A STUDY ON ANT COLONY OPTIMIZATION (ACO)

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Abstract

Ant Colony Optimization (ACO) is a paradigm for designing metaheuristic algorithm for combinational optimization problems. It is a way to solve optimization problems based on the way that ants indirectly communicate directions to each other. The behavior of ants has been documented and the subject of easily writing and fables passed from one century to another century. The successful techniques used by ant colonies have been studied in computer science and robotics to produce distributed and fault tolerance system for solving problems as well as used in fault tolerance storage and networking algorithm. Metaheuristic algorithms are algorithms which, in order to escape from local optima, drive some basic heuristic: either a constructive heuristic, starting from the null solution and adding elements to build a good complete one, or local search heuristic, starting from a complete solution and iteratively modifying some of its elements in order to achieve a better one.

Keywords:-

Ant colony optimization, Swarm Intelligence[3], stigmergy, ant system, MIN-MAX ant system, Metaheuristic.

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Introduction

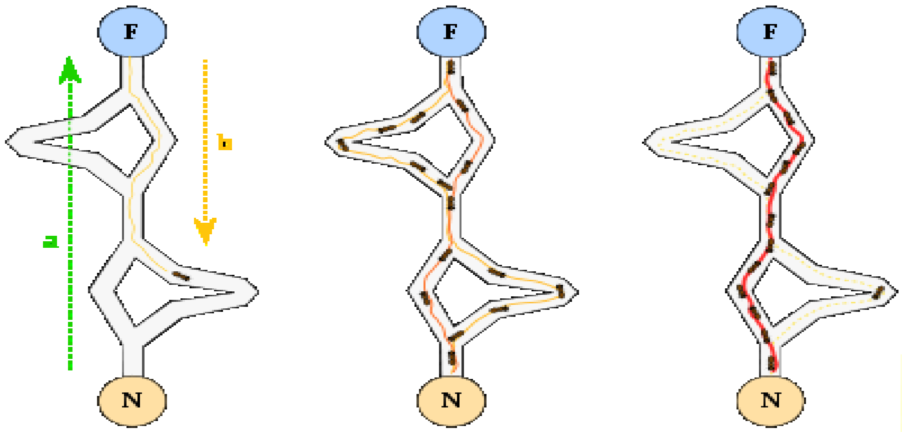
The ACO algorithm is a probabilistic technique for solving optimization problems. The ACO initially proposed by Marco Dorigo in 1992 in his Ph.D thesis [1][2]. The aim of this algorithm is to search for an optimal path in a graph, based on the behavior of the ants finding a path between their colony and a source of food, i.e. finding a shortest route from nest to food source. Ant Colony Optimization inspired from Swarm Intelligence [3]. Basically ant colony optimization is a way to solve optimization problems based on the way that ants indirectly communicate direction to each other.

This article is arranged in the 6 sections. Section 1 gives the information about the nature of natural ants. Section 2 gives the heuristic information of ant colony optimization. General form of ACO Algorithm is given by section 3. Different variants of ACO algorithms which plays an important role in ACO are describe in section 4. Finally applications and conclusion describe in section 5 and section 6 respectively.

Natural Ant Colonies:-

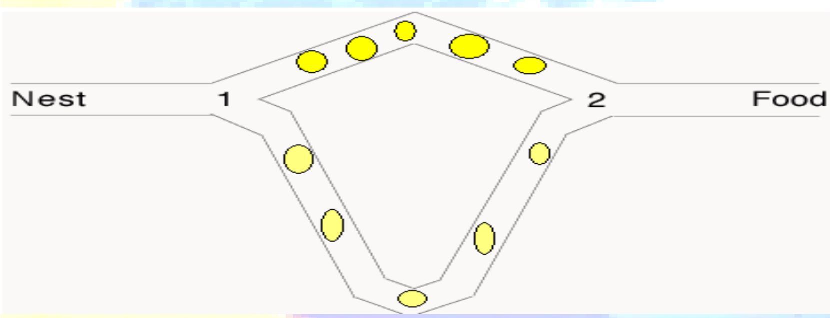
Ants communicate with each other using pheromones, sound and touch. The main important factor for ant communication is the pheromone which is a chemical released by the ants and used as the signals for ant communication. A very interesting point of ant's behavior is that they have the ability to find out the shortest paths between their nest and the food source with the help of the pheromones. Ant use pheromones to direct each other through their environment.

