Electric Vehicle Charging Demand Forecasting Report

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Introduction

The Electric Vehicle (EV) Charging Demand Forecasting project aims to predict and optimize EV charging demand across cities like Seattle, Vancouver, and San Diego for the period 2025–2027. With the rapid rise in EV adoption, understanding and managing charging demand is critical for infrastructure planning and grid stability. This project integrates weather, EV population, and traffic data to forecast demand using advanced time-series models and develops an optimization strategy to minimize peak grid load, providing actionable insights for stakeholders.

Abstract

This project forecasts EV charging demand by merging historical datasets—weather (271,554 rows), EV population (239,747 rows), and traffic (48,204 rows)—into a unified time-series dataset. Two models, Prophet and ARIMA, were employed to predict demand, with Prophet outperforming ARIMA in most cities based on RMSE validation. An optimization strategy was developed to shift charging from peak hours (7–9 AM, 4–7 PM) to off-peak hours (12 AM–6 AM, 10 PM–12 AM), reducing grid strain. Results are visualized via a Streamlit dashboard, featuring historical trends, forecasts, weather impacts, and optimized schedules. Key deliverables include forecast CSVs, a summary for Tableau analysis, an optimized charging schedule, and a comprehensive report, enhancing decision-making for EV infrastructure expansion.

Tools Used

- Programming Language: Python 3.12
- Data Processing and Analysis: Pandas, NumPy
- Forecasting Models: Prophet (Facebook's time-series forecasting library), ARIMA (Statsmodels)
- Visualization:
    - Matplotlib and Seaborn for static plots (e.g., historical trends)
    - Plotly for interactive charts (e.g., weather vs. demand scatter plots)
    - Graphviz for data flow diagrams
- Web Application: Streamlit for building an interactive dashboard
- Development Environment: Jupyter Notebook for project development
- File Formats: CSV for data storage, PNG for visualizations, TXT for reports

Steps Involved in Building the Project

1. Data Collection and Preprocessing:
    - Loaded weather (271,554 rows), EV population (239,747 rows), and traffic (48,204 rows) datasets.
    - Validated and cleaned data, handling missing values and inconsistencies.
    - Merged datasets into a unified time-series format using Pandas, aligning on common timestamps.

2. Exploratory Data Analysis (EDA):
   - Analyzed trends in EV demand, weather patterns (temperature, humidity), and traffic volume.
   - Generated visualizations (e.g., line plots of demand over time, scatter plots of weather vs. demand).
3. Forecasting with Prophet and ARIMA:
   - Applied Prophet and ARIMA models to forecast EV charging demand for 2025–2027.
   - Validated models using RMSE; Prophet generally outperformed ARIMA, except in data-sparse cities like San Diego.
   - Saved forecasts to CSVs (e.g., prophet_forecast_seattle.csv).
4. Optimization Strategy:
   - Developed a rule-based optimization to shift demand from peak to off-peak hours using Prophet forecasts.
   - Distributed daily demand across 24 hours with an hourly profile, ensuring station capacity constraints (100 kWh/hour).
   - Saved the optimized schedule to optimized_charging_schedule.csv.
5. Visualization and Reporting:
   - Built a Streamlit dashboard with tabs for historical trends, forecasts, weather impact, summary statistics, and optimized schedules.
   - Generated a data flow diagram using Graphviz for the project overview.
   - Compiled a summary report (ev_forecast_report.txt) with data insights, forecast results, validation metrics, and optimization details.
6. Export for Stakeholders:
   - Exported a summary table (ev_summary_tableau.csv) for Tableau analysis.
   - Documented the workflow in a PowerPoint presentation for stakeholder review.

Conclusion

The Electric Vehicle Charging Demand Forecasting project successfully delivers a robust framework for predicting and managing EV charging demand. By integrating diverse datasets and leveraging Prophet and ARIMA models, the project provides accurate forecasts for 2025–2027, with Prophet proving more reliable across cities. The optimization strategy enhances practical utility by reducing peak grid load, offering clear charging schedules for infrastructure planners. The Streamlit dashboard ensures accessibility, enabling stakeholders to explore trends, forecasts, and optimized schedules interactively, with summary data prepared for Tableau visualization. Future enhancements could include dynamic pricing, renewable energy integration, and advanced optimization algorithms to further improve grid efficiency and cost-effectiveness.