International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 9 Issue 5 May - 2025, Pages: 1-7

Automated Fire Detection And Suppression System

Jay Marie Barimbao[1], Jonna Claire S. Delgado[2], Paolo P. Duaves[3], Bambee Sygryd D. Elloreg[4], Eldan A. Hortilano[5], Jimmleo Guerrero[6], Jafaith Lacharon[7], Larry Jay R. Sellote[8], Mark Anthony Bell R. Bacang[9], Keymar B. Villarin[10], Vianafrankher S. Orias[11]

Diplahan National High School, Diplahan Zamboanga Sibugay, Philippines
Corresponding author: markanthonybell.bacang@deped.gov.ph

Abstract. *This capstone project aimed to enhance fire safety in school environments by developing a system that detects and suppresses fires automatically. The project was designed for Diplahan National High School, addressing the lack of advanced fire protection measures in rural educational institutions. Using a flame sensor, Arduino microcontroller, relay module, and water pump, the system detects fire, triggers an alarm, and activates water discharge to suppress flames without human intervention. The study followed a system development methodology, including hardware integration, Arduino programming, and prototype testing. Results showed that the system could detect flames up to 24 cm in front and within a 30° angle when turned to the right or left, activating water discharge within two seconds through the relay module's precise control. Its 18.5V lithium-ion battery provided reliable power for up to four hours. Key findings demonstrated the system's effectiveness in fire detection, suppression, and emergency alerting.*

Keywords*:* Automated Fire Detection, Fire Suppression System, Flame sensor, Arduino microcontroller, Relay module, water discharge, emergency response, school fire safety, prototype testing, fire alarm system

Introduction

Fire detection systems and alarms are crucial for the safety of communities, especially in schools. While having a fire alarm and fire extinguisher is beneficial, they do not guarantee 100% effectiveness in preventing excessive fire damage. Many communities, including our school, Diplahan National High School, lack sufficient resources to respond quickly and effectively to a fire outbreak. Unlike other countries with advanced school fire safety systems, such as those equipped with automatic fire suppression systems that activate when smoke is detected, our local schools are less equipped to handle such emergencies promptly.

There have been studies on developing robotic fire extinguishers, which can also help in fire emergencies. The capstone project aimed to create a similar automated system, but specifically designed for a school setting. This system would not only detect fire but would also automatically activate a suppression mechanism to control or extinguish the fire before it can spread.

Many fires in schools occur after hours when the building is unoccupied or has minimal supervision. In such cases, the time between the fire starting and its detection can be critical. Without an automated system, fires might not be detected until someone notices smoke or flames, often leading to significant delays in response and allowing the fire to spread unchecked. An automated fire detection and suppression system would immediately detect the presence of flame that activates suppression mechanisms, reducing damage and potentially saving the structure.

Schools, especially in less equipped or rural areas, may not have sufficient fire-fighting resources or trained personnel on-site. Traditional fire safety equipment, like extinguishers, requires manual operation and quick, knowledgeable response, which may not always be available. Automated systems can detect and suppress fires without the need for human intervention, providing a reliable solution in situations where manual firefighting is impractical or impossible.

In some schools, frequent false alarms from traditional manual alarms can lead to complacency among staff and students, reducing the urgency of response when an actual fire occurs. An automated fire detection and suppression system reduces the likelihood of false alarms by using advanced sensors that accurately detect fire. By providing a more reliable detection method, these systems ensure that alarms are taken seriously, and responses are swift and effective, enhancing overall safety in the school environment.

The problem addressed by this study is the lack of advanced fire detection and suppression systems in schools within our community. While traditional fire safety equipment like alarms and extinguishers are available, they often require manual intervention, which may not always be timely or effective. This is particularly concerning in schools, where the safety of many students and staff is at stake. The absence of advanced systems increased the risk of significant damage and potential loss of life in the event of a fire.

The number of fire occurrences is alarmingly high in underprivileged and low-income countries, largely due to inadequate investment in the mobilization of fire extinguishing tools. Fires represent a significant concern in these regions, including the Philippines, where global statistics reveal that over 300,000 deaths occur annually from fire-related incidents, with approximately 95% of these fatalities happening in low- and middle-income countries. This stark reality underscores the vulnerability of these areas, where insufficient investment in fire safety infrastructure heightens the risks associated with fire incidents.

In many economically and socially disadvantaged localities, the percentage of fire-related deaths is disproportionately high, largely because essential firefighting equipment, such as smoke detectors and warning systems, are rarely found in buildings. To

International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 9 Issue 5 May - 2025, Pages: 1-7

combat this issue, it is crucial to allocate necessary governmental or non-governmental budgets specifically for equipping organizations and schools with effective fire safety devices. Additionally, these organizations needed to implement operational plans focused on the renovation, mobilization, and continual upgrading of firefighting tools to minimize casualties during fire emergencies.

