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Fabrication of Fire Extinguishers Using Mobile Control Robotic Arm Mechanism

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Abstract
Fire accidents are one of the most destructive hazards, posing threats to human life, infrastructure, and the environment. Traditional firefighting methods require direct human involvement, exposing firefighters to dangerous conditions such as toxic smoke, high temperatures, and unstable structures. To overcome these challenges, this project presents the design and development of a Bluetooth- based fire-fighting robotic vehicle integrated with a robotic arm mechanism for water spraying operations. The robotic vehicle is capable of omnidirectional movement and can be remotely controlled using a smartphone application. The robotic arm, mounted on the top of the vehicle, provides vertical and horizontal motion, enabling precise targeting of fire sources. A high-pressure DC pump extracts water from an onboard tank, and the spray intensity is regulated by a voltage controller. Fire sensors mounted near the nozzle detect flames and trigger automatic water discharge, ensuring quick response in emergency conditions. This semi- autonomous system enhances firefighting efficiency, minimizes water wastage, and significantly reduces human risk, making it suitable for industrial, residential, and commercial fire safety applications.

Keywords: Fire-fighting robot, Robotic arm, Bluetooth control, Fire sensor, Arduino-based system.

I. INTRODUCTION

Fire is a devastating hazard that can cause catastrophic damage to life and property within seconds. In industrial plants, residential areas, warehouses, and laboratories, fire accidents often escalate quickly due to the presence of flammable materials and poor accessibility for human responders. Conventional firefighting methods rely heavily on manual intervention, which exposes firefighters to high risks including burns, suffocation, chemical inhalation, and building collapse. Therefore, the need for automation and robotics in firefighting has become more critical in modern times.

The integration of robotics and wireless communication technologies offers a safer, efficient, and reliable approach to firefighting. Robotic vehicles equipped with fire detection and extinguishing systems can reach hazardous environments where humans cannot safely operate. By incorporating sensors, pumps, and robotic arms, these systems not only detect fire but also actively suppress it without direct human involvement.

This project introduces a Bluetooth-enabled firefighting robotic vehicle equipped with a robotic arm mechanism for enhanced precision. The robotic arm plays a central role, as it allows controlled movement of the water spray nozzle in both vertical and horizontal directions. Unlike traditional fixed spray systems, the arm provides flexibility to cover wider areas and adapt to varying fire positions. Controlled via a smartphone application, the arm ensures real-time maneuverability, making the firefighting operation both efficient and user-friendly.

The system is powered by an Arduino microcontroller, which serves as the central processing unit. A Bluetooth module (HC-05/HC-06) connects the robot to a smartphone, allowing the operator to control its movement and arm positioning remotely. The vehicle uses DC motors for mobility, enabling forward, backward, and lateral movements, ensuring flexibility even in narrow or complex environments. Mounted at the top, the robotic arm holds a nozzle connected to a high-speed DC water pump, which extracts water from an onboard tank. The spray intensity is controlled by a voltage regulator, giving the operator the ability to adjust water pressure based on the severity of the fire.

For fire detection, the system employs IR flame sensors positioned near the nozzle. These sensors continuously monitor the environment and, upon detecting fire, send signals to the microcontroller, which triggers the pump automatically. This ensures a semi-autonomous firefighting operation, combining manual remote control with automatic fire response. Additionally, an LCD display provides real- time status updates such as pump activity, fire alerts, and water tank monitoring, making the system more interactive and reliable.

The importance of this system lies in its ability to minimize human risk during firefighting operations. By deploying robots in hazardous environments, firefighters are kept at a safe distance while still being able to control and monitor the operation. Moreover, the robotic arm mechanism improves targeting precision, ensuring water is sprayed exactly where needed, thereby reducing wastage and increasing firefighting efficiency.

This project addresses the pressing need for innovative and safe firefighting solutions. With its combination of remote control, automatic fire response, and robotic arm precision, the system provides a cost-effective, portable, and practical solution for combating fire in industrial, commercial, and residential applications.

