# Predictive EV Battery Charging for Prolonged Battery Life

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## Introduction

Electric vehicles (EVs) are vital to reducing carbon emissions, but adoption is slowed by battery reliability issues, range anxiety, and limited charging infrastructure.

### Our Solution

A Smart Battery Management System (SBMS) that uses machine learning to:

- Predict battery degradation
- Detect faults early
- Optimize charging behavior

20/30 VISION OF EGYPT

### This Ensures

- Better battery health
- Reduced driver anxiety
- Safer, more efficient EV usage

A custom designed hardware board manages power securely and supports real-time system performance.

### Goals

Longer battery life, improved user trust, and accelerated EV adoption for a sustainable future

## Objectives

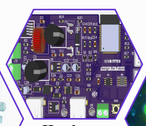
Our system combines intelligent software and integrated hardware to enhance EV battery performance. It uses a high accuracy machine learning model for real time battery health prediction, early fault detection, and continuous data updates. The hardware component ensures stable power distribution, monitors key metrics like State of Charge (SoC), manages control signals across ECUs, and enables real-time user interaction. Together, these elements improve reliability, optimize charging, and support smarter, more efficient EV operation.

## Methods


Data Science Life Cycle

IoT Framework



Hardware Design

Mobile Application

## Testing & Results

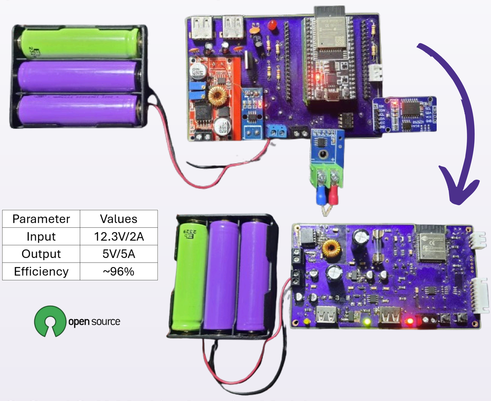
### Hardware Design and Internet of Things (IoT)

We designed a custom hardware board to interface directly with the electric vehicle battery system. The board accepts a 12V/2A input from the battery and steps it down to a stable 5V/5A output using a high efficiency buck converter. This board continuously monitors critical battery parameters, including:

- Current and Voltage
- Temperature
- Charging Cycle Count
- Timestamped Activity Logs

LTspice ALTIUM DESIGNER

All data acquisition and control functions are managed via an IoT-enabled ESP32-WROOM microcontroller, enabling seamless wireless communication and integration with the mobile application. This custom-designed hardware ensures accurate real-time monitoring, improved energy management, and efficient data logging for predictive maintenance and user insights.



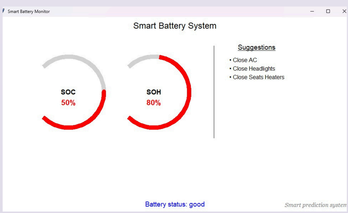
| Parameter | Values |
|---|---|
| Input | 12.3V/2A |
| Output | 5V/5A |
| Efficiency | ~96% |

open source

### SoC and SoH Machine Learning Models

We tested multiple machine learning models with various algorithms to identify the most accurate and reliable approach for battery health prediction. Outlier removal and data optimization techniques were applied to enhance model performance and ensure consistent results across different battery conditions. To implement and evaluate our models in a real-world context, we utilized a Raspberry Pi 5 as the deployment platform for running the selected State of Charge (SoC) and State of Health (SoH) prediction models.

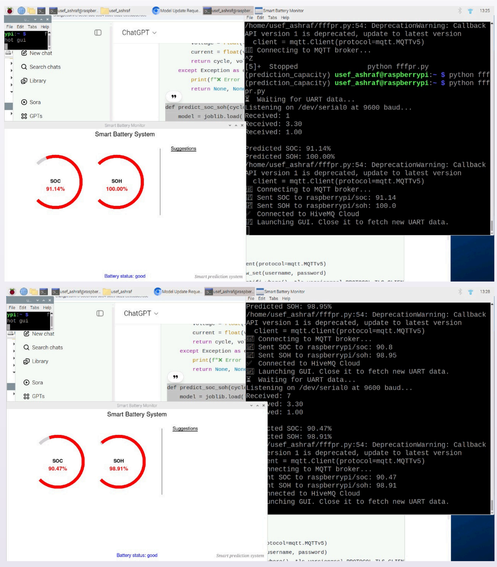
Multiple machine learning models, each based on different algorithms, were developed and tested. These models are illustrated in the figures below. We compared their performance using key evaluation metrics to determine the most suitable one for our use case. After identifying the optimal model, we integrated it into a user friendly graphical user interface (GUI). Based on the selected model, we developed a mobile application designed to enhance user interaction with the electric vehicle. The app provides real-time access to key performance indicators, including SoC, SoH, charging history, and estimated remaining driving range. By offering a comprehensive overview of the vehicle's status and battery metrics, the mobile application empowers users to make informed decisions, improves transparency, and supports smarter, more efficient EV usage.

