



Fire Fighter Robot with Multi-Sensor Detection and SMS Alert: A Comprehensive Literature Review

Sandhya Rani M H	Harshith S	PrajwalGowdaG	Rohith C	Varshith Kumar M
Dept. of EE-VLSI	Dept. of ECE	Dept. of ECE	Dept. of ECE	Dept. of ECE
Sri Krishna Institute of Technology	Sri Krishna Institute of Technology	Sri Krishna Institute of Technology	Sri Krishna Institute of Technology	Sri Krishna Institute of Technology
Bengaluru, India	Bengaluru, India	Bengaluru, India	Bengaluru, India	Bengaluru, India

Abstract—The rapid development of embedded systems, the Internet of Things (IoT), wireless sensing, mobile robotics, artificial intelligence (AI), and cellular communication has created new opportunities for reducing the loss of life and property caused by fire. Conventional fire protection relies on stationary smoke detectors, manual inspection, and human firefighters who must enter hazardous environments to locate and suppress fires. This exposes personnel to heat, toxic gases, and structural collapse, and the response is often delayed when no one is present to notice an incipient fire. Firefighting robots provide an alternative by combining mobile sensing, fire detection, autonomous approach, suppression, and remote alerting.

This paper presents a comprehensive literature review of fire fighter robots with multi-sensor detection and SMS alert. Existing research is analyzed according to robot architecture, sensing technologies, navigation techniques, communication technologies, alert mechanisms, suppression methods, AI integration, and autonomy levels. Prior studies have demonstrated autonomous firefighting platforms, flame, smoke, gas, and temperature sensing, CNN-based video fire detection, and robotics for disaster response. However, several limitations remain, including reliance on a single sensing modality that leads to false alarms, limited fusion of flame, smoke, gas, and temperature data, dependence on Wi-Fi or internet connectivity that may fail during a fire, restricted navigation in smoke-filled and cluttered environments, high computational requirements for vision-based AI, heat and energy limitations, and insufficient integration of detection, suppression, and automatic notification.

Based on the reviewed literature, a research gap is identified for a low-cost, modular fire fighter robot capable of simultaneously performing multi-sensor fire detection, fire source localization, obstacle avoidance, automatic extinguishing, location-aware operation, and real-time SMS alerting of responsible persons independent of internet infrastructure.

Keywords—fire fighter robot, multi-sensor fire detection, SMS alert, GSM, flame sensor, gas sensor, smoke detection, autonomous navigation, IoT, embedded systems, sensor fusion, artificial intelligence.

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I. INTRODUCTION

Fire safety is undergoing a transformation from passive, alarm-only protection toward intelligent systems that can detect, verify, respond to, and report fires automatically. Population growth, dense urban construction, the widespread use of electrical equipment, and the storage of flammable materials in homes, warehouses, laboratories, and industrial facilities have increased the demand for reliable fire protection [2], [8]. Traditional fire response depends on stationary detectors and on human firefighters who must physically enter the hazardous area. Although human expertise remains essential, this approach has several limitations. Firefighters are exposed to extreme heat, smoke, toxic gases, and the risk of structural collapse, while an unattended incipient fire may grow significantly before anyone notices it.

Sensor technology provides an opportunity to overcome part of this problem. Smoke, heat, flame, and gas sensors can detect the physical signatures of combustion and trigger alarms [2], [3]. However, conventional

fire detectors have an inherent limitation: they are installed at fixed locations, respond only to the conditions in their immediate surroundings, and, when based on a single sensing principle, are prone to false alarms or delayed detection. A mobile robot can overcome this limitation by physically moving through a space, combining readings from several sensor types, locating the source of a fire, and acting on it.

Previous research demonstrates increasing interest in autonomous firefighting platforms, deep-learning-based fire detection, and robots for disaster response [1], [4], [5], [8]. These developments indicate a transition from stand-alone detectors toward multifunctional intelligent platforms. The proposed research direction therefore focuses on a fire fighter robot capable of combining autonomous movement, multi-sensor fire detection, obstacle avoidance, automatic suppression, and an SMS alert delivered over the cellular network so that responsible persons are informed even when Wi-Fi or internet access is unavailable.

II. EVOLUTION OF FIRE SAFETY AND FIREFIGHTING TECHNOLOGIES

The development of fire protection and firefighting automation can broadly be divided into four stages [2], [8].

