“Intelligent Battery Management”

A PROJECT REPORT

Submitted by,

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Under the guidance of,

Dr. V Chandrasekar
Professor
School of CSE -PU

in partial fulfillment for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

COMPUTER SCIENCE AND ENGINEERING (DATA SCIENCE).

At

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PRESIDENCY UNIVERSITY

BENGALURU

JANUARY 2024

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CERTIFICATE

This is to certify that the Project report **"Intelligent Battey Management"** being submitted by **PRIYANSHU RAJ, VASOYA RUSHI & CHOVATIYA PARTH** bearing roll number(s) **20201CSD0215, 20201CSD0100 & 20201CSD0082** in partial fulfilment of requirement for the award of degree of Bachelor of Technology in Computer Science and Engineering (Data Science) is a bonafide work carried out under my supervision.

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DECLARATION

We hereby declare that the work, which is being presented in the project report entitled "**Intelligent Battery Management"** in partial fulfilment for the award of Degree of **Bachelor of Technology** in **Computer Science and Engineering**, is a record of our own investigations carried under the guidance of **Dr. V Chandrasekar, Professor, School of Computer Science and Engineering [Data Science], Presidency University, Bengaluru.**

We have not submitted the matter presented in this report anywhere for the award of any other Degree.

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ABSTRACT

"Intelligent Battery Management System," highlighting its pivotal role in optimizing the efficiency and longevity of batteries across a wide spectrum of applications, ranging from portable electronic devices to electric vehicles. By incorporating cutting-edge machine learning algorithms, the system embodies a comprehensive initiative to monitor, analyze, and oversee crucial aspects of battery health, charging practices, and discharging cycles. Key attributes and features encompass proactive health monitoring, adaptable charging methodologies, dynamic load optimization, a user-friendly interface accessible via web or mobile platforms, integration with energy harvesting technologies, seamless connectivity, and effective identification and rectification of faults. The proactive health monitoring aspect enables strategic maintenance and replacement, mitigating unforeseen failures. The intelligent charging algorithms and dynamic load optimization contribute to controlled charging rates and heightened overall efficiency, especially advantageous for electric vehicles and renewable energy setups. The user-friendly interface empowers users to monitor battery health, receive foresighted insights, and personalize system settings. The integration with energy harvesting technologies further amplifies sustainability. The system's connectivity and diagnostic tools facilitate efficient communication, remote monitoring, and swift identification of potential faults, averting severe malfunctions. Positioned at the forefront of technological progress, the "Intelligent Battery Management System" aspires to fulfill evolving energy storage and management needs, amalgamating machine intelligence with effective algorithms to enhance the sustainability, efficiency, and reliability of battery-driven applications.

ACKNOWLEDGEMENT

First of all, we indebted to the **GOD ALMIGHTY** for giving me an opportunity to excel in our efforts to complete this project on time.

We express our sincere thanks to our respected dean **Dr. Md. Sameeruddin Khan**, Dean, School of Computer Science Engineering & Information Science, Presidency University for getting us permission to undergo the project.

We record our heartfelt gratitude to our beloved Associate Deans **Dr. C Kalaiarasan and Dr. Shakkeera L,** School of Computer Science Engineering & Information Science, Presidency University and "**Dr. Jayachandran Arumugam**", Head of the Department, School of Computer Science Engineering & Information Science, Presidency University for rendering timely help for the successful completion of this project.

We are greatly indebted to our guide **Dr. V Chandrasekar**, School of Computer Science Engineering & Information Science, Presidency University for his inspirational guidance, and valuable suggestions and for providing us a chance to express our technical capabilities in every respect for the completion of the project work.

We would like to convey our gratitude and heartfelt thanks to the University Project-II Coordinators **Dr. Sanjeev P Kaulgud, Dr. Mrutyunjaya MS** and also the department Project Coordinators "**Dr. Manjula H M and Mr. Yamanappa**".

We thank our family and friends for the strong support and inspiration they have provided us in bringing out this project.

Priyanshu Raj

Vasoya Rushi

Chovatiya Parth

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CHAPTER-1
INTRODUCTION

In today's fast-paced world, vehicle reliability is of utmost importance, and unforeseen breakdowns due to battery issues can disrupt schedules and leave individuals stranded. To address this challenge, we introduce an innovative and user-friendly battery management tool that provides real-time insights into a vehicle's battery health and state of charge (SOC). This tool empowers users with the knowledge needed to maintain their batteries and prevent unexpected breakdowns. It goes beyond basic metrics by monitoring the battery's state of health (SoH), offering comprehensive information and personalized recommendations for optimization. The tool aims to bridge the gap between vehicle owners and their vehicle's crucial component—the battery—by providing continuous updates, holistic data, and tailored suggestions, enabling users to take proactive measures for optimizing battery health and ensuring reliable transportation while minimizing unexpected disruptions.

CHAPTER-2
LITERATURE SURVEY

1. SOH Assessment Using Decision Tree and Advanced SVM Regression

Limitations:

The incorporation of Decision Trees in the model introduces a susceptibility to overfitting, especially with deep trees, potentially resulting in inadequate generalization beyond the training set. The model's efficacy heavily relies on the quality and relevance of input features, with the absence of vital features or inclusion of irrelevant ones detrimentally impacting its accuracy. (Source: Wang, G. (2022), "Optimized Random Forest Regression Model for Li-Ion Batteries.")

