Design of Monitoring and Fire Extinguishing System Based on the Internet of Things in Unmanned Vehicles

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Abstract— Currently, people are often unaware of the existence of hotspots or gas leaks in the house which can trigger large fires in the house. Therefore, this research focuses on designing a fire monitoring and extinguishing system that can detect early IoT-based fires using the SIM800L GSM module on unmanned vehicles to detect fires and immediately extinguish them, accompanied by sending emergency messages via the SMS application on smartphones. As a warning, a fire has been detected in the house so that people can be more alert. In addition, this system is designed so that the vehicle can be controlled remotely using the HC-06 Bluetooth module and Bluetooth RC Car. This early fire detection process will be tested 30 times, each sample will be tested for the time speed obtained in detecting and extinguishing a fire. Thus, this system has the potential to prevent fires which can cause major losses.

Keywords— Internet of Things, GSM SIM 800L, Fire Detection, MQ-2 Sensor, Bluetooth RC Car, Unmanned Vehicle

I. INTRODUCTION

Fire is one of the disasters that often occurs and can cause great losses, both in terms of material and loss of life [1]. Fire is unpredictable and difficult to control, especially if the fire is allowed to spread without rapid handling [2]. Supporting factors that can cause a fire disaster are the emergence of hotspots and smoke which if left for a long time the fire can spread and threaten human safety, damage property and cause great losses [3]. This incident not only has an impact on humans, but also on infrastructure, the environment, and the economy, thus disrupting daily activities [4]. In Indonesia, within a period of 9 years, based on data from the National Disaster Management Agency (BNPB), between 2014 and 2023 there were 4.254 cases of fire, with the majority of cases occurring on the island of Java [5].

Some of the main factors that trigger fires include land drought, uncontrolled burning of garbage, electrical short circuits due to poor installations, and human carelessness in the use of flammable materials [6]. In addition, fire incidents also often occur in residential areas and open areas, especially during the dry season drought. In Purwakarta Regency, during July - August 2023, there were 80 cases of fires, most of which were caused by land fires and garbage burning [7]. So it can be stated that a fire disaster is an incident that can occur at any time and can endanger anyone because in addition to the risk of damaging the environment, it can also cause losses that have a major impact [8]. To overcome this, previous studies have developed various solutions to overcome fires, especially with a focus on early detection systems.

According to research conducted by Bachri (2017), a radio frequency-based fire detection system using temperature and smoke sensors was proposed. However, this system has weaknesses in accuracy, especially in large buildings where the temperature is easily affected by people's movements, so the data obtained is unstable [9]. Another study conducted by Saputro and Tuslam (2022) used NodeMCU ESP8266 and ThingSpeak platform to detect fires and send the location of the incident via e-mail. While effective in

certain situations, this system is too dependent on the network. Wi-Fi, so it cannot work in locations that are not connected to the internet [10].

Other studies, such as those conducted by Dana et al. (2018) and Sepriando et al. (2020), also contributed to the development of fire detection systems. Dana et al.'s (2018) study used Himawari-8 satellite imagery data to detect forest and land fires, but the accuracy of the system decreased in high-air conditioning, and the system cannot move [11]. Meanwhile, based on research by Sepriando et al. (2020), satellite imagery is also used for fire detection, but the error rate in this system is still high [12]. And based on research conducted by Juwariyah et al. (2018), they developed a home fire detection system based on ESP8266 and the Blynk application, but this system can only work if a network is available. Wi-Fiat the fire scene [13].

Based on the limitations of previous studies, this study aims to develop a fire-based early detection system.Internet of Things(IoT) which is more reliable. This system will use the GSM SIM800L module which is independent of the network. Wi-Fi, and equipped with MQ-2 fire and gas sensors for more accurate detection. In addition, the system will also be equipped with an automatic extinguishing mechanism using a mini water pump to dampen the fire point, providing a more comprehensive solution in dealing with fire disasters.

II. STUDY LITERATURE

A. Internet of Things

Internet of Things (IoT) is a concept with the aim of expanding internet connectivity that is continuously connected [14]. IoT has the ability to share data, remote control, and convey information. For example, there are several objects that use IoT technology, namely, electronics, home appliances and food that can live because they are connected to local and global networks via embedded and active sensors [15].

