Autonomous Robotic System for Identifying and Extinguishing Fire

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ABSTRACT: **Putting out fires is a hazardous profession with a high death rate. The new approach to preserving both theenvironment and human life is robotics. This work suggests an autonomous robot system that uses a flame sensor to invariablydetect and put out fires. The Arduino UNO, water pump, servo motor, motor driver, relay module, Bluetooth HC-06 module, and flame sensor are all part of this project. In addition, the robot's mobility is controlled by commands transmitted to the receiver via the push Bluetooth app on the transmitting end. The robot moves and the fire is doused with water thanks to the motors that are attached to the microcontroller. The robot body has a water pump and tank that are automatically identified by the infrared.The flame sensor and the entire system are managed by a microprocessor from the ATMEGA328 series. The microcontroller and a motor driver integrated circuit (L298N) are interfaced so that the controller may drive the motors. The robot can therefore sense fire at a distance. Around 5.11 cm is the average length for detecting flame, and 300 cm is the typical length for Bluetooth transmission. It might lessen constraints brought on by human mistake and fire extinguishing tasks.**

Keywords: **ATMEGA328, sensitivity, Bluetooth,detectors, controller, and fire extinguisher**

1. INTRODUCTION

Technological advancements have led to a rise in the frequency of developments in situations where human life may be lost. Among these uncontrollably occurring issues brought on by the world's expanding population are fires. As a result, employment in this field is expanding in the robot business. The modern industrial revolution has seen an increase in the use of robotics technologies. Artificially intelligent robots—or even remotely operated robots— must communicate with humans while requiring little to no supervision. A mechanical creation that can carry out human functions or behave in a human-like way is called a robot. Human interaction is decreasing as the science of robotics advances, and robots are more utilized to ensure people's safety. Many humanoid robots are used in many different contexts, such as healthcare, education and entertainment, search and rescue, manufacturing and maintenance, and personal help and caring [1-2, 3-5]. While these robots are more adept at programming some tasks than humans, people should still be in charge of other tasks. With their ever-growing sophistication, robots will eventually replace certain human professions, but not all of them. Just 25% of the unpredictable, human-dependent fields, like nursing and construction, may be made simpler by current robotics technology.Robots, however, are programmed by humans [6-7]. Robots come in as many different varieties as there are jobs [8].

The number of people on the planet is growing, and technology has made fire accidents and hazards more common. Being a firefighter is a dangerous job that frequently ends in death. Robotics has become a practical means of preserving both human life and the environment. The robot will be able to detect fires remotely. Industrial environments are the main applications for these robots [9]. The most popular firefighting robots on the market right now are Colossus [10], Thermite [11], and FireRob [12]. In the age of automation, when self-driving cars and automated technologies are becoming more and more common, firemen face an ongoing risk of death. An explosion could potentially occur in the event of a gas leak. Thus, the system steps in to solve this problem and preserve the hero's life. An autonomous firefighting robot system is used in this work. The main job of the robot is to change into a crewless support vehicle that can find and put out fires.