2. Robust SOH Prediction Model for Electric Vehicle Batteries

Limitations:

Robust models often bring about heightened complexity to handle diverse scenarios and uncertainties, rendering the model more challenging to interpret and implement. Achieving robustness may necessitate computationally intensive techniques, particularly if the model integrates advanced algorithms or ensemble methods, potentially affecting real-time applications or resource-constrained environments. (Source: Ranga, M. S., et al. (2023), "An Unscented Kalman Filter-Based Robust State of Health Prediction Technique for Lithium-Ion Batteries.")

3. Driving Range Prediction Using Gradient Boosting Decision Tree

Limitations:

Gradient Boosting Decision Tree (GBDT) models can become intricate, especially with deep ensembles or a substantial number of trees. This intricacy may pose challenges in interpreting the model and comprehending the individual contributions of each feature. (Source: Shang, Y. (2023), "State of Health Estimation for Lithium-ion Batteries Based on Mechanism Fundamental Learning under Variable Charging Strategy."

4. BMS Insight Pro Software for Battery Management

Limitations:

The user interface lacks intuitiveness and user-friendliness, potentially causing difficulties in navigation and effective utilization of the software. A complex interface may hinder swift and efficient decision-making. (Source: Gupta, V., Patel, S. (2022), "Predictive Maintenance of Automotive Batteries: A Comprehensive Review.")

CHAPTER-3
RESEARCH GAPS OF EXISTING METHODS

Challenges in Choice Trees:

Choice trees, a broadly utilized AI device, experience hardships connected with overfitting, particularly in profound tree structures, undermining their capacity to successfully sum up. Notwithstanding perceiving the effect of element quality and significance on model execution, there exists a hole in exhaustive examinations that methodically investigate the many-sided connection between choice tree profundity, highlight determination, and the model's speculation limit.

Restricted Investigation of Powerful Plan Components:

Momentum research transcendently centers around the unfriendly impacts of non-natural connection points, yet there is a shortage of experimental examinations concerning the particular plan components that add to the improvement of instinctive connection points. A more extensive comprehension of these components is essential for upgrading client experience and connection point viability.

Interpretability Difficulties in Vigorous Models:

Tending to the interpretability challenges related with vigorous models becomes foremost because of their uplifted intricacy in taking care of vulnerabilities. Existing exploration ought to dig into strategies for working on the interpretability of these models, taking into account the multifaceted idea of their plan and the requirement for straightforwardness in dynamic cycles.

Research Gap	**Description**
Lack of Unified Standards	There is a need for standardized protocols and interfaces in battery management systems to ensure seamless integration with diverse battery models.
Limited Understanding of User Behaviour	Current research lacks in-depth analysis of user interactions with battery management interfaces. Understanding user behaviour can lead to more user-friendly designs and effective communication strategies.
User Education and Awareness	There is a gap in research concerning user education and awareness regarding battery health and management. Investigating effective strategies for educating users and raising awareness can contribute to better system utilization.
Real-time Adaptability	Ensuring real-time adaptability of the system to dynamic environmental conditions and user requirements is crucial. Research can focus on improving the responsiveness and adaptability of the system in real-world scenarios.
Scalability Challenges	The scalability of the Intelligent Battery Management System for large-scale applications, such as smart grids, remains a challenge. Research is needed to address scalability issues and enhance system performance.

Table 1

CHAPTER-4
PROPOSED MOTHODOLOGY

Data Collection:

Retrieve a dataset pertaining to the parameters of an Intelligent Battery Management System.

Data Preprocessing:

Utilize diverse machine learning techniques to preprocess the dataset, ensuring it undergoes thorough cleaning, transformation, and preparation for subsequent model training.

Data Splitting:

Divide the preprocessed data into training and testing datasets, fostering a robust evaluation of the model's performance.

Model Building:

Implement machine learning algorithms, such as Random Forest, Decision Tree, and Linear Regression, to construct prediction models tailored for intelligent battery management.

Training the Model:

Train the selected algorithms using the training dataset, allowing them to discern patterns and relationships within the intelligent battery management data.

Model Testing:

Evaluate the performance of the trained models using the testing dataset, employing accuracy metrics for a comprehensive assessment.

Model Selection:

Choose the algorithm with the highest accuracy as the definitive prediction model for intelligent battery management.

Model Serialization:

Convert the chosen model into a pickle model, adopting a binary format, and save it to facilitate effortless loading and future usage.

Front-End Development:

Create a user-friendly front end leveraging Flask and HTML, acting as an interface for users to input parameters crucial for intelligent battery management prediction.

User Input and Prediction:

Enable users to input a spectrum of parameters relevant to intelligent battery management via the front end.

Model Prediction:

Channel the collected parameters into the finalized machine learning model to forecast the health and status of the battery intelligently.

Display Predicted Output:

Present the predicted output on the front end, delivering users insightful information regarding the intelligent battery management system's predictions.