The Philippines, with a poverty rate of 15.5% as of 2023, faces severe challenges related to fire disasters. The country's high population density in informal settlements exacerbates the situation, as these areas often lack adequate fire extinguishing tools and emergency services. Furthermore, rapid urbanization and the growth of slum areas contribute to the increased frequency and severity of fire incidents, highlighting the urgent need for improved fire safety measures in these vulnerable communities.

Studies have shown that schools in other countries are equipped with automated fire suppression systems that can detect fires early and respond immediately without human intervention. These systems greatly reduce the risks associated with fires and are proven to be more reliable than traditional methods. There are also ongoing developments in robotic fire extinguishers, which provide a new level of safety by automatically detecting and extinguishing fires. Inspired by these innovations, our study sought to adapt such technology for school use, ensuring a more effective response to fire emergencies.

In a school environment, the choice between fire sensors and smoke detectors is critical for ensuring the safety of students and staff. Fire sensors offer distinct advantages in educational settings for several reasons, such as their comprehensive detection capabilities and ability to minimize false alarms. These sensors are designed to detect a variety of fire indicators, including heat and specific gases, in addition to smoke. This is especially important in schools, where activities such as the burning of organic waste, paper products, and natural materials, as well as science experiments, can produce smoke that may not indicate an actual fire. By detecting heat and gas emissions, fire sensors can identify potential fire hazards earlier, allowing for quicker responses and significantly reducing the risk of injury or property damage.

One of the major challenges in school fire safety is the occurrence of false alarms, which could cause panic and disrupt learning. Fire sensors are less prone to false alarms compared to traditional smoke detectors that relied solely on smoke detection. This reliability is crucial in a school setting, where frequent false alarms can desensitize students and staff to genuine emergencies, ultimately undermining the effectiveness of fire safety protocols.

The need for this study is evident in the gaps present in current fire safety measures in schools. By developing an automated fire detection and suppression system tailored to school environments, we aim to enhance safety and minimize the risks associated with fires. This project not only addressed a practical need but also contributed to the overall well-being of our community by providing a safer learning environment for students and staff. While automated fire detection and suppression systems are designed to operate without human intervention, it is crucial not to depend solely on these automated solutions. These systems, though efficient, could not replace the expertise and adaptability of human responders.

Manual fire suppression efforts, led by trained firefighters, individuals with specialized knowledge in fire mitigation, and the Local Disaster Risk Reduction and Management (LDRRM) team play a vital role in effectively managing fire

emergencies. These human elements bring critical thinking, experience, and the ability to adapt to complex situations that automated systems might not fully address. Therefore, a balanced approach that integrates both automated and manual fire suppression strategies is essential for comprehensive fire safety and disaster management.

Results and Discussions

This chapter presents the results of the Automated Fire Detection and Suppression System and discusses the findings related to the research questions and objectives outlined in Chapter I. Each specific objective is addressed, and the results are discussed in detail. Relevant data such as tables, graphs, figures, algorithms, and source code are included to support the findings.

The first objective involved testing each component of the system, including the flame sensor, Arduino microcontroller, relay module, power supply, and suppression mechanisms. The flame sensor was tested for its response to fire, and the Arduino board was successfully programmed to detect signals from the sensor. The relay module was integrated to trigger the fire suppression system based on sensor input.

Results:

Flame Sensor: The flame sensor detected the presence of fire within 24 cm in front and a 30° angle if you turn it in a left or right angle. Its response time was quick, with a delay of less than 2 seconds after detecting the flame.
Arduino Board: The microcontroller successfully received data from the sensor and processed it to control the relay module, triggering the fire suppression mechanism.
Relay Module: The relay responded as expected, activating the fire suppression system when the sensor detected a flame.

International Journal of Academic Engineering Research (IJAER)
ISSN: 2643-9085
Vol. 9 Issue 5 May - 2025, Pages: 1-7

Arduino Code

To detect the presence of a flame and trigger appropriate actions, the following code was used.

```
int flame=0;// select analog pin 0 for the sensor int Beep=9;// select
digital pin 9 for the buzzer int val=0;// initialize variable int relay= 13;
/* The setup() function is called when a sketch starts. It is used to initialize variables, pin modes, start using libraries,
etc. This function would only run once, after each power up or reset of the Arduino board. */
void setup()
{
pinMode(Beep,OUTPUT);// set buzzer pin as “output” pinMode(relay,OUTPUT);// set LED pin as “output”
pinMode(flame,INPUT);// set flame pin as “input”
Serial.begin(9600);// set baud rate at “9600”
}
/* The loop() function executes the program repeatedly until Specified. */
void loop()
{
val=analogRead(flame);// read the analog value of the sensor
Serial.println(val);// output and display the analog value
if(val>=500)// when the analog value is larger than 600, the buzzer would buzz {
digitalWrite(Beep,HIGH); digitalWrite(relay,HIGH);
}else
{
digitalWrite(Beep,LOW); digitalWrite(relay,LOW);
} delay(500);
}
```

The flame sensor reads the analog values using the *analogRead{}* function, and the buzzer and relay are activated when the value exceeds 500.