B. Arduino

Arduino is a microcontroller-based open source platform used by programmers to develop systems. Arduino itself has several variants, one of which is the variant that will be used in this research, namely, Arduino Uno R3 is a development board or development board based on the Atmega328P microcontroller which is commonly used in the electronics field and consists of 14 digital pins as input and 6 output pins of which are used as input. analog. The advantage of this development board is that it develops software using a programming language that is easy to understand and simple [16]. Can be seen in Figure 1.

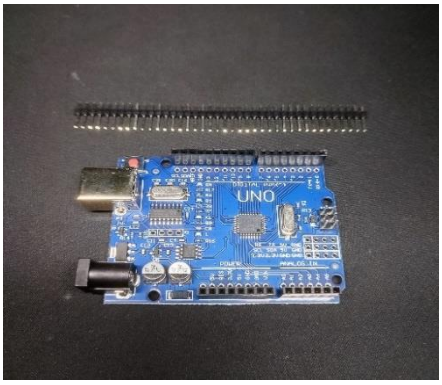


Figure 1. Arduino Uno R3

C. GSM SIM800L Module

The SIM800L GSM module is a communications module that is usually used to send and receive data via the GSM cellular network. Its function is to send monitoring or

warning messages remotely. The advantage of this module is that it can send data information remotely in the form of text messages via the SMS application [17].

D. Bluetooth HC-06 Module

The HC-06 Bluetooth module is a wireless communication module that allows electronic devices to communicate wirelessly via the Bluetooth protocol. The advantages of this module are its easy use and affordable costs [18]. Can be seen in Figure 2.

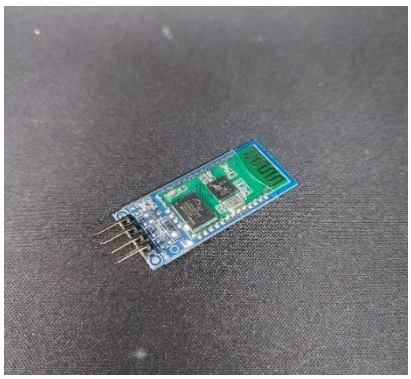


Figure 2. Bluetooth HC-06 Module

E. Bluetooth RC Car

Bluetooth RC Car is software for controlling cars remotely which integrated using a Bluetooth module installed on a microcontroller and uses Bluetooth technology via connected devices such as smartphones or computers. The advantage of this software is that it can be controlled remotely [19]. Can be seen in Figure 3.

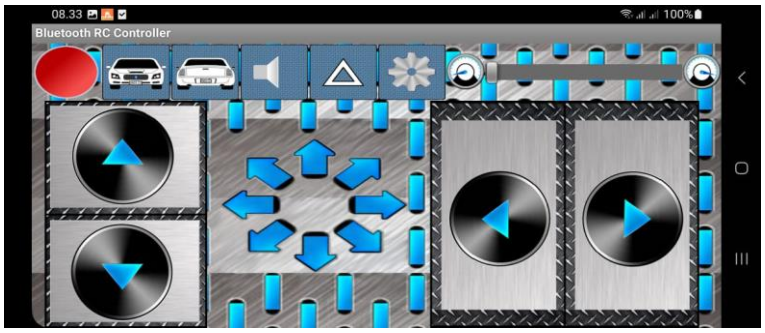


Figure 3. Vehicle control display on the Bluetooth RC Car Application

F. Flame Sensor

Flame sensor is an electronic device designed to detect the presence of fire or excessive heat. This sensor is used to monitor the potential for fire or abnormally high temperatures. The advantage of this sensor is that it can detect the presence of fire or excessively high temperatures at an early stage, so this sensor can detect early fires before the fire spreads widely [20]. Can be seen in Figure 4.