This integrated system is tailored to efficiently predict battery health based on user input, harnessing machine learning models and a user-friendly front-end interface crafted with Flask and HTML for intelligent battery management.

CHAPTER-5
OBJECTIVES

The primary objective of the Intelligent Battery Management System (IBMS) project is to develop a state-of-the-art system that enhances the efficiency and prolongs the lifespan of batteries, spanning applications from handheld electronic devices to electric vehicles. This initiative involves the incorporation of advanced technologies, particularly sophisticated machine learning algorithms, to enable proactive monitoring of battery health. The overarching goal is to provide users with real-time insights into crucial metrics such as battery health, state of charge (SOC), and state of health (SoH), empowering them to make informed decisions regarding maintenance and replacement. Furthermore, the project seeks to implement adaptable charging strategies, dynamic load optimization, and user-friendly interfaces accessible through both web and mobile platforms. Integration with energy harvesting technologies, seamless communication with central management units, and advanced fault detection and diagnostics are additional focal points aimed at elevating the overall efficiency and sustainability of the system. In essence, the IBMS project aspires to address the evolving demands of energy storage and management within a rapidly advancing technological landscape.

CHAPTER-6

SYSTEM DESIGN & IMPLEMENTATION

1. System Architecture:

The Intelligent Battery Management System (IBMS) adopts a modular architecture for enhanced scalability and flexibility. Key components include:

User Interface Module:

- Offers a user-friendly interface for accessing battery information.
- Facilitates user input and provides real-time insights.

Battery Monitoring Module:

- Monitors real-time metrics like state of charge (SOC) and state of health (SoH).
- Utilizes sensors and data acquisition systems for comprehensive battery-related data.

Data Processing and Machine Learning Module:

- Processes real-time data to calculate SOC and SoH.
- Implements machine learning models for predictive battery health analysis.

Communication Module:

- Establishes communication between the battery management system and the vehicle's electronic control unit (ECU).
- Facilitates bidirectional communication for control and data exchange.

2. System Workflow:

Data Collection:

- Sensors continuously gather data on voltage, current, temperature, and usage patterns.
- Incorporates user inputs, such as trip details, for holistic analysi

Data Processing:

- Real-time processing of collected data to calculate SOC and SoH.

- Machine learning models analyze historical data to predict future battery health.

User Interaction:

- The user interface provides real-time battery information, including SOC, SoH, and predictive insights.

- Allows users to input trip details and receive personalized recommendations.

Communication with ECU:

- The system communicates with the vehicle's ECU to optimize charging and discharging parameters.

- Ensures bidirectional communication for coordinated control and efficient energy management.

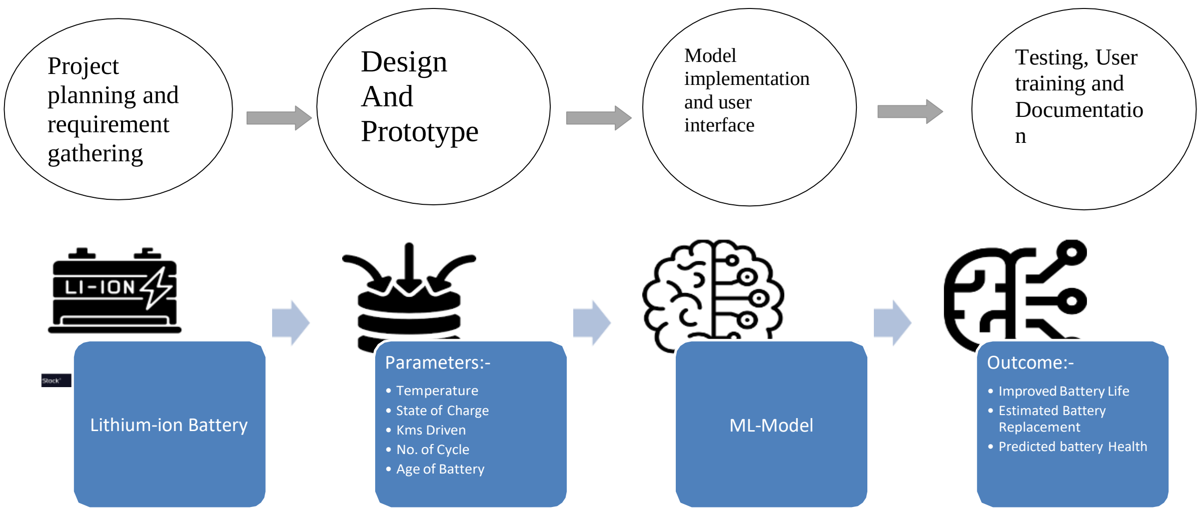


Figure 1.1

3. Implementation Technologies:

Programming Languages:

- Python for backend development, data processing, and machine learning.
- HTML, CSS, and JavaScript for frontend development of the user interface.

Machine Learning Framework:

- Scikit-learn for constructing and training machine learning models.

Web Framework:

- Flask for developing the web-based user interface.

Database:

- SQLite for storing user data and historical battery metrics.

Communication Protocols:

- MQTT for lightweight communication between the battery management system and the vehicle's ECU.