A. Conventional Fire Protection

Traditional fire protection depends on human observation, manually operated extinguishers, fire hoses, and the intervention of trained firefighters. Detection of a fire is generally delayed until it is seen, smelled, or reported by a person.

B. Sensor-Based Fire Detection

Electronic sensors enabled the detection of smoke, heat, flame radiation, and combustible or toxic gases [2], [3]. Smoke alarms and heat detectors made early warning possible. However, most systems remained stationary and provided only a local audible alarm.

C. Alarm and SMS/IoT-Based Notification

Integration of microcontrollers with GSM modules and IoT platforms enabled fire events to be reported wirelessly to mobile phones and cloud dashboards, allowing owners and responders to be informed remotely. Cellular SMS is particularly attractive because it does not depend on local Wi-Fi infrastructure.ref

D. Autonomous Robotic Firefighting

Integration of sensing and communication with robotics allows detection systems to become mobile. Autonomous firefighting robots can travel through a building, detect and localize a fire, avoid obstacles, apply an extinguishing agent, and transmit information to remote users [1], [8].

III. LITERATURE REVIEW

A. Autonomous Fire Fighting Mobile Platform

Khoon et al. presented an autonomous fire fighting mobile platform [1], an early and representative example of a robot that combines fire detection, navigation, and suppression on a single mobile base. The work demonstrates that a mobile platform can approach a fire source and engage it without direct human presence in the hazard zone. A remaining opportunity is the integration of multiple complementary sensors for reliable detection and of an automatic remote notification mechanism so that responsible persons are informed while the robot operates.

B. Fire Sensing Technologies

Gaur et al. reviewed fire sensing technologies, covering smoke, heat, flame, and gas sensing principles and their respective strengths and weaknesses [2]. The review shows that no single sensing modality is reliable in all conditions: smoke detectors respond slowly to fast flaming fires, flame sensors require a line of sight, and temperature sensors respond only near the heat source. This supports the use of several sensors in combination. The reviewed work does not address integration of these sensors on a mobile robot.

C. Gas Sensing for Hazardous Environments

Liu et al. surveyed gas sensing technology, including the electrochemical, semiconductor, and optical sensors used to detect combustible and toxic gases [3]. Such sensors are relevant to firefighting robots because carbon monoxide and other combustion products are often detectable before flames are visible. The survey focuses at the sensor level; deployment of gas sensing on a mobile fire response platform remains an opportunity.

D. Deep Learning for Vision-Based Fire Detection

Muhammad et al. proposed a convolutional neural network (CNN) approach to fire detection in surveillance videos [4], and Frizzi et al. presented a CNN for video fire and smoke detection [5]. Earlier, Çelik and Demirel developed a rule-based fire detection method using a generic color model [6]. These works show that visual information can detect fire with high accuracy, although color-based methods can generate false alarms from fire-like colors and CNN models can be computationally demanding for low-cost embedded hardware. Most of this research addresses fixed cameras and does not include actuation or alerting.

E. Robotics for Disaster Response

Murphy surveyed the field of disaster robotics, describing the roles, requirements, and operational lessons of robots deployed in fires, collapses, and other emergencies [8]. The work emphasizes human–robot teaming, reliability, and operation in unstructured environments. Open-source middleware such as the Robot Operating System (ROS) [9] provides reusable navigation and control components for such robots. A remaining opportunity is a low-cost, small-scale platform dedicated to early fire detection and notification.

IV. COMPARATIVE ANALYSIS OF EXISTING RESEARCH

The reviewed studies demonstrate a clear movement toward multifunctional firefighting and fire detection systems. Table I compares representative works according to their principal technology and research emphasis.

TABLE I. COMPARISON OF REPRESENTATIVE FIRE DETECTION AND FIREFIGHTING RESEARCH

Ref.	Year	Research Work	Technology	Main Application	Major Limitation
[1]	2012	Autonomous Fire Fighting Mobile Platform	Mobile robot + fire sensing	Fire localization and suppression	Limited remote alerting and sensor fusion
[2]	2019	Fire Sensing Technologies: A Review	Smoke, heat, flame, gas sensors	Sensor survey	No mobile platform integration
[3]	2012	Survey on Gas Sensing Technology	Gas sensors	Hazardous gas detection	Sensor-level focus
[4]	2018	CNN-Based Fire Detection in Surveillance Videos	CNN	Video fire detection	Computationally demanding; no actuation
[5]	2016	CNN for Video Fire and Smoke Detection	CNN	Video fire and smoke detection	Fixed cameras; dataset dependent
[6]	2009	Fire Detection Using a Generic Color Model	Color rules	Video fire detection	False alarms from fire-like colors
[8]	2014	Disaster Robotics	Robotics survey	Disaster response	Not focused on low-cost platforms

