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A 360 Degree IoT-Based Firefighting Robot System

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Abstract - This project presents the A 360 Degree IoT-Based Firefighting Robot System, aimed at enhancing fire detection and suppression in hazardous environments. The robot is equipped with a rotating platform allowing full 360-degree surveillance and a suite of sensors, including flame, temperature, and gas sensors, to detect fire incidents in real-time. Upon detection, the robot activates a water or chemical extinguisher system and sends live updates to a remote monitoring system via IoT connectivity. The system also includes a camera module for live video streaming, enabling remote navigation and control. This autonomous and remotely operable robot minimizes human involvement in dangerous fire situations, offering a cost-effective, efficient, and scalable solution for industrial safety, smart buildings, and emergency response operations.

Key Words: Fire Fighting Robot, 360-Degree Surveillance, IoT, Autonomous Navigation, Real-Time Monitoring, Flame Detection, Temperature Sensor, Remote Control, Smart Fire Safety, Hazardous Environment, Wireless Communication, Robotics, Emergency Response.

1. INTRODUCTION

Fire accidents pose a significant threat to human life, property, and the environment. Traditional fire-fighting methods often involve direct human intervention, which can be risky, especially in environments that are difficult to access or extremely hazardous. The incorporate of robotic systems and advanced communication technologies can efficiently enhanced the effectiveness of fire detection and separating duties.

This project focuses on creating a firefighting system that incorporates a robot capable of detecting and extinguishing fires, leveraging modern technologies for enhanced safety and efficiency. The robot is engineered to perform real- time fire monitoring, detection, and extinguishing operations in a fully autonomous or remotely controlled manner. Its ability to rotate 360 degrees allows for complete environmental coverage, while sensors such as flame, temperature, and gas detectors ensure accurate and timely fire detection.

The integration of IoT enables the robot to transmit real-time data and video feeds to a remote control center, allowing operators to monitor the situation and take necessary actions without being physically present at the site. This not only makes things safer but also helps people respond to fire more quickly and effectively. We aim to develop a system that is both effective and affordable for ensuring fire safety in various settings, including industries and remote areas.

2. Procedure to build a system

The development of A 360-Degree IoT-Based Firefighting Robot System involves a systematic approach combining hardware assembly, sensor integration, software programming, and cloud-based communication. The following methods for complete procedure are as follows :

Step 1: Component Selection and Procurement

Select and gather all required components, including:

- **Microcontroller:** NodeMCU ESP8266 for IoT connectivity
- **Sensors:** Flame sensor, Temperature sensor (LM35), Gas sensor (MQ-2)
- **Actuators:** Water pump, Servo motor (for nozzle rotation), DC motors (for mobility)
- **Camera module:** For live video streaming (e.g., ESP32-CAM)
- **Power supply:** Battery pack or Li-ion cells
- **Chassis and structural frame**

Step 2: Circuit Design and Wiring

- Design the wiring diagram using tools like Fritzing or Proteus.
- Connect the sensors to the microcontroller's input pins.
- Interface motor driver (e.g., L298N) to control DC and servo motors.
- Connect the water pump to the relay module for switching.
- Ensure the NodeMCU is connected to a Wi-Fi network for data transmission.

Step 3: Software Development and IoT Setup

- Write a program for the NodeMCU board using the Arduino Software, including the necessary codes for sensors, motors, and internet connection.
- Create a real-time monitoring dashboard using **Blynk**, **Thing Speak**, or similar IoT platforms.
- Set up triggers for alerts (e.g., notification or email when flame is detected).
- Implement camera streaming (if using ESP32-CAM) for remote viewing.

Step 4: Integration and Testing

- Assemble the robot frame with all components securely mounted.
- Power up the system and upload the firmware.
- Test individual components (sensors, motors, pump) to ensure functionality.
- Verify that sensor data is correctly uploaded to the cloud platform and remote control is operational.

Step 5: 360-Degree Rotation Mechanism

- Mount the water nozzle on a servo motor or rotary platform.
- Program it to rotate in intervals or continuously scan the area. When a fire is detected, the nozzle should be move to point directly at the fire.

