Autonomous Firefighting Robot with Enhanced Detection and Communication

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Abstract*— Existing fire detection systems face considerable challenges like delayed responses and limited mobility, hampering effective fire hazard management. To address these issues, this project proposes the development of an autonomous firefighting robot. Equipped with advanced sensors such as infrared sensors for obstacle avoidance and flame detection, alongside a gas sensor for hazardous gas detection, the robot aims to revolutionize fire safety. Integration with a servo-controlled water pump and a GSM module ensures precise firefighting and real-time communication with authorities.

I. Problem Statement

Current fire detection systems often suffer from delayed responses and limited mobility, posing challenges in effectively mitigating fire hazards. To address these issues, this project proposes the development of an autonomous firefighting robot equipped with advanced sensors for early fire detection and suppression. The robot utilizes infrared sensors for obstacle avoidance and flame detection, along with a gas sensor to detect hazardous gases. Integration with a servo-controlled water pump enables targeted firefighting, while a GSM module provides real-time alerts to authorities. By combining mobility, early detection capabilities, and swift response mechanisms, the proposed autonomous firefighting robot offers a promising solution to enhance fire safety and minimize damage.

II. Implementation

The proposed system is an autonomous robot designed to detect fires and gas leaks and extinguish fires as illustrated in Fig 1. It utilizes a servo motor to operate a water pump for firefighting and a GSM module to send alerts via SMS and phone calls. At the core of the robot is an Arduino Uno microcontroller, which functions as its central processing unit. It processes input from flame sensors and a gas sensor (MQ2) to control the actuators, effectively managing the robot's operations and making decisions based on sensor data.

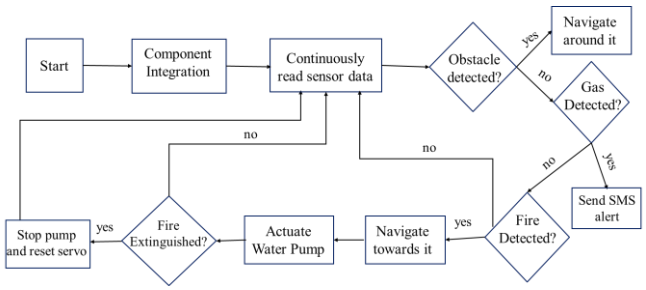

Fig 1. Flowchart of Autonomous Fire Fighting Robot

The servo motor is essential for directing the water spray, enabling the robot to aim accurately at the fire by rotating to different angles and covering a broad area. The GSM module (SIM800L) plays a crucial role in communication by sending SMS alerts and making phone calls to inform authorities or property owners about a detected fire or gas leak, ensuring that alerts are sent even if the robot is in a remote location.

The robot is equipped with flame sensors and a gas sensor. The flame sensors detect fire and help the robot navigate its environment, while the gas sensor identifies the presence of hazardous gases, such as those emitted during a fire, and prompts the robot to send an alert. The robot's movement is powered by motors controlled by the L293 motor driver, allowing it to advance towards the fire or navigate around obstacles. The water pump, activated upon fire detection, directs water to extinguish the flames.

During the setup phase, the robot initializes serial communication and the GSM module, sets pin modes for the sensors, motors, and the pump, and attaches the servo motor. In the main operational loop, the robot continuously reads data from the flame sensors for navigation. If an obstacle is detected, the robot adjusts its movement to avoid it. When gas is detected, it sends an SMS alert. If a fire is detected, the robot moves towards it, activates the water pump, and sweeps the servo motor to spray water over the fire. Once the fire is extinguished, the robot stops the pump and resets the servo motor.

The firefighting function involves the robot advancing towards the fire, activating the water pump, and sweeping the servo motor from 50 to 110 degrees to ensure the fire is adequately covered. After the fire is extinguished, the pump is deactivated, and the servo motor is reset. Additionally, a relay module acts as a switch to control high-power components like the water pump, enabling the microcontroller to turn the pump on and off as needed. This methodical approach ensures that the robot can efficiently detect and respond to fire hazards, providing a reliable and automated solution for fire safety.

