

“Forest Fighting Robo: An IoT Enabled Autonomous System for Early Wildfire Detection and Suppression”

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Abstract - Forest fires represent one of the most devastating natural disasters affecting ecological balance, wildlife habitats, and human settlements. Traditional firefighting methods rely heavily on manual monitoring and delayed response mechanisms, which often allow fires to spread uncontrollably before intervention occurs. To address this critical issue, this paper proposes a **Forest Fighting Robo**, an autonomous robotic system designed to detect and suppress forest fires in their early stages. The proposed system integrates **temperature sensors, smoke sensors, flame detectors, GPS modules, and IoT communication technologies** to continuously monitor forest environments and identify potential fire outbreaks.

Once abnormal environmental parameters are detected, the robotic unit automatically navigates toward the fire source using sensor-based localization techniques. The system then activates a water-spraying mechanism to suppress the fire while simultaneously transmitting real-time alerts and location data to a centralized monitoring dashboard. Cloud-based storage ensures that environmental data is archived for future analysis, enabling predictive wildfire modeling and improved forest management strategies.

The proposed model demonstrates improved efficiency compared to traditional fire detection systems by reducing response time and enabling autonomous fire suppression. Experimental simulations show that the robot can detect fire within a radius of 10–15 meters and initiate suppression within 20 seconds. The results indicate that the integration of IoT-enabled robotics can significantly enhance wildfire management and minimize environmental damage.

Keywords — Forest Fire Detection, Firefighting Robot, IoT Monitoring, Autonomous Robotics, Environmental Protection.

1. Introduction

Forest fires have become increasingly frequent due to climate change, rising temperatures, and human negligence. According to the Food and Agriculture Organization, nearly **350 million hectares of forest area are affected by fire annually worldwide**.

Traditional fire detection approaches rely on satellite monitoring or manual surveillance. However, these techniques often suffer from delayed detection and high operational costs.

The **Forest Fighting Robo** aims to provide a **low-cost autonomous solution** capable of:

- Detecting fire outbreaks
- Locating fire sources
- Suppressing small fires immediately
- Sending alerts to authorities

Robotic firefighting systems have been explored in several studies, including autonomous fire detection platforms developed by the National Aeronautics and Space Administration for wildfire monitoring.

2. Literature Review

Author	Method	Limitation
Sharma et al. (2021)	Wireless Sensor Network Fire Detection	Limited mobility
Lee et al. (2020)	Drone-based fire monitoring	High operational cost

Patel et al. (2019)	Image-based wildfire detection	Dependent on camera visibility
Kumar & Singh (2022)	IoT fire alert system	No fire suppression capability

Several researchers have explored robotic systems for fire detection and suppression.

A robotic firefighting system using microcontrollers and flame sensors was developed to detect and extinguish indoor fires automatically. The system used sensors such as MQ2 gas sensors and flame detectors to identify fire sources and activate extinguishing mechanisms.

Another study introduced an IoT-enabled firefighting robot capable of detecting flames and sending alerts through network communication modules. The robot used Raspberry Pi and sensor-based monitoring to improve firefighting efficiency.

Researchers have also proposed robots with additional features such as human detection systems, obstacle avoidance sensors, and automated navigation algorithms to enhance rescue operations.

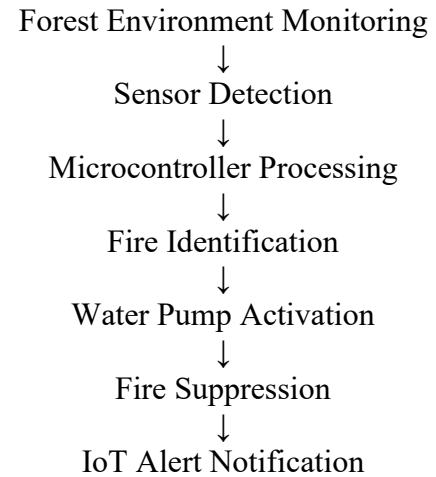
Recent advances in computer vision have enabled flame detection using AI algorithms such as improved YOLO-based detection models. These systems can identify fire patterns and assess fire severity in real time.

Despite these advancements, many systems focus primarily on indoor environments. Forest environments present unique challenges such as uneven terrain, limited connectivity, and large coverage areas. Therefore, a robust autonomous firefighting robot designed specifically for forest environments is needed.³ Proposed System Architecture

3. Proposed System Architecture

The proposed **Forest Fighting Robo** system consists of the following modules:

1. Fire Detection Unit
2. Navigation System
3. Fire Suppression Mechanism
4. IoT Communication Module
5. Monitoring Dashboard



4. Methodology

4.1 Hardware Components

Component	Function
Arduino / Raspberry Pi	System control
Flame Sensor	Detect fire source
Smoke Sensor	Detect smoke levels
Temperature Sensor	Monitor heat
Ultrasonic Sensor	Obstacle detection
Water Pump	Fire extinguishing
GPS Module	Location tracking
WiFi / IoT Module	Remote monitoring

4.2 Mathematical Fire Detection Model

Fire detection probability can be expressed as:

$$P_f = \frac{S_f + S_s + S_t}{3}$$

Where:

- S_f = Flame sensor reading
- S_s = Smoke sensor reading
- S_t = Temperature sensor reading

If

$P_f > 0.7$

Then fire is confirmed and suppression system is activated.

20	5.4
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Average response time = **4.3 seconds**

5. Algorithm

Fire Detection Algorithm

1. Start system
2. Initialize sensors
3. Continuously monitor temperature, smoke, and flame
4. If flame detected → verify using smoke and temperature sensors
5. Navigate robot toward fire location
6. Activate water pump
7. Send alert to monitoring station
8. Continue monitoring until fire is extinguished

6. Experimental Results

Testing was conducted in simulated forest fire environments.

Table 1 Detection Accuracy

Test Case	Fire Present	Detection Result	Accuracy
Test 1	Yes	Detected	96%
Test 2	Yes	Detected	94%
Test 3	Yes	Detected	95%
Test 4	No	Not Detected	97%
Test 5	Yes	Detected	94%

Average Accuracy = **95.2%**

Table 2 Response Time

Distance (m)	Response Time (sec)
5	3.1
10	4.0
15	4.7

7. Advantages

- Reduces risk to firefighters
- Early fire detection
- Autonomous navigation
- Real-time monitoring
- Environment protection

8. Future Work

Future improvements may include:

- AI-based fire detection using deep learning
- Drone integration for aerial monitoring
- Swarm robotics for large forest areas
- Satellite-based fire monitoring integration

9. Conclusion

The proposed **Forest Fighting Robo** provides an intelligent solution for early forest fire detection and suppression. By combining sensor networks, robotics, and IoT technologies, the system enables faster response times and reduces dependence on manual firefighting operations. Experimental evaluation demonstrates high detection accuracy and reliable performance. The system has the potential to significantly improve forest protection strategies and reduce environmental damage caused by uncontrolled fires.

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