Robotic Fire Fighting Vehicle with GSM SMS And Call Alert

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Abstract- The increased number of fire accidents recorded worldwide has led to an increased demand for systems and methods to help reduce this increase and ensure that lives and properties are protected from the dangers of fire incidents. An essential consideration in this regard is the ability to detect and extinguish fire incidents at early stages to prevent further damages and reduce fatalities; this has led to the increased use of technology in firefighting incidents for fire detection, fire alarms, and fire extinguishers. This project is aimed at the design and implementation of a robotic fire fighting vehicle that will automatically detect the presence of fire at a distance of at most 63cm in front of it and 50 cm behind it, automatically navigate to where the fire is, and extinguish the fire using a water pump system without human interference and while extinguishing the fire, it will send an SMS within 10 seconds of activating the pump and a call alert within 20 seconds of starting the pump to the owner of the property where it is deployed.

Indexed Terms: Fire-Fighting, Robotics, IoT, GSM

I. INTRODUCTION

Technology today is fast evolving and has led to the automation of many processes and tasks to make life easier and safer for humans. In today's world, machines, otherwise known as robots, are being used to perform specific tasks that may be dangerous or difficult for humans to carry out efficiently [1]. As the days go by, there is an increase in the number of tasks being performed by robots, making robotics one of the fastest-growing aspects of technology today. The rate at which the number of fire accidents in residential buildings, offices, laboratories, and workshops is increasing is alarming. This is largely due to the increased number of electrical gadgets whose failures can trigger a fire outbreak, flammable solids and liquids in laboratories, workshops, and even residential buildings, electrical hazards, etc. Technology is rapidly growing and affecting almost every aspect of our lives. In situations of fire incidents, we need a technology that will help us detect this fire at its early stage, extinguish this fire without human interference, and also send an SMS and call alert to the property owners notifying them of any fire incident to reduce the number of casualties and lives lost during fire accidents. This is the motivation for this project.

A. Problem Statement

The level of damage caused by fire accidents in homes, offices, laboratories, factories, etc., demands that more ways of securing these facilities from fire incidents and outbreaks be developed. Placing humans in charge of detecting and monitoring buildings for fire incidents is not reliable enough. These humans may be unable to detect small levels of fire in specific locations at all times, especially at night when they are sleeping or when office buildings are closed for the day. Research carried out on fire outbreaks in Nigeria: a case study of Lagos state shows minimal fire management capacity in many public buildings. Most buildings that experience fire outbreaks do not have smoke/fire detectors or mechanisms to detect fire at its early stage [2]. Detecting any fire incident at its early stage is vital in fighting and reducing the damages caused by fire outbreaks; not only is early detection vital, but being able to put out a fire at this stage is key to reducing or eliminating the potential damages. This project is being built with these two vital points in mind to provide a solution to the increasing number of fire disasters and damages caused by late detection and extinguishment of fire at its early stage.

B. Aim of the Project

This project is aimed at the design and implementation of a robotic fire-fighting vehicle that has an embedded GSM SMS and call alert system with the following objectives;

1) To program an Arduino to enable communication between sensor modules and interconnected digital components.
2) To design and construct a robotic vehicle with flame detection abilities to detect fire within its vicinity and navigate automatically to where the flame is to extinguish the fire.
3) To implement a GSM SMS and Call alert system to notify home and office owners of fire detected by the robotic fire fighting vehicle.

C. Scope of the Project
This project is confined to the following scopes;
1) The robotic vehicle will be able to detect fire within a distance of 0-50cm in front and behind it.
2) The robotic vehicle will be able to automatically navigate to the detected fire, stop at a distance of about 5cm from the fire, and attempt to extinguish the fire using a built-in water pump system. In cases where the vehicle is too close to the fire, the robotic vehicle should be able to move back, creating a distance of about 5cm between itself and the fire.
3) Upon reaching where the fire is, the robotic vehicle should be able to send an SMS and call alert within 10 seconds and 20 seconds, respectively, after the fire extinguishing mechanism has been activated.

II. LITERATURE REVIEW

Over the past years' robots have been designed and constructed with the ability to extinguish fire; some of the robots are fully autonomous and can detect and extinguish a fire on their own without any human interference in the process, while some of the robots developed for firefighting are not fully autonomous as they still require the presence of humans to control the robots either using a remote control or their mobile phones, despite these advancements and the involvement of robotics in firefighting, in underdeveloped regions that are prone to fire accidents, the use of robotics for firefighting can be said to be almost non-existent this is largely due to how expensive it is to build most of these robots and the lack of adequate technological resources to carry out research or develop indigenous models of robots for firefighting.

In a similar work, Jayarman. G, Dr. N. Muthukumaran, Vanaja.A, and Santhamariammal.R developed a firefighting robot [3]. The robot uses a fire sensor module (flame sensor) to detect fire; after detecting fire, the robot moves to the fire and attempts to extinguish it using a 5V pump placed in a container with water on the top of the vehicle. In this project, only one flame sensor module and one gas sensor module were placed on the robot, limiting the robot's ability to detect fire from multiple directions.

In another similar work, Ihsan A. Taha, and Hamzah M. Marhoon designed and implemented a controlled robot for fire detection and extinguishing in closed areas using an Arduino [4]. In this project, a four-wheel car as a remote-controlled robot was developed. The robot first establishes a wireless connection through Bluetooth with an Android application that can be used to send motion commands to the robot. The robot has a camera placed on it to enable the user to monitor the robot's surroundings for fire, after which the user sends commands using the Android application for the robot to move and extinguish the fire. The water pump does not work automatically; it has to be commanded to do so by sending commands from the Android application to the robot. This project uses only one flame sensor and camera, meaning the user can only monitor fire directly in front of the robot and not in other directions. The robot still requires human intervention in monitoring and extinguishing fire, which means it cannot detect and extinguish the fire on its own except it is told to do so using commands from an Android application.