Step 6: Final Assembly and Field Testing

- Enclose sensitive parts to protect against water damage.
- Perform testing in a controlled environment with simulated fire sources.
- Observe response time, accuracy, and coverage of the system.

4. Manufacturing data

The manufacturing phase of the 360-degree fire fighting robot involves component procurement, mechanical fabrication, electronic integration, software development, and assembly. The following table and details outline the data related to manufacturing:

Cost Estimation of the Model

Sr. No.	Component	Estimated Cost (INR)
1	Frame	₹6,000
2	ESP32	₹1,000
3	DC Motor	₹1,000
4	Wheel	₹1,000
5	Motor Driver	₹600
6	Wiper Motor	₹3,500
7	Relay	₹800
8	Shaft	₹700
9	Flame Sensors	₹600
10	ESP Camera	₹1,100
11	Water Pump and Nozzle	₹1,200
12	Other Expenses	₹2,000
13	Total Estimated Cost	₹19,500

Table No. 1 Cost Estimation of the Model

Flow Chart :

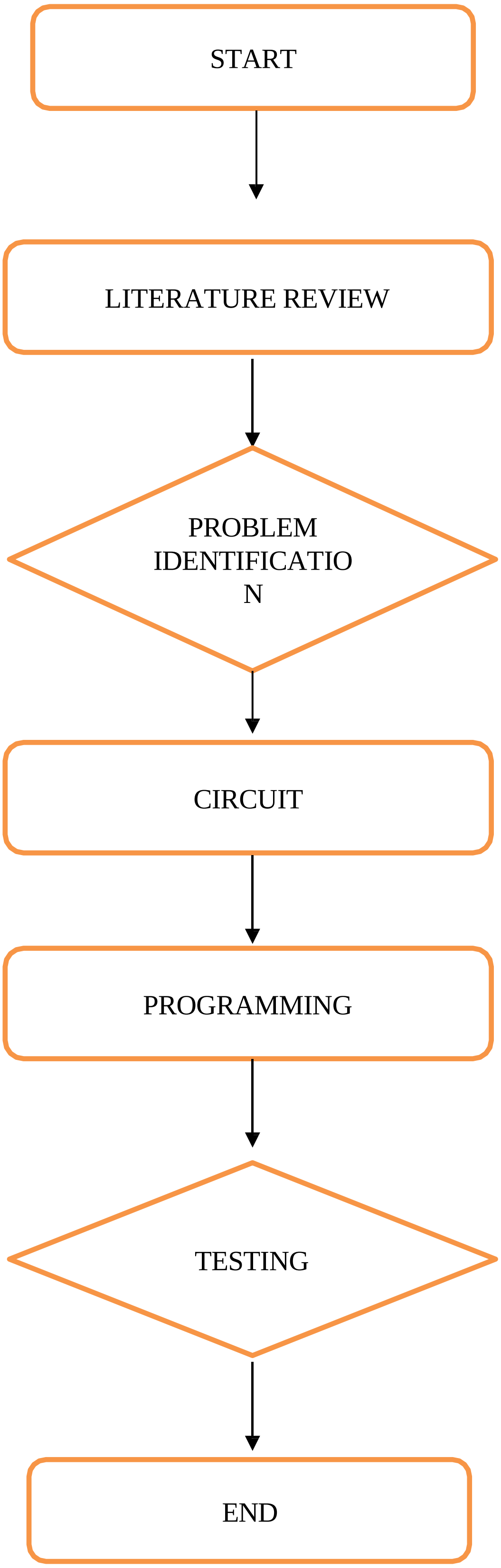

Fig. No. (a) : Flowchart of Model

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Material Components List

Sr.No.	Component Name	Specification / Model	Quantity	Purpose
1	Flame Sensor	IR-based flame detection	1	Fire detection
2	DC Motor	12V, 100 RPM	2-4	Robot mobility
3	Water Pump Module	12V mini submersible	1	Water ejection to extinguish fire
4	Motor Driver Module	L298N Dual H-Bridge	2	Motor control
5	Relay Module	1-Channel, 5V	1	Pump switching
6	Power Supply	Li-ion battery / 12V adapter	1 set	System power
7	IoT Platform	Blynk	-	Cloud monitoring and control
8	Chassis/Body Frame	Stainless Steel	3	Structural support
9	Caster Wheels	360° rotating wheel	4	Balancing support
10	Node MCU ESP8266	Wifi-enabled microcontroller	1	Central control and IoT connectivity

