IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

Smart Fire Protection and Suppression System

Dr. Suresh C[1], Charan T N[2], Chidananda S L[3], Abhilash[4], Praveen Kumar H M[5]
Assistant Professor, Department of Mechanical Engineering[1]
Students, Department of Mechanical Engineering[2-5]
Bangalore Institute of Technology, Bengaluru, Karnataka

Abstract: *Fire hazards pose a significant threat to life, property, and the environment, necessitating the development of smart and efficient fire fighting solutions. This project presents an intelligent Fire Protection System that integrates both manual and automatic operation for enhanced flexibility and control. Unlike traditional fire fighting methods, which are costly and require extensive human intervention, this system leverages advanced sensors, automated suppression mechanisms, and wireless communication to ensure a rapid and effective response to fire incidents. A motorized fire suppression unit with precision nozzles ensures optimized water and CO_2 distribution, minimizing resource wastage. The system is powered by an ESP32 microcontroller, enabling wireless communication via Wi-Fi or GSM, providing remote monitoring and control. The inclusion of LiDAR and GPS-based autonomous navigation allows the system to move toward fire-affected areas independently, making it suitable for hazardous environments.*

Keywords: fire fighting

I. INTRODUCTION

Fire accidents are one of the most devastating hazards, causing loss of life, destruction of property, and environmental damage. Traditional firefighting methods rely heavily on human intervention, which can lead to delayed response times, high operational costs, and safety risks for firefighters. To address these challenges, modern fire protection systems must incorporate automation, remote control, and efficient fire suppression techniques to improve safety and minimize fire-related losses. This project presents an intelligent Fire Protection System that operates in both manual and automatic modes, ensuring adaptability for different fire scenarios. The system is designed to detect fires using temperature, smoke, and flame sensors and can autonomously activate a fire suppression mechanism. To enhance firefighting efficiency, this system integrates both water and CO_2-based extinguishing techniques, making it suitable for various fire types. Additionally, the system features wireless connectivity, allowing users to monitor and control it remotely via a mobile application. To further improve response capabilities, the system incorporates advanced technologies such as ESP32 microcontrollers, LiDAR-based navigation, and GPS tracking. These features enable the system to navigate autonomously toward fire-affected areas, reducing reliance on human operators. The use of precision nozzles optimizes water and CO_2 usage, ensuring effective fire suppression while minimizing resource wastage. While the incorporation of these cutting-edge technologies increases the project's cost, it significantly enhances the system's reliability, efficiency, and effectiveness. The Fire Protection System is designed for residential, industrial, and remote applications, providing a scalable and technologically advanced solution to fire safety. By integrating automation, real-time monitoring, and multi-agent extinguishing mechanisms, this project aims to redefine modern firefighting strategies.

II. LITERATURE REVIEW

Dr. Arvind Mahalle [1], Design and Development of 360 Degree Fire Protection System, The project objectives, which included designing a system that could detect fires in all directions and extinguish them quickly, were successfully met. The system was able to detect fires using a flame sensor and extinguish them using a water pump, nozzle and valve. The system's ability to rotate the main servo motor in the direction of the fire and activate the pump servo motor to spray water made it an efficient solution for fire protection.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

Dhamak Sagar [3], 360 Degree Rotating Fire Protection System, It has sometimes been impossible for fire-fighting personnel to access the site of a fire, even as the fire causes tremendous property damage and loss of human life, due to high temperatures or the presence of explosive materials. In such environments, fire-fighting robots can be useful for extinguishing a fire. Thus, Fire-fighting robots are operated in places where fire fighters are unable to work. Besides that, firefighting robot can be used for protecting fire fighters from extreme danger in petro chemical, chemical dangerous product, toxicity or exploder fire accidents. Therefore, it also can reduce the human injury from a fire burning. The security of home, laboratory, office, factory and building is important to human life. We develop security system that contains a fire protection robot using sensor.

S Muruganantham [4], Design and Fabrication of 360 Degree Fire Protection System, Robots have become out to be an aspect wherein many human beings have shown their interest and gained reputation due to the development of many technologies. Consequently, it has been decided to design something that may make human existence less difficult and cozier, and the interest of this assessment is to make a "far flung managed 360 degree fireplace protection device." The proposed "faraway controlled 360 diploma fire safety machine" is designed for extinguishing hearth in a small floor plan of a residence, workplace, or shopping mall of precise dimensions with the help of family water and a water pump.