V. TECHNOLOGIES USED IN FIRE FIGHTER ROBOTS

A. Microcontrollers

Common embedded controllers include Arduino, ESP32, STM32, Raspberry Pi, and NVIDIA Jetson platforms. Arduino-class boards are attractive for low-cost systems because of their simple analog and digital input/output, while ESP32 additionally provides Wi-Fi/Bluetooth connectivity.

B. Flame and Fire Sensors

Infrared flame sensor modules respond to the infrared radiation emitted by flames and are widely used for direction finding. An array of flame sensors mounted at different angles allows the robot to estimate the direction and relative distance of a fire source.

C. Smoke and Gas Sensors

Metal-oxide semiconductor gas sensors such as the MQ-2 (smoke and combustible gases), MQ-7 (carbon monoxide), and MQ-135 (air quality) provide low-cost detection of combustion products [3]. Smoke and gas detection can reveal a smoldering fire before flames are visible.

D. Temperature and Humidity Sensors

Typical sensors include the LM35, DS18B20, DHT22, and thermocouple amplifiers. Temperature measurements confirm a fire event and can warn of conditions that may damage the robot.

E. Visual and Thermal Imaging

Cameras and thermal array sensors mounted on the robot can support flame and smoke detection, hot-spot localization, and visual verification by remote users. AI models can process images locally using edge computing or remotely through the cloud [4], [5].

F. Suppression Actuators

A water pump with a relay and a servo-mounted nozzle is the most common low-cost suppression mechanism. Fans, CO₂, and dry-powder extinguishers can also be used depending on the class of fire.

G. GSM Communication Module

GSM modules such as the SIM800L or SIM900A send SMS messages using AT commands issued by the microcontroller. SMS delivery depends on the cellular network rather than on local Wi-Fi, which makes it suitable for fire scenarios in which local infrastructure may be damaged.

VI. AUTONOMOUS NAVIGATION

Autonomous navigation is one of the most important components of a fire fighter robot, which must approach the fire while avoiding obstacles.

1) Flame-Direction Following

Differences between readings of an array of flame sensors can steer the robot toward the fire source.

2) Ultrasonic Sensors

Provide low-cost obstacle detection.

3) Infrared Proximity Sensors

Provide short-range obstacle and edge detection.

4) LiDAR

Provides two- or three-dimensional information for mapping and obstacle avoidance.

5) Computer Vision and Path Planning

Cameras can identify obstacles, doors, and fire regions, while navigation frameworks such as ROS support mapping and path planning [9].

Research on disaster robots emphasizes operation in unstructured environments with debris, smoke, heat, and reduced visibility [8]. These conditions can degrade vision-based and some range-based sensing, which motivates the use of multiple complementary navigation sensors.

VII. ALERT ARCHITECTURE FOR FIRE FIGHTER ROBOT

A typical architecture follows the sequence: Sensors > Microcontroller > Multi-Sensor Decision Logic > Actuation and GSM Module > SMS Alert > Responsible Persons.

1) Sensing Layer

Flame, smoke, gas, temperature, obstacle, and optional camera data are collected.

2) Processing Layer

The microcontroller fuses sensor information, confirms a fire event, controls the motors, and activates suppression.

3) Communication Layer

GSM/SMS, Wi-Fi, LoRa, and Bluetooth can be considered depending on range and infrastructure; GSM is preferred when internet access cannot be assumed.

4) Alert/Cloud Layer

SMS messages to registered numbers can be complemented by optional IoT platforms such as Blynk, ThingSpeak, MQTT, or Firebase for dashboards and logging.

5) Application Layer

Owners and responders can receive the fire alert, the location of the robot or fire, sensor values, extinguishing status, and battery status.

VIII. ARTIFICIAL INTELLIGENCE IN FIRE FIGHTER ROBOTS

AI significantly expands fire detection capabilities. A camera can capture images and a CNN-based model can classify them as fire, smoke, or normal [4], [5], and real-time object detectors such as YOLO can localize flames in each frame [7]. The processing pipeline can be represented as Image > Pre-processing > CNN > Feature Extraction > Classification > Decision.

