ISSN (Online): 2583-648X

IJIRID

International Journal of Ingenious Research, Invention and Development

An International, High Impact Factor, Double-Blind Peer-Reviewed, Open-Access, Multidisciplinary Online Journal

Volume 3 | Issue 1 | February 2024

Journal Impact Factor 2023 (Quality Score): RPRI = 6.53 | SJIF = 3.647

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Wireless Mobile Controlled Fire Detection Robot

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Abstract: *The advent of Internet of Things (IoT) technology has revolutionized various sectors, including firefighting, by introducing innovative solutions to enhance safety and efficiency. This paper presents an in-depth exploration of IoT-based firefighter robots, which represent a cutting-edge approach to fire emergency response systems. The IoT-based firefighter robot integrates advanced sensors, actuators, and communication modules, enabling it to navigate hazardous environments autonomously while executing critical firefighting tasks. This abstract outlines the key components and functionalities of such robots, emphasizing their role in mitigating risks and saving lives during fire incidents. This paper reviews the design considerations, sensor technologies, communication protocols, and control algorithms employed in IoT-based firefighter robots. Additionally, it discusses the integration of artificial intelligence (AI) techniques, such as machine learning and computer vision, to enhance the robot's decision-making capabilities and situational awareness in dynamic fire scenarios. Furthermore, the abstract highlights the importance of real-time data acquisition and analysis facilitated by IoT connectivity, enabling remote monitoring and command functionalities for firefighting operations. The paper also addresses challenges related to reliability, scalability, and interoperability in deploying IoT-based firefighter robots in diverse environments.*

Keywords: *Internet of Things (IoT), Wireless Controller, Fire Detection System, etc.*

I. INTRODUCTION

In recent years, the integration of wireless technology and robotics has paved the way for innovative solutions across various domains. Among these, fire detection and monitoring systems have become increasingly crucial for ensuring public safety and property protection. In response to this need, the Wireless Mobile Controlled Fire Detection Robot emerges as a cutting-edge solution, leveraging the power of the ESP32 CAM module and live camera footage accessible via a mobile application.

Traditional fire detection methods often rely on stationary sensors and manual monitoring, which may not provide real-time insights or accessibility in remote or hazardous environments. Moreover, the limitations of fixed systems can impede effective intervention during critical situations.

The Wireless Mobile Controlled Fire Detection Robot addresses these challenges by offering a dynamic, mobile approach to fire detection and monitoring. By integrating the ESP32 CAM module, this system combines the capabilities of wireless communication, image processing, and mobility to create a versatile and efficient solution.

The ESP32 CAM module serves as the core component of the system, providing a compact and powerful platform for capturing high-resolution images and streaming live footage. Equipped with onboard Wi-Fi capabilities, the ESP32 CAM module enables seamless communication with a mobile

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application, allowing users to remotely monitor and control the robot from anywhere with internet access. Furthermore, the live camera footage transmitted to the mobile application enhances situational awareness and enables prompt response to fire incidents. Users can receive real-time updates, assess the severity of the situation, and initiate appropriate actions, thereby minimizing response time and mitigating potential risks.

In addition to its fire detection capabilities, the Wireless Mobile Controlled Fire Detection Robot is designed for versatility and adaptability. Its compact and manoeuvrable design allows it to navigate through various environments, including confined spaces and rough terrain, ensuring comprehensive coverage and accessibility. [1].

II. OBJECTIVES

The objective of the project "Wireless Mobile Controlled Fire Detection Robot using ESP32 CAM module with live camera footage on mobile application" is to design and implement a sophisticated robotic system for fire detection and monitoring.

