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Original Article

Introducing Firefighting Robot Utilizing GSM Technology

Md. Shawkut Ali Khan
Department of Mechanical Engineering, City University, Birulia, Savar, Dhaka, Bangladesh.

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Abstract: *A fire incident is a catastrophic event that has the potential to result in fatalities, destruction of property, and long-term physical impairment for the individuals involved. Additionally, they may have enduring psychological trauma. Firefighters have the main responsibility of managing fire emergencies, however they frequently face increased dangers while putting out fires, particularly in perilous settings like nuclear power plants, petroleum refineries, and gas tanks. In addition, they encounter additional challenges, especially when dealing with fires in confined and constricted areas. This requires thorough exploration of the debris and obstructions within the buildings in order to extinguish the fire and rescue any individuals in danger. Technological improvements can be employed to aid firefighting operations, which are characterized by significant obstacles and hazards. Hence, this study outlines the creation of a firefighting robot named FFR, which has the capability to suppress fires without requiring firefighters to face avoidable hazards. The FFR is specifically built to have a smaller size compared to other traditional fire-fighting robots. This is done to facilitate easy entry into small locations and allow for a more effective smothering of fires in limited spaces. The FFR is additionally outfitted with an ultrasonic sensor to avert collisions with obstructions or nearby objects, while a flame sensor is affixed for the purpose of fire detection. As a result, FFR showcased its capacity to autonomously detect fire spots and extinguish fires from a specific distance. The FFR is designed to autonomously detect the position of the fire and come to a halt at a maximum distance of 40 cm from the fire.*

Keywords: *Fire Incident, Fire Fighters, Firefighting Robot, Sensors.*

I. INTRODUCTION

A robot is an autonomous device that carries out tasks often associated with humans or machinery assigned with repetitive or adaptable sequences of operations. Multiple studies have demonstrated the advantageous use of robots in several fields such as medicine [1], rehabilitation [2–6], rescue operations [7, 8], and industry [9]. Throughout time, robotics has been implemented in diverse sectors. Industrial robots are versatile manipulators specifically intended for handling specialized materials, components, tools, or devices. They utilize programmable movements to carry out a wide range of activities [10].

Aligned with the Fourth Industrial Revolution (4IR), there is a need for a unified system capable of overseeing, facilitating communication, and integrating various robots, irrespective of their types and specifications. Machine learning has sparked increased interest in robotics, yet only a fraction of recent advancements in robotics can be attributed to machine learning. Robotics development initiatives in recent times have included machine learning techniques [11–15] to enhance the cognitive abilities of robots. This will enhance efficiency in the industrial sector while simultaneously decreasing expenses and electronic waste in the long term. Ongoing research is focused on the utilization of humanoid robots to reduce injuries and fatalities among firefighters, while also enhancing productivity, safety, efficiency, and work quality [16].

Robots can be categorized into various groups, including tele-robots, telepresence robots, mobile robots, autonomous robots, and Android robots. A telepresence robot is akin to a telerobot, but it distinguishes itself by offering feedback through video, sound, and other data. Therefore, telepresence robots are extensively utilized in several sectors that necessitate monitoring capabilities, including child nursery and education, as well as enhancing the social and daily activities of older individuals [17, 18]. A mobile robot is specifically engineered to autonomously explore and execute tasks, without the need for direct human involvement [19, 20]. Autonomous robots have the ability to carry out tasks on their own and obtain power from the surroundings. In contrast, android robots are designed to imitate people [21].

