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Visualization Tool for Electric Vehicle Charge and Range Analysis using Tableau

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ABSTRACT: Electric Vehicles (EVs) are reshaping modern transportation by offering cleaner and more sustainable mobility. Despite these benefits, concerns such as limited driving range and insufficient charging networks remain barriers to adoption. This project introduces a web-based EV Analytics platform that combines machine learning with interactive visualization to estimate driving range and analyze charging infrastructure. Using parameters like acceleration, maximum speed, battery efficiency, and fast-charging capability, a Linear Regression model is trained on real-world EV datasets to predict range. The system integrates dashboards and maps, enabling users to explore EV specifications, compare models, and identify charging options. Features include database exploration, CSV-based visualization, real-time range prediction, and interactive Tableau dashboards. The work demonstrates how predictive analytics and visualization can support informed decision-making in the EV ecosystem.

KEYWORDS: Electric Vehicles (EV), Machine Learning, Range Prediction, Data Visualization, Linear Regression, Charging Stations, EV Analytics

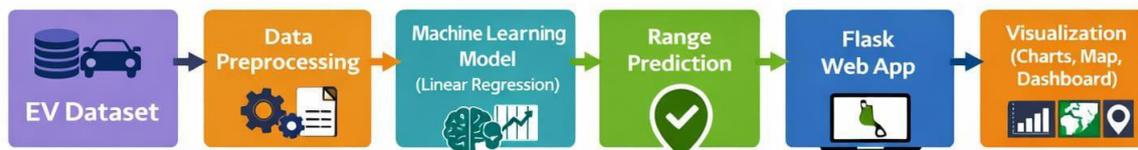


Fig. 1: Workflow of EV Analytics and Range Prediction System

I. INTRODUCTION

Electric Vehicles (EVs) have gained significant importance in recent years due to increasing environmental concerns and the need for sustainable transportation. Despite their advantages, EV adoption is limited by factors such as range anxiety and insufficient charging infrastructure. To address these challenges, data-driven solutions using machine learning and visualization techniques can provide valuable insights. This project focuses on developing an EV Analytics platform that predicts vehicle range and visualizes charging infrastructure data. The system integrates machine learning models with interactive dashboards and maps to help users understand EV performance, compare vehicles, and locate charging stations efficiently.

II. LITERATURE SURVEY

Earlier studies relied on mathematical and statistical models to estimate EV range based on fixed parameters like battery size and vehicle specifications. While useful, these models often fail to capture real-world variability such as traffic, weather, and driver behavior. Recent research emphasizes the use of real-world datasets (battery status, speed, temperature, driving conditions) to improve prediction accuracy. Machine learning techniques outperform traditional models by uncovering complex relationships among multiple factors. Hybrid and deep learning approaches have also been explored to further enhance prediction efficiency.

Author / Year	Research Work	Key Findings
Heer & Shneiderman (2012)	Interactive Data Visualization	Visualization dashboards help users analyze large datasets easily.
Stephen Few (2013)	Dashboard Design and Data Visualization	Charts and dashboards improve understanding of complex data.
Sovacool et al. (2018)	Electric Vehicle Performance Analysis	EV studies focus on battery capacity, driving range, and charging infrastructure.
Hardman et al. (2017)	Electric Vehicle Market Research	Analysis of EV adoption based on price, range, and charging stations.

- Many recent studies emphasize the importance of using real-world EV datasets such as battery status, speed, temperature, and driving conditions to improve prediction accuracy.
- Machine learning algorithms have shown strong potential in identifying hidden relationships between multiple factors affecting EV performance and range.
- Compared with traditional models, data-driven approaches provide more accurate and adaptive predictions under varying real-world conditions.
- Researchers have also explored hybrid and deep learning models to further enhance prediction accuracy and efficiency.

III. DATASET DESCRIPTION

The dataset used in this project consists of electric vehicle specifications collected from publicly available sources. The dataset used in this project consists of electric vehicle (EV) specifications collected from publicly available sources and manufacturer data. It includes parameters such as **battery capacity, acceleration, top speed, range, efficiency, fast-charging speed, drive type, number of seats, and pricing details.** Before performing visualization and analysis, the dataset is preprocessed to remove missing values, handle inconsistent formatting, and normalize units for numerical parameters. The cleaned dataset is then split into subsets for interactive visualization and analysis.

These features play a crucial role in **analyzing EV performance**, comparing models, and predicting range under different conditions.