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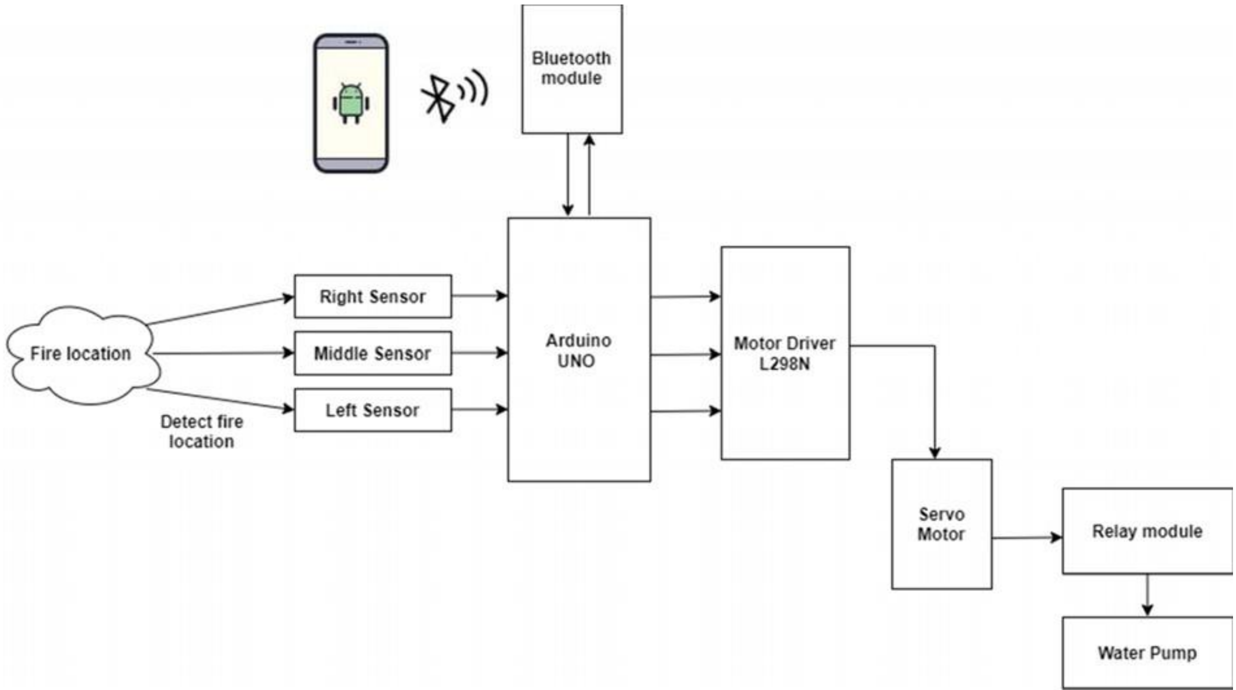
2.PROBLEM FORMULATION

As we are living a modern life, we are under the risk of fire. Fire can take place in any house, school, or any place. It is mostly caused by electric short circuits, or combustible gases we use at home for heating. Fire causes damage to people and property. In 2011 in the US,statistics say that “370,000 fires have caused 2520 civilian deaths and 13,910 civilian injuries with damagesapproximated at 6.9 billion dollars.” Therefore, to protectourselves, our families and our houses, we need a safe fire fighting system to detect and extinguish fires before they spread. What we need is a computerized fire detecting and extinguishing robot assembled with a network of fire sensors to detect the smallest fire and fight it. Other than its main purpose to decrease human and property losses, fire detecting and extinguishing robots could also be a great support to firemen. By using a robot, firemen do not need to risk their lives to extinguish fires, especially that the robot is replaceable atany time.

3. DEVELOPMENT OF PROJECT

The primary tasks are performed by the autonomous robot system, which is able to move in the direction of the fire and extinguish it by pumping out the surrounding water. For remote movement control, this robot system makes use of Bluetooth technology. The water tanker and wirelessly controlled pump on the robot are designed to sprinkling water. The robot can move forward, left, or right at the transmitting end according to directions from the push Bluetooth app. Robots could eventually take the place of people in firefighting roles thanks to technological improvements, notably in robotics. The firefighters' effectiveness would increase with this substitution, and they wouldn't have to jeopardize anyone's life. The robotic system's block diagram is shown in Figure 1



i. Completing the tasks that the robot has been given.
ii. Ascertain where the internal parts of the robot that are necessaryfor its operation are located.
iii. Lighten the burden the robot is carrying to minimize the powerit needs to operate.

Robot design chassis. To achieve the required movement and speed, the main structure of the robotic system consists of one forward-facing wheel and two rearward-facing wheels. The robot may be lifted by the front wheel, which can also rotate 180 degrees.To protect the electronic circuit, the entire robot frame is made of wood plates. Since wood is the most readily available, least expensive material that can support the weight of a large robot, it isutilized for the plate. The design of the robot body using a 2WD smart robot vehicle chassis kit that is compatible with Arduino is shown in Figure 2.

