Mr. Nithin AC, 2026, 14:2
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

Integrated Fire Suppression Robot with Smart Rainwater Harvesting

Mr. Nithin AC[1], Mr. Sharanagouda[2], Mr. Gurukiran G K[3], Mr. Bhuvan H M[4], Dr. Nanda B S[5]

[1,2,3,4]Dept. Of Electronics and Communication Engineering, PES College of Engineering, Mandya
[5]Professor, Dept. Of Electronics and Communication Engineering, PES College of Engineering, Mandya.

Abstract- This project focuses on developing a smart fire suppression robot integrated with a rainwater harvesting system to improve safety while making better use of available water. The system automatically collects rainwater during rainfall and stores it in a tank, while continuously monitoring the water level for effective usage. The robot is equipped with flame sensors to detect fire and can respond either autonomously or through Bluetooth control. A compact water pump draws water from the tank and sprays it through a movable nozzle, allowing accurate and effective fire suppression. The design is simple, portable, and easy to use, making it suitable for real-world applications. It reduces the need for constant human involvement and helps ensure a quick response during emergencies. In addition, the system is built using low-cost and easily available components, making it affordable and practical for wider use. By combining rainwater collection with automated fire response, the project provides a reliable and efficient solution that supports both safety and better use of natural resources.

Keywords: Fire Suppression Robot, Rainwater Harvesting, Flame Sensor, Rain Sensor, Arduino UNO, Bluetooth Control, Water Pump, Servo Motor, Smart Automation, Embedded System, Real-Time Monitoring, Emergency Response.

I. INTRODUCTION

Water scarcity and fire accidents are major challenges in both urban and rural environments, especially in areas with limited infrastructure and emergency support. Efficient water management and quick fire response are essential for ensuring safety and sustainability [1], [3], [6]. However, most existing systems address these problems separately, reducing their effectiveness in real-world situations [4], [7].

Traditional rainwater harvesting systems are often manual and lack automation, making them less reliable and prone to contamination [1]. Some low-cost systems can detect rainfall, but they do not include proper water collection or storage mechanisms [2]. Although rainwater harvesting is widely recognized for its environmental benefits, many systems are fixed and lack portability and adaptability [3].

In fire safety, technologies such as IoT-based monitoring and advanced detection systems improve response time and accuracy [4], [5], [8]. However, these systems often depend on internet connectivity or involve high cost and complexity, making them unsuitable for low-cost and remote applications.

Recent developments in microcontroller-based water storage and Bluetooth-controlled robots have improved automation and mobility [6], [7]. However, these systems still function independently and do not provide a combined solution for both water management and fire suppression.

Therefore, there is a need for a simple, integrated, and cost-effective system that combines rainwater harvesting with fire suppression. The proposed project introduces an Integrated Fire Suppression Robot with Smart Rainwater Harvesting, which automates water collection and utilizes the stored water for firefighting using a mobile robotic platform. This approach provides a practical, portable, and efficient solution for improving safety and resource utilization in diverse environments.

II. LITERATURE REVIEW

Owusu and Asante [1] studied the use of rainwater harvesting in rural communities in Ghana. Their findings showed that most of the collected water was used for daily activities such as cooking and

bathing, while only a small portion was used for drinking. Although the overall water quality was acceptable, some systems experienced issues like turbidity and contamination due to poor storage conditions. The study also highlighted that many systems were manually operated and lacked proper filtration, which reduced efficiency and reliability. In addition, the absence of automation made these systems less effective in adapting to changing environmental conditions.

Yogesh [2] developed a simple rain detection system using an Arduino and a rain sensor. The system successfully detected rainfall and provided alerts, demonstrating the potential of low-cost electronic solutions. However, it was limited to sensing and alerting functions only, without integrating any mechanism for water collection, storage, or utilization. This made the system less practical for real-world applications where efficient water management is required. It also lacked scalability and integration with other systems.

Teston [3] carried out a comprehensive review of rainwater harvesting systems, emphasizing their environmental and sustainability benefits. The study discussed different methods of water collection, storage, and usage, highlighting their role in reducing water scarcity. However, most of the systems analyzed were fixed and building-based, which limited their flexibility. The lack of portability, automation, and real-time monitoring reduced their effectiveness in dynamic environments and emergency situations.

