

Design of Fire Sprinkler System using IoT System

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<p>Peer Review Information</p> <p><i>Type: Article</i> <i>Received: 13 February 2026</i> <i>Revised: 14 March 2026</i> <i>Accepted: 15 April 2026</i> <i>Published: 19 May 2026</i></p>	<p style="text-align: center;">Abstract</p> <p>This paper presents the design and implementation of an IoT-based fire sprinkler system for modern civil structures. The proposed system improves fire safety by integrating automatic fire detection, intelligent sprinkler activation, and real-time monitoring. Traditional fire protection systems often suffer from delayed response and lack of remote monitoring capabilities. The developed prototype utilizes Arduino Uno, flame sensors, relay modules, servo motors, and water pumps to detect fire and activate directional water spraying automatically. Experimental results demonstrate that the system can detect fire within 2–3 seconds and provide effective flame suppression. The system offers enhanced safety, reduced water wastage, and improved automation for smart buildings.</p> <hr/> <p>Keywords: Fire Sprinkler System; IoT; Smart Buildings; Fire Detection; Arduino Uno; Automation; Fire Safety</p>
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Introduction

Fire accidents are among the major causes of property damage and loss of human life in residential, commercial, and industrial structures. Modern buildings require intelligent fire protection systems capable of responding quickly to emergency situations. Conventional sprinkler systems are effective but are generally limited to heat-based activation mechanisms. These systems lack remote monitoring, smart analytics, and efficient directional water control.

The Internet of Things (IoT) has enabled significant advancements in automation and real-time monitoring systems. By integrating IoT technologies with fire sprinkler systems, it becomes possible to achieve faster response times, automated diagnostics, and intelligent fire suppression mechanisms. This research focuses on the design of an IoT-enabled sprinkler system using low-cost embedded components.

Literature Review

Several research studies have emphasized the critical role of automated fire suppression systems in improving building safety and minimizing fire-related damage. Conventional fire sprinkler systems primarily operate on thermal activation mechanisms, where sprinkler heads are triggered only after the surrounding temperature exceeds a predefined threshold. Although these systems are reliable and widely adopted in residential, commercial, and industrial buildings, they are limited by delayed response times and the inability to provide real-time alerts or remote monitoring functionalities. As a result, fire incidents may escalate before suppression mechanisms are fully activated, leading to increased risks to human life and property.

To overcome these limitations, researchers have explored sensor-based fire monitoring systems capable of detecting smoke, flame, gas leakage, and temperature variations during the early stages of fire incidents. Various embedded systems utilizing microcontrollers, infrared flame sensors, smoke detectors, and wireless communication modules have been proposed to enhance detection accuracy and reduce false alarm rates. These systems provide faster response times compared to traditional sprinkler mechanisms and enable automated emergency notifications to building authorities and occupants.

Recent advancements in the Internet of Things (IoT) have further transformed the field of fire safety engineering. IoT-enabled fire protection systems allow real-time monitoring, remote accessibility, cloud-based data storage, and intelligent decision-making. By integrating sensors with wireless communication technologies such as Wi-Fi, GSM, Zigbee, and Bluetooth, modern systems can transmit instant alerts to mobile devices, fire stations, and centralized monitoring centers. This connectivity significantly improves emergency response efficiency and enables continuous monitoring of system health and operational status.

In addition to IoT technologies, advanced computational techniques such as artificial intelligence (AI), machine learning (ML), and predictive analytics have also been investigated for fire safety applications. AI-driven systems can analyze environmental data patterns to identify potential fire hazards before ignition occurs. Machine learning algorithms can improve fire detection accuracy by distinguishing between actual fire events and environmental disturbances, thereby reducing false alarms. Cloud-based monitoring platforms further enhance scalability, allowing multiple buildings and infrastructures to be monitored simultaneously through centralized dashboards and data analytics tools.

