Design and Implementation of a Robot Firefighter for Indoor Applications

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***Abstract* — Background: Keeping people and things safe involves the constant development of novel firefighting technologies. Robots have emerged as viable assets in firefighting, capable of performing dangerous duties and reducing hazards to human life, particularly in enclosed spaces.**

Objective: The purpose of this study is to investigate the feasibility of deploying robots capable of autonomously detecting and extinguishing fires in buildings, thereby improving safety in various indoor settings such as factories, hospitals, schools, and government buildings.

Methods: The robot, constructed modularly with omnidirectional wheels for agility, incorporates several sensors such as thermal imaging cameras, gas sensors, and obstacle detection sensors. The implementation entails rigorous testing in simulated interior environments to examine the robot's capacity to detect and extinguish flames, manoeuvre around obstacles, and function effectively within a restricted period. The architecture of the robot also allows for future upgrades and component replacements.

Results: The trials show that the robot can identify and extinguish flames and traverse obstacles in simulated situations. The robot's modular design emphasises its versatility and application across various interior situations, demonstrating its potential for reducing fire damage and improving safety.

Conclusion: This article demonstrates the feasibility and promise of using robots for firefighting in hazardous indoor situations. The results highlight the developed robot's flexibility and adaptability, paving the way for future advances in robotics and firefighting methods, with implications for boosting safety and lowering hazards in various indoor applications.

I. INTRODUCTION

Robots are utilised in many fields, including firefighting. An autonomous robot that can detect flames and put them out for the fire service would be a game-changer. To put out flames, this project's robot, which has four wheels and a differential driving system, may spray carbon dioxide or water. The robot's 180-degree field of vision and obstacle avoidance make it ideal for spotting fires and navigating hazardous environments[1]. This is accomplished by installing three flame sensors within the robot, each set at an angle of 60 degrees to provide a total field of vision of 180 degrees. After compiling the information from all the detectors, we can determine the overall orientation of the fire. The robot was constructed using a model for avoiding obstacles, which relies on ultrasonic sensors to determine how far away obstacles are[2].

The robot uses a 16g CO2 cartridge to put out the flames. The cartridge was ejected by retrofitting a CO2 bike tire inflator with a servo motor to the release mechanism. An Arduino UNO board is responsible for reading information from the flame and ultrasonic sensors and directing the servo motor accordingly. Nevertheless, when utilised continually, the robot's battery might run out, or the flame detection sensor may fail, resulting in the robot's inability to respond[3].

One way to fix these issues is to upgrade the robot's sensors and batteries to keep it running for longer and with higher voltage and capacity. Creating this robot might significantly improve the safety and effectiveness of firefighting operations. This robot can save lives and lessen the risk of harm to firefighters by removing the need for human involvement in hazardous circumstances [4], [5].

Further sensors and technological advancements that aid in fire detection and suppression might be included in this robot's design to make it even more efficient [6]. Moreover, machine learning techniques may further the robot's skills in identifying and reacting to fire crises. The article also serves as a reminder of the value of open-source hardware and software in robotics since it encourages more individuals to participate in advancing such technologies and makes them available to a broader audience [4].

Creating a fully autonomous firefighting robot with flame and ultrasonic sensors is a significant advancement with game-changing potential. This robot's capacity to independently locate flames and put them out has the potential to save lives and lessen the likelihood of harm to firefighters. However, the robot still has room for development to make it more trustworthy and effective. Open-source hardware and software can be invaluable in enhancing robotic technology that might help humanity further.

A. Problem statement

The article's problem statement centres on a more practical and reliable strategy for dealing with flames within buildings. Indoor fires provide unique difficulties for conventional firefighting methods, particularly in inaccessible or hazardous locations. As a result, it is essential to create a robotic firefighting system that can effectively and safely operate in confined interior environments.

Creating a system that can effectively identify and locate fires, users will be redirected through complex indoor spaces, and effectively extinguish fires without further damaging the building or endangering human lives are the main barriers in designing and implementing a robot firefighter for indoor applications. The robot must also be fully or partially self-sufficient and be able to use various firefighting equipment, including a water hose, an extinguisher, and other similar devices.

In addition, the robot's design must account for the challenges presented by interior firefighting, such as limited sight and potentially dangerous chemicals. The robot must be built to last for long periods without breaking down or needing regular repairs.

B. The aim of the article

This article aims to create a robotic system that can aid human firefighters in putting out house fires more quickly, efficiently, and safely. To accomplish its goals, the project will use a variety of tools and strategies, such as the design of a robotic system that can accurately detect and locate fires in indoor environments, the development of a navigation system that will allow the robot to move through complex indoor spaces, and the implementation of various firefighting tools and techniques.

Also, the robot has to be fully or partially autonomous to function without human intervention and protect human firefighters from harm. The robot must be sturdy, long-lasting, and dependable enough to work for long periods in harsh interior situations without requiring regular servicing.

The project will employ sensors and other relevant technologies to detect and localise fires with pinpoint precision to accomplish these goals. A navigation system will be developed to enable the robot to move through complex indoor spaces, avoid obstacles, and quickly arrive at the fire's location. Also, various firefighting equipment and methods will be implemented, such as a water hose, extinguisher, or other appropriate instruments that may be managed remotely.

