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Arduino Uno fire alarm system with Android connectivity using GSM Module, Temperature, and Smoke Sensor

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Abstract

Traditional fire alarm systems often need to be improved in densely populated urban environments. Thus, the researchers utilized experimental research to develop an Arduino Uno fire alarm system with Android connectivity using a GSM Module, temperature sensor, and smoke sensor. After developing the device, the researchers tested and answered the validated evaluation checklist to determine if the device was properly working or not. Results reveal that the participants strongly agree that the device is effective, with an overall mean of 3.52. Moreover, it was found that the system's Android connectivity improves the timeliness of fire alerts and enhances emergency response coordination. Moreover, no significant difference exists between the Arduino Uno fire alarm system with Android connectivity and the traditional fire alarm system; thus, the device was accepted. Thus, the Arduino Uno fire alarm system with Android connectivity using a GSM module, temperature, and smoke sensor offers a compelling alternative, addressing these shortcomings through its affordability, adaptability, and seamless connectivity. Arduino boards are renowned for their cost-effectiveness, making them a viable option for widespread implementation, even in areas with limited resources. This technology opens doors to improved fire safety in communities that might not otherwise have access. Future researchers can optimize the algorithm's performance and enhance the reliability of early fire detection by training the system on diverse datasets encompassing various environmental conditions and types of fire events.

Keywords: Arduino Uno, GSM module, Android integration, scalable and affordable detection, smoke sensor

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1. Introduction

Recognizing the urgent need for a practical and reliable fire detection and warning system, the researchers explored an Arduino Uno fire alarm system with Android connectivity. They incorporated a GSM module and their temperature and smoke sensors into the system. The researcher's goal was to create a system that not only promptly detects fires but also notifies users remotely via smartphones. Understanding the importance of early fire detection in preventing property damage, injuries, and fatalities, the researchers aimed to advance fire safety by providing a new, accessible solution that combines cutting-edge technology with essential safety measures. This motivation drove them to undertake this study. As Singh (2018) stated, an automatic fire alarm system is designed to detect fires by monitoring combustion-related environmental changes. Fire alarm systems are classified as automatic, manually activated, or both. These automatic systems can alert people to evacuate during a fire or other emergency, summon emergency services, and prepare the building and its systems to manage the spread of fire and smoke. In recent years, fire alarm systems have become more advanced, reliable, and functionally capable. They aim to meet two main objectives: protecting property and assets and ensuring life safety. Due to state and local regulations, the focus on life safety in fire protection has significantly increased over the past two decades.

As indicated in the research by Koggalage et al. (2021), to address this, an intelligent fire and high-temperature detection system has been designed utilizing GSM technology, along with smoke and temperature sensors integrated with Arduino technology. The smoke sensor detects smoke from a fire, while the temperature sensor monitors any rise in temperature within the building. If a fire is detected, the system sends an alert message to the user via SMS through the GSM module. Additionally, the system will send a signal to the main power supply circuit breaker via a microcontroller, causing the power supply to the building to shut down. The results from testing this system are documented and discussed in this paper. This system allows users to respond promptly to fire emergencies, enhancing safety by protecting lives and property from disasters. Fire is a highly hazardous situation, making it crucial to monitor and provide warnings before any unfortunate incidents occur. In many developing countries, homes are not equipped with fire alarm systems, as is common in developed nations like Singapore and the USA. This often results in fires going unnoticed, leading to significant losses of property and human lives. Additionally, in developing countries such as India, there are no stringent laws mandating the installation of fire alarm systems in all homes to alert fire service personnel. Therefore, there is an urgent need to develop an automated fire monitoring and warning system. Such a system is vital for maintaining and monitoring safe conditions and preventing potential disasters (Tarhate et al., 2020).

