BATTERY PROFILING AND CHARACTERIZATION FOR LITHIUM-ION BATTERIES

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Abstract— The optimization of power management and extension of battery life have become critical in the advancement of wireless technologies. Accurate profiling and characterization of lithium-ion batteries are essential for optimizing battery performance, enhancing user experience, and improving overall device efficiency. Traditional methods for battery profiling, which often rely on manual processes, struggle to manage the complexity of data associated with battery parameters and device performance metrics. In contrast, machine learning (ML) models offer a robust solution by excelling at handling complex data and uncovering hidden insights. This paper introduces a novel approach that leverages the Random Forest algorithm, an ensemble learning method known for its robustness in handling both classification and regression tasks. By combining multiple decision trees trained on diverse data subsets, the Random Forest method provides enhanced predictive performance and reduces the risk of overfitting. This approach enables more accurate predictions of battery health, under various conditions.

Implementing machine learning in battery profiling not only improves the accuracy of power management systems but also facilitates the development of smarter charging protocols tailored to user habits. This results in extended battery life, reduced frequency of charging, and overall better user satisfaction. Furthermore, this method has broader implications for the industry, contributing to more sustainable technology practices by reducing electronic waste through prolonged device lifespans.

Keywords: SoH, Random Forest, Arduino WeMOS D1 WiFi UNO

I. INTRODUCTION

The demand for the optimization of power management and battery life extension has increased significantly in wireless technology due to the proliferation of portable devices. Accurate profiling and characterization of battery performance are crucial for achieving these goals. Effective battery management not only enhances the overall user experience by reducing the frequency of charging but also improves the reliability and longevity of devices. This involves monitoring and analysing various battery parameters such as charge cycles, discharge rates, and thermal characteristics. Advanced algorithms and machine learning techniques are often employed to predict battery behaviour and optimize power usage dynamically. Furthermore, optimizing battery performance is essential for supporting the high energy demands of modern applications such as streaming, gaming, and augmented reality. As devices become more sophisticated, the need for efficient power management systems that can adapt to varying usage patterns becomes even more critical. This ensures that users can rely on their devices for extended periods without interruptions, thus maintaining productivity and satisfaction. Ultimately, accurate battery profiling and optimization contribute to the sustainable use of resources by minimizing battery degradation and reducing electronic waste.

Even though the popularity of lithium-ion batteries continues to soar in various applications, the characterization and profiling of these batteries remain a significant challenge. This complexity arises from the intricate relationship between device performance metrics and various battery parameters. Lithium-ion batteries require precise power management to ensure optimal performance and prolonged battery life, but accurately modelling these parameters is difficult due to the dynamic nature of usage patterns and environmental factors.

This work introduces a novel approach that leverages the power of machine learning to address these challenges. Traditional methods, which often rely on manual processes, struggle to manage the complexity and volume of data involved. These methods are limited in their ability to capture the multifaceted interactions between battery characteristics such as charge cycles, discharge rates, temperature, and overall health.

Machine learning models, particularly the Random Forest algorithm, offer a robust solution. Random Forest is an ensemble learning method that combines multiple decision trees, each trained on different subsets of the data. This technique enhances predictive performance and reduces the risk of overfitting by aggregating the predictions of numerous trees. The model excels in handling both classification and regression tasks, making it suitable for predicting battery health states and continuous variables like remaining battery life.

II. LITERATURE REVIEW

Yunus Koc et al., in their paper " State of Health Estimation for Li-Ion Batteries Using Machine Learning Algorithms" (2023)investigated the applications of (ML)machine learning algorithms to estimate the state of health(SoH) of lithium-ion batteries. By employing ML techniques like support vector machines(SVM), random forests, and Artificial Neural Networks (ANN), the study aims to leverage historical battery data to predict SoH accurately.

The practical implications of the research extend to various industries relying on Li-Ion batteries, including electric vehicles, renewable energy storage, and portable electronics. Accurate SoH estimation enables proactive maintenance strategies, such as timely battery replacement or reconditioning, thereby enhancing reliability, safety, and cost-effectiveness.