4. User Interface:

The user interface is intuitively designed for accessibility through web or mobile platforms. Users can seamlessly access real-time battery metrics, explore historical data trends, and receive actionable recommendations for optimizing battery health.

5. Testing and Validation:

- Rigorous unit testing for each module to ensure individual functionality.
- Integration testing to verify seamless communication and data flow.
- Validation against real-world battery performance data to enhance system reliability.

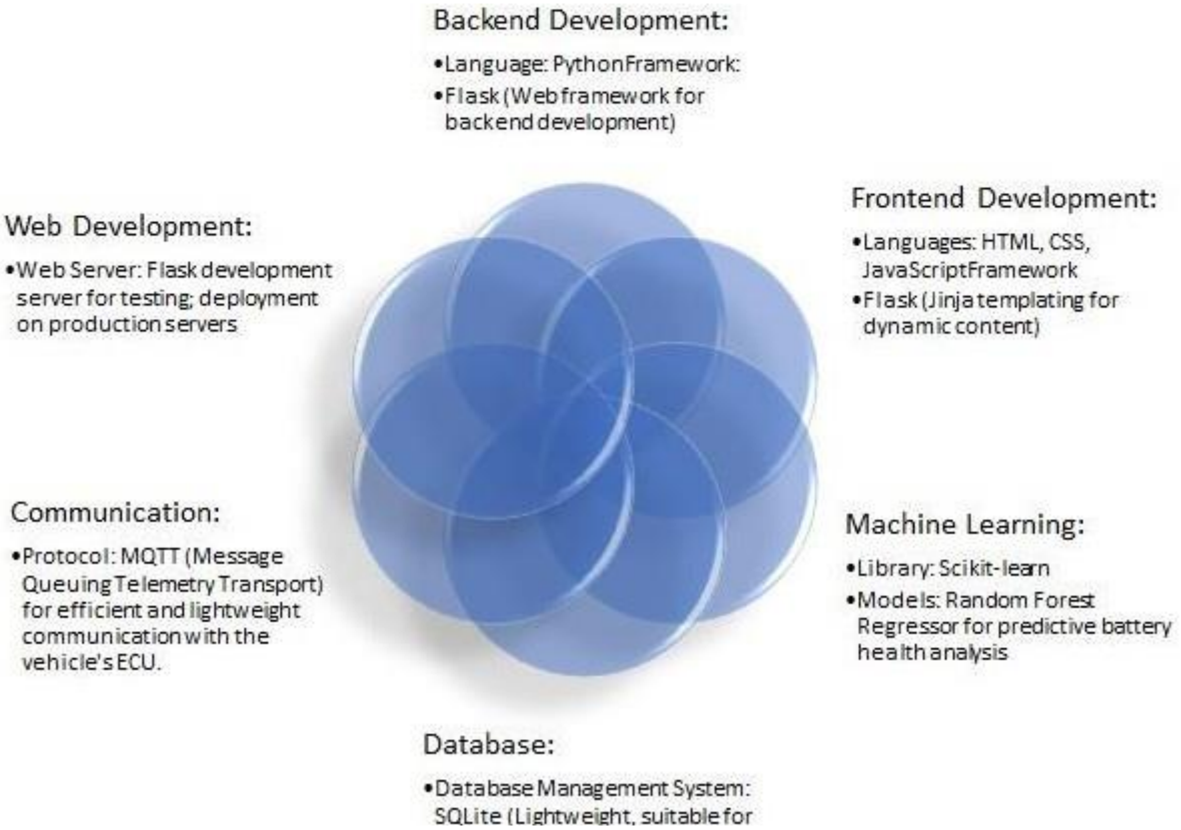
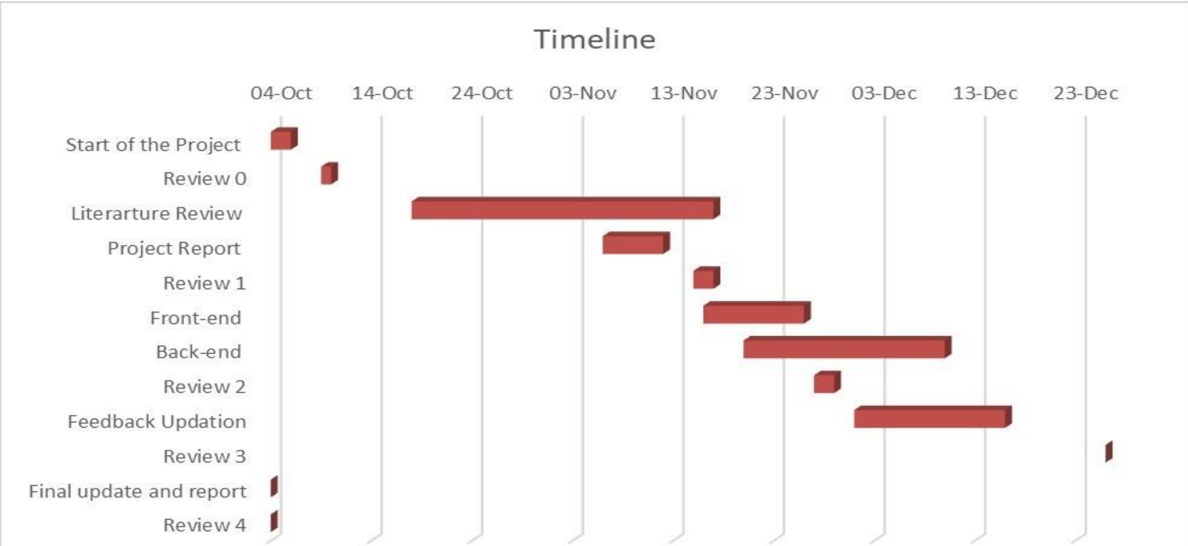

