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Community-Based Fire and Temperature Monitoring System with PIR Sensors for Enhanced Safety and Prevention

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ABSTRACT

Fire suppression systems typically rely solely on sirens for warning, without ensuring that individuals inside the building are accounted for during a fire emergency. This research proposes the design of an integrated fire suppression system that combines fire and temperature sensors with Passive Infrared (PIR) sensors to detect fires while simultaneously monitoring human presence within a room. The alarm system will activate upon detecting a fire, while the PIR sensors will assess the presence of individuals. If the PIR sensors detect no human presence, the ventilation system will be automatically shut off to reduce oxygen levels and prevent further escalation of the fire. The warning system will remain active until the fire is fully extinguished, at which point the ventilation will be restored. This study follows a comprehensive process of nine stages, beginning with the identification of the problem and concluding with final recommendations. Testing and various conditional scenarios were conducted to evaluate the system's performance. The three sensors used—fire, temperature, and PIR—demonstrated good functionality overall. The data collected showed some error rates, which were influenced by external variables, but despite these minor discrepancies, all three sensors performed reliably. These findings suggest that the integrated system can be effectively implemented as a fire detection and safety system, offering a significant contribution to community safety. This research aligns with the broader goals of community service by providing an innovative solution that not only addresses fire hazards but also ensures human safety

Key Word: *Fire Alarm, PIR Sensor, Fire Sensor, Temperature*

I.INTRODUCTION

In modern architecture, buildings are equipped with numerous interconnected systems, making safety and security paramount in their design and construction[1]. The complexity of these systems increases the risk of fire over time, a risk that is further exacerbated by human negligence. Consequently, it is crucial to implement measures that ensure the protection of both the inhabitants and the building, preventing potential hazards that could lead to significant financial losses or, worse, loss of life[2][3].

Fires can be triggered by various factors, including electrical short circuits due to faulty installation, poor quality of cable insulation, or the presence of high temperatures near combustible materials. While these factors alone might seem insufficient to cause a fire, they do significantly increase the likelihood of an incident if left unaddressed. Therefore, it is essential to deploy fire safety systems and equipment that meet national standards, ensuring both effectiveness and reliability[4].

Currently, many office buildings, sports facilities, and other establishments still rely on conventional fire alarms, which only emit a sound to alert occupants to evacuate the premises. This method is risky, particularly during emergencies when panic often ensues, potentially leading to casualties. Given the high risk of fire-related incidents, which can cause financial losses and loss of life, there is a pressing need for fire suppression systems that prioritize human safety[5].

In response to these challenges, this study aims to design an integrated fire safety system that not only detects fires but also ensures human safety through the use of advanced technology[6]. The proposed system incorporates fire and temperature sensors, alongside Passive Infrared (PIR) sensors, to serve as an early warning mechanism for fire and to monitor human presence within the room[7]. The system begins with fire and temperature sensors that continuously monitor the potential for fire outbreaks, followed by PIR sensors that detect human movement[8]. This integrated approach ensures that the system can effectively monitor both the environmental conditions and the presence of individuals, offering a reliable solution for enhancing the safety of people within the building[9].

This research, grounded in the principles of community service, aims to offer a practical and socially relevant solution by developing a system that not only prevents fires but also ensures the safety of occupants, especially in public or communal spaces where the risk of harm is greater[10]. The integrated use of fire, temperature, and PIR sensors provides a comprehensive approach to fire safety, with the potential to significantly reduce risks and enhance emergency response capabilities in various settings.

II.METHODOLOGY

The unique aspect of the research I am conducting lies in integrating flame and temperature sensors to detect fires, while also incorporating motion sensors to monitor human presence within a room. The system, which utilizes PIR (Passive Infrared) sensors, will be used as a safety measure to protect individuals in case of fire[11]. The flame sensor operates within a wavelength range of 760nm to 1100nm, which allows it to detect flames. This sensor can also detect temperatures ranging from 25°C to 85°C, with a fire detection range of 100 cm. The sensor produces an output voltage of 0.5V when detecting at a distance of 100 cm and a 5V output when detecting an object at 20 cm.

The LCD (Liquid Crystal Display) used in this project is a 20x4 character module, consisting of an organic layer between clear glass and transparent indium oxide electrodes[12]. This system functions as a seven-segment display and uses electric fields to align organic molecules, which control the appearance of segments based on the data input. The 20x4 LCD module is chosen for its ability to display data, such as measurements from a digital lux meter, which is crucial for monitoring light intensity in the system. By using a microcontroller, the LCD can be controlled to display this data automatically after proper configuration of the microcontroller's I/O pins[13].

