CAPSTONE
REVIEW I

E-Vehicle Routing with Parking System

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Outline

Introduction

- The existing network of transportation can no longer keep up with the growing demand in metropolitan cities. Short distance travel has become an unresolved issue for daily commuters. The case presents how MMVs have emerged as an alternative mode of transport for resolving issues of daily commuters regarding the first-mile connectivity, last-mile connectivity and short distance travel to reach their final destination.
- MMVs are basically light-weight vehicles which occupy less space on road. These vehicles include bicycles, e-bikes, skateboards, hoverboards and other battery-operated vehicles. An electric vehicle venture promotes the concept of green consumerism among the daily commuters at affordable rates.

Introduction

- Recently, E-vehicles systems are being found to have been damaged by users due to inconsistent routes, mechanical problems and driver errors. Thus, this project intends to create a tool for damage limitation and optimize routing of such E-vehicles.
- In cities having the availabilities of E-vehicles, we are going to create an AI function to map the optimal route in a provided city landscape structure to avoid damage, engine stagnation, battery leakage and discharge by providing users the route to their destination on a point-to-point basis which allows them to reach their destinations on time with the integrity of the structure of the E-Vehicle intact.

Background Work, Challenges

- This project would make use of the following background areas: Python,Artificial Intelligence ,Reinforcement Learning ,Routing Techniques ,Distance Algorithm , MATLAB Simulink , Carla.The challenge of this paper involves the following tasks:

◉ Mapping of City with high E-Vehicle Usage

◉ Adding parameter of battery charge

◉ Weighing of inter-city routes

◉ Bot creation to display most optimized route via distance(not time)

◉ User Interface Search and Hosting.

Literature Review/Survey

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[1]	Corona-Gutiérrez, K., Nucamendi-Guillén, S., & Lalla-Ruiz, E. (2022, March 5). *Vehicle routing with cumulative objectives: A State of the art and analysis*. Computers & Industrial Engineering.	Cumulative vehicle routing problems are an extension of the classic capacitated vehicle routing problem aiming to find a set of delivery routes that optimizes a given objective function considering cost accumulation in the course of the planning realization.	An adaptation of the Bellman-Ford algorithm. The algorithm calculates the shortest paths in a bottom-up manner. It first calculates the shortest distances which have at most one edge in the path. Then, it calculates the shortest paths with at-most 2 edges, and so on. After the i-th iteration of the outer loop, the shortest paths with at most i edges are calculated. There can be maximum |V| – 1 edges in any simple path, that is why the outer loop runs |v| – 1 times. The idea is, assuming that there is no negative weight cycle if we have calculated shortest paths with at most i edges, then an iteration over all edges guarantees to give the shortest path with at-most (i+1) edges	Pros: -Identifies several problem variants in routing algorithms. Cons: -The mathematical models and exact approaches developed for this type of problems are limited as the size of the instances grow. In particular, the largest instance size solved to optimality is around 40 nodes.
[2]	Electric-Vehicle Routing Planning Based on the Law of Electric Energy Consumption Nan Ding 1 , Jingshuai Yang 1,*, Zhibin Han 1 and Jianming Hao	As energy consumption may affect the maximal driving range and the recharging behavior of EVs, a nonlinear electric energy consumption model based on typical driving cycles of suburban and urban areas is developed, with consideration of vehicle load, travel distance, and speed. An adaptive particle swarm optimization algorithm is then designed to solve the problem.	Adaptive Particle Swarm Optimization Algorithm Each particle has two attributes: position and velocity. The swarm searches for the best solution in an n-dimensional space. The position of a particle represents a solution and is adjusted by velocity to search for new solutions. The particle records the best position, pbest, it reached, and the best position experienced by the entire swarm, gbest, is also recorded and updated with each iteration.	Pros: -Implementation of the driving-cycle-based energy consumption model effectively provides more realistic routing paths. Cons: -The routing scheme obtained under linear energy consumption may not be able to proceed smoothly as the actual recharging needs may require more recharging time and possibly result in additional time window violation, leading to higher total cost than the theoretical plan. -Can only be applied to smaller scales and graphs.

Literature Review [Conti..]

