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IoT-Based Fire Safety Detection and Suppression Control System

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Abstract

It is important to identify fires in homes to avoid property loss due to both natural and caused fires. Fire detection will be crucial because every life lost is very meaningful. Fires can occur anywhere and anytime but having a fire detection and suppression control system helps keep the family safe. Some people are unaware of the need for a fire detection and suppression control system. They believe they will smell the burning and run out of time. According to the study, the average time it takes for a building to burn down is only 60 seconds. So, by the time they smell the fire and decide to run to save themselves, the house has most likely been destroyed by the fire. The Internet of Things (IoT) is a network of computers that are both wired and connected to the Internet. This equipment can be linked over the Internet, allowing users to alter or gather data from it. This project used a wide range of sensors to detect the existence of flammable gas, the existence of fire and warn the user. In addition, a preventive approach is frequently used by installing a solenoid valve and a water sprinkler on it that can stop the gas leak when MQ-7 detects the presence of gas and also sprays water when the IR flame sensor detects a fire. The IoT-Based Fire Safety Detection and Suppression Control System plays an important role in helping people take proper precautions and manage the situation when fires happen by getting alerts through their devices.

1. Introduction

In Malaysia, fire cases are one of the tragedies that often occur regardless of large buildings or residential houses and have caused many deaths. Fire can occur due to several factors, which are because of the presence of chemicals and the occurrence of gas leaks. Then, fire can cause by home appliances and equipment as any devices that can generate heat, such as clothes dryers, stoves, heaters, and many more, or from a device that heats up due to long periods of usage such as a computer and fans. These are all the appliances and equipment that can cause fire hazards. Besides, electrical systems and smoking can be the main causes of fire in our homes MATEC Web of Conferences stated the analysis of fire losses based on investigation data in Selangor regarding residential fires from 2012 to 2014 [1]. According to the investigation, Malaysia has an average of fire incidents of around 1024.67 fires per million population per year in 9 years from 2006 to 2014 [1]. This made the rate of approximately 90 residential fires per million population per year, while the rate of fire victims is 7.53 per million population with 3.07 death per million per year [1]. Fires can happen very fast and unpredictably, which are very dangerous. It is necessary to have early detection to warn people about the risk and threats when fires happen near us or in our own residential.

This project detects gas leakage, which happens in the kitchen from gas barrels used for cooking for daily use. Gas leakage is very dangerous since it can cause a devastating explosion and lead to a fire in a short time. Based on an article about an explosion happened that came from the leakage of a gas barrel in Desa Garden Apartment, Pulau Pinang, Malaysia, in 2019. finding that the explosion victim was 80% burned on his entire limb and sought hospital treatment immediately. Gas leaks and sparks from the lighter are believed to cause the explosion [2]. Then, happened in Jertih, Terengganu in 2016. Fires happened at one of the famous restaurants caused by gas leakage [3]. Fortunately, there was no death occurred during the fire. This is because of the acting quickly and the cooperation of all at that incident to go to a safer place.

This project not only detects gas leakage but also detects the presence of fire to warn people that a fire just happened. This project also has an automatic water sprinkler to help prevent the fire from spreading quickly. People nowadays own smartphones and tablets as they are necessary for use doing daily activities such as joining online classes, communicating with people, and many more. The IoT-based fire safety detection and suppression control system plays an important role in helping people take proper precautions and manage the situation when fires happen by getting alerts through their devices.

1.1 Problem Statement

Fire is one of the major incidents often happen in Malaysia [4]. Fire can happen anytime and anywhere. It can happen very fast and unpredictably depending on the causes of the fire, as the fire causes tremendous property damage and can lead to death. It is important to know the cause of the fire caused by a gas leak so that people can prepare to rescue the nearest people inside the house to prevent loss of life. When we do not know the current situation in the event of any high-risk gas leak causing a fire, we probably will panic about the situation.

According to a doctor, gas explosions are one of the most common reasons for admission happened in Malaysia [5], and because of the complexity and severity of such cases, most of them must be managed in government hospitals, needing high critical care [5]. The mortality rate is quite high, and it closely corresponds to the body surface area affected [5]. For example, if the body surface area is 80%, the mortality rate is also 80% [5]. If the victim survives the first 24 hours, they will most likely develop multi-organ problems, infection, and organ failure, all of which contribute to the high fatality rate [5].

This project assists many people detect fires caused by gas leakage or fires involving other flammable materials such as short circuits, irons, and many more appliances and devices, which is a necessity for people in their own residences. So, it will be easier for the firefighter to detect the main causes of the fire to act faster than usual.

1.2 Hypothesis

Theoretically, fires can be prevented and controlled in the event of such an accident. An effective system will be built to reduce the risk of fire spreading to severe while having a fire suppression control function in a system.

1.3 Aim

This project aims to design a fire detection and suppression control system to assist the public in dealing with fires that may occur in their homes. In the meantime, this project is built to make it easier for the fire and rescue department to identify the cause of fire.

1.4 Objectives

The main objective of this project is to create an IoT-based system to detect a fire caused by gas leakage and warn people. Thus, these are the objectives of this project:

a) To detect the presence of gas leakage, warn the user and automatically close the valve.
b) To detect the presence of fire, warn the user and activate the water sprinkle.
c) To evaluate the usability of the system.

