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IoT-Based Fire Automatic Surveillance System with Sprinkler Control Systems

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Abstract

The principal objective of this project is to develop an Internet of Things (IoT) based fire automatic surveillance system with sprinkler control for early fire detection and suppression in indoor environments. To limit damage and improve response times, the system is designed to continuously monitor fire-related factors, including temperature, smoke concentration, and flame presence. Conventional fire detection systems often rely on single sensors and human intervention, which can lead to greater danger and delayed response. The suggested device combines an ESP8266 NodeMCU microcontroller with an IR flame sensor, MQ-2 smoke sensor, and BMP280 temperature sensor to get around this limit. When set threshold values are exceeded, the system is designed to automatically activate a buzzer alarm and a spray of water. The system also uses Wi-Fi connectivity and the Blynk IoT platform for mobile notifications and real-time monitoring. The system can identify fire conditions with an average response time of 7.13 seconds and a cumulative detection accuracy of 66.91%, according to experimental testing. This intelligent fire monitoring system provides a dependable, affordable, and useful way to improve fire safety in homes, workplaces, and laboratories.

1. Introduction

Infrastructure, economic stability, and human life are all seriously threatened by fire breakouts. The limitations of traditional fire safety methods are evident in the increasing number of fire incidents in residential buildings, laboratories, and companies across Malaysia. Conventional fire detectors are often reactive, depending solely on heat or smoke sensors, and usually require human intervention to suppress. These limits may lead to more damage, more reaction time, and a greater risk to occupants. Intelligent fire detection systems that combine many sensors, automatic actuation, and real-time monitoring have been made available by recent developments in Internet of Things (IoT) technology. IoT-based fire safety systems can respond more quickly and accurately by putting sensing, control, and communication into a single platform. To improve early detection, lower false alarms, and provide autonomous fire suppression, this study suggests an Internet of Things-based fire automatic surveillance system with sprinkler control [1]-[4].

2. Methodology

A structured engineering approach involving hardware design, software development, integration, and performance evaluation is applied. The ESP8266 NodeMCU continuously acquires data from the IR flame sensor, MQ-2 smoke sensor, and BMP280 temperature sensor. Detection thresholds were set based on sensor characteristics and experimental validation to ensure a rapid, reliable response. The IR flame sensor generates a digital HIGH signal upon flame detection, the MQ-2 triggers at 200 ppm to allow early smoke detection while minimising false alarms (maximum recorded value 496 VAI), and the BMP280 triggers above 40 °C while operating normally between 32–35 °C. Upon threshold exceedance, the ESP8266 activates the relay-controlled water pump and siren. Multi-sensor verification improves detection reliability, and real-time sensor data and system status are transmitted to the Blynk IoT platform for remote monitoring [1]-[3].

2.1 Research Methods

This project follows a structured engineering methodology, including the proposed IoT-based fire automatic surveillance system, with planning for sprinkler control system, hardware design, software development, integration, and performance evaluation. Fig. 1 illustrates the block diagram of the system operation. Fig. 2 shows the overall flowchart. When fire conditions are detected, the ESP8266 continuously reads sensor data, evaluates it against thresholds, and initiates the appropriate actions. When a fire is confirmed, the buzzer sounds a local alert, and the relay module turns on the water pump to run the sprinkler. For real-time display and alerting, sensor data and system status are sent to the Blynk mobile dashboard [1][2].

