A Comparative study on Ant Colony Optimization

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Abstract
Ant Colony optimization is a computational method which can be used for finding best solutions and the paths for best solutions.Ant Colony Optimization (ACO) is a derivative of Swarm intelligence (SI). It is based on the criterion which the real ants follow. As the ants move in search of food followed by other ants, similarly, the artificial ants are made to move on a weighted graph. Actually the model ants undergo the movement along with some parameters in their routes, dropping pheromones and indicating the following ants. Introduced by Marco Dorigo in the year 1992, ant colony algorithm is having a variety of applications in the field of artificial intelligence.This paper discusses ACO algorithm, improved ant colony optimization algorithm, recent researches in engineering domain and its applications.

1. Introduction

ACO is a type of meta-heuristic, i.e. which gives the globally optimal solution. In ACO, a set of artificial ants search for globally optimal solutions to a given optimization problem. Artificial ants are made to travel on a weighted graph, on which they drop different amounts of pheromone. By moving on the graph in search of the best paths, they provide us different solutions [4]. The real ants move in queues following the foremost ant while sometimes changing the path if one of them finds a better path. Living in the form of colonies in anthills, they always start their food searching phenomenon collectively. The software ants release pheromone in the path of searching the possible solutions to the given problem. The other ants prefer to follow the path of rich pheromone level. The aim of the optimization is to find the globally best solution.[3] In this paper, brief study on ant colony optimization, its algorithm, improved ACO algorithm and its scope in engineering field as well as various optimization problems have been clustered.

Double Bridge Experiment
Pasteels, Deneubourg and Goss introduced the following ‘‘double bridge experiment’’ in 1978.

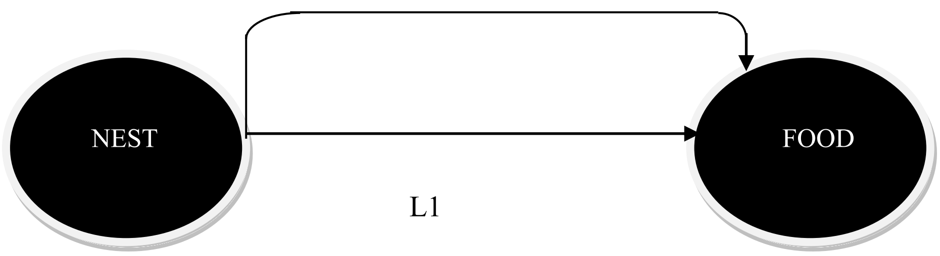


Figure 1. A double bridge method for ACO with different lengths of paths.[2]

They even developed a probability model of the observed behavior of real ants. In this model, m_1 ants choose the first path, m_2 ants choose the second path and probability p_1 for an ant to choose the firstbridge is:

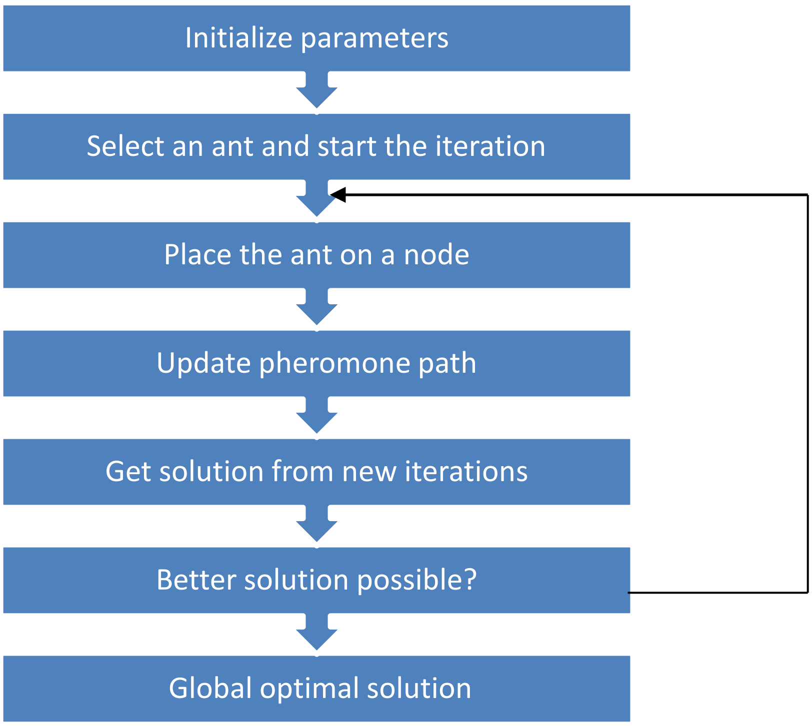
$$p_1 = \frac{(m_1 + k)^h}{(m_1 + k)^h + (m_2 + k)^h}$$

where parameters k and h are constants. This probability is based on the fact that, higher the pheromone concentration on a particular path, higher is the probability for selecting that path [9].

