Applications of Artificial Intelligent and Internet of Things in Electric Vehicle Battery Management System

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Abstract - **Batteries play a crucial role in electric vehicles, serving as the primary components responsible for the charging and discharging functions that supply power to the vehicle's motor. Without properly functioning batteries, an electric vehicle cannot operate efficiently. Variations in current and voltage have a direct impact on the battery system, making accurate predictions of these measurements challenging. The primary objective of this study is to observe and optimize Battery Energy Management Systems (BEMS) using the Internet of Things (IoT) and Artificial Intelligence (AI). The research also aims to explore effective strategies for managing batteries in electric cars. The choice of lithium-ion batteries is based on their higher energy density compared to conventional batteries. Given the costliness of batteries in electric vehicles, there is a significant opportunity to enhance predictions of Battery State of Health (SOH) and State of Charge (SOC) through AI-Powered Cloud Services, promoting cost-effectiveness and durability.The proposed system, driven by artificial intelligence and hosted on a cloud platform, has the capacity to adapt to evolving changes in battery health resulting from operational conditions. It continuously provides updated information to the battery management system, enabling it to make progressively improved management decisions. The neural network algorithm is implemented using a Python script, while Node-RED is employed for designing the user interface and login on the web server. In the realm of embedded devices, sensors, and mobile apps, the Internet of Things plays a significant role, and the MQTT protocol serves as a reasonably lightweight messaging solution.**

Keywords: Battery Management System, Electric Vehicle, Embedded System, Artificial Intelligent and Internet of Things.

I. Introduction

Implementing a Battery Management System (BMS) is crucial for monitoring battery life, charging and discharging processes, and overall system operation. Instruments used to measure physical quantities like temperature, electric current, and battery potential difference fall under this category. Analyzing these characteristics allows for the assessment of the battery's State of Charge (SOC) and State of Health (SOH). Ensuring the reliable and safe operation of lithium-ion batteries in electric vehicles requires the adoption of online monitoring and status assessment techniques. A battery monitoring system enables car owners and service providers to conveniently evaluate their vehicle's battery condition, regardless of location or time constraints. It allows for the timely identification and replacement of failing batteries before they impact others in the pack.The Battery Management System (BMS) supervises and controls individual cell attributes within the battery pack through continuous monitoring. The capacity of the battery pack can vary among cells, showing an upward trend as charging and discharging cycles increase. Advancements in notification system design have popularized the use of Internet of Things (IoT) technology in providing manufacturers and customers with real-time battery status information.

This proposed work is considered a recommended regular maintenance procedure, as suggested by manufacturers.Electric vehicles (EVs) have emerged as environmentally friendly transportation options, but their limited travel range, dependent on battery size and condition, remains a significant drawback. Monitoring the battery's condition is crucial for ensuring the safe and effective operation of EVs. The Internet of Things (IoT), offering real-time monitoring and remote device control, has gained attention across various industries, including automotive. Integrating IoT into EVs has the potential to enhance user satisfaction, improve battery performance, and increase efficiency.This paper proposes an IoT-based battery monitoring system tailored for electric vehicles, comprising battery sensors, a microprocessor, a wireless connection module, and a cloud server. Battery sensors collect voltage, current, and temperature data, transmitting it to the microcontroller. The microcontroller processes the data and sends it to the cloud server via the wireless connection module. Data is stored on the cloud server, allowing analysis to reveal information about the battery's condition. The suggested solution provides real-time monitoring, optimizing performance, and extending battery life. Additionally, the system's data can be utilized to forecast the remaining range of the EV, aiding drivers in route planning.

II. Methodology

The analysis is structured into three main categories: control system, battery monitoring system, and Internet of Things (IoT). In the IoT battery management system, real-time battery-related data, including voltage, current, and temperature, is promptly transmitted to the cloud during both charging and discharging processes. Subsequently, the system employs machine learning and artificial intelligence algorithms to analyze the data. If any battery malfunction or defect is detected, the driver or service provider is promptly notified. Figure 1 illustrates the overall processes.