In another similar work, a fire-fighting robot using master-slave architecture was developed by Reeshma shaundra G, Belfin R.V, and Immanuel Alex Pandian S [5]. When fire is detected, the robot starts to move towards the fire, and its movement changes according to the direction of the fire as measured by IR sensors embedded on it. In this master-slave approach, a master robot is accompanied by a group of slave robots to make the process easier and faster. The master and slave robots are connected using the concept of swarm robotics, and they both coordinate to put off the fire. In this model, a fan was integrated to extinguish the fire; this is an unreliable method of extinguishing fire and could even increase the level of the fire as the fan can supply more oxygen to the fire, even though the slave-master approach could resolve the fire outbreaks in a shorter time, it will require more than one robot to be used at a time which will mean more cost. In this model, no IR sensor was placed

behind the robot, which means that the robot cannot detect fire behind it.
In another similar work, N. N. Mahzan, N. I. M Enzai, N. M. Zin, and K. M. Noh designed an Arduino-based home fire alarm system with a GSM module [6]. This robot uses an LM35 temperature sensor to detect the heat from fire, and an alert message will be sent to the user via a short message service (SMS) through a GSM module. When the system detects a temperature of 40°C or more, it will immediately display an alert notification on an embedded LCD and simultaneously send an SMS alert to the users. This project only serves as a fire alert system and does not have any provision in place for fire extinguishing; the system uses the temperature of its surroundings as a basis for sending an SMS alert to the users. In cases where the temperature of the surroundings gets to 40°C without the presence of fire, the system will send a false alert to the users despite no fire being detected in the building.

In another similar project, a multi-sensor-based fire-fighting robot with wireless control and a visual system was developed by Md. Mahmudul Hasan and, Nayeem Al-Tamzid Bhuiyan [7]. This project has two parts; the autonomous part and the remote-control part. The autonomous part is based on an Arduino mega, 4 Flame sensors, 2 Ultrasonic sensors, Fire extinguishers, 4 Motor and wheels, and 2 Motor drivers. The flame sensors used were placed on the robot's left, right, and middle positions so that if the fire occurs on any of these sides, it will go closer to the fire by moving left, right, or forward. The remote-control part of this project is based on a NodeMCU, motor and wheels, a remote-control application (Blynk), and an IP camera. The NodeMCU controls the robot's wheels using the Blynk application on a mobile phone controlled by the user. If a command is sent from the Blynk application, it will store the data on a server, and the server sends the data to the NodeMCU through wifi, then the NodeMCU commands the motor driver to move according to the given data. The autonomous mode of the robot can also be controlled (Switched on or off) using the blynk application. The IP camera on the robot was placed to allow users to view its surroundings as it operates so the user can know how to control the robot. In this model, no provision was made for detecting fire behind the vehicle. Since the blynk application communicates to the robot using servers, internet connectivity is required for the operation of the robot, and without this, the remote-control part of the robot cannot work, which means this robot cannot be deployed in places without internet access.

In another similar work, J Jalani, D Misman, A S Sadun, and L C Hong, developed an automatic fire-fighting robot with notification [8]. This fire-fighting robot was designed to search for fire in a small floor plan of a house, extinguish the fire, and return to the front of the house at last. When switched on, the robot will operate in auto mode; it will move randomly in the house, office, or any place it is deployed. During the auto mode, if no fire is detected, it will keep moving and scanning; meanwhile, if a fire is detected, it will move toward the fire source and activate the water pump to pump water to extinguish the fire. If the temperature of the fire site is above 40°C, the alarm will start ringing so that the operator can control the firefighting robot to go back and avoid damaging the vehicle. In this model, the robot constantly turns and scans for fire; this process consumes a lot of power and can lead to a quick discharge of the battery power even before fire is detected. There was no provision for a sensor behind the vehicle to improve its sensitivity in different directions, and the robot does not extinguish fire at 40°C as it withdraws from the fire and rings an alarm so the user can come to extinguish the fire themselves. Most fires occur at over 40°C, making this model ineffective in extinguishing fire for most occasions serving only as a fire alarm.

In another similar work, an Arduino-based fire fighter robot was developed by Sushrut Khajuria, Rakesh Johar, Varenyam Sharma, and Abhideep Bhatti [9]. The project consists of a user-controllable firefighter robot with a water tank and a gun for extinguishing fire. An RF remote was attached to the robot for remote operation and an RF receiver-based microcontroller circuit to operate the robotic vehicle and water pump. This robot also has a wireless camera mounted over it; this camera helps the user control the robot to move in different directions as required. The main limitation of this model is that it does not work autonomously and still requires human intervention and cannot operate in the absence of the user.

In another similar project, Komal N. Ambadkar, Vaishnavee A. Gorte, Shravasti M. Rekhate, Renuka

D. Nichit, Pratik A. Gaupal, and P. K .Khedkar designed a fire-fighting robot using Arduino [10]. The heart of the robot is a programmable Arduino UNO, which is connected to the fire-sensing unit. The fire sensing unit consists of a temperature sensor, smoke sensor, and gas sensor. The robot also has a wireless camera that will transfer the front view of the robot to a receiving unit, which is controlled by the user. The receiving unit consists of an XBEE Arduino computer and a camera receiving unit. By operating the GUI and looking at the front view of the camera the operator of the robot can operate the robot. On detection of the direction of the fire, the motors are used to move near the fire by driving the motors through the L298 driver module. When it is near the fire it stops and the fire is put out using a 5v water pump using commands from the operator. This model cannot detect fire behind the vehicle, and cannot be used to monitor fire behind the vehicle. The vehicle still depends on human operation through a mobile phone or computer and cannot operate autonomously to extinguish fire.