In the area of fire-fighting robots, Kumar [4] proposed a system that uses IoT-based monitoring and control to detect and respond to fire incidents. The system allowed remote monitoring and provided alerts, improving response time. However, it depended heavily on internet connectivity, which can be unreliable or unavailable in remote areas or during disasters. This dependency reduced the system's reliability in critical situations and increased implementation complexity.

Similarly, Chen [5] developed a fire detection system using image processing techniques for improved accuracy. The system was capable of identifying fire more precisely compared to basic sensors. However, this improvement came at the cost of increased system complexity, higher power consumption, and greater expense. These factors made it less suitable for low-cost and portable applications, especially in resource-limited environments.

From the review of these studies, it is evident that existing solutions either focus on rainwater harvesting or fire detection independently, with very limited integration between the two. Many systems also suffer from drawbacks such as manual operation, lack of portability, high cost, or reliance on external infrastructure. These limitations highlight the need for a simple, integrated, and cost-effective solution that can perform both water collection and fire suppression efficiently. The proposed system addresses these gaps by combining automated rainwater harvesting with a Bluetooth-controlled fire-fighting robot, ensuring portability, ease of use, and reliable performance without dependence on complex infrastructure.

III. ANALYTICAL CONCLUSION

From the review of existing studies, it is clear that most research has focused on either rainwater and useful, but many of them still rely on manual operation and lack proper automation and monitoring features. On the other hand, fire-fighting robots have shown good potential, but many designs depend on internet connectivity or use advanced technologies that increase cost and complexity.

Another key observation is that many existing systems are not portable and are designed for fixed installations, which limits their use in different environments. In addition, some solutions require continuous external support such as water supply or harvesting or fire-fighting systems separately, with very little work combining both functionalities.

Rainwater harvesting systems are generally simpl network connectivity, which may not be reliable during emergency situations.

These limitations highlight a clear gap in developing a system that is simple, portable, and capable of handling both water collection and fire suppression effectively. The proposed system addresses this gap by integrating automated rainwater harvesting with a Bluetooth-controlled fire-fighting robot. By focusing on low cost, ease of use, and reliable operation, the system aims to provide a practical solution suitable for real-world applications.

Table 1. Comparison of Existing Methods and Proposed Syst

Reference (Paper & Authors)	Technology Used	Key Features	Limitations	Proposed System Impr
Rainwater Harvesting and Primary Uses Among Rural Communities in Ghana – Owusu & Asante (2020)	Manual rainwater harvesting systems	Widely used; supports basic water needs	Manual operation; no filtration; contamination issues	Introduces automated collection and better usability
Rain Detection System Using Arduino and Rain Sensor – Yogesh S., Sreedhar T. M., and G. T. Bharathy (2021)	YL-83 rain sensor, Arduino UNO	Detects rainfall and provides alerts	No water collection or storage	Adds automatic water collection and storage
Comprehensive Environmental Assessment of RWH Systems – Parker (2022)	Life cycle assessment, Hard RWH systems	Highlights environmental benefits	Fixed systems; no automation or portability	Provides portable and automated harvesting system
Autonomous Fire Extinguishing Robot with IoT-Based Alert System – Kumar (2021)	Flame sensors, IoT (Wi-Fi), water pump	Remote monitoring and fire detection	Depends on internet connectivity	Removes internet dependency; works offline
Development of Fire Fighting Mobile Robot Using Image Processing – Chen (2022)	Image processing, AI-based detection	High accuracy in fire detection	Expensive; complex; high power usage	Uses low-cost sensors for simple implementation
Proposed System	Rain sensor, Arduino, Bluetooth module, flame sensor, water pump, —		Combines automation, portability, low cost, and multi-functionality	

IV. METHODOLOGY

Design Approach

The proposed system combines rainwater harvesting and firefighting into a single compact unit. It is designed to automatically detect rainfall, collect and store water, and reuse the stored water for fire

The system operates independently without requiring internet connectivity and capable of suppression of fire without humaan needs.

