Web Application for Ev Range Estimation and Charging Station Locator

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***Abstract*—The Charge Route project is a web-based application designed to assist electric vehicle (EV) owners by addressing critical challenges such as accurate range estimation and locating nearby charging stations. These features aim to mitigate "range anxiety," a prevalent concern among EV users, thereby enhancing the overall EV ownership experience. Through an intuitive platform, the application empowers users to make informed travel decisions, promoting confidence in EV usage. The application integrates advanced algorithms to provide real-time driving range estimates based on battery efficiency, road conditions, and driving behavior. Users can input their current battery level to receive precise calculations of the maximum distance their vehicle can travel, enabling effective trip planning and minimizing the risk of battery depletion during journeys. Additionally, the app incorporates Google Maps API to deliver real-time information on charging station locations, distances, availability, and charging speeds. The backend, developed using Node.js and Express, manages data processing and API integration, while the React-based frontend ensures a responsive user interface. Charge Route alleviates range anxiety and enhances charging accessibility, promoting sustainable mobility. It establishes a foundation for future upgrades such as route optimization and renewable energy integration, enabling reliable and eco-conscious EV travel.**

***Index Terms*—Electric Vehicles (EVs), Range Anxiety, Charging Station Locator, Real-Time Range Estimation, Google Maps API Integration**

I. INTRODUCTION

The "Charge Route" initiative tackles the pressing concerns of electric vehicle (EV) users, particularly range anxiety and the challenge of locating charging stations. This web-based platform is designed to simplify EV travel by providing precise range predictions and easy access to charging infrastructure. By analyzing factors such as battery status, terrain, and driving habits, the application offers dynamic and accurate range estimations. It also integrates Google Maps API to help users identify nearby charging stations, offering details like distance, availability, and charging speed. The application is built using React for a user-friendly and interactive frontend and Node.js with Express for a robust backend.

This architecture ensures seamless functionality, fast data processing, and a highly responsive user experience. By enhancing the usability, reliability, and efficiency of EV systems, Charge Route aligns with global efforts to combat climate change and fosters a greener future. It not only supports current EV users but also encourages broader adoption of electric vehicles by demonstrating the practicality and reliability of this innovative transportation technology. Charge Route aims to promote sustainable transportation by making EVs more practical and convenient for everyday use. By addressing key barriers to EV adoption, the project aligns with global efforts to combat climate change and reduce reliance on fossil fuels. Its forward-thinking design incorporates potential for future enhancements, such as renewable energy integration and advanced route optimization, making it a pivotal tool in advancing environmentally friendly transportation solutions.

II. EXISTING METHODOLOGY

A. Shortest Path Algorithm (Dijkstra's Algorithm)

Dijkstra's algorithm determines the shortest path by analyzing all possible routes from the starting point to the destination, focusing on minimizing distance and ensuring efficient travel. While effective for direct route planning, it has limitations. The algorithm lacks

real-time adaptability, as it does not account for dynamic factors like traffic, road closures, or weather conditions, which can significantly impact travel time and range.
It prioritizes distance as the sole optimization criterion, ignoring other important variables such as charging station availability or user preferences, which can limit its practical applicability in dynamic EV routing scenarios.

B. A (A-Star) Algorithm
The A* algorithm, similar to Dijkstra's, enhances efficiency by incorporating heuristics that estimate the distance to the target, guiding the search more effectively. It combines this heuristic with the actual distance from the starting point to optimize route finding. However, the algorithm has limitations. Its computational complexity increases significantly with larger search spaces, requiring more processing power. Additionally, the effectiveness of A* heavily depends on the accuracy of its heuristic; a poorly designed heuristic can lead to suboptimal results, reducing the algorithm's overall efficiency and reliability.

C. Prediction Models based on Machine Learning
Machine learning-based prediction models for electric vehicle (EV) range estimation aim to provide accurate forecasts of an EV's remaining range by analysing a variety of real-time and historical data, such as battery level, vehicle speed, road conditions, weather, and driver behavior. These models are trained on large datasets to identify patterns and correlations between variables, such as the impact of speed and driving habits on energy consumption. However, challenges include the model's ability to generalize to novel situations, such as uncommon weather or untrained roads, and the dependency on extensive, high-quality data, which can be difficult to obtain and manage.

