Firefighting Robot Based On IoT and Ban Levels Technique

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Abstract— **Internet of Things (IoT) technology is known as a system where various sensors are connected to the Internet for various real-world applications. This paper presents a prototype fire fighting robot system. The system is designed and developed by implementing IoT and ban-level techniques for monitoring and control. The robot aims to eliminate human involvement and deliver an effective firefighting system. Arduino UNO V3 is used as a microcontroller, connected to a wireless mobile application, enabling the implementation of remote control. The robot is designed in such a way that inputs taken from the infrared flame sensor, water level sensor, and smoke level detector are used to determine the movement of the water spray nozzle so that it will be directed to the fire source precisely. A prototype was successfully designed and the functionality of the system was tested. The results show that the IoT infrastructure can successfully track and control the movement of the robot and the spray direction of the nozzle.**

Keywords—firefighting robot, Arduino, IoT, sensor, remote control

I. Introduction

The Internet of Things (IoT) has developed rapidly over the past decade, combining the use of today's advanced technology that goes hand in hand with the Industrial Revolution 4.0, shows that many sophisticated systems can be designed using the latest electronic components to help firefighters control fires, save lives and protect themselves from being injured in their workplace [1-5]. Connecting all the different objects by adding sensors will increase the intelligence of those devices and hardware that does not have intelligence [6-8]. This allows every piece of equipment and hardware to communicate in real-time with data without involving humans [9-12]. IoT makes the world around us smarter and more responsive through the combination of digital and physical environments. However, the use of IoT infrastructure in the Malaysian fire department is still at an early stage where the use of technology in the fire department that goes beyond computers and software is expected to improve the firefighting and rescue work system more effectively in the future.

The main objective of this paper is to design and develop an automatic firefighting robot system using an Arduino UNO V3 as a microcontroller. The system is intended to control water spray angle, monitor the water level, taking readings of the gasses and temperature surrounding via the IoT infrastructure. In this work, IoT implementation is to eliminate human involvement and delivers an effective firefighting system.

II. Methodology

The process of developing a firefighting robot system begins with selecting the appropriate electronic components to be used based on the system's maximum load requirement. Then, continued with developing the program code, and designing the Graphical User Interface (GUI) using Remote XY. A fire fighting robot system is designed that enables the robot to detect fire automatically and direct the movement of the extinguishing spray nozzle toward the source of the fire. In this paper, a smartphone is used as a remote control that connects to a wireless module on the microcontroller to control the movement of the robot and the spray nozzle.

At the same time, the robot is also designed to determine the level of safe conditions from Carbon Monoxide (CO) gases before fire rescue takes place. The level of the condition is determined by the gas content through the presence of smoke detected by the gas sensor.

The robot that has been developed is tested in terms of functional aspects of gas detection and also flame detection in the fire area. For flame detection, the signal is taken from the flame sensor which enables the robot to move and direct the nozzle spray toward the source of the fire. In this work, both analog and digital I/O ports on the Arduino microcontroller for analog and digital control robot actuators are used where the robot's capabilities in smoke and gas detection, flame detection, and water level monitoring are tested. The detected readings are then interfaced with a GUI for real-time observation.

Fig. 1 shows the flowchart of robot operation that starts with powering up ESP8266 and Arduino UNO R3 and connecting them with input and output modules. ESP8266 needs to be connected with mobile applications first via a Wi-Fi internet connection before enabling the function of the robot remote control. A GUI is used to display the status of the connection.

A GUI is designed using the "Remote XY". The design is in such a way that there are two buttons to ON and OFF the DC water spray and turning ON and OFF automatic fire