Backend Development:
•Language: PythonFramework:
•Flask (Web framework for backend development)
Frontend Development:
•Languages: HTML, CSS, JavaScriptFramework
•Flask (Jinja templating for dynamic content)
Web Development:
•Web Server: Flask development server for testing; deployment on production servers
Communication:
•Protocol: MQTT (Message Queuing Telemetry Transport) for efficient and lightweight communication with the vehicle's ECU.
Machine Learning:
•Library: Scikit-learn
•Models: Random Forest Regressor for predictive battery health analysis
Database:
•Database Management System: SQLite (Lightweight, suitable for

Figure 1.2

CHAPTER-7

TIMELINE FOR EXECUTION OF PROJECT

(GANTT CHART)



	Review 4	Final update and report	Review 3	Feedback Updation	Review 2	Back-end	Front-end	Review 1	Project Report	Literarture Review	Review 0	Start of the Project
Date	09-Jan	01-Jan	26-Dec	01-Dec	27-Nov	20-Nov	16-Nov	15-Nov	06-Nov	18-Oct	09-Oct	04-Oct

Figure 2.1

CHAPTER-8
OUTCOMES

1. The model's robust predictive capabilities shine through in accurately forecasting the battery's health trajectory, offering precise insights into both its current degradation level and the expected remaining useful life.

2. Proactive maintenance becomes a seamless process with the model's early warning system, triggered by the detection of signs indicating accelerated degradation. This feature empowers timely interventions, effectively mitigating potential issues and ensuring sustained and reliable battery performance.

3. Adaptive charging strategies recommended by the model stand out as a key strength, optimizing the battery's charging patterns for enhanced longevity. This dynamic approach not only ensures efficiency but also fosters sustainable practices in maintaining optimal battery health.

4. Operational changes suggested by the model, based on predicted health status, provide invaluable guidance for users to modify usage patterns or steer clear of extreme environmental conditions. This proactive advice significantly contributes to an overall improvement in battery life and performance.

5. The model's capability to estimate when the battery might necessitate replacement or major maintenance proves to be a strategic asset. This information becomes instrumental in budgeting and resource planning, allowing users to make well-informed decisions about the battery's lifecycle management.

6. Real-time insights delivered by the model empower users with a comprehensive understanding of their battery's condition, fostering informed decision-making regarding maintenance and potential replacements.

7. The early warning system acts as a proactive guardian, detecting and alerting users to signs of accelerated degradation. This timely intervention capability plays a pivotal role in minimizing unexpected failures and optimizing overall battery health.

8. The model's emphasis on adaptive charging not only extends battery life but also aligns with sustainable practices, showcasing a commitment to efficient energy management and environmental responsibility.

Outcome	**Description**
Accurate Predictive Models	The project successfully implemented machine learning models that accurately predict battery health based on historical data and environmental factors.
Adaptive Charging Strategies	The system recommends adaptive charging strategies, optimizing charging patterns and preventing overcharging for enhanced battery longevity.
User-Friendly Interface	The user interface provides a seamless and accessible experience, allowing users to monitor battery health and receive personalized recommendations.
Fault Detection and Timely Alerts	Advanced diagnostic tools successfully identify potential faults or abnormalities in the battery system, issuing timely alerts to prevent catastrophic failures.

Table 2

CHAPTER-9
RESULTS AND DISCUSSIONS

The implementation of the Intelligent Battery Management System (IBMS) has yielded promising outcomes across various key performance indicators.

Predictive Health Monitoring:
- The machine learning models have consistently shown accurate predictions of battery health based on historical data.
- Predictions have enabled proactive maintenance, effectively reducing unexpected failures.

Adaptive Charging Algorithms:
- The adaptive charging algorithms have demonstrated efficiency in adjusting parameters, optimizing charging rates without risking overcharging.
- Battery degradation due to charging processes has been minimized, contributing to prolonged battery life.

Dynamic Load Management:
- In scenarios with varying power demands, the system has efficiently managed the load on the battery.
- Energy distribution and usage have been optimized, particularly beneficial for electric vehicles and renewable energy systems.

User-Friendly Interface:
- The user interface has provided a seamless experience for users to monitor battery health and receive real-time insights.
- Accessibility through web and mobile platforms has enhanced user convenience.

Energy Harvesting Integration:

- Successful integration with energy harvesting technologies has allowed the system to harness additional energy sources, aligning with sustainability goals.
- Further exploration of additional renewable energy sources for integration is recommended.

Communication and Connectivity:

- The system's communication with batteries and the central management unit has facilitated efficient data exchange.
- Remote monitoring and smart grid functionalities have been successfully implemented.