III. METHODOLOGY

The setup of this project consists of both hardware and software (Arduino programming in C/C++) implementation. The hardware part consists of the robot chassis, the Dc motors, L298N Driver module, GSM Module, Arduino UNO board, Arduino nano board, two 18650 batteries, 9V battery, a one-way switch, mini submersible water pump, servo motor and flame sensor modules. The other requirements for the project are; the glue needed to glue some of its parts together, the soldering iron, plastic to be used as a water tank and a laptop for programming the Arduino boards as well as the design of the circuit of the project. The methods and processes used in the realization of this project include the physical implementation, the programming of the robot, and the circuit design of the project. The whole process of the project is represented using a Gantt chart as shown in figure below.

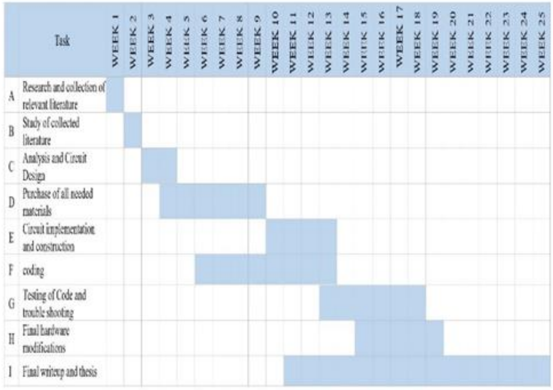

Figure 3.1: Gantt chart

A. Design Process

The design process of this project involves analyzing already existing works that are similar to the intended design, and then carrying out research on the needed components for the execution of the project, the design of the project was then created using Fritzing software which shows the interconnections between all the various components of the project. During the whole process of design and implementation, several modifications were made to the design to suit available materials and circumstances until the final design was obtained.

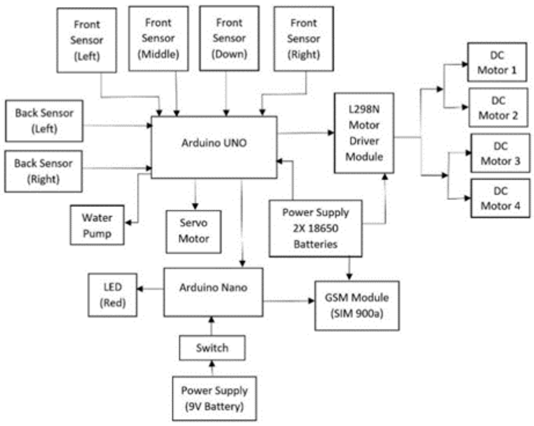

Figure 3.2: Functional Block Diagram

B. Implementation process

The full implementation of the project began after most of the components needed for the implementation were obtained. The first step done was to couple the robot chassis with the four individual motors and tires together, the L298N driver module which controls the direction of movement of the individual motors was then coupled to the lower vehicle chassis and the wires of the four individual motors connected to the L298N driver module.

C. L298N Driver module implementation

After the L298 Driver module was connected to the Arduino UNO board, the various directions of movements for the robot were programmed. Because the L298N driver module can be used to control only two motors, the left motors were connected together, and the right motors were also connected together, this was to enable to L298N driver module to control the direction of movement of the left and right motors of the vehicle. The left motors were connected to the 'OUT1' and 'OUT2' pins of the L298N driver module, while the two right motors were connected to the 'OUT3' and 'OUT4' ports of the L298N driver module. Connecting the motors this way, allows the left motors to be controlled using the IN1, IN2 (used to control the spinning direction), and ENA pins of the L298N driver module. The two right motors are then controlled using the IN3, IN4 and ENB pins of the L298N driver module. All four motors are powered through the L298N driver module by connecting the 12V pin of the L298N driver module to two (2) 18650 batteries.

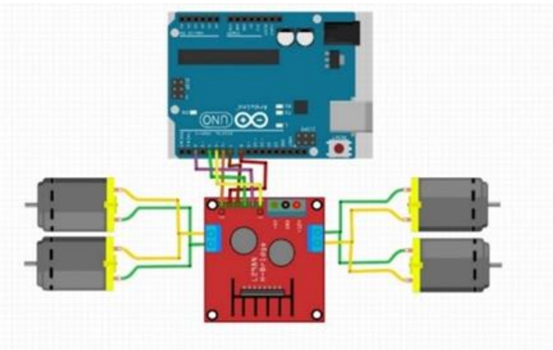

Figure 3.3: DC Motors and L298N implementation

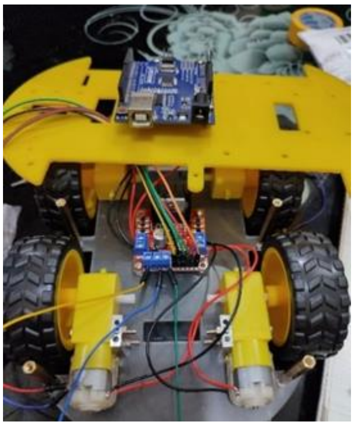

Figure 3.4: L298N driver module Implementation

bvcfcghvgghTo program the direction of movement of the robot, the IN1, IN2, IN3, IN4, ENA, and ENB pins of the L298N driver module were connected to the pins 2,4,7,8,5 and 6 respectively of the Arduino UNO board. The direction of movement of the robot is then controlled by setting the IN1, IN2, IN3, and IN4 to either high or low depending on the intended direction as shown in table 3.1 below, while the speed of rotation of the motors is controlled using the ENA and ENB pins, in this project the speed of the motors was set to 120 rpm.