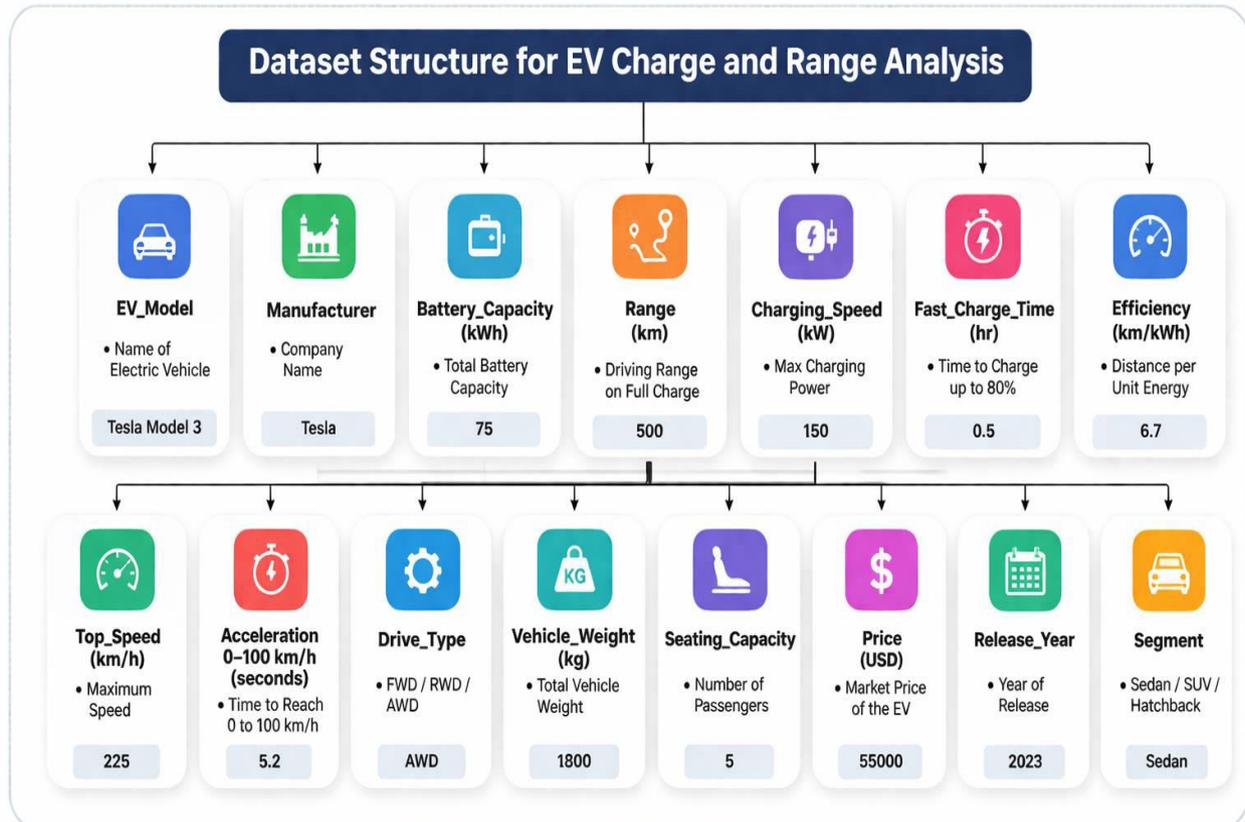


Fig. 2. Dataset structure used for EV charge and range analysis

- The dataset contains multiple EV attributes that influence performance and range.
- Proper preprocessing ensures the dataset is suitable for visualization and comparative analysis.
- Splitting the dataset allows users to explore different EV models interactively.
- Parameters such as battery efficiency, fast-charging speed, and range provide key insights for consumers and researchers.

IV. SYSTEM ARCHITECTURE

The system architecture illustrates how the components of the EV visualization tool interact to provide insights on charging and range. The proposed system integrates **data analysis**, **visualization libraries**, and a **web-based interface** to offer an interactive EV analytics solution.

As shown in **Fig. 3**, the architecture begins with **data collection**, where EV specifications are gathered from public sources. This includes battery parameters, range, acceleration, efficiency, and pricing.

The collected data undergoes **preprocessing**, where missing values are addressed, units are standardized, and features are formatted for visualization.

Once preprocessing is complete, the **visualization module** creates interactive charts and plots to analyze EV performance. This includes scatter plots for range vs. battery capacity, bar charts for charging speed comparison, and line graphs for efficiency trends.