The specific objectives include:

1. **Development of a Mobile-Controlled Robotic Platform:** Design and construct a robust robotic vehicle equipped with an ESP32 CAM module capable of wireless communication and live video streaming.
2. **Integration of Fire Detection Capabilities:** Incorporate sensors and algorithms for real-time fire detection, allowing the robot to autonomously identify potential fire hazards.
3. **Implementation of Wireless Communication:** Establish a reliable wireless communication link between the robot and a mobile application, enabling remote control and live video feed transmission.
4. **Creation of a User-Friendly Mobile Application:** Develop an intuitive mobile application interface for users to remotely control the robot, receive live video footage, and monitor fire detection alerts in real time.
5. **Testing and Validation:** Conduct comprehensive testing to ensure the reliability, accuracy, and responsiveness of the system under various environmental conditions and fire scenarios.
6. **Optimization and Refinement:** Continuously refine and optimize the system to improve its performance, responsiveness, and user experience based on feedback and testing results. [2]

III. LITERATURE REVIEW

In recent years, the integration of wireless communication, robotics, and mobile applications has paved the way for innovative solutions in various domains, including fire detection and monitoring. The utilization of ESP32-CAM modules for real-time video streaming combined with mobile control offers promising avenues for enhancing fire detection robotics. This literature survey aims to explore existing research, methodologies, and technologies relevant to the development of a Wireless Mobile Controlled Fire Detection Robot using ESP32-CAM modules with live camera footage on a mobile application. [3]

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Wireless communication technologies are integral to facilitating seamless data transmission between robotic systems and remote controllers. The literature is rich with studies focusing on integrating wireless protocols like Wi-Fi, Bluetooth, and Zigbee to establish robust communication links between mobile devices and robotic platforms. Various approaches have been proposed to tackle latency, reliability, and range limitations inherent in wireless communication systems. The ESP32-CAM module, featuring a microcontroller and camera, has garnered attention in the IoT and robotics realms for its compact design and versatile capabilities. Researchers have demonstrated its feasibility for real-time video streaming applications, enabling remote surveillance, object detection, and environmental monitoring. Optimization techniques have been explored to enhance video quality, reduce latency, and improve network bandwidth utilization.[5]

Fire detection robotics is emerging as a critical research area aimed at mitigating the risks associated with fire outbreaks in residential, commercial, and industrial settings. Traditional fire detection systems rely on stationary sensors and manual intervention, which pose limitations in coverage and response time. Robotics-based approaches offer mobility advantages, allowing for rapid deployment and navigation in dynamic environments. Meanwhile, mobile applications serve as intuitive interfaces for remotely controlling and monitoring robotic systems. Studies have investigated diverse applications ranging from teleoperation and navigation to data visualization and analysis. These applications leverage modern smartphone capabilities such as touchscreens, sensors, and wireless connectivity, providing users with seamless interaction and real-time feedback. [4]

IV. HARDWARE

A. Fire Sensor:

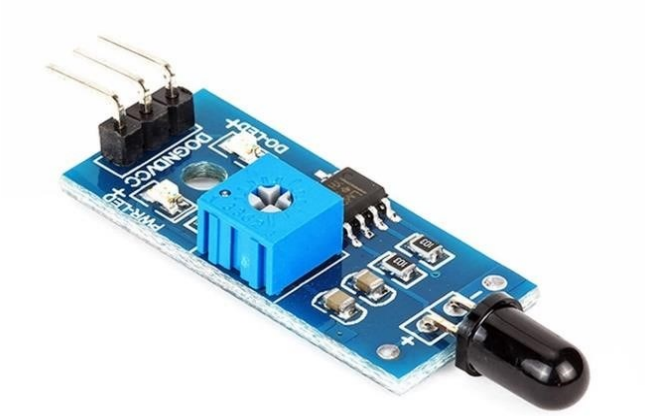

Figure 1: Fire Sensor

A flame-sensor is one kind of detector that is mainly designed for detecting as well as responding to the occurrence of a fire or flame. The flame detection response can depend on its fitting. It includes an alarm system, a natural gas line, propane & a fire suppression system. This sensor is used in industrial boilers. The main function of this is to authentication whether the boiler is properly working

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or not. The response of these sensors is faster as well as more accurate compared with a heat/smoke detector because of its mechanism while detecting the flame.