This paper presents a proposal for a firefighting robot. This robot primarily serves as an autonomous support vehicle designed for the purpose of locating and suppressing fires. There are multiple preexisting categories of vehicles designed for the purpose of combating domestic fires and extinguishing wildfires [22]. The robot we propose is designed to operate autonomously or be commanded remotely. Utilizing these robots enables the execution of fire detection and rescue operations

with enhanced safety measures, eliminating the need to expose firefighters to hazardous and perilous circumstances. Put simply, robots can decrease the necessity for firefighters to enter hazardous circumstances. Moreover, the robot's compact dimensions and automated control enable its utilization in confined and restricted areas with perilous conditions, such as tunnels or nuclear power plants, in the event of a fire [23, 24]. Thermite and FFR are two fireman robots that are now in operation and have gained significant popularity in several industries. Thermite, developed by Howe and Howe Technologies Inc., is a firefighting robot equipped with a remote control system, enabling it to work at distances of up to 400 meters.

The system has the capacity to deliver a maximum of 1200 gallons per minute (gpm) of water or 150 pounds per square inch (psi) of foam. The dimensions of this robot are 187.96 cm in length, 88.9 cm in width, and 139.7 cm in height. This robot utilizes a diesel engine to provide up to 25 brake horsepower (18.64 kilowatts) of power. The primary element in the construction of this robot is a versatile nozzle that can spray in multiple directions. This nozzle is supported by a high-capacity pump capable of delivering 600 gallons per minute (2271.25 liters per minute). This robot is specifically engineered for deployment in high-risk environments, such as aircraft fires, manufacturing facilities, chemical plants, or nuclear reactors.

A FFR, or Firefighting Robot, is an autonomous firefighting vehicle operated by a sole operator using remote control. The device suppresses fires autonomously, utilizing a hydraulic arm that propels water with significant force up to a distance of 55 meters. The vehicle is capable of transporting 1800 liters of water and 600 liters of foam in its two built-in tanks. The FFR coating has the ability to endure a critical temperature of 250^{o}C and heat radiation of 23 kW/m for duration of 30 minutes. A little and efficient fireman robot has been created in this research. The robot is referred to as FFR, an abbreviation for Rescue Robot. This robot possesses the ability to effectively avoid obstacles, conduct thorough searches, and successfully extinguish fires. Moreover, this robot has the capability to enhance the productivity, safety, efficiency, and quality of the assigned task. FFR exhibits greater compactness and flexibility in comparison to both thermite and FFR. FFR also offers the benefit of maneuvering via compact entrances or tight spaces.

II. MATERIALS AND METHODS

A. L298 Motor Driver

A high power motor driver module for DC and stepper motors is the L298N Motor Driver Module. An L298 motor driver integrated circuit and a 78M05 5V regulator make up this module. Up to four DC motors or two DC motors with directional and speed control can be operated by the L298N Module.

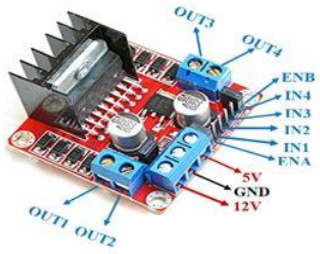

Figure 1: Motor Driver

a) Pins of L298 Motor Driver IC

Table 1: Pins of L298N Motor Driver

S. No	Pin Name	Description
1	IN1 & IN2	Motor A input pins. Used to control the spinning direction of Motor A
2	IN3 & IN4	Motor B input pins. Used to control the spinning direction of Motor B
3	ENA	Enables PWM signal for Motor A
4	ENB	Enables PWM signal for Motor B
5	OUT1 & OUT2	Output pins of Motor A
6	OUT3 & OUT4	Output pins of Motor B
7	12V	12V input from DC power Source
8	5V	Supplies power for the switching logic circuitry inside L298N IC
9	GND	Ground pin