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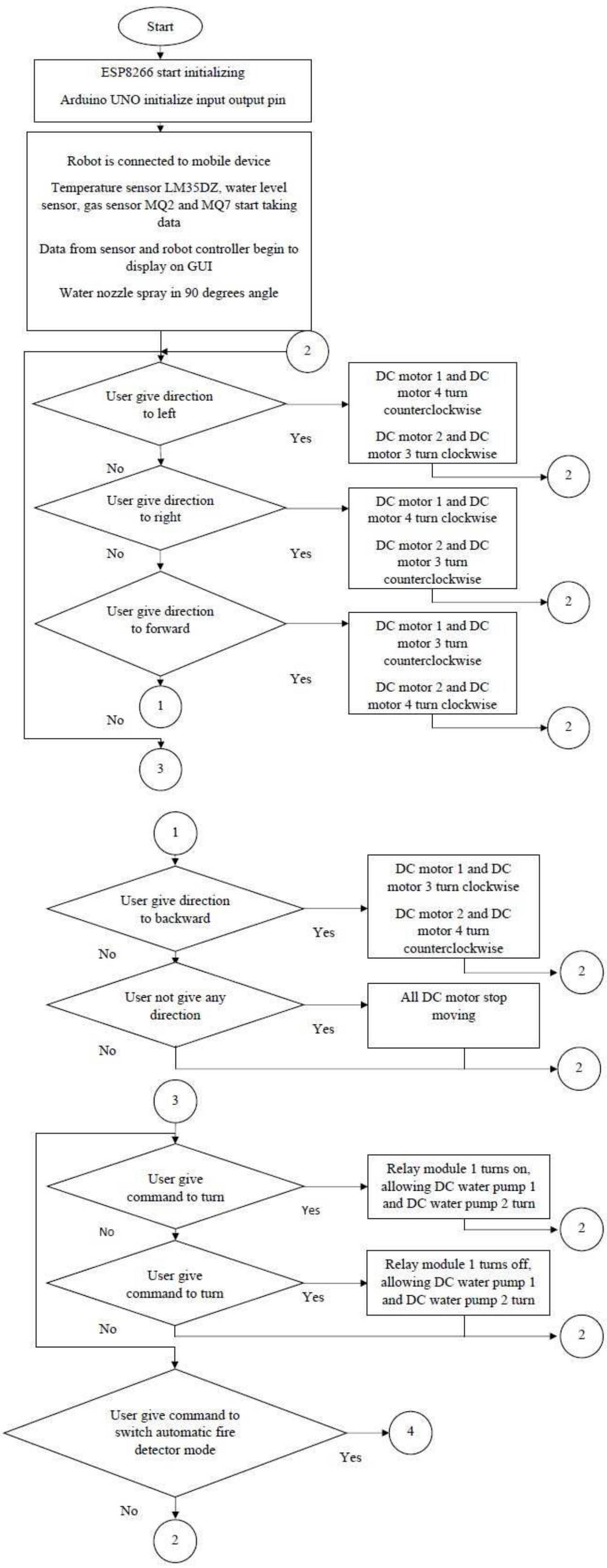
detection mode. If the automatic fire detection mode button is turned OFF, the water spray nozzle will keep the 90-degree angle in the center direction. Apart from that, there are also indicators for temperature readings, water level, and gas smoke detection.



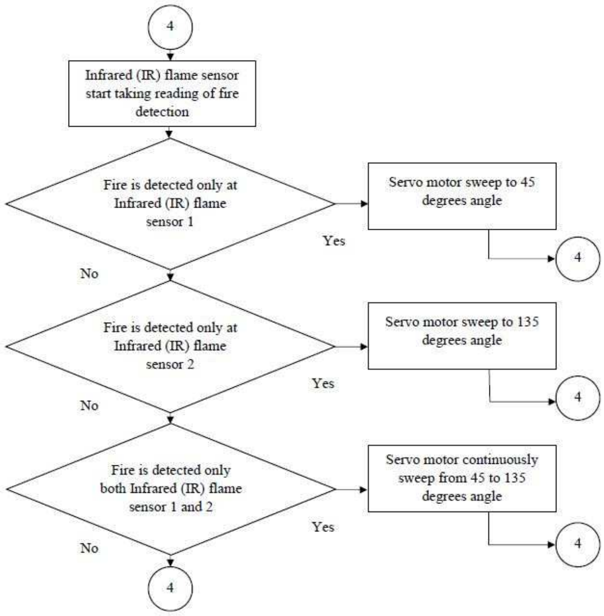


Fig. 1. Flowchart of the robot system working operation

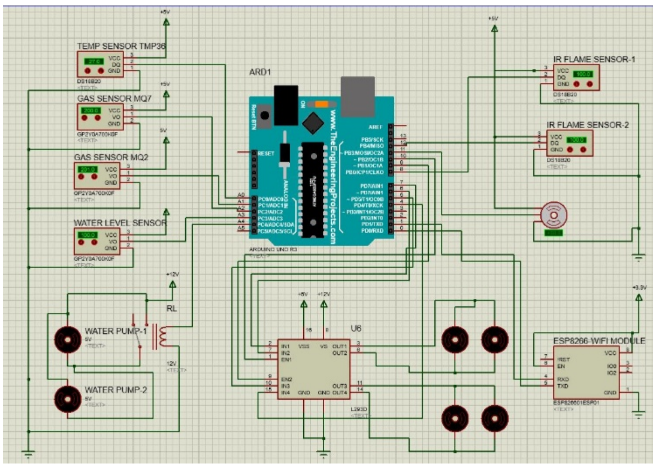


Fig. 2. System circuit diagram

Fig. 2 is the circuit diagram showing the input and output connection of the robot done using Proteus 8.0 Professional. Table I shows a list of Arduino IO pin assignments.