The robot firefighter system will be put through its paces in a series of tests designed to mimic real-world firefighting situations to determine how well it can detect and put out flames without endangering human lives. The project's ultimate goal is to create a fully functional robot firefighter system that can augment human firefighters to control fires within buildings better. This will improve the odds of saving lives and avoiding property damage during a fire while decreasing the danger of injury or death to firefighters**.**

II. LITERATURE REVIEW

The potential for firefighting robots to improve safety and reduce damage to buildings and people has attracted much interest in recent years. The papers in this analysis of the available literature provide insight into many facets of firefighting robot design and implementation.

For example, Krasnov and Bagaev [7] investigated firefighting robots' control systems. This research often concentrates on the control systems and algorithms utilised to run the robots [8]. If you want firefighting robots to identify fires automatically, you should look at Su's [9] suggested adaptive fusion technique.

Hwang et al.[10] created a unique fire detection device for robotic firefighting by using image processing methods to identify flames; other research has focused on the hardware and sensors used in firefighting robots in similar ways. The autonomous firefighting robot developed by Rakib and Sarkar [11] has a PID controller and many sensors for detecting fires.

Qasim et al. [8] looked at ways to increase energy efficiency in digital broadcasting; their findings might be used in firefighting robots. Image colour correction via multimedia channels was another topic covered by Qasim et al. [12]. The current and future potential of LTE technology in establishing the Internet of Things was examined by Qasim et al. [13]

Robotic motion control may be broken down into two distinct types: sensor-based and vision-based. Feedback from obstacle, infrared, and flame sensors is utilised to guide the robot in sensor-based control systems. On the other hand, vision-based systems pinpoint the target area using cameras and other forms of image processing. Many types of fires may be fought with the help of these robots [1]. A firefighting robot may be part of an intelligent multimodal security system that is vital for protecting human life, according to Qasim et al.[12], [13] The Security and Firefighting Advanced Robot project in the United Kingdom provides a low-cost and efficient fire detection and suppression method. Amano [14]. Moreover, Hashim et al. [15] apply cutting-edge image processing and device control techniques to swiftly and precisely identify environmental flames [7]. Robotic devices may be put in tunnels under roads and railroads to reduce fire danger without significantly changing the tunnels' architecture. Rakib, T., & Sarkar, M. A. R. [11]. Autonomous mobile robots, which use sensors to find a candle flame and put it out, are one example of an interdisciplinary design. The primary references here are Su [9] and Krasnov and Bagaev [7]. Fires caused by water may be mitigated by gaseous fire extinguishers such as carbon dioxide and nitrogen. This is according to Qasim et al. [12]. Obstacle avoidance and identification employing ultrasonic sensors and anti-jamming processing are possible in huge fire fields with smoke and high-temperature circumstances. A study by Jawada et al. Qasim et al. [15] suggest PID controllers based on back-propagation neural networks, while Hashim et al.[16] present an intellectual PID control that uses error and error rate information to determine system dynamics and states. Significant challenges in building firefighting robots include dealing with issues of size, weight, cost, and performance [17]

The review's aggregate findings reflect the breadth of studies on robots that fight fires. Designing and developing realistic robots for different purposes presents several obstacles that may be met in some ways [18]. The potential of firefighting robots to improve safety and reduce fire-related damages in a wide range of buildings and environments bodes well for their further development.

III.METHODOLOGY

Ultrasonic sensors were used throughout the piece to map the area immediately around a moving vehicle. The researchers want to use arrays of sensors in the front, sides, and back, with the sensors in the front and back organised in perpendicular rows and the sensors in the sides in hyperbolic or parabolic arrays [19-21]. The following methodology details the procedures that were used to complete this study.

Step 1: Hardware Setup. To begin, the sensor array hardware must be installed. The first step is to choose suitable ultrasonic sensors and set up an array according to your specifications. The sensors should be safely fastened to the car and connected via wire to data processing equipment.

Step 2: Calibration. You calibrate the sensors to get precise distance readings. This is achieved by taking measurements at fixed, known distances and modifying the sensor parameters until the measured values match the known ones. This process is essential to the system's reliability and may include several rounds of testing and fine-tuning.

Step 3: Testing in a Controlled Environment. After the hardware has been installed and calibrated, the system should be tested in a safe setting to ensure it works as intended. The vehicle should be driven around an obstacle course, and the sensor data should be collected and assessed for accuracy.

Step 4: Field Trials. The system's efficacy can only be determined once tested in controlled and real-world settings. In order to test the system's object detection and data accuracy, it may be necessary to drive the car in various locations, including cities and rural areas.

Step 5: Analysing the Information. To evaluate the system's performance, it is necessary to examine the information gathered by the sensor arrays. In order to do this, it may be necessary to do statistical analysis to determine patterns in the data, such as the prevalence and nature of false positives and false negatives.

Step 6: Optimisation of the System

Optimisation of the system may be required to enhance its precision and efficiency in light of the data analysis findings. The sensors themselves may need to be moved or readjusted, the data processing algorithms may need to be fine-tuned, or both.

