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Design of a prototype firefighting robot based on an Arduino microcontroller using machine learning technique

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ABSTRACT

The design and implementation of this paper are mainly based on control of the autonomous firefighting robot. In recent years, robotics has turned out to be an ingredient in which many people have shown their interest. Robotics has gained popularity due to the advancement of many technologies of computing and nanotechnologies. The output of the fire sensor is connected to the Arduino controller that controls the movement of the vehicle and the operation of spraying water. An infrared sensing circuit is designed with the infrared sensors placed in front of the vehicle to avoid collision with the obstacles. A total of two inbuilt reduction geared direct current motors are used in the paper for the robot movement in all the directions forward, backward, right, and left directions. For more practicality, a small water tank with a pumping motor is also arranged over the chassis and the water sprinkler pipe that is firmly fixed over the plate where the sensor is arranged can deliver water with some force. When the sensor detects the fire, the sprinkler is positioned toward fire flames; the pumping motor will be energized automatically to extinguish the fire. The main advantage of the proposed system automatically controls the fire by using advanced control techniques.

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1. INTRODUCTION

The authors present a multi-robot energy-saving system (MRESS) designed to extend the operating time of firefighting robots. MRESS improves traction efficiency by incorporating a sub-robot that assists in drawing fire hoses, thus reducing the energy consumption of the main firefighting robot. The system combines a vision-based fire hose tracking method, end-running navigation, and limit-cycle navigation to ensure efficient cooperation and smooth path planning. These methods work together to minimize the risk of fire hose twisting and optimize energy usage, allowing the robots to reach their destination efficiently and safely [1]–[5]. The authors proposed a system to assist firefighters during fire accidents by deploying hardware-based robots that navigate the site, detect fire using a flame sensor, and extinguish it with a water pump. The robots are equipped with wireless cameras to live stream the entire scene to a remote display. The paper also explores the use of multiple robots in the same area, which can avoid obstacles and share livestreamed footage through a simulation environment created with the CoppeliaSim Edu robot simulator. The goal is to enhance technological innovations that assist firefighters in rescue and damage control operations more efficiently [6]–[10].

The authors highlighted the importance of firefighting robots in enhancing fire security, given the increasing frequency and severity of fire incidents. The proposed robot uses a temperature sensor to detect fires and an ultrasonic sensor to avoid collisions while navigating to the fire. Upon detecting fire, the robot sends feedback to a microcontroller and transmits real-time images via a camera sensor to aid in understanding the situation. The system incorporates fuzzy logic and is controlled using Arduino and MATLAB to ensure smooth navigation around obstacles. Through simulations and practical tests, the robot successfully supports firefighters by improving safety during fire incidents [11]–[15]. This paper presents a control strategy for the autonomous docking of firefighting robots with fire hydrants, combining a multilayer perceptron and an admittance controller. The multilayer perceptron predicts the deviation of the robotic arm's position and orientation based on real-time contact force data from the fire hose and hydrant. The admittance controller adjusts the arm’s position to minimize contact force and torque, ensuring precise docking. Experimental results on a custom test system demonstrate that this strategy reduces the impact of parameter changes and environmental noise, minimizes contact force during docking, and enhances the safety and effectiveness of the task [16]–[20].

2. BLOCK DIAGRAM

Figure 1 shows an autonomous firefighting robot that provides a visual representation of the main components and their interactions in the system. At the core of the robot is the Arduino microcontroller, which acts as the central processing unit, receiving input from various sensors and controlling the actuators based on the programmed logic. The block diagram provides the necessary power to all components, typically via a battery, which powers the Arduino, motors, sensors, and other modules. Flame detection sensors are usually infrared flame sensors that detect the presence of fire by sensing infrared radiation emitted by flames [21]–[25]. The sensors output a signal to the Arduino, indicating the presence of a fire. The motor driver is responsible for controlling the direct current (DC) motors that move the robot. It receives control signals from the Arduino to drive the motors forward, backward, or stop based on sensor input. The movement control receives data from the sensors and determines how the robot moves towards or away from the fire. It commands the motor driver to direct the robot accordingly. When the fire is detected, the Arduino activates the water pump or a servo-controlled sprayer to extinguish the fire. This mechanism is controlled by the Arduino through a relay or directly via a motor driver.

The buzzer sounds an alert when a fire is detected, while light-emitting diodes (LEDs) serve as visual indicators to show the robot’s status, such as when it is extinguishing the fire or when it has completed its task. In the block diagram, these components are connected through wires or communication lines that allow the flow of power, data, and control signals, enabling the robot to autonomously detect a fire, move towards it, and extinguish it efficiently. The overall system works in real-time, with sensors providing data to the Arduino, which processes the information and commands the motors and sprayer to act.