Prof. V. D. Yadav [5], 360 Degree Rotating Fire Protection System, Usual fire protection systems installed in buildings have the following disadvantage. They spray small amounts of water from each sprinkler which may not be enough to put out the fire. The sprinklers are not targeted and spray an entire floor or building ruining computers, furniture and paperwork. While this sprayer gun can spray water in desired quantity only at fire outbreak point to stop fire without ruining complete office furniture and electronics. This demo version is made to be remote controlled from few meters but future version will operate remotely from fire department.

Dr. Vishnu Agrawal [6], 360 Degree Rotating Fire Protection System, Fire monitors and sprayers are an amiable and controllable high-capacity water jet used to deal with large fires. Unlike Fire extinguishers, Fire Monitors are permanently installed and cannot be moved.

III. PROBLEM STATEMENT

Fire accidents pose a serious threat to human life, property, and the environment, often leading to irreversible damage and economic losses. Traditional fire protection systems rely heavily on manual intervention, which can result in delayed response times, inefficient fire suppression, and increased risks for firefighters. Moreover, many existing systems use only water-based suppression, which may not be suitable for electrical or chemical fires. To address these challenges, this project proposes the Smart Fire Protection and Suppression System, which integrates both manual and automatic operation to ensure quick and effective fire control. The system is designed to detect fire in real-time using flame, smoke, temperature, and gas sensors and can autonomously activate fire suppression mechanisms based on the severity of the fire. It incorporates both water and CO_2-based extinguishing methods, making it adaptable for different fire types. Additionally, the system features IoT-based remote monitoring, allowing users to control and monitor the fire suppression process from a mobile application. It also includes advanced technologies such as GPS, LiDAR navigation, and AI-based fire detection, enhancing response efficiency and reducing human dependency. By integrating smart sensors, automation, and IoT-based connectivity, the proposed system aims to minimize fire damage, improve safety, and offer an efficient, scalable, and cost-effective alternative to traditional firefighting methods.

IV. METHEDOLOGY

The methodology carried out for this project is as follows

- System Design & Planning – Identify fire risks, define system requirements, and develop a block diagram.
- Component Selection – Choose sensors (flame, smoke, gas, temperature), ESP32, water pump, CO_2 system, and wireless modules.
- Fire Detection System – Use sensors to detect fire, process data via ESP32, and integrate AI- based fire recognition (optional).

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 8, May 2025
Impact Factor: 7.67

- Fire Suppression Mechanism – Activate water or CO_2 suppression based on fire type; allow manual and automatic operation.
- Communication & Remote Monitoring – IoT-enabled real-time alerts and control via a mobile app or web interface.
- Autonomous Navigation (Optional) – Use GPS & LiDAR for mobile fire suppression unit to move toward fire locations.
- Testing & Optimization – Conduct test runs, calibrate sensors, and optimize water/CO_2 discharge for efficiency.
- Implementation & Deployment – Deploy in residential, industrial, or remote locations and monitor performance.

V. SYSTEM ARCHITECTURE

The proposed Intelligent Fire Protection System is a modular, mobile platform integrating sensor arrays, wireless communication, navigation modules, and an active fire suppression unit. The architecture can be divided into five key subsystems: sensing, processing, communication, navigation, and suppression.

1. Sensing and Detection Unit

The system uses a combination of sensors to detect fire-related parameters:
• Flame Sensor – Detects infrared light emitted by open flames.
• Gas Sensor (MQ-2) – Identifies the presence of combustible gases such as CO, CH_4, and smoke.
• Temperature Sensor (LM35 or DHT11) – Monitors ambient temperature changes indicating potential fire activity.
Sensor data is collected in real time and transmitted to the microcontroller for processing. Redundant sensing improves detection accuracy and minimizes false positives.

2. Processing and Control Unit

At the core of the system lies an ESP32 microcontroller, selected for its dual-core processing capability, integrated Wi-Fi/Bluetooth modules, and GPIO flexibility. The ESP32 handles:
• Sensor data acquisition and fusion.
• Activation of the motorized suppression unit.
• Wireless communication with the remote operator.
• Navigation and obstacle avoidance algorithms.
An L298N motor driver is used to control the motors responsible for platform mobility and nozzle actuation.

3. Communication Interface

The system supports multiple wireless interfaces:
• Wi-Fi for local area monitoring via a custom mobile or web-based interface.
• GSM (SIM800L Module) for long-range SMS alerts and control in remote locations.
• Bluetooth (HC-05) for close-range manual override and debugging.
These interfaces allow for both remote monitoring and bidirectional control, enabling users to switch between manual and autonomous operation.

4. Navigation and Mobility

The mobility system includes:
• Brushless DC motors with encoders for precise movement.
• GPS Module (Neo-6M) to provide real-time location coordinates.
• LiDAR sensor to detect obstacles and map surroundings.