As evidenced by Kodur et al. (2019), delays in coping with fires can cause the loss of human life or materials. Most of the fire cases occurred in residential houses. A house is an object that is vulnerable to fire because of its activities. Human safety is an essential factor that must be considered and prioritized in a house fire. Hence, authorities should issue early warnings to residents of disaster-affected homes when a fire occurs, enabling them to evacuate independently. Conventional fire alarm systems in the Philippines often lack comprehensive fire detection capabilities, real-time communication with emergency responders, and effective remote monitoring, leading to delayed response, increased damage, and reduced response to actual fire incidents. In 2021, Ahmed et al. created an Arduino-based fire alarm system with Android connectivity that utilizes a GSM module to send SMS notifications to designated users upon detecting fire hazards. The system also incorporates a buzzer for local alarms and a relay to control electrical appliances, such as fire extinguishers and sprinkler systems.

This developed system comprised several key components: an Arduino Uno microcontroller board for

central processing, a GSM module for real-time communication, temperature and smoke sensors for continuous monitoring, and an alarm mechanism for timely notifications. This functionality offers several advantages, including enhanced fire detection, real-time notifications, improved response time, and remote monitoring capabilities. This research anticipates challenges related to the seamless integration of Arduino Uno components, reliable GSM communication, and sensor coordination. Future work will address these challenges and refine the system's performance, including exploring the integration of additional sensors for enhanced capabilities. Increased temperatures or fires frequently result in deaths and other disasters, highlighting the importance of taking immediate action to prevent fires. Traditional fire alarms often need to provide complete monitoring and instant communication. Inadequate fire extinguishing systems, insufficient fire alarms, and insufficient emergency exits can increase the impact of disasters. Using technology in the modern day can help with alerts and warnings that arise early, allowing for quick responses to possible threats. The Philippines faces a pressing need for improved fire safety measures. Conventional fire alarm systems often fail to meet the country's requirements. Arduino Uno fire alarm systems with Android connectivity offer a promising solution. They leverage Arduino's versatility and affordability, the ubiquity of Android devices, and the potential for local innovation to enhance fire safety for a large population.

This study aimed to produce an Arduino Uno Fire Alarm System with Android Connectivity Using a GSM Module, Temperature, and Smoke Sensor to address the critical demand for enhancing fire safety regulations. Despite the limitations of conventional fire alarm systems, this study uses the affordability, adaptability, and widespread use of Android-powered mobile devices to develop an innovative solution using Arduino Uno. By integrating temperature, smoke, and GSM connectivity, the system provides instant communication and real-time monitoring, allowing early detection of possible fire risks. This study has the potential to enhance public safety significantly by establishing a dependable and practical approach to alerting and managing fire emergencies, thus addressing the deficiencies in the nation's traditional systems.

Statement of the Problem - This study aimed to produce an Arduino Uno fire alarm system with Android connectivity using a GSM module, temperature sensor, and smoke sensor to send SMS notifications for remote monitoring and alerts. The study sought to address the following questions: (1) What is the level of effectiveness of an Arduino Uno fire alarm system with Android connectivity using a GSM module, temperature sensor, and smoke sensor in terms of early detection, efficiency, and alert capabilities? (2) Can the system's Android connectivity improve the timeliness of fire alerts and enhance emergency response coordination? (3) Is an Arduino Uno fire alarm system with Android connectivity more effective than a traditional fire alarm in detecting fires in their early stages?

Significance of the Study - The importance of this study is to provide real-time alerts to users, enabling swift response and evacuation procedures with the integration of cutting-edge technologies. This system offers a more advanced and efficient means of detecting fire incidents. This research aimed to provide an alarm for detecting fires that could be highly beneficial to the following: Residents/Homeowners. This study is an essential safety tool that offers early detection, possibly saving lives, defending property, and giving homeowners peace of mind. For establishments, this study provides early warning, saves lives, follows rules, and preserves property; fire alarms are necessary safety equipment for buildings. Fire alarms are essential to risk management and safety in commercial and public spaces. For schools, this study is necessary for school safety tools because they offer early detection, life-saving notifications, and regulatory compliance. Fire alarms are crucial for safeguarding the well-being of students, faculty, and the school's physical property. Future Researchers. This study may benefit future researchers and provide the basis for improving and developing more high-tech fire alarms.

