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Survey on Ant Colony Algorithm

Sony V Johny, Sakhi S Anand

Abstract— **Ant colony algorithm is an intelligent algorithm and is inspired by the behaviour of ants. Ants are blind and have the ability to find the shortest path from their colony to the food source. Using the capabilities of ants, ant colony algorithm solves combinatorial optimization problems which are hard problems such as TSP, 0-1 knapsack, graph colouring and so on. Ants solve their problem by cooperation using indirect communication or pheromone. Ants put pheromone on the ground while walking and each ant like better to follow a direction where amount of pheromone is high. When ants explored the shortest path which is blocked by an obstacle, each ant tries to find new shortest path. If an ant found the shortest path, it lays pheromone on the path, thus marking that path by a trail of its pheromone. The function of this trail is to guide other ants towards that path, reinforcing it with their pheromone and makes that path, the best path. Intensity of pheromone becomes higher on the shortest path. Pheromone evaporates on the longest path, thus reducing the intensity of pheromone. One of the problems of ant colony algorithm is stagnation behaviour in which all ants traverse the same path. Another problem is that it consumes more searching time to get better solutions. A large number of ants are required to avoid this situation.**

Index Terms— **TSP, 0-1 knapsack, QAP, graph colouring.**

I. Introduction

The basis of swarm intelligence is depends on the studies of interaction between animals. Swarm intelligence is an intelligent system which depends on the collective, decentralized behaviour of many self organized subsystems. A swarm intelligent system contains a population of simple agents which only interact locally with each other and their environment. That means, each individual agent in the system only follows simple rules and may not have the knowledge of the overall system. The local interactions between such agents can lead to the emergence of very sophisticated and complicated group behaviour. Examples of biological swarm intelligent systems include ant colonies, bird flocking, fish schooling, bacterial growth etc.

Ant colony algorithm was first proposed by Marco Dorrigo [1]. It is based on the studies of how blind animals like ants are capable of finding the shortest path from their nest to a food source. Pheromone, the chemical used for indirect communication between ants helps to explore the shortest path. Initially ants wander randomly to search food. If an ant succeeds, it lays pheromone on the ground, thus marking the path by a trail with its own pheromone. More ants can detect it and agree to follow it, thus reinforcing it with their pheromone. When an established path is blocked by an obstacle, each ant tries to find the new path. The major steps of ant colony algorithm are initialization, solution construction, update of pheromone and iteration. In first step, the values of pheromone on each node are set to a constant value. In second step, each ant begins on a start node and moves to one of its neighboring node based on the pheromone values using transition probability. In the last step, second and third steps are repeated until a stop criterion is met.

The main characteristics of ant colony algorithm are positive feedback, distributed computation or decentralized control and the use of greedy heuristic. Positive feedback explains to observe the good solution. Distributed computation avoids slow convergence speed. Greedy heuristic helps to discover the satisfactory solutions in the early steps of the search process.

Ant colony algorithm solves combinatorial problems which are difficult to find the solution. The main benefit of ant colony algorithm is to find the optimal solution of difficult problems in reasonable amount of computation time.

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Sony V Johny, *Department of Computer Science and Engineering, College of Engineering, Trivandrum.*

Sakhi S Anand, *Department of Computer Science and Engineering, College of Engineering, Trivandrum.*

II. Motivation

Ant colony algorithms are effective and robust. Combinatorial optimization problem is the issue of finding an optimal object from a finite set of objects. In such problem, exhaustive search is not feasible. So ant colony algorithm can be used to solve this.

III. Related Works

A. Ant Colony Algorithm for TSP

Travelling salesman problem (TSP) is an NP-hard problem in combinatorial optimization. There are a list of towns and their pair wise distances, the job is to find the shortest route that visits each town exactly once and returns to the source town.

There are three aspects in the ant colony algorithm for TSP which is initialization, shortest path construction and pheromone update.

In [1], each ant is placed on each town. Each ant has taboo list which avoids transition to an already visited town. Initially the values of pheromone on the edges are set to a constant value. Each ant wants to select the next town based on the limit of the taboo list according to probability until it creates a local path. The length of the local path produced by each ant is calculated. The pheromone on the local paths of all ants is updated. The new shortest path after all ants has completed the pheromone update is recorded.

In [3], stagnation behaviour is the problem of ant colony algorithm. Stagnation means solution becomes more similar or easily falls in to the local optimal solution. To avoid stagnation, increase the diversity of solutions i.e. finds the best solution rather than the old one. This is due to the direct exchange of pheromone on some edges i.e. pheromone starts to evaporate on some edges in the shortest path and the strength of pheromone increases on some edges in the longest path.

B. Ant Colony Algorithm for 0-1 knapsack

0-1 knapsack problem is an NP-hard problem in combinatorial optimization. There are a set of items, each item has a value and a weight, maximize the total values of items in the knapsack so that the total weights is less than or equal to the knapsack's capacity. 0-1 knapsack problem restricts the number of copies of each kind of item to zero or one.

In [4], each ant is placed on each item. Each ant has a taboo list and a flag list. Each ant wants to select the next item based on the limit of taboo list and flag list according to the probability until it is beyond the capacity of knapsack. Total weights of the selected items in the taboo list is less than or equal to the knapsack's capacity. Flag list restricts the number of copies of each item to zero or one. The total weight that each ant loads is calculated. The pheromone on the weight of all ants is updated. The new total weight after all ants has completed the pheromone update is recorded.

