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Autonomous Firefighting Robot for Detection and Prevention

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Abstract

In order to combat the growing number of fire events occurring globally, autonomous firefighting technologies are desperately needed. In order to satisfy this need, this study presents an autonomous firefighting robot system. With the help of sophisticated robotics, sensor technologies, and AI algorithms, the system is able to locate, identify, and put out flames on its own. It has sensors, such as LiDAR and thermal cameras that allow it to sense its environment precisely. It has the ability to forecast fire behavior and create the best firefighting tactics thanks to real-time data analysis and machine learning. With the aid of motion planning algorithms, the robot moves quickly through intricate surroundings. It uses a variety of firefighting tactics, such as the spraying of foam and water, based on the kind and intensity of the fire. The suggested method represents a substantial improvement in firefighting technology, improving safety and property protection with its dependable and effective approach.

Keywords: Firefighter, Flame Sensor, Internet of Things, Robotics.

Introduction

The task of controlling the spread of a fire and putting it out is known as firefighting. It is regarded as a dangerous task for firefighters who operate in high-risk environments (1). Firefighters also have challenges when trying to save victims who have become engulfed in flames. A firefighter robot can effectively put out a fire in place of a human firefighter. Robots can be operated autonomously or by remote control, which is the rationale behind the use of robots in place of human firefighters during risky fire rescue missions (2). There robot can also be used to aid firefighters in figuring-out a safer route to the fire if it has a monitoring system for surveying the area. The fire rescue operation may be challenging in a huge building since it will be challenging for a firefighter to locate victims (3). A robot that is programmed to recognize objects can locate those trapped in a fire setting with ease. Efficient fire extinguishment is facilitated by the IoT firefighter robot. The robot is linked to the authority and is present in the area where the fire happens. Those in positions of authority keep an eye on their surroundings. The Internet of Things connects all of these (IoT). Connecting and enabling communication between devices is known as the Internet of Things (IoT). Here, IoT facilitates better communication between the authorities and the robot. Authorities are able to see their surroundings through the robot and take the necessary action to put out the fire.

Fabrication of Mechanical Components

Every component needed to build the robot may be found nearby. The concept aims to showcase an effective and safe method of fabricating a fire extinguisher robot.

Making of the Platform: The "Kerosene wood" is utilized to create the base light. This wood is renowned for being the "Rashed tree" wood (4). This wood has a density of between 370 and 400 kg/m3. Thus, it can offer a greater surface area while being lightweight. It is one inch thick. It is also quite strong and capable of withstanding shocks. It is also important to note that because of its water resilience, this wood is also utilized to create boat bases. The platform is 12 by 7 by 1 (5).

Mobility of the Robot: This mobile robot has excellent functionality. The robot is moved by use of a caster ball and two nylon wheels. This vehicle is primarily rear-wheel drive. Two different shafts support two motors that are positioned alongside

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the nylon wheel (6). The wheels have a diameter of 3 inches and a thickness of 0.8 inches. A motor driver (L298) that reacts to an Arduino signal controls the movement of the motors. Both torque and speed are high in the motors. Even when empty, these locally produced motors do not operate at the same pace. Additionally, the robot's weight does not appear to be distributed evenly. Thus, an algorithm is developed and coded to independently control each of the two motors (7). Then, in order to match the speeds of both motors and enable them to travel straight in a designated direction, an extreme calibration is performed. Caster balls are used because they are inexpensive and simple to use. The back wheels of the robots primarily govern their movement. A caster ball is utilized to provide flexible motion and front support.

Water Spreading Mechanism: The water container may hold a minimum of one liter of water. It is constructed from sturdy cardboard with water resistance. The screw and glue mechanism is used to secure the pump to the container. Here, the glue is waterproof (8). The pump is connected to a lengthy metal pipe. Water should be thrown away from fire, which is why the pipe is roughly two feet long. A locally made water spreader is used to distribute the water at the pipe's front. When a spreader is used, the water flow from the pump is significantly reduced while still spreading the water efficiently for extinguishing purposes illustrated in Figure 1. Thus, extending the pipe maintains a safe distance from the source.

