Final Year Project Proposal

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Title of Final Year Project:

Using Machine Learning to Learn a Solution to the Vehicle Routing Problem with Time Windows (VRPTW)

Aims and Objective:

The objective of a project in this area would be to use machine learning techniques to learn a solution to a variant of the Vehicle Routing Problem with Time Windows (VRPTW). Additionally, the algorithm must ensure fairness is maintained such that the total delivery charge earned is equal across all drivers currently on shift.

The aim is to automate the creation of food delivery routes (and move away from relying on an empirical judgment that is resulted from specialized knowledge and trial-and-error) to improve delivery speed and timing while ensuring the drivers receive equal opportunity to earn delivery charges. Ultimately this should result in improved satisfaction in both the customer and the drivers.

Background and Justification:

Optimal delivery times and routes are a challenge faced by many takeaways during peak hours and are especially notable with newer delivery drivers. Google Maps is perhaps the most common application that provides the optimal shortest path with the constraint of traffic. Unfortunately, this disregards all the other crucial aspects to the most optimal delivery route leading to perhaps an unhappy customer. Such include, but not limited to:

1. The number of available delivery drivers to deliver when they return to the shop
2. The time window for delivery.
3. An equal share of delivery orders to per driver to upkeep equality
4. The duration of the food waiting for delivery since the completion of the food ticket.
5. Whether the temperature of the food is hot or not.
6. The type of food (deep-fried, soup, carbohydrates, and much more.)
7. The capacity of fuel that is remaining in the delivery car to complete the journey.

It provides itself as a combinatorial optimization problem. The experienced staff does consider the listed aspects where they have empirically judged the best route

(developed a heuristic from specialized knowledge and trial-and-error). The use of heuristics yields approximate optimal solution, and despite often being quick and effective, do not guarantee a theoretical guarantee of optimality. Aforementioned, the development of the route utilizes little theory. Also, the size of the search space grows exponentially with the size of the problem's input. Thus, it is another reason why we rely on heuristics due to the computational infeasibility of finding the exact solution. However, is it possible to automate this challenging, tedious process and learn such algorithms instead? The use of ML (A.I. in general) shows promise in automating and systematize the heuristic design. It will result in less time manually planning the route and may also produce a more near-optimal solution. In particular, this project aims to take the expressed constraints of 2) and 3) into consideration to create the VRPTW. As the VRP involves multiple drivers, I automatically consider the first constraint.

Methodology

Mandatory:

1. The creation and cleansing of data that includes the shop details and each order detail.
2. The making of a graph using the shop and order data.
3. The usage of machine learning techniques to train a model on the data to automate the process and learn an algorithm

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Discretionary:

1. The creation of a user interface that displays the pruning of the search space (learning the algorithm).

Exceptional:

1. A serverless full-stack web application where the user can input their CSV file such that the machine learning model trains on the input data and produces the most optimal solution.

Data Sources:

A potential data source would be to generate fake data by randomly creating cartesian coordinates as nodes and setting a particular node as the root. The edges between the nodes will be the distance in kilometers. If desired, I can use a library to produce mock-up credentials such as name, address, and much more.

Another viable data source, although much more difficult to obtain due to GDPR and commercial laws, would be to get real-world data from the food industry. Anonymization of sensitive data is necessary, only keeping beneficial information.

Related Work:

The related work depends on the approach I choose to take. Such approaches are:

1. A supervised deep-learning method.
2. A reinforcement learning approach
3. An unsupervised approach based on restricted Boltzmann Machines
4. A scaling-up approach to exact combinatorial optimization algorithms.

Regardless, there are many works in the area of VRP, and here are a few of the examples

1. Academia - Vehicle Routing Problems
2. Cornell - Reinforcement Learning for Solving the Vehicle Routing Problem
3. Hindawi - Machine Learning-Based Parameter Tuned Genetic Algorithm for Energy Minimizing Vehicle Routing Problem
4. Research Gate - Learning fine grained search space pruning and heuristics for combinatorial optimization
5. Cornell - A Deep Reinforcement Learning Algorithm Using Dynamic Attention Model for Vehicle Routing Problems
6. Cornell - Scalability of using Restricted Boltzmann Machines for Combinatorial Optimization
7. Cornell - Learning Combinatorial Optimization Algorithms over Graphs
8. Semantic Scholar - Pointer Networks
9. Cornell - Neural Combinatorial Optimization with Reinforcement Learning

Bibliography:

The sources I have used to research this problem are the following:

1. Wikipedia Vehicle Routing Problem.
2. Wikipedia - Combinatorial Optimization
3. Wikipedia - NP Complete Problems
4. Research Gate - Learning Fine Grained Search Space Pruning and Heuristics for Combinatorial Optimization
5. Cornell - Learning Combinatorial Optimization Algorithms over Graphs
6. Medium - Machine Learning and Combinatorial Optimization Problems
7. Papers With Code - Combinatorial Optimization
8. Cornell - Reinforcement Learning for Solving the Vehicle Routing Problem
9. Cornell - Attention, Learn to Solve Routing Problems!
10. Research Gate - A Survey on the Vehicle Routing Problem and its Variants
11. Research Gate - Vehicle Routing Problem with Time Windows
12. Science Direct - Approaches to Solve the Vehicle Routing Problem in the Valuables Delivery Domain

13. Elsevier - An Optimization Model for the Vehicle Routing Problem in Multi-product Frozen Food Delivery
14. Cornell - A Deep Reinforcement Learning Algorithm Using Dynamic Attention Model for Vehicle Routing Problems
15. Cornell - Scalability of using Restricted Boltzmann Machines for Combinatorial Optimization
16. Hindawi - Machine Learning-Based Parameter Tuned Genetic Algorithm for Energy Minimizing Vehicle Routing Problem
17. Semantic Scholar - Pointer Networks
18. Cornell - Neural Combinatorial Optimization with Reinforcement Learning
19. Academia - Vehicle Routing Problems

Furthermore, the communication between Deepak Ajawani and I also provided insightful information and great help towards this problem and proposal.