The comparison between ant colony algorithm for TSP and 0-1 knapsack problem has been discussed in [2].

C. Ant Colony Algorithm for 0-1 knapsack

Quadratic assignment problem is an NP-hard problem in combinatorial optimization. There are a set of objects and a set of locations. For each pair of locations, a distance is specified and for each pair of objects, a flow cost is specified. The problem is to assign all objects to different locations with the goal of minimizing the sum of the distances multiplied by the corresponding flow costs.

In [9], ant colony algorithm for QAP is based on the hybridization of the ant system with local search method; each ant associated with a permutation that is first modified using pheromone trail and latter is improved using local search method. In this paper, local updates of the pheromone trails are not performed but only a global update. Initially the values of pheromone are set to a constant value. Then, each ant constructs a solution (assign all objects to different locations until all objects have been assigned) according to heuristic and pheromone information. A better solution than the old solution is generated based on the intensification and diversification. Intensification deals with reinforcing the pheromone trails and diversification deals with evaporating the pheromone trails. The pheromone trail on the better solution is updated based on the evaporation and permutations of all ants. Pheromone trails will disappear by evaporation. Permutation is a complete solution in which locations and objects are coupled.

D. Parallel Ant Colony Algorithm

In [8], Parallel ant colony algorithm solves large optimization problems. In synchronous master/slaves model for parallel ant colony algorithm, the pheromone matrix and the best solution will be managed by the master. Rows and columns of pheromone matrix represent the number of vertices in the graph and each entry represents the cost between two vertices or pheromone. Each ant is placed on each vertex. The master transmits the pheromone matrix to all slaves. Each slave generates a solution with pheromone matrix and sends the solution to the master. When the master receives all the solutions, update the pheromone matrix and find the best solution. The process is repeated until stopping criteria.

E. Ant Colony Algorithm for Graph coloring

The problem is assigning a colour to every vertex in a graph such that no adjacent vertices have the same colour. Graph colouring is useful for assignment type problems such as frequency assignment to radio stations and register allocation in compilers. Graph colouring is an NP-hard problem in combinatorial optimization.

In [7], each individual ant wanders the graph. Each ant applies colour to each vertex as it goes. Each ant wants to select vertex based on the probabilistic combination of pheromone trail and heuristic. After colouring the graph, pheromone collects in a matrix. Elements of the matrix represent the quality of solutions found when two vertices have the same colour. Update the pheromone matrix based on the number of colours used by all ants.

F. Improved Ant Colony Algorithm

In [5], Ant colony algorithm costs too much time in order to get an optimal solution. A fast ACO algorithm for solving TSPs i.e. pheromones in local and global update mode is discussed.

In [6], Ant colony algorithm consumes more searching time to get better solutions. To avoid this situation, a large number of ants are required to complete the task. Parallelization or map reduce is a capable method to solve large scale ant systems. In map reduce based ant colony algorithm, there are two phases which are map phase and reduce phase. In map phase, no data exchange between map tasks and no partition are take place. Integration or combination of outputs from different map tasks are made in reduce phase. There are two approaches used in map reduce based ant colony algorithm. They are replication approach and partition approach. In replication approach, the ant colony or input is replicated in the number of map tasks. Each map task perform ant colony algorithm independently. For example one map task performs ant colony algorithm for TSP and other performs ant colony algorithm for 0-1 knapsack. The outputs of map tasks are combined in the reduce phase. The output of reduce phase is the optimal solution. In the partition approach, solution is decomposed into the map phase and can be solved in parallel mode.

IV. ADVANTAGES AND DISADVANTAGES

For TSP, ant colony algorithm is relatively efficient. For a small number of nodes, TSP can be solved by exhaustive search. For a large number of nodes, TSP is difficult to solve. Ant colony algorithm performs better against other global optimization techniques for TSP and 0-1 knapsack. Ant colony algorithm is robust and is applied with only minimal changes to other combinatorial optimization problems. Ant colony algorithm is also applied to the similar versions of the same problem. The main advantages are positive feedback, decentralized control and collective behavior or cooperation.

Theoretical analysis is difficult due to sequences of random decisions and probability distribution changes by iteration. Convergence is guaranteed, but time to convergence uncertain. Coding is complicated, not straightforward for pheromone trail additions/deletions, global and local updates and large number of different ant colony algorithms to exploit different problem characteristics.

V. Challenges

Stagnation behavior is the major challenge of ant colony algorithm. Stagnation means solution becomes more similar or easily falls in to the local optimal solution. If the best solution is blocked by an obstacle for example network failure, ant colony algorithm tries to find other optimal solution which consumes more time.

Ant colony algorithm consumes more search time to get better solutions. A large number of ants are required to avoid this situation. So we need a sufficient number of ants or number of iterations is another challenge.

VI. Conclusion

In this paper, we have studied how ant colony algorithm solves combinatorial optimization problems or hard problems such as TSP, 0-1 knapsack, graph coloring and QAP. Stagnation behavior is the main challenge of ant colony algorithm. Our future work is to find the multiple optimal solutions of ant colony algorithm.

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