Scope and Delimitation of the Study - This study focused on producing an Arduino Uno Fire Alarm System with Android Connectivity powered by a GSM Module, temperature, and smoke sensors. One primary objective is to evaluate the effectiveness of the developed system as a potential substitute for existing commercial fire alarm solutions. However, researchers acknowledge inherent limitations hindering further product improvement. These limitations include natural constraints of the Android operating system, budget restrictions, resource scarcity, and

insufficient personnel within the projected timeframe. Despite these limitations, the researchers remain optimistic about the possibility of creating a novel product that challenges existing paradigms and sets a new standard in fire safety technology. To ensure reliable communication in areas with limited or no internet access, the researchers integrated GSM technology into the system to enhance communication reliability, as the system's ability to provide real-time alerts may be compromised due to potential delays or notification failures. While the Arduino Uno performs well within its intended scope, larger deployments may necessitate the adoption of a more robust and scalable microcontroller platform to guarantee optimal responsiveness and performance in various fire safety scenarios. By actively addressing these limitations and incorporating innovative solutions, the researchers hope to develop a groundbreaking fire alarm system that offers enhanced safety and reliability while challenging established industry norms. This science investigatory project was conducted at the Divine Word College of San Jose, Occidental Mindoro. The project commenced in August 2023 and was scheduled to be completed in April 2024.

2. Methodology

Research Design - This applied research aimed to assess the practical implementation of Arduino Uno fire alarm systems with GSM connectivity in residential settings. By evaluating user experiences, system reliability, and real-world impact, the research seeks to provide valuable insights into the feasibility and effectiveness of adopting such systems for enhancing home fire safety. Applied research is an original investigation undertaken to acquire new knowledge; it is directed primarily toward a specific, practical aim or objective. It is about using the existing stock knowledge with the appropriate methodology for a particular purpose, usually related to resolving a practical problem.

Data Gathering Procedure - The researchers used an observational approach, closely observing the system's performance in real-time scenarios to test the prototype's efficiency. This included setting up regulated settings with temperature and smoke sensors to activate the system during a simulated fire. The main observation points were the system's fire detection response time and the effectiveness and dependability of the GSM module's alerts to users' smartphones. The coding development stage commenced on March 21, 2024, and concluded on March 24, 2024, following the product phase from March 25, 2024, to March 26, 2024. Subsequently, the experimental phase, utilizing trial-and-error techniques, occurred for four days, from March 30, 2024, to April 2, 2024. Furthermore, the evaluation checklist was validated by the experts to determine the functionality of the developed device. The seven researchers tested and evaluated the product. It took two days to finish the testing and answer the evaluation checklist.

Research Process: Stage 1 Preparation and Gathering of Materials - Cutting-edge components and novel materials are given priority in this project to improve the Arduino Uno fire alarm system with Android connectivity using a GSM module, temperature sensor, and smoke sensor. All the components needed to construct the device were bought online, specifically from MarkerLab Electronics. The cost of these materials was ₱1608. The following is a list of materials:

For the electronic device:

- Arduino Uno R3

- Temperature sensor -Smoke Sensor - Piezo Buzzer - GSM Module

Stage 2: Building and Development of the Project - Components like an Arduino board (such as the Arduino Uno), piezo buzzer, battery, connecting wires, and smoke sensor (MQ series) are needed to build an Arduino Uno fire alarm. Attach the buzzer to a digital pin on the Arduino Uno, power it on, and connect the smoke sensor to the analog pin. Create a basic Arduino Uno sketch to read sensor values and sound the buzzer when smoke is detected. Ascertain an appropriate power source and adhere to safety protocols. Maintain a fire safety plan at all times, and think about reviewing pertinent fire alarm system standards. The components are arranged methodically after the functional codes are entered. It took four days to finish the coding, while another two days

were spent developing the whole device. The last phase is to watch and record the system's operation, which takes another two days.