Figure2. Design of robot body

Deck design structure. Figure 3 uses an acrylic board to display the robot design with a deck on top. The robot's deck was made out of an acrylic board since it was the least expensive option and would allow for the optimum hardware layout to be installed neatly on the robot. Because acrylic is translucent and allows light to pass through to the hardware components, the acrylic board that was placed above the robot was an ideal housing area. It also gave the impression of being more organized and visible.

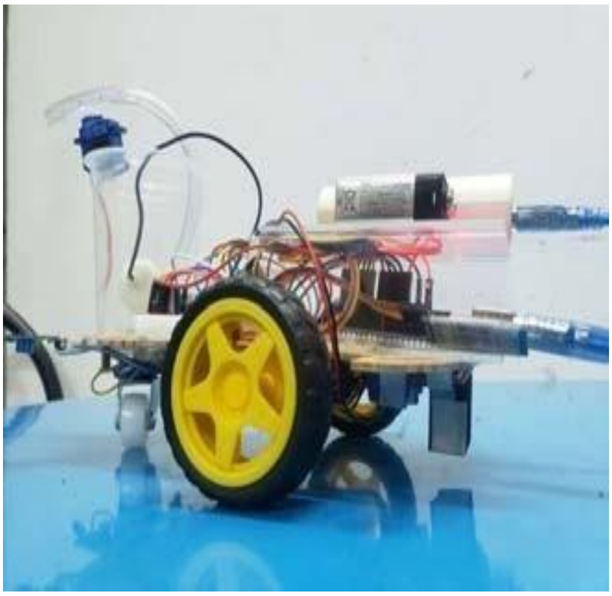


Figure3. Robot design with a deck

B. Hardware development

An essential part of the robot's development is the electronic component. Included were flame sensors, an Arduino relay module,a DC submersible pump, a microprocessor, a DC motor with wheels, a servo motor (SG90), an L298N motor driver module, and others [13]. Using code from the Arduino IDE, the

microcontroller reads input from the components—most notably the flame sensors—and lighting them. An Arduino UNO R3 is used for this project since it contains all of the native ATMEGA328P functionality plus some extras. DC motors, a servo, a water pump, and three flame sensors are all connected to the Arduino board. The robot system's motors and pumps require a 12V power supply, while all of the associated sensors require a 5V power supply.
Utilized as a slave Bluetooth module designed for wireless serial communication is the HC-06 Bluetooth module [14]. When a master device, like a PC or smartphone, sends out serial data, the slave module indicates that it can receive it.

C. Development of software

The process of developing and managing software, including frameworks and applications, is known as software development. The source code for the robotic system was developed using two applications: MIT App Inventor and Arduino 1.8.13. The source code was created using each of these applications independently.

Design process flow. The process flow of the autonomous robotic fire detection and extinguishing system is depicted in Figures 4 and 5. Setting up all of the system's pins and sensors will be the first stage. The next step is to look for fire; if it finds one, it will go on and keep looking for fire until it does. After the fire is detected, the system determines which sensor—the left, middle, or right—saw it. The pump motor will start to extinguish the fire as soon as the fire sensor senses which movement. The robot then begins to move once more and ignites. The mobile application is used to control the robot's movement when the manual option is enabled. The left touch key will control the left path, while the right touch key will control the right direction. The straight and reverse movement, on the other hand, is controlled by the up and down touch keys. The robot's direction at the fire scene is controlled via the manual mode.

