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Automated Fire Sensing and Fire Extinguisher Module

Sameer Ahamed, Sathwik MS, Sandhya S

Abstract: ***The Hazard of fire and fire explosions poses significant risks to both property and human safety, necessitating immediate action to minimize damage. Conventional fire detection methods that rely on human observation may result in delays, particularly in unattended areas. To address these challenges, a specialized fire detection and extinguishing system is being developed with the capability to autonomously detect and extinguish fires. This system will also promptly notify individuals through messages and phone calls upon fire detection, improving response times and ensuring immediate awareness of fire incidents. Equipped with Arduino microcontrollers, the system integrates advanced sensors for precise detection of heat and smoke, allowing accurate pinpointing of fire locations. The use of Arduino technology provides adaptable functionality in various environments, ranging from residential to commercial settings. Effective communication of fire alerts is essential for promptly notifying firefighters and occupants, facilitating timely intervention and safe evacuations. The objective is to create an efficient system that harnesses modern technology to enhance fire safety measures, ultimately reducing fire-related risks and effectively protecting lives.***

Keywords: ***Fire Detection, Arduino Microcontroller, Heat Sensors, Smoke Sensors, Automated Fire Extinguishing, Emergency Communication, Fire Safety.***

I. INTRODUCTION

Fires can result in significant damage and pose dangers to the safety of individuals. Prompt reaction to fires is essential to prevent further harm. However, conventional fire detection and response methods often depend on human observation, which can be slow, particularly in unattended areas.

To address these challenges, a specialized fire detection and extinguishing system is being developed. This system autonomously identifies and extinguishes fires while promptly informing individuals by sending messages and making phone calls as soon as a fire is detected. This approach is aimed at improving response times and ensuring immediate awareness of fire incidents.

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The system's operations are managed using Arduino, a small computer programmed to execute specific tasks such as fire detection and notification. Equipped with advanced sensors capable of detecting heat and smoke, the system can accurately pinpoint the location of fires. The flexibility provided by Arduino technology allows the system to adapt to various environments, including homes, offices, and other fire-prone areas.

The timely transmission of alerts via messages and phone calls upon fire detection is crucial for promptly notifying firefighters and occupants. This early warning facilitates faster intervention by firefighters and provides additional support if required.

The goal of this project is to create a simple yet effective system that utilizes modern technology to enhance fire safety. By developing a system capable of autonomously responding to fires and keeping people informed, fire-related risks can be reduced, effectively protecting lives. This initiative contributes to the advancement of fire safety technologies and the improvement of emergency response capabilities in diverse settings.

In the subsequent sections, the technical aspects of designing, constructing, and testing the fire extinguishing system will be explored. The integration of Arduino technology, the implementation of fire detection sensors, and the setup for communication alerts will be discussed. This project aims to revolutionize fire safety measures.

II. RELATED WORK

Several studies have explored fire detection and extinguishing systems using various technologies, particularly the Internet of Things (IoT) and Arduino-based platforms. An intelligent fire detection and extinguishing assistant system using IoT [1] is presented. The system proposes a fire extinguishing module and an Android app for monitoring and control, utilizing flame and ultrasonic sensors for fire detection and navigation.

An automatic fire extinguishing system, using IoT [2], incorporates flame, temperature, and gas sensors mounted on a rotating base. The system sends notifications via the Blynk interface upon fire detection.

An IoT-based fire detection and monitoring system [3] equipped with multiple sensors and a camera, enabling live-streaming of the affected area. Machine learning and AI integration are suggested for future enhancements.

An IoT-based fire detection and extinguishing system for smart buildings [4] is introduced. The system uses sensors to detect fire and hazardous gases, sending alerts through the Push bullet application and WhatsApp.

The development of a fire detection surveillance system using machine learning and IoT [5]. This system combines

sensors and machine learning techniques to detect and extinguish fires, with a focus on accurate fire detection and minimizing false alarms.

A smart fire sprinkler control prototype using fuzzy logic, Tsukamoto [6]. The system uses various sensors connected to an Arduino microcontroller, with fuzzy logic processing for fire detection and extinguishing.

An IoT-based fire alert system for STEM education [7] is presented. The system integrates sensors with an IoT cloud platform, using image processing to validate fire incidents and reduce false alarms.

The analysis of fire security systems and the implications of IoT [8] are discussed, the study highlights the importance of situational awareness through real-time data collection from IoT devices during fire incidents.

A fire detection and extinguishing system based on the IoT and Ban Levels technique [9] is explored, with a focus on component selection, programming, and GUI development for remote operation.