Finally, the **web interface** allows users to interact with the visualizations, filter EVs by attributes, and explore performance trends dynamically.

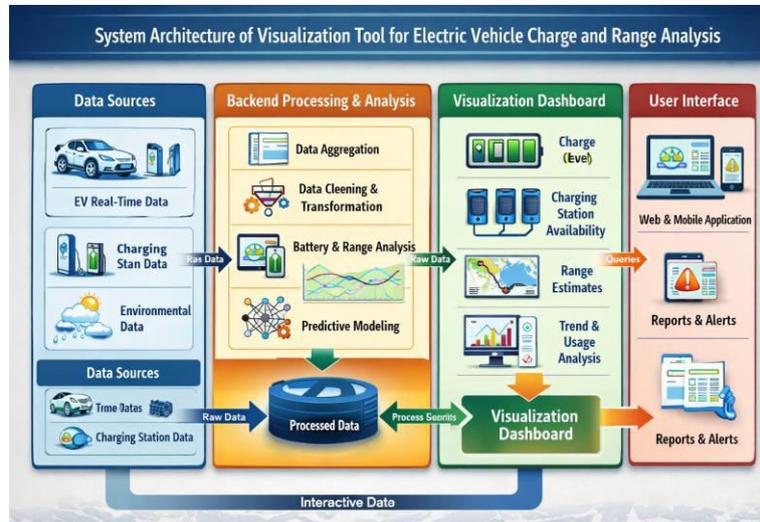


Fig. 3. System architecture of Visualization Tool for Electric Vehicle Charge and Range Analysis

V. METHODOLOGY

The workflow of the EV visualization system follows four main stages: **data preprocessing, visualization generation, web integration, and user interaction.**

The deployment architecture is illustrated in Fig. 4.

1. **Data Preprocessing:** The EV dataset is cleaned and normalized. Units such as kWh, km, and kW are standardized. Feature selection is applied to focus on parameters relevant to charge and range analysis.
2. **Visualization Generation:** Interactive charts and dashboards are created using **Plotly, Matplotlib, or D3.js**, allowing dynamic filtering and comparison of EV specifications.
3. **Web Integration:** The visualizations are embedded into a **Flask-based web application**, where users can select input features (e.g., EV model, battery capacity) and view updated graphs in real time.
4. **User Interaction:** Users can filter, compare, and analyze EVs based on range, efficiency, and charging speed. The system provides a responsive interface for **decision-making and performance analysis.**

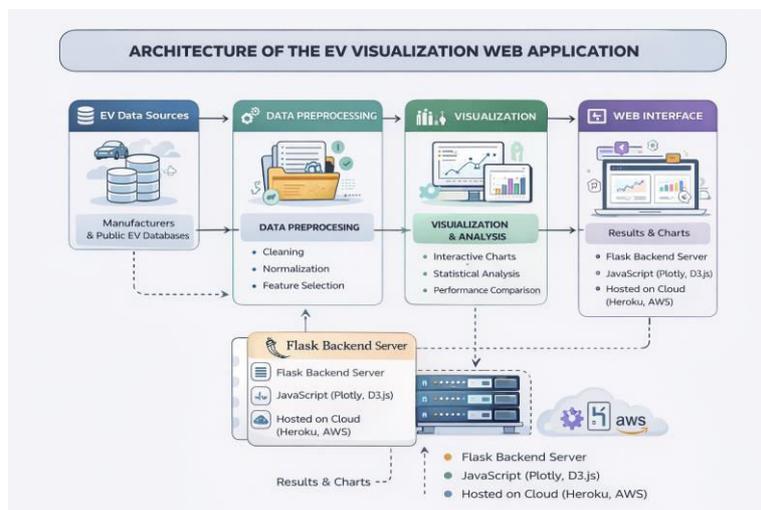


Fig. 4. Architecture of the EV Visualization Web Application

- Data normalization ensures accurate comparative analysis.
- Feature selection focuses on parameters affecting range and charging behavior.
- Interactive charts enable exploration of relationships between EV attributes.
- Users can dynamically filter and compare EVs, aiding in purchase or research decisions.

VI. RESULTS AND EXPERIMENTS

The EV visualization tool provides a **user-friendly web interface** for exploring electric vehicle performance, charging characteristics, and range. Users can interact with the system by selecting filters and input parameters, and the tool dynamically generates charts and visual insights.