System Architecture

The system is built around an Arduino UNO, which acts as the central controller and coordinates the operation of all components. It receives inputs from different sensors and processes them to control the actuators accordingly. A rain sensor (YL-83) is used to detect rainfall, and based on its signal, the Arduino activates a DC gear motor that operates a motorized lid. This lid opens during rainfall to collect water and closes when there is no rain, helping to keep the stored water clean.

The collected rainwater is stored in a tank, and a water level sensor is used to monitor the amount of water available. This ensures that the system has sufficient water for fire suppression when required. A display unit can also be included to show real-time information such as water level and system status, making it easier for users to monitor the system.

For fire detection, flame sensors are placed on the robot to continuously monitor for the presence of fire. Once a flame is detected, the Arduino processes the signal and activates a water pump. The pump draws water from the storage tank and delivers it through a pipe to a servo-controlled nozzle. The servo motor allows the nozzle to adjust its direction, helping to spray water accurately towards the fire.

The movement of the robot is controlled using a motor driver connected to DC motors, which drive the wheels. A Bluetooth module (HC-05) is used to control the movement of the robot wirelessly, allowing the user to navigate it easily in different directions. This provides flexibility in operation, especially in situations where precise positioning is required.

All components are powered through a common power supply unit, ensuring stable and continuous operation. The overall architecture is designed to be simple, compact, and efficient, enabling easy integration of all modules. By combining sensing, control, and actuation in a single system, the architecture supports reliable performance for both rainwater harvesting and fire suppression tasks.

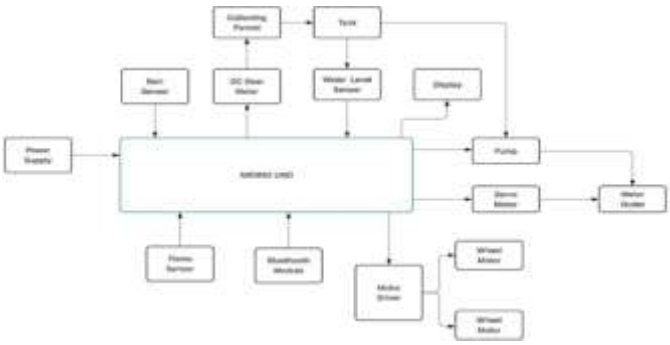

Figure 1. Block Diagram of Integrated Fire Suppression Robot with Smart Rainwater Harvesting

Working Principle

The system works based on two main functions: rainwater collection and fire suppression. When rainfall is detected, the rain sensor sends a signal to the Arduino, which activates the motor to open the collection lid. The rainwater is then collected and stored in a tank. If no rain is detected, the lid remains closed to prevent unwanted entry of dust or contaminants.

For fire safety, the flame sensor continuously checks for the presence of fire. When a fire is detected, the Arduino activates the pump motor, which draws water from the tank and sprays it through the nozzle to suppress the fire. The movement of the robot can be controlled using a Bluetooth module, allowing the user to direct it towards the fire when needed.

The flowchart of the system clearly represents this process. It starts with system initialization, where all components such as sensors, motors, and the Arduino are activated. The system first checks the water level in the tank. If sufficient water is available, it proceeds to monitor the rain sensor and flame sensor continuously. Based on the sensor inputs, it either collects rainwater or activates the fire suppression mechanism. If no specific condition is detected, the system remains in a monitoring state. This continuous loop ensures real-time operation and quick response to both rainfall and fire conditions.

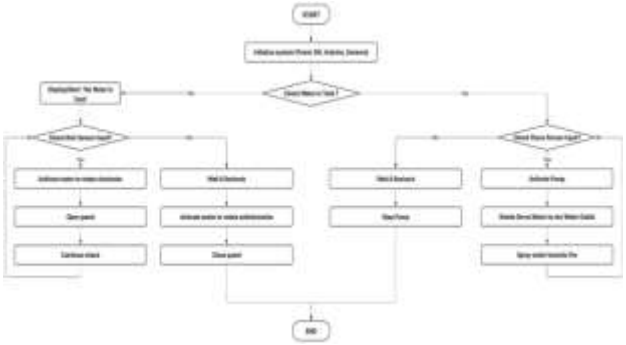

Figure 2. Flow Chart of Integrated Fire Suppression Robot with Smart Rainwater Harvesting

ALGORITHM

Step 1: Initialize all components, including sensors, Bluetooth module, and motors.