Step 7: Validation and Verification

As a last step, the system should be evaluated and checked to ensure it achieves its goals. In order to verify the reliability of the system, it may be necessary to compare the sensor data with manual observations or information from additional sensors.

This approach details how to perform studies using a network of ultrasonic sensors to monitor the area immediately around a moving vehicle. All steps are setting up the hardware, calibrating it, testing it in both lab and field conditions, analysing the results, optimising the system, and validating and verifying its results. Creating increasingly sophisticated and trustworthy car safety systems is made possible by adhering to this process, which ensures accurate data gathering and analysis.

The item is created as indicated in Fig. 1, which proposed to employ ultrasonic sensors placed in an array to detect things surrounding the vehicle. There are arrays of sensors at the front, sides, and back. The arrays of the front and rear sensors are perpendicular, whereas the arrays of the side sensors are either parabolic or hyperbolic (Fig.1).

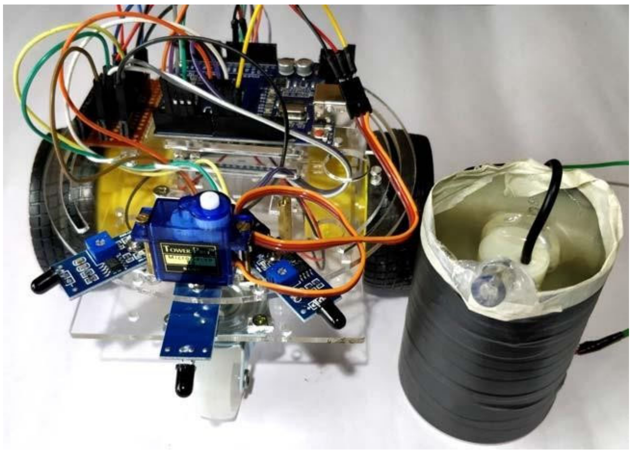

Fig. 1. The position of the sensors in the car

A. Materials

This article's findings show that Arduino Uno is a powerful tool for creating embedded systems. Digital and analogue input/output pins, a USB port, and a power connector are some of the features tested and proven to expand the board's potential applications significantly [22].

Also, the Arduino Software (IDE) is readily available and user-friendly, so even inexperienced programmers can easily pick it up and start making projects with Uno. Help with issues and learning more about the system is available because of the platform's extensive user base [23].

In addition, the Uno may help developers save money on embedded system design and creation since the board is cheap, and the microcontroller chip can be swapped out in case of damage.

According to the findings, the Arduino Uno might be used in various settings, such as smart homes, robots, and the Internet of Things. It is an excellent tool for developing embedded systems because of its low price, flexibility, and intuitive UI.

1) Exploring the Potential of Arduino Uno for Embedded System

The Arduino Uno is built around the ATmega328P microcontroller, serving as the foundation for this versatile microcontroller board [datasheet]. Equipped with essential components, the Uno features a USB port, power connector, ICSP header, reset button, 14 digital I/O pins (with six capable of PWM outputs), six analogue inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), and a 16 MHz crystal oscillator (CXO). This comprehensive setup provides everything needed to begin working with the microcontroller - connect it to a computer via USB or power it with an AC-to-DC converter and a battery.

One of the remarkable features of the Arduino Uno is its forgiving nature, allowing users to experiment without undue worry about mistakes. If the need arises, the microcontroller chip can be easily replaced at an affordable cost. This convenience encourages exploration and innovation in various projects [24].

The naming of the Arduino Uno holds significance as it symbolises "one" in Italian. The developers aptly chose this name with the introduction of Arduino Software (IDE) 1.0. The Uno and version 1.0 of the IDE marked the debut of the Arduino boards and software. Since their inception, subsequent versions have been continually enhanced, building upon the Uno's legacy.

As part of the USB Arduino series, the Uno board is the foundational model, representing the reference platform for the entire Arduino ecosystem. It has played an essential role in motivating and aiding the creation of several creative initiatives, and it continues to be a popular option for both novices and seasoned aficionados. For a comprehensive overview of current, historical, and outdated Arduino boards, the Arduino index of boards provides a valuable resource for users seeking the most suitable hardware for their specific needs.

The technical specifications of the Arduino Uno microcontroller board, including its operating voltage, recommended input voltage range, number of digital I/O and PWM pins, analogue input pins, flash memory, SRAM, EEPROM, clock speed, and physical dimensions. The microcontroller uses an ATmega328P and has a clock speed of 16 MHz. It has 14 digital input/output pins, six of which can be used as PWM outputs and six analogue input pins. The board is powered by a 5V input voltage, with the recommended input voltage range being 7-12V and the limit being 6-20V. It has a flash memory of 32 KB, of which 0.5 KB is used by the bootloader, 2 KB SRAM, and 1 KB EEPROM. The board's LED_BUILTIN is located on pin 13. The physical dimensions of the board are 68.6 mm in length and 53.4 mm in width, and it weighs 25 grams. These specifications make the Arduino Uno a versatile and widely used microcontroller board for embedded system design and development [25].