1.5 Scopes of Study

This project's scope is to design a hardware system for people as a precaution, and the fire can be controlled from spreading to getting worse using IoT-based fire detection and warning.

a) To detect gas leakage and the presence of fire and warn the user with an automated water sprinkler.
b) This project uses the MQ-7 gas detector and IR flame sensor, and the Durian UNO with Blynk application.
c) This system covers gas leaks and other flammable materials that can cause a fire.
d) This project can be done in a residential's kitchen where there can be a cause of gas leakage.
e) The testing and analysis of this project will be done at least 10 times.

2. Methodology

Fire detection and warning system project mostly exist to detect and control various problems that can cause a fire. However, in this project, the IoT-Based Fire Safety Detection and Suppression Control System will have some functions that will be improvised from previous research, such are using multiple sensors in a system that will be used to extinguish and control to prevent the fire from spreading. This system will use an MQ-7 gas detector sensor and an IR flame sensor. It will detect the presence of gas and detect the presence of fire if any fires happen. Then, the system can detect and warn the user by sending notifications to the user's smartphone through the Blynk application and using the Durian UNO as the main microcontroller. For the gas detection function, it also will close the valve to stop the leakage of gas from spreading, while the other one will detect temperature to identify the situation that it is a fire happen.

In addition, this system has a suppression control system since it can detect the causes of the fire, warn the user through the smartphone, and have features to prevent the fire from spreading. The system will provide a modest result to be added to the existing current safety equipment as it has many functions in a system. All the components used are affordable, bringing down the overall cost. So, many people will afford to purchase it in their own kitchen. It can save many lives in the future, and it will be easier for firefighters to investigate the causes of the fire and ways to stop the fire if it spreads in the blink of an eye.

2.1 Work Planning

A general overview of the project is established before beginning. Before the project starts, a significant degree of preparation and planning is required to guarantee that it follows the flow. It also assures that the project goes off without a hitch. The time management for this project is methodically planned, and the procedure is created using a flowchart. After that, the process flow and block diagram will be provided an overview of the flow and assign the task that the project must fulfil.

2.2 Work Flowchart

The implementation of this project will be based on the objectives and scopes. To fulfil the objective and with the improvements to this project will be able to assist many people so that the fire can be overcome by alerting the user and controlling the spread of fire. To develop the hardware project, the existing application, which is the Blynk application used to connect the Durian UNO remotely. Below is the information gathered or the flowchart of this project.

The flowchart in Fig. 1 shows the overall process to be executed to complete the work successfully. The main task that needed to be done was to identify the problem statement and formulate the objectives. It is important to obtain a clear objective and scope as a guideline to perform the work. This project consists of two sensors which are MQ-7 sensor to detect gas leakage and an IR flame sensor to detect the presence of fire. This project is controlled by Durian UNO as the system's main microcontroller, and ESP8266 ESP-01 Wi-Fi Module functions as a transceiver to transmit data from the system to the smartphone. Fig. 2 shows the block diagram of the system.

Firstly, the system will initialize all the required libraries, sensors, serial, and Blynk. Then, it will declare the variables and constant as the first process. After completing the process, the system will automatically connect to the network via ESP8266 ESP-01 Wi-Fi Module as its transceiver as long as have a Wi-Fi connection. All the functions in the system will be controlled by Durian UNO. Next, the MQ-7 sensor will be calibrated to have an accurate value of gas in ppm. The calibration method has been declared in the code. When the system starts, the MQ-7 gas sensor will automatically calibrate. Then, the system will read the sensor's data to be displayed in the Blynk application. For the MQ-7 gas sensor will be displayed current air quality, and for the IR flame sensor, there is a button to represent if there is a presence of fire or vice versa.

The continue will be continuing to declare if the MQ-7 gas sensor is $\geq$ 50 ppm. If YES, the notification "Gas Leak Detected!" will be sent via the Blynk application to the user's devices. Red LED will light up and will activate the solenoid valve to energize it to close the main tube of the gas; then, if there is the presence of fire which the changes of colour from 0 to 1. The IR flame sensor will be triggered, the notification "Fire Detected!" will be sent via the Blynk application, red LED will light up and will activate the water pump to the water sprinkler as the element to extinguish the fire.

After the situation is safe, the gas has decreased, and the MQ-7 sensor displays normal current air quality through the Blynk application, and Red LED will be turned off. The solenoid valve will be de-energized for the IR flame sensor change from condition 1 to 0. The water pump will stop pumping water to the water sprinkler, and Red LED will turn off. So, the process will be repeated when the MQ-7 and IR flame sensor are triggered.