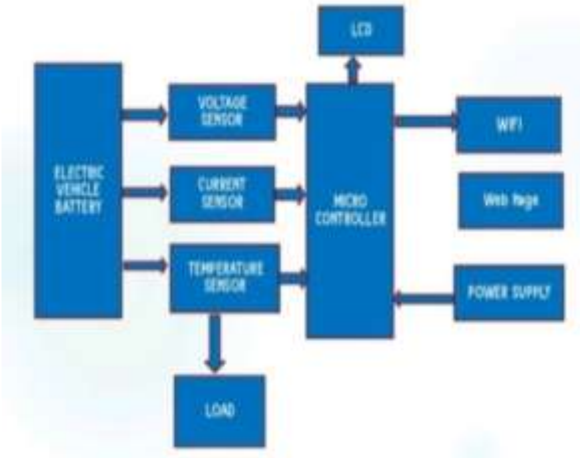

Fig.1. Block Diagram Representation

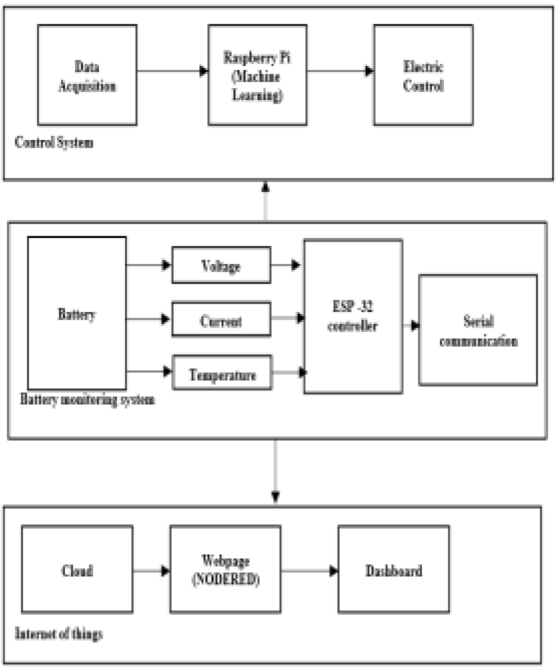

Fig.2. General Flow Diagram

Lithium-ion batteries are composed of one or more lithium-ion cells, along with a protective circuit board and additional components. When these cells are integrated into a device equipped with a safeguarded circuit board, they are commonly referred to as batteries. In the lithium-ion battery, the process involves the migration of lithium ions (Li+) from the cathode to the anode. Simultaneously, electrons exhibit migratory behavior in the external circuit, moving in the opposite direction. This electron movement generates the electrical current, powering the device. During discharge, the anode transports lithium ions to the cathode, facilitating an electron flow that contributes to powering the associated device.

III. Working Principle:

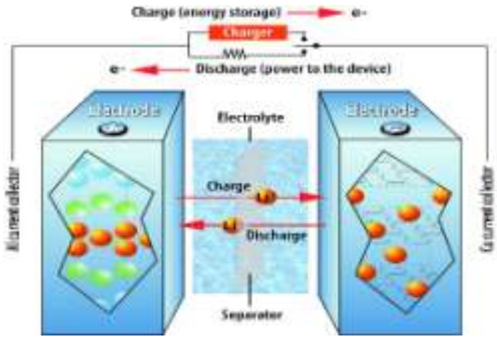

Fig. 3. Overview of Lithium-ion Battery

The operation of a rocking chair powered by lithium-ion batteries involves the conversion of chemical energy into electrical energy through redox reactions. Typically, a lithium-ion battery comprises two or more electrochemical cells that are electrically interconnected. During the charging of the battery, ions tend to migrate towards the anode, the negatively charged electrode. Upon complete discharge, lithium ions undergo a process of returning to the positive electrode, or cathode. This illustrates the reciprocal migration of lithium ions between the positive and negative electrodes during the charging and discharging process.Batteries are equipped with anode and cathode electrodes, where the cathode forms the positive terminal, and the anode forms the negative terminal.