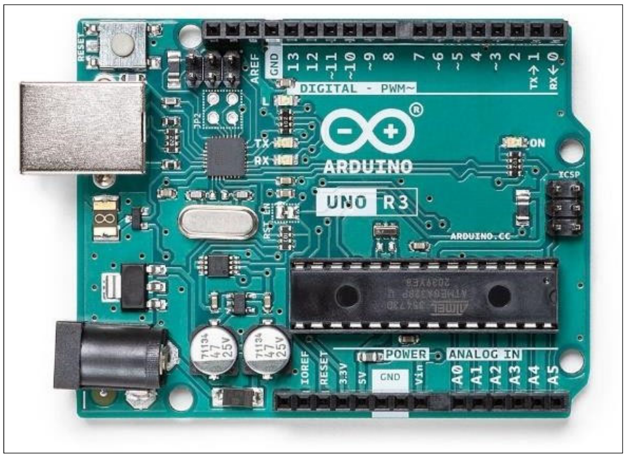

Fig. 2. Microcontroller Arduino Uno

2) 3.1.2 IR Proximity Sensor Electromagnetic Reflection Principles

The table and figure below provide briefly an overview of the Infrared (IR) Sensor Module's key characteristics and specifications. This proximity sensor is used to identify an item or barrier within relative proximity. To determine how far away an item is, the module applies the concept of electromagnetic reflection, which states that the IR receiver will pick up a more excellent signal from the IR emitter the closer the object is. There are two LEDs on the sensor, one that sends infrared light and another that receives it. The output switch mode shifts when the IR receiver picks up an electromagnetic detection stronger than the threshold level [26].

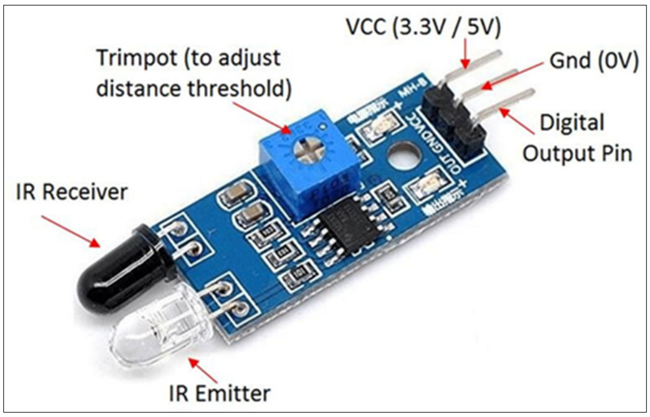

Fig. 3. Infrared (IR) Sensor Module

The module has a single digital output signal that goes high (5V or 3.3V) or low (0V), depending on whether or not an obstruction is detected. The sensor has a detection range of 2-30 cm, and the distance threshold is adjustable through the on-board potentiometer/trim pot. The trigger distance, however, may be affected by factors such as the object's surface material, colour, and form. Because of this, the module is suggested for use in applications that need a range of just 10cm or less, such as obstacle avoidance and virtual touch switches.

TABLE I. THRESHOLD LEVEL ADJUSTMENT WITH POTENTIOMETER/TRIMPOT IN INFRARED SENSOR MODULE

Property	Description
Type	Infrared Sensor Module
Detection Range	2cm to 30cm
Detection Angle	60°
Output Signal	Digital Output
Voltage	5V or 3.3V (depends on input voltage)
Output Signal Voltage	High (5V or 3.3V) when there is no obstacle, Low (0V) when obstacle detected
Potentiometer / Trimpot	Adjust the threshold level for distance detection
Trigger Distance	Subjective to an object's surface material, colour and shape
Recommended Application Range	Less than 10cm
Use Cases	Obstacle avoidance, virtual touch switch application

3) Optimising LCD Display Selection for Embedded Systems Design

There are 16 columns and two rows on an LCD screen. Many permutations are attainable, including 81, 82, 102, 161, etc. However, the 162 LCD is the most popular, so that is what we have gone with.

The LCDs have 16 Pins, and their programming methods are equivalent; the decision is yours. A description of each pin on a 16x2 LCD module and its pinout is provided below.

4) Developing Pixel Matrix Bell Shape Characters for LCD16x2

Liquid crystal displays (LCDs) are increasingly used in everything from consumer electronics to industrial control systems. The 16x2 LCD has 16 columns and two rows of characters and is one of the most widely used LCD screens. It is possible to construct and show each character in LCD16x2 utilising 40 pixels thanks to the character's 5x8 pixel grid.

This article will concentrate on designing a bespoke bell-shaped character for the LCD16x2. The bell-shaped character will be created using a pixel matrix, where each pixel has a binary value of either 0 (off) or 1 (on). The character will be shown on the LCD16x2 with the proper programming methods.

Each row of the bell-shaped character's pixel values will be set initially. There will be 5 pixels in the first row, 8 in the second row, and 10 in the third row. There will be no data in the remaining rows. Each row's pixel values will be binary, with 0 denoting an off state and 1 indicating an on state [27].

After defining the pixel values for each row, the whole bell-shaped character may be created. In the Arduino programming environment, this can be accomplished by constructing a character array in which each element represents a column of the bell-shaped character.

The uploaded character array can be shown on the LCD16x2 connected to the Arduino board using the proper programming methods. The LCD16x2 lets you show off the bell-shaped character alongside other characters, giving your work a more customised feel.