	IN1 (Pin 2)	IN2 (Pin4)	IN3 (pin 8)	IN4 (pin 9)
Move forward	Low	High	Low	High
Move backward	High	Low	High	Low
Turn left	High	Low	Low	High
Turn right	Low	High	High	Low
Stop moving (remain static)	High	High	High	High

Table 3.1: Robot direction of movement

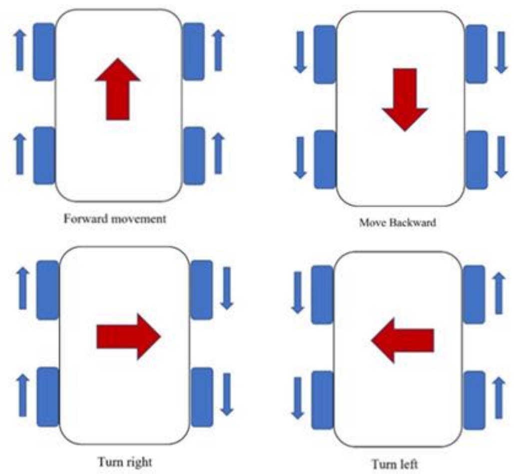

Figure 3.5: Direction of movement

D. Flame sensor module implementation

Two types of flame sensors were used; three (3) KY-06 flame sensor modules and three (3) LM393 flame sensor modules, both types of flame sensors are infrared sensors, they detect and respond to the presence of infrared rays. Three of the KY-06 flame sensors were placed in front of the vehicle to detect fire in three directions (left, middle and right), one of the LM393 flame detection sensor module was placed in front of the vehicle but attached to the lower chassis of the vehicle, while the other two of the LM393 flame detection sensor modules were placed behind the vehicle and attached to the lower chassis of the vehicle to detect fire behind the vehicle. Each flame sensor module can detect flame at about 60° around it, the three sensors in front ensure the robot can detect flame at about 180° in front of it, while the two back sensors ensure that the robot can detect flame at about 120° behind it. The KY-06 flame sensor outputs a high voltage from its digital output pin when fire is detected, while the LM393 flame detection module outputs a Low from its digital output pin when it detects fire as its digital output pin is always high when fire is not detected. The sensitivity of both types of flame sensor modules can be adjusted using a potentiometer attached to the flame sensor modules, adjusting the sensitivity allows the distance of detection of both types of flame sensors to be set, for this project the distance of detection is about 50cm. The digital output pins of the three front flame sensors attached to the upper chassis; left, middle and right, were connected to the A2, 9 and A3 pins of the Arduino UNO board, the digital output pin of the middle front sensor attached to the lower chassis was connected to the pin 12 of the Arduino UNO board, while the digital output pins of the back sensors; left and right, were connected to the A4, and A5 pins of the Arduino UNO board respectively.

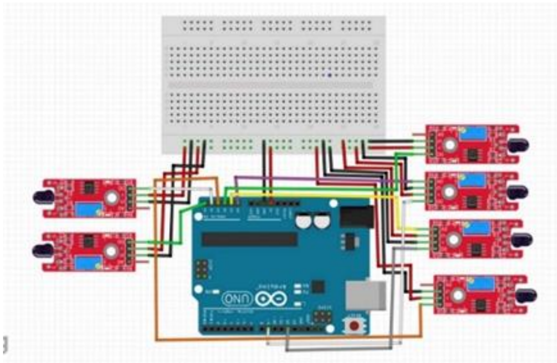

Figure 3.6: Flame sensors Implementations

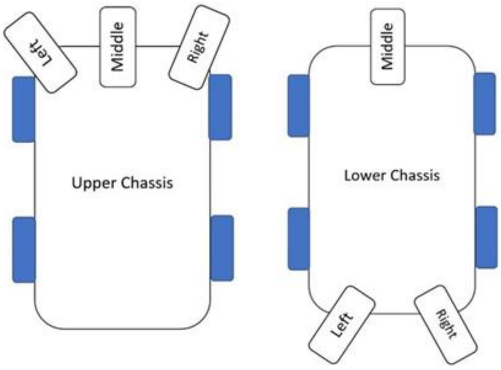

Figure 3.7: Position of the Flame Sensors on the robot chassis

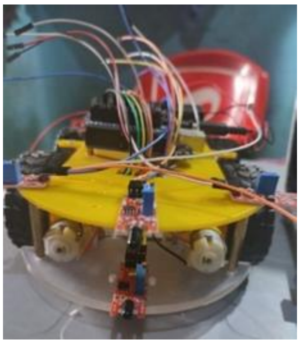

Figure 3.8: Robot after implementing the flame sensors

E. Integrating the flame sensor modules to the robot

After the six flame sensors were implemented on the vehicle by attaching it to the chassis and connecting its relevant pins to the Arduino UNO board with the help of an Arduino UNO shield, it was then important to integrate the flame sensor modules with the robot, this is to ensure that whenever fire is detected by any of the six flame sensor modules, the robot will move in the direction of the flame to extinguish the fire. In this project priority was placed on the front middle sensors so that if fire is detected across all the sensors, the robot will first move to extinguish the fire in front of it before responding to fire in other directions. When fire is detected in any of the two back sensors, the robot will turn at an angle of 360° corresponding to the direction the fire was detected to face the fire and attempt to extinguish it.

After integrating the flame detection sensor modules with the robot, it was then necessary to tell the robot when to stop if it detects and moves in the direction of fire, this is to prevent the robot from running into the fire. The two middle flame sensors in the front of the vehicle were used to tell the robot when to stop using the analog pins of the sensor modules, the flame sensor modules respond to the intensity of the fire by producing values from their analog output pins that match bit values between 0 and 1024. The robot was programmed to stop if the value of the intensity of fire becomes 25, increasing the sensitivity of both types of sensors will demand that this value be reduced as the values are dependent on the sensitivity of the flame sensor modules. The analog pins of the middle sensors in front were connected to the A0 and A1 pins of the Arduino UNO board respectively, it is from these pins that the analog values used to control when the robot stops are obtained.