Despite these technological developments, several challenges remain in the implementation of intelligent fire suppression systems. Many existing solutions are expensive, complex, and difficult to deploy in small-scale or developing infrastructure projects. Furthermore, some systems focus primarily on detection rather than automated suppression and lack efficient water management mechanisms. There is therefore a strong need for affordable, reliable, and energy-efficient smart sprinkler systems that integrate IoT-based monitoring, automated fire suppression, real-time communication, and intelligent control mechanisms specifically tailored for civil engineering and smart building applications.

Methodology

The proposed system consists of Arduino Uno, flame sensor, relay module, servo motor, and water pump. The flame sensor continuously monitors the environment for infrared radiation emitted by flames. Once a fire is detected, the Arduino activates the relay module, which powers the water pump. Simultaneously, the servo motor adjusts the nozzle direction to spray water directly toward the detected flame.

The system follows a sequential process involving fire detection, signal processing, pump activation, directional water spraying, and continuous monitoring until the fire is extinguished.

Design of Fire Sprinkler System using IoT System

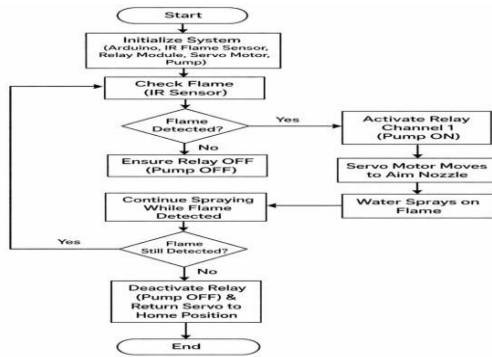


Fig. 1. System Illustration

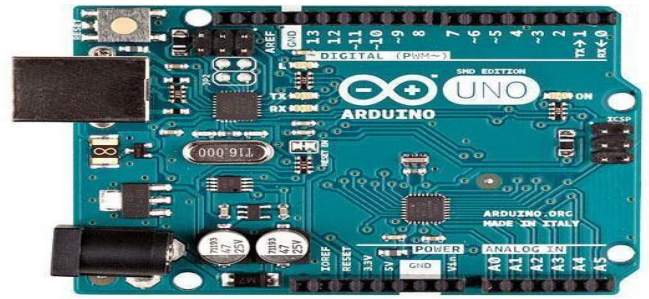


Fig. 2. System Illustration

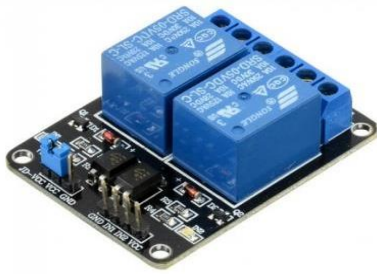


Fig. 3. System Illustration



Fig. 4. System Illustration



Fig. 5. System Illustration

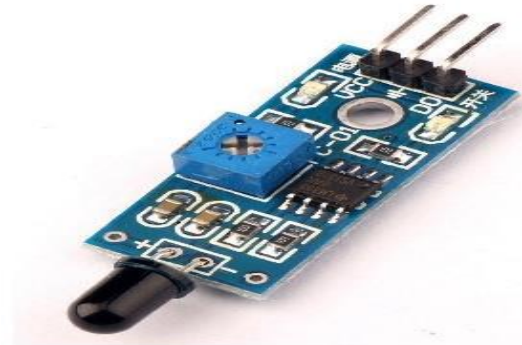


Fig. 6. System Illustration

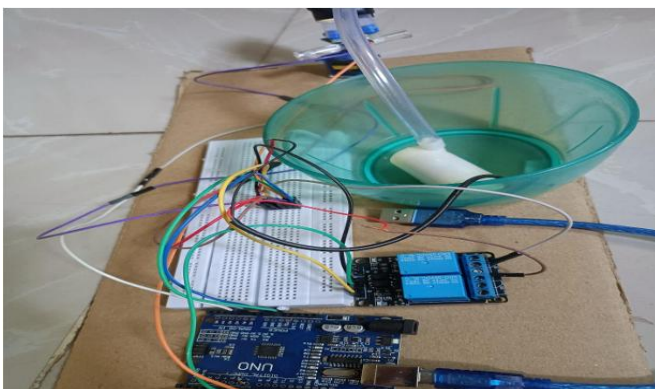


Fig. 7. Smart Water Pump Automation System

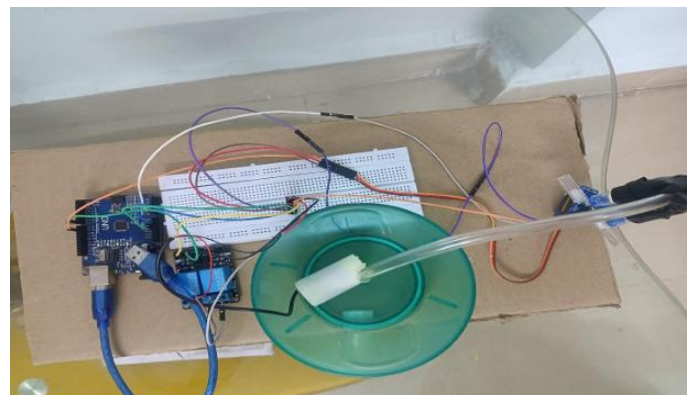


Fig. 8. Automatic Liquid Transfer System Using Arduino

Components Used

1) ARDUINO UNO: - “UNO” means one in Italian. Arduino UNO consists of Atmega 328, 8 bit microcontroller from AVR Family. The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, 16 MHz ceramic resonator, USB connections, power jack, ICSP header , and reset button. It contains everything needed to support the microcontroller; simply connect to a computer with a USB cable or power it is with a AC-to-DC adapter or battery to get started.

2) RELAY MODULE: - A relay module is an electronic switch that lets a low-power device like an Arduino control high power devices (like pumps, motors, lights). 2-channel = it has 2 relays, so you can control 2 devices separately . 5V = it works with 5V signal (perfect for Arduino Uno) .