The cathode in a lithium-ion battery primarily consists of a lithium emulsion, while the anode is predominantly composed of graphite. The movement of lithium ions within the battery occurs from the cathode to the anode, or from the positively charged electrode to the negatively charged electrode when the battery is electrically connected. This represents the charging process of the battery. During the discharge phase, lithium ions transfer from the anode to the cathode, corresponding to the movement of ions from the negative electrode to the positive electrode. This discharge process results in the generation of electrical energy.

IV. Sensors

This detector serves to calculate, cover, and determine voltage force. It can ascertain the presence of AC or DC voltage, offering the capability to take voltage as an input and provide switches, analog voltage signals, current signals, or audio signals as output.

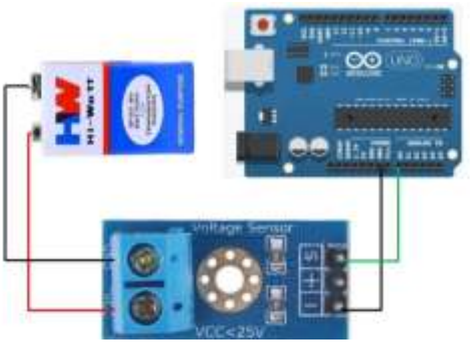

Fig.4. Voltage Sensor

Fig.5. Current Sensor

To measure the current flowing through a circuit, the ACS712 Current Sensor is employed as a detector, capable of detecting and quantifying the amount of current passing through the circuit.For device functionality, the ACS712 Current Sensor is crucial in accurately assessing current flow. In the context of physical processing, the Raspberry Pi, a Linux-based computer, features a set of GPIO (general-purpose input/output) pins. These pins enable the Raspberry Pi to both gather information about and manipulate electronic components. The ESP32, known as the Expressive Systems chip, is a significant component in this setup. It facilitates bidirectional Bluetooth and Wi-Fi connectivity for embedded devices. While manufacturers commonly refer to modules and development boards utilizing this technology as "ESP32," it's essential to recognize that ESP32 is fundamentally a chip.

Fig.6. ESP32 Chip

The Gated Recurrent Unit (GRU), a variation of the recurrent neural network (RNN), is utilized to address challenges associated with long-term memory and gradients during backpropagation. In comparison to the Long Short-Term Memory (LSTM), the GRU boasts a simpler structure with one fewer gate. Figure 7 illustrates the two gates in the GRU model: a reset gate and an update gate. This simplicity results in a model that requires fewer parameters, demands reduced computing power, and facilitates faster training. The reset gate manages the preservation of historical data, with a higher reset gate value indicating fewer disregards of past data. The update gate governs the integration of current and new input.The flow diagram depicted in Figure 7 highlights the effectiveness of GRU in handling large time series data.

