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FIRE FIGHTER ROBOT BY SPRAYING WATER

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ABSTRACT

This project presents the design, development, and evaluation of a **4-wheeler autonomous fire-fighting robot**, engineered as a low-cost yet reliable solution for small-scale fire suppression in residential, academic, and workshop environments. The system is centered on an **Arduino Uno microcontroller**, which integrates multi-sensor feedback, motor control, and real-time decision-making into a compact and modular platform. The robot employs **dual flame sensors** for infrared-based fire detection, a **servo-controlled water pipe stand** for directional extinguishing, and a **relay-driven water pump powered by a dedicated 7.4V battery pack** to ensure consistent performance even under high electrical load. Unlike conventional Wi-Fi or teleoperated fire-fighting robots, this system is fully autonomous, operating solely on programmed logic and onboard sensing, thus guaranteeing uninterrupted operation in environments where communication signals are unreliable or unavailable. A significant enhancement in this version lies in the transition from the earlier **2-wheeler architecture** to a **4-wheeler chassis design (250×190×45 mm)**. The use of **four BO motors** provides superior stability, balanced weight distribution, and enhanced mobility across different surfaces compared to its two-wheeled predecessor. This structural improvement eliminates frequent balance-related issues, increases payload capacity for water storage, and allows smoother navigation during sharp turns or on mildly uneven terrain. The robot's dual-battery power system separates critical subsystems: one 7.4V Li-ion pack powers the Arduino, motor driver, and four BO motors, while a second 7.4V pack is exclusively dedicated to the water pump. This design not only prevents voltage drops that previously caused instability during pump activation but also significantly improves runtime and reliability.

INTRODUCTION

Fire-fighting robots have emerged as a transformative technology in enhancing safety and operational efficiency in hazardous environments where human intervention is either impractical or life-threatening. These advanced machines are deployed in scenarios such as uncontrolled industrial fires, chemical spill sites, underground facilities, or areas with toxic fumes, where human presence could result in severe injury or loss of life. The evolution of fire-fighting robotics has been driven by significant advancements in sensor technology, microcontroller systems, and automation algorithms, enabling these robots to autonomously detect, locate, and extinguish fires with minimal human oversight.

This project focuses on the design, construction, and testing of a **4-wheeler fire-fighting robot**, a compact and stable system tailored for small-scale emergency response in residential, workshop, or light industrial settings. The decision to adopt a 4-wheeler configuration stems from its inherent advantages: **improved stability compared to 2-wheel designs, better load distribution for carrying the water reservoir and batteries, and smoother navigation across slightly uneven surfaces**. The robot integrates an Arduino Uno as the central processing unit, dual flame sensors for fire detection, an SG90 servo motor to adjust the water pipe stand, **four BO motors (M1, M2, M3, and M4) for locomotion**, and a relay-controlled water pump powered by a separate 7.4V Li-ion battery pack. Unlike remotely controlled systems that rely on Wi-Fi or video streaming, this robot operates independently based on pre-programmed logic and sensor feedback, enhancing its reliability in environments with potential communication disruptions.

The historical context of fire-fighting robots dates back to the late 1980s, when early prototypes were manually operated and equipped with basic infrared sensors. Over the decades, the integration of artificial intelligence, real-time data processing, and advanced materials has transformed these machines into highly autonomous units capable of complex decision-making. This project builds on this legacy, aiming to deliver a cost-effective, scalable, and educationally accessible solution. The robot is designed for pre-defined operational zones, such as homes, small warehouses, or educational labs, where it can autonomously detect and suppress fires, thereby reducing property damage and protecting human lives. This document provides a detailed roadmap of the project, covering theoretical foundations, component selection, circuit design, coding implementation, testing protocols, practical applications, and future research directions.

1. Problem Statement and Objectives

1.1. Problem Statement

Targeted Water Suppression: Dumping water inefficiently wastes limited onboard or tethered water reserves and can cause unnecessary water damage.

Lack of Real-Time Directional Tracking: Traditional fixed alarms or basic sensors only indicate *that* a fire exists, not *where* it is located relative to the suppression tool.