B. 5V Relay Module

A relay is an electromagnetic switch that is used to join two circuits magnetically and electrically delay them. Relay driver receives the signal from the Arduino and begins operating upon it. An electrical circuit that operates at a very high voltage is often interfaced with an electronic circuit that operates at low voltage. For example, a hand-off can switch a 230V AC mains circuit by making a circuit with a 5V DC battery. This allows a small sensor circuit to operate an electric knob or fan, for example. Information and yield are the two sections that make up a transfer switch. When a small amount of voltage from an electrical circuit is linked to the loop in the information area, an attracting field is created. The working voltage is the name given to this voltage. Used transfers are typically available in a number of working voltage arrangements, including as 6V, 9V, 12V, 24V, and so forth. Three contactors are involved in a simple hand-off: normally closed (NC), routinely open (NO), and normal (COM).The COM is connected to NC at no info express. The transfer curl charges and the COM switches to a NO contact at the moment the working voltage is applied. There are other transfer configurations available, such as DPDT and SPDT, each of which has a different number of changeover contacts. It is possible to turn on the electrical circuit by using a suitable combination of contactors. Transistors act as intensifiers, allowing the base lead to receive enough current to create an increasingly strong current stream from the transistor's emitter to the collector.

Figure 2: 5V Relay Module

a) Pin Description of 5V Relay Module

Table 2: Pin Description of 5V Relay Module

Pin Name	Descriptions
DC +	Positive supply voltage
DC -	Ground
IN	Relay control port

C. Water Pump

This inexpensive little submersible water pump runs on 12 volt direct current. It's very straightforward to use and quite basic. To begin pumping water, just submerge the pump in water, attach an appropriate pipe to the output, and supply 12V to run the motor. Excellent for constructing scientific projects, fire extinguishers, firefighting robots, waterfalls, fountains, plant watering systems, etc.

Figure 3: Water Pump

D. DC Gear Motor

An electrical machine that rotates and transforms direct current (DC) electrical energy into mechanical energy is called a motor. When DC power is delivered to the terminal of an inductor (coil) within a DC motor, a magnetic field is created that causes the motor to rotate.

Figure 4: DC Gear Motor

E. Jumper Wire

An electrical wire or group of them in a cable, with a connector or pin at each end (or occasionally without them – simply 'tinned' is called a jumper wire, jumper, or jumper. It is typically used to connect the components of a breadboard or other prototype or test circuit, either internally or with other.

Figure 5: Jumper Wires

F. 12V DC Power Supply

The most widely utilised rechargeable battery chemistry nowadays is lithium-ion. Electric cars and cell phones are among the everyday gadgets that run on lithium-ion batteries. Lithium-ion batteries are made up of a protective circuit board and one or more lithium-ion cells. For our setup, two power supplies are required. One 12 volt DC for our pump and one for the entire apparatus. We use three 3.7 volt Li-Ion batteries that are connected in series to provide a 12 volt power source.

Figure 6: Li-Po Battery

G. Arduino Nano

The Arduino Nano is a multipurpose microcontroller-based device featuring sixteen digital pins. Almost any task, from small to large industrial-scale tasks, can be completed with it. Additionally, it can be utilised for designing new applications and prototyping.

Figure 7: Arduino Nano

a) Pins of Arduino Nano

Table 3: Pins of Arduino Nano

Pin Category	Pin Name	Details
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source (6-12V). 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: Ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A7	Used to measure analog voltage in the range of 0-5V
Input/Output Pins	Digital Pins D0 - D13	Can be used as input or output pins. 0V (low) and 5V (high)
Serial	Rx, Tx	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.

PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source (6-12V). 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: Ground pins.

H. GSM Module

The SIM800L is a tiny cellular module that supports voice calls, SMS sending and receiving, and GPRS transmission. Any project requiring long-range connectivity can benefit greatly from this module's low cost, small footprint, and compatibility for quad band frequencies.

Figure 8: GSM Module

a) Pins of GSM Module

Table 4: Pins of GSM Module

S. No	Pin Name	Elaboration
1	NET	Antenna
2	VCC	+ 5V
3	RST	Reset
4	RXD	Data receive
5	TXD	Data transmit
6	GND	Ground

I. Arduino IDE Software

To make this project we used 2 software. One is programming code editor software which name is Arduino Ide. The one is an Android app which is for controlling our appliances for coding for Node MCU we need an IDE which is compatible to our NodeMCU. The Arduino IDE is one of the easiest and compatible IDE for Node MCU. So we choice Arduino IDE for our coding.