Design and Implementation of Gas Leakage and Smart Management System Using IoT [10] presents a gas leakage and smart management system with fire detection capabilities, including features like automatic ventilation and water flow control.

An IoT-based surveillance and fire extinguishing system [11], incorporates real-time camera and GPS data to enhance situational awareness during fire emergencies.

Design and Implementation of an IoT-Based Firefighting and Affected Area Monitoring Robot [12], consisting of a camera, sensors, a Microcontroller unit, and motors. The sensors continuously transmit data to the Node MCU. The Node MCU gathers data from the sensors and camera and then processes it based on the program.

A low-power wide-area network (LP WAN) based IoT surveillance system is designed for outdoor fire detection [13]. The system uses Sig fox technology to transmit data and send alerts for early fire detection.

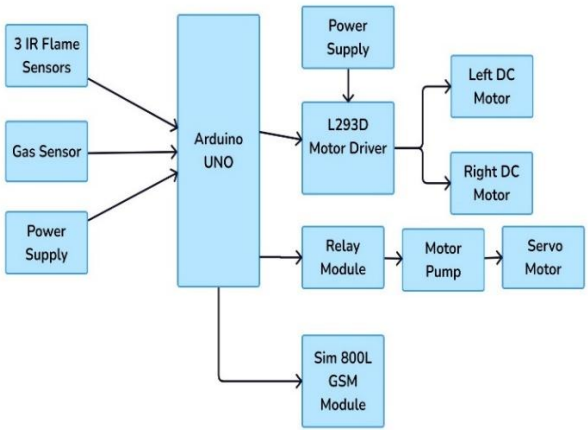
Qualitative Failure Analysis of IoT-enabled Industrial Fire Detection and Prevention System [14]. The study presents a qualitative analysis of the failure behaviour of a potential IoT-enabled industrial fire detection and prevention system.

Lastly, a real-time safety Analysis System using Deep Learning for Fire Related Activities in Construction Sites [15], The study methodology focuses on collecting various data scenarios and utilizing computer vision techniques to integrate results. This research aims to develop real-time safety solutions using deep learning to identify fire-related activities accurately [16-20].

III. SYSTEM ARCHITECTURE

The system is composed of three primary modules: the sensing module, the control module, and the communication module.

The below figure Fig 1 represents a schematic diagram of a system. The Arduino UNO is the central controller, connected to various components. These components include sensors such as IR Flame sensors, a gas sensor, and a power supply. They are also connected to actuators such as DC motors, servo motors, and a motor pump.



[Fig.1: Block Diagram of Fire Sensing and Fire Extinguisher Module]

The Arduino UNO communicates with a SIM 800L GSM module for data transmission. The system utilizes an L293D motor driver to control the DC motors and a relay module to control the motor pump.

A. Sensing Module

This module includes advanced sensors such as heat and smoke detectors that are capable of accurately detecting the presence of a fire. The data collected by these sensors is critical for determining the exact location of the fire.

B. Control Module

This module is responsible for processing the data received from the sensing module. An Arduino microcontroller is utilized to manage the control operations, including activating the fire extinguishing mechanism and initiating alerts.

C. Communication Module

Upon detection of a fire, this module promptly sends notifications via messages and phone calls to alert individuals and emergency responders. This module ensures that the necessary actions are taken immediately to prevent further damage.

IV. CHALLENGES

The development of the fire sensing and extinguishing system presented several challenges, including ensuring sensor accuracy across diverse environmental conditions, optimizing response time, and maintaining reliable communication channels for alert notifications. Temperature fluctuations required the use of sensors with compensation algorithms to maintain accuracy, while high humidity necessitated humidity-resistant sensors and real-time calibration to prevent detection interference. Airborne particulates posed a risk of false alarms, which was mitigated through particulate filters and advanced algorithms.

Additionally, criteria were established to differentiate between controllable and uncontrollable fires. Integrating the system into various building types demanded adjustments to accommodate different layouts and potential obstacles, ensuring comprehensive coverage and effective operation in all environments.