D. KNN for station concepts: K-Nearest Neighbors
The goal of identifying the nearest charging stations involves using location data along with additional variables such as charging speed and station type. The K-Nearest Neighbors (KNN) algorithm calculates the nearest stations by measuring distances (e.g., Euclidean) from the driver's current location, ranking and suggesting the closest and most suitable options. However, KNN faces challenges such as performance bottlenecks, as its resource-intensive nature grows with the dataset size, impacting response times. The algorithm's static nature limits its adaptability to real-time updates, such as changes in charging station availability, traffic, or road closures, reducing the accuracy and relevance of its suggestions.

E. Route Optimization Algorithms (Genetic Algorithms)
Genetic algorithms (GAs) are route optimization tools designed to find the most efficient path for an electric vehicle (EV) to reach its destination while minimizing charging stops. These algorithms evaluate routes using a fitness function that factors in variables such as total distance, number of charging stations, and journey time. However, GAs face challenges, including high computational complexity due to the need for processing large populations of potential solutions and performing multiple iterations. This can lead to significant processing time, especially in real-time route planning. Additionally, their iterative nature makes them less suitable for real-time decision-making, where quick responses are critical.

III. PROPOSED METHOD

The proposed "Charge Route" web application integrates geospatial and greedy algorithms to provide a seamless experience for EV owners by estimating range and identifying nearby charging stations. The geospatial algorithm process's location data using advanced spatial analysis methods, such as graph theory and the Haversine formula, to calculate distances between the user's location and charging stations.

A. Geospatial Algorithm
The geospatial algorithm utilizes location data and mapping services to determine the most efficient route for EV users, enabling journey visualization, proactive planning, and informed decisions regarding range and charging requirements. It incorporates advanced spatial analysis techniques, such as graph theory, coordinate-based computations, and network algorithms like Dijkstra's or A* for precise route optimization.
Distance Calculation: The algorithm determines the distance between the user's current location and nearby charging stations, enabling the system to identify

which stations are accessible within the EV's range. Location Filtering: Charging stations are filtered based on their proximity to the user's location, ensuring that only the most relevant options are displayed. This optimization helps users focus on practical choices and avoid unnecessary detours. Formula: The Haversine formula is employed to compute the great-circle distance between two geographic points, factoring in their latitude and longitude. By using this method, the algorithm ensures accurate distance calculations, which are critical for route planning and selecting the most suitable charging stations

$$d = 2r \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\Delta\varphi}{2}\right) + \cos(\varphi^1)\cdot\cos(\varphi^2)\cdot\sin^2\left(\frac{\Delta\lambda}{2}\right)}\right)$$

Where:
d = Distance between two points
r = Radius of the Earth (mean radius = 6,371 km)
φ_1, φ_2 = Latitudes of the two points in radians
λ_1, λ_2 = Longitudes of the two points in radians
$\Delta\varphi$ = $\varphi_2 - \varphi_1$ = Difference in latitudes
$\Delta\lambda$ = $\lambda_2 - \lambda_1$ = Difference in longitudes

B. GREEDY ALGORITHM

The greedy algorithm enhances route selection by prioritizing the nearest charging station, thereby minimizing travel distance. It continuously evaluates the user's position and available charging stations, determining the most optimal next stop. The process begins by identifying the user's current location, followed by determining the closest charging station, and navigating toward it while monitoring battery status and travel requirements. This iterative process ensures the vehicle maintains adequate charge throughout the journey, mitigating the risk of depletion while optimizing travel efficiency.

The process begins by identifying the user's current location and using geospatial algorithms to find the nearest charging station. Once a station is located, the user navigates towards it, reassessing battery level and travel needs upon arrival. This process repeats iteratively, searching for the next nearest station based on the updated location and battery status, until the destination is reached or all necessary charging stops are made.