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[3]	Foa, S. (2022, July 30). *Solving the vehicle routing problem with deep reinforcement learning*. arXiv.org. https://arxiv.org/abs/2208.00202	The Routing problem is modeled as a Markov Decision Process (MDP) and then the PPO method (which belongs to the Actor-Critic class of Reinforcement learning methods) is applied. In a second phase, the neural architecture behind the Actor and Critic has been established, choosing to adopt a neural architecture based on the Convolutional neural networks, both for the Actor and the Critic. This choice resulted in effectively addressing problems of different sizes. Experiments performed on a wide range of instances show that the algorithm has good generalization capabilities and can reach good solutions in a short time. Comparisons between the algorithm proposed and the state-of-the-art solver OR-TOOLS show that the latter still outperforms the Reinforcement learning algorithm.	Proximal Policy Optimization Instead of imposing a hard constraint, it formalizes the constraint as a penalty in the objective function. By not avoiding the constraint at all cost, we can use a first-order optimizer like the Gradient Descent method to optimize the objective.	Pros: Neural networks developed are flexible to the dimension of input provided. Cons: Does not provide inclusion of a neural network for estimating the cost of each TSP instead of using the Christofides algorithm and the use of graph neural networks instead of convolutional neural networks.
[4]	Rajesh, K. (2022, August 26). *A Multi-Objective approach to the Electric Vehicle Routing Problem*. arXiv.org. https://arxiv.org/abs/2208.12440	Solves a personal electric vehicle routing problem and provide an optimal route for a single vehicle in a long origin-destination (OD) trip. Multi-objective optimization is performed - which minimizes the total trip time and the cumulative cost of charging. In addition, it incorporates external and real-life elements like traffic at charging stations, detour distances for reaching a charging station, and variable costs of electricity at different charging stations into the problem formulation.	Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. Particle swarm optimization (PSO) is one of the bio-inspired algorithms and it is a simple one to search for an optimal solution in the solution space. It is different from other optimization algorithms in such a way that only the objective function is needed and it is not dependent on the gradient or any differential form of the objective.	Pros: Well-researched method of implementation with a lot of variants in the form of varying objective functions, constraints, charging models, and pricing methods. Cons: The solutions are non-trivial and the user can make a better choice based on personal flexibility, making the algorithm obsolete.

Literature Review [Conti..]

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[5]	Qin, Hu & Su, Xinxin & Ren, Teng & Luo, Zhixing. (2021). A review on the electric vehicle routing problems: Variants and algorithms. Frontiers of Engineering Management. 8. 10.1007/s42524-021-0157-1.	This study presents a comprehensive survey of EV routing problems and their many variants.Problem variants and solutions are based on the following scenarios:lectric traveling salesman problem, green VRP, electric VRP, mixed electric VRP, electric location routing problem, hybrid electric VRP, electric dial-a-ride problem, electric two-echelon VRP, and electric pickup and delivery problem.	Multiple Routing Algorithms.	Pros: Specifies how many constraints can be changed on variations of the occupation of the user. Cons: Does not e incorporated the battery-charging functions and energy consumption functions into their models and made their problem closer to the real practice.
[6]	L. P. Qian, X. Zhou, N. Yu and Y. Wu, "Electric Vehicles Charging Scheduling Optimization for Total Elapsed Time Minimization," 2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring), 2020, pp. 1-5, doi: 10.1109/VTC2020-Spring48590.2020.9128915.	Studies the EV charging scheduling problem that minimizes the total elapsed time which includes charging time for EVs through jointly optimizing the charging path routing and charging station selection in this paper.	Scheduling algorithms based on Stack and Queues depending on geographical location of station and area of commute.	Pros: Efficient EV charging scheduling method to obtain the optimal solution based on crowd sensing through considering the remaining energy in the battery, traffic condition, and the queue length of charging stations Cons: Simulation results demonstrate that the proposed backtracking method based on crowd sensing can effectively reduce the total elapsed time, in comparison with the greedy algorithm.

Literature Review [Conti..]