3) PUMP: - A 5V pump is a mini electric motor with an impeller inside that moves water when powered. Works on low voltage (5V) Safe and easy to use with Arduino (via relay) Used for water spraying, circulation, and small irrigation.

4) SERVOMOTOR :- A servo motor is a small motor that can rotate to a specific angle (like 0° to 180°) instead of spinning continuously like a normal motor. Arduino sends a signal (PWM signal) Servo reads the signal It moves to a specific angle. Holds that position until a new signal comes.

5) FLAME SENSOR: - The flame sensor is a simple and widely used module in Arduino projects to detect fire or flame. Flame produces IR light. Sensor receives this light Internal circuit (often using LM393 comparator IC) processes it Output signal changes (HIGH/LOW)

Hardware Setup

The hardware setup of the proposed system integrates all electronic components on a compact breadboard-based platform for efficient prototyping and testing. The Arduino Uno acts as the central control unit, interfacing with the flame sensor, relay module, servo motor, and water pump to coordinate system operations. The flame sensor continuously monitors the surroundings for the presence of fire and sends detection signals to the Arduino controller. Upon detecting a flame, the Arduino activates the relay module, which powers the water pump to initiate water spraying. Simultaneously, the servo motor controls the nozzle direction for targeted fire suppression. The developed prototype successfully demonstrated real-time flame detection, rapid system response, and automated water spraying, validating the effectiveness of the proposed IoT-based fire protection mechanism.

Software Used

The Arduino IDE (Integrated Development Environment) was utilized for programming, testing, and monitoring the proposed fire sprinkler prototype system. It provides a simple and user-friendly platform for writing, compiling, and uploading code to the Arduino Uno microcontroller. The software supports embedded C/C++ programming and includes essential features such as a built-in serial monitor, debugging support, and extensive library integration for sensors and actuators. Using the Arduino IDE, the flame sensor, relay module, servo motor, and water pump were successfully interfaced and controlled to achieve automated fire detection and suppression. Its cross-platform compatibility and open-source nature make it an efficient and reliable development environment for IoT-based automation projects.

