ANT COLONY OPTIMIZATION FOR SOLVING COMBINATORIAL OPTIMIZATION PROBLEMS

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Abstract: When examining nature, people often find that animals and plants have evolved in an ingenious manner to survive. These new techniques can sometimes be used in modern day technology to solve problems that might be too time-consuming to solve by conservative means. After all, nature has had many millions of years to evolve into what it is now, whereas we have had less than 100 years to get technology to where it is now. In this paper, we investigate the runtime behaviour of modified AntNet algorithm using Multiple Ant Colony Optimization for Travelling Sales Man Problem (TSP). The choice of selecting TSP is for easy analysis and illustration. Different pheromone coefficient and problem domain is taken for the same. With different parameter and types of problem domain, it is analyzed that the convergence of solution is dynamic in nature.

Keywords: Multiple Ant Colony Optimization, Travelling Salesman Problem, pheromone.

1. Introduction

Ant colony optimization is a probabilistic technique for solving computational problems for finding good paths through graphs. Ant colony optimization is a component of Swarm Intelligence. Ant-based behavioral patterns are used to address combinatorial Optimization problems. It was first proposed by Marco Dorigo and his colleagues as a multi-agent approach to solve difficult combinatorial optimization problem such as Network Routing Problem, Wavelength allocation problem, Travelling Salesman Problem, Quadratic Assignment Problem etc. Till date different optimization problems have been explored using a simulation of this real ant behaviour. Ants deposit a trail of pheromones-chemicals whose smell can inform or influence the behaviour of other ants along the route they travel in search of food. When a food source is found, the ant that discovered it communicates this information to its peers, who thus follow that insect's pheromone trail. As more and more ants travel to the food source the pheromone track becomes thicker and thicker attracting more and more ants who in turn deposit their own pheromone and so on. Eventually the ants abandon other avenues of exploration in favour of the route which has already been tried and tested.

2. Multiple Ant Colonies

Multiple ant colony optimization (MACO) is an extension of the ACO framework where a number of ant colonies working together to solve some combinatorial optimization problem. Varela and Sinclair) adopted MACO for the problem of virtual wavelength path routing and wavelength allocation. Repulsion was proposed as one way of attraction between colonies which means that ants repelled by the pheromone of other colonies. In this way, an ant prefers to choose path with high concentration of its own colony's pheromone and with no or lesser amount of other colonies' pheromone. This gives a higher opportunity to explore a wide area of the search space. In their proposed algorithm, the pheromone attraction is used the same way like other routing algorithms, while the repulsion increases the chance of distributing different wavelength on different links. They used two parameters to weight the degree of the importance of attraction and repulsion.

A MACO algorithm based on colony level interaction has been proposed by Kawamura et al. The algorithm work based on ant system and used large number of parameters α that must be set in advance. These parameters determine the effect of each colony to all other colonies and they organized as an array of size M×M, where M is the number of colonies. No specific way of choosing this large number of parameters was shown. The effect of a colony towards another colony may be positive or negative. Different colony structures were tested with some parameter setting.

Sim and Sun propose some conceptual ideas of MACO approach as a new ACO framework for network routing problem. The authors believe that using multiple ant colonies to explore the network offers the opportunity to find new and better paths and reduces the chance of stagnation. However, the authors think that this approach offers a new direction for ant-based optimization in general and for network routing problem in specific. Better solution may result when it searches through multiple possible checkpoints and generic number of iterations.

3. Ant System for Travelling Salesman Problem

In Ant System, artificial ants build solutions (tours) of the Travelling Salesman Problem (TSP) by moving on the problem graph from one city to another. The memory (or internal state) of each ant contains the already visited cities. The memory is used to define, for each ant k, the set of cities that an ant located on city i still has to visit. By exploiting the memory therefore an ant k can build feasible solutions by an implicit state-space graph generation. The "probability" with which ant 'k' chooses to go from city 'i' to city 'j' while building its tour at the t^{th} iteration is

$$p_{ij}^{k}(t) = \frac{a_{ij}(t)}{\sum_{l \in \chi_i^k} a_{il}(t)}$$

where, $a_{ij}(t)$ = decision table value

χ_i^k = set of node in the neighbour of i that 'k' has not visited 'yet'.

After ants have completed the tour, pheromone evaporation of arcs is triggered and then each ant 'k' deposits a quantity of pheromone $\Delta\tau_{ij}^{k}(t)$ on each arc it has used as

Where $\Delta\tau_{ij}^{k}(t) = \begin{cases} 1/L^k(t) & \text{if } i, j \in T^k(t) \\ 0 & \text{if } i, j \notin T^k(t) \end{cases}$

where, T^k (t) = tour done by ant 'k' at iteration't'.

L^k (t) = length of city 'i' to city 'j'

It is clear from above that the shorter the tour the greater the pheromone deposited.

The addition of new pheromone by ants and pheromone evaporation are implemented by

$$\tau_{ij} \leftarrow (1-\rho)\tau_{ij}(t) + \Delta\tau_{ij}(t)$$

where, ρ = pheromone decay coefficient.

3.1 Artificial Ant

An ant has memory that it can use to store the information on the path it followed so far. They have a probabilistic preference for path with a larger amount of pheromone. As real ants, they tend to choose the paths by their pheromone amount.

Artificial ant is an agent which moves from city to city on a TSP graph. Artificial ants probabilistically prefer cities that are connected by edges with a lot of pheromone trail and which are close-by. Initially, m artificial ants are placed on randomly selected cities. At each time step they move to new cities and modify the pheromone trail on the edges used –this is termed local trail updating. When all the ants have completed a tour the ant that made the shortest tour modifies the edges belonging to its tour –termed global trail updating– by adding an amount of pheromone trail that is inversely proportional to the tour length.

3. Conclusion and Future Work

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 groundings have been demonstrated, making ACO one of the most successful paradigms in the meta-heuristic area.

ACO is a novel and very promising research field. Firstly, the method belongs to the relatively new wave of stochastic meta-heuristic such as evolution strategy, simulated annealing, tabu search and neural computations. Secondly, the algorithm is amenable to efficient parallelization which could greatly improve the performance for finding good solution. It is also to be noted "computations based on ant-colony optimization do not always work well" Dorigo admits. Luckily many real world problems posses enough of a pattern for the technique to be efficient" Dorigo says.

The proposed algorithm divides the ants' population into multiple colonies and effectively coordinates their works. An average pheromone evaluation function is used in the process of the ant's decision making. The results show that the proposed algorithm outperforms the ACS algorithm with similar number of ants. Future work is the use of the proposed algorithmic framework on some other combinatorial optimization problems. New pheromone evaluation mechanism is another possible future direction. Another interesting future work is in the global pheromone update mechanism. In this paper the global best solution of each colony is considered. It is interesting to test the case where some colonies consider global best solution while others consider iteration best solution in the global pheromone update mechanism.

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