Working Principle

This sensor/detector can be built with an electronic circuit using a receiver like electromagnetic radiation. This sensor uses the infrared flame flash method, which allows the sensor to work through a coating of oil, dust, water vapour, otherwise ice.

Features & Specifications

The features of this sensor include the following.

- Photosensitivity is high
- Response time is fast
- Simple to use
- Sensitivity is adjustable

B. Solar Panel:

Figure 2: Solar Panel

Features

Small/Mini solar panels have several features that make them a convenient and practical choice for everyday use. Some of these features include:

- **Portability:** Small solar panels are designed to be lightweight and portable, making them easy to transport and use on the go.
- **Durability:** Most small solar panels are made with high-quality materials that can withstand harsh weather conditions and regular use.
- **Easy Installation:** Small solar panels are easy to install and typically come with mounting hardware or adhesive backing.

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- **Compatibility:** Many small solar panels are compatible with a variety of devices and appliances, making them a versatile and convenient energy source.

Benefits

- **Lower Electricity Bills:** By using solar energy to power your devices and appliances, you can reduce your reliance on grid electricity and lower your monthly electricity bills.
- **Environmental Sustainability:** Mini solar panels produce clean energy that is free from harmful emissions, making them an environmentally friendly choice.
- **Portability:** Small solar panels are lightweight and easy to transport, making them ideal for outdoor activities like camping trips, hiking, boating, and other off-grid adventures.
- **Off-Grid Capabilities:** Small solar panels can be used in remote or off-grid locations where access to traditional energy sources is limited or unavailable.
- **Low Maintenance:** Small solar panels require little to no maintenance, making them a hassle-free and cost-effective solution for powering your everyday needs.

C. Lithium Ion Battery:

Figure 3: Lithium Ion Battery

Lithium-ion batteries (Li-ion) are a type of rechargeable battery that has become ubiquitous in modern electronics and portable devices due to their high energy density, relatively low self-discharge rate, and lightweight properties. They are widely used in smartphones, laptops, tablets, electric vehicles, and many other applications.

Here are some key aspects and information about lithium-ion batteries:

1) Composition: Lithium-ion batteries consist of several key components:

- ***Anode:*** Typically made of graphite, which allows lithium ions to intercalate during charging.

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- ***Cathode:*** Composed of lithium metal oxides such as lithium cobalt oxide (LiCoO2), lithium manganese oxide (LiMn2O4), lithium iron phosphate (LiFePO4), or lithium nickel cobalt aluminium oxide (NCA).
- ***Separator:*** A permeable membrane that keeps the electrodes from touching and causing a short circuit while allowing the lithium ions to pass through.
- ***Electrolyte:*** Usually, a lithium salt dissolved in an organic solvent, which allows the movement of lithium ions between the cathode and anode during charge and discharge cycles.

2) Working Principle: During charging, lithium ions move from the cathode to the anode through the electrolyte and get intercalated into the anode material. During discharge, the ions move back to the cathode, generating an electric current that can be used to power devices.

D. Microcontroller

Figure 4: Controller Board

The ESP32-CAM module is a versatile development board based on the ESP32 microcontroller and designed specifically for camera applications. Here is some information about the ESP32-CAM module:

- **ESP32 Microcontroller:** The ESP32 is a powerful microcontroller developed by Espressif Systems. It features a dual-core Tensilica LX6 processor, Wi-Fi, and Bluetooth connectivity, as well as a wide range of peripheral interfaces.
- **Camera Sensor:** The ESP32-CAM module integrates a small camera module that can capture still images and videos. The camera sensor is typically an OV2640, capable of capturing images in resolutions up to 1600x1200 (2MP).
- **Wi-Fi Connectivity:** One of the key features of the ESP32 is its built-in Wi-Fi connectivity, which allows the ESP32-CAM to connect to local networks and the Internet. This makes it suitable for applications requiring remote monitoring or control.