Using GPS and LiDAR data, the system can autonomously navigate toward fire-affected zones. A predefined path planning algorithm helps avoid obstacles and ensures efficient routing.

5. Suppression Mechanism

The active firefighting mechanism comprises:

- A pressurized tank carrying water or CO_2.
- An adjustable spray nozzle, capable of directional targeting.
- A pump system controlled via relay or motor driver.
- Customizable spray intensity based on detected fire magnitude.

VI. WORKING PRINCIPLE

The Intelligent Fire Protection System operates in two modes: automatic and manual.

1. Automatic Mode

- Fire Detection: The onboard sensors continuously monitor for heat, smoke, and flame signatures.
- Data Processing: ESP32 analyzes sensor readings using predefined thresholds and fusion algorithms.
- Navigation: Once a fire is detected, GPS coordinates of the origin are determined. The LiDAR system scans for obstacles, and the path is dynamically planned.
- Movement: The motorized platform moves autonomously toward the fire source while avoiding obstacles.
- Suppression Activation: Upon reaching proximity, the nozzle aligns with the fire source. The system activates the suppression pump, spraying water or CO_2.
- Termination: Sensors continue to monitor the area until the fire is extinguished. If the fire persists, the system adjusts position or repeats the suppression cycle.

2. Manual Mode

In manual mode, the system can be operated remotely via:

- Mobile app/web interface over Wi-Fi.
- SMS commands over GSM.
- Bluetooth control via a paired device.

The user receives sensor alerts and live data, allowing real-time decision-making. They can control movement, adjust nozzle orientation, and initiate suppression manually when needed.

1. Water Flow Rate Calculation

The water flow rate can be calculated using: $Q = A \times v$

Where:

- Q is the flow rate (m^3/s),
- A is the cross-sectional area of the nozzle (m^2),
- V is the velocity of water (m/s).

Step 1: Nozzle Area Calculation

The nozzle diameter is 0.15 cm = 0.0015 m. The area of the nozzle is:

A= (πd^2)/4 = (π(0.0015))/4 = 1.767 × 10^(-6) m^2

Step 2: Flow Rate in m^3/s

Given that the pump flow rate is 90 liters/hour

= 90/3600 = 0.025 liters/second

= 2.5 \times 10^{-5} \text{ m}^3/s,

we assume for any quantity of water existing through the nozzle. Using continuity equation Q=Av, we solve for v:

v = Q/A = (2.5 ×10^(-5))/(1.767 ×10^(-6))

$v \approx 14.15$ m/s

2. Pipe Diameter Selection

The pipe diameter is 0.5 cm = 0.005 m. The pipe cross-sectional area is:

$A(pipe) = (\pi d^2)/4 = (\pi(0.005)^2)/4 = 1.963 \times 10^{-5}\ m^2$

Velocity in the pipe:

V (pipe) = Q

$(pipe)$= 2.5 × 10−5

1.963 × 10−5

V (pipe) ≈ 1.27 m/s

3. Nozzle Discharge Rate

Using the orifice discharge formula:

$Q = CdA\sqrt{2gH}$

Where:

- Cd (discharge coefficient) ≈ 0.98 (for a well-designed nozzle),
- $g = 9.81\ m/s^2$,
- H=pump head (29 cm = 0.29 m).

$Q = 0.98 \times 1.767 \times 10^{-6} \times \sqrt{2 \times 9.81 \times 0.29}$

$Q \approx 2.47 \times 10^{-5}\ m^3/s = 0.0247\ L/s$

4. Pump Power Calculation

The power required by the pump is: $P = \rho gQH/\eta$

Where:

- $\rho = 1000\ kg/m^3$ (density of water),
- $g = 9.81\ m/s^2$,
- $Q = 2.5 \times 10^{-5}$
- η = efficiency (assume 50% or 0.5 for estimation).

$P = (1000 \times 9.81 \times 2.5 \times 10^{-5} \times 0.29)/0.5$ $P \approx 0.14\ W$

This is within the pump’s range (0.4 W to 1.3 W), so the pump can handle the system.

5. Pressure Loss in Pipes (Darcy-Weisbach Equation)

The pressure loss (ΔP) in a straight pipe can be estimated using:

$\Delta P = f\ L/D\ (\rho V^2)/2$

Where:

- f = friction factor (approx. 0.02 for smooth small pipes),
- L = pipe length (assume 0.5 m),
- D = pipe diameter = 0.005 m,
- $\rho = 1000\ kg/m^3$,
- V = 1.27 m/s (from pipe velocity calculation).

