Application of Ant Colony Optimization to Solving the Traveling Salesman's Problem

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ABSTRACT

Ant colony optimization algorithm was developed by Marco Dorigo in 1991 as an algorithm for solving optimization problems in computer applications. This algorithm models the behavior of natural ants' colonies and has been used exclusively for solving problems in the discrete domain. This article fully implements and evaluates a specialized version of Ant Colony Optimization (A.C.O) capable of solving the Traveling Salesman's Problem (T.S.P) using the Object Modeling Technique (O.M.T) and evaluates its performance under a range of conditions and test cases. The work highlighted in this article has shown that a number of cooperating artificial ants using pheromone trails as a method of communication is capable of solving both simple and obviously difficult optimization problems with encouraging results. The Traveling Salesman's Problem arises as a sub-problem in many transportation and logistics applications, such as the routing of packets in a networking environment, delivery of meals to homebound people, arranging school bus routes to pick up children in a large city, routing of trucks to pick up parcels, the scheduling of stalker cranes in a national sea or airports and all such similar cases[10,12].

KEYWORDS: Ant Colony Optimization, Object Modeling Technique, Traveling Salesman's Problem, discrete domain, artificial ants, sub-problem

1.0 INTRODUCTION

The Ant colony Optimization algorithm (ACO), inspired by the behavior of natural ants foraging for food and returning to their nest at the end of their search, usually through a shorter route, is a probabilistic technique for solving computational problems which can be reduced to finding food paths through a graph [1,2,3]. This algorithm is a member of swarm intelligence. The Travelling Salesman's Problem (TSP) is the problem of a salesman who has to visit a number of cities with the constraint having to visit a city only once. The salesman's problem can be viewed as a weighted graph containing a set of nodes (cities) with the aim of finding a shortest round trip between two extreme points [12]. The ACO attempts the solution of this problem by using a population of ants to construct tours through moving from city to city on the graph, applying pheromones trails to the arcs that connect the nodes (cities). The ants are able to use the pheromone trail information to build good solutions [4,5,6].

The first attempt at solving the TSP only involved 20 cities and it took Sir William Rowan Thomas Penyngton several hours to resolve this in the 1800s [10,11,12]. In this article, attempt is made to apply the ACO to solving a traveling salesman's tour of 300 cities in less than 10 minutes. The motivation for this research is to explore the possibility of solving complex logistical and transport problems as well as other complex networking problems that confront humanity using the ACO.

2.0 MATERIALS AND METHODS

Basically, an ACO can be assumed to be interplay of three procedures: Construct Ants Solutions, Update Solutions and Daemon Actions. Construct Ant Solutions manages a colony of ants and visits adjacent states of the problem to be solved by moving through neighbor nodes of the problem construction graph. This movement is based on stochastic local decision policy that uses pheromone trails and heuristic values. So the ants gradually build solution to the optimization problem. While the solution is being constructed or has been constructed, the ant evaluates the initial efforts (solutions) that will be worked on by Update Pheromone procedure and determines how much pheromone to deposit on a route depending on its evaluation [7].

The Update Pheromone is the procedure that modifies the pheromone trails. The pheromone trail values is either increased or decreased depending on their regular use or disuse respectively. Pheromone evaporation occurs with disuse and implements a useful form of forgetting and thus avoiding a too rapid convergence of the algorithm towards a suboptimal region. This way, the algorithm favors the exploration of new areas. Lastly, the Daemon Actions implements group actions that cannot be performed by a single ant such as the activation of local optimization processes or the gathering of global information to determine the usefulness or otherwise of depositing additional pheromones to bias the search[9,10,11].

For the purpose of this research, the OMT method is preferred because of its obvious advantages in terms of ease of use and because of its suitability in achieving the thesis objectives. First the nest is modeled, and then the ants and their movements within a graph biased by heuristic and pheromone values in their attempt to arrive at a solution. Next, the results are noted and discussed. The OMT was combined with hypothesis-experiment-evaluation methodology which follows a pattern of (a) Hypothesis development (b) Build mathematical models (c) Test hypothesis via a set of experiments (d) Analysis of experimental results (e) Drawing conclusions and discussing the conclusions, impact and rigors of the result. In the initial implementation of the ant movement procedure, the search radius is determined by the algorithm and the ants are given regions closest to them to explore with higher probability values cum higher heuristic values

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assigned via Gaussian distribution approach. The fittest ant i.e. the ant with greater exploratory success is allowed to lay pheromone on its trails from node to node while the routes of ants with less success are abandoned and discarded. If ant reports a fitness greater than the best recorded ant, the algorithm updates the vector position and allows the successful ants to lay pheromones.

The search radius contracts with each breakthrough trip of successful ants throughout the search, thus enabling the ants to arrive at an optimal solution. As the search progresses pheromone concentration reveals the best result and the search ends

2.1 Pheromone Evaporation

Ants whose search does not lead to good results are not allowed to lay pheromones, so with time, the pheromones already laid begins to evaporate like every other natural fragrance. This makes such routes less attractive to incoming ants who will rather favor the routes with higher pheromones. As more and more ants divert from fruitless routes, the pheromones in such routes continue to evaporate. Ants in such unfavorable routes are allowed to exceed the current radius limits in their quest for a more successful search effort [11].

2.2 Algorithm termination

A number of termination conditions are built into the algorithm, else, it will enter into a perpetual loop. One of such conditions is the arrival at a globally known solution. Another is when the search radius reduces to zero, and thirdly, when the maximum number of allowed search trips has been reached

3.0 RESULTS AND DISCUSSIONS

The Ant Colony Optimization algorithm to solving the Traveling Salesman's Problem was coded in Java and was successfully complied and tested in NETBEANS IDE and the Windows XP environments. Because the code was fully portable between a number of different platforms, evaluation trials was carried out on several different platforms, evaluation platforms were carried out on different systems. It was necessary to validate the algorithm, ensuring that it has behaved as intended before testing the algorithm on complex problems. So the algorithm was tested on simple problems to assert the veracity of the algorithm. After several of such runs, the algorithm truly achieved its purpose. Following the algorithm verification and validation, it was tested on more complex problems and the result show that the ants were able to explore the search space and communicate effectively. This gives the ACO the ability to explore multiple locations simultaneously and this capability places the ACO head and shoulders above other nature-inspired systems such as Genetic Algorithm and Simulated Annealing.

The ACO algorithm implemented in this article has generally proven to be very potent when cross tested against other test function suites with no modification to the default run-time parameters, especially when we set the search radius to some suitably large values. This way, the ants have ample space to explore the search radius before homing in on the best solution. Moreover the use of pheromone as a means of communication allows independent search to progress and at the same time being useful individually to the ant group objective. The ACO outperforms the blind search and distributed hill-climbing because of the ACO communication and versatility ability.

4.0 CONCLUSION

The overall objective of this research is achieved and the ACO has been found to be very capable of solving complex routing problems of the traveling salesman's and by extension such day-to-day logistic problems as a school bus driver's choice of routes in a large city to pick up children. This work has demonstrated that the Ant Colony Optimization algorithm can be successfully adapted to solve the traveling salesman's problem of traversing several cities strictly once by offering a great balance between exploration and exploitation by a population of cooperating ants using pheromone as a method of communication. Beyond this, the ACO is capable of solving simple and complex optimization and routing problems with outstanding results in terms of time and resource.

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