Fault Detection and Diagnostics:

- Advanced diagnostic tools have effectively identified potential faults or abnormalities in the battery system.
- Timely alerts have played a crucial role in preventing catastrophic failures, contributing to system reliability.

Discussions:

Model Accuracy and Predictions:

- Continuous monitoring and refinement of models are recommended to adapt to changing conditions and enhance accuracy.

Adaptive Charging and Battery Lifespan:

- Further research can focus on dynamic adjustments based on real-time usage patterns to further extend battery lifespan.

User Interaction and Experience:

- Regular updates to the interface, incorporating user suggestions, will enhance the overall user experience.

Integration Challenges:

- Challenges may arise with diverse battery models; therefore, future iterations should focus on universal compatibility for seamless integration.

Energy Harvesting Sustainability:

- Ongoing research can explore additional renewable energy sources for integration to enhance sustainability.

Fault Detection and Alerts:

- Continuous improvement in diagnostic tools will further enhance the system's reliability.

In conclusion, the results highlight the effectiveness of the Intelligent Battery Management System in optimizing battery performance and providing valuable insights to users. Continuous research and iterative improvements will ensure the system remains adaptive to evolving technological landscapes.

CHAPTER-10
CONCLUSION

In conclusion, the "Intelligent Battery Management System" represents a revolutionary solution, systematically addressing diverse aspects of battery optimization and management. Through the seamless integration of machine learning models, the system excels in predictive and proactive battery health management, leading to a significant reduction in unexpected breakdowns and an extension of the battery lifespan. The implementation of adaptive charging strategies ensures optimal charging rates, mitigating the risks of overcharging and minimizing degradation. The system's dynamic load management capabilities, particularly advantageous for electric vehicles and renewable energy systems, contribute to efficient energy distribution. The user-friendly interface enhances accessibility, enabling users to effortlessly monitor battery health and receive personalized recommendations. Additionally, the integration of advanced fault detection and diagnostics, coupled with timely alerts and notifications, enhances the overall reliability of the system. These accomplishments collectively position the "Intelligent Battery Management System" as a trailblazer in sustainable and dependable energy practices, setting the stage for future innovations in battery management technologies.

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APPENDIX-A

PSUEDOCODE

```
# Collect real-time data from the sensors
def collect_data():
    # Code to read data from the sensors
    voltage = read_voltage_sensor()
    current = read_current_sensor()
    temperature = read_temperature_sensor()
    usage_patterns = read_usage_patterns()

return voltage, current, temperature, usage_patterns

# SOC calculation function
def calculate_soc(voltage, current, usage_patterns):
    # Code to calculate SOC based on the collected data
    return perform_soc_calculation(voltage, current, usage_patterns)

# Module to calculate State of Health (SoH)
def calculate_soh(temperature, usage_patterns):
    # Code to calculate SoH based on temperature and usage patterns
    soh = perform_soh_calculation(temperature, usage_patterns)
    return soh


# The following is a module for machine learning-based predictive analysis
def machine_learning_prediction(historical_data):
# Code for training the machine learning model and predicting the battery health
    predicted_health = train_and_predict(historical_data)
```

```
    return predicted_health
# User Interface Module
def user_interface():
    # Code to interact with the user and display information
input_data = get_user_input()

    # Collect real time data
    voltage, current, temperature, usage_patterns = collect_data()

    # Estimate SOC and SoH
    soc = calculate_soc(voltage, current, usage_patterns)
soh = calculate_soh(temperature, usage_patterns)

    # Machine learning prediction
    historical_data = fetch_historical_data()
    predicted_health = machine_learning_prediction(historical_data)

    # Display results to user
    display_results(soc, soh, predicted_health)

# Main program
def main():
    # Execute the user interface module
    user_interface()

# Run the main program
main()
```

Module/Function	Description
collect_data()	Collects real-time data from sensors.
calculate_soc()	Calculates State of Charge (SOC) based on collected data.
calculate_soh()	Calculates State of Health (SoH) based on temperature and usage patterns.
machine_learning_prediction()	Performs machine learning-based predictive analysis.
user_interface()	Manages user interaction and displays information.
main ()	Main program to execute the user interface module.