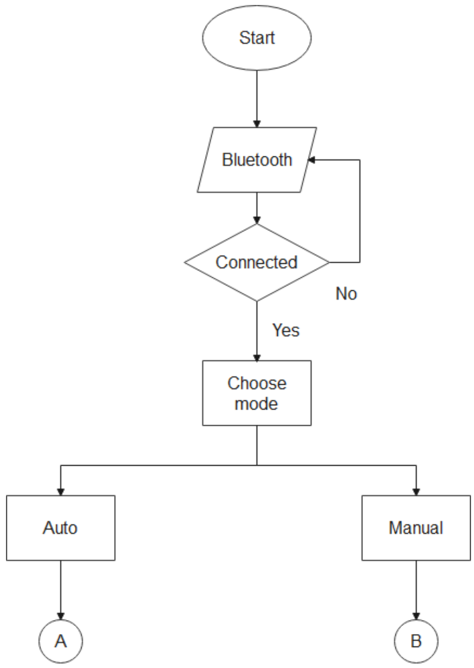


Figure4. Process flow of Bluetooth Connection

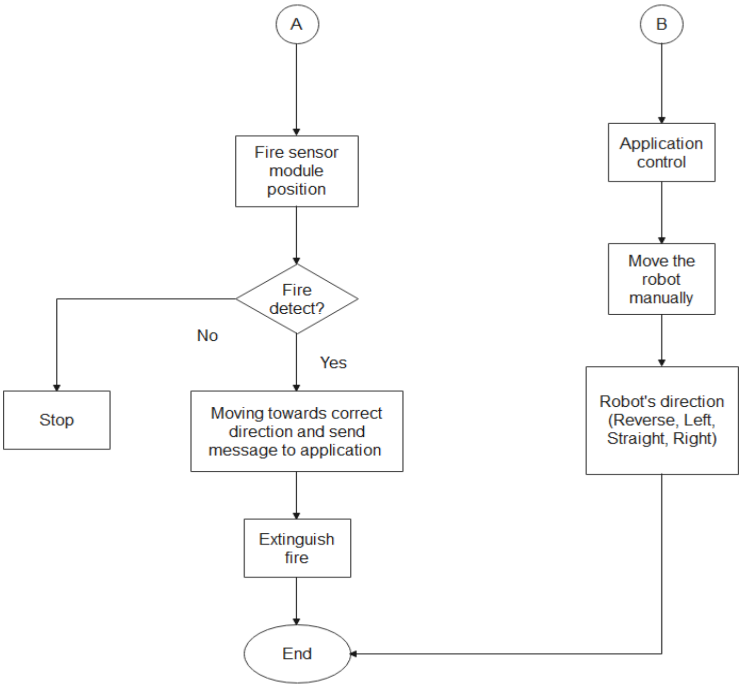


Figure5. Fire sensor module operation and robots's movement

D. Testing environment

A three-by-three-meter area is used to test the autonomous robotic system prototype. After entering the area, the automated system moved at random in response to the environmental factors. There was no designated path for the robotic system to follow. There are sporadic fires ignited all around the testing area. By calculating the flame detection distance, the sensors' accuracy is evaluated. In accordance, the responses of various sensor positions are computed. The robotic system and a smartphone running an Android application are tested for Bluetooth control replies by measuring the Bluetooth transmission length.

4. RESULT AND DISCUSSION

The android application for the autonomous robotic system is shown in Figure 6(a). The application's FiBot title is displayed on this interface. By clicking on the "ENTER" button, users will be redirected to the main page, which is the second page, as seen in figure 6(b). The Android application's home screen is separatedinto three sections: action keys for manual mode, mode selection, and Bluetooth connectivity. The user must first "ON" Bluetooth in order to utilize it, which displays an interface with a list of all the associated Bluetooth devices. To connect to the FiBot Bluetooth module, users must choose the HC-06 Bluetooth.

Once the Bluetooth module is chosen, the status "CONNECT THE DEVICE" will show and the main page will reload with the HC-06selected.

To connect the device, users can click the "CONNECT" button onemore time. The status will update to "CONNECTED" after the connection is complete. The user will then be able to choose whether they want to operate the robot in manual or automatic mode. When in automatic mode, the robot uses a flame sensor to automatically detect a fire. It then moves in the direction of the fireto pump out water and continue putting it out.

Figure 7 displays the real-time replies displayed in the FiBot android application. Depending on the direction of the fire, the datawill automatically indicate which flame sensor has spotted it.