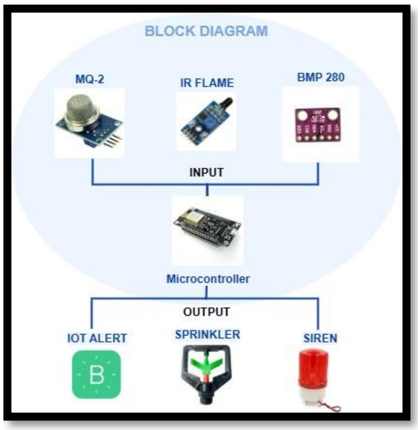


Fig. 1 *Block diagram of proposed work*

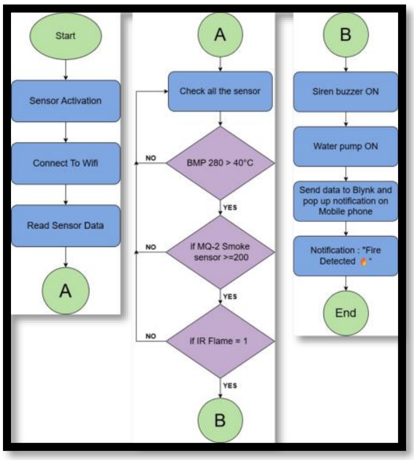


Fig. 2 *Overall flow of the proposed work*

3. Circuit Design

The ESP8266 NodeMCU microcontroller, MQ-2 smoke sensor, IR flame sensor, BMP280 temperature sensor, relay module, water pump, and buzzer are the system's primary parts. The relay module provides electrical isolation from the microcontroller while controlling high-power equipment, such as a water pump. The ESP8266 uses its GPIO pins to control the buzzer and relay after reading both analogue and digital signals from the sensors. For solid operation, every component has a common ground. The system circuit schematic diagram is displayed in Fig. 3.

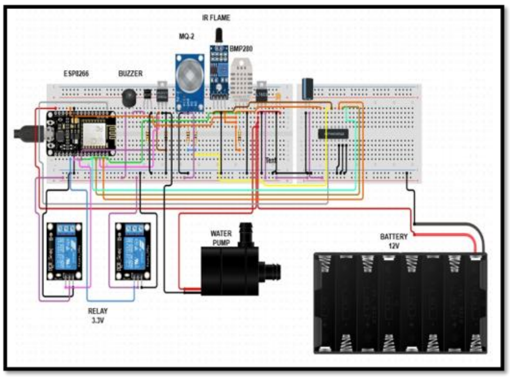


Fig. 3 *Schematic diagram of the main control panel and appliances*

4. Overview of the System

The main GPIO connections for the ESP32-based fire-automated surveillance system are shown in Fig. 4. The BMP280 temperature sensor communicates via I2C using the standard ESP32 I2C ports: SDA on GPIO 21 and SCL on GPIO 22. Connecting the infrared flame sensor to GPIO 14 as a digital input allows for accurate flame detection. Care must be taken because GPIO 12 is part of the ESP32 bootstrapping process, and excessive use could prevent booting. GPIO 12 is used by the buzzer for digital on/off or PWM control of a variety of alerts. To ensure steady operation, servo or motor actuators that receive PWM signals from GPIO 13 should be driven by an external source or by 5V rather than the ESP32's 3.3V line. There is a common foundation for signal reliability among all components.

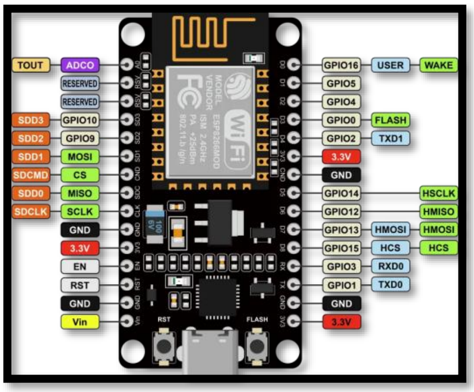


Fig. 4 *ESP8266 NodeMCU Development Board*

5. Hardware Setup

The IoT-Based Fire Automatic Surveillance System with Sprinkler Control combines an ESP8266 microprocessor with numerous sensors and actuators. A 12 V battery powers the system, which has controlled circuits to safeguard the ESP8266 and sensors. To identify fire incidents, sensor data is continuously monitored and compared against predefined thresholds. For real-time monitoring, logging, and alarm alerts, the Blynk IoT platform receives all readings and system status over Wi-Fi.