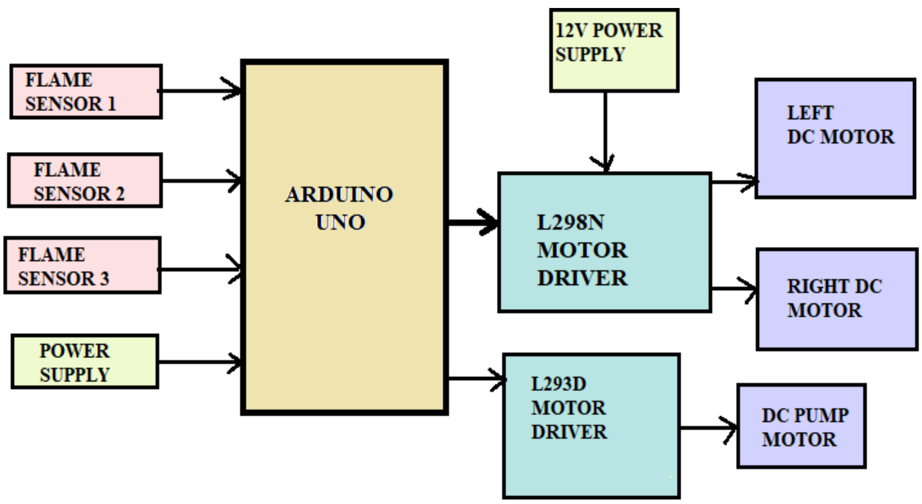

Figure 1. Autonomous firefighting robot

3. ARDUINO IN TINKERCAD DESIGN

Figure 2 shows the schematic diagram of firefighting robot. Figure 3 shows the firefighting robot using Arduino in Tinkercad involves creating a functional prototype that can detect and extinguish fire. The robot integrates an Arduino Uno as the microcontroller, along with essential components like infrared flame sensors, a water pump or servo mechanism, DC motors, and motor driver module L298N for movement control. The flame sensors detect infrared light emitted by fire and send signals to the Arduino. Based on the sensor data, the robot moves toward the detected flame using DC motors and extinguishes it using a water sprayer or pump. Additional features, such as a buzzer and LED indicators, can provide audible and visual alerts when a fire is detected or extinguished. Powered by a battery, the robot operates autonomously and can be programmed to navigate toward the fire, stop at a safe distance, and activate the extinguishing mechanism. The entire design can be simulated in Tinkercad, allowing users to visualize the functionality and troubleshoot the circuit before physical implementation.