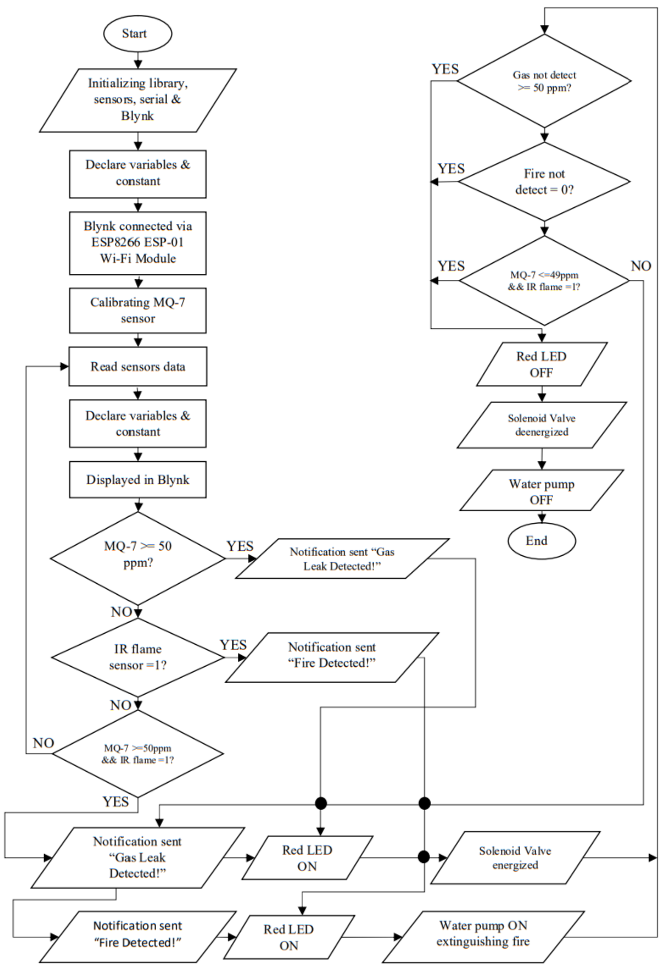

Fig. 1 *Flowchart for IoT-Based Fire Safety Detection and Suppression Control System*

2.2.1 Block Diagram

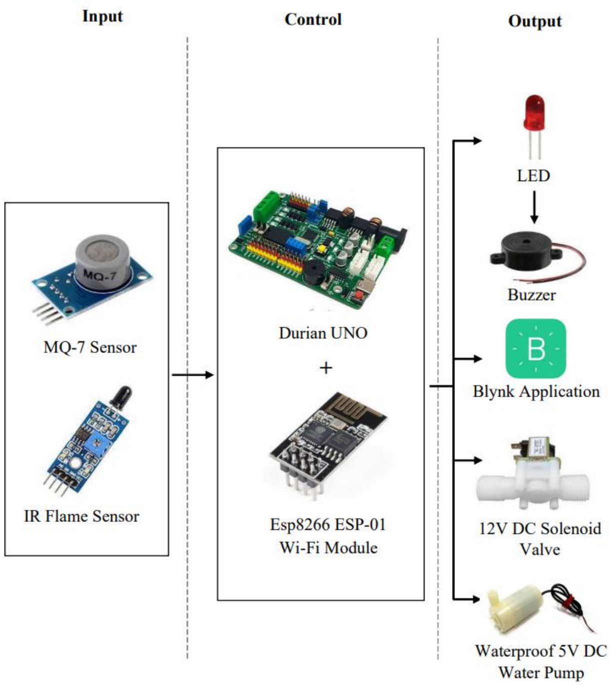

Fig. 2 *Block Diagram of IoT-Based Fire Safety Detection and Suppression Control System*

3. Results and Discussion

The last design stage of an IoT-Based Fire Detection and Suppression Control System is discussed in this chapter. This project's design stage can be broken down into two parts:

(i) Circuit simulation result using Tinkercad via the online platform.
(ii) Sensor calibration for MQ-7 sensor for gas detection to have accurate readings in ppm value.
(iii) Developing and designing the hardware with Durian UNO, MQ-7 gas sensor with an output of LED, 12V DC solenoid valve, and the implementation to Blynk application.
(iv) To develop the IR flame sensor with an output of LED and 5V DC water pump for water sprinkler. Then, connect to the Blynk application.

3.1 Simulation Results

Fig. 3 shows circuit simulation that was done using Tinkercad online simulator to see how the flow of the overall design works in simulation and also to compare it with the real system that wants to be implemented. Nevertheless, Tinkercad online simulators have only basic components, so that use substitute components that have the same function or are almost the same. However, it is successfully designed and runs the code. Some components may be different from the real project, in this simulation used, Arduino UNO as its microcontroller, and Durian UNO is an upgraded version of Arduino UNO. Then, in Tinkercad online simulator does not have an IR flame sensor in the library, so need to substitute it with a temperature sensor, so does the MQ-7 gas sensor. Both servo motors are shown below, and both of them represents the suppression control in the system. The servo motor is used to open doors when there is the presence of gas and fire.

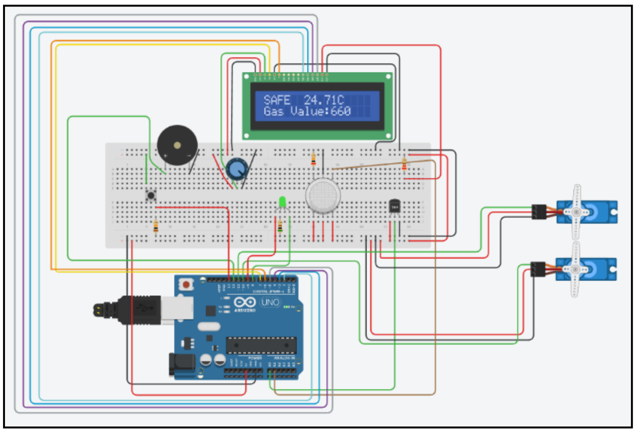

Fig. 3 *Circuit Diagram for Simulation*

The buzzer will be triggered, and Red LED will turn on when the gas value exceeds 700 gas value. As in the simulation, the gas sensor did not perform any calibration, so the gas sensor only displays the gas value, not in ppm. When the gas sensor value exceeds 700, the LCD will show "DANGER!!" on the first line of the LCD, while on the second line, it will show "VACATE BUILDING!" as shown in Fig. 4.

