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Early Detection of Fire Accident in Electric Vehicle using Battery Management System

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Abstract

In today's world, Electric Vehicles (EVs) have transfigured the automobile industry. EVs are the best means of transportation of people as they are easy to drive, convenient and make less noise. The Lithium-Ion Batteries (LIB) are used to power the vehicle. However, In recent years the main disadvantage of EVs are catching fire and becoming one of the most important fault in EVs. The primary cause of EVs catching fire are faulty Battery Management System (BMS), and improper venting mechanisms for cells to release heat. Over time, many fire detection and fire handling techniques have been proposed and developed that consists of sensor values, temperature, voltage which focuses mainly on battery health. Accordingly, in the proposed work consists of two phases. First phase performs exploratory data analysis on dataset and diagnosis the fault. In, Second phase Machine learning (ML) algorithms are used to check and detect the fire in advance.

Keywords: Battery Management System (BMS), Machine Learning (ML), Electric Vehicles (EVs), Datasets, Lithium-Iron Batteries (LIB).

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1. Introduction

The Vogue of electric vehicles (EVs) has significantly impacted the automobile industry. EVs are the key source of attraction for transportation. Most of the people use EVs, as they are easy to drive, eco-friendly and comfortable to travel. There are many reasons for switching from conventional vehicles to EVs. Conventional vehicles uses non renewable energy resources such as coal, petroleum, and natural gas which causes adverse effects in the environment and pollution which leads to increase in global warming, green house gas effect , leading to many health problems. Also, the use of EVs is cost efficient when compared to the conventional vehicles which uses petrol and diesel as its primary fuel which is highly expensive. The use of EVs have been replaced the combustion engine by an electric battery. The supremacy or merit of EV batteries are rechargeable batteries.

Fire is the major cause that does not make electric vehicles acceptable to everyone. Due to fire accidents there is a irreparable loss of human life and property. Many scientists studied that the fire may beyond its limit in summer due to overheating of the battery. The main reasons of EVs caught fire is due to electrical short circuits, gas leakage, use of an old battery, low maintenance, low cell quality, faulty charging, and overheating.

Thermal runaway is the prime cause of EVs being exposed to fire or explosion. It is the process in which one cell of the LIB catches fire, then the adjacent cell also catches fire and the Lithium-Ion cell goes into an uncontrollable heating state and results in fire. BMS is the electronic brain of the electric vehicle that controls and coordinates the battery's charging and discharging, overheating and safety operation. It alerts the user to take corrective measures in case of any problematic condition.

Over the period many different approaches have been discovered. Some of the Machine Learning Techniques such as Random Forest (RF), Logistic Regression (LR), K-Nearest Neighbour (KNN), Support Vector Machine (SVM), are employed in predicting and detecting the fire in advance which seems to give desirable results.

1.1. Problem Statement

In recent years , EVs involved in fire accidents do not have safety systems and also there is no availability of mechanism that can predict the fire early. Further, there is a need of functional safety mechanism to detect the thermal runaway within a traction of battery that warns the user about the error and gets a few minutes to leave the EV before dangerous situation occurs safely. An well organized early warning system is needed obtain a safety feature in the BMS of EVs. Also the optimization of BMS needs to be done to protect from hazards.

1.2. Contributions

To design and develop an enhanced algorithm that detects the fault and fire hazards in advance using various sensor values, Voltage values, temperature values, and external environment conditions. The paper aims to advance the integration of On-board Diagnostics (OBD) into vehicle systems. OBD functions as a user-friendly self-diagnostic tool equipped with reporting capabilities.

Battery storage holds paramount importance in Electric Vehicles (EVs) as it stores the requisite energy for their operation. Core tasks of Battery Management Systems (BMS) encompass monitoring parameters, determining State of Charge (SOC), and furnishing indispensable services for ensuring the safe operation of batteries. Consequently, BMS assumes a pivotal role in EVs, spurring continuous research endeavors aimed at refining system efficiency.

The primary objective of this paper is to develop an advanced BMS equipped with integrated OBD capabilities, aimed at fortifying the safety, reliability, and performance of EVs. Key objectives encompass enhancing fault detection, broadening reporting capabilities, optimizing battery performance, ensuring safe operation, and contributing to the ongoing research initiatives in BMS technology.

2. Literature Review

The proposed system successfully realized the monitoring and detecting of both temperature and voltage status of electric vehicle, but also sends out sound and light warning when temperature of a electric vehicle exceeds a safety limit to avoid fire accident [1]. There are several kinds of batteries available in the market such as Lithium-Iron batteries (LIB), Lead acid batteries, Nickel cadmium batteries (Ni-Cd), in the proposed system LIBs are used to charge the vehicle [2]. Over the time, It has been noticed that more than 30% of the electric vehicles are involved in fire accidents due to poor and faulty battery management system [3]. Fire accidents in electric vehicles leads to the irreparable loss to both human life and property. The fire detection and alarm systems are often capable of making an error. The proposed model detects the fire at smoldering stage and buzzes an alarm if an actual fire or smoke is detected. This system can obtain the desired results using sensors namely temperature, Infrared [4]. In the proposed system, The (BMS) not only detects the fire in advance it also monitors the health of battery, charging and discharging of battery to prevent thermal runaway and degradation of the Lithium-Ion batteries. The batteries are allowed to charge above its cutoff voltage to avoid over-discharging (current voltage is greater than the cutoff voltage). So, to avoid this problem the two layer fault diagnosis system is proposed. The first layer is to detect the discharge by comparing cutoff voltage with the battery voltage. The Second layer detects the previous discharge by extreme gradient boosting [5].