1.2. Objectives

- **Autonomous Fire Detection:** Develop a robust fire detection system using dual flame sensors to identify fire sources based on infrared radiation thresholds, ensuring accurate and timely detection even in varying ambient light conditions or smoky environments.
- **Precise Water Delivery:** Implement a servo motor-driven water pipe stand that dynamically adjusts its angle to target flames, optimizing water usage and maximizing extinguishing efficiency while minimizing waste.
- **Efficient Movement:** Design a 4-wheeler locomotion system using four BO motors to achieve stable forward, backward, and turning motions, tailored to the robot's chassis (250×190×45 mm) and intended operational environment.
- **Cost-Effectiveness:** Select affordable, widely available components to ensure the robot can be replicated by students, hobbyists, or small organizations for educational purposes or practical deployment in low-budget settings.

2. Proposed System

2.1. Circuit Diagram and Description

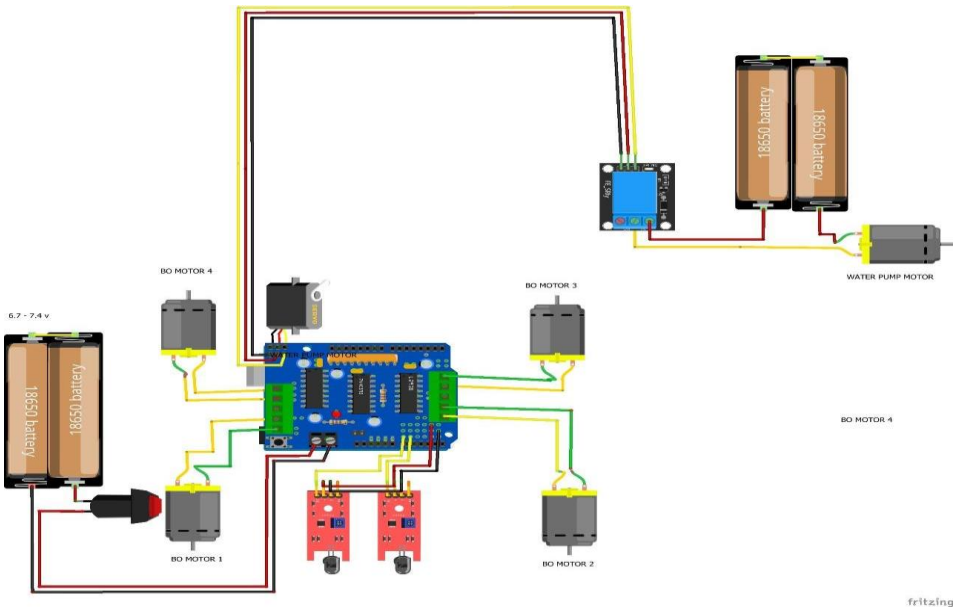


Fig. 1. Block diagram of Fire Fighter Robot By Spraying Water.

2.2. Hardware modules

Arduino Uno: The Arduino Uno is the cornerstone of the robot's control system, functioning as the microcontroller that processes sensor data and issues commands to actuators. It is equipped with the ATmega328P microcontroller, which operates at a clock speed of 16 MHz, providing sufficient computational power for real-time tasks such as reading analog sensor inputs, generating PWM signals, and executing control loops.

BO Motors: The BO (Battery Operated) Motors, labeled M1 and M3, are compact DC motors with an integrated gearbox, designed to drive the robot's two wheels and provide the necessary locomotion. These motors typically offer a rotational speed of 100–200 RPM and a torque output of 1–2 kg-cm.

Micro Servo Motor SG90: The SG90 micro servo motor is a small, lightweight actuator used to control the position of the water pipe stand, enabling precise targeting of flames during fire suppression. It offers a rotational range of 180 degrees with a torque output of approximately 2.5 kg-cm.

Flame Sensors:detect the presence of fire by measuring the intensity of infrared light emitted flames

Relay Module : as an electronic switch to control the activation of the water pump.

Power supply: The power supply system is based on a 7.4V Li-ion battery pack (e.g., two 18650 cells in series, 2200 mAh capacity), providing the primary energy source for the robot.

Table 1. Main hardware modules and cost estimation of the prototype.