Step 2: Use the Bluetooth module to control the movement of the system.

Step 3: Monitor the rain sensor.

- If rainfall is detected, the lid opens automatically and water is collected.
- Otherwise, the lid remains closed.

Step 4: Monitor the flame sensor.

- If fire is detected, the pump is activated to spray water.
- Otherwise, the pump remains off.

Step 5: Repeat the process continuously for real-time operation.

V. EXPERIMENTAL RESULTS

The proposed system was tested under different conditions to evaluate its performance and reliability. During rainfall conditions, the rain sensor was able to detect water droplets accurately and triggered the automatic opening of the collection lid.

The motor-driven mechanism operated smoothly, and storage tank without leakage, showing that the harvesting setup works effectively.

The water storage system maintained proper containment, and the water level monitoring helped in ensuring that sufficient water was available for fire suppression. The overall rainwater collection process was stable and required no manual intervention once the system was activated.

For fire detection, the flame sensor showed reliable performance by quickly identifying the presence of small flames. The response time was fast, and the system immediately activated the pump motor when fire was detected. Water was sprayed through the nozzle with enough pressure to suppress small fires effectively. The servo-controlled nozzle also helped in directing water more accurately towards the flame.the lid responded without noticeable delay. The collected rainwater was successfully directed into the

The Bluetooth module provided stable and responsive control for the robot's movement. The robot could be easily maneuvered in different directions, allowing better positioning during fire suppression. The communication between the

controller and the robot remained consistent without major signal loss within the tested range.

The integration of all components worked smoothly, and the system operated without major delays or failures. Power consumption was within acceptable limits, and the system maintained consistent performance during repeated tests.

Overall, the experimental results confirm that the system is capable of performing both rainwater harvesting and fire suppression efficiently. Its reliable operation, quick response, and ease of use make it suitable for practical applications, especially in emergency situations.

