

Fire Detection and Prevention System for Electric Powered Vehicles

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Abstract— The increasing adoption of electric vehicles (EVs) has raised significant concerns regarding fire safety, particularly due to the unique risks associated with lithium-ion battery systems. This research presents a comprehensive fire prevention and precaution system designed specifically for EVs, addressing the potential hazards posed by circuit malfunctions and short circuits. The proposed system integrates advanced detection technologies, including infrared monitoring, to identify early signs of thermal anomalies, alongside a robust suppression mechanism. This dual approach not only enhances the safety of passengers but also mitigates environmental risks associated with EV fires. The two types of threats - electrical hazards and traditional hazards, each equipped with tailored detection and suppression solutions. Through systematic testing and evaluation, this study demonstrates the effectiveness of the fire prevention system in reducing response times and improving overall vehicle safety. The findings underscore the necessity for proactive fire safety measures in the evolving landscape of electric mobility, ultimately contributing to safer urban environments and enhanced public confidence in electric vehicle technology.

Index Terms—component, formatting, style, styling, insert (key words)

I. INTRODUCTION

Over the last decade, the electric vehicle (EV) has significantly changed the car industry globally, driven by the fast development of Li-ion battery technology. However, the fire risk and hazard associated with this type of high-energy battery has become a major safety concern for EVs. This review focuses on the latest fire-safety issues of EVs related to thermal runaway and fire in Li-ion batteries. Thermal runaway or fire can occur as a result of extreme abuse conditions that may be the result of the faulty operation or traffic

accidents. Failure of the battery may then be accompanied by the release of toxic gas, fire, jet flames, and explosion. This paper is devoted to reviewing the battery fire in battery EVs, hybrid EVs, and electric buses to provide a qualitative understanding of the fire risk and hazards associated with battery powered EVs. In addition, important battery fire characteristics involved in various EV fire scenarios, obtained through testing, are analyzed.

For the full-scale EV fire test, limited data have revealed that the heat release and hazard of an EV fire are comparable to that of a fossil-fueled vehicle fire. Once the onboard battery involved in fire, there is a greater difficulty in suppressing EV fires, because the burning battery pack inside is inaccessible to externally applied suppressant and can re-ignite without sufficient cooling. As a result, an excessive amount of suppression agent is needed to cool the battery, extinguish the fire, and prevent reignition. By addressing these concerns, this review aims to aid researchers and industries working with batteries, EVs and fire safety engineering, to encourage active research collaborations, and attract future research and development on improving the overall safety of future EVs. Only then will society achieve the same comfort level for EVs as they have for conventional vehicles.

II. EASE OF USE

Building an Arduino-based bot is highly accessible for beginners due to its modular design, intuitive programming environment, and extensive community support. The hardware setup leverages plug-and-play components like motors, ultrasonic sensors, and motor drivers (e.g., L298N), which can be assembled without soldering using jumper wires and breadboards, while pre-made chassis kits simplify

mechanical integration. The Arduino IDE's user-friendly interface and simplified C/C++ syntax lower the programming barrier, with pre-built libraries (e.g., New Ping for sensors) handling complex tasks and sample code widely available for basic functions like obstacle detection or motor control. While challenges such as sensor calibration or power management may arise, they are well-documented and solvable with online tutorials. The platform's scalability allows seamless upgrades from adding Bluetooth modules to integrating advanced controllers making it adaptable for both initial projects and future expansions. Coupled with a vast repository of tutorials, forums, and troubleshooting guides, the Arduino ecosystem ensures that even novices can achieve functional results quickly while offering room for growth into more sophisticated applications.

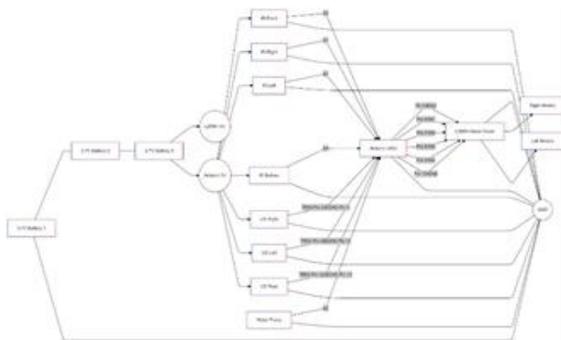
III. OBJECTIVE

Testing alternate methods to prevent and manage traditional and electrical fire hazard by:

- sensing and moving vehicle to safe distance
- extinguishing electric fire in battery region both without human intervention

The goal is to design and build an autonomous Arduino-based robot capable of performing tasks like obstacle avoidance and line following using modular hardware (e.g., ultrasonic sensors, motors, motor drivers) and programmable logic. This project aims to provide hands-on experience in integrating hardware (sensors, actuators) with software (Arduino code), fostering skills in electronics, programming, and problem-solving, while creating a scalable platform for future upgrades like wireless control or advanced navigation algorithms.