Table No. 2 Material Components List

5. LITERATURE REVIEW

I. "Design and Implementation of an IoT Based Firefighting and Affected Area Monitoring Robot"by Md. Anowar Hossain , Himaddri Shakhar Roy , Md. Fazlul Karim Khondakar , Md. Fazlul Karim Khondakar , Md. Azad Hossain

This project is about a robot that helps fire fighters fighting and putting out fires, checking for toxic gases, and monitoring the area. The robot uses special sensors to gather information and can be controlled manually or automatically. It also sends data to a server for further review. The robot has been tested and works well in emergency situations.

Key Features

1. Finds and puts out fires
2. Detects toxic gases
3. Finds people in the area
4. Ckecks temperature and humidity
5. Can be controlled manually or automatically
6. Sends data for monitoring

Benefits

1. Keeps firefighters safer
2. Helps put out fires efficiently
3. Provides important information in real-time

The robot is designed to help firefighters do their job better and safety safe.

II. "Arduino based firefighting Robot" by S Kirubakaran1, S P Rithanyaa2, S P Thanavarsheni2, E Vigneshkumar2

Firefighters have a tough job. They have to put out fires, which can be very dangerous. When they're fighting fire, they can get hurt by the flames, heat, or bad gases.

Our goal is to make firefighting a safer job. We want to help firefighters do their job without pitting themselves in too much danger. By using new technology, we hope to reduce the risks they face and keep them safe.

III. "Design of Home-use Fire Fighting Robots and Research on Automatic Control System" by Yuchen Ma1, SiYang Zhang1,*, Yifan Wang1

A new type of robot has been made to help fight fires at home. It's built to move around easily and reach the fire, and it has a tool to put the flames out. The robot is designed to be tough and dependable, making sure it can do its job well when needed. It moves quickly and smoothly, and uses a camera to find and follow the fire. The main purpose of the robot is to stop fires fast and safely, keeping people and their homes safe.

As the economy grows rapidly, fires are becoming more common in high-risk areas. Investigations into past fire tragedies show that there were very few advanced mobile fire-fighting tools available. Traditional methods, like regular fire extinguishers and fire-fighting vehicles, often failed to control fires quickly and effectively. Intelligent fire-fighting robots, a type of advanced technology, are now playing an increasingly vital role in fire-fighting and rescue operations. This study explores the design of such robots, which typically include a movement system, a water spray system, a control system, and other components. These systems work together seamlessly to carry out fire-fighting tasks.

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IV. "Design and Development of Intelligent Fire-fighting Robot Based on STM32" by Changzhong Wu1,*, Fan Ge2, Guangchao Shang1, Mingpeng Zhao1, Guitao Wang1, Hengshuai Guo1, Liang Wu1

As the economy grows rapidly. Fires are becoming more common in high risk areas. Investigations into past fire tragedies show that there were very few advanced mobile fire-fighting tools available. Traditional methods like regular fire extinguishers and fire fighting vehicles, often failed to control fires quickly and effectively. This study explores the design of such robots , which typically include moment system, water spray system, a control system and other components

V. "Implementing a Prototype Autonomous Fire Detecting and Firefighting Robot" by Joseph Azeta 1*, Idowu Ayoade 2, Cosmas Nwakanma 3 and Timileyin Akande

Fires are very dangerous and can hurt people and damage things. A new robot can help by finding and putting out fires all by itself . It uses special tool to detect fires and stop them. When tested, the robot worked really well. This robot could be a big help in keeping people safe and stopping fires quickly.