Written in functions from C and C++, the Arduino Integrated Development Environment (IDE) is a cross-platform application available for Windows, macOS, and Linux.It is used to build and upload programmes to boards that are compatible with Arduino, as well as other vendor development boards with the aid of third-party cores.The GNU General Public Licence, version 2 governs the publication of the IDE's source code. The Arduino IDE has specific code architecture guidelines to support the languages C and C++. A software library from the Wiring project, which offers numerous standard input and output operations, is provided by the Arduino IDE. With the GNU toolchain, which is also included with the IDE distribution, user-written code only needs two basic functions to be compiled and linked into an executable cyclic executive programme. These methods are for initiating the sketch and the main programme loop, and they are connected with a programme stub called main (). The executable code is converted by the Arduino IDE using the programme avrdude into a hexadecimal text file, which is then loaded into the Arduino board using a firmware loader programme. Typically, official Arduino boards are flashed with user code using the avrdude uploading tool.

Repository github.com/arduino/Arduino Edit this at Wikidata Written in C, C++ Operating system Windows, macOS, Linux Platform IA-32, x86-64, ARM TypeIntegrated development environment License LGPL or GPL license Website blog.arduino.cc/2019/10/18/arduino-pro-ide-alpha-preview-with-advanced-features.

Figure 9: Arduino IDE

J. Flame Sensor

A flame sensor is a type of sensor that is most responsive to ambient light. This sensor module is utilised in flame alarms for this reason. This sensor picks up flames at wavelengths between 760 and 1100 nm from the light source. High temperatures have the potential to easily harm this sensor. This allows for the placement of the sensor at a specific distance from the flame. The flame may be detected with a 600 degree detection angle and at a distance of 100 cm. This sensor produces either an analogue or digital signal as its output. These sensors are found in robots that battle fires, such as flame alarms. One type of detector that is primarily intended for identifying and reacting to the presence of a fire or flame is a flame-sensor. The fit of the flame detector may affect the reaction. It has a fire suppression system, a propane line, an alarm system and a natural gas line. Boilers in the industrial sector employ this sensor. This is mostly used to authenticate whether or not the boiler is operating correctly. Because of the way these sensors detect flames, their response time is both faster and more precise than that of a heat/smoke detector.

Figure 10: Flame Sensor

K. Servo Motor

Micro Servo Motor SG90 is a tiny and lightweight server motor with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos.

Figure 11: Servo Motor

L. IP Camera

An IP camera, or Internet Protocol camera, is a type of digital video camera that is used for surveillance and can send and receive data via the internet or a computer network. Unlike traditional analog cameras that transmit video signals as electrical signals through a coaxial cable, IP cameras digitize the video signal and then compress and transmit it as data packets over an IP network. Key features of IP cameras include: Network Connectivity: IP cameras can connect to a network using wired Ethernet or wireless Wi-Fi connections. This allows for remote access to the camera feed over the internet. Resolution: IP cameras often provide higher resolution compared to analog cameras, allowing for clearer and more detailed images. Digital Signal Processing: The digital nature of the video signal allows for various digital processing capabilities, such as motion detection, video analytics, and the ability to store and manage video footage on network-attached storage (NAS) devices or in the cloud. Power over Ethernet (PoE): Many IP cameras support Power over Ethernet, which means they can receive power and data over a single Ethernet cable, simplifying installation. Remote Access: Users can access the camera feed remotely through the internet, using a computer, smartphone, or tablet. This feature is often facilitated through a dedicated software or mobile app provided by the camera manufacturer. Security: IP cameras may offer advanced security features, including encryption and password protection, to secure the video feed and prevent unauthorized access.