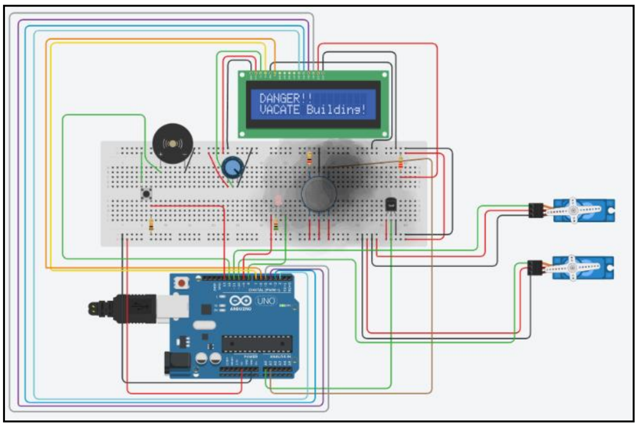

Fig. 4 *Simulation when the Presence of Gas ≥ 700 Sensor Value*

As for fire detection in Tinkercad online simulator, the buzzer will be triggered when temperatures exceed more than 45°C as shown in Fig. 5. Nevertheless, in Tinkercad online simulator does not have any option for the IR flame sensor. Then, need to substitute it with a TMP temperature sensor to represent the IR flame sensor. Both sensors work to detect the presence of fire, for the TMP sensor work to detect the presence of fire through a certain temperature, while the IR flame sensor detects through infrared radiation. As for the code, the TMP sensor needs to declare the required temperature, while for IR flame sensor needs to declare it as 0 or 1.

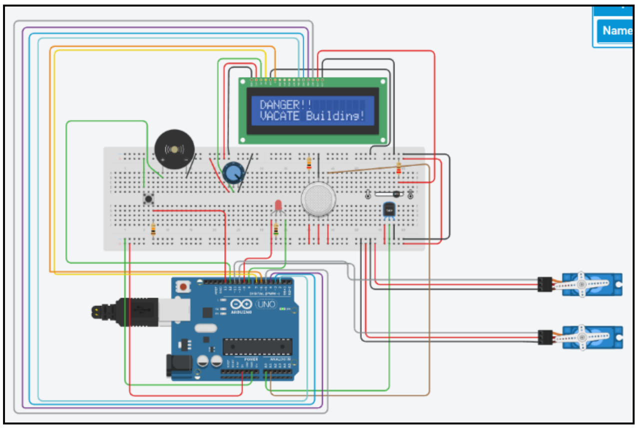

Fig. 5 *Simulation when the Presence of Fire ≥ 45°C*

Some of the code, such as the while loop function, delay function, and else may interrupt the background process and subsequently cause an error. Durian Uno + ESP8266 ESP-01 Wi-Fi module (with Durian Blynk Firmware) overcome this problem as the Durian UNO, and ESP8266 ESP-01 Wi-Fi module works independently. The code will be uploaded into Durian UNO, and it will not affect the process inside the ESP8266 ESP-01 Wi-Fi module (with Durian Blynk Firmware). Therefore, the IoT project runs smoothly with Durian UNO + ESP8266 ESP-01 Wi-Fi module (with Durian Blynk Firmware). As in this Tinkercad online simulator, the design uses Arduino UNO as its microcontroller. So, it is quite difficult to implement the code without any errors. As a precaution, the reset button function was added to the design to make it easier to work properly in simulation. The reset button can be used when the gas sensor and TMP sensor are triggered. Then, the solution to start over the system is to press and hold the reset button so the system can work properly in Tinkercad online simulator.