Results and Discussion

Table 1. Hardware Components and Performance Evaluation of the IoT-Based Fire Sprinkler System

Component	Specification	Performance
Arduino Uno	ATmega328	Successful Integration
Flame Sensor	IR LM393	Detected fire within 2 sec
Relay Module	5V, 2-channel	Reliable activation
Servo Motor	0°–180°	Accurate nozzle positioning
Water Pump	5V	Adequate water spraying

The developed IoT-based fire sprinkler system successfully demonstrated efficient and reliable automated fire detection and suppression capabilities under prototype testing conditions. The integration of Internet of Things (IoT) technologies significantly enhanced system

response time, operational efficiency, and overall fire safety performance compared to conventional fire protection methods. The flame sensor continuously monitored the surrounding environment and rapidly detected the presence of fire within a few seconds, enabling immediate activation of the suppression mechanism. Once a flame was identified, the Arduino Uno microcontroller processed the sensor signals and automatically triggered the relay-controlled water pump without requiring any manual intervention.

The experimental results confirmed that the automated response mechanism effectively minimized fire spread during the early stages of ignition. The relay module ensured reliable switching operations, while the water pump provided continuous and adequate water flow for fire suppression. In addition, the servo motor-based directional spraying mechanism allowed targeted water discharge directly toward the flame source. This intelligent directional control reduced unnecessary water wastage commonly observed in traditional sprinkler systems and minimized potential damage to surrounding equipment, furniture, and infrastructure.

The integration of real-time automation and smart sensing technologies also improved system reliability and operational accuracy. The prototype demonstrated stable performance throughout repeated testing cycles, highlighting the suitability of embedded IoT technologies for modern fire safety applications. Furthermore, the system architecture is cost-effective, energy-efficient, and easy to implement using readily available electronic components such as Arduino Uno, flame sensors, relay modules, and servo motors. These characteristics make the proposed solution highly suitable for residential buildings, commercial complexes, industrial facilities, educational institutions, and smart city infrastructures.

Another important advantage of the proposed system is its scalability and future adaptability. The framework can be extended by integrating wireless communication modules such as Wi-Fi, GSM, Bluetooth, or cloud-based IoT platforms for remote monitoring and emergency alert generation. Advanced technologies such as artificial intelligence and machine learning can also be incorporated in future developments to enable predictive fire detection, risk assessment, and intelligent decision-making capabilities.

Conclusion

The proposed IoT-based fire sprinkler system provides an intelligent, reliable, and cost-effective solution for modern fire protection in civil engineering structures and smart buildings. The system was designed to overcome the limitations of conventional sprinkler systems by integrating advanced sensing technologies, automated control mechanisms, and real-time monitoring capabilities. Through the combination of flame sensors, Arduino-based automation, relay-controlled water pumps, and servo motor-driven directional spraying, the developed prototype successfully demonstrated efficient fire detection and rapid suppression performance.

One of the major advantages of the proposed system is its ability to detect fire incidents at an early stage. The flame sensor continuously monitors the surrounding environment and immediately sends signals to the Arduino Uno microcontroller whenever fire is detected. This rapid sensing capability significantly reduces response delays and allows the suppression mechanism to activate within a few seconds. The automated relay module controls the operation of the water pump without requiring human intervention, thereby improving operational reliability during emergency situations.

The implementation of a directional water spraying mechanism further enhanced system efficiency. Unlike traditional sprinkler systems that distribute water over a wide area, the proposed system directs water specifically toward the fire source using a servo motor-controlled nozzle. This targeted suppression approach minimizes unnecessary water wastage, reduces damage to nearby equipment and infrastructure, and improves overall firefighting effectiveness. As a result, the system offers both environmental and economic benefits while maintaining high fire safety standards.

The integration of IoT-based technologies also contributes to improved monitoring and automation in smart building environments. The Arduino-controlled system can easily be expanded to support wireless communication technologies such as Wi-Fi, GSM, Bluetooth, or cloud connectivity for remote monitoring and alert generation. In practical applications, building administrators and emergency responders could receive instant notifications through mobile devices or centralized monitoring platforms whenever fire hazards are detected. This real-time communication capability enhances emergency response coordination and improves occupant safety.

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