Figure 12: IP Camera

M. Circuit Diagram

Hardware connection is same as like as the circuit diagram.1st we program the Arduino, Nodemcu and ESP 32 Cam then we connect all the equipment as per our circuit diagram.

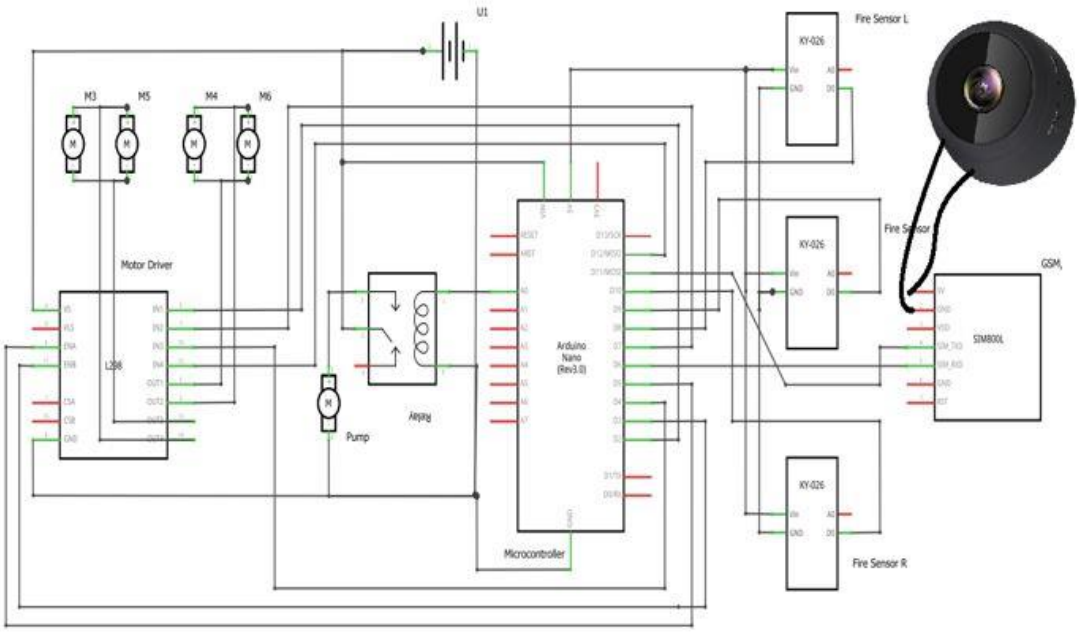

Figure 13: Circuit Diagram

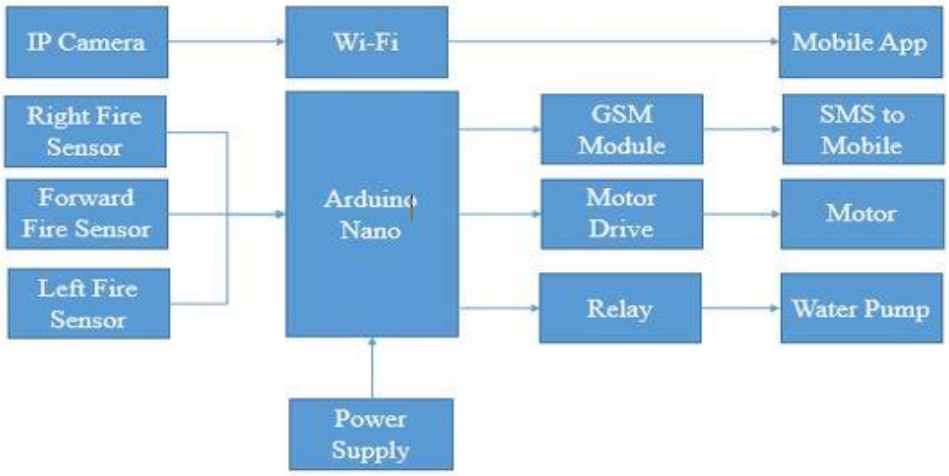

Figure 14: Block Diagram

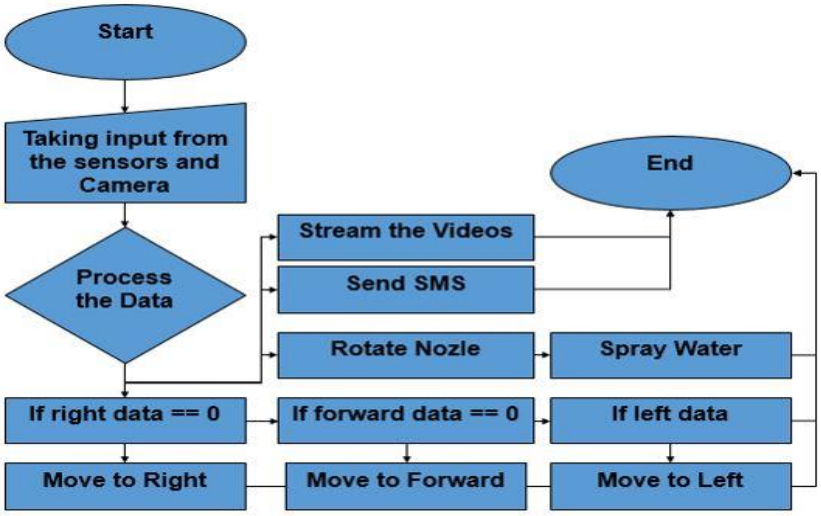

Figure 15: Flow Chart

N. Required Software and Their Setup Process

To complete our project, we need many types of software, most important of them are following

1. Arduino IDE-1.8.9

O. Software

The software that is used to program the microcontroller is open-source-software and can be downloaded for free on www.arduino.cc. With this "Arduino software" we can write little programs with the microcontroller. These programs are called "Sketch".

In the end the sketches are transferred to the microcontroller by USB cable. More on that later on the subject "programming".

a) Arduino IDE Installation