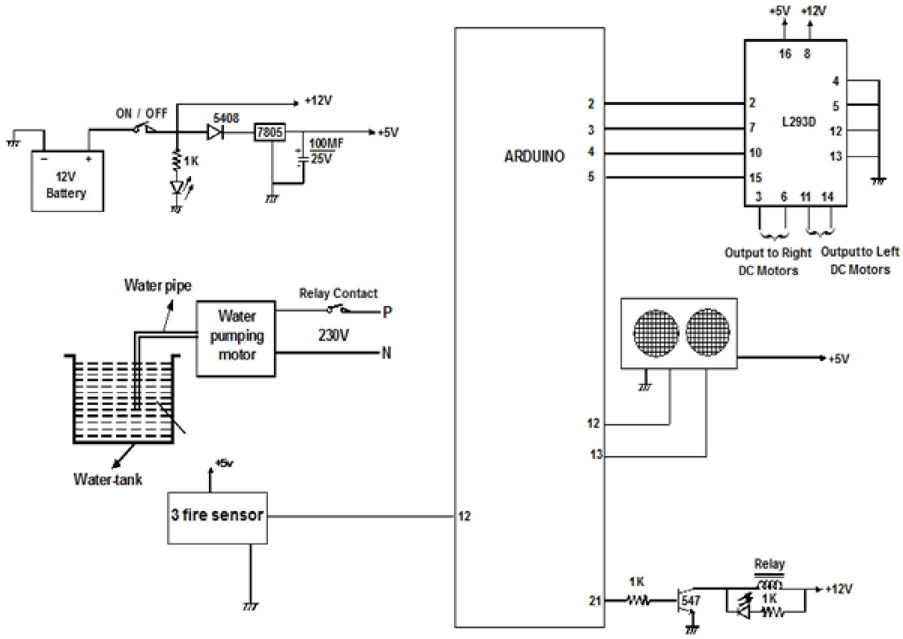

Figure 2. Schematic diagram firefighting robot

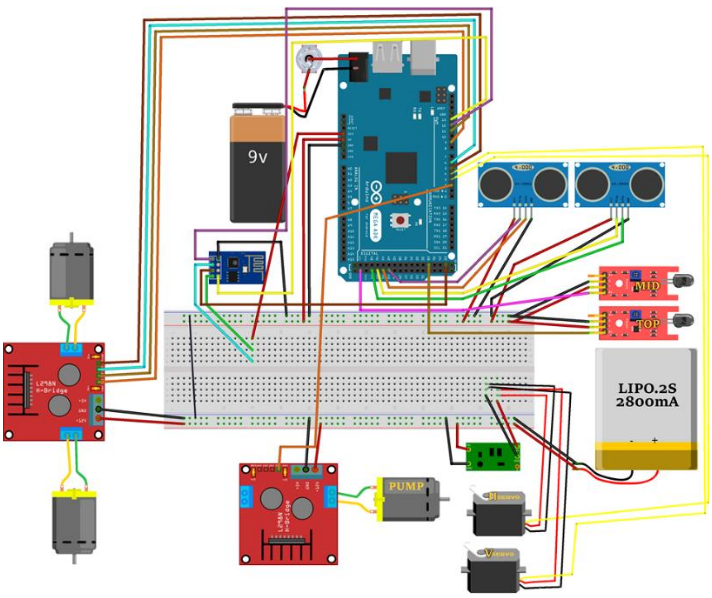

Figure 3. Firefighting robot in Tinkercad

4. MECHANICAL DESIGN

Figure 4 shows the design of an autonomous firefighting robot using an Arduino microcontroller involves creating a physical structure that houses the sensors, motors, and extinguishing mechanism, while allowing for autonomous movement and efficient fire detection. Table 1 shows a breakdown of the mechanical components and their design. The chassis is typically made from lightweight materials like plastic, acrylic, or aluminum to ensure durability while keeping the robot's weight manageable. It serves as the foundation to hold all other components. The robot chassis should have a rectangular or square shape to accommodate the components efficiently, with spaces for the motors, sensors, and water pump. A compact and balanced design helps maintain stability when the robot moves. The robot usually employs DC motors (or servo motors for more precise movement) to control its movement. The motors are connected to the wheels using gears or wheels with motor shafts to rotate them. The robot typically has two or four wheels. Omni-wheels (which allow for 360-degree movement) or standard wheel-and-axle systems are commonly used, depending on the type of movement and control desired. Each motor is securely mounted onto the chassis to ensure stability and precise movement. The motor driver module L298N is connected to the motors to control the robot's speed and direction.

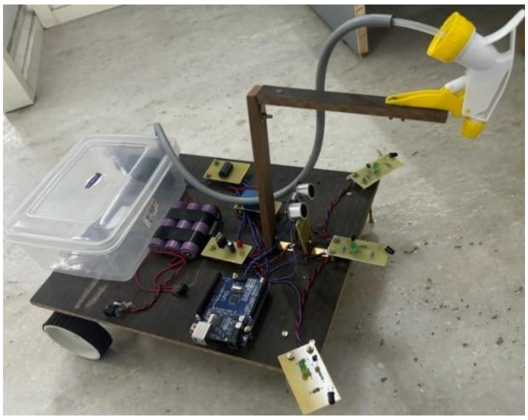

Figure 4. Prototype firefighting robot side view

Table 1. Firefighting robot components

Component name	Quantity
Arduino board	1
L298 motor driver module	1
Flame sensor module	1
Servo motor	1
On-off switch	1

Figure 5 shows the prototype firefighting robot’s front view. The infrared flame sensors are positioned on the front or sides of the robot, ensuring they can detect fire from different angles. These sensors need to be placed at an optimal distance from the ground to detect flames effectively. The sensors should be fixed on a sensor holder or bracket that is mounted to the chassis. This keeps the sensors stable and at the correct angle for accurate fire detection. The robot should have a small water reservoir to hold the water required to extinguish the fire. The tank needs to be compact but sufficient for the task at hand. The water is pumped out through a water pump or a servo-controlled nozzle. The pump is connected to the water tank, and when the robot detects fire, it activates the pump using the Arduino. The servo can be used to control the direction of the spray. The water is delivered through flexible tubing from the tank to the nozzle or pump mechanism. The nozzle can be directed at the fire source, either automatically or manually based on the design. The pump and nozzle are mounted securely on the chassis, ensuring that water can be sprayed effectively at the fire source. The buzzer is placed at an accessible location on the robot, often near the top or front, so that its sound is clearly audible. It alerts when the fire is detected and when the robot is performing the extinguishing task. LEDs can be placed in visible locations such as on the top or sides of the chassis. These LEDs light up to show the robot’s status indicating when it is moving, extinguishing the fire, or completing its task. The robot requires a compact yet powerful battery pack such as a Li-ion or Li-Po battery to supply power to the motors, Arduino, sensors, and water pump. The battery is typically mounted on the chassis in a way that maintains the robot's balance.

Figure 5. Prototype firefighting robot front view

A power distribution board can be used to distribute power to different components from the battery. The Arduino board should be securely mounted on the chassis, often using an Arduino holder or custom-designed compartment to keep it safe from movement and external damage. The various components are connected using wires and connectors. These wires should be carefully routed and organized to avoid tangling or interference with the robot's movement.

5. CONCLUSION

The design of an autonomous firefighting robot combines mobility, fire detection, and extinguishing capabilities into a cohesive structure. The robot's chassis serves as the foundation, while motors, sensors, and the water delivery system are carefully arranged to allow the robot to navigate, detect flames, and respond with the appropriate action. This design enables the robot to operate autonomously, moving towards the fire, detecting its presence, and extinguishing it efficiently. The main advantages of firefighting robots can navigate through narrow spaces, climb stairs, and move through debris to reach fires that are difficult for humans to reach.

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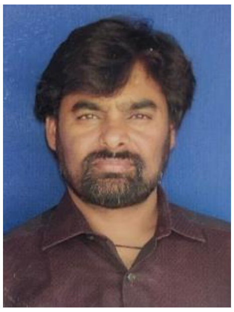

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