F. Integrating the water pump system with the robot

The water pump system was integrated into the robot using a 5v mini submersible water pump, a water pipe, and a servo motor. The servo motor was integrated to move the nozzle of the water pipe during pumping action between 0° and 120 ° in front of the vehicle to spread the water. The servo motor was programmed to always be at 90° whenever the robot is turned on and then spreads the water by moving the nozzle between 0° and 130°. The digital input pin of the servo motor was connected to pin 10 of the Arduino UNO board, while the positive pin of the water pump was connected to pin 11 of the Arduino UNO board. The servo motor is powered through the 5V pin of the Arduino UNO board, whenever the robot detects fire in any of the three directions, it automatically moves towards the direction of the fire detected and stops when the analog values of the two front middle sensor modules are below the programmed value. When it stops, the water pump is activated and the servo motor begins moving the water nozzle between 0° and 130° to spread the water during water pumping until the fire is extinguished then the pumping action is stopped.

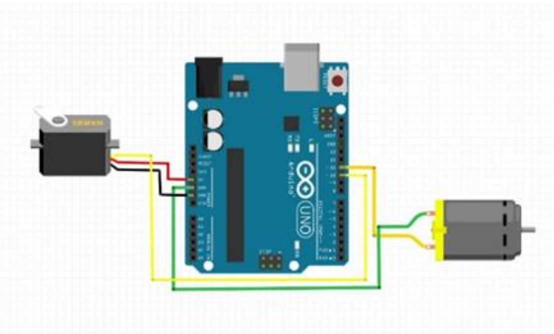

Figure 3.9: Water Pump system implementation

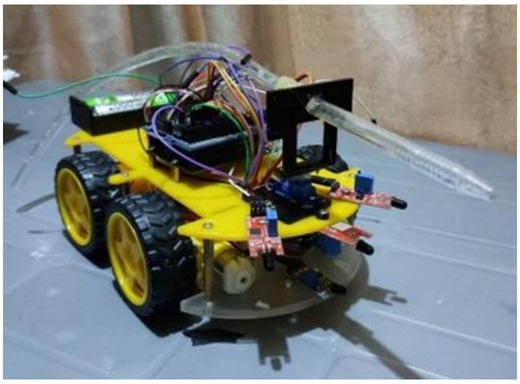

Figure 3.10: Robot after Implementing the Pumping System

G. Implementing the GSM module

The GSM module used for this project is the SIM 900a GSM module, the purpose of the GSM module in this project is to send an SMS and a call alert to the user whenever fire is detected in their property. The implementation of the GSM module was done using an Arduino nano board, a one-way switch, a red LED, and a 9V battery to power the Arduino nano board through its Vin pin. The GSM module was powered using the two (2) 18650 batteries that power the entire robot. The transmit and receive pins of the GSM Module were connected to pins 9 and 10 of the Arduino UNO board, and the positive pin of the red LED was connected to pin 4 of the Arduino UNO board.

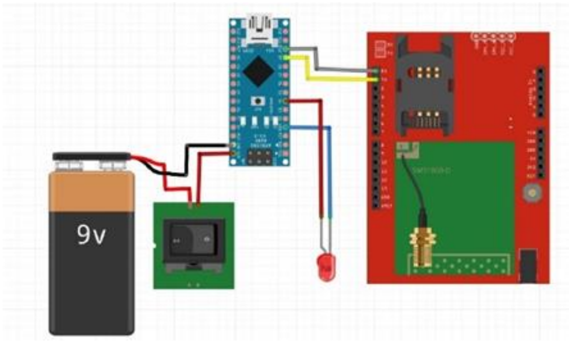

Figure 3.11: GSM module implementation

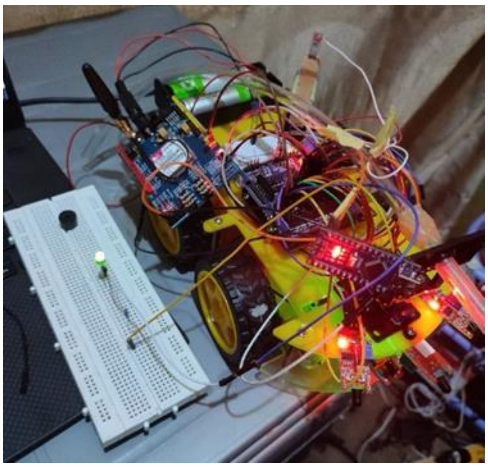

Figure 3.12: Robot with GSM Module Implementation

G. Integrating the GSM module with the robot operation

After the GSM Module was implemented, it was then integrated with the robot. The GSM module was programmed to send an SMS Alert and a call alert to a mobile phone number. A duly subscribed and registered SIM card of any mobile operator can be inserted into the GSM module to send the SMS and call alert, the Arduino Nano which controls the GSM module was connected to the Arduino UNO board of the robot by connecting the pin 5 of the Arduino nano board to the pin 3 of the Arduino UNO board. Whenever the robot detects fire in any direction and moves to the fire, it stops to activate the pumping system and while the pumping system has been activated, the Arduino UNO then sends a high voltage signal (5v) to the Arduino nano board through the interconnected pins, upon receiving this voltage signal, the Arduino nano then triggers the GSM module to send an already programmed message to the programmed mobile phone number of the owner of the property using the inserted mobile SIM card. For this project, the programmed SMS message to be sent is "Hello Jonah There is Fire In your office".

H. Full integration of all parts of the robot

After all, the individual parts of the project were implemented, the parts were then integrated to get the complete intended functionalities of the project, the water pump was placed in a plastic tank that was attached to the upper chassis of the vehicle. Before placing the water tank on the chassis four plastic bottle covers were used to provide the seat on which the tank was to be placed, and the battery slot housing the two 18650 3.7v batteries powering the robot was attached to the back of the water tank, the GSM module was attached to the side of the water tank, the Arduino Nano board was placed at the back of the robot directly on the upper chassis and below the water tank, while the Arduino UNO board which has an Arduino UNO Shield mounted on it to enable connection of all the sensor modules and servo motor was placed at the middle of the robotic vehicle on the upper chassis. The complete implementation of the project is shown in the diagram below.