III. Results and Discussion

The autonomous firefighting robot was tested under various conditions to evaluate its performance in detecting and extinguishing fires. The primary metrics measured were response time, accuracy in fire detection, and the effectiveness of firefighting maneuvers. Overall, the results demonstrated the robot's capability to respond promptly to fire hazards, navigate towards the fire, and effectively extinguish it using the integrated water pump.

The flame sensors provided consistent and reliable readings, with a detection threshold set at 900 to ensure prompt fire detection as in Fig 2. A stop threshold of 80 was implemented to prevent the robot from moving too close to the fire, thereby enhancing safety as depicted in Fig 3. The MQ2 sensor detects hazardous gases and gives more accurate fire detection and alerts.

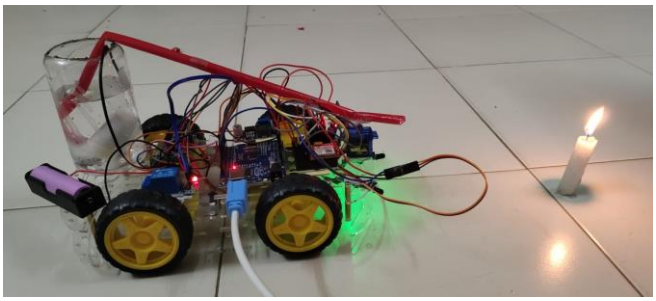

Fig 2. Fire Fighting Robot Detecting Fire

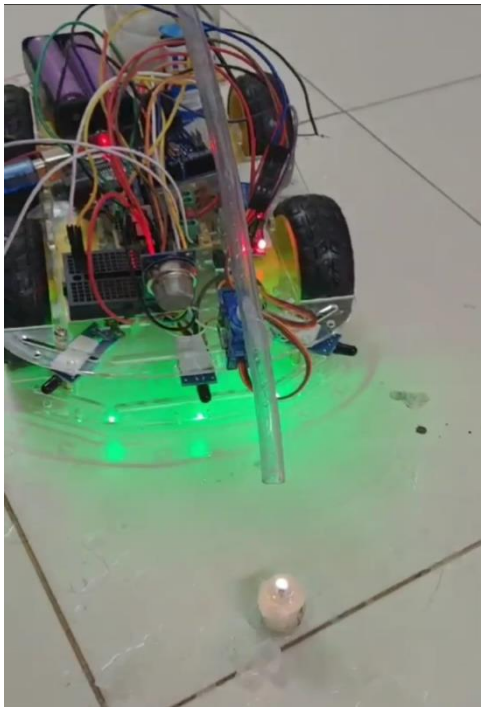

Fig. 3. Robot Moving towards the Fire after Detection

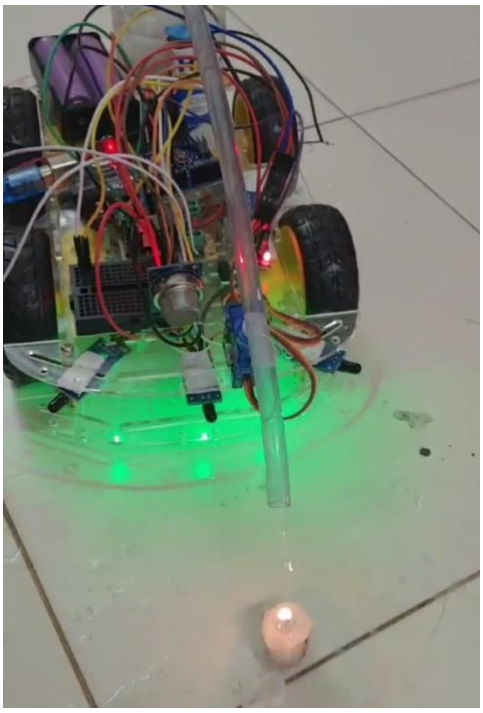

Fig. 4. Robot Spraying Water on Moving towards the Fire

Regarding the fire extinguishing mechanism, the robot effectively activated the water pump upon detecting a fire. The servo motor controlled the direction of the water spray by sweeping between 45 degrees, ensuring coverage of the affected area as in Fig 4.