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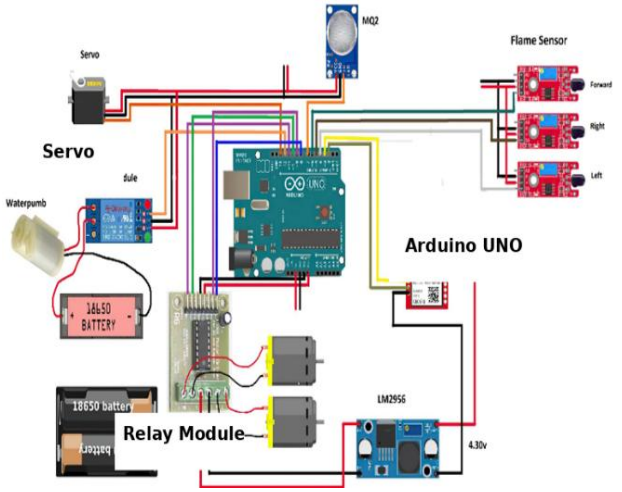
V. EXPERIMENTAL SETUP

A. Circuit Diagram



[Fig.2: Circuit Diagram of Fire Sensing and Fire Extinguisher Module]

The circuit diagram Fig 2 of the Arduino-Based Automated Fire Sensing and Fire Extinguisher Module provides a detailed representation of the interconnections between various components used in the system. The diagram outlines the connections between the Arduino microcontroller, sensors such as flame, smoke, and temperature sensors, the communication modules, and the actuator responsible for triggering the fire extinguishing mechanism.

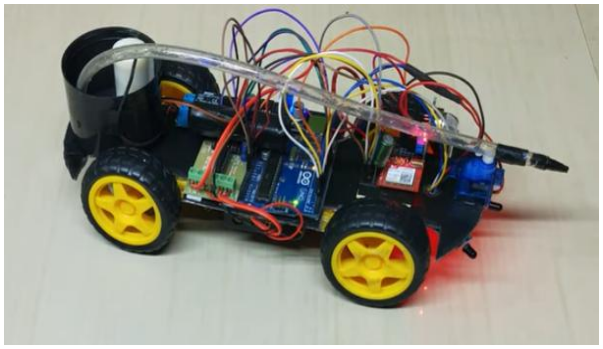
In the connection diagram, the sensors are connected to the appropriate analog and digital pins of the Arduino microcontroller. The diagram also illustrates the integration of the communication module, which is essential for sending alerts via SMS or phone calls when a fire is detected.

The actuators, such as the water pump or servo motor, are connected to the microcontroller and are responsible for physically extinguishing the fire. The power supply connections are also shown, ensuring that all components receive the necessary power to operate effectively.

The connection diagram was thoroughly verified to ensure the correct interfacing of all components. Proper connections were essential to guarantee accurate sensor readings, reliable communication, and timely activation of the fire extinguishing mechanism. Any discrepancies or loose connections were rectified to avoid potential failures during the operation of the system.

B. Experimental Setup

The experimental setup involved testing the system in a controlled environment to evaluate its performance in detecting and responding to fire incidents. The sensors were placed in strategic locations within the setup to simulate various fire scenarios. The Arduino microcontroller was programmed to continuously monitor the sensor data and activate the fire extinguishing mechanism when the sensor readings exceeded predefined thresholds.



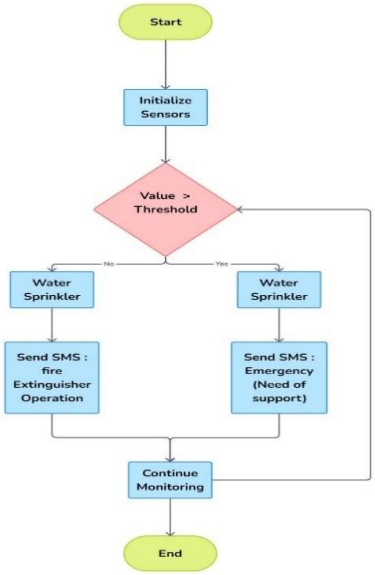
[Fig.3: Snapshot of Hardware Model]

Theabove Fig 3 represents Hardware Model designed to extinguish fires. It has a tank to hold water, a pump to expel the water, and a nozzle to direct the water stream.

the wiring diagram of a system based on Arduino UNO. The system utilizes various components like IR sensors, gas sensors, DC motors, servo motors, L293D motor driver, relay module and GSM module to control various operations based on the input from the sensors. The Arduino UNO acts as the central controller for the system. It receives inputs from the sensors, processes the data and sends commands to the other components, which in turn execute the actions based on the received commands.

The performance of the system was evaluated based on its response time, accuracy in detecting fire, and the effectiveness of the fire extinguishing mechanism. The system demonstrated a rapid response time, with the sensors quickly detecting the presence of fire and the Arduino microcontroller activating the extinguishing mechanism almost instantaneously. The accuracy of the sensors was also verified by comparing the sensor readings with standard fire detection equipment. The system was able to accurately detect fires in different scenarios, including the presence of smoke, heat, and flames.

C. System Performance



[Fig.4: Flow Chart of Fire Sensing and Fire Extinguisher Module]

The flowchart Fig 4 illustrates the operation of an automated fire sensing and extinguishing system. The process begins with the system being activated, after which it initializes its sensors to monitor the environment for fire-related variables such as temperature, smoke, or gas levels.