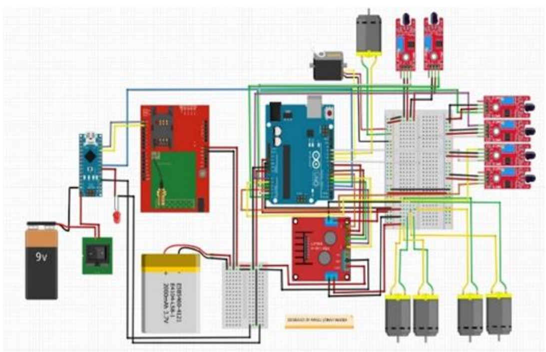

Figure 3.13: Full implementation of the project

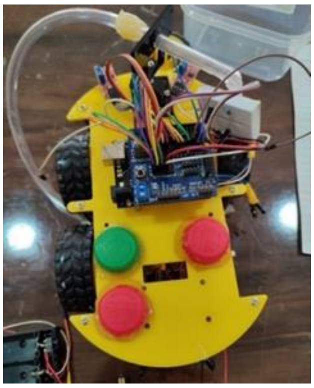
Figure 3.14: Robot while creating a seat for placing water tank

I. Programming and other processes

Several other processes were involved during the design and implementation of this project some of which includes; Soldering of wires and connections on the motors, water pump, and broken infrared sensors from the flame sensor modules, the use of a glue gun to glue most of the components in the desired positions such as the water tank seats, the waters tank, the battery slots, the Arduino nano board, and the one-way switch for the GSM module part of the robotic vehicle. After implementation, the robot was then programmed through the Arduino IDE by uploading the programmed code onto the Arduino UNO and Arduino IDE boards of the robotic vehicle, the code for the Arduino UNO was 223 lines including the spaces added while that of the Arduino nano was 40 lines of codes including the added spaces. The entire process of the design and implementation of this project did not strictly follow the scheduled plan as shown in the Gantt chart of Figure 3.1, because during the implementation of this project, a lot of troubleshooting was done to ensure the robot operated as intended, this involved programming and re-programming, changing of sensor positions, use of multiple batteries, etc.

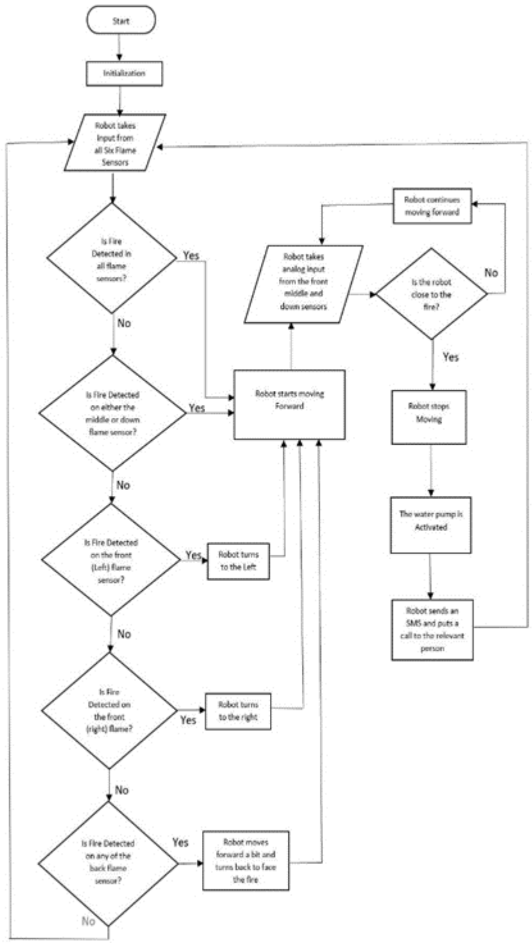

Figure 3.25: Flow Chart

IV. RESULTS AND ANALYSIS

All the individual parts of the project integrated together produced the desired functionalities to fulfill the objective of this project within the scope laid out in the first chapter of this report. The entire robotic vehicle was designed and implemented to serve two main functions; as an alert system for fire incidents, and as a mini firefighter in cases of small fire outbreaks. The entire project design was achieved using Fritzing software.

A. Power supply testing

The robot is powered using two (2) 18650 batteries of 3.7v with a rating of 8800mah. The 18650 batteries directly power the SIM GSM module, the Arduino UNO board, and the L298N driver module. During operation the GSM module consumes 26mA and 23mA when idle, the Arduino UNO consumes 11.45mA when idle and 42mA when in full operation, while the L298N driver module consumes 36mA during operation and 21mA when idle. The total amount of current consumed during operation by the robot is 104mA while when it is idle it consumes 55.45mA therefore during full operation the battery can sustain the robot for 8800mAh/104mA (84 hours) while when idle it can sustain the robot for 8800mAh/55.45mA (158 hours).

B. Fire Detection Distance Test

The robot was tested to see the maximum distance for which it can detect candle fire from all directions, left, right, front, and back of the robot, and the distance away from the fire at which it stops. The distances obtained are tabulated below.

Table 4.1: Fire detection test

S/N	Direction	Distance (cm)
1	Front	63
2	Back	45
3	left	57
4	Right	55
5	stop	17

C. GSM SMS and Call alert test

During the test, the robot sends an SMS alert within 10 seconds of activating the water pump, and a call alert is made when the pumping has persisted for 20 seconds making the total time for the call and SMS alert to be sent about 30 seconds after pumping has started.