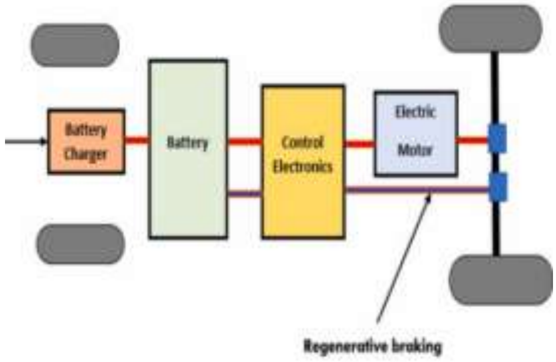

Fig.7. GRU Block Diagram

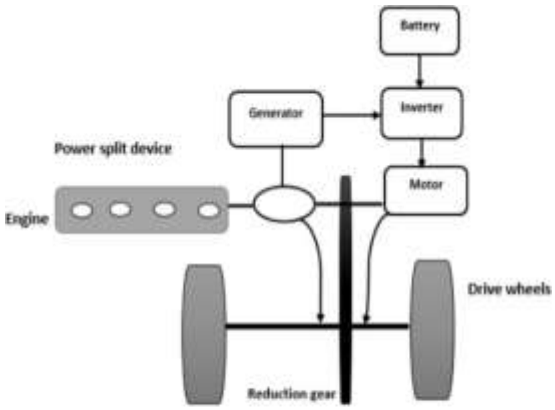

Fig.8. Architect of Electric Braking System

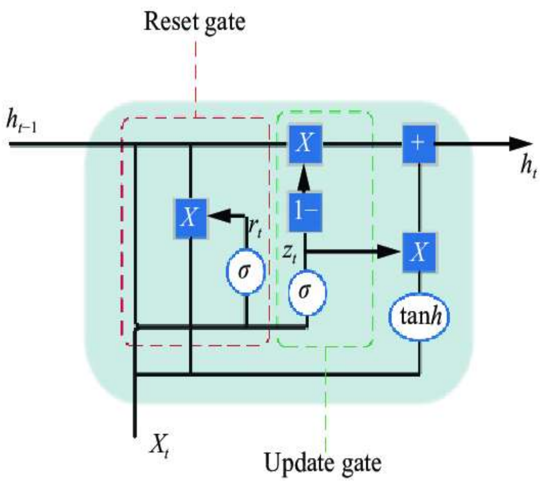

Fig.9. GRU Mathematical Representation

The GRU design allows for the utilization of the same parameters at different time steps, making it well-suited for one-dimensional time series data from batteries, encompassing voltage, current, and temperature.Shifting focus to Long-Short-Term Memory (LSTM), the memory cell in the Hidden Layer plays a pivotal role as the foundational building block of the neural network. It characterizes the transient dynamics within a group of objects, underscoring the significance of memory in item categorization. Hidden Layer 1 reflects variants through the connections between memory cells and gates, while Hidden Layer 2 dictates the frequency of a cell's state updates. The output layer integrates an LSTM block, relying on LSTM architecture for the recognition of a battery system.

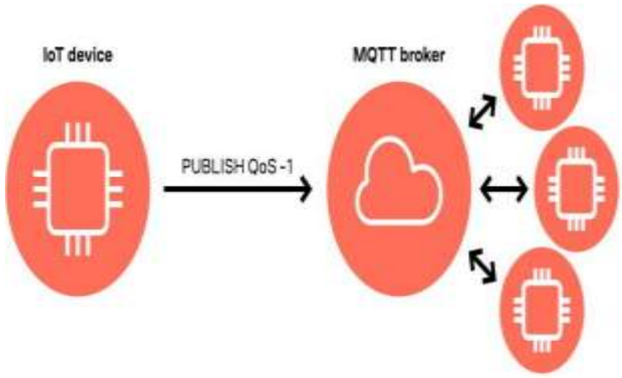

Fig.10. MQTT Cloud with IoT Device

Conclusion:

This research undertakes a thorough exploration of the battery management system, emphasizing two pivotal aspects: state of charge and state of health. The primary aim of this undertaking is to pinpoint the most cutting-edge AI technology applicable to battery management systems. Consequently, an exhaustive review of pertinent literature concerning these specific AI technologies is undertaken, with a special emphasis on the associated challenges. The selection of Li-ion batteries as the optimal energy storage solution for electric vehicles is driven by factors such as extended lifespan, diminished discharge rates, heightened efficiency, and superior power and energy densities. Our research focus is dedicated to scrutinizing and evaluating these crucial characteristics.To ensure the secure and dependable operation of batteries in electric vehicles, this study offers a comprehensive analysis of primary parameters and their respective roles in facilitating safe operation and the operational lifespan of a battery management system. These parameters are regularly updated on the webpage, and notifications are accessible on the dashboard. The IoT and artificial intelligence-based battery energy management system prove to be highly efficient.

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