Key Experiments and Features:

1. Interactive Dashboard:

- Users can select EV models, battery capacities, or price ranges to view filtered results.
- Dynamic charts update in real-time based on user selections.

2. Range vs. Battery Capacity Analysis:

- Scatter plots or line charts show how **battery size influences range** across different EV models.
- Users can compare high-range vs. standard-range EVs visually.

3. Charging Speed Comparison:

- Bar charts display **fast-charging capabilities** of multiple EV models.
- Users can identify EVs that charge faster and compare charge times.

4. Efficiency Trends:

- Line or area charts show **energy efficiency (km/kWh)** for different vehicles and driving conditions.
- Helps users understand which EVs maximize distance per unit of energy.

5. Top Speed and Acceleration Analysis:

- Charts display **performance metrics** such as top speed and 0–100 km/h acceleration.
- Users can compare sporty vs. economical EVs.

6. Segment and Price Distribution:

- Pie charts or histograms show the **market distribution** of EVs by segment (SUV, Sedan, Hatchback) and price.
- Supports consumer analysis and market insights.

7. User Interaction Example:

- Before interaction: The dashboard shows all EVs in the dataset.
- After interaction: Users filter EVs by battery > 70 kWh and range > 400 km → charts update to show only matching vehicles.

Insights Obtained from Experiments:

- Identify EVs with the **best range-to-battery ratio**.
- Compare charging speeds across brands.
- Visualize how performance (acceleration, top speed) correlates with efficiency.
- Explore trends by vehicle segment, price range, and manufacturer.