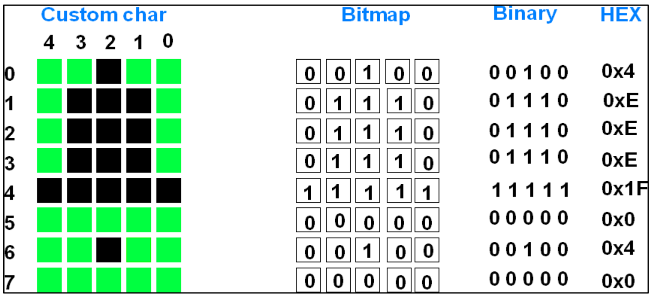

Fig. 4. Results of Custom Character

B. Building a Custom Robot Car Kits with a Basic Framework

Makers, students, and enthusiasts interested in robotics are driving the rising popularity of robot car kits. These kits provide an excellent foundation for constructing a unique robot car, suitable for everything from basic line-following robots to complex autonomous automobiles.

Popular robot vehicle kits are often more complicated than a base plate and a couple of DC motors. There are often holes on the bottom plate for attaching parts like a microcontroller (like an Arduino), sensors, and other electrical modules[13], [28], [29].

The first stage in this article's creation of a bespoke robot vehicle from such a kit is selecting the supplementary parts that will be required. In this case, the motors and their speed and direction may be controlled by a motor controller, which can power a rechargeable battery or set of batteries.

An Arduino microcontroller may manage the motor controller and other electronic components. The kit's base plate often has mounting holes for an Arduino board, facilitating the installation and securing it in place.

After selecting and assembling the parts, the next stage is to write code for the Arduino board that will direct the motors and other sensors and modules. Arduino's programming language is based on C/C++ and is popular among makers and hobbyists because of its accessibility.

Now that the robot car's bones are in place, it may get new sensors for obstacle avoidance, line following, and computer vision. The only thing holding a builder back is their creativity.

The choice of power source is crucial while designing a one-of-a-kind robot automobile. The motors need a voltage of 3-9 V DC to function correctly; thus, the supply must be selected appropriately. A rechargeable battery pack is preferable since it can provide adequate power for the motors and other electrical components and can be charged quickly and easily.

Fig. 5. Body Robot Car

1) The Versatility of DC Motors in Building Custom Robot Car Kits

Due to their simplicity and control, DC motors are famous for bespoke robot vehicle kits. Direct current motors feature two electrical contacts: positive and negative. The voltage between these two connections creates a magnetic field that rotates the motor.

DC motors in robot car kits provide adaptability. From amateur projects to major robotic systems, they may be employed. They are affordable and straightforward to locate, making them popular with beginners and seasoned builders.

DC motors in robot car kits may cause various complications. Motor failure is a typical issue caused by overheating, mechanical stress, and electrical faults.

Selecting the suitable motor, power supply, and motor control methods will increase performance.

DC motors in robot car kits also have additional challenges to consider. The gear ratio must be selected to obtain the necessary speed and torque, and the motor must be appropriately installed and aligned to reduce mechanical stress [30].

Custom robot vehicle kits with DC motors are popular. Builders can keep their robot vehicle kits running well by knowing typical faults and fixing them.

2) L298N Dual H-Bridge Motor Controller

The L298N Dual H-Bridge Motor Controller, which is widely used and powerful, regulates the velocity and rotational direction of a motor. It is used in kits for making robot cars and other motorised creations. The LED arrays, relays, and solenoids are all controlled by the L298N motor driver.

The L298N's dual H-bridge configuration is significant. It regulates the speed of two separate motors. The motor controller can regulate current in both directions thanks to the four transistors in each H-bridge.

The L298N is rated for 2A current and 5V-35V motor voltages, as shown in the table. You can use it with the motors from your robot vehicle kit. The 5V regulator in the motor controller can output 1A, which is more than enough current to run other 5V devices.

TABLE II. THE L298N DUAL H-BRIDGE MOTOR CONTROLLER: IDEAL FOR ROBOT CAR KITS

Parameter	Value
Motor channels	2
Operating voltage	5V to 35V
Peak current per channel	2A
Continuous current	1.2A
Maximum power	25W
Control signal voltage	5V to 7V
Logic circuit current	36mA
Built-in protection	Over-current, Over-temperature, and Undervoltage
Dimensions	43mm x 43mm x 27mm
Mounting holes diameter	3mm

Up to four motors may be connected to the L298N through its six screw connectors. The on-board 5V regulator may overheat and fail if more than 12V is supplied to the motors.

For robot car kits, the L298N is recommended because of its interoperability with the Arduino platform. The signals from a digital microcontroller can precisely regulate the speed and direction of a motor.