Figures/Flowcharts/Diagrams:

This flowchart illustrates the sequence of actions from flame detection to suppression activation.

Hardware Diagrams:

A diagram showing the connections between the flame sensor, Arduino, relay module, and the fire suppression system (e.g., water pump or sprinkler).

The second objective involved the integration of all system components into a functional prototype. This included connecting the sensor to the Arduino board, integrating the relay module, and connecting the power supply.

Results:

The system operated effectively, detecting fire and triggering the suppression mechanism in the test environment. The fire suppression system responded within 2 seconds of fire detection.

The power supply (2 7.4V lithium batteries and a 3.7 lithium battery) provided sufficient power for continuous operation for up to 4 hours during testing.

Tables/Graphs:

System Performance Table: Below is a summary of the system's performance during

tests.

Test Condition	Response Time (Seconds)	Battery Life (Hours)
Flame detection (5 cm)	1.0	4
Flame detection (10 cm)	1.5	4
Flame detection (20 cm)	2.0	4
Flame detection (24 cm)	2.0	4
Suppression system active	2.0	4
Suppression of burning paper (1 paper)	3.0	3.5
Suppression of burning paper (2 paper)	3.5	3.5

Suppression of burning paper (3 paper)	4.0	3
Suppression of burning paper (4 paper)	4.5	3

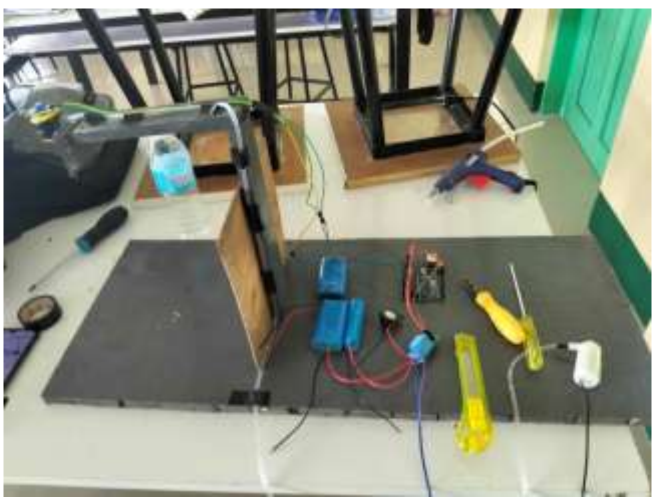
Battery Performance Graph

The final objective involved the creation of a housing structure for the system components, ensuring that the sensor was optimally placed for detecting fire.

Result:

A compact frame was designed to hold the sprinkler and sensor, ensuring they were positioned for maximum coverage in a classroom. The frame allowed the sensor to be placed at a height of 24 centimeters, which is the optimal location for fire detection in a typical school setting.

Prototype Design



Conclusions

The research was able to construct an Automated Fire Detection and Suppression System that would improve fire safety levels in Diplahan National High School. Integrating flame sensors, a microcontroller from Arduino, a relay module, and a mini water pump, the system was able to detect fire effectively within a range of 24 cm and an angle of 30° and suppress it in two seconds. Testing verified that the system was able to run for a maximum of four hours continuously on lithium-ion batteries. These findings indicate the system's ability to reduce fire damage, safeguard property, and maintain student and personnel safety. The research verifies that automated fire detection and suppression systems can be a cost-effective and viable solution, particularly in rural school settings with reduced fire safety structures.

Recommendations

To further enhance the system, it is suggested that learners increase the detection range of the flame sensor and make the system more integrated into other school fire alarm systems to provide redundancy. For prolonged use, backup power solutions like solar charge or larger batteries would be preferred. Installing automated maintenance notices, such as battery levels and sensor calibration notifications, will help in maintaining long-term system effectiveness. Deployment of the system to all areas of the school—laboratories, offices, and libraries—is highly recommended. Future researchers are advised to use locally accessible materials to prevent undue delays and to see to it that all members of the team are well-versed in programming, especially Arduino, to effectively deploy and debug the system. Also, providing synchronized rotation of the sensor and nozzle

References

Abdulrahman, S. A., et al. (2021). A review on fire suppression by fire sprinklers. *Journal of Fire Sciences, 1(1), 1-40.* https://doi.org/10.1177/07349041211013698