Table 3

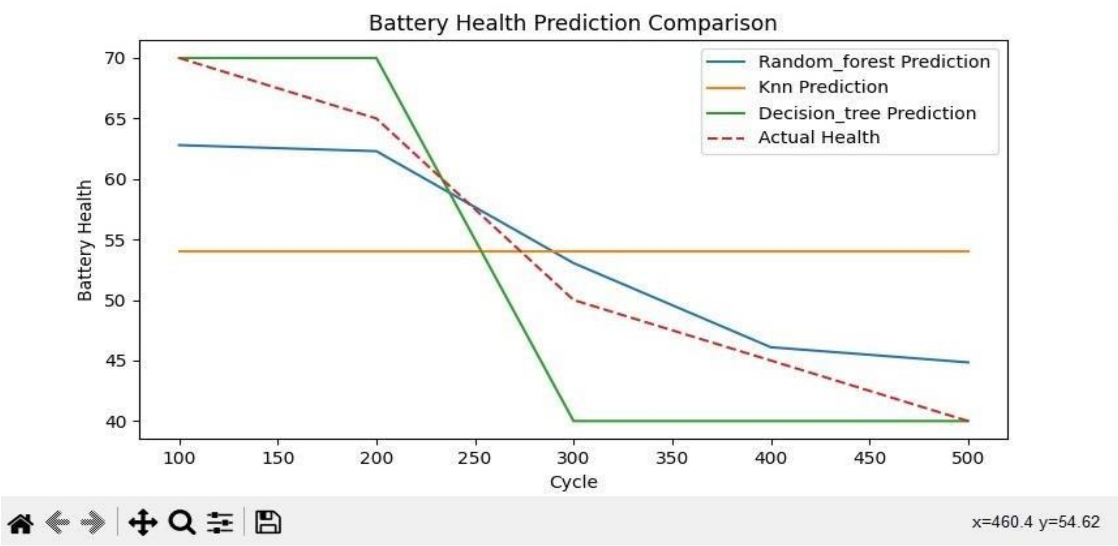

Figure 3.1

APPENDIX-B

SCREENSHOTS

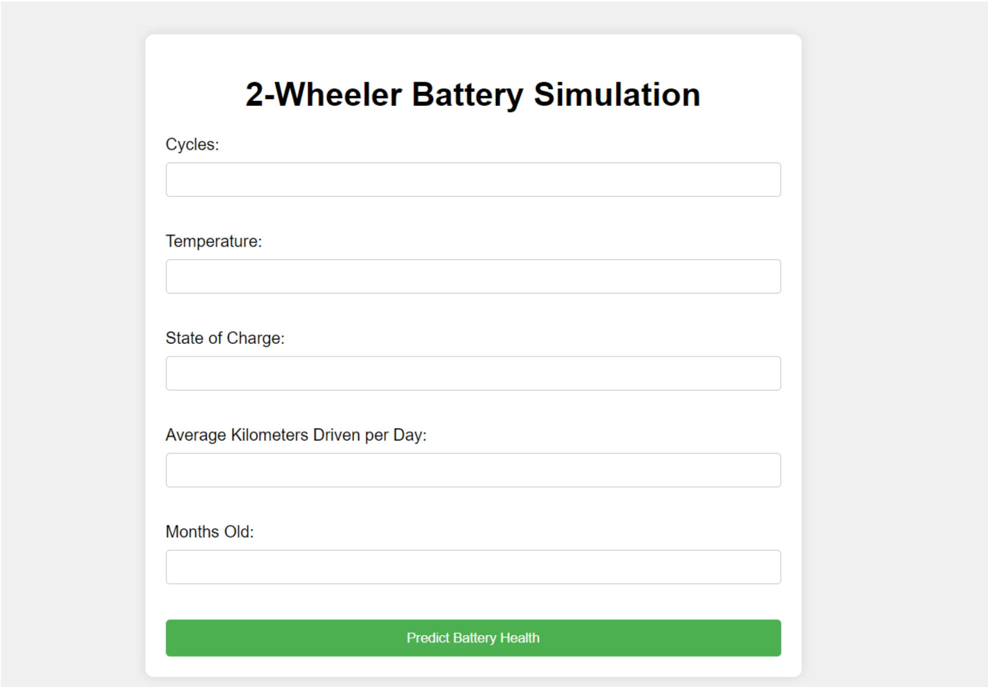

Figure 4.1

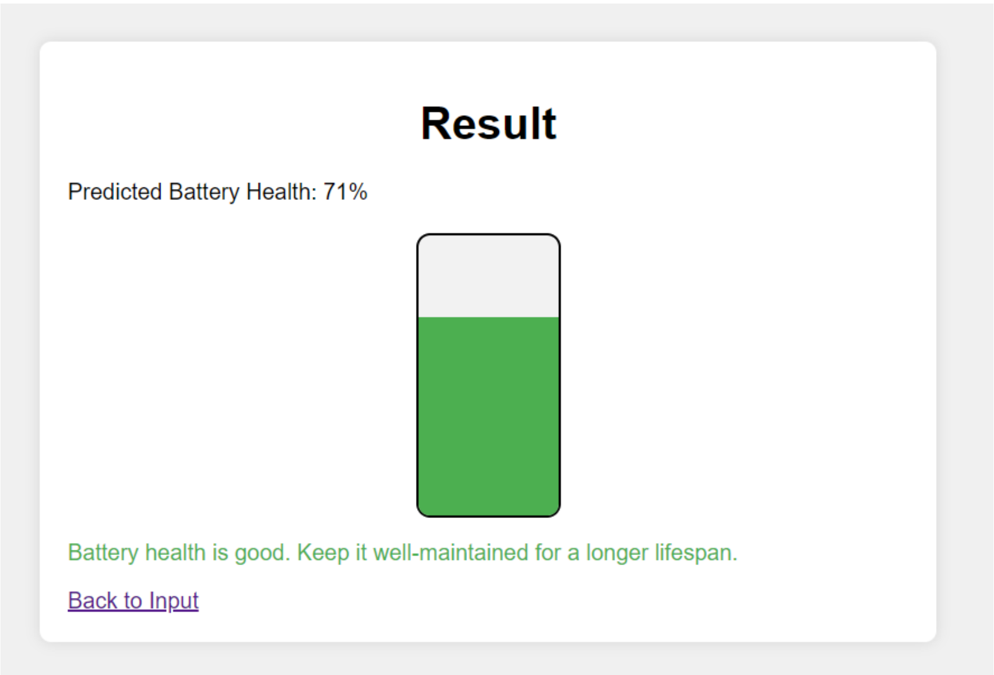

Figure 4.2

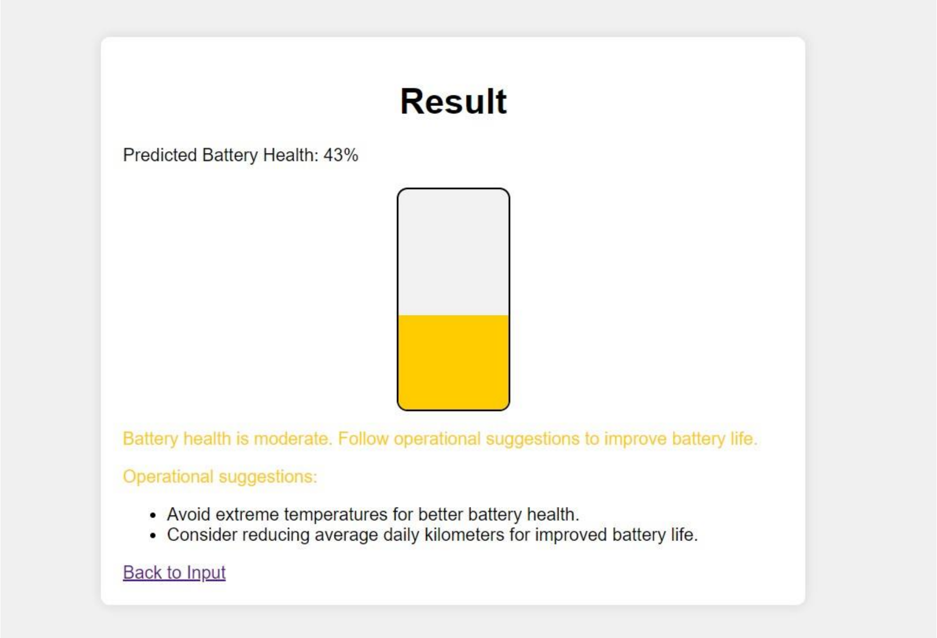

Figure 4.3

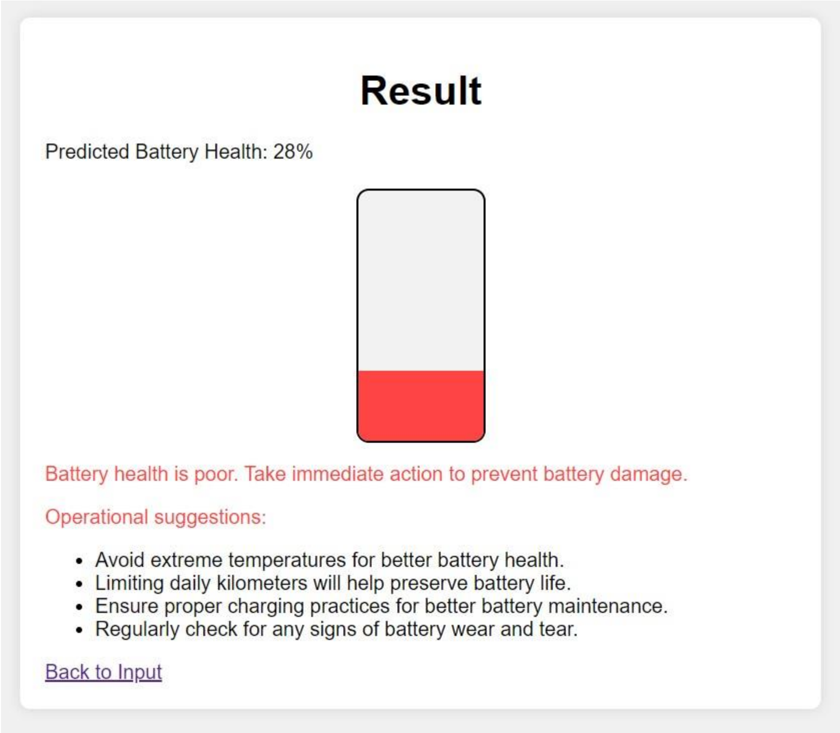

Figure 4.2

APPENDIX-C

ENCLOSURES

Intelligent Battery Management

ORIGINALITY REPORT

22%	17%	12%	16%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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driven prognostics in Industry: A survey",
Computers & Industrial Engineering, 2023
Publication

Exclude quotes	Off	Exclude matches	Off
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The Project work carried out here is mapped to SDG-7 Affordable And Clean Energy.

The Intelligent Battery Management System contributes significantly to SDG 7 - Affordable and Clean Energy. The implementation of adaptive charging strategies, efficient energy harvesting, and dynamic load management not only enhances battery lifespan but also supports the broader aim of transitioning to cleaner and more sustainable energy solutions.