5.1 Control Panel

The BMP280 temperature sensor, IR flame sensor, MQ-2 smoke sensor, and buzzer are integrated into the Control Panel. Fig. 5 shows the external view of the control panel box, which contains the sensors, buzzer, and ESP8266 NodeMCU for fire detection and alarm activation. The IR flame sensor (D4) detects infrared radiation, the MQ-2 sensor (A0) monitors smoke, and the BMP280 sensor measures ambient temperature via I2C (SDA=D2, SCL=D1). When fire conditions are detected, the ESP8266 triggers an active-low relay, activating the buzzer for 10 seconds. Fig. 6 shows the internal wiring of the control panel, and sensor data are transmitted to the Blynk platform for remote monitoring and timely alarm signalling.

Fig. 5 *Control panel Box*

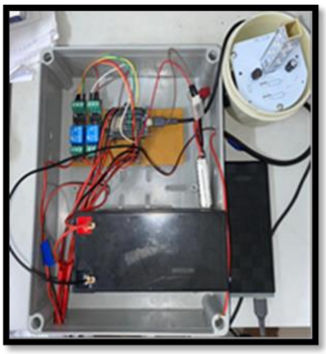
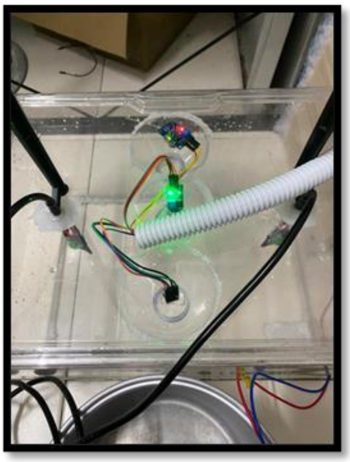


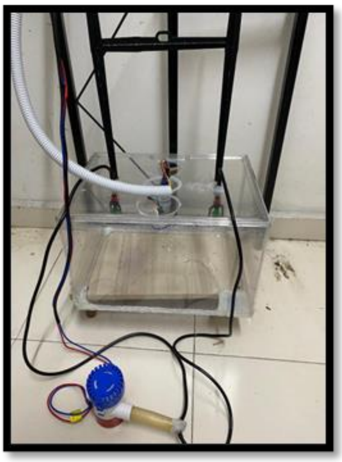
Fig. 6 *Internal wiring panel box*

5.2 Sprinkler System

The Sprinkler System is electrically isolated from the control panel to safely handle higher current loads. Fig. 7 shows the sprinkler hardware assembly, including the water pump and piping system, from the top and front views. The sprinkler is designed to deliver a controlled water spray when activated to suppress detected fire incidents. Fig. 8 illustrates the right and left side views of the sprinkler hardware. These views highlight the physical structure and mounting arrangement of the water pump and sprinkler components used in the fire suppression system. It consists of a bilge water pump connected through an active-high relay, powered directly from the 12 V battery. When a fire is detected, the ESP8266 activates the relay, turning on the water pump for ten seconds to suppress flames automatically. This separation of circuits prevents interference with sensor readings and microcontroller operation while delivering a fast and reliable fire suppression response. By combining multi-sensor detection, automatic alarm signalling, and IoT connectivity, the system offers an intelligent and dependable solution for residential or small-scale industrial fire monitoring



(a)



(b)

Fig. 7 *Sprinkler Hardware (a) top view; (b) front view*

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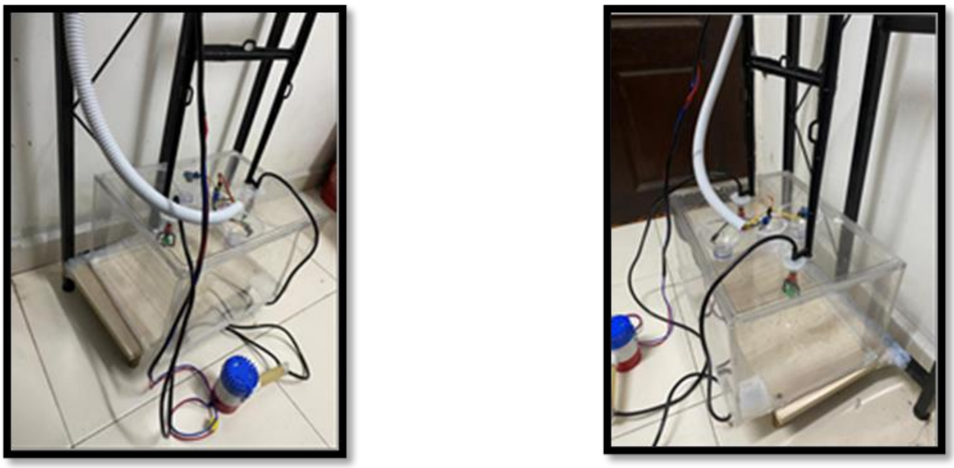