3. **Proposed Methodology**

3.1. Selection of fire related sensors and Data Collection

The proposed system consists of several types of sensors such as temperature, flame, vibration, Infrared. However, fire detection sensors play a significant role and also these sensors are required for continuous monitoring and managing the performance level of the battery. BMS with advanced features helps in increasing the battery performance and readings of the sensors are integrated with the BMS. In the proposed system one of the machine learning techniques called Automatic Speech Recognition (ASR) which is used for voice to text conversion for the user interface. LiFePO4 a type of LIB is used as power for the vehicle in our proposed system. SW18020P is used as Vibration Sensor-used to detect the vibration of the engine. DS18B20 is used as Temperature Sensor-used to monitor the temperature of both battery and vehicle.

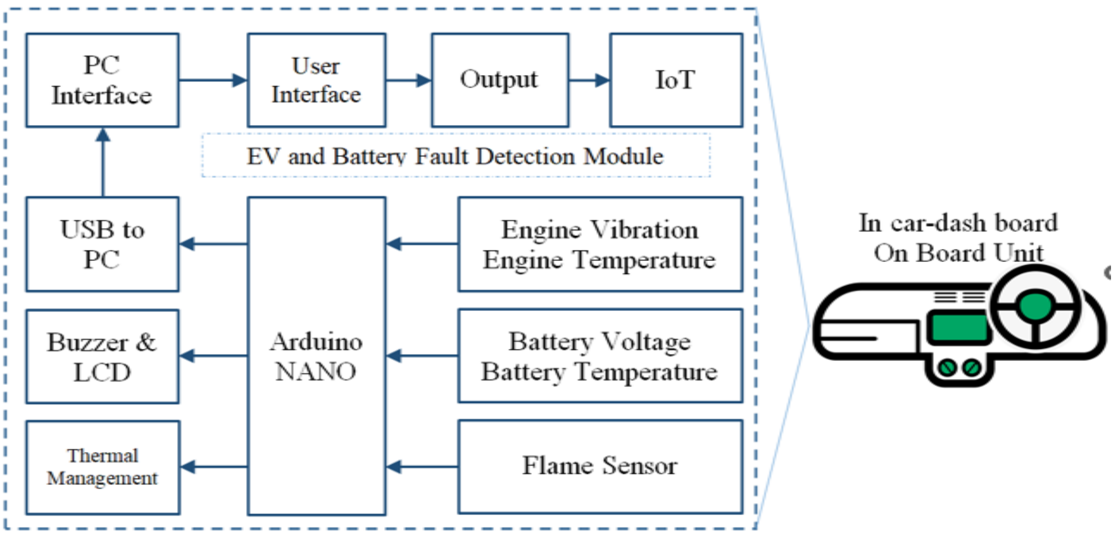

Figure.1 Block Diagram

3.2. Thermal Management

The thermal management block in an electric vehicle encompasses a range of technologies and components designed to regulate the temperature of critical systems, primarily the battery pack, electric motor, power electronics, and other key components. Its primary objectives are to maintain operating temperatures within safe limits, optimize energy efficiency, and extend the lifespan of the vehicle's components. Its major functions are Motor Cooling, Temperature Regulation, Efficiency Optimization, Battery Health Management, Safety Assurance.

3.3. Flame Sensor

A flame sensor block is a crucial component in early fire accident prevention systems for electric vehicles (EVs). Its primary function is to detect the presence of flames or high temperatures in critical areas of the vehicle, such as the battery pack, electrical wiring, or other components prone to overheating.

3.4. Battery Voltage and Battery Temperature

A battery voltage and temperature monitoring block is an essential component of early fire accident prevention systems in electric vehicles (EVs). This block is responsible for continuously monitoring the voltage levels and temperature of the vehicle's battery pack, which are critical indicators of its health and safety.

3.5. Engine Vibration and Engine Temperature

This component monitors the vibrations produced by the electric motor or other moving parts within the vehicle's propulsion system. Unusual vibrations can indicate mechanical stress, loose components, or malfunctions within the motor assembly. The engine temperature block continuously measures temperature levels and triggers alarms or initiates cooling mechanisms to maintain safe operating conditions and prevent thermal incidents.

4. Results and Discussion

The technological landscape is evolving at a rapid pace, with innovations emerging constantly to meet the demands of an increasingly digital world. From powerful processors to advanced operating systems and specialized programming languages, the components and tools powering our devices play a crucial role in shaping our digital experiences. In this article, we'll delve into the specifications of a computing system, exploring each component's significance and how they contribute to overall functionality.