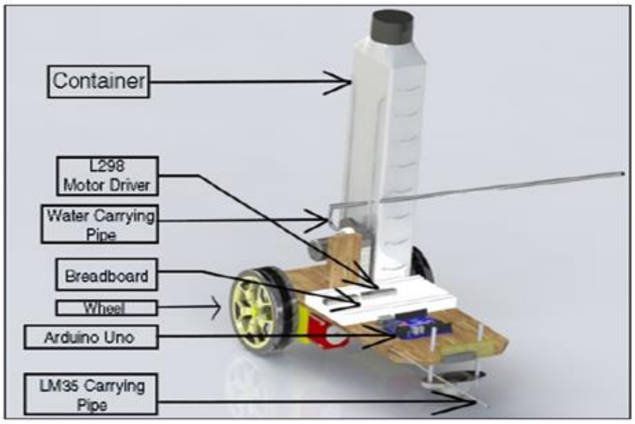

Figure 1: Design of Mechanical Body

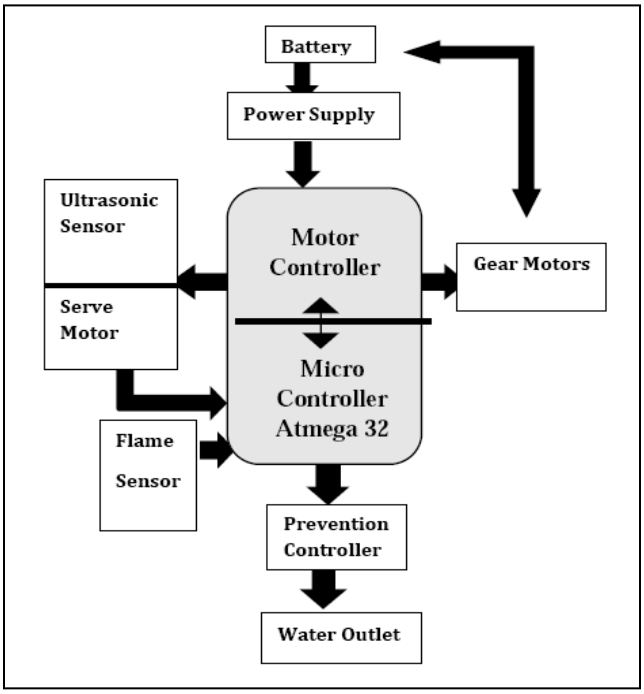

Figure 2: IoT Controlled Autonomous Fire Fighting Robot

Methodology

The authority environment and the fire scene environment make up the two environments that an IoT firefighting robot operates in. IoT Controlled Autonomous Fire Fighting Robot block diagram in the Figure 2. The robot's webcam is used to watch the fire, and it is within authority to do so. The Internet connects these two settings.

System Components

The solution is provided by the hardware and software system. Remote desktop program, Flame sensor, Ultra Sonic sensor, and Web-Cam are the main parts (9). The user input/output interface is provided by the application. Using a flame sensor and a webcam, the Raspberry Pi processes the data gathered from the fire scene.

Arduino: The Arduino UNO controller, which precisely controls every activity, is the central component of this system. Among its many useful functions are the following: it can locate the fire's origin, put it out, and gather further information on the behavior of fires from the scene of the incident.

Flame Sensor: A type of sensor that is extremely responsive to flame light is the flame sensor. Consequently, flame alarms employ it. If the light source has a wavelength between 760 and 1100 nm, this sensor will detect flame (10). The sensor may output an analog or digital signal. Robotic firefighting units use these sensors to detect flames.

Ultrasonic Sensor: Ultrasonic distance sensors use ultrasonic waves to detect the distance between a source and a target. This sensor helps the robot avoid making contact with obstructions. This sensor calculates the safer separation between the obstacle and the robot.