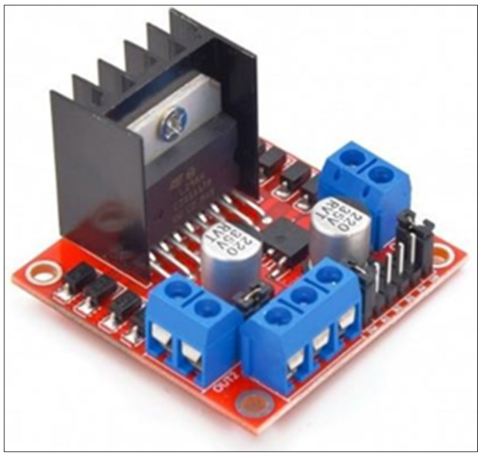

Fig. 6. Motor Driver L298N

3) Power Battery 9V

Building and using a robot vehicle kit requires power. 9V batteries are popular. Hobbyists and novices should use a 9V battery for tiny robot vehicle kits.

A robot vehicle kit powered by a 9V battery requires several considerations. First, connect the kit's battery. The kit's motor controller's input terminals receive the battery's positive and negative leads.

Choose a battery with a suitable capacity for the robot vehicle kit. Battery type is also crucial. Rechargeable batteries may be reused but may have a decreased capacity.

Low battery voltage might harm the motor controller or impair performance. Several robot vehicle kits include voltage monitoring or low-battery alerts.

Beginners can power a robot vehicle kit with a 9V battery. Robot vehicle kits may function well if properly connected and monitored for battery capacity and voltage.

C. Software Implementation

Arduino IDE, or Arduino Integrated Development Environment, is used to write and compile code into an Arduino module. This is the authorised Arduino software. The Arduino IDE has a code editor, a chat window, a text terminal, a toolbar with frequently used buttons, and a menu system. It communicates with and may be programmed through Arduino/Genuine hardware [20].

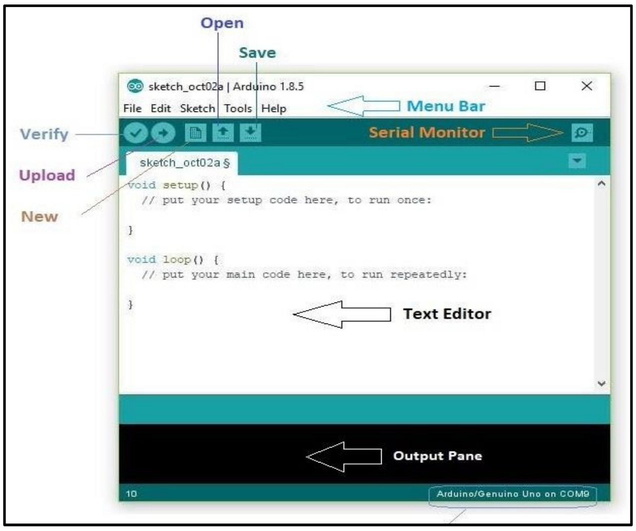

Fig. 7. Arduino IDE

As robot technology improves, robots may one day be used in fire stations, possibly replacing human firefighters. Such developments could increase efficiency in firefighting operations while minimising the risks to human lives. In this tutorial, we will explore using Arduino [21] to build a firefighting robot capable of detecting a fire and activating the water supply autonomously. This exercise will teach you how to construct a rudimentary robot to approach a fire and dispense water in the surrounding area. This fundamental robot serves as a stepping stone towards developing more sophisticated machines. So, let us embark on this exciting journey and begin building the firefighting robot.

1) System Circuit Design for Firefighting Robot with Sensor Integration

Firefighting robots are gaining popularity for their capacity to detect and extinguish flames in dangerous places. Sensor integration and circuitry design make these robots successful. This article discusses firefighting robot system circuit design with sensor integration.

Figure 4.1 depicts the firefighting robot system circuit. Four Arduino Uno digital ports (8, 9, 11) connect four sensors. They detect fire direction.

Port (11) connects the servo motor to spin the robot towards the fire. Motor drive ports (2, 3, 4, 5) govern robot movement.

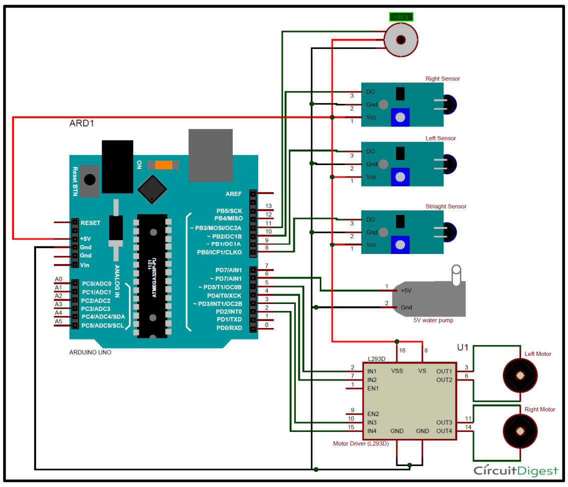

Fig. 8. System Circuit

The sensors measure the difference in fire and ambient temperatures. The motor drive moves the robot towards the flames. Arduino signals control the robot's direction and speed through the motor drive. The motor drive powers four motors that move the robot.

The power supply powers circuitry and motors.

The success of a firefighting robot with sensor integration depends on its system circuit architecture. Sensors, servo motors, and motor drives detect and extinguish dangerous flames. The robot can perform well in many conditions with proper design and integration.