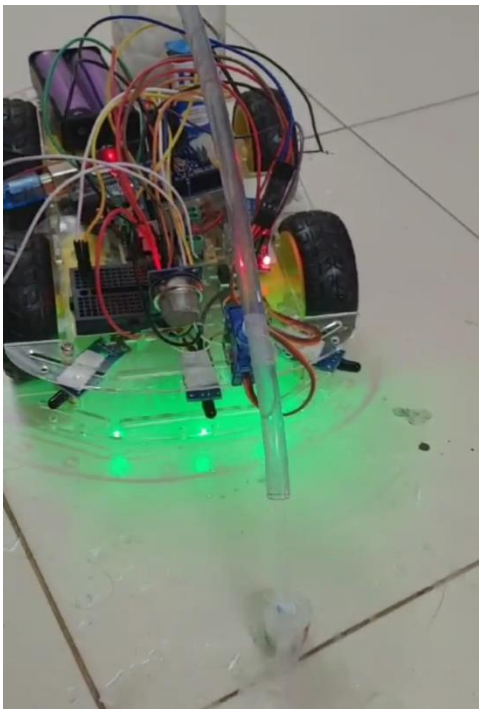

Fig. 5. Robot Extinguished the Fire on Detection

The robot successfully extinguished small to medium-sized flames in a controlled environment, and the pump deactivation mechanism worked correctly, stopping the water flow once the fire was no longer detected as depicted in Fig 5. In various scenarios with fire sources located at different distances and angles, the robot consistently moved towards the fire and engaged the extinguishing mechanism. The robot's ability to detect and respond to multiple fires in different locations was validated through repeated tests.

On the communication front, the integration of the GSM module for sending SMS alerts and making phone calls was tested separately. The robot successfully sent alerts to predefined numbers, ensuring timely communication with authorities. This feature adds a critical layer of real-time alerting, which is essential for prompt response and coordination during fire emergencies.

Overall, the results indicate that the autonomous firefighting robot effectively detects and responds to fire hazards. The combination of flame sensors, MQ2 sensors, and the servo-controlled water pump provided accurate and targeted firefighting capabilities. The response time of approximately one second for directional movement and pump activation demonstrated the robot's efficiency in handling fire emergencies.

IV. Conclusion and Future Work

The autonomous firefighting robot presents a significant advancement in fire safety technology, addressing critical limitations of current fire detection and response systems. By integrating advanced sensors for early detection of flames and hazardous gases, coupled with a servo-controlled water pump

for precise firefighting, the robot ensures a timely and effective response to fire hazards. The inclusion of a GSM module for real-time communication with authorities further enhances its utility, ensuring that alerts are sent promptly, even from remote locations. Overall, the robot's mobility, early detection capabilities, and swift response mechanisms provide a comprehensive solution for mitigating fire-related damages.

Future developments could focus on expanding the sensor array to include thermal imaging cameras could improve fire detection accuracy in various conditions. Improving battery life and integrating solar charging systems could extend operational time, making the robot even more reliable in long-duration firefighting scenarios. By continuing to refine and expand its capabilities, the autonomous firefighting robot can become an even more indispensable tool in fire safety and hazard management.

REFERENCES

[1] Dubey, A., Singh, B., Kumar, N., Alkhafaji, M.A. and Isam, M., 2023, May. Fire Fighting Robot With More Accuracy and Implementation Using Arduino Uno. In *2023 3rd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)* (pp. 20-23). IEEE.

[2] WABBA, J.A. and EGBUJO, F.I., 2024. Robotic Fire Fighting Vehicle with GSM SMS And Call Alert.

[3] Shekar, M.M.R., Rakesh, B., Aravind, S. and Yogesh, K., FIRE FIGHTING ROBOT USING ARDUINO WITH CALL AND SMS ALERT SYSTEM.

[4] Helonde, P. and Patil, P., 2023. Intelligent Firefighting and Alert Automation.

[5] Owoeye, S.O., Olaonipekun, O., Akinade, A. and Emele, B., Development of a Fire Extinguishing Robot with SMS Alert Capabilities.