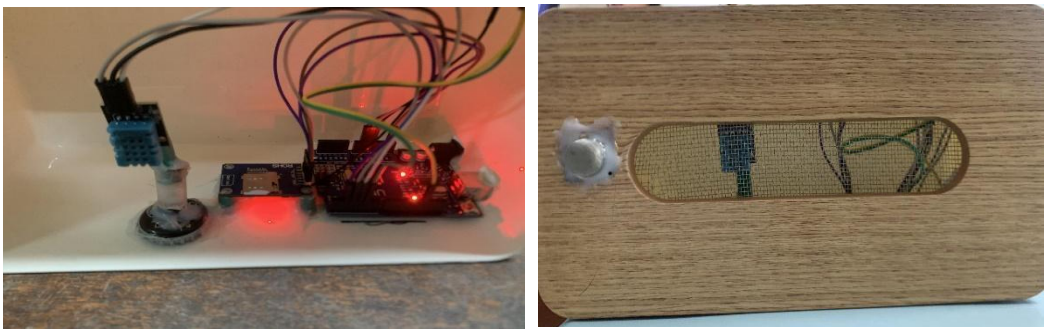

Figure 1. Actual Product of Arduino Uno-Based Sound Sensor System for Waste Sorting of Metal and Non-Metal

Stage 3: Experimental Stage, Observation and Data Recording - The Arduino Uno microcontroller processed inputs from the temperature and smoke sensors, triggering the fire alarm upon detection of predefined hazard levels. Participants interacted with the system, observing its responsiveness and ensuring it accurately detected and communicated potential fire situations to an Android device through the GSM module. The experiment included scenarios designed to test the system's real-time alerts, temperature sensitivity, smoke detection accuracy, and effectiveness in providing timely warnings. Through rigorous testing and data collection, this experimental stage aims to evaluate the system's functionality, reliability, and user-friendliness, contributing valuable insights for further refinement and enhancement. This paper emphasized safeguarding residential or industrial spaces through sensor-based surveillance and predictive measures to prevent potential issues. It introduced advancements in wireless sensor network (WSN) techniques, proposing new design methods to enhance cost-effective industrial and home safety systems. In addition to temperature and humidity sensors, the study incorporates flame and gas sensors for a comprehensive safety approach. The straightforward hardware circuit design facilitates the user-friendly implementation of this wireless home safety system. User notification is a communication method to inform users about the system's status. An Arduino Uno device, programmed with Android Studio, receives signals from gas, flame, temperature, and humidity sensors. To proactively assess the fire risk, the system activates communication with the WIFI network and sends alarm notifications to mobile users when collected data surpasses predefined threshold levels.

Statistical Treatment of the Data - The researchers used frequency and weighted mean to determine how effective a fire alarm with Android connectivity and the Arduino Uno fire alert system with real-time notifications are. Moreover, a t-test analysis was used to compare the performance of the Arduino Uno fire alarm system with Android connectivity and that of a traditional fire alarm system.

3. Results and Discussions

Table 1 shows the extent of the effectiveness of a fire alarm through Android connectivity. These advantages include a reduced false alarm rate, improved early detection reliability, and enhanced fire prevention and mitigation effectiveness. This underscores the potential benefits of integrating modern technology, such as Android connectivity, into fire safety systems to improve performance and efficiency. As observed in the study by Rakshit et al. (2019), fires pose a significant risk to life and property, often caused by the chemical reaction of carbon-based materials with oxygen, leading to flammable vapor and a rapid increase in temperature. Detecting fires early is crucial to preventing serious accidents. This project involves creating an Arduino Uno Fire Alarm System with Android Connectivity Using a GSM Module, Temperature Sensor, and Smoke Sensor. The system can detect smoke and temperature changes, activate a buzzer, and send the building or property owner warning

messages via the GSM module. Smoke detectors are commonly used in high-security areas to prevent fire-related injuries. The hardware includes an Arduino Uno, a temperature sensor, a smoke sensor, a GSM module, and a buzzer. By detecting smoke early and sounding an alarm, this system can help evacuate people and take immediate action to prevent the fire from spreading. Additionally, a smoke detector that activates a fan to remove smoke has been developed in this project.