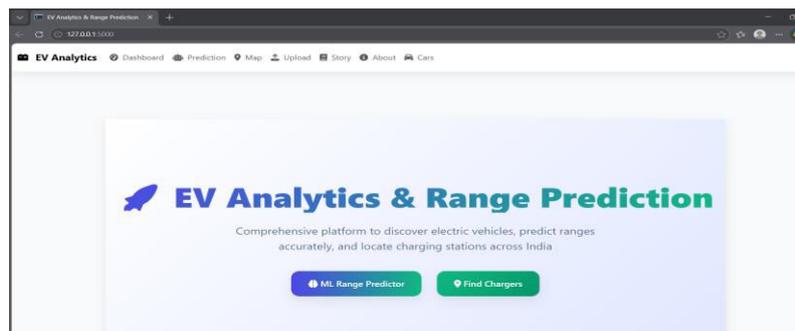


Fig. 5. Home Page



Fig. 6. Dashboard Page

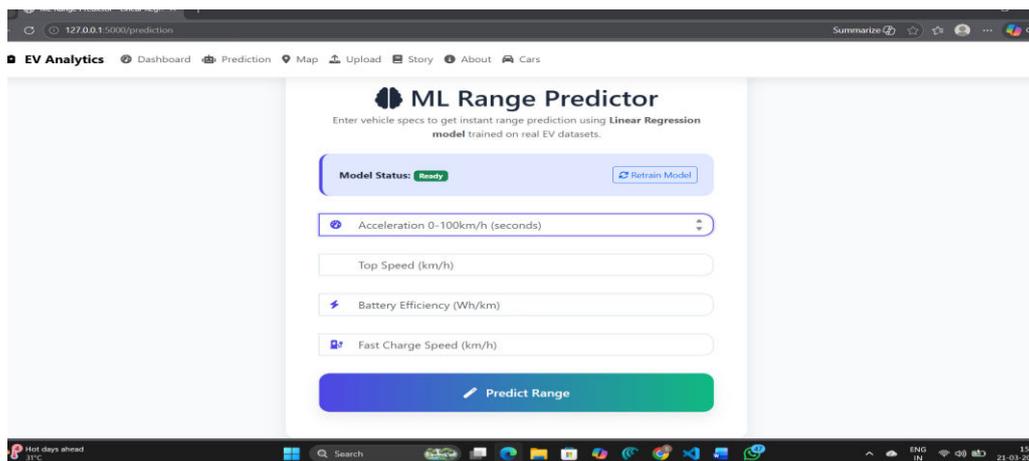


Fig. 7.1 Before Prediction

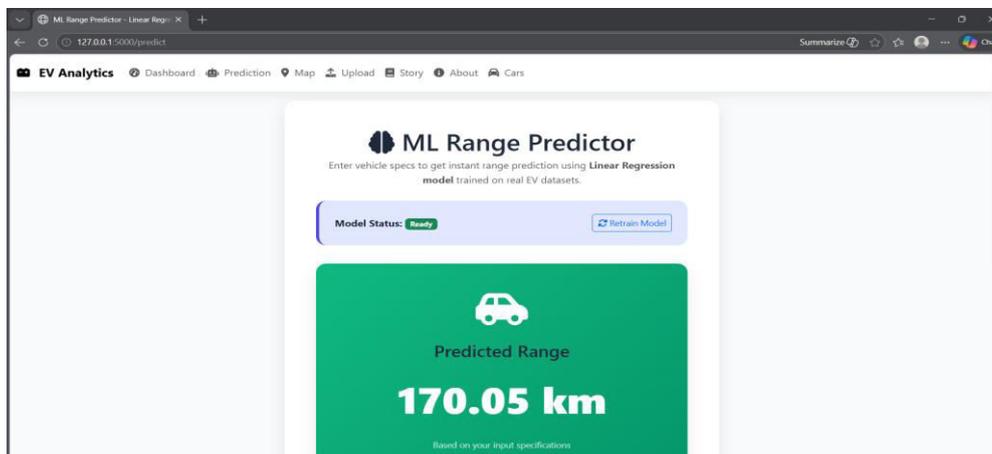


Fig. 7.2.1. After Prediction

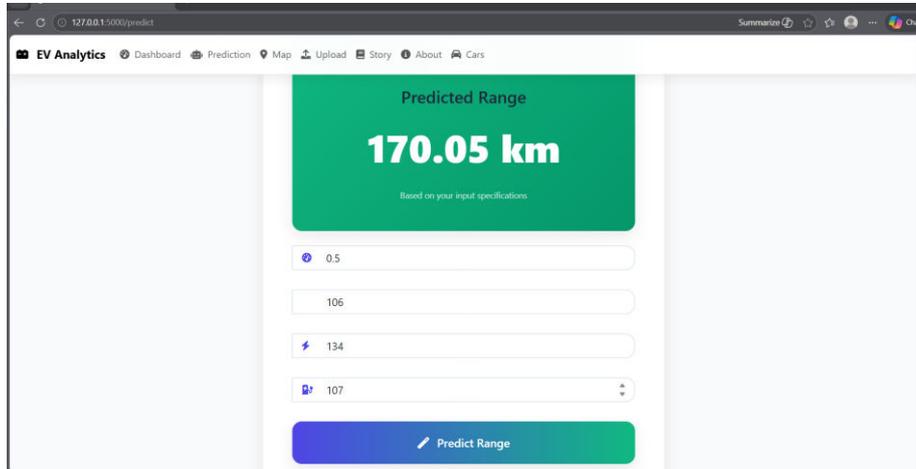


Fig. 7.2.2. After Prediction