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- **GPIO Pins:** The ESP32-CAM module exposes several GPIO pins that can be used to interface with external devices and sensors. These pins can be configured for digital input/output, analog input, PWM output, and more.
- **MicroSD Card Slot:** The ESP32-CAM module typically includes a microSD card slot, allowing for the storage of captured images and videos locally.
- **Programming:** Like other ESP32-based development boards, the ESP32-CAM can be programmed using the Arduino IDE, ESP-IDF (Espressif IoT Development Framework), or other development environments that support the ESP32 platform.
- **Power Supply:** The ESP32-CAM module requires a 3.3V power supply. It can be powered through a micro-USB port or using an external power source.
- **Applications:** The ESP32-CAM module is suitable for a wide range of applications including surveillance cameras, IoT projects, home automation, and more. Its small form factor and low power consumption make it particularly suitable for battery-powered applications.
- **Limitations:** While the ESP32-CAM module is a powerful and versatile platform, it does have some limitations. For example, the OV2640 camera sensor may not provide the image quality or features of higher-end cameras. Additionally, the module's Wi-Fi connectivity may be limited by factors such as signal strength and interference.

E. Pump Motor:

Figure 5: Submersible Pump

Here 9v DC submersible pump is used. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation, a problem associated with a high elevation difference between the pump and the fluid surface. Submersible pumps push fluid to the surface as opposed to jet pumps which create a vacuum and rely upon atmospheric pressure. water is fed throughout the farm using a pump motor. It forms as an irrigation unit. The submersible pumps used in ESP installations are multistage centrifugal pumps operating in a vertical position. Although their constructional and operational features underwent a continuous evolution over the years, their basic operational principle remained the same. [5]

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Specification:

- 8V to 9v input require.
- Work under water.
- Pump maximum rating: 9v

V. BLOCK DIAGRAM

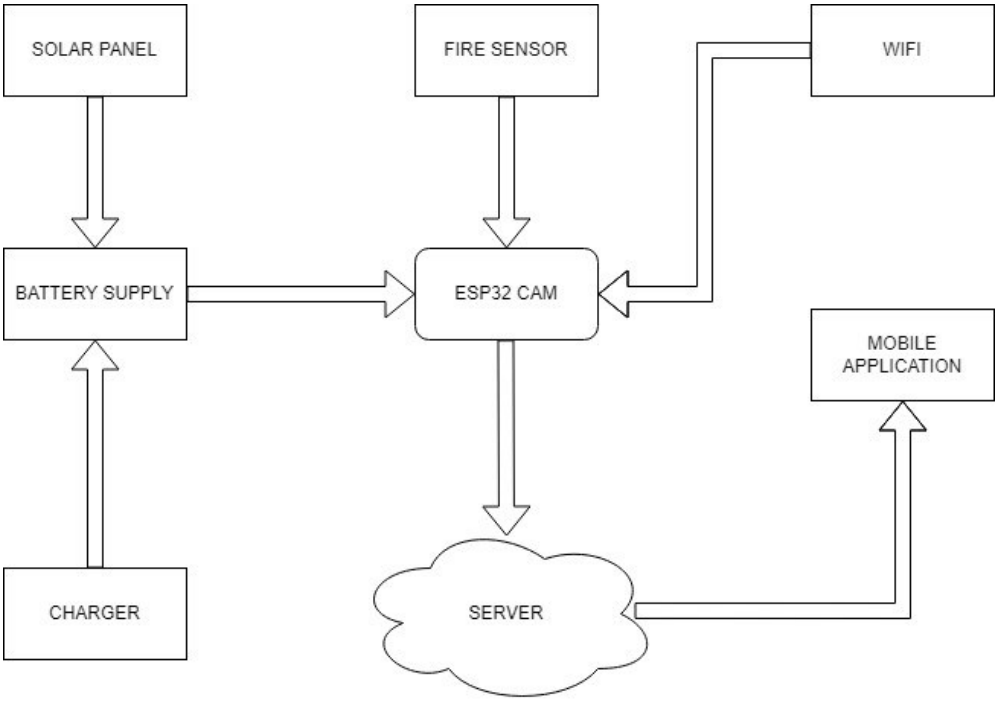

Figure 6: Block Diagram of Wireless Mobile Controlled Fire Detection

Description:

Experience cutting-edge fire detection technology with our Wireless Mobile Controlled Fire Detection Robot, featuring the powerful ESP32-CAM module and live camera footage streamed directly to your mobile application. This innovative robotic solution is designed to enhance fire safety measures by providing real-time monitoring and swift response capabilities.

