CSI 5165 [W] Combinatorial Algorithms

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Project Proposal & Student Lecture Topic

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Solving a Dynamic Travelling Salesman Problem using an Ant Colony Optimization algorithm.

Introduction

The Travelling Salesman Problem (TSP) is a well-known problem in computer science, which seeks to find the shortest route that visits every node in a given graph exactly once. However, the Dynamic Travelling Salesman Problem (DTSP) adds an additional layer of complexity by considering real-time factors that can change the optimal route during the course of the journey. The motivation behind this project stems from a similar challenge presented at uOttaHack 5, a hackathon organized by uOttawa.

This project aims to solve the DTSP using an Ant Colony Optimization (ACO) algorithm. ACO is a metaheuristic algorithm inspired by the behaviour of ant colonies in finding the shortest path between their nest and a food source. It has been successfully applied to various combinatorial optimization problems, including the TSP. The proposed algorithm will take into account the distance between nodes and the real-time factors of traffic and weather, which can affect the delivery time between two nodes. Depending on the category of traffic and weather, the algorithm will adjust the delivery time by a defined multiple or remove a path entirely. As the courier progresses along the route, the algorithm will recalculate the optimal path taking into account the nodes already covered and the current real-time factors.

Proposed Approaches

Problem formulation: The problem is a graph with nodes and edges, where the nodes represent the delivery locations and the edges represent the paths between them. Each edge has an associated distance and real-time factors (traffic and weather), which will be used to calculate the delivery time between two nodes.

Ant Colony Dynamic Optimization algorithm: Traditionally ACO algorithms have been used to address static optimization problems like the Travelling Salesman Problem. In dynamic optimization problems (DOPs), various factors such as objective function, decision variables, problem instances, constraints, etc. may change unpredictably over time. This introduces uncertainties that can shift or alter the optimal solution, making the problem more complex and relevant to real-world situations. **[1, 2]** shows that ACO algorithms are capable of adapting to dynamic changes due to their inspiration from the continuous adaptation process found in nature. Specifically, they can adjust to changes by drawing from past environments. However, traditional ACO algorithms may struggle to adapt to dynamic changes once the ants have reached stagnation behaviour, where they follow the same path and deposit pheromones on a single trail. One approach is to restart the algorithm after a dynamic change by re-initializing the pheromone trails with the same pheromone value. Another approach **[3]** involves utilizing local restart strategies for the DTSP when the cities' topology is altered. These strategies must detect any changes and consider the exact location of the problem instance that was altered. Rather than restarting all the pheromone trails, only the trails of cities impacted by the dynamic changes (i.e., added or removed cities) are reset. **[4]** suggests a population-based ACO algorithm in which the majority of pheromone information pertains to solutions that belong to the current population. This approach is considered advantageous since it holds the potential for addressing dynamic optimization problems. **[5]** Suggests a hybrid method based on Particle Swarm Optimization, Ant Colony Optimization and 3-Opt algorithms in order to avoid getting stuck in local optima. Additional references will be added based on research on optimizing the ACO algorithm to solve this problem.

Goal

The main objective of this project is to develop an efficient algorithm that can solve the DTSP and provide an optimal route for couriers that considers the real-time factors of traffic and weather. The delivery time will depend on the distance between the two nodes. For example, if the distance between 2 nodes is 1 km, the time taken will be 15 minutes. The factor Traffic will have 3 categories (low, medium and high). Depending on the category, the delivery time between two nodes will be increased by a defined multiple. Similarly, the factor Weather will also have 3 categories (light, medium and heavy) with similar effects on the delivery time.
Evaluation of the algorithm will be done using TSPLIB **[6]**, a library of sample instances for the TSP (and related problems) from various sources and of various types. The current best solution for each instance is also available. The algorithm will initially be evaluated, without any real-time factors, against the best solution. This will be the baseline. Another program will be developed to simulate real-time factors based on randomness. The algorithm's solutions, with these factors, will then be compared with the initial baseline.

References

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[5] Mahi et al., "A new hybrid method based on particle swarm optimization, Ant colony optimization and 3-opt algorithms for traveling salesman problem," *Applied Soft Computing*, 11-Feb-2015. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1568494615000940.

[6] TSPLIB. (n.d.). Retrieved February 23, 2023, from http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/index.html

Student Lecture Topic

Metaheuristic optimization algorithm - Ant colony optimization (ACO)

Reference

M. Dorigo, M. Birattari and T. Stutzle, "Ant colony optimization," in IEEE Computational Intelligence Magazine, vol. 1, no. 4, pp. 28-39, Nov. 2006, doi: 10.1109/MCI.2006.329691.