3.2 Calibration

Before uploading the full code to the system, the MQ-7 gas sensor had been calibrated alone without any other required code for the overall system. This method is to ensure the precision of the sensor to get the output value in ppm units. Calibration of the MQ-7 gas sensor has been done using code in Arduino IDE uploaded to the Arduino that is connected to the sensor. Shown above is the code for the calibration. As shown in Fig. 6. the result obtained from the calibration is the MQ-7 gas sensor can detect up to 99.042 ≈ 100 ppm. Based on the datasheet of the MQ-7 sensor. It is recommended to calibrate the detector for 200ppm Carbon Monoxide, CO in the air. The required value of Load resistance (R_L) is about 10 K΄Ω (5K΄Ω to 47K΄Ω).

```
|23.00| v = ADC*5.00/1023.00 | 0.11 | RS = ((5.00*RL)/Voltage) - RL| 444.67 | Ratio = RS/R0| 27.37 | ratio*a + b | 0.65 |
|373.00| v = ADC*5.00/1023.00 | 1.82 | RS = ((5.00*RL)/Voltage) - RL| 17.46 | Ratio = RS/R0| 1.07 | ratio*a + b | 88.77 |
|423.00| v = ADC*5.00/1023.00 | 2.06 | RS = ((5.00*RL)/Voltage) - RL| 14.24 | Ratio = RS/R0| 0.88 | ratio*a + b | 120.98 |
|478.00| v = ADC*5.00/1023.00 | 2.33 | RS = ((5.00*RL)/Voltage) - RL| 11.42 | Ratio = RS/R0| 0.70 | ratio*a + b | 169.06 |
|501.00| v = ADC*5.00/1023.00 | 2.45 | RS = ((5.00*RL)/Voltage) - RL| 10.40 | Ratio = RS/R0| 0.64 | ratio*a + b | 195.00 |
|513.00| v = ADC*5.00/1023.00 | 2.51 | RS = ((5.00*RL)/Voltage) - RL| 9.94 | Ratio = RS/R0| 0.61 | ratio*a + b | 208.78 |
|528.00| v = ADC*5.00/1023.00 | 2.58 | RS = ((5.00*RL)/Voltage) - RL| 9.37 | Ratio = RS/R0| 0.58 | ratio*a + b | 228.23 |
|548.00| v = ADC*5.00/1023.00 | 2.68 | RS = ((5.00*RL)/Voltage) - RL| 8.67 | Ratio = RS/R0| 0.53 | ratio*a + b | 257.08 |
|573.00| v = ADC*5.00/1023.00 | 2.80 | RS = ((5.00*RL)/Voltage) - RL| 7.85 | Ratio = RS/R0| 0.48 | ratio*a + b | 298.62 |
|578.00| v = ADC*5.00/1023.00 | 2.83 | RS = ((5.00*RL)/Voltage) - RL| 7.68 | Ratio = RS/R0| 0.47 | ratio*a + b | 308.69 |
|564.00| v = ADC*5.00/1023.00 | 2.76 | RS = ((5.00*RL)/Voltage) - RL| 8.09 | Ratio = RS/R0| 0.50 | ratio*a + b | 285.46 |
|633.00| v = ADC*5.00/1023.00 | 3.09 | RS = ((5.00*RL)/Voltage) - RL| 6.20 | Ratio = RS/R0| 0.38 | ratio*a + b | 427.58 |
|686.00| v = ADC*5.00/1023.00 | 3.35 | RS = ((5.00*RL)/Voltage) - RL| 4.91 | Ratio = RS/R0| 0.30 | ratio*a + b | 608.72 |
|733.00| v = ADC*5.00/1023.00 | 3.58 | RS = ((5.00*RL)/Voltage) - RL| 3.97 | Ratio = RS/R0| 0.24 | ratio*a + b | 842.45 |
|764.00| v = ADC*5.00/1023.00 | 3.74 | RS = ((5.00*RL)/Voltage) - RL| 3.37 | Ratio = RS/R0| 0.21 | ratio*a + b | 1077.41 |
|581.00| v = ADC*5.00/1023.00 | 2.87 | RS = ((5.00*RL)/Voltage) - RL| 7.40 | Ratio = RS/R0| 0.46 | ratio*a + b | 326.97 |
|188.00| v = ADC*5.00/1023.00 | 0.94 | RS = ((5.00*RL)/Voltage) - RL| 43.14 | Ratio = RS/R0| 2.66 | ratio*a + b | 22.49 |
|54.00| v = ADC*5.00/1023.00 | 0.26 | RS = ((5.00*RL)/Voltage) - RL| 179.44 | Ratio = RS/R0| 11.04 | ratio*a + b | 2.58 |
|51.00| v = ADC*5.00/1023.00 | 0.25 | RS = ((5.00*RL)/Voltage) - RL| 192.57 | Ratio = RS/R0| 11.85 | ratio*a + b | 2.32 |
|47.00| v = ADC*5.00/1023.00 | 0.23 | RS = ((5.00*RL)/Voltage) - RL| 210.00 | Ratio = RS/R0| 12.92 | ratio*a + b | 2.04 |
|41.00| v = ADC*5.00/1023.00 | 0.20 | RS = ((5.00*RL)/Voltage) - RL| 236.51 | Ratio = RS/R0| 14.56 | ratio*a + b | 1.70 |
|40.00| v = ADC*5.00/1023.00 | 0.20 | RS = ((5.00*RL)/Voltage) - RL| 242.59 | Ratio = RS/R0| 14.93 | ratio*a + b | 1.64 |
|38.00| v = ADC*5.00/1023.00 | 0.19 | RS = ((5.00*RL)/Voltage) - RL| 259.21 | Ratio = RS/R0| 15.95 | ratio*a + b | 1.48 |
|37.00| v = ADC*5.00/1023.00 | 0.18 | RS = ((5.00*RL)/Voltage) - RL| 262.80 | Ratio = RS/R0| 16.17 | ratio*a + b | 1.45 |
```

Fig. 6 *Calibration Result for MQ-7 Gas Sensor*

In the Serial Monitor, current air quality has been displayed, as shown in Fig. 7. The value of gas increased when there was the presence of gas, and the value decreased when the presence of gas was getting faded, as shown in Fig. 8. Testing had been made for the MQ-7 gas sensor calibration, as shown in Fig. 9, to assess the change in the value of the sensor detecting the presence of Carbon Monoxide, CO, by using a lighter.

```
ratio*a + b  |  0.65  |
ratio*a + b  |  0.65  |
ratio*a + b  |  0.65  |
ratio*a + b  |  0.65  |
ratio*a + b  |  0.63  |
ratio*a + b  |  0.65  |
ratio*a + b  |  0.61  |
ratio*a + b  |  0.63  |
ratio*a + b  |  0.63  |
ratio*a + b  |  0.63  |
ratio*a + b  |  0.65  |
ratio*a + b  |  0.63  |
ratio*a + b  |  0.65  |
```

Fig. 7 *Result Obtained in Serial Monitor Displays Current Normal Air Quality from the Calibration*

```
  |  ratio*a + b  |  1.70
  |  ratio*a + b  |  1.64
  |  ratio*a + b  |  1.48
|  ratio*a + b  |  485.45
|  ratio*a + b  |  658.06
|  ratio*a + b  |  989.25
|  ratio*a + b  |  1215.26  |
|  ratio*a + b  |  1320.60  |
|  ratio*a + b  |  1366.21  |
|  ratio*a + b  |  1622.50  |
|  ratio*a + b  |  1706.74  |
|  ratio*a + b  |  1593.30  |
|  ratio*a + b  |  642.54
 |  ratio*a + b  |  36.85
 |  ratio*a + b  |  3.66  |
 |  ratio*a + b  |  3.06  |
```