Key Features:

- **ESP32-CAM Module:** The heart of our fire detection robot is the ESP32-CAM module, a versatile and high-performance microcontroller with built-in Wi-Fi and camera capabilities. This compact yet powerful module enables seamless communication between the robot and yourmobile device.
- **Wireless Connectivity:** Utilizing advanced wireless technology, our robot establishes a reliable connection to your mobile application, allowing you to remotely control its movements and

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monitor live camera footage. This wireless communication ensures flexibility and accessibility from any location within the network range.

- **Live Camera Footage:** The integrated camera on the ESP32-CAM provides real-time video streaming, allowing you to visually inspect environments for potential fire hazards. Access the live camera feed on your mobile application to make informed decisions and respond promptly to any detected threats. [4]
- **Mobile Application Control:** Take command of the fire detection robot effortlessly through a user-friendly mobile application. Control the robot's movements, adjust the camera angle, and receive live updates on the surrounding environment all at your fingertips. [5]
- **Fire Detection Algorithm:** Equipped with a sophisticated fire detection algorithm, the robot autonomously scans its surroundings for signs of flames or smoke. Upon detection, the system sends instant alerts to your mobile application, ensuring quick and effective response times. [8]
- **Customizable Alerts:** Tailor the alert settings on the mobile application to suit your preferences. Receive notifications via push alerts, SMS, or email, keeping you informed about potential fire incidents even when you are not actively monitoring the live feed. [7]
- **Efficient Mobility:** The robot is designed with a robust chassis and efficient mobility systems, allowing it to navigate diverse environments. Its versatility makes it suitable for a wide range of applications, from homes and offices to industrial settings. [6]

VI. RESULT

A "wireless mobile-controlled fire detection system" refers to a sophisticated technological solution that integrates wireless communication, mobile application interfaces, and robotic capabilities to detect and respond to fire incidents remotely. This system typically utilizes wireless protocols like Wi-Fi, Bluetooth, or Zigbee to establish communication links between a mobile device and a robotic platform equipped with fire detection sensors. Researchers and developers have focused on optimizing these communication channels to ensure reliability, low latency, and sufficient range, enabling real-time monitoring and control of the fire detection robot from a remote location.

Furthermore, the integration of mobile applications enhances user interaction by providing intuitive interfaces for controlling the robotic system and accessing live camera footage for fire detection. This approach offers scalability, flexibility, and accessibility, making it suitable for various environments and applications. Challenges in this domain include optimizing power consumption for prolonged operation, improving the robustness of wireless communication in complex environments, and integrating advanced algorithms for real-time fire detection and localization.

VII. CONCLUSION

In conclusion, the development of the Wireless Mobile Controlled Fire Detection Robot utilizing the ESP32 CAM module marks a significant advancement in fire detection and prevention technology. By integrating live camera footage accessible through a mobile application, this system offers enhanced

 DOI: 10.5281/zenodo.10958850

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situational awareness and real-time monitoring capabilities, empowering users to respond swiftly to potential fire incidents.

The utilization of wireless mobile control enhances the flexibility and accessibility of the system, allowing users to remotely navigate the robot through various environments, even in hazardous conditions. Moreover, the incorporation of the ESP32 CAM module provides high-quality video streaming, enabling precise and efficient fire detection through advanced image processing algorithms.

This innovative solution holds immense potential for improving fire safety measures in diverse settings, including industrial facilities, residential buildings, and public spaces. Its ability to deliver real-time visual data to mobile devices equips users with valuable insights, facilitating prompt decision-making and proactive fire management strategies.

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