Servo Motor: The robot's servo motor is used to move its nozzles, arms, and other moving components. In short, these components enable the self-sufficient firefighting robot to identify fires, intervene on their behalf without requiring human support, and apply water or foam to extinguish them. One kind of motor that turns extremely precisely and accurately is a servo motor. A control circuit that gives feedback on the motor shaft's current position often makes up this kind of motor (11). This feedback enables the servo motors to rotate with extreme accuracy. With a servo motor, you may spin an object at a desired angle or distance. A simple motor is all that is needed to power the servo system.

Water Pump: The robot body is equipped with a water tank and a water pump, which are automatically identified by infrared. The entire system, including the flame sensor, is managed by a microprocessor from the ATMEGA328 series. The microcontroller is interfaced with a motor driver integrated circuit (L298N), which allows the controller to drive the motors.

Motor Driver: Typically, autonomous robots use an integrated circuit chip known as a motor driver to manage its motors. An interface between Arduino and the motors is provided by motor drivers. The L293 series, which includes the L293D, L293NE, and so forth, is the most widely used variety of motor driver integrated circuits. Two DC motors can be run simultaneously with the aid of these integrated circuits. In L293D, there are two H-bridges. The easiest method for controlling a motor with a low current rating is to use an H-bridge circuit.

Sensor unit: The goal of the Multi-sensor Fire Detection System (MSFDS) is to detect and put out fires. This technology enables the cooperation of the sensors as well as the usage of several sensors at once. The Arduino Uno is connected to the LM35 and the Arduino Flame Sensor, two extremely sensitive sensors is shown in Figure 3.

The Arduino flame sensor is extremely responsive to light between 760 and 1100 nm in the infrared spectrum. Short-range fire detection is accomplished by using these kinds of sensors. There are four pins holding it down. An analog positive voltage input of five volts is designated as VCC. (A0): Analog output; (D0): Digital output; D) Digital is at 3.3 volts; GND is ground. An analog output is produced once it has received input from the environmental data. When the infrared wavelength noticeably changes, it recognizes a flame and raises the analog output. The robot then starts to move toward the flame as a result of its programming.

Precisely proportional to the temperature in degrees Celsius, the LM35 is an integrated-circuit temperature sensor that produces an output voltage. The temperature reading that this sensor outputs is proportional. The LM35 detects a notable temperature rise close to the flame source when the robot travels in its direction and modifies the output. In the event that this output varies drastically, the robot is designed to stop. Two safety precautions have been implemented because LM35 needs to be quite close to the source in order to detect heat. A single LM35 sensor is connected to the control unit by means of an elongated jumper wire, which is contained within a roughly 10-inch-long pipe. As a result, the sensor stays well away from the main body. Two, it senses an increase in temperature and immediately stops the motor to return to a safe and convenient throwing distance.