IV. METHODOLOGY



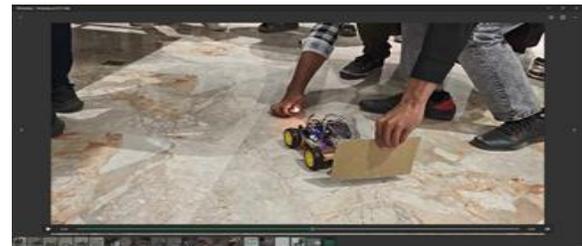
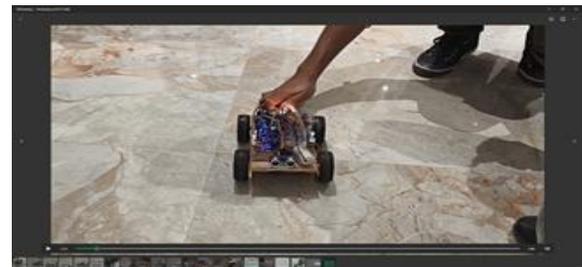
Arduino uno-> as micro –controller

- L298N motor driver-> helps control B.O motors
- IR sensors (front, right, battery and left) -> to sense fire and respond to as per program
- Us sensors (right, left and rear) -> to detect and avoid obstacles as per program
- Battery with modules -> 4 batteries of 3.7v total=14.8v to supply power to circuit

V. APPROACH

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- sensing and moving vehicle to safe distance
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VI. TESTING





To validate the bot's functionality, preliminary tests included sensor calibration (e.g., tuning ultrasonic sensor thresholds for reliable obstacle detection), motor driver performance checks (ensuring balanced PWM signals for smooth forward/backward movement), and line-follower accuracy trials (adjusting IR sensor sensitivity to track paths under varying lighting). Code logic was stress-tested via edge-case scenarios, such as sudden obstacles or sharp turns, while power stability was verified under load to prevent Arduino resets. Iterative debugging resolved issues like sensor noise interference and motor synchronization delays, ensuring reliable autonomous operation

VII. SCALABILITY

Challenges for Consumer Vehicle Implementation:

1. Safety & Regulatory Requirements:
 - Current system lacks redundancy required for automotive safety standards
 - Needs to comply with ISO 26262 (Functional Safety for Road Vehicles)
 - Requires ASIL (Automotive Safety Integrity Level) certification
 - Must integrate with existing vehicle systems (CAN bus, ECU)
2. Hardware Scaling:
 - Current sensors insufficient for automotive use
 - Speed/timing values need significant adjustment
 - Power management system inadequate for automotive use
 - Limited emergency response capabilities
- Key Adaptations for Consumer Vehicles:
 - Enhanced Safety Features:
 - Multi-level redundancy in critical systems
 - Advanced sensor fusion (LIDAR, RADAR, cameras)
 - Real-time threat assessment

- Emergency response protocols
- Driver monitoring systems
- Integration Requirements:
 - CAN bus interface for vehicle communication
 - ECU integration capabilities
 - Compliance with automotive standards
 - Support for OTA (Over-The-Air) updates
 - Diagnostic and maintenance systems
- Performance Improvements:
 - Real-time processing capabilities
 - Parallel sensor data processing
 - Advanced threat assessment algorithms
- Multiple emergency response levels
- Environmental condition adaptation
- Additional Considerations:
 - Cost optimization for mass production
 - Manufacturing scalability
 - Maintenance requirements
 - Service technician training
 - Documentation and user manuals
 - Warranty and liability considerations
 - Machine learning integration
 - Remote monitoring and control
 - Data logging and analysis
 - Multiple operation modes
- 5. Hardware Scalability:
 - Support for different motor configurations
 - Multiple safety systems
 - Various sensor types and quantities
 - Different robot sizes and configurations

The current robotic navigation system demonstrates significant potential for scalability, particularly in its transition to consumer vehicle applications, though it requires substantial modifications. The core architecture can be expanded from its basic sensor array (ultrasonic and IR sensors) to incorporate more sophisticated sensor systems like LIDAR, RADAR, and camera arrays, essential for automotive-grade safety systems. The modular design allows for easy integration of additional safety features, sensor fusion capabilities, and advanced driver assistance systems (ADAS). However, scaling to consumer vehicles demands rigorous compliance with automotive safety standards (ISO 26262), implementation of redundant systems, and integration with existing vehicle electronic control units (ECUs) and CAN bus

networks. The system's current fire suppression mechanism could evolve into a comprehensive vehicle safety system, while its obstacle avoidance logic could be enhanced to handle complex traffic scenarios. The main challenge in scaling lies not in the basic navigation principles, which remain sound, but in adapting the system to meet the stringent reliability, safety, and performance requirements of consumer vehicles while maintaining cost-effectiveness for mass production. This would require significant architectural changes to support real-time processing of multiple sensor inputs, advanced threat assessment, and multi-level emergency response protocols, all while ensuring seamless integration with existing vehicle systems.

VIII. CONCLUSION

Some of key findings are:

- 1) integration of advanced technology -> concurrent utilization of cutting-edge technologies like fire sensors and obstacle sensors
- 2) real time monitoring and response -> with advance programming concepts like polling (obstacle detectors) real time information is taken and appropriate response utilized in real time
- 3)enhanced safety protocol -> this significantly enhances safety of electric vehicle with respect to fire hazards
- 4)challenges in industrial utilisation-> needs separate constant power supply that has to be maintained for this to work.

REFERENCES

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- [2] A Review of Fire Safety in Electric Vehicles This comprehensive review examines fire hazards associated with EVs, including thermal runaway and manufacturing defects. It analyzes historical fire incidents and contemporary technologies aimed at mitigating these risks, underscoring the need for improved safety measures in EV design and manufacturing.
- [3] Electric Vehicle Fire Staged to Study Environmental, Health Ramifications Researchers at the University of Miami conducted staged EV fires to assess environmental impacts and improve safety measures. The study utilized wearable sensors to monitor exposure levels, aiming to enhance safety protocols for firefighters and the public during EV fire incidents.
- [4] A Review on Fire Prevention and Suppression Solutions for EV Battery Packs - This paper reviews various strategies for preventing and suppressing fires in EV battery packs, focusing on technological advancements and best practices to enhance safety in battery design and management.
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- [7] Fire Safety of Battery Electric Vehicles: Hazard Identification, Detection, and Mitigation - This review provides a detailed overview of fire hazards associated with battery electric vehicles (BEVs), identifying key failure mechanisms and proposing detection and mitigation strategies to improve overall safety.