TABLE I. INPUT AND OUTPUT PIN ASSIGNMENT

Pin Arduino UNO R3	Electronic Component
A0	Temperature sensor LM35DZ
A1	Gas sensor MQ-2
A2	Gas sensor MQ-7
A3	Submersible water level sensor
A4	Relay module
D0	Rx pin ESP8266
D1	Tx pin ESP8266
D4	IN3 Motor driver L298N
D5	IN4 Motor driver L298N
D6	IN2 Motor driver L298N

D7	IN1 Motor driver L298N
D8	IR flame sensor-1
D9	ENB Motor driver L298N
D10	ENA Motor driver L298N
D11 (PWM)	Servo motor
D12	IR flame sensor-2

A. Hardware

The hardware component used for the robot consists of one microcontroller Arduino UNO R3 board for controlling input and output modules. Generic ESP8266 Wi-Fi module is connected with Arduino UNO R3 board and has an inbuilt TCP/IP protocol stack that can provide Wi-Fi access to board enabling remote control robot function. four unit DC motors are used for actuators to control robot movement through control signals from motor driver L298N, a dual H-Bridge motor driver which allows speed and direction control of DC motor. In the functionality of electronic transducers, two unit Infrared (IR) flame sensors are mounted to detect and respond to the presence of flame or fire in the range. MQ2 and MQ7 gas sensors detect smoke and CO in the environment and deliver real-time ppm readings. The robot is equipped with a single LM35DZ temperature sensor that continuously monitors the ambient temperature.

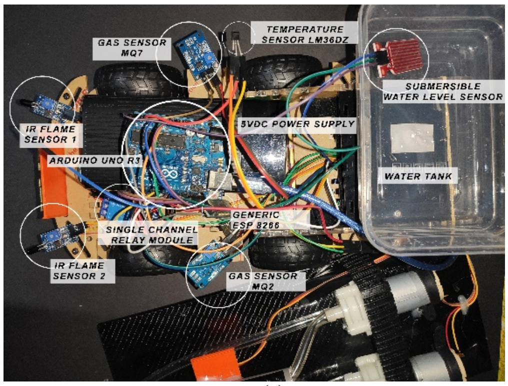
A single submersible water level electronic sensor is equipped inside a robot water tank, which is to observe water level conditions for the fire extinguishing act. For the firefighting part, the robot used two units 6 VDC water pumps, where the water inlet is received from the water tank and the switching state is controlled by a single channel relay module. Water outlets of both DC motors are joined with a PVC pipe equipped with a water nozzle. The PVC pipe is mounted on a servo motor shaft which allows turning according to the set angle from the PWM signal.

B. Software

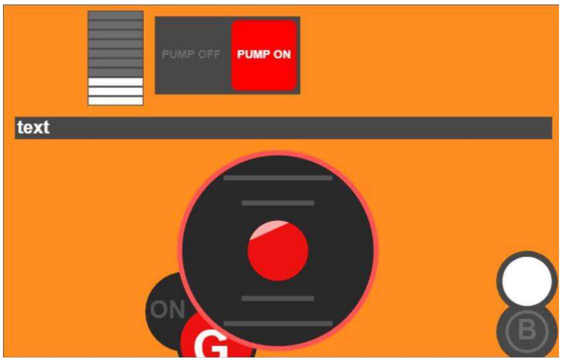
The software used in developing this robot prototype is Arduino IDE, a platform for writing program code that is readable by the microcontroller Arduino UNO R3 before the code is uploaded and embedded into the microcontroller board. Apart from that, the Proteus 8.0 Professional is used to sketch PCB designs and run electronic circuit simulators.

The RemoteXY is used to develop a graphical user interface (GUI) for board control, including assigning and designing each button from the available element and properties bar. The GUI program code is then generated and combined with defined IO ports on Arduino IDE before being embedded on a microcontroller Arduino and Wi-Fi module. The RemoteXY apps will display the designed GUI after connecting a mobile phone and a Wi-Fi control unit, generic ESP 8266/ESP-01 on an Arduino board to the same Wi-Fi network.