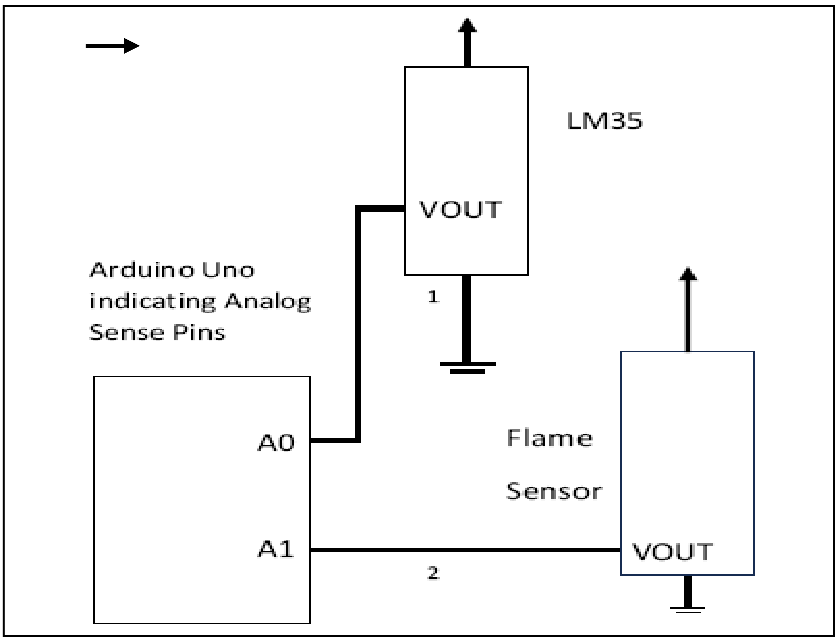

Figure 3: Connections of Sensors with Control Unit

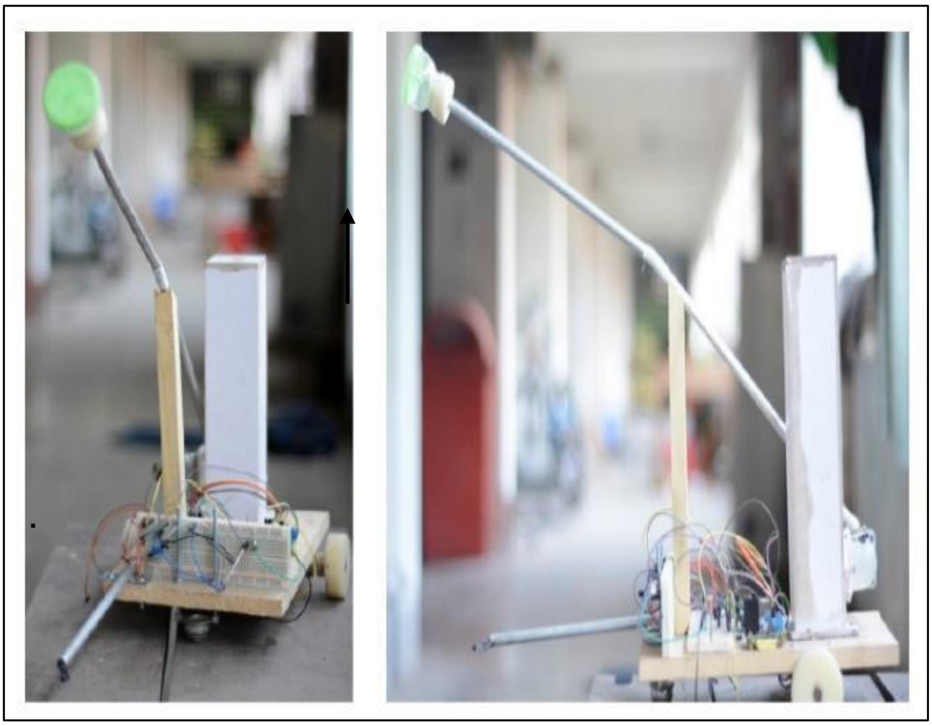

Figure 4: Automated Firefighting Robot's Initial Prototype

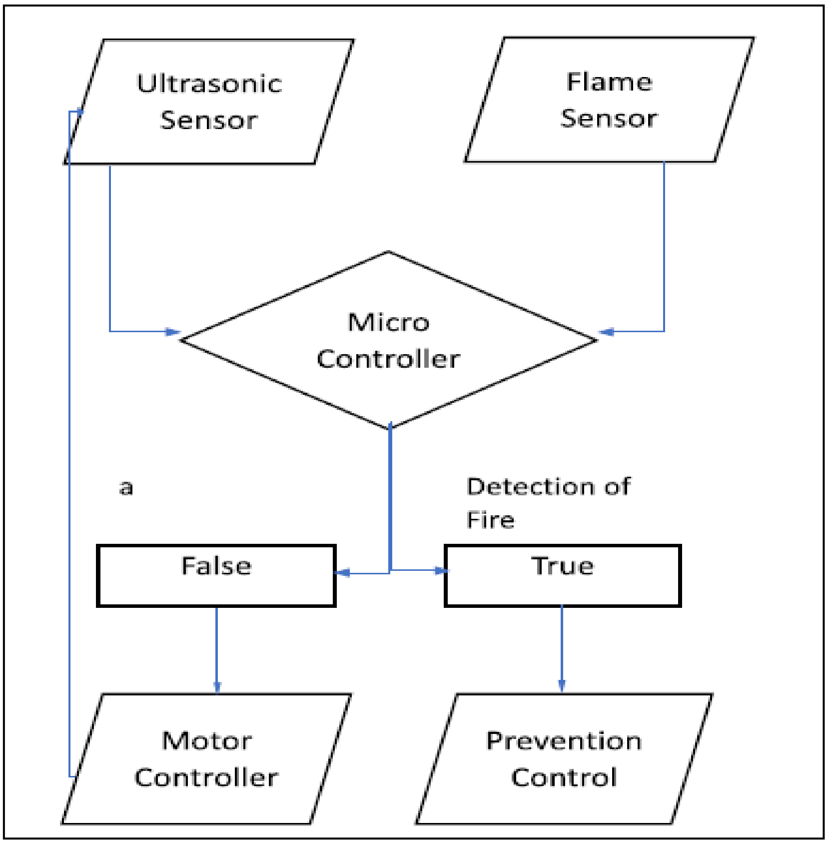

Figure 5: Flowchart: The Fire Fighting Robot's Operational Concept

Working Principle

The idea behind how it works is quite basic. The robot spins on its own axis when it first starts up. Arduino will use the motor driver to control the motor. The body will revolve as a result of one motor remaining off and the other moving in Figure 4. The robot rotates in this manner to check for fire in various room corners. If there is a fire, the Arduino flame sensor will eventually find it. The robot will then gradually advance toward the fire. In this case, an algorithm is required to enable the robot to approach the fire slowly. For the robot must come to an endpoint and it must not interfere with the fire in any way. To put out fire, a centrifugal pump then squirts water at it. Water can be dispersed tank to a special mechanism. The flowchart of the whole operation is given below Figure 5.

Analysis of Performance

Definition of the Issue: Voltage sensitivity is a feature of the LM35 and Arduino Flame Sensor. They take input voltages between 0 and 5 volts. For the Arduino serial monitor, these voltages are translated to an analog value (0–1023). This conversion results in an output with a better range and good variance. As a result, the robot can be programmed in many scenarios. The analog output changes when the flame is detected by the flame sensor. The sensitivity of this sensor varies depending on the time of day. As a result, the robot's performance changes over time. When the robot is close to the source, the LM35 also reacts to temperature changes by altering the analog output. The output value from the serial monitor is used in this instance