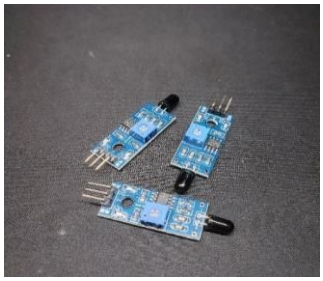


Figure 4. Flame Sensor

G. MQ-2 Sensor

The MQ-2 Sensor is a sensor used to detect the presence of gas in the air, for example dangerous gases such as LPG gas, methane gas, smoke, alcohol, propane and carbon monoxide (CO). The advantage of this sensor is that it can detect various types of gas, making it a versatile gas sensor because it can detect dangerous gases and this sensor has a high level of sensitivity to the gas it measures [21]. Can be seen in Figure 5.

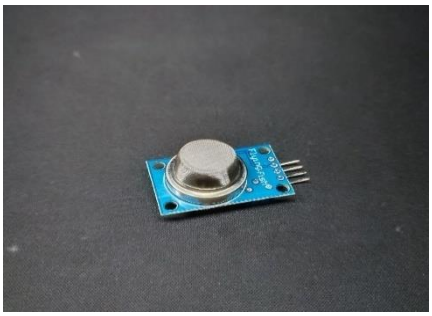


Figure 5. MQ-2 Sensor

H. Conventer LM2596

LM2596 step down converter module which functions to reduce the input voltage to a lower output voltage, with high efficiency. This is also called a buck converter, where a higher input voltage (for example from a battery or other power source) is converted into a lower output voltage according to the needs of the electronic device [22]. Can be seen in Figure 6.

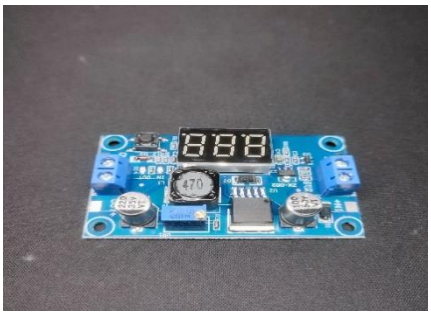


Figure 6. Conventer LM2596

I. Driver L293D

L293D is a motor driver IC that is often used to control DC motors, stepper motors, or other inductive devices in various robotics and embedded systems applications. This IC works using the H-Bridge principle, which allows the motor to rotate in two directions (clockwise and counterclockwise) easily [23]. Can be seen in Figure 7.

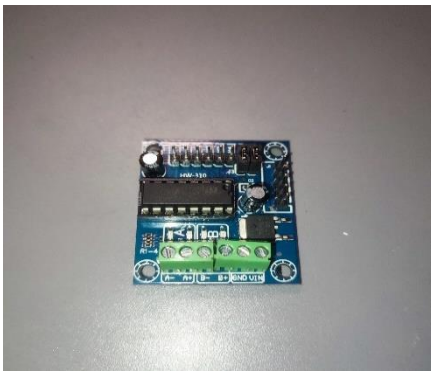


Figure 7. Driver L293D

III. METHODS

A. General Description of the System

This research focuses on designing early fire detection and extinguishing of fire points, in the design of this system it is based on Internet of Things(IoT) which means that this system is made like an unmanned vehicle that detects fire and extinguishes fire points that can move anywhere in one room. In addition, the design of this system uses the GSM SIM800L module to receive information data from the three fire sensors and one MQ-2 gas sensor as inputon a system that aims to send warning messages if a fire point is detected to users via SMS application and emergency calland the Arduino Uno R3 microcontroller as a controller to detect early fires based on the information data generated by the two sensors. Three fire sensors are needed to detect fire points at an angle of 180^{o} , which means that by using three fire sensors placed on the left and right sides of the unmanned vehicle or on different sides, the system can validate information from several sources, thereby reducing the possibility of detection errors or failure of a single sensor. While the smoke sensor only uses one sensor because the smoke sensor has good sensitivity and is quite reliable in detecting smoke. In the design of early fire detection, a model scheme is made which can be seen in Figure 8.