Now consider a colony of ants that are searching for food. Suppose that ant colony starts out with no information about the location of the food in the environment. And each ant leaves a trail of pheromone as it look for food. As shown in figure

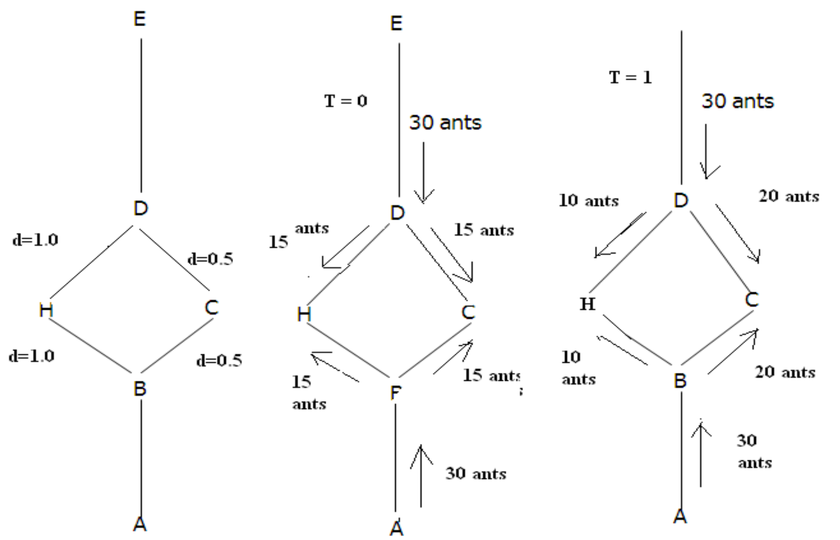


When an ant finds food, it can follow its own pheromone trail back to the nest. When other ants run into a trail of pheromone, they give up their own search and start following the trail.

The sample rules followed by the natural ants are



Ants are behaviorally unsophisticated but collectively they can perform complex tasks. If an ant has a choice of two pheromone trails to follow, then it will be the path which has strong pheromone trails



ACO Metaheuristic:-

Ant Colony Optimization takes inspiration from the forging behavior of ant species. ACO exploits the same mechanism for solving optimization problem.

Ant colony optimization is an iterative process and at each iteration number of artificial ants (agents) is considered.

Ant Colony Optimization Algorithm is essentially construction algorithm i.e. in each algorithm iteration every ant construct a solution to the problem by travelling on a construction graph. Each edge of graph representing the possible steps of an ant can make, and has associated two kind of information that guide the ant movement:

1. Heuristic Information: - Which measure the heuristic preference of moving from node 'r' to node's'. It is denoted by η_{rs} and this information is not modified by the ant during algorithm run.

2. Pheromone (Artificial) Trail Information:- it measures the learned desirability of the movement. This information is modified during the algorithm run depending on the solution found by the ants and denoted as τ_{rs}.

The general form of algorithm for Ant Colony Optimization meta heuristic:-

Set parameters, initialization pheromone trails

While terminators condition is not met

Do

Construct Ant Solutions

Apply Local Search (optional)

Update pheromone

End While

Variants for Ant Colony Optimization:-

The main successful variants for Ant Colony Optimization algorithms are:-

1. Ant System [4][5]
2. Min-Max Ant System [6]
3. Ant Colony System [7][8]

The basic difference between all these three variants is on the basis of updation of their pheromone level as well as their creation of path at each iteration.

1. **Ant System:-** Ant System is the first Ant Colony Optimization Algorithm. The main characteristic is that, at each iteration, the pheromone values are updated by all the 'm' ants that builds a solution in the iteration itself. And the updated value of pheromone τ_{rs} with the edge 'r' and 's' will be

$$\tau_{rs} \leftarrow (1-\rho).\ \tau_{rs} + \sum^{m}_{k=1} \Delta\ \tau_{rs}^{k}$$

where ρ is the evaporation rate, m is the number of ants and τ_{rs}^{k} is the quantity of pheromone laid on edge (r, s) by the ant k.

$$\Delta\ \tau_{rs}^{k} = \begin{cases} Q/L_k & \text{if ant k uses edge (r,s) in its tour} \\ 0 & \text{Otherwise} \end{cases}$$

Where Q is a constant and L_k is the length of the tour constructed by the ant k.

2. **Min-Max Ant System:-** Min-max ant System is an improvement over the original ant system. The main characterizing element of min – max algorithm is that only best ant will update the pheromone trails and that the value of pheromone is bound.