Potential AI applications include flame and smoke detection, false-alarm reduction by fusing visual and sensor data, fire severity estimation, hot-spot localization, and obstacle recognition. Compared with the color-rule methods of [6], learned models can reduce false alarms from fire-like colors, although they require greater computing resources.

IX. RESEARCH GAP ANALYSIS

Based on the reviewed literature, the following gaps are identified [1]–[3], [8]:

1) Single-Sensor Dependence

Many systems rely on one sensing principle, which can lead to false alarms or missed detections.

2) Limited Multi-Sensor Fusion

Flame, smoke, gas, and temperature data are often not combined to confirm a fire before action is taken.

3) Connectivity Dependence

Notification that relies on Wi-Fi or the internet may fail during a fire; SMS over the cellular network is more robust.

4) Navigation Challenges

Buildings contain furniture, doors, debris, smoke, and people.

5) Heat and Energy Management

Robots require energy for motors, pumps, sensors, processors, and communication, and must tolerate heat. Efficient power management is therefore important.

6) Limited Integration

Many systems concentrate on detection, suppression, or alerting rather than integrating all three.

7) High Cost

Commercial firefighting robots may be inaccessible to homes, small businesses, and educational institutions. Low-cost modular architectures remain important.

X. PROPOSED RESEARCH FRAMEWORK

The proposed fire fighter robot with multi-sensor detection and SMS alert can combine mobile sensing, navigation, suppression, and automatic notification. Core modules include:

- Multi-sensor fire detection unit (flame, smoke, gas, temperature)
- Microcontroller-based processing and decision controller
- Motor driver and geared motors
- Ultrasonic/IR/LiDAR obstacle detection
- Water pump and servo-controlled nozzle
- GSM module for SMS alerts
- Optional camera and AI-based fire verification
- Optional GPS and IoT dashboard
- Buzzer and display for local indication
- Battery monitoring and power management

The robot can patrol a predefined area, continuously read its sensors, confirm a fire when more than one sensor type crosses predefined thresholds, move toward the fire source while avoiding obstacles, activate suppression, and send an SMS alert containing the event type, sensor values, and status to registered phone numbers.

XI. EXPECTED CONTRIBUTIONS OF THE PROPOSED SYSTEM

- 1. Multi-Sensor Detection:** Combined flame, smoke, gas, and temperature sensing improves reliability.
- 2. Mobile Sensing:** Measurements can be collected from multiple locations instead of fixed detector positions.
- 3. Autonomous Operation:** The robot can navigate toward a fire with minimal human intervention.
- 4. SMS Alerting:** Responsible persons are informed over the cellular network without depending on Wi-Fi or the internet.
- 5. Automatic Suppression:** The robot can act on an incipient fire before it spreads.
- 6. Reduced Human Risk:** The system reduces the need to send personnel into hazardous areas during early response.
- 7. Low-Cost Implementation:** A microcontroller-based architecture can improve accessibility for homes, small businesses, and institutions.

XII. FUTURE RESEARCH DIRECTIONS

- A. Edge AI:** Moving AI processing onto the robot can reduce latency and enable vision-based fire verification.
- B. Thermal Imaging:** Thermal array cameras can detect hot spots through smoke and in darkness.
- C. Swarm Firefighting Robots:** Multiple low-cost robots can cooperate to cover larger areas.
- D. 4G/5G and LoRa Connectivity:** Higher-bandwidth or long-range links can support live video and remote supervision.
- E. Building Integration:** Integration with existing fire alarm and sprinkler systems can coordinate robot and building response.
- F. Heat-Resistant Design:** Improved shielding and materials can extend operation in high-temperature environments.
- G. Autonomous Decision-Making:** Future systems can progress from Sense > Communicate to Sense > Analyze > Decide > Act.

XIII. CONCLUSION

This literature review investigated developments relevant to fire fighter robots with multi-sensor detection and SMS alert. The reviewed studies demonstrate substantial progress in fire sensing, gas sensing, vision-based fire detection, autonomous firefighting platforms, and disaster robotics.

Nevertheless, significant opportunities remain in integrating multi-sensor fire detection, autonomous navigation, automatic suppression, and cellular SMS notification within a single low-cost platform. A fire fighter robot with multi-sensor detection and SMS alert is therefore a promising research direction. Such a system can reduce risk to human responders, shorten detection and response time, reduce false alarms, and contribute to safer homes, workplaces, and institutions.

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