Fig. 8 *Result Obtained in Serial Monitor Displays Current Air Quality when There is Presence of Gas from the Calibration*

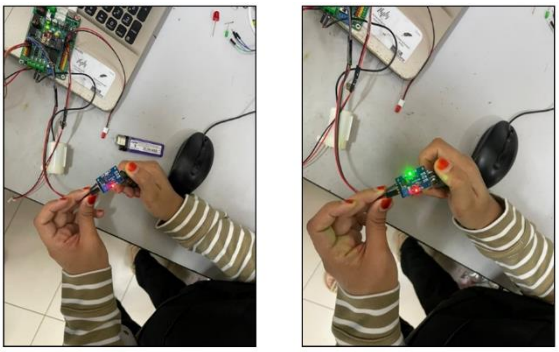

Fig. 9 *(Left) MQ-7 Gas Sensor when No Presence of Gas. (Right) When MQ-7 Gas Sensor Detects the Presence of Gas*

3.3 Experimental Circuit and Component Testing

For experimental testing, both sensors, MQ-7 gas sensor and the IR flame sensor, are tested repeatedly to ensure the system is working properly. As for the MQ-7 gas sensor, the result obtained from the testing is already calibrated in ppm unit since it has been declared in the code. So, the result displays the current smartphon of the MQ-7 gas sensor in the Blynk application is also the result of the calibration. The advantages of Durian UNO are the microcontroller does not require many external components such as a relay and buzzer. It is because the Durian UNO itself can run up to 4 motor components. So, it will be no problem if the 12V DC motor is connected to the microcontroller without any relay required so do the 5V DC water pump. Nowadays, the used of gadgets are widely used. Notification testing through smartphones and tablets has also been done in this experiment.

Fig. 10 and 11 show a complete circuit connection without and with power supply, respectively. When the Durian UNO been plugged in to 12V power supply, both LED that attaches to the sensor light up, showing that the connection works properly without any incorrect input power supply and grounding for each sensor.

Overall circuit testing had been done with complete components such as plastic pipe and water sprinkler as shown in Fig. 12. By using a 12V input power supply, all the required features work successfully. However, there is a problem that appear when testing. When IR flame sensor detects the presence of gas. The system suddenly goes OFF and is connected to Wi-Fi a few seconds later. Yet, the problem occurs once each time when plugged into the supply. After that, the system all works perfectly fine.

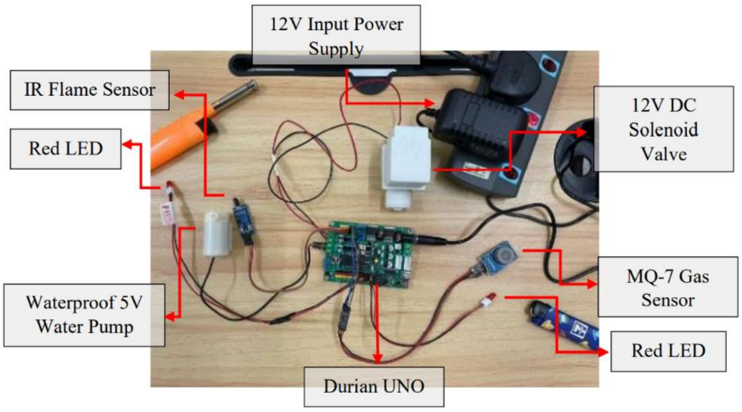

Fig. 10 *Complete Circuit Connection for the System before Plug in Power Supply*

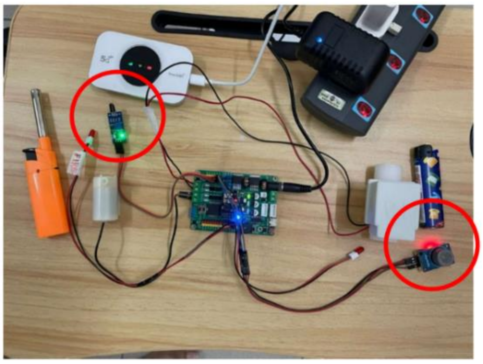

Fig. 11 *Complete Circuit Connection for the System when Plug in Power Supply*

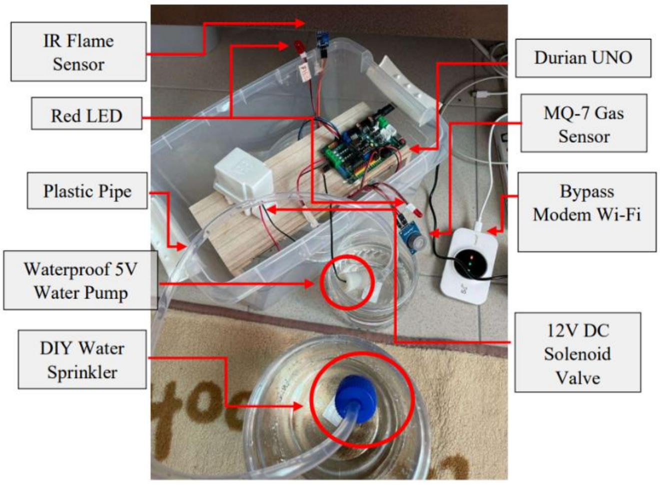

Fig. 12 *Overall Circuit Testing with the Suppression Control Element*

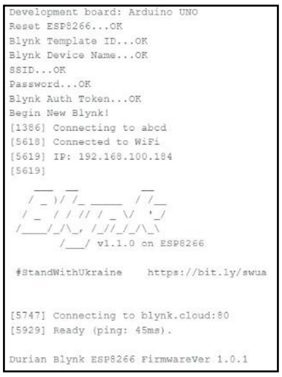

Fig. 13 *The System is Connected to Blynk Application*

As shown in the serial monitor in Fig. 13, the system needs to clarify the Blynk template ID, Blynk Device Name, and Blynk Auth Token. For the Wi-Fi connection, the system needs to identify the required Wi-Fi with all the details in the code. After successfully connecting to Wi-Fi, Blynk goes online, and the circuit system is working properly. The serial monitor also shows the IP address for the connection.