The Intel(R) Core(TM) processor, running at 1.60GHz, serves as the computing powerhouse of the system. With its high processing speed and efficiency, it enables swift execution of tasks ranging from basic computing functions to complex computational processes. Whether handling everyday office tasks, multimedia editing, or running resource-intensive software, the processor's capabilities are fundamental to the system's performance.With 4GB of RAM, the system has ample memory capacity to handle multitasking and run multiple applications simultaneously. RAM serves as temporary storage for data and program instructions that are actively being used by the processor. A sufficient amount of RAM ensures smooth operation and responsiveness, preventing slowdowns or system crashes when navigating between programs or working on memory-intensive tasks.

The 2GB hard drive provides storage space for the system's operating system, applications, files, and user data. While relatively modest in capacity compared to modern storage solutions, it is sufficient for basic computing needs. However, users may need to manage their storage space carefully to avoid running out of disk space. Additionally, advancements in solid-state drive (SSD) technology offer faster read/write speeds and increased reliability compared to traditional hard disk drives (HDDs), presenting opportunities for upgrading storage capabilities.

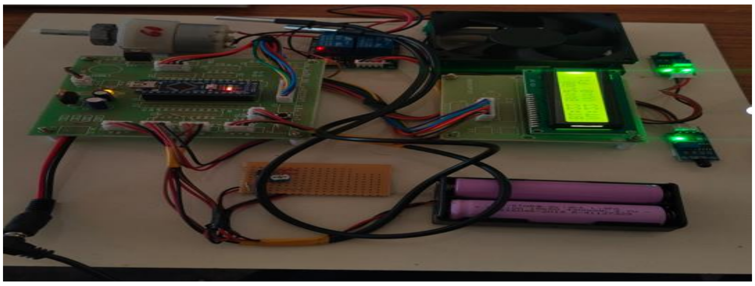

Figure.1. Proposed Output

The 8V, 4000mAh Lithium-Iron Phosphate battery is a robust and reliable power source, commonly used in portable electronic devices. Known for their high energy density, long cycle life, and enhanced safety features, LiFePO4 batteries are ideal for powering devices such as laptops, smartphones, and electric vehicles. The specified voltage and capacity ensure extended usage time and dependable performance, making it suitable for mobile computing applications.

The system supports either Windows 7 or Windows 10, providing users with a familiar and versatile computing environment. Both operating systems offer a range of features, security enhancements, and compatibility with a wide variety of software applications. Users can choose the version that best suits their preferences and requirements, ensuring seamless integration with their workflow and software ecosystem. The system supports programming languages such as C and C++, providing developers with powerful tools for software development and system programming. Known for their efficiency, speed, and versatility, C and C++ are widely used in various domains, including system software, application development, game development, and embedded systems programming. With access to these programming languages, users can create custom software solutions, perform system-level programming tasks, and develop complex algorithms to meet their specific needs.

The system is compatible with software tools such as Matlab and Arduino IDE, offering users versatile platforms for data analysis, algorithm development, and hardware prototyping. Matlab is a powerful numerical computing environment used for mathematical modeling, simulation, and data analysis, while Arduino IDE provides an intuitive interface for programming Arduino microcontroller boards. Together, these software tools enable users to design, prototype, and deploy a wide range of innovative projects and applications.

Table.1. System Configuration

S. No.	Part	Specification
1	Processor	Intel(R) Core(TM) 1.60GHz
2	RAM	4GB
3	Hard Drive	2GB
4	Lithium-Iron Phosphate Battery (LiFePO4)	8V,4000Ah
5	Operating System	Windows 7 or Windows 10
6	Programming Language	C , C++
7	Software and Interface	Matlab, Arduino IDE

In conclusion, the specifications outlined above represent a capable computing system equipped with essential components and tools for various computing tasks and applications. Whether for personal use, professional work, or educational purposes, the system offers versatility, performance, and reliability to meet the diverse needs of users in today's digital age.

5. Conclusion

This paper introduces an IoT-based Battery Management System (BMS) coupled with Fire Accident prevention utilizing Arduino Microcontroller for sensor integration and a user interface compatible with Matlab. The integration involves various sensors including Temperature Sensor, Voltage Sensor (V Sense), Flame Sensor, and Vibration Sensor. The system is designed to optimize battery usage, extend battery lifespan, and improve overall vehicle efficiency.

By integrating these sensors, the system enables detection, monitoring, and allows users to oversee the vehicle's status in real-time while receiving alerts promptly. The user interface displays real-time data on Battery Health, Battery Temperature, and Engine Temperature, offering users comprehensive insights into the vehicle's performance.

Utilizing cutting-edge technologies such as Arduino and MATLAB, we've developed a robust and intelligent system aimed at ensuring the safety of both passengers and vehicles. Looking ahead, further research and development efforts are necessary to enhance and expand upon the capabilities of our system, thereby contributing to the safety and sustainability of electric vehicles in the future.

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