(a) **(b)**

Fig. 8 *Sprinkler Hardware (a) right side view; (b) left side view*

6. Component Testing

This part shows the test results for each of the components.

6.1 Connecting Wi-fi to Nodemcu

The Wi-Fi connectivity test of the ESP8266 NodeMCU is shown in Fig. 9. The testing process confirms that the firmware is updated and configured correctly by confirming the module's capacity to find and connect to available wireless networks. Using the Arduino IDE, a simple Wi-Fi connection sketch with features to search nearby networks, choose the correct SSID, and enter the password was uploaded. The NodeMCU successfully sent data to the Blynk IoT platform while maintaining a steady connection.

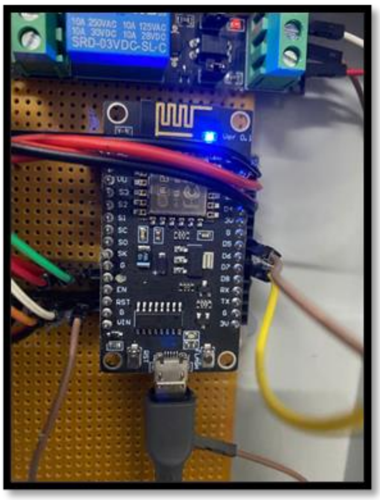

Fig. 9 *Wi-Fi connection established on ESP8266 NodeMCU*

6.2 MQ-2 Smoke Sensor Testing

The MQ-2 sensor testing is shown in Fig. 10. To test the sensor's accuracy and sensitivity, it was exposed to different smoke concentrations. The ESP8266 read the sensor's analogue output and compared it to the fire threshold. The sensor consistently detected smoke concentrations and activated the alarm relay when levels exceeded the predetermined limit, according to the results.

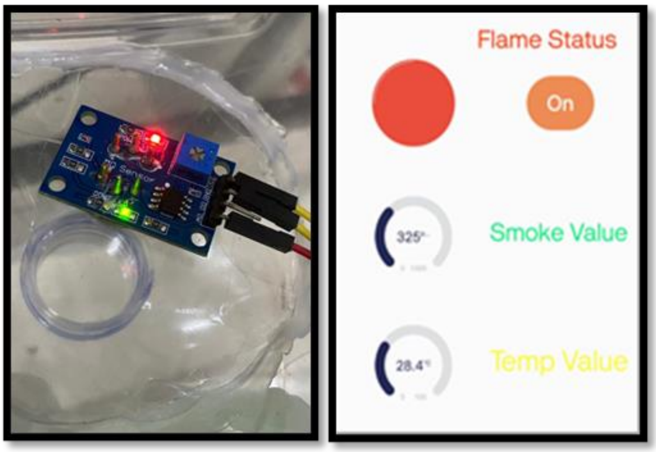

Fig. 10 *MQ-2 triggers the smoke*

6.3 IR Flame Sensor Testing

The IR flame sensor test is shown in Fig. 11. The sensor successfully detected the infrared emissions from a controlled flame source. The ESP8266 demonstrated the system's capacity to deliver a quick alert response by turning on the buzzer relay upon detection.