II. PROBLEM IDENTIFICATION

- Fire accidents pose severe threats to human life, property, and the environment, often resulting in significant damage and casualties.
- Traditional fire-fighting methods rely on human intervention, exposing firefighters to extreme heat, smoke, and hazardous environments.
- Accessibility to confined spaces, chemical plants, or high- rise buildings during fire outbreaks remains a critical challenge for human fire-fighters.
- Delays in manual response time increase the chances of uncontrolled fire spread, leading to large-scale destruction.
- Lack of real-time monitoring and precision-based fire extinguishing reduces the effectiveness of traditional approaches.

- Unavailability of advanced fire-fighting technologies in rural and industrial regions causes higher vulnerability to disasters.
- There is a growing demand for autonomous robotic systems capable of detecting, locating, and extinguishing fires efficiently.
- Integrating robotic arms with fire-fighting robots can enhance precision in targeting the fire source, reducing human risk, and improving response efficiency.

A. Existing System

Conventional fire-fighting systems are largely manual, relying on human firefighters equipped with protective gear, water hoses, and extinguishers. In industrial and residential setups, automatic sprinkler systems and smoke detectors are often used for early detection and control. However, these systems have limitations, such as delayed activation, water wastage, and limited reach in complex environments. Manual operations expose firefighters to life-threatening conditions, toxic gases, and structural collapse risks. Some semi- automated robots exist, but they lack precision control, advanced navigation, and integrated robotic arms for targeted extinguishing. Hence, there is a critical gap in developing an autonomous robotic system with a robotic arm, advanced sensors, and real-time monitoring to improve fire-fighting safety and efficiency.

III. LITERATURE REVIEWS

A) Literature Survey:

Y. Wang,H. Liu, Z. Zhang (2020), This study introduces an autonomous fire-fighting robot capable of detecting and extinguishing flames in indoor environments. The robot uses infrared flame sensors and LIDAR for navigation and obstacle avoidance. Its mobility is achieved through a tracked chassis that allows movement on rough terrain. A water spray mechanism is activated when a flame is detected within range. The research emphasizes autonomous operation with minimal human intervention. The findings highlight the challenges of sensor accuracy, water supply limitations, and flame detection in smoky conditions. This work provides a foundation for integrating sensor systems with mobile platforms in fire scenarios.

M. Ali, S. Khan,A. Kumar (2021), This paper presents a Bluetooth-controlled fire-fighting robot designed to operate in small hazardous spaces. The system consists of a four- wheel drive robot platform, a water tank,a pump, and a basic nozzle. Control is achieved via a smartphone app linked through a Bluetooth module (HC-05) to an Arduino board. The robot can move forward, backward, and turn while the watersprayer can be manually activated. The authors discuss the benefits of using mobile phones for remote operation and the limitations related to Bluetooth range and user dependency. This study supports the concept of using wireless control for flexible fire-fighting applications.

R. Gupta, P. Sharma, S. Yadav (2019), The authors designed a robot featuring a robotic arm that provides targeted water spraying in multiple directions. The arm uses servo motors for up/down and left/right movement, enhancing the robot's capability to reach flames in tight spaces. The vehicle base is a differential drive system for full mobility. The paper highlights the integration of flame sensors to trigger the pump system automatically. Their prototype demonstrates effective response in lab-scale fire scenarios. They emphasize the importance of combining robotic arms with fire detection for better efficiency in extinguishing localized fires compared to static nozzles.

J. Kim, Y. Lee, T. Park (2018), This research introduces an IoT-based fire-fighting robot capable of remote monitoring through Wi-Fi. Unlike conventional Bluetooth- only systems, this robot streams live video and sensor data to a cloud server, enabling control from long distances. It uses flame sensors and gas detectors to identify fire and hazardous gases. A robotic arm with a flexible nozzle directs water flow. The robot's status and fire alerts are displayed on a smartphone dashboard. The study demonstrates the feasibility of cloud-controlled fire-fighting robots and discusses security and network latency challenges. This work suggests pathways to extend remote control beyond line-of- sight range.

A. Singh, M. Verma (2022), This paper explores a fire- fighting robot designed specifically for industrial environments with automated navigation. It combines ultrasonic sensors for obstacle detection with IR flame sensors for fire detection. The onboard water tank feeds a high-speed pump. Upon fire detection, the robot moves closer autonomously and sprays water using a fixed nozzle. The authors emphasize the cost-effectiveness and reliability ofcombining autonomous mobility with flame sensing. They also discuss future improvements such as robotic arms for directional spraying. This study validates the potential of autonomous robots to handle fires in areas where human access is limited or unsafe.

