Route Optimization for EVs Considering Charging Station Availability

Abstract

With the rapid adoption of electric vehicles, route planning has become more complex due to limited battery ranges and varying charging infrastructure. Efficient route optimization for EVs is essential to ensure smooth long-distance travel and reduce range anxiety. This project, **Route Optimization for EVs Considering Charging Station Availability**, develops a data-driven system that determines optimal paths from source to destination, factoring in EV range, charging station type, and charging points. The system uses geospatial analysis and routing algorithms in R (via OSRM and sf) to compute feasible routes with intermediate charging stops. By visualizing routes, estimating charging times, and analyzing station availability, this solution helps EV users make informed travel decisions. The study demonstrates how R's spatial, mapping, and optimization capabilities can transform raw location and charging station data into actionable trip plans, improving EV adoption, travel efficiency, and user experience.

Data Description

The dataset for this project consists of publicly available EV charging station data combined with synthetic station locations for testing scenarios.

- **Dataset Name:** EV Charging Station and Route Dataset
- **Source:** Government or open datasets (e.g., Open Charge Map, Kaggle EV datasets) and synthetic stations generated in R.
- **Size:** Approximately 500–1000 charging stations across a given geographic region with attributes including station ID, latitude, longitude, charging points, and station type (fast/slow).
- **Additional Inputs:** Users can input or click on the map to add custom stations

Data Cleaning and Preprocessing

1. **Removal of Duplicates**
    - Checked for duplicate station entries using station ID and coordinates; redundant stations were removed.
2. **Handling Missing Data**
    - Missing numeric fields (e.g., number of charging points) were imputed using median values.
3. **Feature Engineering**

- **Distance Calculation:** Straight-line (Haversine) distances between stations.
- **EV Range Compliance:** Determined which stations are reachable based on EV battery range.
- **Charging Time Estimation:** Calculated expected charging time based on station type (fast/slow) and number of charging points.
- **Route Path Features:** Ordered sequence of stops from source to destination including charging stations.

4. **Encoding Categorical Variables**
    - Station type encoded as "Fast" or "Slow" for algorithmic decision-making

Exploratory Data Analysis (EDA)

EDA was conducted to understand station distribution, EV range limitations, and potential route challenges.

1. **Descriptive Statistics**
    - Average charging points per station: 3–4 points.
    - Majority of stations are fast chargers (~60%).
2. **Distribution Analysis**
    - Map-based visualization showed clusters of stations in urban areas.
    - Histogram analysis of station distance showed gaps where EVs may require intermediate stops.
3. **Visualization Tools**
    - **Leaflet Maps:** Interactive route mapping.
    - **Bar Plots:** Number of charging points per station.
    - **Route Lines:** EV paths including recommended stops