Zhong Ren, Changqing Du et al., in their paper “A Review of Machine Learning State-of-Charge and State-of-Health estimation algorithms for lithium-ion batteries”(2022) provided an extensive overview of machine learning (ML) algorithms utilized for the estimation of state-of-charge(SoC) and state-of-health(SoH) in lithium0ion batteries. They also discuss the significance of dataset quality and size in training ML models effectively. Practical implications of the reviewed algorithms are explored, including their application in battery management systems (BMS) for real-time monitoring and optimization. The review underscores the need for further research to address challenges such as model interpretability, scalability, and generalization to diverse battery chemistries and operating conditions.

Sungwoo Jo, Sunkyu Jung and Taemoon Roh et al., in their paper “Battery State-of-Health Estimation Using Machine Learning and Preprocessing with Relative State-of-Charge” investigates the utilization of machine learning (ML) techniques coupled with preprocessing methods involving relative state-of-charge (SoC) for estimating the state-of-health (SoH) of batteries. The study addresses the critical need for accurate SoH estimation in battery management systems (BMS) for various applications including electric vehicles and renewable energy storage. The paper explores the application of ML algorithms such as support vector machines (SVM), artificial neural networks (ANN), and decision trees for SoH estimation. Additionally, it introduces preprocessing techniques that leverage relative SoC data to enhance the accuracy of the ML models.

Niankai Yang, Ziyou Song, Heath Hofmann, Jing Sun et al., in their paper "Robust State of Health Estimation of Lithium-Ion Batteries Using Convolutional Neural Network and Random Forest” (2022) proposes a novel approach for accurately estimating the state of health (SoH) of lithium-ion batteries. The study addresses the growing demand for reliable battery management systems (BMS) in various applications, including electric vehicles and renewable energy storage. The paper introduces a hybrid model combining convolutional neural networks (CNN) and random forest algorithms for SoH estimation. CNNs are well-suited for processing spatial data, making them ideal for analyzing battery images or spatial features, while random forests offer robustness and interpretability in handling structured data.

Zheng Chen, Mengmeng Sun, Xing Shu, Jiangwei Shen, Renxin Xiao et al., in their paper” On-Board State of Health Estimation for Lithium-ion Batteries Based on Random Forest”(2022) explores a method for estimating the state of health(SoH) of lithium-ion batteries directly on board the battery system. This approach is crucial for real-time monitoring and management of battery health, particularly in applications such as electric vehicles and renewable energy systems.The study focuses on utilizing random forest algorithms, a type of ensemble learning method, for SoH estimation. Random forests are well-suited for handling complex datasets and can provide robust predictions even in the presence of noise or uncertainty. The findings of the study highlight the effectiveness of the random forest approach for on-board SoH estimation, offering practical implications for implementing battery management systems in real-world applications.

III. IMPLEMENTATION DETAILS

The proposed system for finding SoH of battery involves Random Forest Algorithm, Arduino WeMOS D1R1 UNO, IoT, a web page using Flask and 16*2 LCD Display. The microcontroller acts as the central device and facilitates communication between the PC and LCD Display. The software implementation utilizes the Arduino Integrated Development Environment (IDE), which provides a user-friendly interface for programming the Arduino WeMOS microcontrollers. The source code is developed using the Arduino programming language and libraries such as the Scikit-Learn and Panda libraries. The web page is created using Flask and input is obtained through it. The HTTP protocol in IoT is utilized for data exchange between the microcontroller and PC. The percentage of health and the condition of the battery is displayed in the LCD. The results are analyzed to validate the feasibility and effectiveness of the proposed system. The accuracy of the algorithm is found, and the SoH algorithm is integrated into the TWS system