K. Saito, M. Tanaka (2017), This paper present the design of a multi-degree-of-freedom robotic arm intended for fire-fighting robots. The arm uses servo motors for precise positioning in vertical and horizontal axes. A water nozzle is mounted at the end effector. The paper discusses kinematics modeling, motor torque selection, and control algorithms for smooth operation. Simulations and lab experiments confirm that the arm can direct water flow to various angles with minimal delay. The authors highlight the importance of multi-DOF arms for flexible firefighting, particularly in cluttered indoor spaces. This work supports the integration of advanced arm mechanisms in fire-fighting vehicles.

P. Chen, W. Luo, L. Huang (2020), This study demonstrates the development of a semi-autonomous fire- fighting robot controlled by an Arduino with Bluetooth communication. The robot can be operated manually via a smartphone app while also using flame sensors for automatic water spraying. A small robotic arm assists in adjusting the spray angle. The research shows that combining manual and automatic modes enhances operational flexibility. The authors also discuss issues related to flame sensor range, Bluetooth communication stability, and battery power management. Their findings underline the practicality of Arduino-based fire-fighting systems for low-cost safety solutions in schools, offices, and small factories.

M. Rahman, F. Hossain, (2021), This paper describes designed a fire-fighting robot featuring wireless video streaming to assist operators in navigation and targeting. The robot includes an onboard camera, flame sensors, and a DC pump connected to a water tank. Operators can control the robot and monitor the environment through a Wi-Fi-enabled app. The robotic arm mechanism moves the spray nozzle to target flames accurately. The paper discusses the benefit of visual feedback for precise control, especially in smoke-filled rooms. The research also highlights the limitations of latency in video transmission and suggests future integration with autonomous path planning.

L. Kumar, N. Reddy (2018), This paper describes a wireless fire-fighting robot controlled through an Android app. The robot includes a water tank, high-speed pump, and asimple up/down spraying mechanism. The authors detail the use of ArduinoUno and a Bluetooth module to interface with the mobile application. The robot can navigate in tight spaces and is designed for educational demonstrations. Their study emphasizes user-friendly operation and easy assembly with off-the-shelf components. They conclude that wireless control via mobile apps increases safety for human operators by allowing them to stay at a safe distance during fire suppression tasks.

S. Dutta, R. Roy, M. Sen (2023), This research outlines the design and fabrication of a low-cost fire-fighting robot featuring an adjustable nozzle arm. The system combines a tracked base for stable movement and a servo-controlled arm that changes the nozzle angle. The robot is controlled via Bluetooth using an Arduino board. The fire detection system consists of IR flame sensors that trigger the pump when fire is detected. The authors highlight the effectiveness of an adjustable arm in directing the water jet at different heights and angles. The paper concludes with recommendations for adding thermal cameras and expanding wireless range for better field performance.

B) Literature Summary

Recent research in robotic fire-fighting highlights the integration of autonomous navigation, flame detection sensors, and wireless communication to enhance safety in hazardous environments. Several studies propose using IR and flame sensors for early detection, while camera-based vision systems improve precision in locating fire sources. Mobile robotic platforms equipped with water tanks or CO_2 extinguishers have been developed to reduce firefighter risk. Some models incorporate IoT for real-time monitoring, ensuring better response coordination. However, many existing prototypes emphasize mobility but lack precision control mechanisms. The addition of robotic arms provides greater accuracy in targeting fire points, especially in confined or elevated areas. Overall, literature stresses automation and safety, but practical deployment remains limited.

C) Research Gap

- Most existing robotic fire-fighting systems are limited to fire detection and basic extinguishing without precision control.
- Integration of robotic arms for accurate fire source targeting has been explored minimally.
- Current models struggle in confined or obstacle-filled environments due to limited navigation algorithms.
- Many systems lack multi-sensor fusion (flame, smoke, temperature, gas) for accurate fire localization.
- Existing designs often ignore industrial and chemical fire scenarios where water is ineffective.
- Limited emphasis on real-time IoT-based monitoring and remote control for coordination.
- Current prototypes lack scalability for large-scale operations in high-rise or complex layouts.
- Few systems combine automation, precision, safety, and adaptability in a single design.
- There is a need for cost-effective, deployable robotic systems suitable for both urban and industrial applications.