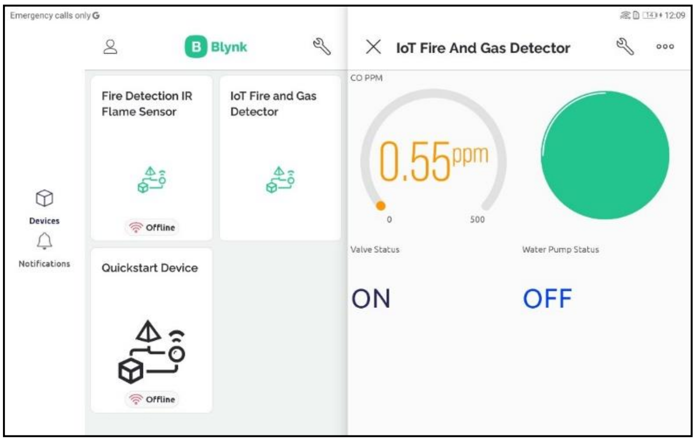

Fig. 14 *Current Air Quality Displayed and Green Button to Represent no Presence of Fire via Blynk Application in Tablet Device*

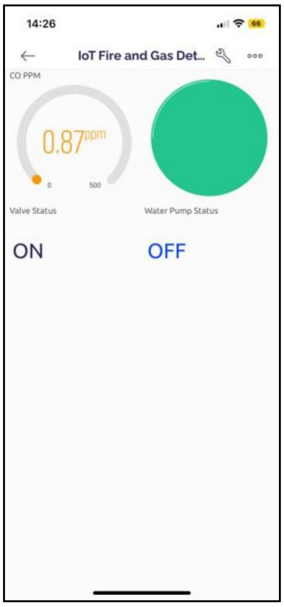

Fig. 15 *Current Air Quality Displayed and Green Button to Represent no Presence of Fire via Blynk Application in Smartphone Device*

The MQ-7 gas sensor is linked to the Durian UNO. Fig. 11 shows the circuit connection between the MQ-7 sensor and the Durian UNO. Based on the red LED coming from the MQ-7 sensor module, it has been confirmed that the module is compatible with the microcontroller and works perfectly. As a result, obtained from the testing in Fig. 16 and Fig. 17, Red LED will light up when the presence of gas exceeds ≥ 50 ppm, and at the same time, the notification "Gas Leak Detected!" was sent to the user's devices through Blynk application. Then, the solenoid valve will change from de-energized to energized as it closes the tube to prevent the gas from spreading.

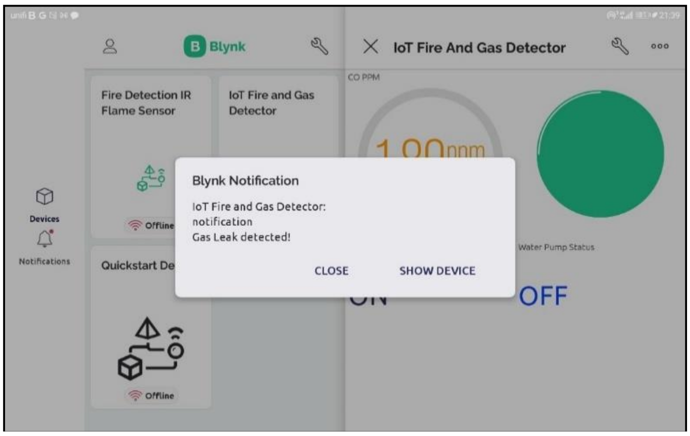

Fig. 16 *Notification "Gas Leak Detected" was Sent via Blynk Application in Tablet Device*

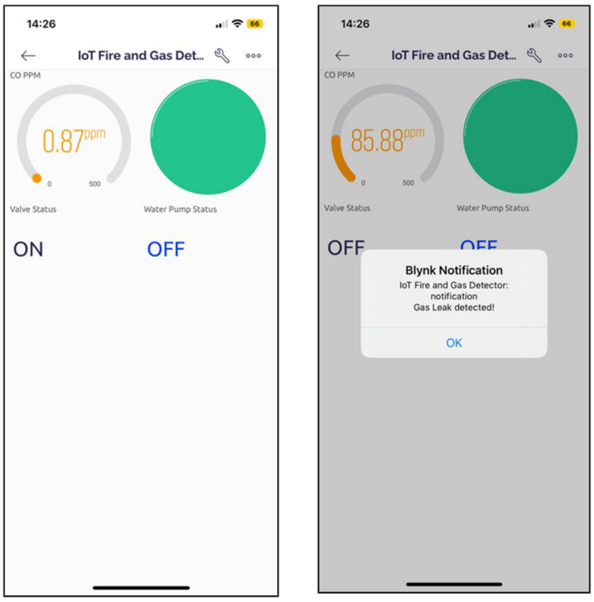

Fig. 17 *(Left) Current Air Quality Display in Valve Status via Blynk Application in the Smartphone Device (Right) Notification "Gas Leak Detected" was Sent via Blynk Application in the Smartphone Device*