Table 1

Mean Extent of the Effectiveness of a Fire Alarm through Android Connectivity

Indicators	4 (SA)	3 (A)	2 (DA)	1 (SDA)	Weighted Mean	Descriptive Indicator
There is a significant difference in the false alarm rate between the early detection system and the conventional detection method.	3	4	0	0	3.43	Strongly Agree
The reliability of early detection systems compares to traditional systems in terms of detecting fires accurately and consistently.	4	2	1	0	3.43	Strongly Agree
Considering early detection, early efficiency, and alert capabilities, the system demonstrates a significantly higher overall effectiveness in fire prevention and mitigation than a conventional system.	5	2	0	0	3.71	Strongly Agree
Overall Mean					3.52	Strongly Agree

Legend: 3.26 - 4.00 Strongly Agree, 2.51 - 3.25 Agree, 1.76 - 2.50 Disagree, 1.00 - 1.75 Strongly Disagree

Table 2

Mean Level of Effectiveness of the Arduino Uno fire alert system with real-time notifications

Indicators	4 (SA)	3 (A)	2 (DA)	1 (SDA)	Weighted Mean	Descriptive Indicator
The Arduino connectivity feature enables real-time notification of fire alerts to designated personnel or emergency services.	5	2	0	0	3.71	Strongly Agree
The system can automatically send notifications to predefined contacts or emergency responders upon detecting a fire	4	2	1	0	3.43	Strongly Agree
Overall Mean					3.57	Strongly Agree

Legend: 3.26 - 4.00 Strongly Agree, 2.51 - 3.25 Agree, 1.76 - 2.50 Disagree, 1.00 - 1.75 Strongly Disagree

Table 2 reveals a positive perception of the system's capabilities, particularly regarding real-time notification and automated response to fire incidents. While there may be some minor disagreement regarding certain aspects, the sentiment strongly favors the system's effectiveness in enhancing fire safety and emergency response coordination. As shown in the study by Ehsan et al. (2022), studies have been conducted on systems for delivering fire information, including those that use microcontrollers and mobile phones to provide the information. As part of this system, MQ-2 smoke sensors are used, UVTRON fire sensors are used, a mobile phone represents a data sender, and an ATmega32 microcontroller represents a controller. SMS is used to notify users of fires using the SIM900, MQ-2 smoke sensors, and the LM35 temperature sensor. The system can warn the homeowner if a fire occurs outside the house. Arduino Uno is used to control all the components. Temperature and smoke sensors are used in this detector to help detect fires early. System components include temperature sensors, smoke sensors, 0809 digital-to-analog converters, system controllers with AT89S52 microcontrollers, and an alarm system to indicate a fire. Upon detecting fires using temperature and smoke sensor information, this prototype fire detection system activated an alarm as soon as the indicator sounded.

Table 3 shows the t-test results comparing the Arduino Uno fire alarm system with Android connectivity and the traditional fire alarm system. Monitoring home or industrial areas using sensors and preventing issues through predictive measures are crucial for ensuring safety in these environments. The results proved the rejection of the null hypothesis since the t statistic (5.83) is greater than the t critical value (2.45). Therefore, the system's Android connectivity improves the timeliness of fire alerts and enhances emergency response coordination. Thus, it enhances wireless sensor network (WSN) techniques by developing new design methods and creating cost-effective safety systems for industrial and home use. This study incorporated temperature, humidity, and flame and gas sensors to provide precise solutions. A straightforward hardware circuit design ensures that any user can operate this wireless home safety system. Notifications were employed to inform users about the system's status and alerts (Design and Implementation of the Mobile Fire Alarm System Using Wireless Sensor Networks, 2016).