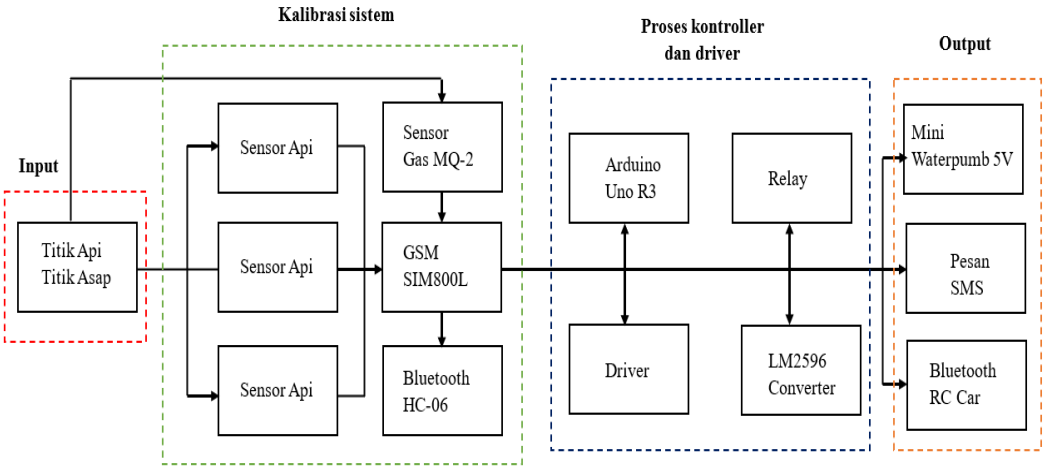


Figure 8. System Overview

B. Design System

Designing an early fire detection system requires several components, including Flame Sensor, MQ-2 Sensor, Converter LM2956, Driver L293D, GSM SIM800L, Bluetooth HC-06 Module, Servo and DC Motor. Next, the GSM SIM800L is designed to be able to create signals in the form of GSM and GPRS which can produce output in the form of messages and emergency callto notify the user if a fire is detected nearby. If the sensor successfully detects a fire point, the fire extinguishing unmanned vehicle cannot be controlled on the Bluetooth RC Car application and the vehicle will move forward towards the fire point and then send a signal tosmartphoneUsers as a media for information, then the unmanned vehicle will extinguish the fire with the installed water. water pumpmini on the vehicle body automatically. The following is Figure 9. which is a design of the interconnection between components on an unmanned vehicle.

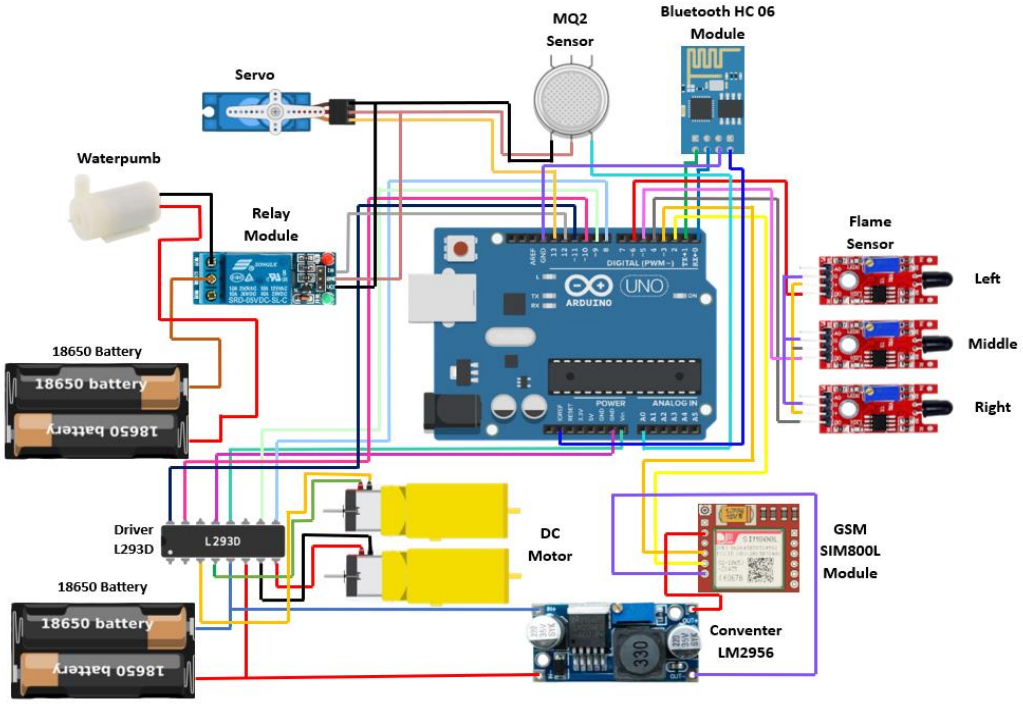


Figure 9. Interconnection Between Component

C. Research Methods

The research method used in this research is Research & Development (R&D), is development research that can be a link from basic research to applied research [24]. By using this type of research, it will be developed a product or to improve previously existing products.