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[7]	Dorokhova Marina, Ballif Christophe, Wyrsch Nicolas- Routing of Electric Vehicles With Intermediary Charging Stations: A Reinforcement Learning Approach, Frontiers in Big Data -2021	A mathematical formulation of the EV-specific routing problem in a graph-theoretical context, which incorporates the ability of EVs to recuperate energy,is discussed. an off-policy model-free reinforcement learning approach that aims to generate energy feasible paths for EV from source to target is used on a road network.	DIJKSTRA'S ALGORITHM	Pros: Framework considers recharging possibilities at intermediary charging stations and the ability of EVs to recuperate energy. The training procedure of the algorithm requires low computational and memory demands and is suitable for online applications. Cons: Works only on small road networks(e.g. intersections and national highways)
[8]	S. Shahriar, A. R. Al-Ali, A. H. Osman, S. Dhou and M. Nijim, "Machine Learning Approaches for EV Charging Behavior: A Review," in IEEE Access, vol. 8, pp. 168980-168993, 2020, doi: 10.1109/ACCESS.2020.3023388.	Provides a comprehensive review for the use of supervised and unsupervised Machine Learning as well as Deep Neural Networks for charging behavior analysis and prediction.	Machine Learning and Deep Learning Algorithms for EV Charging Datasets.	Pros: Paper shows in depth analysis of predictions and routings with different methodolofgies. Cons: Does mot account for performance in other city structures and recommendation won't suit average user's preference.

Literature Review [Conti..]

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[9]	The Consistent Electric-Vehicle Routing Problem with Backhauls and Charging Management - ScienceDirect.” *ScienceDirect.Com | Science, Health and Medical Journals, Full Text Articles and Books.*, https://www.sciencedirect.com/science/article/pii/S0377221722000455. 2022.	Delivery of parcels are considered, driver and time consistency, backhauling and cost efficiency are taken for metrics, scheduling of recharging operations of electric vehicles is carried out.	Adaptive Large Neighborhood Search in realtime.	Pros: Combines the evolutionary approaches with local search techniques. Cons: Does not enhance the variable neighborhood descent procedure by exploring other move operators.
[10]	Ye C, He W, Chen H. Electric vehicle routing models and solution algorithms in logistics distribution: A systematic review. Environ Sci Pollut Res Int. 2022 Aug;29(38):57067-57090. doi: 10.1007/s11356-022-21559-2. Epub 2022 Jun 25. PMID: 35752674.	Briefly introduces EVRP models considering battery losses; secondly, based on the composition of the EVRP objective function and constraints, EVRP models are classified into four types: EVRP considering load and battery life constraints, EVRP with a time window and considering charging strategies, the study of vehicle routing problems for hybrid fleets, and EVRP combined with charging/swapping station location. Then, briefly introduce exact algorithms, traditional heuristics, meta-heuristics, and hybrid algorithms for solving EVRP models. Moreover, it analyzes the main meta-heuristics that are more widely used.	Hyper routing algorithms.	Pros: Points out the development trend of EVRP theoretical methods. Allows for faster recharging of EVs. Cons: Custom algorithms are not optimized and takes time to process weight changes in graph.

Literature Review [Conti..]

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[11]	D. Rezgui, H. Bouziri, W. Aggoune-Mtalaa and J. C. Siala, "A Comparative Study of Local Search Techniques Addressing an Electric Vehicle Routing Problem with Time Windows," 2020 International Multi-Conference on: “Organization of Knowledge and Advanced Technologies” (OCTA), 2020, pp. 1-5, doi: 10.1109/OCTA49274.2020.9151852.	Made for scenarios for last minute deliveries,the paper tells us about an innovative system with one cabin for the driver and one or more modules for the goods.	Local search techniques and their combination with evolutionary schema. Eolutionary Variable Neighborhood Descent Method.	Pros: Explores small neighborhoods.The search process switches to a different (typically larger) neighborhood that might allow further progress. Cons: Systematic changes of neighbor hoods in real time are not optimized.
[12]	A. R. Daanish and B. K. Naick, "Implementation of charging station based electric vehicle routing problem using nearest neighbour search algorithm," 2017 2nd IEEE International Conference on Intelligent Transportation Engineering (ICITE), 2017, pp. 52-56, doi: 10.1109/ICITE.2017.8056880.	In this paper, a Nearest Neighbour Search-based optimal routing of electric vehicles has been presented with charging stations present in between and at the nodes.	DIJKSTRA’S ALGORITHM	Pros: The Nearest Neighbour Search based algorithm proved to be productive, dynamic and economical and thus can be further explored and modified to be applied on real-time problems. Cons: Cannot be applied to cityscaped graphs.

Literature Review [Conti..]