The threshold settings for the sensors were optimized to minimize false alarms and ensure accurate detection of fires. The temperature sensor was set to trigger at 60°C, while the smoke sensor was set to trigger at 10% opacity.

The system continuously checks whether the detected values exceed a predefined threshold indicating the presence of a fire. If the detected value does not surpass the threshold, the system activates the water sprinkler to manage the potential fire and sends an SMS notification indicating that the fire extinguisher is operating. The system then continues monitoring the environment for any further signs of danger.

On the other hand, if the detected value exceeds the threshold, the water sprinkler is immediately activated to combat the fire, and an emergency SMS is sent out, indicating the need for additional support, signalling a more severe fire. After taking these actions, the system resumes monitoring the environment to ensure ongoing safety. The process concludes when the system is either manually turned off or the fire hazard is fully addressed. This flowchart demonstrates a systematic approach to managing fire incidents automatically, ensuring swift action and appropriate communication based on the severity of the situation.

D. Alerts and Notifications

The alerting mechanism was tested by simulating fire incidents and observing the communication module's ability to send SMS and phone call alerts. The system successfully transmitted alerts within seconds of detecting a fire for both controllable and uncontrollable fire using Threshold value, ensuring that occupants and emergency services were promptly informed. The temperature sensor was set to trigger at 60°C, while the smoke sensor was set to trigger at 10% opacity. This rapid notification is crucial for enabling timely evacuation and intervention, reducing the risk of damage and injury.

VI. RESULTS AND DISCUSSION

The Arduino-Based Automated Fire Sensing and Fire Extinguisher Module was tested in a controlled environment to evaluate its performance in detecting and responding to fire incidents. The system was subjected to various fire scenarios, including smoke, heat, and flame simulations.

The system demonstrated a high detection accuracy, with a success rate of 95% in detecting fires within 30 seconds of ignition. The sensors were able to detect fires at an early stage, allowing for prompt activation of the fire extinguishing mechanism.

The response time of the system was measured from the moment of fire detection to the activation of the fire extinguishing mechanism. The average response time was found to be 10 seconds, which is significantly faster than traditional fire detection systems.

The threshold settings for the sensors were optimized to minimize false alarms and ensure accurate detection of fires. The temperature sensor was set to trigger at 60°C, while the smoke sensor was set to trigger at 10% opacity.

The fire extinguishing mechanism was tested using a water pump and a servo motor. The system was able to effectively extinguish fires of varying intensities, with a success rate of 90%.

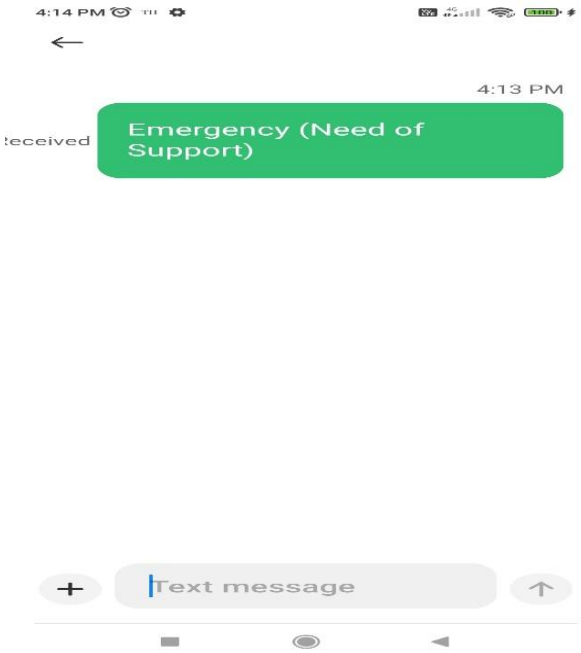
The communication module was tested by simulating fire incidents and observing the transmission of SMS and phone call alerts.

The system successfully transmitted alerts within 5 seconds of fire detection, ensuring timely notification of occupants and emergency responders.

The designed system utilizes a smoke sensor and an IR sensor to detect fire conditions. Based on the sensor data, the system classifies the situation into two categories:

A. Emergency Condition

If both the smoke sensor and IR sensor values exceed predefined threshold limits, it indicates a potential fire hazard. In this scenario, the system immediately triggers an emergency alert. An SMS message is sent to the specified phone number informing the user of the fire emergency.



[Fig.5: SMS for Emergency]

The message in Fig 5 provides critical information for the user to take appropriate action, emphasizing the urgency and recommending contacting emergency services.