The purpose of this study is to create a "Prototype of IoT-Based Fire Extinguishing and Monitoring System for Unmanned Vehicles" that can detect fire and smoke and then extinguish it with water that has been integrated using a water pump. In addition, the GSM SIM800L module will immediately send data information in the form of warning messages to the SMS application.

D. System Workflow

In the system workflow process that begins with sensor initialization, the system will then read the sensor data and data processing will occur to process data from the sensor that has read the detection of a point of smoke and fire, then the system will print the condition of the fire so that the water pump will turn on and move to extinguish the fire, at the same time the system will send a warning or alert message to the user via the GSM SIM800L module that has received information data from the sensor that detected the fire point.

Furthermore, the process will return to the sensor reading and will continue to repeat as long as the system is active. Related to this process can be seen in Figure 10.

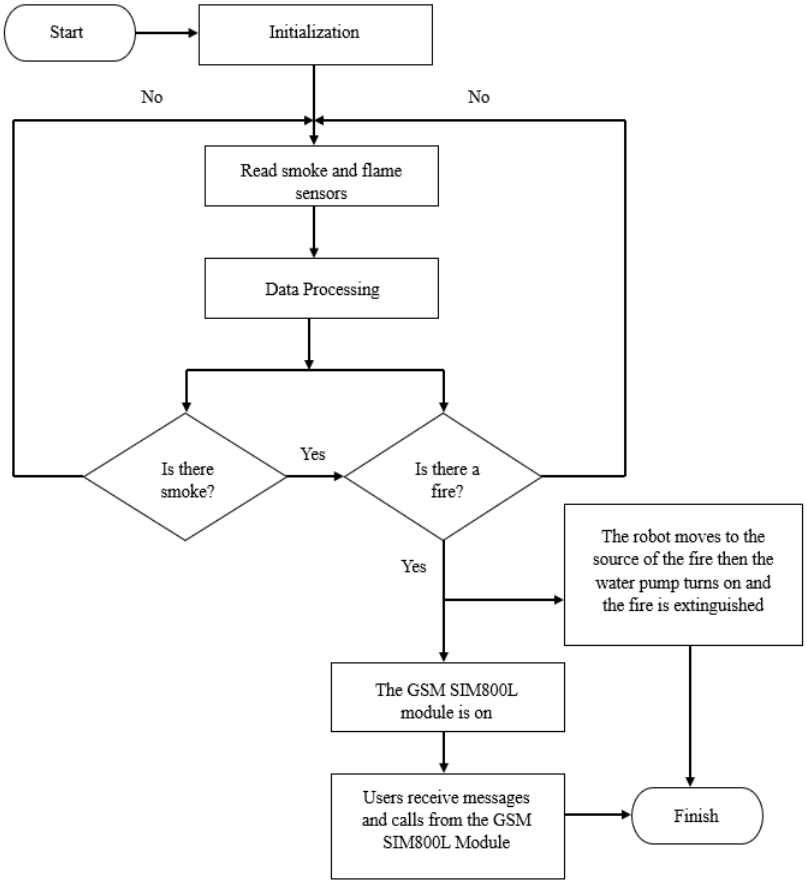


Figure 10. System Workflow

E. System Implementation

At this stage it is very important to ensure that the system functions according to the specifications and needs that have been previously set. The prototyping process includes several steps. First, the collection and preparation of components needed to build the prototype. Second, the assembly of these components is carried out according to the design that has been made. Third, the testing stage is carried out to ensure that each component functions properly and according to expectations which can be seen in Figure 11.