In addition, figure 8 provides an illustration of the manual mode commands that will appear when you click the stop and arrow buttons. The Bluetooth connection causes a two to three second delay for certain functions. There are five motion operations in the manual: forward, reverse, left, right, and stop.

Robotic system prototype

The side view of the robot prototype is depicted in Figure 9, and the top perspective is shown in Figure 10. An acrylic board thatwas specially made to suit the chassis kit and hold all of the parts as well as the power sources was added to the housing area. A clear container that serves as a water reservoir is positioned at the front end of the chassis kit and is connected to the servo motor so that water may be sprayed in an 80° radius.

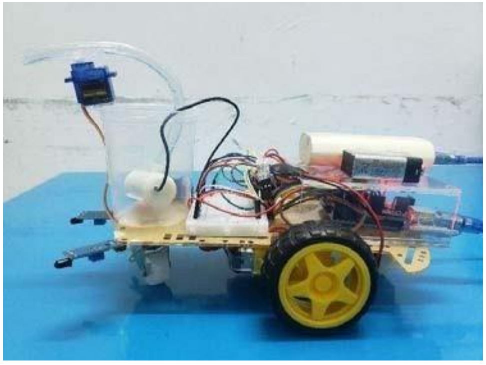


Figure6. Prototype of the robot (side view)

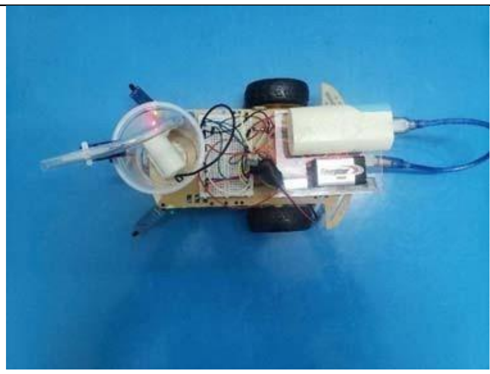


Figure7. Prototype of the robot (Top view)

The typical distance at which flames can be detected is 5.11 cm. The difference in distance between the theoretical and practical values is substantial. As shown in table 1, the length is tested by measuring flame detection in various directions. The accuracy of the sensor needs to be improved by more testing and analysis. Step 3 was taken to mean a 1-meter distance, which was designated as a control variable for the Bluetooth communication. The Bluetooth transmission distance was checked using the number of measures, as shown in table 2. In conclusion, a Bluetooth connection can be established anywhere between one and three hundred centimeters. As a result, it is believed that the Bluetooth transmission range between the smartphone and Bluetooth module is around three meters.

Table 1: Distance to the detected flame

Distance (cm)	Front detected by the sensor
4.5	Front
6.0	Left
5.5	Right
5.6	Left
4.5	Front
4.7	Left
3.0	Right
6.3	Front

Table 2: Bluetooth connection distance

Distance(cm)	Steps for connecting using Bluetooth	Status of Bluetoothconnection
1	-	Connected
100	3	Connected

150	6	Connected
200	9	Connected
250	12	Connected
300	15	Connected
350	18	Disconnected
400	21	Disconnected

5.CONCLUSION

The suggested modular design approach was a great way to put an autonomous robotic system in place that would help people in dire circumstances. The robot can move left, right, and forward in addition to stopping. It protects their property and reduces the need for human labor. In addition, the robotic system has the ability to locate the fire, navigate in its direction, and use a water pump to put it out. The robot operates as predicted and was also successfully controlled with the help of the Bluetooth module. The hardware of the robotic system was improved and developed after the original design was made, taking into account new circumstances. The code was designed and developed using Arduino software. The project's procedure is made simpler by the software library's completeness when real-time simulation is used. The fire extinguisher's accuracy could be increased, even if the firefighting robot created and shown here offers substantial human help. The above-mentioned disaster response robot system appeared to be functioning properly and efficiently. The design of the prototype is deemed dependable and economical, and it ought to be employed in firefighting operations to assist in lowering the quantity of fatalities and property loss in buildings and infrastructure, given that the project's goals have been achieved.

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