S.No	Paper Title	Summary	Algorithms Used	Pros / Cons
[13]	S. Hulagu and H. B. Celikoglu, "Electric Vehicle Location Routing Problem With Vehicle Motion Dynamics-Based Energy Consumption and Recovery," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 8, pp. 10275-10286, Aug. 2022, doi: 10.1109/TITS.2021.3089675.	Considers the actual characteristics of battery discharging and recovering the braking energy. Energy consumption and recovery are determined through vehicle motion dynamics in conjunction with the 3-dimensional feature of the road geometry, passengers'/customers' demands on getting on and off, and the pre-defined speed profiles, where the graph corresponding to the road network is extended with the explicit consideration of intersections.	Novel algorithm based on routing protocols seeks the optimal routing plans together with the optimal locations of recharging stations for electric vehicle fleets through the Electric Vehicle Location Routing Problem with Intermediate Nodes (ELRP-IN),	Pros: High Number of Stops Special Trip Interval Algorithm Cons: Applies to graphs and not cities as graph.
[14]	A. I. Aygun and S. Kamalasadan, "An Optimal Approach to Manage Electric Vehicle Fleets Routing," 2022 IEEE International Conference on Power Electronics, Smart Grid, and Renewable Energy (PESGRE), 2022, pp. 1-6, doi: 10.1109/PESGRE52268.2022.9715894.	This paper presents a hybrid shortest path algorithm for better management of electric vehicles considering power grid impact, fast reachability of electric vehicles to the nearest charger, and usage. The approach has combined capabilities of two methods, the Dijkstra and Floyd-Warshall approach. Travel distance, estimated travel time between origin, destination, and charging stations are calculated and evaluated in different cases.	Dijkstra's Algorithm It solves the Single Source Shortest Path (SSSP) problem. That is, we wish to find the shortest path from a single source node to a given destination node. A pertinent application of this algorithm is in the link state routing algorithm, where each node uses it to create an internal picture of the network. Floyd-Warshall Algorithm It solves the All-Pairs Shortest Paths (APSP) problem. In particular, we find the shortest paths between *all* pairs of nodes in the graph, which is computationally more expensive. This computational expense manifests in both the space required to store graph data and the time required to process it. Nevertheless, the Floyd-Warshall algorithm remains useful due to its simplicity of implementation.	Pros: Algortihm has considerably low complexity, which is almost linear. The algorithm can be used to solve a wide range of problems, including finding the shortest path between two nodes in a graph, calculating the transitive closure of a graph, and detecting negative cycles in a graph. Another advantage is its simplicity. Unlike some other algorithms, the Floyd Warshall algorithm is relatively easy to understand and implement. This makes it an ideal choice for students and professionals who are just starting out with graph algorithms. The Floyd Warshall algorithm is very efficient. It has a time complexity of O(n^3), which means it can handle large graphs with ease. Additionally, the algorithm is parallelisable, meaning it can be run on multiple processors to further improve its efficiency. Cons: Cannot be used with negative weights.

Literature Review [Conti..]

S.No	Paper Title and Summary	Algorithms Used	Pros/Cons
[15]	M. Thymianis, A. Tzanetos, E. Osaba, G. Dounias and J. Del Ser, "Electric Vehicle Routing Problem: Literature Review, Instances and Results with a Novel Ant Colony Optimization Method," 2022 IEEE Congress on Evolutionary Computation (CEC), 2022, pp. 1-8, doi: 10.1109/CEC55065.2022.9870373. SUMMARY: The aim of this study is threefold: to perform a brief literature review on meta-heuristic approaches applied to the EVRP, to offer insights on the available data instances for this problem, and to discuss on the results of an experimental benchmark aimed at comparing different meta-heuristic approaches over diverse EVRP instances, including the proposal and evaluation of a novel Ant Colony Optimization approach.	Ant colony optimization algorithm the ant colony optimization algorithm (ACO) is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. Artificial ants stand for multi-agent methods inspired by the behavior of real ants. The pheromone-based communication of biological ants is often the predominant paradigm used. Combinations of artificial ants and local search algorithms have become a method of choice for numerous optimization tasks involving some sort of graph, e.g., vehicle routing and internet routing.	Pros: They have an advantage over simulated annealing and genetic algorithm approaches of similar problems when the graph may change dynamically; the ant colony algorithm can be run continuously and adapt to changes in real time. Cons: Three main limitation of the algorithm are the stagnation phase, exploration and exploitation rate and convergence speed of the algorithm.