Hence the updated pheromone will be

$$\tau_{rs} \leftarrow (1-\rho).\ \tau_{rs} + \left[\Delta\ \tau_{rs}^{best}\right]_{\tau_{min}}^{\tau_{max}}$$

Where τ_{max} and τ_{min} respectively the upper and lower bounds imposed on the pheromone. And $\Delta\ \tau_{rs}^{best}$ is defined as :

$$\Delta\ \tau_{rs}^{best} = \begin{cases} 1/L_{best} & \text{if (r,s) belongs to the best tour} \\ 0 & \text{otherwise} \end{cases}$$

Where L_{best} is the length of the tour of the best ant. This may be either the best tour found in the current iteration or the best tour found since the start of the algorithm or the combination of both. Concerning the lower and upper bounds on the pheromone values τ_{max} and τ_{min} , they are typically obtained empirically and tuned on the specific problem considered [9]. Nonetheless, some guidelines have been provided for defining τ_{max} and τ_{min} on the basis of analytical considerations [6]

3. **Ant Colony System(ACS):-** The most interesting contribution of ACS is the introduction of a local pheromone update with the performance at the end of the construction process known as offline pheromone update. The

local pheromone update is performed by all the ants after each construction step and each ant applies it only to the last edge traversed:-

$\tau_{rs} = (1-\Phi).\ \tau_{rs} + \Phi.\ \tau_0$

where $\Phi \in (0,1)$ is the pheromone decay coefficient and τ_0 is the initial value of the pheromone. The main goal of the local update is to diversify the search performed by subsequent ants during an iteration by decreasing the pheromone concentration on the traversed edges, ants encourage subsequent ants to choose other edges and hence to produce different solutions.

The updation of offline pheromone is similar to Min-Max Ant System i.e. applied at the end of each iteration by only one ant which can be either iteration best or the iteration –so – far.

The updation formula:-

$$\tau_{rs} = \begin{cases} ((1-\rho).\ \tau_{rs} + \rho.\ \Delta\ \tau_{rs} & \text{if (r, s) belongs to the best tour} \\ \tau_{rs} & \text{otherwise} \end{cases}$$

The main difference between Ant Colony System and Ant System is in its decision rule used by the ants during the construction process. In ACS these rules are called pseudorandom proportional rule is used

Applications of Ant Colony Optimization:-

Ant colony optimization have been applied to many optimization problems including quadratic assignment, routing vehicle, protein folding and many other derived methods have been adapted to dynamic problems in different problems.

ACO also used to produce near optimal solution of many problem including travelling salesman problem, simulated annealing problems. ACO have an advantage of over genetic algorithm approaches of similar problems when the graph may change dynamically.

S.No	Problem Types	Problem Names
		Job-shop scheduling problem[10]
		open-shop scheduling problem[11][12]
		Permutation flow shop problem[13]
		Resource constraind project scheduling problem[14]
1	Scheduling Problem	Group-shop scheduling problem[15]
		Capacitated vehicle routing problem[16][17][18]
		Multi depot vehicle routing problem[19]
		Vehicle routing problem with pick up and delivery[20][21]
		Vehicle routing problem with time window[22][23][24]
2	Routing Problems	Split delivery vehicle routing problem[25]
		Quadratic assignment problem[26]
		Generalized assignment problem[27][28]
		Frequency assignment problem[29]
3	Assignment Problems	Rdundancy allocation problem[30]
		Set covering problem[31][32]
		Set partition problem[33]
		Weight constrained graph tree partion problem[34]
		Multiple Knapsack problem[35],
4	Set Problems	Maximum independent set problem[36]
		Classification[37]
		Data mining[37][38][39][40]
		Distributed information retrieval[41][42]
		Image processing[43][44]
		Intelligent testing system[45]
		System Identification[46][47]
		Protien folding[48][49]
		Power electronic circuit design[50]
		Connectionless network routing[51][52]
5	Others	Grid workflow scheduling problem[53]

Conclusion: - Ant Colony Optimization has been and continues to be a fruitful paradigm for designing effective combinatorial optimization solution algorithms. After more than ten years of studies, both its application effectiveness and its theoretical grounding have been demonstrated, making ACO one of the most successful paradigms in the metaheuristic area.

This overview tries to propose the reader both introductory elements and pointers to recent results, obtained in different directions pursued by current research on ACO.

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