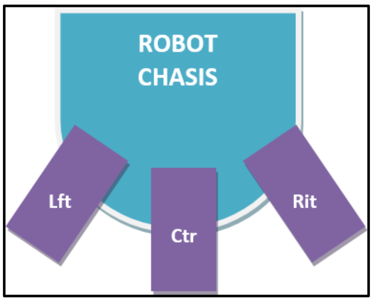

Fig. 9. Robot Design

IV. RESULTS

The development of a Firefighting robot is crucial for the safety of human life and property in case of a fire accident. In this study, we have successfully developed a robot that can detect flames and extinguish them using a CO2 cartridge. The robot is designed for indoor application and has obstacle avoidance capability to navigate around obstacles.

The robot's design is based on a robotic chassis, a common platform used in various robotic applications. However, the type of container used for the pumping system may vary depending on the robotic chassis used. In this study, a small aluminium can was used as the container for the pump system. In order to fill the container, we first inserted the pump inside. The servo motor used to steer the water flow into the can was then attached to the top of the structure. The servo motor was bolted to the chassis, and the servo fin was attached to the bottom of the container. The servo allows the container to be turned, allowing the flow of water to be directed in the desired direction. An Arduino board and a motor drive are in charge of operating the robot. The motor controller manages the robot's motion, while the Arduino board serves as an interface to the sensors and a controller for the pump. The robot has a flame sensor and two ultrasonic sensors to help it navigate hazards. The flame sensor used in this study is an IR flame sensor. It is based on the principle that a flame emits IR radiation, which can be detected using an IR receiver. The IR receiver used in this study has a built-in amplifier and a bandpass filter to detect only the IR radiation emitted by the flame. The output of the flame sensor is an analogue voltage that varies depending on the intensity of the flame's emitted

IR radiation.

A dynamic limit value is required to account for variations in lighting conditions to improve flame detection. This is because the flame's IR emission strength may be changed by the ambient light, which fluctuates throughout the day as the sun rises and sets. In this piece, we adjusted for variations in lighting by using a dynamic threshold setting. A light-dependent resistor measured the surrounding illumination and was used to modify the threshold (LDR).

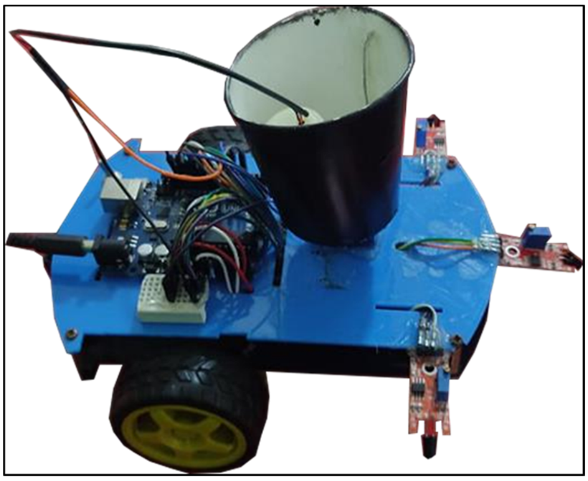

Fig. 10. Robot Design

TABLE III. THE CONTROL SEQUENCE OF FLAME SENSOR AND DC MOTOR IN FIREFIGHTING ROBOT

Control Sequence	Action
Flame Sensor	Fire Fighting Robot will not react when the sensor is not activated, and it will react when the sensor is activated.
Sensor Connection	Flame Sensor is connected to DC motor
Sensor State	Flame Sensor is OFF when fire is not detected and DC motor
Flame Sensor = 1	DC Motor = 0
Flame Sensor = 0	DC Motor = 1
DC Motor	Motor is connected to the driver motor and Arduino Uno
Motor State	Motor is ON when Flame Sensor is ON or OFF
Motor State	Motor is OFF when Flame Sensor is ON

After sensing a fire, the device will begin releasing water from the storage vessel onto the fire. The fire is doused with water, and a CO_2 cartridge is released to prevent reoccur. To release the CO_2 cartridge, a high starting torque power supply is required.

We have created a firefighting robot to sniff out fires and douse them with carbon dioxide. The robot can avoid obstacles and is intended for use inside. Depending on the robot's chassis, several pump systems may be installed. The robot can pick up the flame better by adjusting the threshold value depending on the brightness of the surrounding environment. To release the CO_2 cartridge, a high-torque servo motor is required

V. DISCUSSION

The design of a firefighting robot using Arduino IDE and an Infrared (IR) sensor module holds significant potential for enhancing fire emergency response and ensuring the safety of human lives and property. In the last few years, much study and development has gone into finding ways to use robots in firefighting. These attempts aim to develop and use better and more efficient ways to fight fires [1]. Firefighting robots play a crucial role in situations where human intervention may be too dangerous, providing assistance and support to firefighters by navigating through hazardous environments and locating sources of fire [4].

Incorporating an Arduino Uno microcontroller, a u-blox NEO-6Q GPS receiver module, and a u-blox LEON-GIOO GSM module in the firefighting robot's hardware prototype forms the foundation of its functionality [7]. The Arduino Uno microcontroller acts as the robot's brain, processing data from various sensors and controlling its movements and actions. The GPS receiver module enables the robot to determine its precise location, aiding in effective navigation through complex and large-scale fire scenes. The GSM module allows the robot to communicate its status and findings remotely, facilitating seamless coordination with human responders [8].