Table 3

t-Test Results on the Comparison of Arduino Uno Fire Alarm System with Android Connectivity and Traditional Fire Alarm System

t-Test: Two-Sample Assuming Unequal Variances		
	Arduino Uno- Fire Alarm System (Variable 1)	Traditional Fire Alarm System (Variable 2)
Mean	3.836734694	2.602040816
Variance	0.05563654	0.120505345
Observations	7	7
Pearson Correlation	-0.842674323	
Hypothesized Mean Difference	0	
df	6	
t Stat	5.828364915	
P(T<=t) one-tail	0.000561286	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	0.001122572	
t Critical two-tail	2.446911851	

Legend: *Highly Significant at p≤0.01 *Significant at p≤0.05

Table 4

t-Test Results on the Difference between the Arduino Uno Fire Alarm System with Android Connectivity and Traditional Fire Alarm System

t-Test: Two-Sample Assuming Unequal Variances		
	Arduino Uno- Fire Alarm System (Variable 1)	Traditional Fire Alarm System (Variable 2)
Mean	41.57142857	90
Variance	1070.952381	0
Observations	7	7
Hypothesized Mean Difference	0	
df	6	
t Stat	-3.91530499	
P(T<=t) one-tail	0.003922147	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	0.007844295	
t Critical two-tail	2.446911851	

Legend: *Highly Significant at p≤0.01 *Significant at p≤0.05

Table 4 shows the difference between an Arduino Uno fire alarm system with Android connectivity and a traditional fire alarm system. The statistical result shows no significant difference between the developed device and the traditional alarm system. This implies that the development of a home fire alert system is centered around the Arduino Uno board, enabling early detection of fires. When a fire is detected, the system triggers an alarm. It sends SMS or call alerts to predefined mobile numbers stored within the Arduino Uno program, facilitated by the GSM module. As signified by Yadav & Rani (2020), the utilization of various IoT devices for home automation has surged in popularity in recent years. One crucial application of home automation through IoT is fire detection and prevention of fire accidents. Traditional fire alarm systems entail substantial installation costs and labor, often incorporating fire extinguishing capabilities. Thus, the Arduino Uno is useful for monitoring the environment for potential fire incidents using fire and gas sensors, just like traditional alarms.

4. Conclusions

The evaluation of the Arduino Uno fire alarm system with Android connectivity has demonstrated its potential to improve home fire safety measures significantly. Through standardized testing and statistical analysis, the researchers have shown that this innovative system offers enhanced capabilities for detecting fires in their early stages compared to traditional systems. Integrating multiple sensors and Android connectivity allows for a more comprehensive detection process and timely alert dissemination, potentially minimizing damage and saving lives. Additionally, this system proved that Android connectivity improves the timeliness of fire alerts and enhances emergency response coordination. Moreover, no significant difference exists between the Arduino Uno fire alarm system with Android connectivity and the traditional one. Thus, it shows the acceptability of the device.

4.1 Recommendation

It was advised that future studies on Arduino Uno fire alarm systems connected to Android devices concentrate on improving the incorporation of machine learning methods. In particular, researchers may investigate the viability of using machine learning models for sensor data analysis to enhance the system's precision in identifying and categorizing fire dangers. Conducting thorough testing and validation of the machine learning-based fire detection algorithm under real-world scenarios will be crucial to ensuring its effectiveness in practical applications. Researchers may optimize the algorithm's performance and enhance the reliability of early

fire detection by training the system on diverse datasets encompassing various environmental conditions and fire events. This focused line of inquiry may significantly increase the capabilities of fire alarm systems with Android connectivity built on Arduino Uno.

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