The LM35 temperature sensor is a thermal sensor that generates an output voltage directly proportional to the temperature it senses[14]. It can measure temperatures between -55°C and +150°C. This temperature sensor is used to ensure that the system can monitor environmental temperature fluctuations accurately, which is vital for early fire detection.

A relay switch, which operates electromagnetically, is employed to control various electronic devices[15]. This relay system enables a low-power current to control a high-voltage circuit. For example, a 5V electromagnetic relay can switch a 220V 2A current, which is essential for managing devices like fans, lights, or other electronics in the fire prevention system. The relay operates based on output signals processed by the microcontroller, which determines when the system should activate or deactivate certain components.

The battery is an essential electrical component in this system, responsible for storing energy. In this project, battery modeling is based on equivalent circuit models, such as the Shepherd Model, to simulate the power requirements effectively.

Instead of the typical computer fan, the prototype uses a heatsink fan designed with four pins: power, ground, tachometer, and control/PWM[16]. However, for this prototype, only the power, ground, and control/PWM pins are utilized. This fan helps control airflow and ventilation within the system to manage temperature and prevent overheating, which can contribute to fire risk.

An early warning system plays a crucial role in providing timely information about disturbances or unstable conditions that may lead to undesirable events, such as fires. It helps minimize the impact of these events by preparing individuals and the surrounding environment in advance. Early warnings are essential in community-based fire safety systems to ensure that people have enough time to evacuate and take preventive actions[17].

Jumper wires are used to connect components on a breadboard without the need for soldering. These wires are essential for prototyping and testing the system, as they allow for flexible and quick adjustments. Jumper wires come with male and female connectors for easy attachment to the breadboard and components.

A buzzer, commonly used in electronic systems, converts electrical vibrations into sound vibrations. In this fire safety system, the buzzer acts as an alarm to alert individuals to a fire or system malfunction[18]. Similar to a loudspeaker, the buzzer consists of a coil mounted on a diaphragm and is activated by the electrical signals generated by the system.

Fires often start from a small spark, but they can spread rapidly when supported by flammable materials. The "Fire Triangle" consisting of Heat, Fuel, and Oxygen explains the essential components required to sustain a fire[20]. If any one of these elements is disrupted, the fire will be extinguished. The goal of the fire safety system is to intervene before the fire can reach dangerous levels, protecting both human life and property from devastating losses. If not promptly addressed, a fire can lead to severe consequences, not only endangering workers but also causing significant damage to businesses and communities.

1. Method

The system begins with a temperature sensor designed to issue an alert when a potential fire hazard arises due to a temperature increase above the average ambient temperature. When the system detects a temperature rise beyond the set threshold, it activates a short buzzer sound as a warning signal. This serves as an early indicator that there may be a fire risk[13].

Following this, a flame sensor is employed to detect the presence of fire within the room. If the flame sensor detects fire, it triggers the activation of the PIR (Passive Infrared Receiver) sensor, which then detects human movement within the vicinity[14]. Simultaneously, a fire notification is displayed on the LCD screen, and the buzzer sounds again, indicating the escalation of the fire hazard. The buzzer will continue sounding until the fire extinguishing process is completed, ensuring the alert remains active until the threat is eliminated[12].

The system also integrates a ventilation control mechanism that works in tandem with the fire detection process. Once the flame sensor confirms the presence of fire and the PIR sensor detects no human movement, the system automatically closes the ventilation to limit the supply of oxygen, a crucial element of the fire triangle. This step helps to reduce the intensity of the fire and prevent further spread. When the fire is successfully extinguished and the flame

sensor detects the absence of fire, the ventilation is reactivated to restore airflow to the room. This comprehensive approach ensures both the detection of fire and the safety of any occupants within the space.

The procurement phase involves acquiring the necessary tools, equipment, and materials for building the prototype. This includes both measurement tools and components for the system, as well as consumable materials. The tools and materials required for the project include:

- Arduino Mega 2560
- Flame Sensor
- PIR Sensor
- Buzzer
- LCD Display
- Relay Module
- LM35 Temperature Sensor
- Battery
- Cooling Fan

III.RESULT & DISCUSION

1. Fire Sensor

The purpose of testing the flame sensor is to evaluate its ability to accurately detect the presence of fire. In this test, a candle flame was used as the source of fire, and it was placed at varying distances from the sensor. The tests were conducted at different distances, with the maximum distance being 80 cm. The objective was to determine the sensor's range and sensitivity in detecting the flame. The testing involved multiple trials to ensure reliable and consistent results.