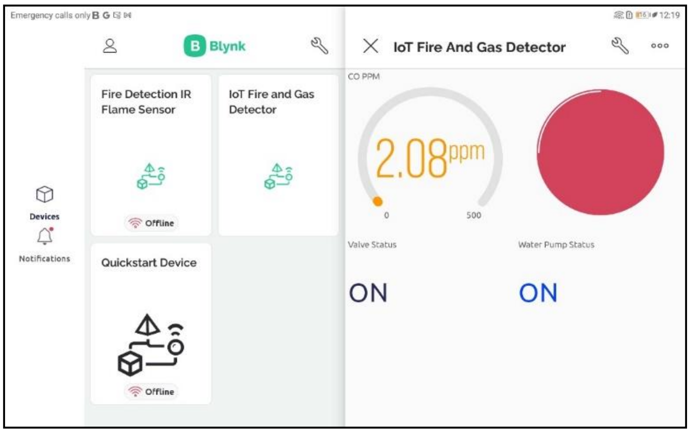

Fig. 18 *Water Pump Status Button in Blynk Application will Change to Red Color when there is a Presence of Fire*

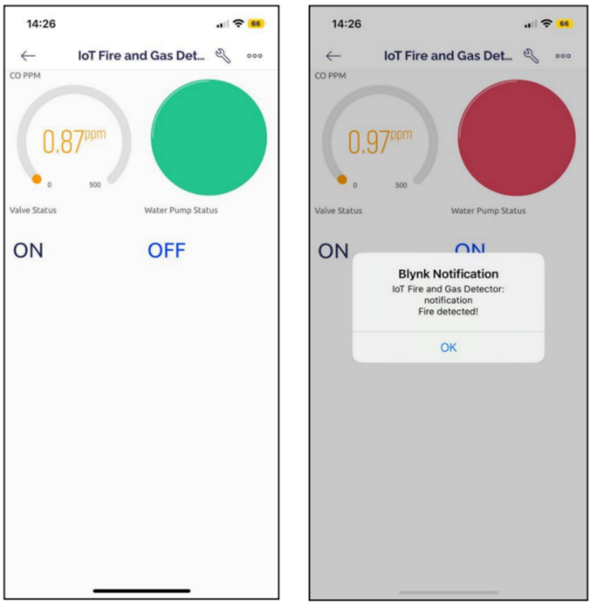

Fig. 19 *(Left) Water Pump Status Button is Green when IR Flame Sensor has not been Trigger via Blynk Application in the Smartphone Device. (Right) Notification "Fire Detected!" was Sent, and Water Pump Status Turning Red via Blynk Application on the Smartphone Device*

The result obtained from the testing in Fig. 18 shows, red LED will light up when there is the presence of fire, which IR flame sensor can detect the changes in light declared as 0 and 1 in the code, the red LED will light up and at the same time, the notification "Fire Detected!" was sent to user's devices via Blynk application.

As shown in Fig. 14 and Fig. 15, the water pump status button in the Blynk application is Green and will change to a red color button, as shown in Fig. 19 when the IR flame sensor detects the presence of fire.

Overall circuit testing had been done with complete components such as plastic pipe and water sprinkler. By using a 12V input power supply, all the required features work successfully. However, there is a problem that appears when testing. When IR flame sensor detects the presence of gas. The system suddenly goes OFF and is connected to Wi-Fi a few seconds later. Yet, the problem occurs once each time when plugged into the supply. After that, the system all works perfectly fine.

Table 1 *The Case and Either the System Works Properly or Vice Versa for Overall Circuit Testing*

	MQ-7 Gas Sensor		IR Flame Sensor	
Case	**Working Properly**	**Not Working Properly**	**Working Properly**	**Not Working Properly**
1	YES	-	YES	-
2	YES	-	YES	-
3	YES	-	YES	-
4	YES	-	-	NO (Connection suddenly OFF and automatically connected to the network again)
5	YES	-	YES	-
6	YES	-	YES	-
7	YES	-	YES	-
8	YES	-	YES	-
9	YES	-	YES	-
10	YES	-	YES	-

From the result obtained in Table 1, it can conclude that the system is 95% working according to the required features. As for the IR flame sensor, during one-time testing, suddenly, the system goes Off, causing the entire system to shut down for a while and automatically connect to the network again a few seconds later. After the connection is back to normal, the IR flame sensor can detect the presence of fire successfully, along with the Red

LED, notification, and water pump activated. Nine and a half out of ten times testing the system is working properly.

3.4 Experimental Circuit and Component Testing

To fulfill the third objective of the system, which is to evaluate usability of the system. A survey was done with 50 respondents to answer the questionnaire provided. The survey is to retrieve data from users related to IoT-Based Fire Safety Detection and Suppression Control Systems. Here is the survey that comes from different backgrounds.

Respondents answered the questionnaire questions after evaluating the system. 29 of the respondents evaluated the system in real terms, while 21 respondents watched the provided video through the WhatsApp application.

4. Conclusion

In conclusion, the implementation IoT-Based Fire Safety Detection and Suppression Control System were designed and developed successfully throughout the two semesters. The system can detect the presence of gas, display the current air quality, warning elements from the LED, and provide notification, also solenoid valve works well. Then the same goes for the IR flame sensor works according to the required objectives. When there is the presence of fire, Red LED will light up and the notification "Fire Detected!" will be sent through the Blynk application. The water pump will automatically pump water to the water sprinkler.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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