia.org/wiki/Ant_colony_optimization_algorithms

[6] "*Ant colony optimization algorithm and applications*" https://www.scribd.com/doc/65793947/38/DISADVANTAGES