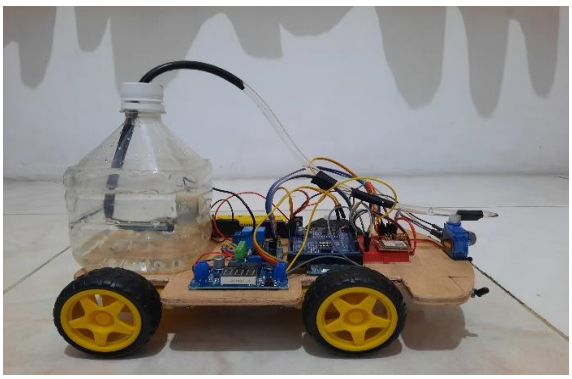
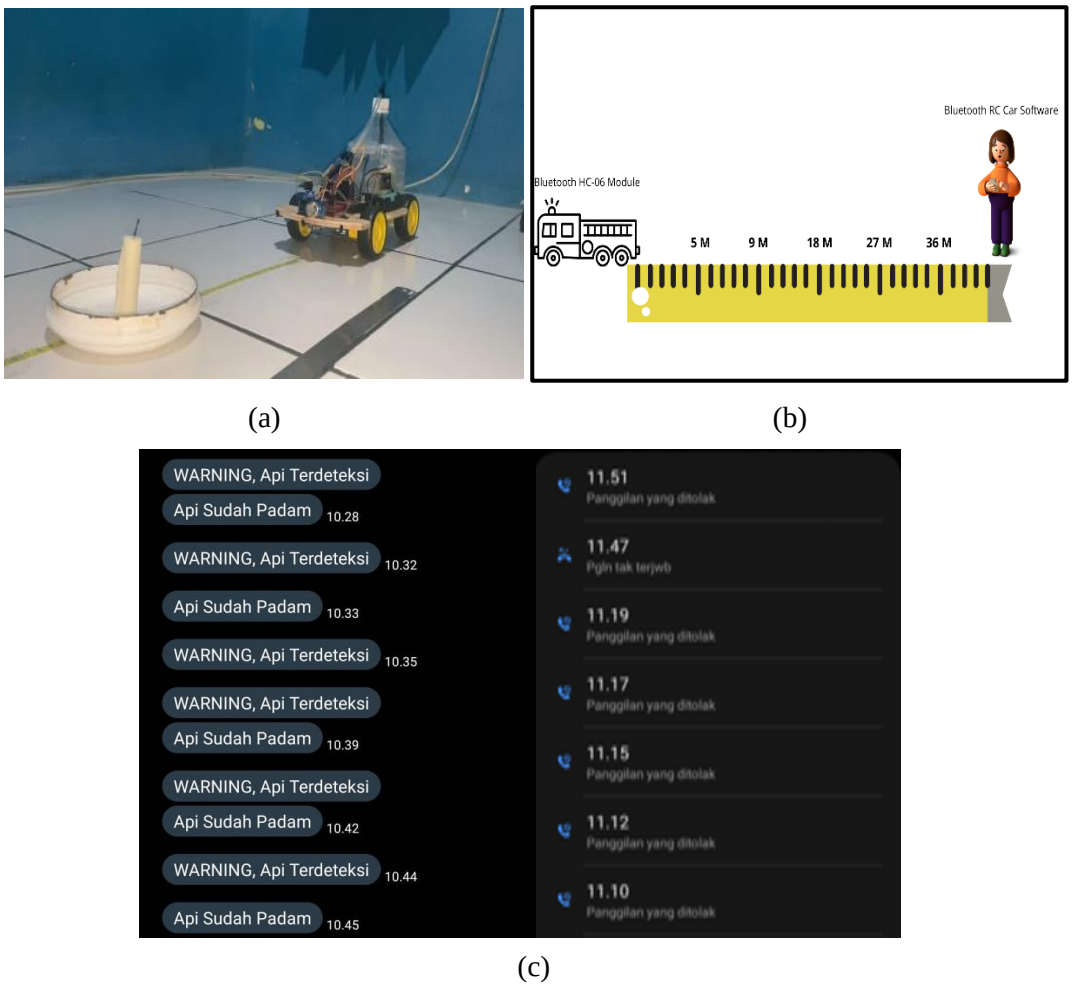