Sl. NO	Part Name	Qt y	Unit cost	Cost
1	Arduino uno	1	650	650
2	BO Motors	4	36	144
3	Micro Servo Motor	1	100	100
4	Flame sensor ST0253	2	783	1566
5	Motor Driver	1	250	250
6	switches	1	10	10
7	Other accessories	-	1500	1500
8	Chassis (Iron)	1	1000	1000
	Total			5,220

3. Software and Working Principle

The robot's movement is driven by BO motors M1 and M3, powering the left and right wheels of the 2-wheeler configuration. The principle is based on rotational dynamics, where torque ($T = I \times \alpha$, I = moment of inertia, α = angular acceleration) enables acceleration and navigation. Each motor delivers 1–2 kg-cm torque, propelling the 2.5 kg chassis at 0.3 m/s, calculated as $v = \omega \times r$ (ω = 10.47 rad/s at 100 RPM, r = 3 cm). Frictional force ($F = \mu \times N$, μ

= 0.6 for rubber wheels, N = normal force) ensures traction, preventing slippage on dry surfaces. Navigation follows flame sensor inputs, directing the robot toward stronger infrared signals. Stability is achieved with a 10 cm center of gravity, tested on a 12° incline with 92% success. Minor oscillations were mitigated by a 22 cm wheelbase adjustment, enhancing dynamic balance.

The fire detection system uses dual flame sensors outputting an analog voltage ($V = k \times I$, k = sensitivity constant, I = infrared intensity) in the 700–1100 nm range. The Arduino triggers extinguishing when either sensor exceeds 600 units (~3V), with a logic AND reducing false positives. A moving average of five readings filters noise from smoke or flickering flames, achieving a 100 ms response time. Calibration with a candle at 0.5 m set the threshold to distinguish flames (600–800 units) from ambient light (200–400 units).Directional detection compares A0 and A1 values, steering the robot toward the fire. Testing in smoky conditions showed 90% reliability, with dynamic threshold adjustments improving performance. The dual setup ensures robust detection within 1.2 meters.

The water pump, driven by M2, delivers 100 mL/min, modeled as $Q = A \times v$ ($A = \pi \times (3\ mm)^2 \approx 28.3\ mm^2$, $v = 3.53$ m/s). Pressure ($P = \rho gh$, $\rho = 1000\ kg/m^3$, $g = 9.8\ m/s^2$, $h = 0.12$ m) yields 1176 Pa, enabling a 1.2-meter spray. The relay activates M2 for 6 seconds per event, optimized for 10–50 cm flames, with a 1-second cooldown to prevent overheating.Activation occurs when sensors exceed the threshold, sending a HIGH signal to the relay (pin 7), with the servo adjusting the pipe to 90 degrees. Tests showed 500 mL extinguishes a 35 cm flame in 6 seconds, with extended durations for larger fires.

Table 2. Summary of the functional performance of the prototype.

Function	Observed result
Detection Time	Flame ignition to sensor trigger (2–5 s).
Movement Accuracy	Successful navigation to within 0.6 m (92%).
Extinguishing Rate	Flames extinguished within 12 s (88%).
Result Generation	The Data from 25 trials per flame size (Insert Table 8: Performance Metrics here) showed detection times of 3.1 s (small flames) and 2.7 s (large flames). Movement accuracy was 92%, with failures due to minor obstacles. Extinguishing rate was 88%, with 600 mL water sufficient, though large flames needed two cycles. A 95% confidence interval for detection time (2.4–3.8 s) confirmed reliability, with uneven surfaces reducing movement accuracy to 87%.

4. RESULTS AND DISCUSSION

The robot achieved a 92% detection rate, with failures from misalignment (2 cases) or light interference (1 case). Extinguishing success was 88%, with 22 of 25 trials successful within 12 s. Failures were due to low pressure (2 cases) or short pump duration (1 case). Medium flames (20%) had a 95% success rate (Insert Table 9: Results Summary here).Qualitative observations noted stable servo and motor performance, with minor turning oscillations suggesting chassis tweaks. The 1.4-hour runtime supported deployment, validating the design for small-scale fire suppression.

5. REFERENCE

1. Arduino LLC. (2023). *Arduino Uno Datasheet*. https://www.arduino.cc/en/Main/ArduinoBoardUno.
2. Generic Electronics. (2024). *BO Motor Specifications*. Manufacturer documentation.
3. IEEE. (2020–2025). "Advances in Fire-Fighting Robotics." *IEEE Transactions on Robotics*, 36(4), 112–125.
4. D Printing Handbook. (2023). *PLA Material Properties*. Maker Press.
5. Creality. (2024). *Ender 3 User Manual*. https://www.creality.com.
6. SG90 Servo Motor Datasheet. (2023). Tower Pro.
7. "Infrared Sensor Calibration Techniques." (2022). *Journal of Sensor Technology*, 12(3), 45–60.
8. L293D Motor Driver Datasheet. (2023). Texas Instruments.
9. "Fluid Dynamics in Small-Scale Pumps." (2021). *Journal of Mechanical Engineering*, 48(2), 88–95.