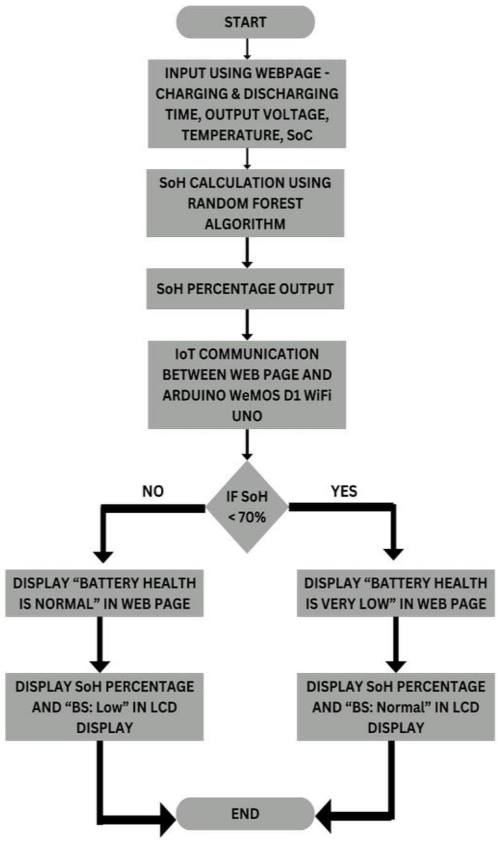

Fig. 1 Workflow of the proposed work

On the user side, input is obtained using a web page. The required inputs are charging time, discharging time, output voltage, temperature and SoC of the battery. The SoH is calculated using the algorithm and the status of health is displayed on the web page. The SoH value is pushed to an IoT server. Communication between the server and Arduino WeMOS D1R1 UNO is established using HTTP protocol. Arduino WeMOS D1R1 UNO requests the SoH and sends the response of the server to the LCD it is interfaced with.

The LCD displays the SoH percentage and battery status

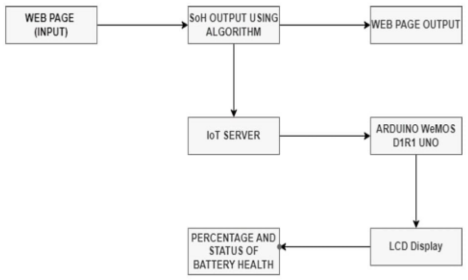

Fig. 2 Block Diagram of the proposed work

The system design is implemented. The SoH of the battery is classified into two categories – normal and low, based on the input provided by the user. The web page gets the input from the user. Communication between the server, Arduino WeMOS D1R1 UNO and the algorithm is established using WiFi. The Arduino WeMOS D1R1 UNO is interfaced with the LCD. The data transfer between the PC and Arduino WeMOS D1R1 UNO occurs using IoT communication via HTTP protocol.

A. Initial Setup

The web page is implemented using Flask framework. The values of charging time, discharging time, output voltage, temperature and SoC are to be entered as the input.

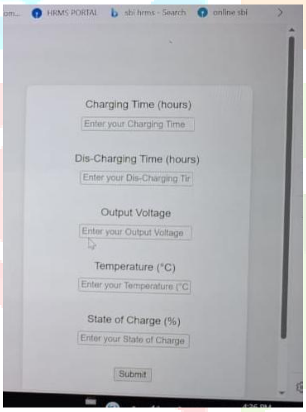

Fig. 3 Web page for input

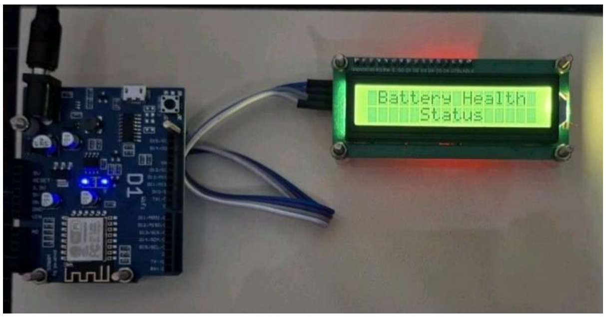

Fig. 4 Initial Setup of the system

B. Battery Health Normal

If the calculated SoH is greater than 70%, the health is classified as “Normal”. The web page displays a general statement regarding the health of battery, “Battery Health is Normal”. The LCD displays the SoH percentage and the battery status as “Normal”.