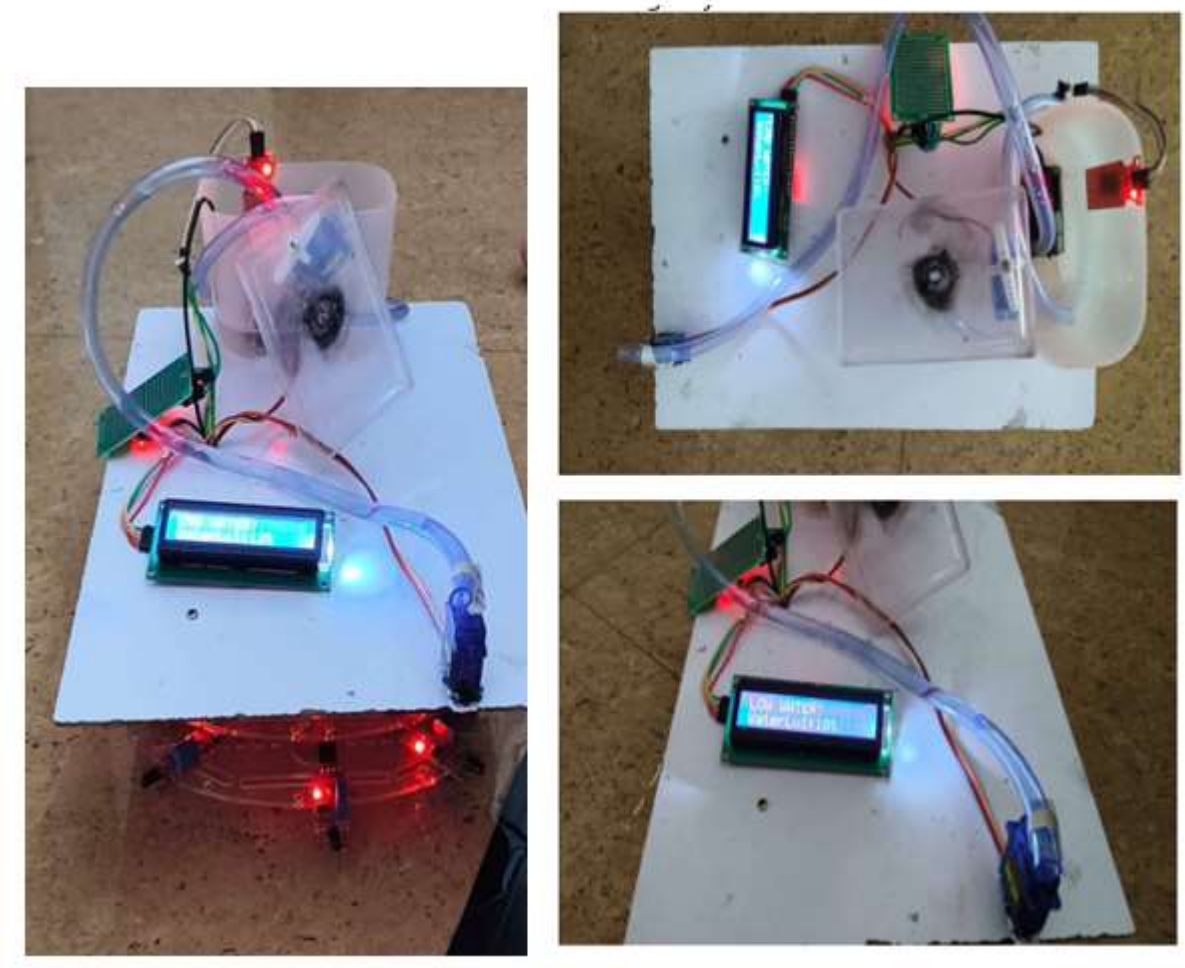

Figure 3: Integrated Fire Suppression Robot with Smart Rainwater Harvesting

VI. CONCLUSION

The proposed system successfully integrates automatic rainwater harvesting and firefighting capabilities into a single, low-cost and portable solution. By combining rain detection, water collection, and fire suppression, the system reduces the need for continuous manual intervention while improving efficiency. It achieves key objectives such as automatic rain detection and water collection, storage and reuse of water for firefighting, reliable fire detection and suppression, and movement control using a Bluetooth module. The system also operates independently without relying on internet connectivity, making it suitable for remote and resource-limited environments. Experimental results demonstrate that the system performs reliably under different conditions, and compared to existing solutions, it offers improved automation, portability, and multi-functionality. The proposed system provides a practical and cost-effective approach to

water management and fire safety, making it suitable for real-world applications, particularly in rural and disaster-prone areas.

Future Scope

Although the proposed system performs effectively, several enhancements can further improve its functionality and real-world applicability. Future developments may include integrating IoT technologies such as Wi-Fi or GSM for remote monitoring and alerts, and adding water level sensors for better storage management. The use of solar panels can improve energy efficiency, while advanced filtration systems can enable the use of collected water for drinking purposes. Incorporating camera-based fire detection using AI/ML can enhance accuracy, and developing a mobile application can provide better user control.

Additionally, the system can be scaled for larger applications such as agriculture or industrial use. These improvements can make the system more intelligent, autonomous, and suitable for large-scale deployment.

REFERENCES

1. S. Owusu and R. Asante, “Rainwater harvesting and primary uses among rural communities in Ghana,” Journal of Water, Sanitation and Hygiene for Development, 2020.
2. Y. S., S. T. M., and G. T. Bharathy, “Rain detection system using Arduino and rain sensor,” International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), 2021.
3. A. Teston, “Comprehensive environmental assessment of rainwater harvesting systems,” Water (Switzerland), 2022.
4. Kumar, “Autonomous fire extinguishing robot with IoT-based alert system,” International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), 2021.
5. Chen, “Development of fire-fighting mobile robot using image processing,” International Journal of Advanced Robotic Systems (IJARS), 2022.
6. M. J. Kim and S. H. Lee, "Design of a Smart Rainwater Storage System Using Low-Cost Microcontrollers," Journal of Sustainable Development and Engineering, 2023.
7. R. Gupta and A. Verma, "Bluetooth-Controlled Robotics for Hazardous Environment Navigation," International Journal of Robotics and Automation Systems, 2024.
8. T. Nguyen and H. Park, "Early-Stage Fire Detection Using Arrayed Flame Sensors in Indoor Environments," Emergency Response Technology Review, 2023.