$\Delta P = 0.02 \times 0.5/0.005 \times (1000 \times (1.27 \times 1.27))/2$ $\Delta P = 0.02 \times 0.02 \times 100 \times (1000 \times 1.61)/2$

$\Delta P \approx 1610\ Pa = 1.61\ kPa$

6. Fire Suppression Coverage:

Using a conical spray pattern: $R = H \tan(\theta)$

Where H = 0.29 m (nozzle height), and assuming a 30^0 spray angle: $R = 0.29 * \tan(30^0)$

$R \approx 0.167m = 16.7$ cm
The coverage area:
$A=\pi r^2 = 3.14\ (0.167)(0.167)$
$A \approx 0.0875\ m^2$

VII. FUTURE SCOPE

1. Automation and AI Integration

• Implement AI and machine learning algorithms to predict fire hazards based on temperature, smoke levels, and environmental factors.

• Use image processing and thermal cameras to detect fire locations more accurately. Develop a self-learning system that adapts to different fire scenarios for improved efficiency.

2. Smart Sensing and IoT Connectivity

• Integrate multiple sensors (temperature, smoke, flame) for better fire detection.

• Use IoT (Internet of Things) for real-time monitoring and control through a cloud- based system.

• Enable remote operation and alerts via mobile apps and smart home systems.

3. Advanced Fire Suppression Mechanisms

• Develop multi-agent fire suppression using water mist, foam, or dry chemicals based on fire type. Page 34 Department of Mechanical Engineering, BIT 360 Degree Fire Protection System 2024-2025

• Implement a dual-mode system that switches between mist and direct spray for better Efficiency.

• Optimize nozzle designs for better coverage and minimal water wastage.

4. Enhanced Mobility and Deployment

• Create portable, drone-mounted fire fighting systems for hard-to-reach locations.

• Design autonomous fire response robots that navigate towards fire hotspots.

• Develop a modular system that can be quickly installed in homes, industries, and remote areas.

5. Renewable Energy Integration

• Power the system using solar panels for off-grid and sustainable operation.

• Implement energy-efficient components to reduce power consumption.

VIII. CONCLUSION

The Smart Fire Protection and Suppression System successfully integrates modern technology to provide an efficient, automated, and scalable fire suppression solution. By incorporating manual and automatic operation, as well as CO_2-based suppression, this system enhances fire safety across various applications, including residential, industrial, and emergency scenarios. Through detailed mechanical calculations, the system ensures optimal water flow, pressure, and nozzle performance, maximizing fire suppression while minimizing resource wastage. The implementation of microcontrollers, sensors, and wireless communication enhances its usability, allowing for remote monitoring and control via a mobile application. With its compact, cost-effective, and adaptable design, this project presents a viable alternative to traditional firefighting methods. The real- world application potential of this system makes it a significant step toward accessible and advanced fire protection technology. Future improvements can further enhance efficiency by integrating AI-based fire detection, IoT connectivity, and smart automation. This project demonstrates a practical and innovative approach to fire suppression, making fire safety more reliable, affordable, and technologically advanced.

REFERENCES

[1]. Dr. Arvind Mahalle, Design and Development of 360 Degree Fire Protection System., International Journal of Innovations in Engineering and Science, www.ijies.net

[2]. P. Naveenkumar, 360 Degree Rotating Fire Protection System., International Journal of Engineering Research & Technology, www.ijert.org

ISSN: 2581-9429

Volume 5, Issue 8, May 2025

Impact Factor: 7.67

[3]. Dhamak Sagar, 360 Degree Rotating Fire Protection system., International Journal of Advances in Engineering and Management, www.ijaem.net

[4]. S Muruganantham, Design and Fabrication of 360 Degree Fire Protection System., International Research Journal of education and Technology, www.irjet.net

[5]. Prof. V. D. Yadav , 360 Degree Rotating Fire Protection System., International Journal of Advanced Research in Science, Communication and Technology, www.ijarsct.co.in

[6]. Dr. Vishnu Agrawal, 360 Degree Rotating Fire Protection system, International Journal of Innovative Research in Science, Engineering and Technology, www.ijirset.com

[7]. Shrirang Sandip Panat, Design and Development of a 360-degree Fire Extinguisher Robot using Microcontroller., International Research Journal of Engineering and Technology, www.irjet.ne

[8]. Veeresh Kumar K S, Fabrication of Automatic Fire Protection System., International Journal of Engineering Research & Technology, www.ijert.org

DOI: 10.48175/IJARSCT-26948