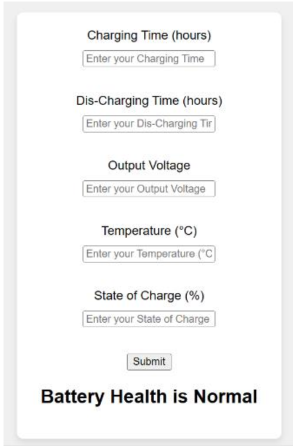

Fig. 5 when the battery health is normal

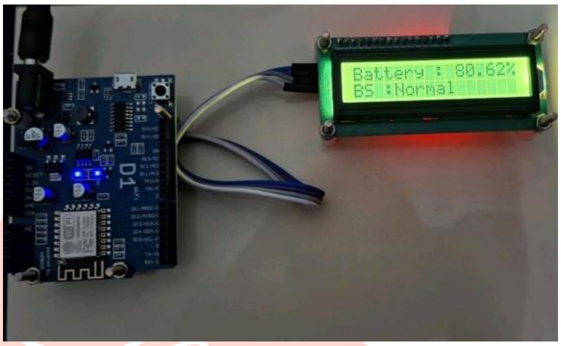

Fig.6 LCD Display which shows the battery health as normal

C. Battery Health Low

If the calculated SoH is less than 70%, the health is classified as “Low”. The web page displays a general statement regarding the health of battery, “Battery Health is very Low”. The LCD displays the SoH percentage and the battery status as “Low”.

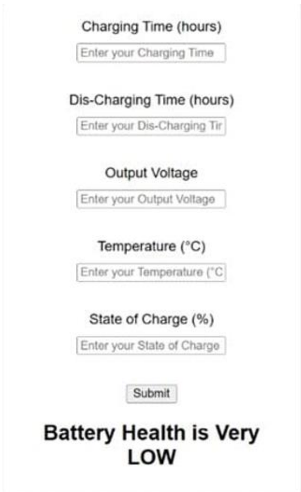

Fig. 7 When the battery health is low

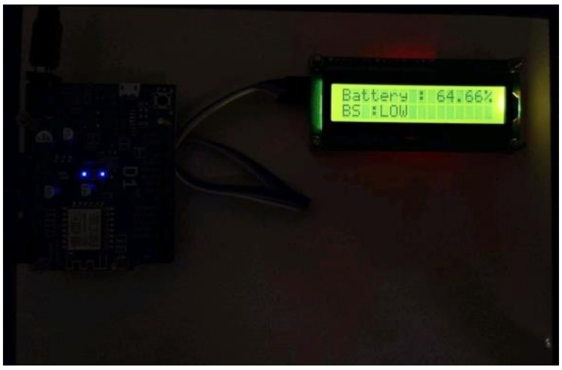

Fig. 8 LCD Display which displays the battery health as low

IV. CONCLUSION AND FUTURE SCOPE

In conclusion, the project successfully achieves its objective of finding the SoH of the battery of the TWS system. By integrating the Arduino WeMOS D1 WiFi UNO, Random Forest Algorithm, LCD Display and IoT , the system allows users to view the percentage of health of the battery and its condition . Throughout the project, various components and technologies were utilized effectively. HTTP Protocol in IoT facilitated reliable and low-power connectivity between the algorithm and the user. The Arduino WeMOS D1 WiFI UNO boards served as the central microcontrollers, handling data processing and communication tasks. The integration of the LCD Display and the SoH algorithm provided the users with the details of State of Health of the battery. The webpage created using Flask Framework acts as an user friendly interface, enhancing user interaction and convenience. There are several potential future works that could be considered, which includes expanding the user interface to include more detailed visualizations of battery health metrics over time. Graphs and charts could provide insights into battery degradation trends, helping users make informed decisions about battery replacement or maintenance, implementing remote monitoring capabilities using IoT connectivity to allow users to check battery status and receive alerts remotely. This could include notifications for low battery health levels or abnormal behaviour, enabling timely intervention and troubleshooting, and Developing algorithms to provide personalized recommendations for optimizing battery health and prolonging battery life. This could include suggestions for charging patterns, usage habits, and environmental factors that impact battery performance

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