III. Result and Discussion



(a)



(b)

Fig. 3. (a) the prototype and (b) its Graphical User Interface (GUI) on the mobile application

Fig. 3 shows the prototype and GUI for the system. The status of the pump, the reading for smoke, the temperature reading, the status of the water level, and the joystick for the nozzle movement are shown on the GUI.

TABLE II. Robot Gas Level Detection Data

Condition	MQ-2 smoke level (PPM)	MQ-7 CO smoke level (PPM)
No burning	120 119 118	10 10 10
Average	119	10
Low burning	127 127 143	12 10 16
Average	132.33	12.667
Medium burning	144 147 146	7 7 6
Average	145.66	6.67
Heavy burning	231 233 234	157 156 157
Average	232.67	156.67

Table II shows the reading of gas levels detected by MQ-2 and MQ-7 sensors. The safe level of smoke concentration in the burning area starts at 0 until 299 parts per million (PPM)[13]. The experimental results show that the prototype is able to detect the smoke present in the surroundings, ranging from no burning, low burning, medium burning, and heavy burning in an enclosed space. The average smoke reading (ppm) in no-burning areas is 119, while CO levels are 10ppm, and the value rises as the burning level rises. Fig. 4 shows the status of the detection that appears on the GUI.

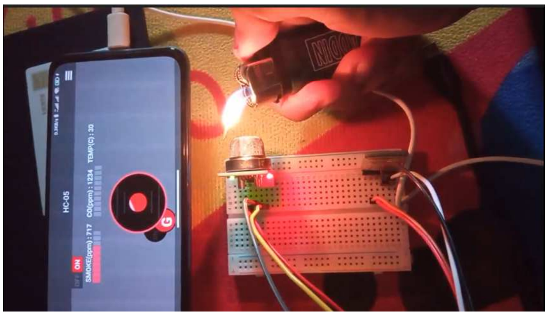


Fig. 4. Flame and smoke detection status on the GUI

TABLE III. ROBOT FLAME DETECTION DATA

Input **(Test Range)**	**Output**			
Distance (m) ***(for the single sensor)***	***Digital Reading***	***Analog Reading***	***Voltage (V)***	***Servo Motor Rotation Angle (º)***
0.30	0	60	0.3136	135°
0.45	0	34	0.1666	135°
0.60	0	32	0.1568	135°
0.75	0	33	0.1617	135°
0.90	0	39	0.1911	135°
0.105	1	560	2.744	90°
0.120	1	510	2.499	90°
0.135	1	730	3.577	90°

Table III shows the ability of the robot in detecting flame within the short test distance from the sensor. As shown, the digital output read as ‘1’ (HIGH) when there is no fire detected nearby. Otherwise, the signal will turn to “0” (LOW).

Analog output reading when there is no fire presence at a distance of 105 cm is 560 which is equal to 2.744 V, causing servo motor shaft in default facing angle 90° degrees. When the sensor is not detecting fire, the resistance of the phototransistor increases causing the sensor to draw a high amount of voltage across the phototransistor. The voltage value is compared with the threshold voltage in the comparator IC inside the IR flame sensor. Since the voltage produced is higher than the threshold value, the sensor produces digital output “1” or HIGH.

On the other hand, in presence of fire at a distance of 90 cm, the sensor is able to produce an analog reading of 39 equivalent to 0.1911V, which results in servo motor shaft rotation to 135° degrees. This is because, when the sensor detects a fire, the resistance of the phototransistor decreases causing the sensor to draw a low amount of voltage across the phototransistor. The voltage value is then compared with the threshold voltage in the comparator IC inside the sensor. Since the voltage produced is lower than the threshold value, the sensor produces digital output “0” or LOW.

IV. CONCLUSION

Automated Fire Fighting Robots have been successfully developed using IoT technology. The robot prototype is capable of extinguishing fires within a range by shooting high-pressure water at the flames. The DC water spray is manually controlled using a mobile app. The developed GUI serves as a controller installed in the smartphone to control the robot's directional movement as well as select the robot's operation mode in the fire extinguishing action. The virtual Joystick controller displayed on the GUI can control the direction of the robot's movement by sending a signal to trigger the DC motor. The GUI can also display the real-time temperature, CO gas, and smoke reading in the surrounding area, and the water level in the water tank for fire extinguishers.

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