Additionally, the testing process aimed to assess the response time of the flame sensor when exposed to different intensities of fire. The candle flame was chosen because it provides a controlled and consistent heat source. In each trial, the flame was moved gradually closer to the sensor, and the time taken for the sensor to activate the alert was measured. This allowed for an evaluation of how quickly the sensor responds to a potential fire hazard. By varying the distance and flame intensity, the test results provided valuable data on the sensor's reliability and helped fine-tune its sensitivity settings for optimal performance in real-world conditions.

Table 1.Fire Sensor Result

No.	Distance (cm)	LCD Detected
1	1	Fire Detected
2	10	Fire Detected
3	20	Fire Detected
4	30	Fire Detected
5	40	Fire Detected
6	50	Fire Detected
7	60	Fire Detected
8	70	Fire Detected
9	80	Fire not Detected

2. Temperature Sensor

The temperature sensor testing was conducted to evaluate its accuracy in detecting room temperature, with the results compared to readings obtained from a traditional thermometer. This test aimed to assess the sensor's precision in monitoring ambient air temperature within indoor spaces, ensuring its reliability for integration into a community-based fire and temperature monitoring system. By using a thermometer as a reference, the sensor's performance could be evaluated against a standard measurement tool. The testing process included multiple trials, with various room temperature conditions simulated to observe how the sensor responded to fluctuations in the environment.

For the testing procedure, specific calculations were applied to compare the values from the temperature sensor with those measured by the thermometer. The sensor was placed at various points within the room, and temperature readings were taken at consistent intervals to monitor any changes. The accuracy of the temperature sensor was assessed by calculating the margin of error between the sensor's readings and the thermometer's values. The results showed that the sensor accurately detected temperature variations within a narrow margin of error, making it suitable for integration into a larger system aimed at ensuring safety in public or community spaces. This precision is crucial for early detection of abnormal temperature fluctuations, which could signal potential fire hazards.

$$Error = \frac{thermometer - sensor}{thermometer} x\, 100$$

Table 2. Temperature Sensor

NO.	Thermal gun	LM35	Error (%)
1	30,83	30,87	0,22
2	30,97	30,87	0,09
3	31,49	31,36	1,16
4	31,34	30,87	1,05
5	30,75	30,87	0,22
6	31,12	30,87	0,73
7	31,42	30,87	1,68
8	31,33	31,36	0,19
9	31,22	30,87	1,05
10	31,31	30,87	1,37
	Averange		0,42

The data collected from the tests indicate that the temperature sensor demonstrated a high level of accuracy in detecting temperature changes. The sensor recorded a margin of error of only 0.42°C, which signifies its reliability for use in monitoring temperature fluctuations within indoor environments. This small error percentage suggests that the sensor is capable of providing precise measurements, making it suitable for integration into systems aimed at enhancing safety and preventing potential fire hazards in community-based settings.

The low error margin of 0.42°C highlights the potential effectiveness of using this temperature sensor in a community-based fire and safety monitoring system. Given that temperature variations are often one of the first signs of a fire, the accuracy of the sensor plays a crucial role in detecting potential risks early on, thus allowing for a prompt response to prevent widespread damage. With its high precision, the sensor can contribute to creating a safer environment for communities, ensuring that systems designed for fire detection and temperature regulation are both reliable and effective in preventing accidents and mitigating risks to public safety.

3. Motion Sensor

The testing of the Passive Infrared (PIR) motion sensor was conducted to evaluate its sensitivity in detecting motion in its vicinity. The primary objective of this test was to observe the sensor's response to human movement, specifically through the motion of a hand being waved in front of the sensor. By varying the distance and speed of hand movements, the test aimed to determine the optimal detection range and responsiveness of the sensor. This motion detection capability is a critical component in the development of a community-based fire and safety monitoring system, where the PIR sensor would be used to detect the presence of individuals within a space in real-time, enhancing safety measures in emergency situations.

The PIR sensor's ability to accurately detect motion plays a significant role in ensuring the safety and prevention of fire-related incidents in public spaces. In the context of a community-based system, the sensor can serve as an alert mechanism, notifying authorities or occupants of any movements within an area at risk. In the event of a fire, where swift evacuation is critical, the PIR sensor can help monitor the movement of people, aiding in the coordination of emergency responses. The successful testing of this sensor, particularly its motion detection efficiency, demonstrates its potential to be integrated into a fire and temperature monitoring system that can further safeguard communities by facilitating timely responses to hazardous situations.