Figure 11. System Implementation

IV. RESULT AND DISCUSSION

A. System Functionality Testing

System functionality testing aims to ensure that tools, systems, and software work according to predetermined specifications. In this test, the system will be tested to ensure that the designed system can produce accuracy values that can be validated. To determine the level of success of this system, 30 trials were conducted. This test was carried out by calculating how many unmanned vehicles can extinguish fires in 30 trials along with the average time delaywhen the vehicle detects fire, then count how many phone calls and SMS came in when the vehicle successfully detected fire anddelayaverage and trial remote controlin the form of a Bluetooth RC Car on an unmanned vehicle with a distance of 5 m, 9 m, 18 m, 27 m, and 36 m to get the results that the unmanned vehicle can be controlled withbluetoothwhich is connected at a maximum distance of 36 m. Next, the accuracy of the system will indicate whether the fire sensor used on the vehicle without whether the crew can function well or not and how many unmanned vehicles can extinguish the fire in 30 trials as in Figure 12 below.



(a) (b)

(c)

Figure 12. System Testing : (a) fire detection, (b) test vehicle remote control connectivity, (c) SMS and call emergency

Furthermore, the level of accuracy in the system can indicate whether the designed system can function properly or not.The accuracy can be calculated using the following quation formula 1.

$$Accuracy = \frac{(V.Experiment - V.Fail)}{V.Experimen} \times 100\% \quad (1)$$

Based on the error rate obtained, the accuracy level of the system can be determined by comparing it from the number of trials conducted with the results of the failed variable value when the sensor successfully or not detects fire and when the vehicle successfully or not when extinguishing the fire. This level of accuracy indicates whether the designed system is functioning properly or not. And the value error ratecan be calculated using the following equation formula 2.

$$Error\ Rate = 100\% - Accuracy \quad (2)$$

Based on the equation formula 3.2, accuracy can be calculated and the data obtained are then categorized into validation assessment categories. Various organizations, industrial sectors, and research institutions have developed the ISO/IEC 17025 standard, which covers various validation sectors to assess the performance of measuring instruments and systems [25]. Therefore, Table 1. shows the validation score categories as follows:

Tabel 1.
Accuracy Validation Score

Category	Validation Score
Invalid	25% - 43%
Less Valid	44% - 62 %
Valid	63% - 81%
Very Valid	82% - 100%

B. Test Result of Unmanned Fire Fighting Vehicle

The test was conducted to evaluate the early fire detection system on the unmanned fire extinguishing vehicle to determine whether the vehicle can detect and extinguish fire properly according to the concept and purpose. The test results will provide information on the reliability and effectiveness of the unmanned vehicle in detecting fire in various directions and to determine how far the unmanned vehicle can be remote controlusing Bluetooth RC Car. This evaluation is important to ensure that the unmanned fire fighting vehicle can function optimally and provide the expected benefits. Therefore, system testing is carried out with two scenarios, including the follows:

Tabel 2.
Scenario I Testing Bluetooth HC-06 Control Connectivity Against Distance

Testing to	Control Distance (m)	Control Vehicle	HC-06 Bluetooth RC Car App
1	5 m	Functioning	Connect
2	9 m	Functioning	Connect
3	18 m	Functioning	Connect
4	27 m	Functioning	Connect
5	36 m	Does not work	Connect

Table 2. shows scenario I, namely testing carried out 10 times for each control distance on the installed Bluetooth HC-06. in unmanned vehicles to the vehicle control distance insmartphonedisplayed with the Bluetooth RC Car application. So that it produces a level of success of unmanned vehicles with an effective distance of less than 27 m. While unmanned vehicles at a distance of more than 27 m cannot function or move

when the vehicle is controlled using the Bluetooth RC Car application. This is to provide information to users about the connectivity of unmanned vehicle control with its distance.