to represent sensitivity. Our study's primary goals are to measure the flame sensor's sensitivity at various times of the day and at various distances from a fire source, both with and without a fire, and to see how the LM35 sensor responds. Thus, our analysis illustrates the optimal and worst-case scenarios that the manufactured firefighter robot model may encounter during a typical day.

Test Protocol: The aim of the test is to determine the LM35 and Arduino flame sensors' sensitivity in respect to the fire source and at various times of the day. A candle is set apart from the Arduino flame sensor at various intervals for every test. Three feet from the fire source is where you'll find the most accurate reading at the analog output of the serial monitor. At that distance, readings are obtained every 30 minutes, at different times of the day, and with or without the fire source present. Robotics proceeds in the direction of the fire source when it is detected by the flame sensor. At intervals of three inches, the measurements are taken. Approaching the source, Figure 6 shows the temperature increases and the output of the LM35 varies; these variations are also recorded. It was an average temperature of 26 degrees Celsius throughout the day.

Results and Discussion

The water spreader at the front of the pipe greatly lowers the velocity of the water supply pump while efficiently distributing the water for a successful extinguishment. During the day, the analog output measurements are at their lowest. On a limited scale, The Robot to Fight Fires can put out fires with effectiveness. It is more accurate in detecting flames in poorly lit areas. Its function is to prevent robots from doing things due to its ability to quickly detect flames and put them out before they spread. Its improved sensor unit and larger reserve capacity enable even faster fire detection in all situations.