D. Fire Extinguish Test

The robot was tested to extinguish candle fire when detected from the front sensor at different distances and the time it takes for extinguishing the fire was tabulated.

Table 4.2: Fire Extinguish Test

S/N	Distance (cm)	Time (s)
1	60	10
2	50	8
3	30	5
4	25	4

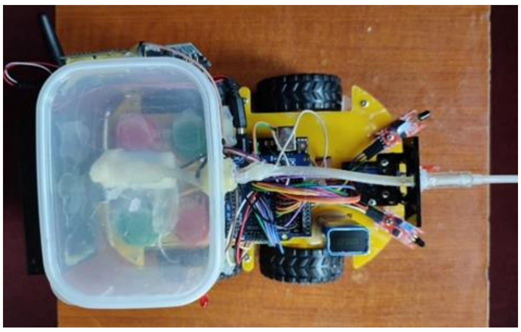

Figure 4.3: Top View of the robotic vehicle

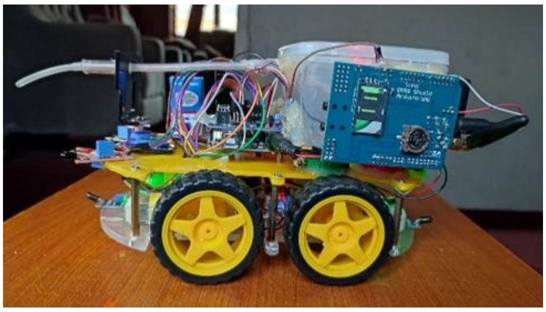

Figure 4.4: Left side view of the robotic vehicle

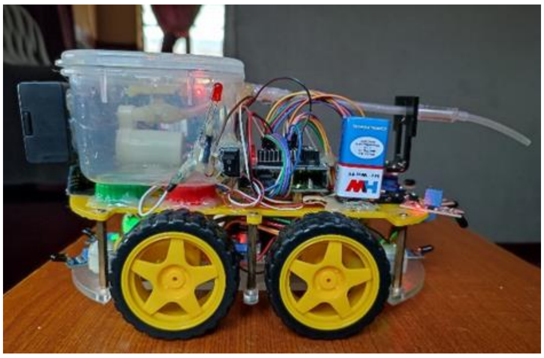

Figure 4.5: Right side view of the robotic vehicle

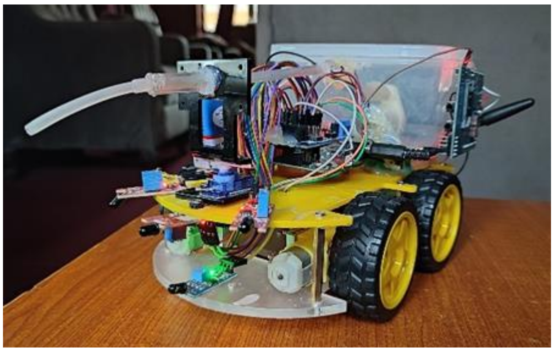

Figure 4.8: An inclined front view of the robotic vehicle

Figure 4.9: An inclined back view of the robot

E. Operation of the Robot

When the robot is turned on, all its sensors get activated and the robot starts taking inputs from all six flame detection sensor modules, priority is placed on the front middle sensor so that if fire is detected on all sensors, the robot moves to extinguish the fire in front of it before turning to other directions, the robot continuously takes input from all the sensors. If fire is detected in any of the front sensors, the robot turns in the direction of the fire and then moves forward towards it, if fire is detected behind the robot using any of the two back sensors, the robot turns 180° through either the left or right direction depending on which sensor module fire is detected, after turning 180° it then moves forward towards the fire, whenever the robot moves forward towards the fire, it takes analog inputs from the two middle sensor modules in front to detect the intensity of the fire, once it gets close enough to the fire, the robotic vehicle automatically stops, it then automatically activates the water pump. When the water starts pumping, the servo motor moves the nozzle between 0° and 130° to spread the water as it pumps, while the water is pumping, the GSM module is then triggered to send an SMS alert to the owner of the property notifying them of the fire outbreak in their property and after few seconds if the fire persists, a call alert is made to the owner of the property this is for situations where the owner does not quickly notice an SMS on their mobile phones. When the fire has been extinguished, the robot stops pumping the water and then continues taking input from all the sensors to detect fire.

V. SUMMARY AND CONCLUSIONS

The use of robots to aid in human operations, and provide solutions to several problems is becoming more popular by the day, and when it comes to fire outbreaks and disasters, this project which is a robotic fire-fighting vehicle that can be deployed indoors in laboratories, workshops, offices, libraries, and any other property where fire outbreak is to be prevented to serve as a solution to the early detection of fire and to send an SMS and call alert to users. The robot will also attempt to extinguish the fire except in situations where the fire becomes too big for the robot to handle, in such cases, the robot would have already sent an SMS or call alert to the property owner. More ways and methods of providing solutions to this problem should be developed and alongside robots like this, many lives and property will be protected from fire disasters.

A. Achievements
In this project, an Arduino-based firefighting robot was successfully designed and implemented to serve as a solution to the problem of increasing number of lives and properties lost due to fire outbreaks and disasters the objectives fully achieved in this project are;
1) The design and construction of a robotic vehicle that can detect fire within the property it operates, navigate automatically to where the fire is, and start pumping water to extinguish it.
2) The design and implementation of a GSM SMS and Call alert system that will notify property (homes, offices, etc.) owners of fire accidents within their property even during their absence.
3) Proper study and understanding of how to interface sensor modules with an Arduino board, and also program an Arduino board to enable communication between the sensor modules and other digital components.
4) The design of a robotic firefighting vehicle that is cost-effective and can be used to protect lives and properties that are far greater in value than the entire cost of constructing the project. Fire incidents can cause losses running into millions of naira and this can be avoided by using a project like this to detect fire at early stages preventing such huge losses as the case may be.