ACO algorithm

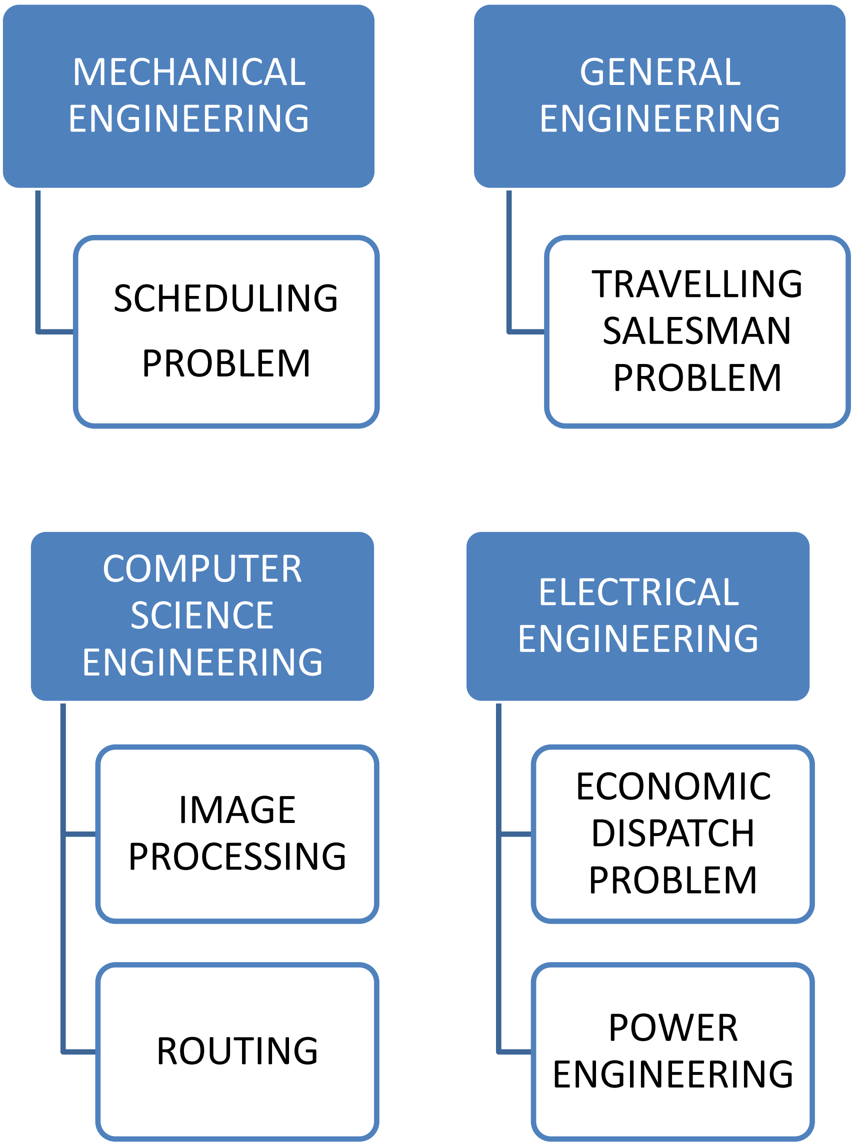
i. Firstly, determine the different paths possible with pheromone level zero in the start.
ii. Keep the ants on the weighted graph, of which the solution is required.
iii. Trace the paths followed by ants.
iv. Terminate any loop in the traced trail.
v. Retrace steps.
vi. Update the path by evaporating a portion of the pheromone according to parameters assigned.
vii. Put some amount of pheromone to again retrace the path.
viii. Loop or exit

The flow chart of the ACO algorithm is illustrated below ([10]):-



2. Recent research in ACO on various engineering domain

ACO has a vast dimension in various fields for solving diverse problems. Even in the field of engineering, such as Electrical, Electronics, Mechanical, Civil as well as Bio-medical engineering use the Ant Colony Optimization techniques and algorithms. Some of the tasks where ACO is used are Wireless sensor networks, Data mining, grid computing, digital image processing and plenty of others.
Following flow chart shows the fields of engineering and their respective applications ([1]).



3. Improved Ant Colony Optimization Algorithm

After successful implementations, ACO algorithm has been further modified to more dynamic and capable of global searching ability based algorithm i.e. IMPVACO. This algorithm uses the fact that the path with less pheromone level should also be considered for global search because the pheromone on unattended path will reduce to zero, as the path with shortest distance between the food source and the nest is considered by all the other following ants. So, it definitely affects the global searching ability. Here, not only the case of less pheromone level is considered, but also the case of excess pheromone level is considered. If the pheromone level is way too large, it also affects the global search.

It involves three basic steps:-

- Adaptive adjustment strategy of pheromone
- Dynamic Evaporation Factor Strategy
- Boundary Symmetric Mutation Strategy

For more details on this topic one may refer to [8].