Using Infrared (IR) sensor modules in the robot's design enhances its ability to detect the presence of flames and identify potential sources of fire [3]. The IR sensors are particularly effective in distinguishing between real flames and other heat sources, thereby minimising false alarms and improving the robot's decision-making capabilities. Integrating adaptive fusion algorithms with the fire detection system further enhances the robot's accuracy and reliability in identifying and combating fires [3].

One of the key advantages of employing firefighting robots is their ability to access areas that may be inaccessible or too hazardous for human responders, such as confined spaces or buildings on fire [13]. These robots can work autonomously, reducing the risk to human lives and enabling more efficient firefighting operations [10]. Additionally, robots with multiple sensors, including IR sensors, can provide real-time data to incident commanders, enabling them to make well-informed decisions and allocate resources effectively [12].

The development of firefighting robots has also seen advancements in using IoT applications, enabling enhanced data sharing and communication between robots and human responders [5]. This integration of IoT technologies offers real-time updates and situational awareness to incident commanders, allowing for better coordination and resource allocation during fire emergencies [14].

Despite the promising advancements, challenges remain in the development of firefighting robots. Ensuring the reliability and robustness of these robots in harsh fire conditions is crucial for their widespread adoption. Additionally, continuous research and development are needed to enhance the efficiency and intelligence of these robots, enabling them to adapt to dynamic fire scenarios [15].

The design of firefighting robots using Arduino IDE and Infrared (IR) sensor modules represents a significant advancement in fire emergency response and human safety. Integrating robotics and advanced sensor technologies facilitates efficient and effective firefighting operations, allowing these robots to access hazardous areas and communicate vital information to human responders. With this article and innovation, in the future, firefighting robots are likely to play a big part in making fires safer and making it easier to respond to emergencies [19]. Further efforts are necessary to address the challenges of deploying these robots in real-life fire scenarios [22].

VI. CONCLUSIONS

The design of a firefighting robot using Arduino IDE and Infrared (IR) sensor modules holds tremendous promise in revolutionising fire emergency response and mitigating the risks faced by human responders. This innovative technology combines the power of robotics, advanced sensor systems, and IoT applications to create a competent and efficient firefighting solution.

Integrating Infrared (IR) sensor modules enhances the robot's fire detection capabilities, enabling it to identify flames accurately while minimising false alarms. Adaptive fusion algorithms further improve the robot's fire detection accuracy, ensuring rapid and effective response to fire incidents.

Firefighting robots offer numerous advantages, including their ability to access hazardous areas and confined spaces, reducing the risks human responders face. With their autonomous capabilities and multiple sensor systems, these robots provide critical real-time data to incident commanders, enabling better decision-making and resource allocation during fire emergencies.

Making sure people and their belongings are protected in the event of a fire makes the creation of a robot that can put out fires an absolute need. The article's authors have created a robot that can sniff out fires and put them out using a CO_2 cartridge. The robot is built with the capacity to avoid and go around obstacles, making it ideal for use in confined spaces. The robot is built on a standard robotic chassis, and the pumping system's container may change depending on the chassis. The pump system employed in this investigation was housed in a tiny aluminium can.

An Arduino board and a motor controller are responsible for the robot's operation. Infrared (IR) flame sensors were chosen because they operate on the premise that an IR receiver may pick up a flame's IR radiation. Using a dynamic threshold value, the fluctuation in the surrounding light was accounted for, allowing for more accurate flame detection. At the first sign of fire, the pump system is set in motion, and water is pumped from the container onto the flame while a CO_2 cartridge is released to prevent the fire from restarting.

Due to this article's success, we can see how valuable robots may be in the firefighting industry and other similar fields. The danger of injury or death during firefighting operations may be significantly reduced by using the robot, thanks to its capacity to avoid hazards, identify fires, and put them out from a safe distance. A high torque servo motor is required for the robot's CO_2 cartridge discharge mechanism to work correctly.

Despite the promising advancements, there remain challenges to overcome in developing and deploying firefighting robots. Ensuring the reliability and durability of these robots in extreme fire conditions is paramount. They must be made more intelligent and more malleable to changing fire conditions via ongoing R&D work.

The advancement of contemporary fire safety and emergency response has taken a significant leap forward with the creation of specialised firefighting robots. These robots can revolutionise firefighting practices, enabling firefighters to extinguish fires more efficiently and with reduced collateral damage, ultimately saving lives. As research and development in this field progress, it is becoming increasingly evident that firefighting robots will play a vital role in enhancing urban safety and the ability to combat fires effectively. Their integration into fire response strategies promises to make cities safer and better prepared to handle fire incidents, ensuring responders' and civilians' protection. The continuous evolution of firefighting robots holds great promise for the future of firefighting, fostering resilience and improved outcomes in the face of fire emergencies.

Improving firefighter safety and effectiveness is a significant goal of this article's robot firefighter development. Research in this field may proceed with an eye on creating robots that can function in the outdoors or under more demanding settings.

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