B. Future Scope
During the research stage of this project, a lot of other similar works designed to perform a similar function with either similar or fewer features were discovered. A unique feature of this project is the flexibility it provides its users to decide on whether the robot will serve just as a fire extinguishing system or as both a fire extinguishing system and a fire alert system as the user can simply switch off the fire alert part of the robotic vehicle. Several modifications and additions can be made to improve this project, some of which include;
1) Instead of tires, tracks can be used to increase the durability of the project especially when it is to be used or placed in locations that can cause damage to its tires, as tires can easily get damaged.
2) The robot can be enhanced by interfacing it with a camera so that the property owner can view the robot's surroundings remotely when it is in operation wherever they are.
3) To increase the distance of sensitivity of the robot to fire, the infrared flame sensors can be upgraded to ultraviolet flame sensors which can sense fire at a longer distance.
4) Bigger components such as the chassis and the tank can be used to increase the size of the robot as well as the amount of water it can hold so that it can be used for bigger scenarios.
5) A water level detector can be installed in the water tank of the robotic vehicle so that whenever the robotic vehicle sends an SMS alert to the owner it can also send the water level of the tank as well.
6) In cases where fire is detected in all the sensors, the robot can be modified so that priority should be placed on the intensity of the fire and not the direction of the fire, this can be achieved by using bigger microcontroller boards with multiple pins and durability.
8) Alongside a GSM alert system, a fire alarm system can also be included in the project to alert neighbors of fire outbreaks.

C. Limitations
The limitations observed in this project include;
1) The robot cannot detect fire at longer distances beyond 50cm due to the limited range of detection of the infrared flame detection sensor modules, this can be solved by using ultraviolet flame sensors, but they are more expensive and will increase the overall cost of the project.
2) The robot cannot last long during pumping action as the water tank provided is small in size and the water will run out quickly. In a bigger model, bigger water tanks can be provided.
4) The robotic vehicle can only be used indoors as the infrared sensor modules respond to the infrared rays coming from the sun when used outdoors.

D. Problems encountered and solutions
During the entire process of design and implementation of this project, certain problems were encountered, these include;
1) Most of the components and materials used in the project were imported which led to a huge delay in the project due to the time it took for the ordered components to arrive in the country.
2) Several sensors were burnt, while some had their infrared sensors broken and had to be resoldered back to their positions and the burnt sensors were replaced with new ones.
3) In the course of integrating the whole project together, there were times when the robot did not operate as intended due to one or two connecting cables not being tightly fixed into the pins of the

Arduino shield this was difficult to identify as there were many cables and parts integrated together.
4) The project was programmed and re-programmed countless times to achieve the desired outcome This was time-consuming due to the complexity of the codes as the number of parts integrated was much.

E. Conclusion
The entire process of design and implementation of this project was a very interesting one, the project will improve the safety of indoors, from fire incidents and contribute positively to reducing the number of lives, property, and infrastructure that are lost daily due to fire incidents. By placing this project in multiple infrastructures, a lot of fire incidents will be detected at early stages, giving the users of the property an advantage of time to quickly alert firefighting agencies and prevent fire disasters.

REFERENCES

[1] Built in, "Robotics," Built In, 21 July 2021. [Online]. Available: https://builtin.com/robotics. [Accessed 21 July 2021].

[2] A. A. Umanah, K. Ibe and I. M.Rukewe, "Statistical Analysis of Fire Outbreaks in Homes and Public Buildings in Nigeria: A case study of Lagos State," *International Journal of Engineering Research and Advanced Technology (IJERAT),* vol. 4, no. 8, p. 29, 2018.

[3] Jayaraman.G, N. Muthukumaran, Vanaja.A and Santhamariammal.R, "DESIGN AND ANALYSIS THE FIRE FIGHTING ROBOT," *International Journal of Emerging Technology and Innovative Engineering,* vol. 5, no. 9, pp. 2,4, 2019.

[4] Ihsan A. Taha and Hamzah M. Marhoon, "Implementation of Controlled Robot for Fire Detection," *TELKOMNIKA,* vol. 16, no. 2, pp. 654-664, 2018.

[5] Reeshma shaundra G, Belfin .R.V and Immanuel Alex Pandian S, "FIRE FIGHTING ROBOT USING MASTER-SLAVE ARCHITECTURE," *Journal of critical reviews,* vol. 7, no. 04, pp. 4212-4218, 2020.

[6] N N Mahzan, N I M Enzai, N M Zin and K S S K M Noh, "Design of an Arduino-based home fire alarm system with GSM," *Journal of Physics,* vol. 10, no. 01, pp. 1-8, 2018.

[7] Md. Mahmudul Hasan and Nayeem Al-Tamzid Bhuiyan, "A multi-sensor based fire fighting robot with wireless control and visual system," *Recent Research in Science and Technology,* vol. 12, no. 10, pp. 6-13, 2020.

[8] J Jalani, D Misman, A S Sadun and L C Hong, "Automatic fire fighting robot with notification," *Materials Science and Engineering,* vol. 12, no. 02, p. 637, 2019.

[9] Sushrut Khajuria, Rakesh Johar, Varenyam Sharma and Abhideep Bhatti, "Arduino Based Fire Fighter Robot," *International Journal of Scientific Engineering and Research (IJSER),* vol. 05, no. 05, pp. 124-125, 2017.

[10] Komal N. Ambadkar, Vaishnavee A. Gorte, Shravasti M. Rekhate, Renuka D. Nichit, Pratik A. Gaupal and P. K .Khedkar, "Fire Fighting Robot Using Arduino," *International Research Journal of Engineering and Technology (IRJET),* vol. 06, no. 04, pp. 3577-3578, 2019.