Now one after another the Arduino software and the USB driver for the board have to be installed.

b) Installation and Setup of the Arduino Software

We have downloaded the Arduino software from www.arduino.cc and installed it on the computer (This was NOT connected to the PC). After that we opened the software file and installed the program named arduino.exe. Two set ups on the program are important and should be considered.

c) The board that we want to connect has to be selected on the arduino software. The “Arduino Nano” is here known as “Arduino / GenuinoUno, Nano, Lilipo or any name can be”.

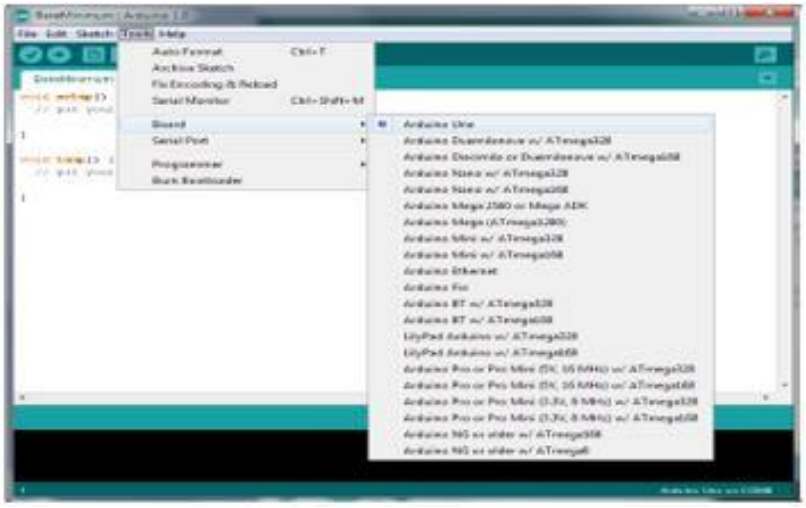

Figure 16: Program Installation Process -1

d) To inform the computer about the port to which the board has been connected, we must select the appropriate "Serial-Port." Only if the USB driver has been installed correctly is that feasible.
This is one method to check it:
The Arduino and PC were not currently linked. We will now see one or more ports here (COM1/COM2/COM3) if we select "Port" under the "Tool" box.