"SELF-DIRECTED FIRE FIGHTING ROBOT USING INTERNET OF THINGS AND MACHINE LEARNING" by Rajeshwarrao Arabelli1, T.Bernatin2

Now a day, fire accidents in houses, apartments and communities, threatening to the victims and property. As it is a very dangerous job to involve any person like fire fighters during fire accidents, that potentially cause loss of property and human lives due to lack of technology innovation. Hence the firefighting robots are used to rescue the operation instead of humans. In our project, Firefighting robot is used to alert whenever fire accidents are detected and moves in the direction of flame or smoke to extinguish it. Hence the firefighting robot operation is to rescue victims and stop fire in a house within a little span of time. Thus, it reduces the risk of injury to the victims and also property damage. This device includes various sensors like Proximity Infrared Sensor (PIR), flame sensor, ultrasonic sensor, MQ2 (LPG) sensor, and actuators like Motors and buzzer.

6. METHODOLOGY

The methodology for developing a 360-degree fire-fighting robot using IoT involves systematic planning, designing, prototyping, testing, and deploying the robot with real-time communication and control capabilities. The development process includes both **hardware** and **software integration**, focusing on automation, fire detection, and IoT-based monitoring.

System Overview

The robot is designed to:

- Detect fire using flame, gas, and temperature sensors.
- Rotate its nozzle 360 degrees using a servo or wiper motor for complete area coverage.
- Send real-time alerts and live video feed to a remote user using an IoT platform.
- Extinguish fire automatically using a water pump system once fire is detected.

Hardware Architecture

Major Components Used:

- **ESP32 Microcontroller:** Controls the system and enables IoT functionality.
- **Flame Sensors:** Detects the presence of flame in the environment.
- **Temperature Sensor (LM35):** Monitors temperature levels to sense heat intensity.
- **Gas Sensor (MQ-2):** Detects smoke or flammable gases.
- **ESP32-CAM:** Captures and transmits live video footage.
- **Wiper Motor/Servo Motor:** Enables 360-degree rotation of the water nozzle.
- **DC Motors and Wheels:** Provides mobility to the robot.
- **Motor Driver (L298N):** Drives the motors based on microcontroller commands.
- **Relay Module:** Controls the switching of the water pump.
- **Water Pump and Nozzle:** Sprays water to extinguish fire.

Software and IoT Setup

- **Platform Used:** Arduino IDE for coding, Blynk/ThingSpeak for IoT dashboard.
- **Programming Language:** C/C++ (Arduino Framework)
- **Cloud Connectivity:** Wi-Fi module in ESP32 connects to IoT platform via internet.
- **IoT Features:** Live monitoring of sensor values, control of movement/pump, real-time alerts.

Working Mechanism

Initialization:

System powers up and initializes sensors, motor drivers, and IoT connectivity.

Surveillance Mode:

Robot begins continuous scanning using flame, gas, and temperature sensors, while streaming live video.

Detection Phase:

- If any sensor crosses the threshold (e.g., flame detected or temperature exceeds limit), the system triggers an alert.
- The location of fire is identified by rotating the nozzle.

Fire Suppression Phase:

- Relay activates the water pump.
- Wiper motor rotates the nozzle to cover 360° and spray water on the fire source.
- The process continues until the fire is extinguished.

Real-Time Monitoring and Control:

- Sensor data is uploaded to the cloud (e.g., Blynk dashboard).
- Remote user receives notification and can view the live video feed via ESP32-CAM.
- Manual override control is available in the app for movement or reactivation.