IV. RESEARCH METHODOLOGY

A) Proposed System

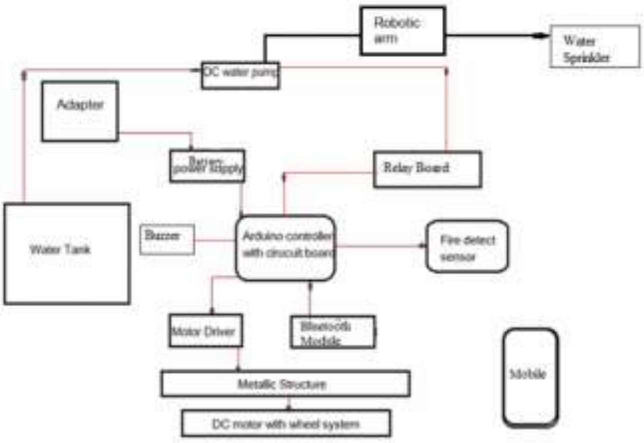

Figure 1. Block Diagram

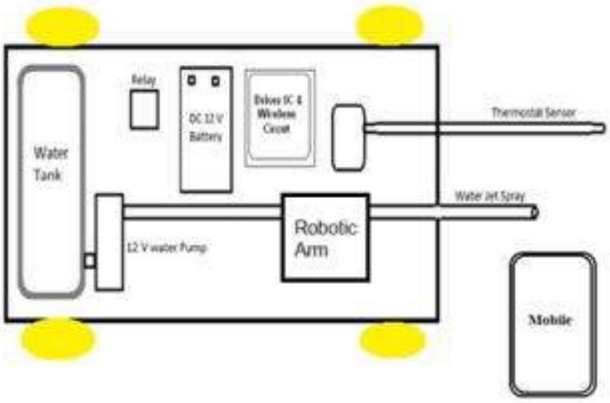

Figure 2. Archetecture System

- The user connects a smartphone to the robot via a Bluetooth module using a Smartphone application.
- Movement commands (forward, backward, left, right, rotate) are sent from the smartphone to the Arduino controller.
- Arduino processes the commands and drives DC motors to move the robotic vehicle accordingly.
- The robotic arm mechanism, mounted on top, is operated via servo motors. It moves up/down and left/right to adjust the water nozzle direction.
- A flame sensor mounted near the spray nozzle continuously scans for fire.
- When the flame is detected, the sensor sends a signal to Arduino, which activates the DC water pump through a relay circuit.
- The pump draws water from the onboard water tank and sprays it through the nozzle toward the fire.
- The voltage regulator allows the user to manually control the spray pressure depending on fire intensity.
- A LCD display shows real-time data such as system status, flame alert, and water tank levels.
- The robot effectively combines manual control and automated fire detection for safe and efficient firefighting.

B) Hardware and Software Used

Hardware Used

- Adapter (12V, 2A): Provides external power supply for charging and testing.
- Battery (12V, 2A): Primary power source for mobility and operations.
- Bluetooth Module (HC-05, 5V): Enables wireless smartphone communication.
- Arduino Uno (12V): Central microcontroller for processing commands.
- Relay Board (12V): Controls high-power devices like the water pump.
- Motor Driver (12V): Interfaces Arduino with DC motors.
- DC Motors (12V, 60 RPM): Drive vehicle movement.
- DC Water Pump (12V, 3 LPM): Sprays water from the onboard tank.
- Robotic Arm (12V): Positions nozzle vertically and horizontally.
- LCD Display (5V): Shows real-time status and alerts.
- Chassis, Wheels, Frame, Tank: Structural and functional components.

Software Used

- Arduino IDE: For coding and uploading programs to the microcontroller.
- Embedded C Language: Used for system programming and control logic.