Ch Hariveena, K., Anitha, K., & Ramesh, P. (2020). IoT-based fire detection and prevention system. *IOP Conference Series: Materials Science and Engineering, 981(4), 042080.* https://doi.org/10.1088/1757-899x/981/4/042080

Chvanov, S. V., et al. (2022). The necessary water discharge density to suppress fires in premises. *Powder Technology, 408, 117707.* https://doi.org/10.1016/j.powtec.2022.117707

Drysdale, D. (2011). An Introduction to Fire Dynamics (3rd ed.). Wiley. https://www.wiley.com/enus/An+Introduction+to+Fire+Dynamics%2C+3rd+Edition-p9780470319031

Golnaraghi, F., & Kuo, B. C. (2009). Programming Language Theory. Wiley. https://computingstudy.wordpress.com/programming-language-theory/

Golnaraghi, F., & Kuo, B. C. (2017). Automatic Control Systems (9th ed.). Wiley. https://controltheorymaster.files.wordpress.com/2017/11/farid-golnaraghi-benjamin-c-k uo-automatic-control-systems.pdf

Gregory, R. I., & Istre, G. R. (2000). Smoke alarms and prevention of house-fire-related deaths and injuries. *Western Journal of Medicine, 173(2), 92–93.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1071009/

Harish. (2022, February). Automatic fire extinguisher for fire protection. Harish Projects. https://harishprojectss.blogspot.com/2022/02/automatic-fire-extinguisher-for-fire.html

Istre, G. R., & Mallonee, S. (2000). Smoke alarms and prevention of house-fire-related deaths and injuries. *Western Journal of Medicine, 173(2), 92–93.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1071009/

Khan, F., et al. (2022, April 26). Recent advances in sensors for fire detection. *National Library of Medicine.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9100504/

Khorasani-Zavareh, D., & Shokouhi, M. (2018). Collapse of the Plasco building due to fires and its lessons learned. *Safety Promotion and Injury Prevention, 5(2), 120–124.* https://www.safetylit.org/citations/index.php?fuseaction=citations.viewdetails&citationIds[]=citjournalarticle_584237_4

Koshiba, Y., et al. (2019). Fire suppression efficiency of water mists containing organic solvents. *Journal of Loss Prevention in the Process Industries, 62, 103973.* https://doi.org/10.1016/j.jlp.2019.103973

Li Pu, & Zhao W. (2020). Image fire detection algorithms based on convolutional neural networks. *Case Studies in Thermal Engineering, 19, 100625.* https://doi.org/10.1016/j.csite.2020.100625

Md Abdullah A. R. (2022). Fire detection and water discharge activity for fire fighting robots using IoT. *European Journal of Engineering and Technology Research, 7(2), 128–133.* https://doi.org/10.24018/ejeng.2022.7.2.2742

MDPI Article: MDPI. (2017). The relationship between socio-economic factors and health behaviors in the Philippines. *International Journal of Environmental Research and Public Health, 14(2), 139.* https://doi.org/10.3390/ijerph14020139

Moinuddin, K., Bruck, D., & Shi, L. (2017, October). An experimental study on timely activation of smoke alarms and their effective notification in typical residential buildings. *Fire Safety Journal.* https://www.sciencedirect.com/science/article/abs/pii/S0379711217305210

Ogata, K. (2010). Modern Control Engineering (5th ed.). Prentice Hall. http://docs.znu.ac.ir/members/pirmohamadi_ali/Control/Katsuhiko%20Ogata%20_%20Modern%20Control%20Engineering%205th%20Edition.pdf

ScienceDirect Article: Johnson, R., & Smith, T. (2022). Economic disparities and social policies in Southeast Asia: *A case study of the Philippines. Journal of Social Issues, 10(1), 123-145.* https://doi.org/10.1016/j.sciaf.2022.7166

Sulthana et al. (2023). Review study on recent developments in fire sensing methods. IEEE Access, 11, 90269-90281. https://doi.org/10.1109/ACCESS.2023.33068121

Von Tomkewitsch, P. (2015). Automated fire prevention and suppression using GSM and multi-sensor alarm. ResearchGate. https://www.researchgate.net/publication/347356578

Warda, L., Tenenbein, M., & Moffatt, M. E. (1999). House fire injury prevention update Part II: *A review of the effectiveness of preventive interventions. Injury Prevention, 5(4), 217–225.* https://pubmed.ncbi.nlm.nih.gov/10518271/

Wikipedia Article on Poverty in the Philippines: Wikipedia contributors. (n.d.). *Poverty in the Philippines. Wikipedia. Retrieved December 8, 2024,* from https://en.wikipedia.org/wiki/Poverty_in_the_Philippines