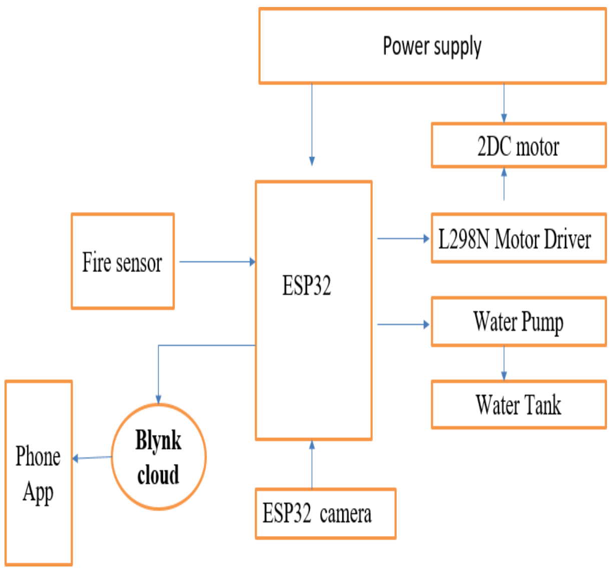

Fig. No. (b) Block Diagram of Model

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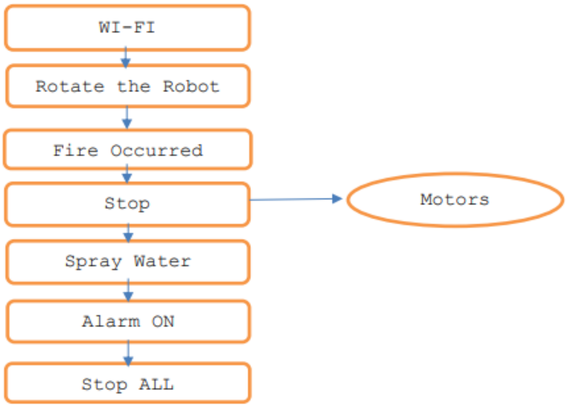


Fig. No. (c) Flowchart of Working Procedure

7. Layout

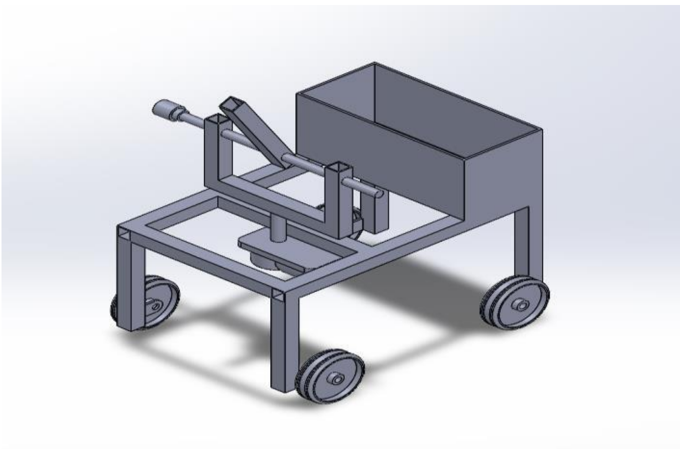


Fig. No. (d) CAD Design

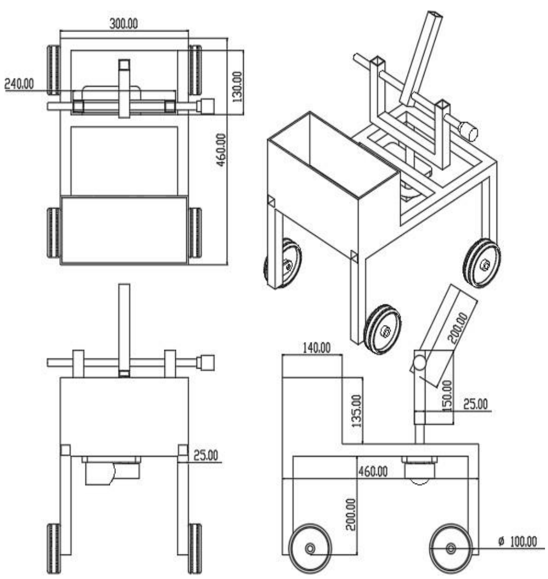
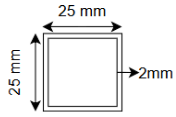


Fig. No. (e) CAD Drawing

8. Design Calculation :

Load on frame considered P = 5 kg = 49.05N
y = D/2 = 25/2 = 12.5mm
D = 25 mm, B = 25 mm, t = 2mm thickness
Length of frame is 460 mm
Moment of inertia in x direction
I = 16345.34 mm^4
Mb = 5640.75 N-mm



Bending stress of pipe ,

$$\frac{Mb}{I} = \frac{\sigma b}{y}$$

Where,

σ = is bending stress (Pa or N/m^2)
M = Bending moment applied to the object (N·m)
y = the perpendicular distance between the neutral axis and a specific point on the object's cross-section
I = the area moment of inertia of the object (m^4)
= 4.31 N/mm^2

Theoretical bending stress
$\sigma b(th) = \frac{Syt}{f.s} = \frac{310}{1} = 310\ N/mm^2$
Hence design is safe.