Daytime and Night-time Sensitivity of the Flame Sensor

Both with and without a fire, the Arduino Flame Sensor's sensitivity is measured three feet from the source of the flames. The results can be seen in Figure 6, respectively. Figure 7 illustrates that the sensor produces a greater output around 7 o'clock, regardless of the presence of a fire source. However, the reading continues to decline with time. This can be attributed to the infrared radiation found in sunlight. The sun reaches its peak strength at 12 or 13 o'clock, increasing the amount of infrared light available for the flame sensor to detect.

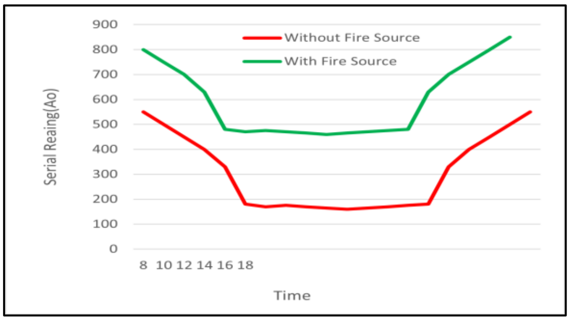

Figure 6: Daytime Effects of the Flame Sensor's Sensitivity

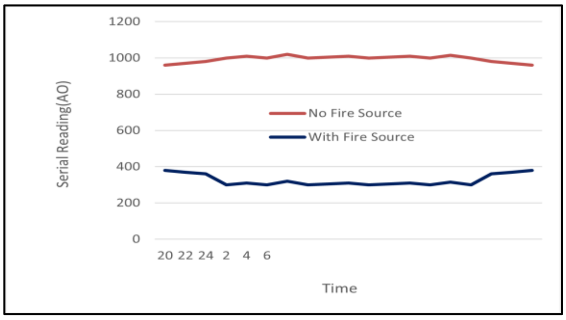

Figure 7: The Impact of a Flame Sensor's Sensitivity during Night-time

Table 1: Change of Output Readings of LM35

Temperature (°C)	Serial Reading (AO)
26	56
40	87
55	127

Whether there is a fire source or not, this time of day yields the lowest output reading. But around fifteen o'clock, the sun's intensity starts to decrease, which raises the output reading. When the Sun sets at the end of the day, it reaches its highest value. It was also observed that almost parallel patterns were found and that the serial reading illustrated in Table 1 and profiles virtually stayed at the same offset all day.

With or without the fire source, Figure 7 shows how the values stay rather constant throughout the night. The output value peaks between 23 and 03 o'clock when the Sun's impact starts to wane and troughs while the fire source is active. Thus, during this part of the night, there is the most difference between these two values. The most suitable difference for correctly differentiating between a fire source and normal conditions is provided by this time range. Therefore, it is a proven fact that flame sensors reliably and painlessly recognize fire in the evening.

Robot Approaches a Fire, Changing the Flame Sensor's Output

The impact of the flame sensor's output at 10 AM and 10 PM, respectively, is shown in Figure 6 as the robot approaches the fire's source after detecting it. The source's increasing intensity causes the analog output to diminish as it moves closer to the source. Additionally, at the furthest point from the source, readings at 10 PM are found to be greater than those at 10 AM. At 10 PM, the reading declines more sharply than it does at 10 AM because the Sun's infrared rays at 10 AM cause the sensor's analog reading to be disturbed. However, it's also discovered that the readings during the day and night are nearly identical when they're close to the safe distance from the fire source. Because the fire source's effect starts to dominate. Additionally, it is noted that in both circumstances, the curve steepens equally at close proximity to the fire source. Since infrared rays are produced in greater quantities when a source's intensity increases. Figure 8 shows the results in a slight attenuation at 10 AM but a substantial attenuation of the output measurement at 10 PM.