4. Applications

Based on its meta-heuristic, stochastic, dynamic and multi-objective problems solving abilities, it has a wide range of applications. TSP, being its first solved problem, can be reached by transforming other problems as TSP and then solving with the same method as of TSP. Various applications associated with ACO are Routing, assignment, scheduling, machine learning problems and many more. Some of the applications are illustrated below:

TRAVELLING SALESMAN PROBLEM (TSP)
This is the easiest implementation of ACO, and the first one to be optimized by ACO too. In the traveling salesman problem, a set of cities are given and the salesman is assumed to take up a tour of the cities whose distances are known. The aim is to find the shortest traversed tour along-with the condition of each city to be visited only once. In ant colony optimization, we place the artificial ants moving on the connected graph i.e. transforming the TSP to ACO. Pheromone along each edge can be examined and modified by ants. In this connected graph, vertices represent cities and edges represent distance between the cities [5].

JOB SCHEDULING PROBLEM (JSP)
This one is the most difficult problem in the combinatorial optimization. This problem is defined as NP-hard problem. The job scheduling problem is linked with allocating limited resources. The aim is to achieve high performance computing. This optimization problem is difficult due to the fact that finding an optimal resource allocation for specific job that minimizes the schedule length of jobs is a complicated problem [5].

QUADRATIC ASSIGNMENT PROBLEN (QAP)
These assignment problems are the problems of assigning facilities to destinations such that the aim is to minimize the cost. Here, the quadratic function is the cost. An example can be of a company vehicle carrying different commodities to be delivered in different cities [7].

VEHICLE ROUTING PROBLEM (VRP)
These are the problems in which set of vehicles at a depot have to fulfill the requirements of customers by travelling and carrying the commodities to be served to customers. The objective is to minimize the number of vehicles used and the total distance travelled by the vehicles. It is an extension of TSP. Capacity constraints, time, maximum tour length, backhauling, rear loading, vehicle objections, etc. constraints are imposed on the vehicle [5].

5. Conclusion

Ant Colony Optimization continues to be a productive model for combinatorial optimization problem. We gave a detailed description of how ants are used as software agents which are inspired by real ants, its algorithms (basic and improved), its scope in engineering field and its applications. In the IMVPACO algorithm, the updating rules and adaptive adjustment strategy of pheromones are modified in order to better reflect the quality of the solution based on the increment of pheromone. Ant Colony Optimization is one of the best examples of nature-inspired algorithms which are being used in day-to-day life in fields such as mathematics, engineering, machine learning, artificial intelligence etc. With the advancement in technology and science, the applications of these optimization problems are gaining more importance. Many optimization techniques such as swarm optimization, spider monkey optimization, grey wolf optimization etc. have a high scope in many fields and must be heeded towards for solving some everlasting pertaining problems which can be minimized or exhausted completely [6].

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References

[1] Chandra Mohan, B. &Baskaran, R. “Survey on recent research and implementation of Ant Colony Optimization in various engineering applications”, International Journal in Computational Intelligent Systems, vol. 4, no. 4, (**2011**), pp. 556–582.

[2] E. Walid, E. A. Haikal, A. Ajith and A. M. Alimi, “A comparative study of the improvement of performance using a PSO modified by ACO applied to TSP. “Soft Computing Journal”, vol. 25, no. 12, (**2014**), pp. 234-241.

[3] K. Shima, N.P. Hossein, “An advanced ACO algorithm for feature subset selection”, Neurocomputing, vol. 147, no. 1, (**2015**), pp. 271-279.

[4] M. Dorigo and G. D. Caro, “Ant algorithms for discrete optimization”, Artificial Life, vol. 5, no. 3, (**1999**), pp. 137-172.

[5] M. Dorigo, L. M. Gambardella, “Ant Colony System: A Cooperative Learning Approach to the Traveling Salesman Problem,” IEEE Transactions on Evolutionary Computation, vol. 1, no. 1, (**1997)**, pp. 53-66.

[6] M. Dorigo, T. Stutzle, “Ant Colony Optimization,” MIT Press, Cambridge, MA, (**2004)**.

[7] Maniezzo V, Colorni A. “The Ant System applied to the quadratic assignment problem”, IEEE Trans. Data Knowledge Engineering, vol. 11, no. 5, (**1999**), pp. 769–778.

[8] Ping Duan, Yong Al, “Reseasch on Improved Ant Colony Optimization Algorithm”, International Journal of Hybrid Informatio Technology, vol. 9, no. 4,(**2016**), pp. 223-234.

[9] Sapna Katiyar, Avneesh Mittal, A. Q. Ansari, T. K. Saxena, "Ant Colony Algorithm Based Adaptive PID Temperature Controller," Proc. 7th Int. Conf. on Trends in Industrial Measurements and Automation (**2011**), CSIR, Chennai.

[10] Wanli Lei and Fubao Wang “Research on Improved Ant Colony Optimization Algorithm for solving Travelling Salesman Problem”, International Journal of Database Theory and Application, vol. 9, no. 9, (**2016**), pp. 25-36.