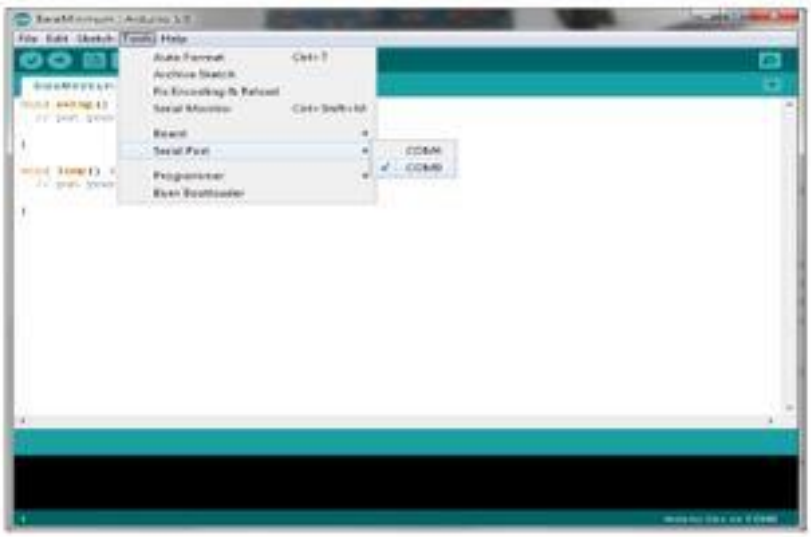

Figure 17: Program Installation Process -2

P. Programming
The development cycle is divided into 4 phases:

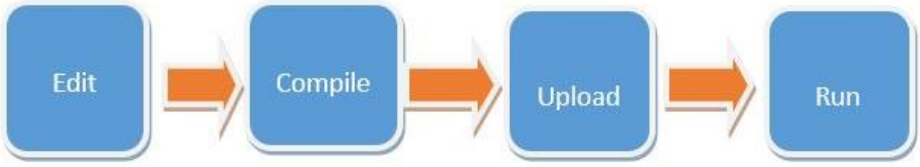

Figure 18: Flowchart Of The Compiling Process

Compile: Compile means to translate the sketch into machine language, also known as object.
Code Run: Arduino sketch is executed as soon as terminates the step of uploading on the board.

III. RESULTS AND DISCUSSION

Currently, the notion of a firefighting robot is very prevalent. However, this GSM-enabled fireman robot effectively addresses certain limitations of the current firefighter robots. They possess both autonomy and control. The device is equipped with a surveillance mechanism that may identify both fire outbreaks and individuals trapped within the premises. Additionally, the monitoring system can be deployed as an Android application. The robot assists firefighters by providing them with a more secure route to the fire. Due to the high number of fatalities among male firefighters who risk their lives to rescue others. The robot's robotic arm is capable of rescuing individuals who are trapped by lifting them to safety. This fireman robot, which operates on the GSM network, can be deployed as a drone. By employing artificial intelligence, the robot can be programmed to identify fire categories and select suitable methods for extinguishing them. For certain significant fires, such as forest fires, the expanded version of this robot aids in extinguishing the fire on a substantial scale. Currently, the significance of this robot is growing.

Some of the advantages of this work are given below:

- To ascertain the precise orientation of the fire's origin.
- Enhanced capacity for precise perception with heightened adaptability.
- Minimize human exertion.
- Dependable and cost-effective.
- Weather-resistant.
- Real-time video broadcasting.