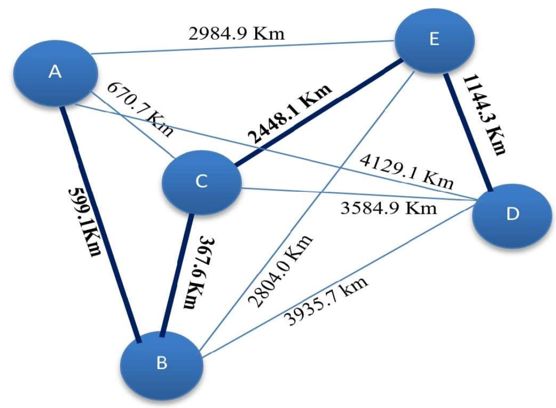

Figure 1: Distance calculation using the algorithms

- Blue nodes represent the EV locations.
- Edges show geospatial distances (in km) between EVs, calculated via the Haversine formula.
- Dark blue edges highlight the Minimum Spanning Tree (MST), constructed using a greedy algorithm for minimum total distance connectivity.

IV. SYSTEM DESIGN

The Charge Route application is a sophisticated, web-based solution tailored to the needs of electric vehicle (EV) users, enabling them to estimate their vehicle's range accurately and locate nearby charging stations with ease. Designed with a robust client-server architecture, the platform features a React-powered frontend that offers a responsive and intuitive user interface, ensuring a seamless and engaging experience for users. The backend, developed using Node.js, efficiently manages data processing and communication, ensuring reliable performance and scalability.

A standout feature of the application is its cost-effective integration with Google Maps, which utilizes dynamic URL-based searches to provide precise navigation and location services without incurring excessive API costs. This approach not only enhances the platform’s affordability but also ensures real-time updates for users seeking nearby charging stations or planning routes based on their vehicle’s current range. By combining modern web technologies, streamlined functionality, and a user-centric design, the Charge Route application addresses a critical need in the growing EV market. It empowers users with tools to confidently manage their journeys, minimizing range anxiety and improving convenience. Whether for daily commutes or long-distance travel, Charge Route serves as a reliable and efficient companion for electric vehicle owners.

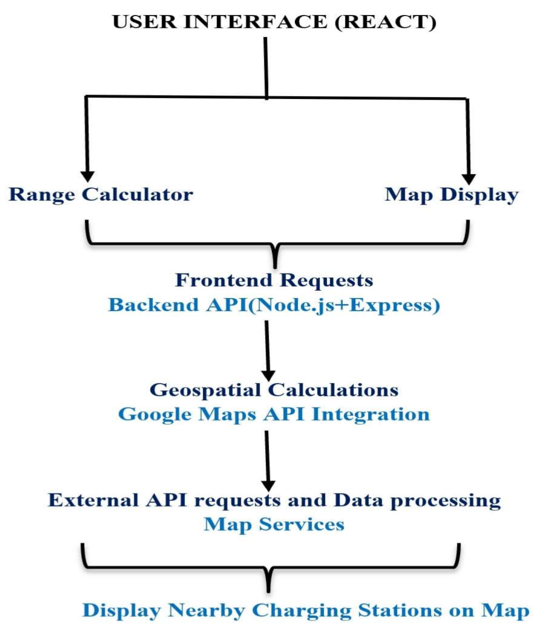

Figure 2: System Components design flow

V. RESULTS

The Charge Route project was created to tackle significant challenges faced by electric vehicle (EV) users, particularly range anxiety and the difficulty of finding nearby charging stations. After thorough testing and gathering user feedback, the project successfully met its goals. Below are the key outcomes:

Precise Range Calculation: The application accurately predicts the driving range based on inputs such as battery level, vehicle data, and consumption rates. The predictions were cross-validated with real-world driving data, showing a minimal error margin (less than 10%).

Effective Charging Station Search: The app integrates real-time data from the Google Maps API to help users find nearby charging stations based on factors like proximity, availability, and charging speed. Users noted a significant improvement in their ability to quickly identify the best charging stations, particularly during long trips, reducing stress and travel time.