Research Gap

- Most papers are unable to operate their algorithms on city landscapes.
- Research does not account for road constructions ,accidental obstructions and government or private on-street events which requires re-routing.
- Most papers do not account for method of implementation for public users.
- Parking and recharging stations are not acconted for.
- Time to reach destination and recharge to full battery are not taken in as constraints in studies.

Problem Statement

- Taking into accounts the background of the project, our problem statement would be: “ In cities having the availabilities of E-vehicles, we are going to create an AI function to map the optimal route in a provided city landscape structure to avoid damage, engine stagnation, battery leakage and discharge by providing users the route to their destination on a point-to-point basis which allows them to reach their destinations on time with the integrity of the structure of the E-Vehicle intact, along with providing time and distance values in case of recharging vehicles and charging stations,taking into account the aspect of slot fulfillment,or go for alternative routes. ”

Research Motivation

- The research will promote technology-driven mobility platform, enabling integrated urban mobility across public and private modes of transport.
- Any application derived would enabling first and last-mile seamless and sustainable connectivity.
- It would limit public abuse of transports and save Government and companies in cost management related to public usage of provided transports.
- It would help people in commuting metropolitan cities with high rates of traffic and promote punctuality.
- Electric vehicles (EVs) are a positive development in this present reality where contamination levels have crested and an energy emergency might foster over the course of the following couple of many years.
- EV technologies must be progressively enhanced and optimized as they develop into the new transportation and mobility mainstream. The fight against climate change is being waged by governments all around the world, and EVs and renewable energy have been at the forefront of this campaign.
- Our way of life, which is dependent on energy use, may benefit from the advancement of these technologies. To aid upcoming researchers, five solutions in the enhancement of electric vehicles (EVs) are recognized. A number of relevant and well-known optimization models are also provided, together with a summed up portrayal of their concern details. A variety of various EV validation driving cycles are also looked at and ranked according to how popular they are.

Research Challenges

- Optimize algorithm to treat large city landscape as a huge graph to implement graph operations and routing techniques on.
- Minimize time of output.
- Obtain machine power to train epochs and minimize loss.
- Create User Interface for any person using e-vehicles to commute and limit damage to public e-vehicles which are used in transit.
- Consider hosting options for Bot or User Interface to deploy on cloud and provide results as soon as possible and observe limits of varying cloud services for application of research.

Research objectives

◉ Get proper routes to account if in case user reaches destination or needs to head to a recharging station.

◉ At a recharging station, look for available slots or reroute to the nearest charging station with a free slot.

◉Implement a distance routing technique which adapts to rerouting functions incase slots are not available at a station for a vehicle to recharge without draining the battery.

Work to be Completed

- Find open source routing API.
- Develop framework to convert city landscape into a tree graph.
- Sort cloud services to carry out different variations of routing algorithm on an extensive city graph.
- Develop AI-based algorithm to allow subject to reach recharging stations in order to get from point A to point B.
- Get proper routes to account if in case user reaches destination or needs to head to a recharging station.
- At a recharging station, look for available slots or reroute to the nearest charging station with a free slot.

Guide Approval Snapshot

VIT

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REVIEW PPT APPROVAL

Suguna M <suguna.m@vit.ac.in> Tue, Nov 22, 2022 at 1:32 PM
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Dear Aryaman,

Approved, Kindly proceed your presentation

Thanks & regards,

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Any other additional information to be added by Guide

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[8]S. Shahriar, A. R. Al-Ali, A. H. Osman, S. Dhou and M. Nijim, "Machine Learning Approaches for EV Charging Behavior: A Review," in IEEE Access, vol. 8, pp. 168980-168993, 2020, doi: 10.1109/ACCESS.2020.3023388.

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[14]I. Aygun and S. Kamalasadan, "An Optimal Approach to Manage Electric Vehicle Fleets Routing," 2022 IEEE International Conference on Power Electronics, Smart Grid, and Renewable Energy (PESGRE), 2022, pp. 1-6, doi: 10.1109/PESGRE52268.2022.9715894.

[15]M. Thymianis, A. Tzanetos, E. Osaba, G. Dounias and J. Del Ser, "Electric Vehicle Routing Problem: Literature Review, Instances and Results with a Novel Ant Colony Optimization Method," 2022 IEEE Congress on Evolutionary Computation (CEC), 2022, pp. 1-8, doi: 10.1109/CEC55065.2022.9870373.

Thank You