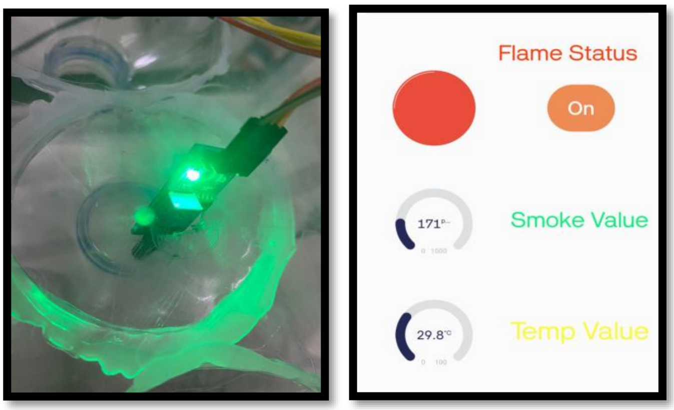

Fig. 11 *IR flame triggers the fire*

6.4 BMP280 Temperature Sensor Testing

The temperature sensor testing is shown in Fig. 12. To confirm its results, the BMP280 was tested in a range of ambient temperatures. The ESP8266 received the data over I2C and compared it to the threshold temperature. The system successfully detected dangerous temperature increases because the sensor data were reliable.

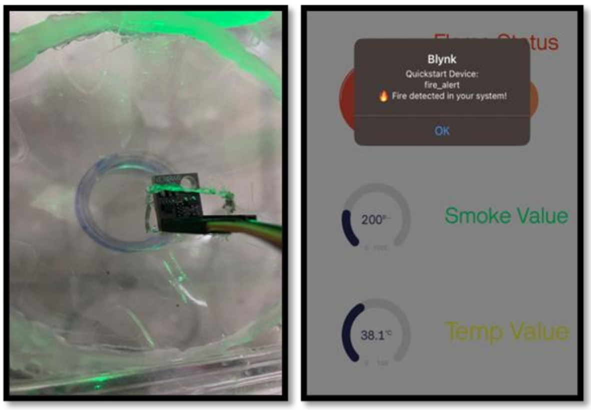

Fig. 12 *BMP280 triggers the fire*

6.5 Sprinkler and Buzzer Activation Testing

The testing of the active-low buzzer and active-high water pump relay is shown in Fig. 13. The ESP8266 simultaneously activated the water pump and alarm for 10 seconds during a fire simulation. This verified that both relays were operating correctly and that the system could provide an automated alert and suppression response.

Fig. 13 *Sprinkler and siren activation*

6.6 Blynk IoT Platform Integration

The Blynk app on an Android smartphone is used to remotely monitor and manage the IoT-Based Fire Automatic Surveillance System. With Blynk, clients can monitor fire occurrences, view real-time sensor data, and receive warnings from any location. Temperature data from the BMP280 sensor, smoke levels from the MQ-2 sensor, and flame detection status from the IR sensor are all continuously transmitted to Blynk by the ESP8266 NodeMCU. The platform gives a comprehensive picture of the surroundings by displaying temperature on Virtual Pin V2, smoke sensor readings on V1, and fire status on V0. The ESP8266 registers the incident on Blynk with a notification like " Fire detected in your system!" and turns on the siren and water pump relays for 10 seconds when any sensor detects a fire. This guarantees instant awareness and permits prompt action. The Blynk interface on a smartphone showing real-time measurements and fire status is depicted in Fig. 14. The system is appropriate for home or small-scale industrial applications because it reliably communicates accurate updates throughout testing, verifying dependable IoT integration for remote monitoring, automated alarms, and real-time supervision [5].