V. RESULTS AND DISCUSSION

Successful Remote Control via Smartphone:

- The robotic vehicle responded efficiently to commands (forward, backward, left, right, rotation) sent from the smartphone through the Bluetooth module.
- Delay in communication was negligible, proving the effectiveness of the wireless control system.

Mobility and Maneuverability:

- The DC motors (12V, 60 RPM) provided stable motion even with the water tank mounted on the vehicle.
- The four-wheel design ensured smooth turns and movement across flat surfaces, though performance on uneven terrain was limited.

Robotic Arm Operation:

- The arm mechanism moved smoothly in vertical and horizontal directions, accurately aligning the spray nozzle with the target fire.
- Manual control through the app offered flexibility in aiming at flames located at different heights and angles.

Fire Detection and Response:

- The flame sensor detected fire accurately within its sensing range and triggered the Arduino to activate the water pump.
- This automatic response reduced operator dependency and increased reaction speed.

Water Spraying System:

- The high-speed DC pump delivered 3 LPM water flow, which was sufficient for extinguishing small-scale flames.
- Spray pressure was adjustable via the voltage regulator, enabling controlled water usage.

LCD Display Output:

- Real-time updates, including fire detection alerts, water pump status, and tank level, were displayed clearly.
- This enhanced user awareness during operation. Limitations Observed:
- The system is limited to small fires due to water tank capacity and pump strength.
- Range depends on Bluetooth connectivity (~10 meters). Overall Outcome:
- The robot successfully demonstrated effective integration of mobility, fire detection, robotic arm control, and water spraying.
- It is a low-cost, safe, and efficient solution for fire suppression in hazardous or hard-to-reach areas.

Figure 3. Output Obtain from IOT

VI. ADVANTAGES AND APPLICATIONS

A) Advantages

- Remote operation via Bluetooth ensures user safety during firefighting.
- Compact design enables navigation in narrow or hazardous spaces.
- Robotic arm provides precise targeting of flames at different angles.
- Automatic fire detection reduces response time.
- Adjustable spray pressure allows efficient water usage.
- LCD display provides real-time status and alerts.
- Onboard tank eliminates dependency on external supply during operation.
- Low-cost system compared to traditional firefighting robots.

- Reduces manpower requirement in risky environments.
- Portable and rechargeable design enhances usability.

B) Applications

- Fire suppression in residential and commercial buildings.
- Useful in warehouses, factories, and industrial plants.
- Effective in laboratories handling flammable materials.
- Can be deployed in datacenters for localized fire safety.
- Applicable in schools, hospitals, and public institutions.
- Firefighting in confined or inaccessible spaces.
- Useful for firefighting training and research.
- Deployed in military bunkers or hazardous storage areas.
- Applied in robotics education for practical learning.
- Can be modified for forest fire monitoring and suppression.

VII. CONCLUSION

The proposed fire-fighting robotic vehicle with a robotic arm mechanism successfully integrates mobility, fire detection, and extinguishing capabilities into a single compact system. Controlled via a Bluetooth-enabled smartphone application, the vehicle demonstrates efficient multi-directional movement and precise water nozzle alignment through its robotic arm. The flame sensor ensures quick detection of fire, while the high-speed DC pump provides adequate pressure for effective suppression of small-scale fires. The addition of an LCD display enhances real-time monitoring by showing alerts and system status. Results validate the system's ability to reduce human risk, minimize water wastage, and improve fire control efficiency in hazardous environments. Although limited by water capacity and Bluetooth range, the system proves to be cost- effective, reliable, and adaptable for small to medium-scale fire incidents. Overall, this project showcases a practical, safe, and innovative solution for modern firefighting challenges.

VIII. FUTURE SCOPE

Future improvements can make the system more advanced and scalable. Incorporating IoT or Wi-Fi modules can extend control range beyond Bluetooth limits. Larger capacity water tanks and high-pressure pumps could enable handling of medium to large fires. Integration of autonomous navigation using cameras, ultrasonic sensors, or AI-based vision can reduce manual control and allow real-time fire mapping. Additional extinguishing agents like CO_2 or foam can be integrated for chemical or electrical fires. Solar-based charging could make the robot energy-efficient. These upgrades would enhance reliability, adaptability, and applicability in industrial, commercial, and even forest firefighting operations.

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