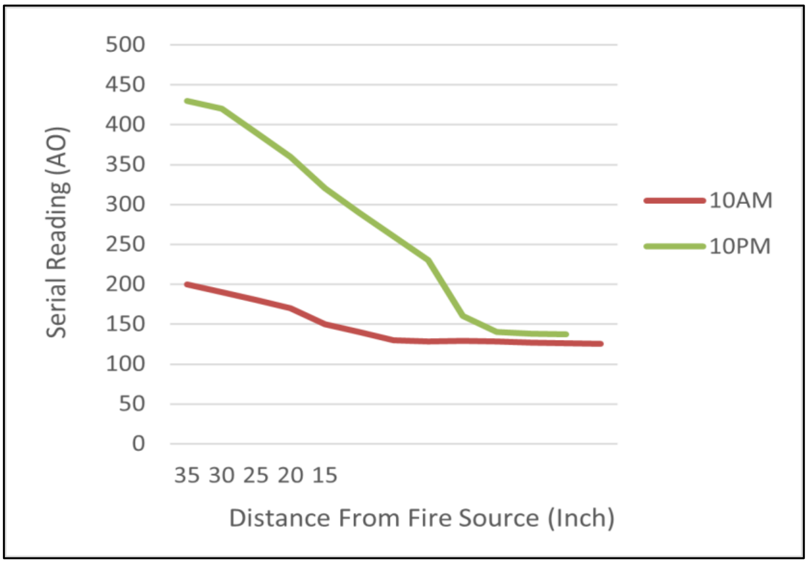

Figure 8: A Shift in the Flame Sensor's Signal Occurs When the Robot Approaches the Source of Fire

Modification of LM35's Output

There is a rise in temperature as the robot gets closer to the fire. Close proximity sensing is possible with the LM35 sensor. Sometimes, in order to detect the presence of fire, it must come into contact with the fire source, even for minor fire sources. Because of the creative design of the robot, heat can be detected by the LM35 sensor up to six inches from the source. As a result of its conduit-based placement at the robot's front, the sensor stays even closer to the heat source. This allows the robot to maintain a safe distance from itself as well. So, in response to a rise in temperature, the LM35 adjusts the output. The robot is designed to halt and perform the required extinguishment when the change reaches an indisputable threshold.

Conclusion

Locally obtainable materials are used to build the firefighting robot, and testing are conducted to assess how well it performs under various circumstances. Because the Fire Fighter Robot must withstand a variety of conditions, the results of this effectiveness test will aid in the development of a more precise model. In concluding, the following observations can be made regarding the relevant robot design and testing: The robot's platform is constructed from "rashed tree" wood that is readily available in the area. It is strong enough and capable of withstanding water and fire. Its low density contributes to the creation of a solid support-free, less-weighted structure. The water container is composed of weather-resistant white cardboard. Defense against water leaks is provided by this. An alloy of aluminium used to make the pipes is fire-resistant. These help put out fires by moving water at a safe, calculated distance. An extra pipe is utilized to convey an LM35 sensor, which is equipped with an accurate distance sensor for detecting heat.

The water spreader at the pipe's front effectively distributes the water for a successful extinguishment while significantly reducing the water delivery pump's velocity. The lowest analog output readings occur during daytime hours. It produces an output value differential between 300 and 350 that is roughly consistent, regardless of the existence of the fire source. As such, an efficient method may be constructed in this circumstance even with the poorest possible output reading. The values that are recorded at night have a relatively high value when there is no fire source, while the lowest value is found in the absence of fire. It has an adequate detection range. 23 to 03 hours is the ideal time window to look for a fire source. For configuring the gadget at any time of day, this offers the most convenient platform. The robot detects the fire and starts to proceed in its direction. Temperature variations affect the output of the LM35. There is a nonlinear variation in the LM35 output. As a result, readings are taken at different distances, and the robot is adjusted to stop when it is safely far straight from the origin.

The Robot to Fight Fires is capable of effectively fighting flames on a small scale. In dimly lit locations, it detects flames more precisely. Its purpose is to act as a robot preventer. Because of its capacity to identify fires promptly and put them out before they spread. Under every condition, its enhanced sensor unit and increased reserve capacity provide even faster fire detection.

Abbreviations

Nil.

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Nil.

Author Contributions

All Authors contributed the entire manuscript in writing, reviewing, implementing and analyzing.

Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval

Not applicable.

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