No.	Distance (cm)	Detected on LCD
1	5	Motion Detected
2	20	Motion Detected
3	40	Motion Detected
4	60	Motion Detected

Table 3. Motion Sensor Result

The testing results above indicate that the PIR sensor is capable of detecting motion up to a distance of 60 cm. This was observed through various tests where movement was detected and recorded at varying distances from the sensor. These findings are in line with the specifications provided in the datasheet for the motion sensor, which states that the sensor is capable of detecting movement at a range of up to 6 meters (600 cm). The consistency between the testing results and the datasheet supports the reliability and accuracy of the sensor's detection capabilities within the expected range.

These results are crucial for the development of a community-based fire and temperature monitoring system, as the ability to accurately detect human movement within a designated area plays a vital role in ensuring safety during fire emergencies. The motion sensor's ability to detect individuals within a radius of 60 cm offers an added layer of security, especially in scenarios where the presence of people in a high-risk area, such as a building at risk of fire, needs to be monitored. This feature allows the system to trigger timely notifications or alerts, assisting in enhancing safety and prevention efforts for communities by monitoring both fire hazards and human activity within vulnerable spaces.

4. Discussion

The research conducted in this study integrates three distinct sensors, each serving a unique function in a comprehensive community-based fire and temperature monitoring system. These sensors include a flame sensor for detecting fire, a temperature sensor for monitoring the ambient temperature, and a PIR (Passive Infrared) sensor to detect human movement. The combination of these sensors enhances the system's ability to respond dynamically to various environmental changes, providing critical safety measures for public spaces.

The temperature sensor used in this study has demonstrated a remarkably low error rate of only 0.42%, making it highly accurate in detecting temperature fluctuations within the monitored area. This level of precision is essential for identifying potential fire hazards early, allowing for timely intervention to prevent catastrophic events. The flame sensor, on the other hand, is capable of detecting flames within a 70 cm radius from the source of the fire, offering a responsive means to identify ignition sources quickly and activate appropriate safety measures.

In terms of human movement detection, the PIR sensor has proven to be effective in monitoring activities within a 60 cm range, with the potential to detect movement over greater distances. The PIR sensor is critical in applications where human presence needs to be tracked, especially in emergency scenarios where rapid evacuation is required, or where a fire detection system must differentiate between environmental changes and the presence of individuals. This capability is essential in ensuring that the system can not only identify fire risks but also safeguard individuals in high-risk areas.

The data collected from these sensors are instrumental in the functioning of the system, particularly in triggering an alert mechanism such as a buzzer. When an anomaly such as an elevated temperature or the presence of a flame is detected, the system automatically activates the buzzer, alerting individuals in the area of a potential emergency. This integration of multiple sensors provides a robust community-based safety and prevention mechanism that can be widely implemented in various settings to enhance public safety and prevent the devastating consequences of fire-related accidents. The system's accuracy and responsiveness are key to its potential for use in community-oriented safety initiatives, ensuring that both environmental risks and human factors are closely monitored and addressed.

IV.CONCLUSION

In general, the three sensors—flame sensor, temperature sensor, and PIR sensor—function effectively and efficiently for the implementation of a fire detection system. These sensors work seamlessly together to detect potential hazards such as fire outbreaks and human movement, ensuring a proactive response to environmental changes. The flame sensor accurately identifies the presence of fire, while the temperature sensor provides reliable readings of ambient temperature fluctuations that may indicate fire risks. The PIR sensor effectively detects human movement, further enhancing the system's capacity to monitor both environmental conditions and human activity in real time.

Additionally, the integrated buzzer system responds optimally to these sensor inputs, providing timely alerts to occupants or users in the area. When any of the sensors detect abnormal conditions, such as a fire or the presence of individuals in a restricted area, the buzzer sounds, warning people of the potential danger. This feature significantly contributes to the safety and prevention measures, ensuring that individuals are promptly informed of any threats, enabling them to take appropriate actions for their protection. Overall, the system's ability to monitor fire risks, detect human presence, and activate immediate warnings demonstrates its potential for enhancing safety in community spaces, thereby serving as a vital tool for public safety initiatives.

Conclusion:

- The combination of flame, temperature, and PIR sensors offers a comprehensive solution for fire detection and human movement monitoring.
- The system provides accurate readings and rapid response to environmental changes, significantly enhancing safety.
- The buzzer system provides an effective alert mechanism, ensuring timely notification to occupants in case of emergencies.
- The proposed system is a practical tool for community-based fire safety initiatives, contributing to the overall protection of individuals and property.

In conclusion, this system's integration of multiple sensors and alert mechanisms makes it a valuable asset for improving public safety and preventing fire-related incidents.

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