Tabel 3.
Scenario II Testing of Unmanned Vehicle System for Detection

Testing to	Location Point Fire	Emergency Call	Emergency SMS	Blackout Fire	Distance (cm)	Long Detection (s)	Long Turn off Fire (s)
1	Middle	✓	✓	Success	15 cm	0.15 s	0.05 s
2	Middle	✓	✓	Fail	20 cm	0.04 s	×
3	Middle	×	✓	Fail	25 cm	0.02 s	0.04 s
4	Middle	✓	✓	Fail	23 cm	0.02 s	0.04 s
5	Middle	✓	✓	Success	20 cm	0.06 s	0.04 s
6	Middle	✓	✓	Success	25 cm	0.01 s	0.05 s
7	Middle	✓	✓	Success	18 cm	0.04 s	0.03 s
8	Middle	✓	✓	Success	30 cm	0.01 s	0.05 s
9	Middle	✓	✓	Success	29 cm	0.02 s	0.05 s
10	Middle	✓	✓	Success	28 cm	0.02 s	0.02 s
11	Right	✓	✓	Success	20 cm	0.05 s	0.01 s
12	Right	✓	✓	Success	15 cm	0.08 s	0.03 s
13	Right	✓	✓	Success	18 cm	0.04 s	0.05 s
14	Right	✓	✓	Success	21 cm	0.03 s	0.05 s
15	Right	✓	✓	Success	16 cm	0.05 s	0.04 s
16	Right	✓	✓	Success	22 cm	0.06 s	0.05 s
17	Right	✓	✓	Success	21 cm	0.04 s	0.05 s
18	Right	✓	✓	Success	23 cm	0.03 s	0.04 s
19	Right	✓	✓	Success	24 cm	0.02 s	0.04 s
20	Right	✓	✓	Success	18 cm	0.04 s	0.05 s
21	Left	✓	✓	Success	22 cm	0.07 s	0.05 s
22	Left	✓	✓	Success	23 cm	0.04 s	0.04 s
23	Left	✓	✓	Success	20 cm	0.08 s	0.04 s
24	Left	✓	✓	Success	22 cm	0.01 s	0.04 s
25	Left	✓	✓	Success	22 cm	0.03 s	0.05 s
26	Left	✓	✓	Success	23 cm	0.02 s	0.03 s
27	Left	✓	✓	Success	24 cm	0.02 s	0.04 s
28	Left	✓	✓	Success	14 cm	0.11 s	0.04 s
29	Left	✓	✓	Success	16 cm	0.04 s	0.04 s
30	Left	✓	✓	Success	20 cm	0.01 s	0.04 s
Averange					**21.23 cm**	**0.042 s**	**0.039 s**

Table 3. shows scenario II, namely the results of testing unmanned vehicles on the fire detection and extinguishing system, resulting in an accuracy value of 90% and a failure rate (error rate) of 10% of the total of 30 trials, it was proven that 27 times the unmanned vehicle successfully extinguished the fire and 3 times the unmanned vehicle failed to extinguish the fire. In addition, when the unmanned vehicle successfully detected the fire, emergency call experienced failure 1 time, namely no calls came in, whereas on emergency unmanned vehicle SMS successfully sends 30 messages emergency as a form of information to users to be more alert if a fire is detected. For the average distance traveled when 30 times the unmanned vehicle detected a fire, which was 21.23 cm, the unmanned vehicle could detect the fire point. And the duration delay when the unmanned

vehicle detects fire is 0.042 s, and the length of time the unmanned vehicle takes to extinguish the fire is 0.039 s.

V. CONCLUSION

The prototype of the fire monitoring and extinguishing system with Arduino Uno R3 and GSM SIM800L Module showed success in accordance with expectations in terms of indicators. softwareand alsohardware. Use Bluetooth HC-06 Moduleallows users to control unmanned vehicles effectively at a distance of less than 27 m, and the SIM800L GSM Module helps users to detect fire points by providing information via emergency callAndemergency SMS.In addition, based on the results of the calculation of the accuracy of the prototype fire extinguishing monitoring system and fire detection based on IoTfor this unmanned vehicle, it gets a fairly high accuracy value of 90%, this figure is included in the very valid validation score based on the ISO/IEC 17025 standard validation table. This accuracy figure proves that the system can work or move well and optimally in detecting or extinguishing fires accurately.

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