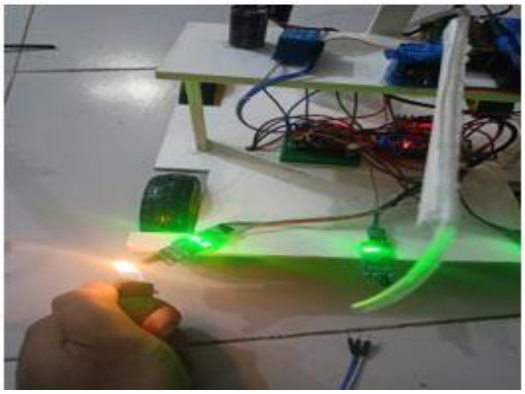

Figure 19: Movement of Robot

Figure 20: Water Spraying and Water Nozzle Movement

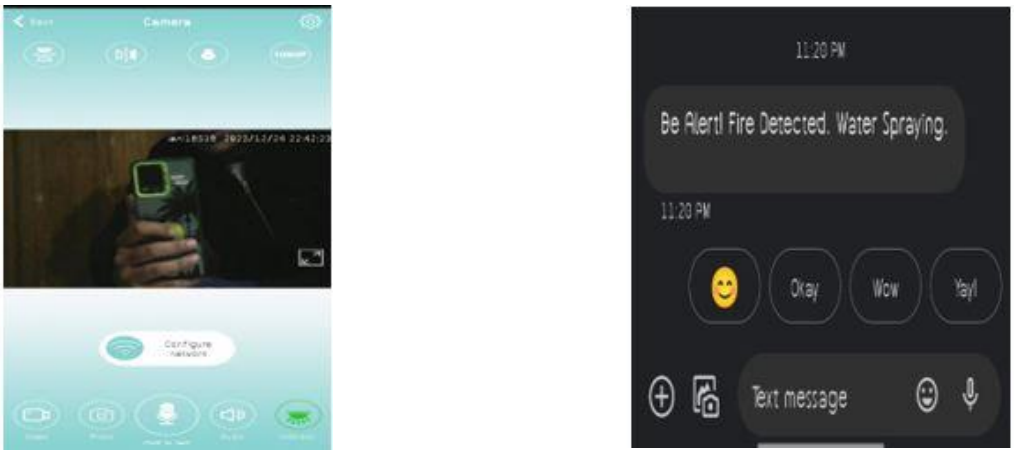

Figure 21: SMS for Fire Accident and Live Streaming

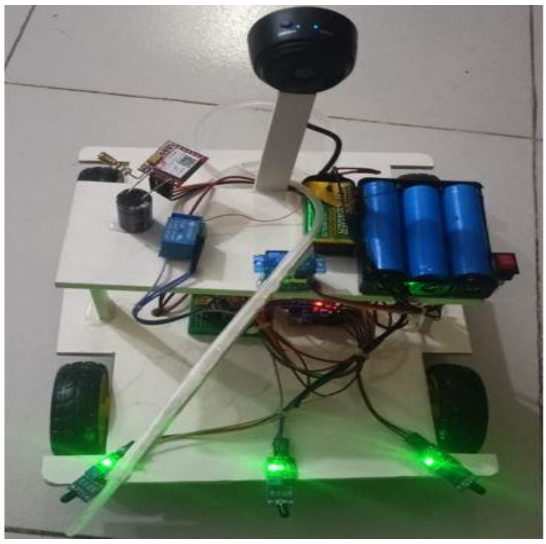

Figure 22: Project Outlook

VI. LIMITATIONS AND FUTURE SCOPE

A. Limitations

- The sensing area is limited in size.
- Insufficient water storage capacity.
- Internet bandwidth

B. Future Scope

- Sensors can be adjusted to accurately detect a wider spectrum of infrared light.
- Future implementation of self-calibration techniques is possible.
- Port management.
- In the future, we will incorporate Internet of Things (IoT) technology.
- AI will be incorporated in the future.

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Conflict of Interest: The Author declares he has no conflict of interest.

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