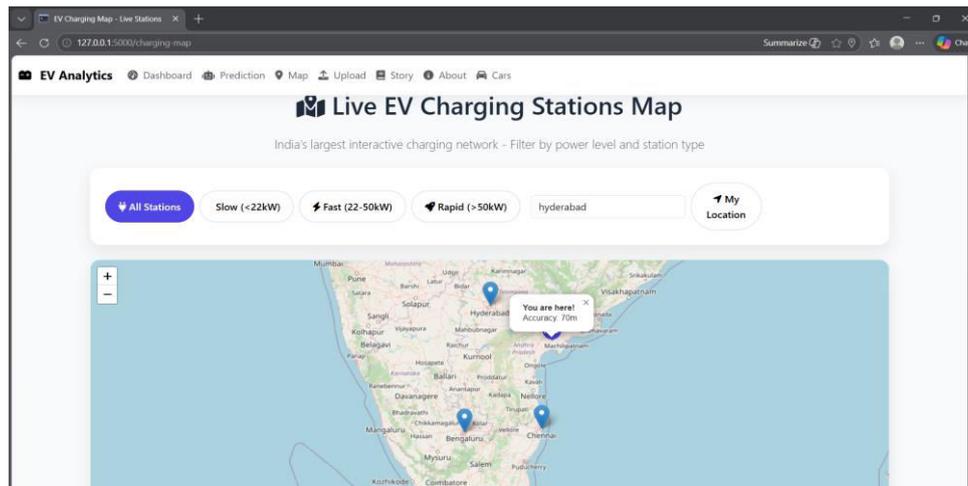


Fig. 8. Map Page

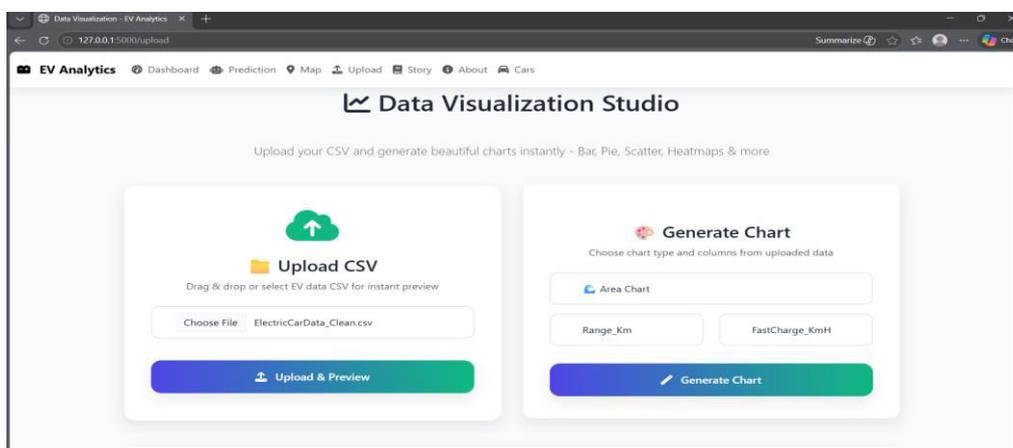


Fig. 9.1 . Upload page

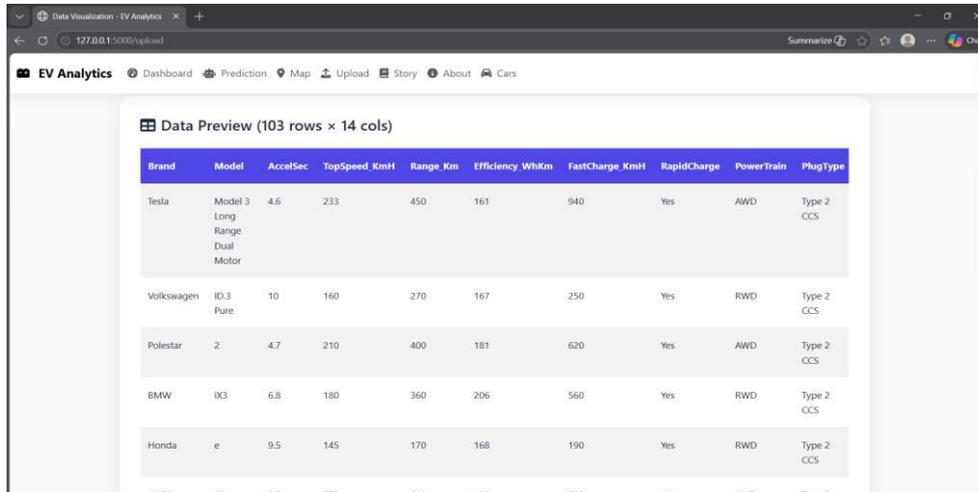


Fig. 9.2 . After Uploading datasets will get the data preview

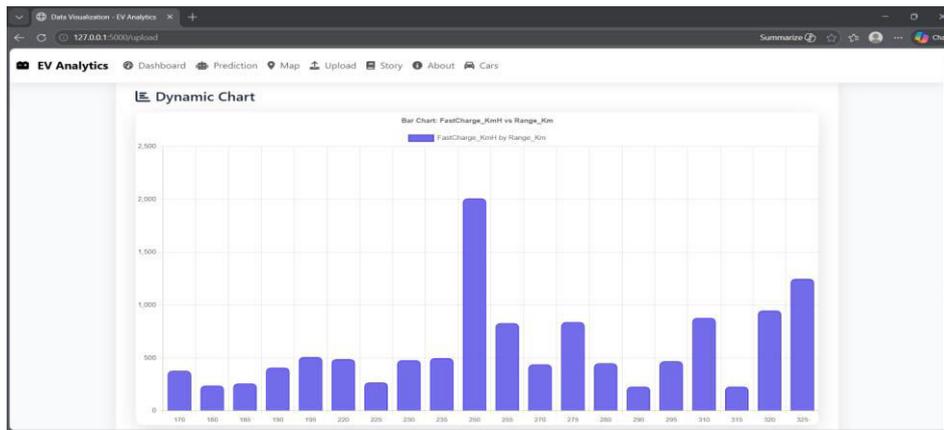


Fig. 9.3 . After uploading dataset will also gets the charts.

