Examining the Efficiency and Significance of Various Travelling Salesman Algorithms

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Introduction

Professor Carlsson's research involves TSP (the Travelling Salesman Problem)

- Involves determining the shortest route when travelling to many different locations
- Each location must be visited only once, and the route should end at the starting location.
- Goal: to find the most optimal tour (route) throughout a set of nodes (location points in real instances)
- TSP is classified as an NP-Hard (Non-deterministic Polynomial time) problem.

Objective & Impact of Professor's Research

Professor Carlsson's research focuses on optimizing the delivery of packages. In the paper *Coordinated logistics with a truck and a drone*, he discusses the horsefly problem in which an unmanned aerial vehicle (UAV), a drone, provides service to customers while making return trips to a truck that is itself moving.

- This shortens the truck's route and decreases the total distance of the tour.
- His research demonstrated that the improvement in efficiency is related to $\sqrt{v_{truck}/v_{UAV}}$, where v_{truck} and v_{UAV} are the speeds of the truck and UAV.

(1)

(2)

Figure 1. (1) An example of an UAV: a delivery drone from Amazon Prime Air. Adapted from the official Amazon website. (2) TurtleBots were used in the lab. Adapted from the official TurtleBot website.

Skills Learned

These algorithms used to solve TSP were coded in Matlab®, a coding software primarily for numerical computing:

- **The Cheapest Insertion algorithm**: starts with selecting an arbitrary node and then sequentially inserts nodes into the existing tour by minimizing the insertion cost
- **The Nearest Neighbor algorithm**: starts with a node and generates a tour by sequentially connecting the closest node to the last added node
- **Brute force algorithm**: generates the most optimal route by trying all the possible combinations, but this takes too long when there are many nodes
- **Near-optimal algorithm**: a fast algorithm used to approximate the optimal tour

Heuristics:

- Problem-solving methods using intuitive ideas
- Not guaranteed to have an optimal solution, but solves a problem in a quick way

Graph Theory & Network Theory:

- Complete/Incomplete, Directed/Undirected, Weighted/Unweighted graphs
- Tree: Acyclic graph in which each path from one node to another is unique
- Minimum Spanning Tree (MST): subgraph that connects all the nodes of a larger graph with the least cost of edges

TSP Transformations:

- The transformed graph is used to solve the TSP problem on the original graph
- Incomplete to complete TSP
- Asymmetric to symmetric TSP
- Vehicle Routing Problem (VRP): delivery-related problem with a solution that creates a tour for k trucks and one depot

Programming Experience:

- Matlab® coding
- The TurtleBot, a personal robot kit, was explored.

Projects and Experiments

Experiment: Comparison of algorithms

- Random nodes were generated
- The efficiency of the cheapest insertion, nearest neighbor, and near-optimal algorithms were compared.

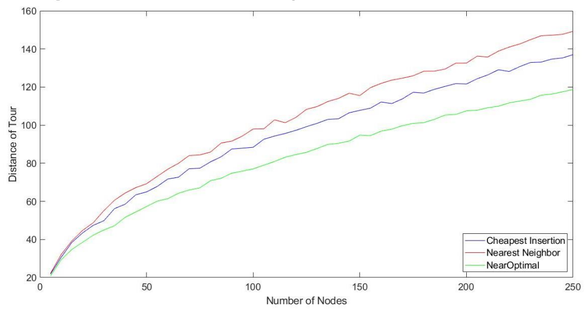

Figure 2. Comparison of algorithms.

Application 1: Fashion Line Delivery Instance

- Data: clients' addresses were taken from Google Maps and geocoded into latitude and longitude
- Goal: find the shortest tour that visits each place once and returns to the start location

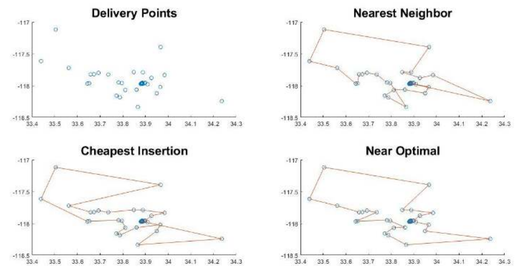

Figure 3. Tours created by each algorithm.

Application 2: Generalized TSP (GTSP):

- Nodes are placed into different categories
- Only one node in each category is chosen to form a TSP tour
- Solution requires transforming GTSP graph into a regular TSP graph by manipulating the graph's edges and their values

GTSP as a real-world problem: A person is running errands and needs to go to a market, gas station, and post office. There are many locations that offer the same services, but he only needs to visit one place of each category. What is the shortest route that he can take to fulfill his errands?

Projects and Experiments Cont.

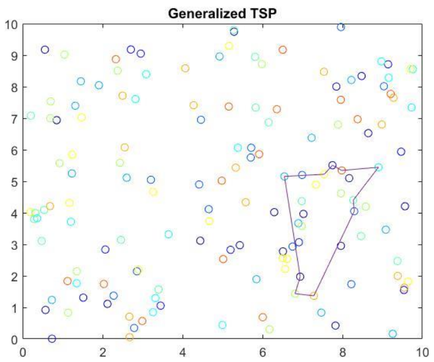

Figure 4. Tour for GTSP with 10 categories and 15 choices.

How This Relates to My STEM Coursework

My SHINE experience has broadened my understanding of my STEM coursework through hands-on experiences in the lab. Through the SHINE program, I am able to further comprehend the importance and impact of STEM-related research in my daily life.

Next Steps

After my experience in the lab at SHINE, I would like to delve further into the topic of TSP by learning about more algorithms related to this problem. I will also try to learn more about the horsefly problem.

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