CALCULATION FOR DC MOTOR
Rpm = 60 Voltage =12 v Current = 0.3 amp
Power = V x I
= 12*0.3
P = 3.6 watt
Torque required for motor is

$$P = \frac{2\pi NT}{60}$$

$$3.6 = \frac{2*3.142*60*T}{60}$$

T = 0.57Nm

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9. RESULTS

The developed 360-degree fire fighting robot was successfully built, tested, and deployed under controlled conditions. The prototype fulfilled its primary objective of detecting fire and extinguishing it through automated and remote-controlled mechanisms, supported by IoT integration. The performance of the robot was evaluated based on key functional parameters:

Fire Detection Accuracy

- The flame sensor accurately detected fire within a **range of 1 to 1.5 meters**.
- False positives were reduced by cross-verifying readings with the **temperature sensor and gas sensor**.
- The system successfully distinguished between ambient heat and an actual flame source.

360-Degree Coverage

- The **wiper motor** allowed the nozzle to rotate continuously, achieving **full circular coverage**.
- The water spray reached a radius of approximately **1.5 meters**, sufficient for small fire extinguishing applications.

Remote Monitoring and Control

- **ESP32 and ESP32-CAM modules** effectively transmitted live sensor data and video feed via **Wi-Fi**.
- A smartphone app (e.g., Blynk or custom interface) allowed remote:
    - Monitoring of fire status
    - Control of robot movement (if implemented)
    - Activation of the water pump
- The **response time** from detection to actuation was under **2 seconds**, ensuring rapid intervention.

IoT Dashboard Performance

- Real-time alerts and sensor status were displayed with **minimal latency**.
- The system remained connected and stable under extended operation (tested for **2+ hours**).
- Cloud-based logs helped track event history for further analysis.

- The robot operated efficiently on a **12V battery pack**, giving a runtime of approximately **1 hour** per full charge.
- Mobility (optional feature) was smooth over flat surfaces using **DC motors and rubber wheels**.
- The structure was stable during nozzle rotation and water pumping.

Cost Efficiency

- The total cost of the project was **₹19,500**, making it a highly affordable and scalable solution for small-scale fire safety applications in:
    - Homes
    - Warehouses
    - Data centers
    - Industrial units

10. CONCLUSIONS

The project successfully achieved the design and development of a 360-degree fire fighting robot integrated with IoT, capable of detecting and extinguishing fire automatically as well as remotely. The system utilized a combination of flame sensors, temperature and gas sensors, a water pump with a 360-degree rotating nozzle, and real-time monitoring through IoT platforms such as Blynk or ThingSpeak.

The robot demonstrated effective performance in real-time fire detection, rapid actuation, and full-area water dispersion. The inclusion of IoT technology provided enhanced safety and convenience, enabling users to receive instant alerts and control the robot from a remote location via Wi-Fi. The ESP32-CAM module offered live visual feedback, adding another layer of situational awareness.

From a cost and implementation perspective, the robot was developed using readily available, low-cost components, making it a viable solution for small-scale fire protection applications such as homes, storage areas, data centers, and light industrial setups. The modular design also allows for future upgrades, including autonomous navigation, AI-based decision-making, and integration with smart home ecosystems.

In conclusion, this fire fighting robot serves as a powerful demonstration of how embedded systems, automation, and IoT can come together to create an efficient, responsive, and intelligent solution for fire hazard prevention and mitigation. With further enhancements, this prototype has the potential to evolve into a fully autonomous firefighting system suitable for larger and more complex environments.

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