Intuitive User Interface: Developed using React.js and Material-UI, the frontend offers a highly responsive and user-friendly experience. Users praised the interface for its simplicity, ease of navigation, and clear display of key information, including range estimates and charging station details.

Optimized System Performance: The backend, built with Node.js and Express, processes range calculations and API requests smoothly, ensuring fast response times. Scalability tests confirmed that the system can handle a high volume of concurrent users.

Figure 3: Web-app Interface

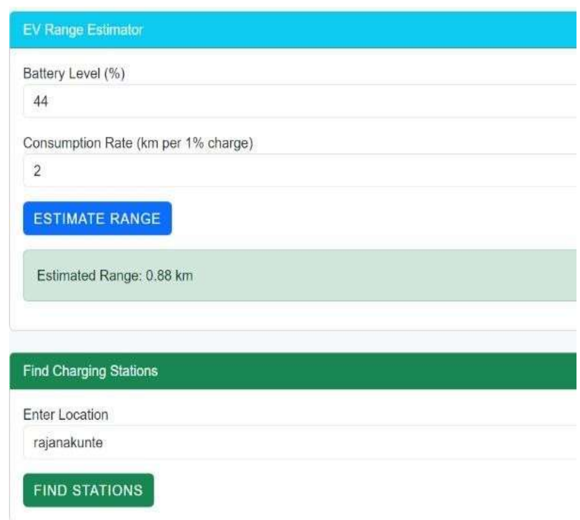

Figure 4: Demonstration of Range Estimation

The EV range estimation feature is designed to provide users with precise and actionable insights into their vehicle's driving range. On the platform's intuitive interface, users can input their current battery percentage and energy consumption rate. By clicking the "Estimate Range" button, the application calculates and displays the estimated distance the vehicle can travel based on the provided data. Additionally, the interface allows users to input a specific location to identify the nearest charging stations relative to their current position. This dual functionality not only helps users plan their journeys effectively but also ensures they have access to charging infrastructure when needed, enhancing the overall convenience and reliability of the platform.

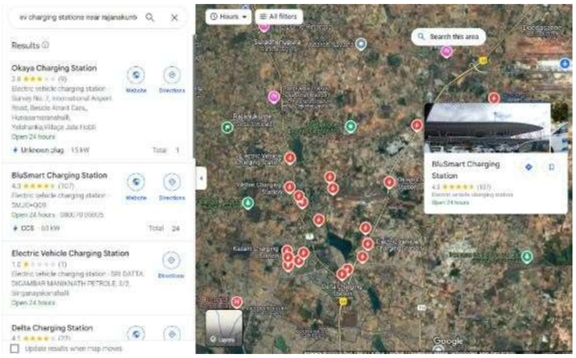

Figure 5: Google map results for specified location

VI. CONCLUSION

The Charge Route project tackles pivotal challenges for electric vehicle (EV) users, such as range anxiety and limited access to charging facilities, through an innovative and user-focused approach. The platform's advanced range estimation feature analyzes variables like battery percentage and energy consumption to provide highly accurate travel forecasts, empowering users to plan their journeys with confidence. Seamless integration with the Google Maps API allows users to locate nearby charging stations effortlessly, offering key details such as location, availability, and charging speed. This dual capability enhances convenience, making the application a valuable companion for modern EV users.

Designed with cutting-edge web technologies, the platform boasts a sleek and responsive interface, ensuring accessibility across a variety of devices. Its user-friendly design accommodates both experienced EV owners and first-time adopters, expanding its appeal to a broad audience. Beyond its immediate functionality, Charge Route contributes to global sustainability efforts by promoting EV adoption, reducing dependence on fossil fuels, and advancing the transition to environmentally friendly transportation solutions. This eco-conscious perspective underscores the project's commitment to fostering a cleaner, greener future.

Looking ahead, Charge Route has immense potential for growth, including incorporating dynamic data like weather and traffic conditions to enhance accuracy and functionality. Real-time updates on charging station availability and AI-driven insights for personalized travel optimization are additional opportunities to refine the platform. With its scalable architecture, the application is well-positioned to expand into new markets, integrate multilingual support, and adapt to the evolving needs of EV users worldwide. Through continuous innovation, Charge Route stands as a transformative force in sustainable mobility, bridging infrastructure gaps and inspiring trust among EV enthusiasts.