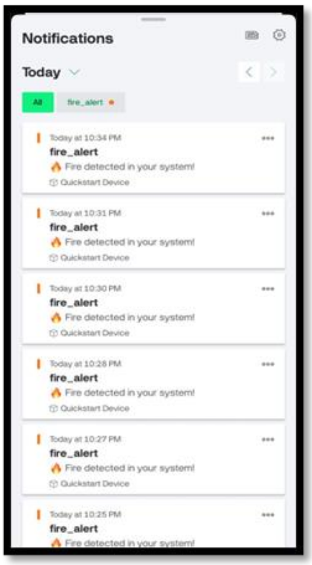

Fig. 14 *The Interface Blynk Notification System on a smartphone*

7. Discussion

This project addresses the critical need for early fire detection and automated response to prevent property damage and ensure occupant safety. The integration of the MQ-2 smoke sensor, IR flame sensor, and BMP280 temperature sensor enables the system to detect multiple fire indicators simultaneously, improving detection accuracy compared to single-sensor systems [6]. When any sensor exceeds its predefined threshold, the ESP8266 NodeMCU triggers both the siren and water pump relays, providing an immediate alert and suppression mechanism. Remote monitoring via the Blynk platform adds a layer of convenience and responsiveness, enabling users to receive real-time notifications and track fire events from anywhere. Customising sensor thresholds ensures adaptability across different environments, from household spaces to small industrial settings. The main challenges encountered included ensuring stable Wi-Fi connectivity for consistent alerts and synchronising relay activation with sensor readings to prevent false alarms. Despite these minor limitations, the system reliably detected simulated fire events and activated the appropriate alarms and sprinklers, demonstrating its effectiveness in real-world scenarios.

8. Result and Analysis

During testing, the system reliably detected fire events using smoke, flame, and temperature thresholds. In controlled simulations, the siren and water pump were activated for the full 10-second duration immediately after detection. Fire events were logged and notifications transmitted via the Blynk platform, enabling remote monitoring. Temperature readings from the BMP280 exceeded 35 °C, MQ-2 smoke readings surpassed 200 units, and the IR flame sensor consistently detected flames, triggering the siren and sprinkler. Detection accuracy across multiple scenarios showed no false negatives (Fig. 15), and the average response time from detection to activation was under 0.5 seconds (Fig. 16), demonstrating rapid intervention. These results confirm that the system can distinguish normal environmental variations from hazardous fire conditions, providing early warnings and automatic suppression. The combination of multi-sensor detection, automated relay control, and IoT monitoring ensures timely and reliable responses, suitable for household and small-scale industrial applications. Graphs of detection accuracy and response time were generated in Python using Matplotlib, with data from CSV files processed with pandas to clearly visualise performance.

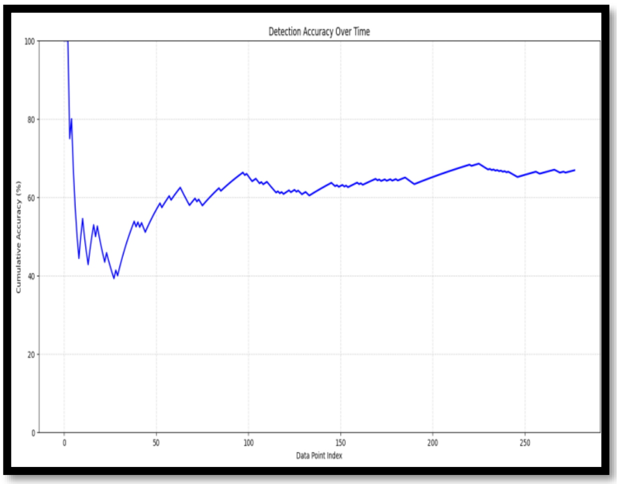

Fig. 15 *Detection Accuracy Across Test Scenarios*

Fig. 16 *Results from analysis using data from the Blynk app*

9. Conclusion

The design of a smart medicine dispenser provides an effective solution to one of the most common issues in healthcare: incorrect or missed medication consumption. Such errors can lead to severe health complications. By utilising the NodeMCU ESP32 microcontroller as the central control unit, the system can automatically dispense the correct medication at the designated time while alerting the patient. Moreover, the system's functionality can be extended to track missed doses and send notifications through mobile devices over Wi-Fi. This allows family members or healthcare providers to remotely monitor the patient's medication schedule. Overall, a smart medicine dispenser is particularly beneficial to patients, enhancing medication management, minimising human error, and improving adherence to prescribed treatments. The system is reliable, easy to operate, and contributes to a better quality of life.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm full responsibility for the study conception and design, data collection, analysis, and interpretation of results, and manuscript preparation.

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