**The Traveling Salesman Problem: How The Ants Solve It**

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**Abstract**

The dilemma faced by the traveling salesman wherein he has a finite number of cities to visit and a desire to minimize the total distance traveled by visiting each one once without backtracking is a popular mathematics problem in combinatorial optimization. Our goal is to implement an Ant Colony Optimization (ACO) algorithm so as to improve upon a simple brute force solution of selecting the nearest neighbor.

**Introduction**

Though the origins are unclear, the Traveling Salesman Problem, or TSP, was mathematically formulated by several mathematicians in the 1800s and later studied in depth in the 1930s. Practical applications range from planning/logistics to DNA sequencing to aircraft scheduling (Xu, 2017). It is the most well-known combinatorial optimization problem. It is well-studied, and its existence has even affected pop culture (Lanzone & Lanzone, 2012).

There are many algorithm optimization models used to solve TSP, and a subset of these are derived from observation of ant behavior. These Ant Colony Optimization Algorithms (ACO), or “ant algorithms,” exploit the behavior of ants to coordinate artificial agents to solve computational problems. The ant colony is a distributed system wherein the whole colony is capable of solving complex tasks that are impossible for a single ant to solve.

Ants have limited vision, and some species are completely blind. Their primary means of communication is through stigmergy, which is “a form of indirect communication mediated by modifications to the environment.” (Dorigo & Stützle, 2004) When searching for food, ants achieve this by leaving a trail of special chemical signals. Other ants detect these chemical signals, called pheromones, and can follow the path to a food source. These pheromones slowly break down; consequently, there is a direct correlation between the strength of the pheromone trail and the frequency of travel. In other words, less-traveled paths disappear and optimal paths persist. In absence of any pheromone trails, ants tend to wander randomly in search of food. Even with trails, ants will still deviate on occasion, and this may result in a more optimal path.

**Algorithm Explanation**

As with other implementations of the ACO algorithm, individual ants programmatically and simulate the random choices made as each “ant” travels from one node of a graph to another. In the context of the solving a TSP, once an ant has identified a (semi-)optimal path, this path is marked with pheromones by altering the semi-random decision tree used by each ant when determining the next node. Subsequent iterations of the algorithm cause improvements as future ants avoid less-optimal paths and identify more optimal ones.

**Complexity**

Lorem

**Analysis of Results**

As expected, our version of the ACO algorithm performance difference, when compared with the Branch and Bound algorithm, was negligible at smaller node quantities (and less optimal in some cases).