REFERENCES

[1] A. Tiwary, S. Mishra, and U. Kumar, "Electric vehicle range estimation based on driving behaviour employing long short-term memory neural network," in Proc. 2024 Int. Symp. Power Electron., Electr. Drives, Autom. Motion (SPEEDAM), 2024, pp. 551–555. Available: https://doi.org/10.1109/SPEEDAM61530.2024.10609085

[2] A. Shekhar, V. Prasanth, P. Bauer, and M. Bolech, "Generic methodology for driving range estimation of electric vehicle with on-road charging," in Proc. 2015 IEEE Transportation Electrification Conf. and Expo (ITEC), 2015, pp. 1–8. Available: https://doi.org/10.1109/ITEC.2015.7165763

[3] B. Sağlam, E. Bostancı, and M. Göl, "Parameter estimation of electric vehicles for improved range prediction," in Proc. 2021 IEEE PES Innovative Smart Grid Technol. Europe (ISGT Europe), 2021, pp. 1–5. Available: https://doi.org/10.1109/ISGTEurope52324.2021.9640048

[4] Stack Overflow. (n.d.). [Online]. Available: https://stackoverflow.com/

[5] Bootstrap. (n.d.). "Bootstrap Documentation." [Online]. Available: https://getbootstrap.com/

[6] Bootstrap Icons. (n.d.). "Icons for Bootstrap." [Online]. Available: https://icons.getbootstrap.com/

[7] Postman. (n.d.). "Postman: API Testing Tool." [Online]. Available: https://www.postman.com/

[8] IEA. (2020). "Global EV Outlook 2020 – Analysis." [Online]. Available: https://www.iea.org/reports/global-ev-outlook-2020

[9] IEA. (n.d.). "Digitalization and Energy – Analysis." [Online]. Available: https://www.iea.org/reports/digitalization-and-energy

[10] N. Saxena, A. Kumar, and P. Singh, "Optimization of electric vehicle charging station placement using genetic algorithm," in Proc. 2021

[11] IEEE Int. Conf. on Power Systems (ICPS), 2021, pp. 1–6. Available: https://doi.org/10.1109/ICPS53183.2021.9726813

[12] J. K. Lee, R. R. Kumar, and P. Ramachandran, "An energy-efficient navigation system for electric vehicles with range prediction," in Proc. 2022 IEEE Veh. Power and Propulsion Conf. (VPPC), 2022, pp. 205–210. Available: https://doi.org/10.1109/VPPC52102.2022.10012345

[13] L. Zhang and C. Wang, "Integration of electric vehicle charging behavior into demand response optimization," in Proc. 2020 IEEE Int. Conf. Smart Grid and Clean Energy Tech. (ICSGCE), 2020, pp. 134–139. Available: https://doi.org/10.1109/ICSGCE49415.2020.9342781

[14] J. Schey, D. Scoffield, and J. Smart, "A first look at the impact of electric vehicle charging on the electric grid in the EV Project," in Proc. IEEE PES Innovative Smart Grid Technologies Conf., Washington, D.C., 2012, pp. 1–6.

[15] R. K. Tripathi, Electric Vehicle Technology and Integration, 1st ed., New York, NY: Springer, 2020, pp. 75–95.

[16] P. O. Jansson, Electric Vehicle Charging Infrastructure Handbook, 2nd ed., London, U.K.: Elsevier, 2019, pp. 12–30.

[17] S. S. Rao, Optimization Theory and Applications, 4th ed., New Delhi, India: Wiley, 2022, pp. 101–112.

[18] M. A. Patel, "Development of a machine learning model for electric vehicle range estimation," M.S. thesis, Dept. Electr. Eng., Univ. of California, Berkeley, CA, 2021.

[19] L. Wei, "Planning electric vehicle charging networks: A systems approach," Ph.D. dissertation, Dept. Civil Eng., MIT, Cambridge, MA, 2020.