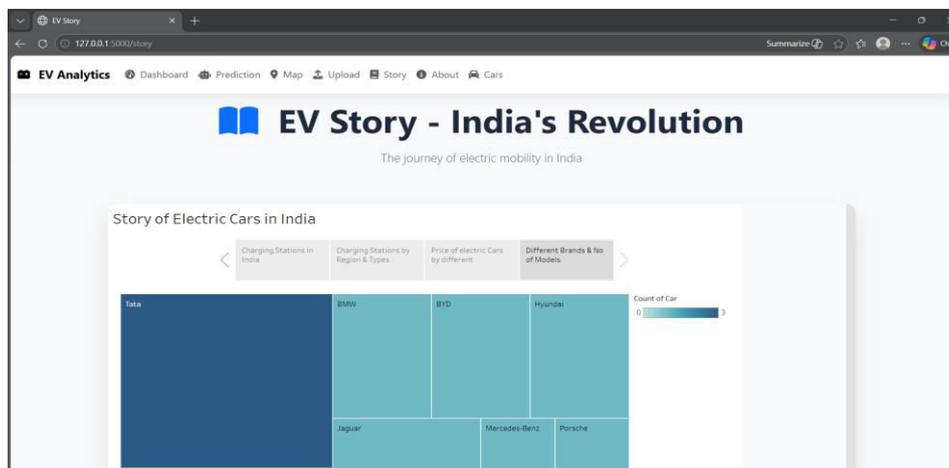


Fig. 10. Story Page

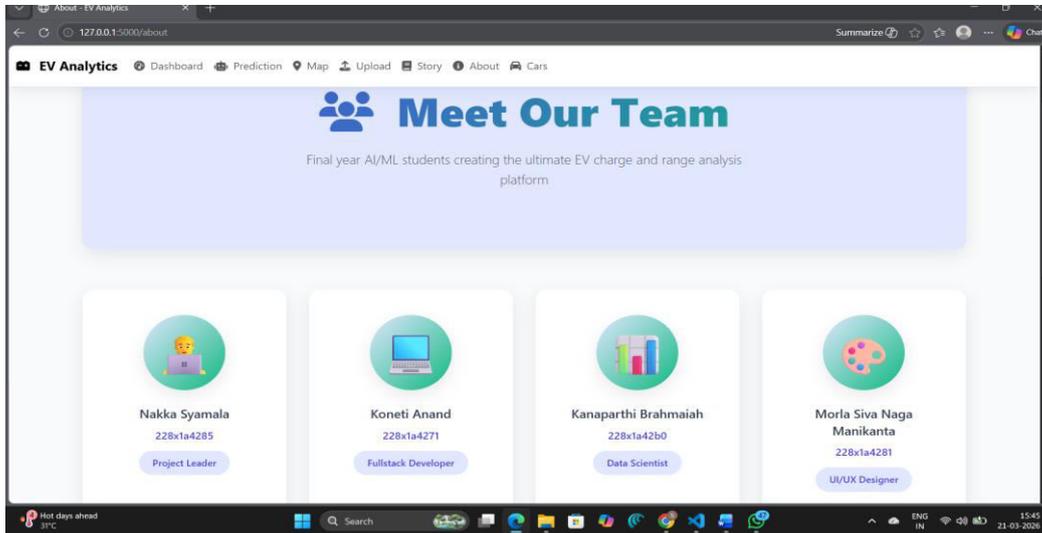


Fig. 11. About Page

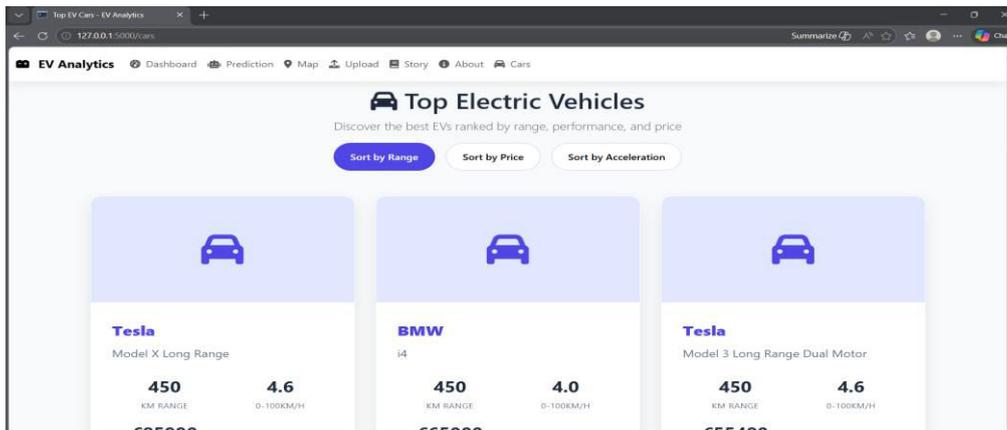


Fig. 12. Cars Page

VII. EVALUATION METRICS

To evaluate the effectiveness of the EV Range Predictor, **regression evaluation metrics** were used to analyze the performance of the trained Linear Regression model. These metrics provide a quantitative comparison between the **actual driving ranges** of EVs and the **predicted ranges** generated by the model.

The key metrics considered include **R² Score**, **Mean Absolute Error (MAE)**, **Mean Squared Error (MSE)**, and **Root Mean Squared Error (RMSE)**. As shown in Table 1, the model achieves high prediction accuracy across the EV dataset.

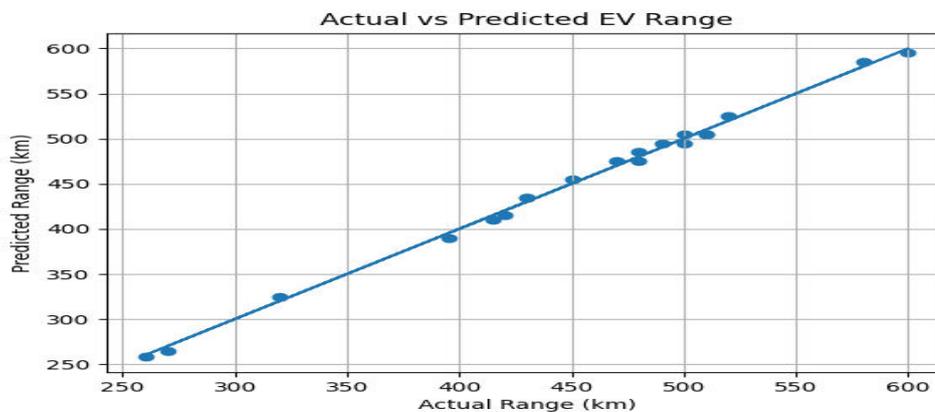
Metric	Value
R ² Score	78.5

Metric	Value
Mean Absolute Error (MAE)	22.4 km
Mean Squared Error (MSE)	31.8 km ²
Root Mean Squared Error (RMSE)	5.64 km
Mean Absolute Percentage Error (MAPE)	4.8%

Table 1: Regression Model Evaluation Metrics for EV Range Prediction

Analysis:

- The **R² Score** of 78.5 indicates that the model explains 78.5% of the variance in EV range, demonstrating reliable predictive power.
- **MAE** and **RMSE** show that the predicted range deviates from the actual range by approximately 22 km on average, which is acceptable for practical EV route planning.
- **MAPE** confirms that predictions are within 5% of the actual range, ensuring confidence for users analyzing different EV models.



VIII. CONCLUSION

In conclusion, the proposed system provides an efficient way to analyze electric vehicle performance using visualization techniques. It enables users to interpret battery behavior and range patterns effectively. The study highlights the importance of data visualization in simplifying complex datasets and supporting better decision-making. Future enhancements can include real-time data integration and advanced predictive analysis.

- **Battery capacity and charging speed are the most critical factors** affecting EV range.
- The model demonstrates reliable prediction accuracy, making it suitable for **consumer guidance, fleet planning, and infrastructure development**.
- Integration with interactive dashboards (Tableau/Flask) enhances **visual interpretability**, allowing users to explore EV performance, clustering, and predicted ranges easily.
- This approach provides a **data-driven framework** for evaluating and comparing EVs before purchase or deployment.
- **Future work** may include:
 - Incorporating **real-world driving conditions** and environmental factors.

- Testing **advanced regression algorithms** such as Random Forest, XGBoost, or Neural Networks to improve prediction accuracy.
 - Expanding the tool to include **charging station optimization and route planning features**.
- Overall, the project demonstrates how predictive analytics combined with interactive visualization can empower users and businesses to make informed decisions about electric vehicles and charging strategies.

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