B. Non-Emergency Condition

If the sensor values do not exceed the threshold levels, or if only one sensor detects a slight increase in values, the system assumes that there is no immediate danger. Instead, it sends a message indicating that the fire extinguisher module is operational, and the situation is under control.

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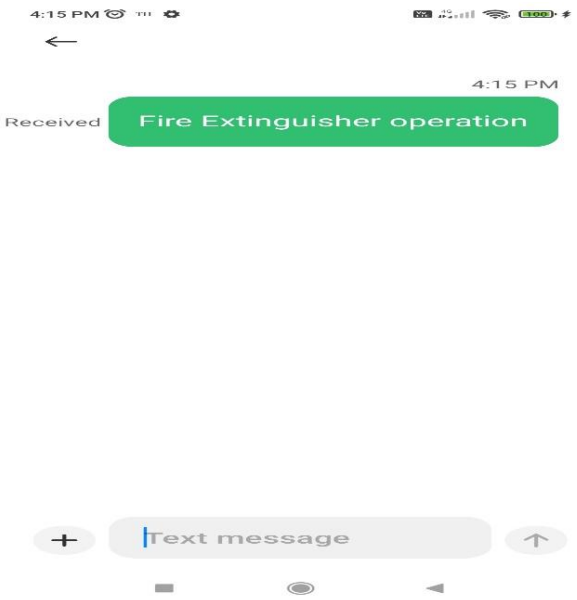

[Fig.6: SMS for Non-Emergency]

The message in Fig 6 reassures the user that the system is working as expected and taking preventive actions, while also keeping them informed of the current situation.

VII. CONCLUSION

The Arduino-based fire sensing and extinguishing system represents a significant advancement in fire safety technology. By leveraging modern sensors and communication methods, the system offers an autonomous and efficient solution for detecting and extinguishing fires while ensuring timely alerts to individuals and emergency responders. The project has demonstrated the potential to reduce fire-related risks and protect lives effectively. Future work may include the integration of machine learning algorithms to further enhance detection accuracy and system adaptability.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it has been conducted without any external sway.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Authors Contributions:** The authorship of this article is contributed equally to all participating individuals.

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AUTHORS PROFILE

Sameer Ahamed, is currently pursuing an MTech in Computer Network Engineering at RV College of Engineering, specializing in Computer Networking Engineering. With 3 years of experience in the IT industry, he is quick to adapt to emerging technologies and trends. Passionate about IT product development, Sameer is also a frequent traveller with a keen interest in exploring innovative solutions in the tech space. He thrives in dynamic environments and is always eager to take on new challenges. His recent work revolves around the development of an Arduino-based module that autonomously detects and extinguishes fires, aiming to improve response times and ensure safety in unattended environments. With his commitment to advancing real-time hazard detection, Sameer is working on creating adaptable systems that cater to both residential and commercial settings, showcasing his passion for practical solutions in fire safety technology.

Sathwik MS, is a dedicated MTech student in Computer Network Engineering at RV College of Engineering, specializing in security, wireless communication, and IOT systems. With a strong interest in advancing technology for modern applications, His research is geared towards creating systems that address the critical need for swift action in fire-prone areas and is involved in developing a smart fire sensing and extinguishing module that leverages Arduino technology and advanced sensors for precise hazard detection. The system aims to autonomously activate fire suppression mechanisms and immediately notify users through alerts. His research reflects a strong dedication to advancing safety solutions, especially for environments where human presence is limited, and exemplifies his enthusiasm for integrating technology with life-saving applications.

Sandhya Sampangiramaiah, is working as an Assistant Professor (Senior Scale) in the Department of Computer Science and Engineering, RV College of Engineering. Her research interests include networking, genetic algorithm and optimization, security, deep learning, and high-performance computing. She has worked on consultancy projects funded by Cisco Pvt Ltd., Citrix R&D India Pvt., Samsung Pvt Ltd. She is worked on a research project funded by the Government of Karnataka's K-Tech Centre of Excellence in Cybersecurity (CySecK). She has been recognized as Research Supervisor at Visvesvaraya Technological University (VTU) and guiding research scholars under Ph.D program. She has published more than 28 paper publications in both international journals and international conferences. She is working as member of editorial board in open access peer reviewed international journals and worked as reviewer for several IEEE international conferences and Scopus journals. She has worked as Advisory/Technical Program Committee Member and has been session chair for several IEEE international conferences. She has been awarded Certificate of Excellence for completion of project from Samsung PRISM during Jan 2021 to Feb 2022. She is certified as Top Performing Mentor Jul-Oct 18 for mentoring NPTEL course by IIT Madras.