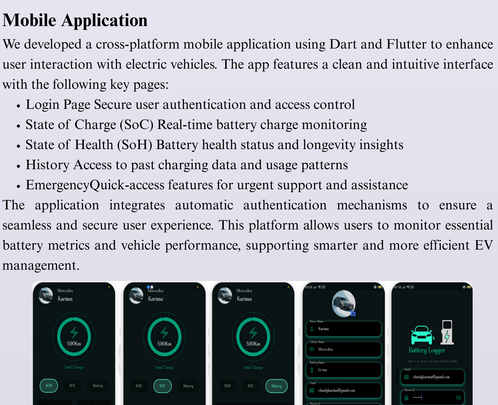



ubuntu

MQTT

| *Algorithm* | Metric | Overall | With Outliers |
|---|---|---|---|
| *Decision Tree* | MAE | 0.0008 | 0.0306 |
| | RMSE | 0.0077 | 0.0561 |
| | $R^2$ | 0.9983 | 0.9126 |
| *KNN* | MAE | 0.0466 | 0.0262 |
| | RMSE | 0.0591 | 0.0369 |
| | $R^2$ | 0.9033 | 0.9621 |
| *Linear Regression* | MAE | 0.0565 | 0.0583 |
| | RMSE | 0.0674 | 0.0687 |
| | $R^2$ | 0.8744 | 0.8693 |
| *LSTM* | MAE | 0.0280 | 0.1645 |
| | RMSE | 0.0396 | 0.2461 |
| | $R^2$ | 0.9564 | -1.4564 |
| *Random Forest* | MAE | 0.0008 | 0.0274 |
| | RMSE | 0.0059 | 0.0378 |
| | $R^2$ | 0.9990 | 0.9604 |
| *SVM* | MAE | 0.0365 | 0.0463 |
| | RMSE | 0.0444 | 0.0529 |
| | $R^2$ | 0.9454 | 0.9223 |
| *XGBoost* | MAE | 0.0088 | 0.0140 |
| | RMSE | 0.0144 | 0.0244 |
| | $R^2$ | 0.9942 | 0.9797 |




### Mobile Application

We developed a cross-platform mobile application using Dart and Flutter to enhance user interaction with electric vehicles. The app features a clean and intuitive interface with the following key pages:

- Login Page Secure user authentication and access control
- State of Charge (SoC) Real-time battery charge monitoring
- State of Health (SoH) Battery health status and longevity insights
- History Access to past charging data and usage patterns
- EmergencyQuick-access features for urgent support and assistance

The application integrates automatic authentication mechanisms to ensure a seamless and secure user experience. This platform allows users to monitor essential battery metrics and vehicle performance, supporting smarter and more efficient EV management.




## Team Members

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## Recommendations

- **Integrate Smart BMS in All EVs**
- Manufacturers should adopt intelligent battery systems to enhance safety, efficiency, and user confidence.
- **Standardize Predictive Maintenance**
- Use ML-driven diagnostics to detect early faults and schedule proactive maintenance, minimizing unexpected failures.
- **Expand Charging Infrastructure**
- Governments and stakeholders should accelerate development of smart, connected charging stations to reduce range anxiety.
- **Encourage Open-Source Collaboration**
- Promote research and innovation through shared datasets and open platforms to advance battery health prediction models
- **Utilize Charging Log Data for Optimization**
- Continue building on the collected charging history to train machine learning models
- **Encourage Industry Wide Adoption of Smart BMS**
- Promote the integration of intelligent battery systems across all EV models to enhance reliability and lifespan