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DESIGN OF FIRE EXTINGUISHER ROBOT USING IOT WITH ANDROID APPLICATION CONTROL

Budy Satria[1*]; Syarif Hidayatullah[2]; Fitra Yuda[3]; Leonard Tambunan[4]; Siti Sahara Lubis[5]; Irzon Meiditra[6]

Department of Informatics, Faculty of Information Technology[1]
Universitas Andalas, Padang, Indonesia[1]
https://unand.ac.id[1]
budy.satria@it.unand.ac.id[1]

Department of Computer Engineering[2, 4]
Institut Teknologi Mitra Gama, Riau, Indonesia[2, 4]
https://itmg.ac.id[2,3]
zthsyarif.03@gmail.com[2], tambunan.leonard81@gmail.com[4]

Department of Information System[3], Department of Information Technology[5, 6]
Institut Teknologi Rokan Hilir, Riau, Indonesia[3, 5, 6]
https://itr.ac.id[3, 5, 6]
fitrayuda110199@gmail.com[3], saharalubis448@gmail.com[5], meiditrairzon@gmail.com[6]

(*) Corresponding Author
(Responsible for the Quality of Paper Content)

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Abstract— *Fire is an unsupervised incidental disaster. This disaster has a detrimental impact on living and non-living things in the surrounding environment. This study was conducted to design an intelligent firefighting robot using Arduino Mega 2560 and Android-based IoT technology. This firefighting robot uses several Node MCU ESP8266 components as additional devices to connect to wifi. The L298N module regulates the speed and direction of the DC motor rotation, followed by the L9110 fan as hardware to extinguish the fire. The mobile robot prototype uses a DC motor as its driver. In addition, an Android application has been programmed to control the firefighting robot. This application has features that allow the robot to move in various directions and adjust the fan speed when extinguishing fires, all through an internet network connection. The study results showed that the application can be connected within a distance of 1-8 meters with good network quality. The test results showed that at a distance of 1-28 cm, the fan worked very well according to its function, and the Android application also worked optimally. In that range, the fan can extinguish the simulated fire source. The results of this study obtained a new approach to autonomous fire detection and extinguishing using IoT and robotic technology. In addition, it is able to integrate an Android-based IoT controller to enable remote control with real-time monitoring to overcome problems in previous research.*

Keywords: *android, arduino mega 2560, fire extinguisher, IoT, robot.*

Intisari— *Kebakaran merupakan bencana insidentil tanpa pengawasan. Bencana ini memberikan dampak yang merugikan bagi makhluk hidup maupun tak hidup di lingkungan sekitar. Penelitian ini dilakukan untuk merancang robot pemadam kebakaran cerdas menggunakan Arduino Mega 2560 dan teknologi IoT berbasis Android. Robot pemadam kebakaran ini menggunakan beberapa komponen Node MCU ESP8266 sebagai perangkat tambahan untuk terhubung dengan Wi-Fi. Modul L298N mengatur kecepatan dan arah putaran motor DC, diikuti oleh kipas L9110 sebagai perangkat keras untuk memadamkan api. Prototipe robot bergerak menggunakan motor DC sebagai penggeraknya. Selain itu, telah diprogram sebuah aplikasi android untuk*

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mengendalikan robot pemadam kebakaran. Aplikasi ini dilengkapi fitur yang memungkinkan robot bergerak ke berbagai arah dan mengatur kecepatan kipas saat memadamkan api, semuanya melalui koneksi jaringan internet. Hasil penelitian menunjukkan bahwa aplikasi dapat terhubung dalam jarak 1-8 meter dengan kualitas jaringan yang baik. Hasil pengujian didapatkan bahwa pada jarak 1-28 cm kipas angin bekerja sangat baik sesuai fungsinya dan aplikasi android juga bekerja dengan optimal. Pada rentang tersebut kipas angin dapat memadamkan sumber api yang disimulasikan. Hasil penelitian ini memperoleh suatu pendekatan baru untuk deteksi dan pemadaman kebakaran secara otonom dengan menggunakan IoT dan teknologi robotik. Selain itu mampu mengintegrasikan pengontrol IoT berbasis Android guna memungkinkan pengendalian jarak jauh dengan pemantauan waktu nyata guna mengatasi permasalahan pada penelitian sebelumnya.

***Kata Kunci**: android, arduino mega 2560, pemadam api, IoT, robot.*

INTRODUCTION

Robotics is proof that human civilization has advanced over time. The shape of a robot is not just a shape that resembles a human or animal but moves to resemble the shape it imitates. The robot blends computer science, mechanics, and electronic devices. The robot's entire body can travel from one location to another thanks to its driving wheels. Robots can also perform activities and tasks similar to humans [1]. Besides putting out flames, robots can also keep an eye on them and warn firefighters [2]. A robot is a mechanical machine that mimics human behavior or performs tasks. Robotics and autonomous systems have advanced significantly. As a result, the manufacturing industry has changed, with robots now handling most of the repetitive and dangerous jobs. However, there are a lot of other areas where robotics and robotic systems can be used to their full potential. The applications of this technology are practically limitless and might have a significant influence on society and people's lives. The ability of the robot to complete its mission is very calculated; for that, a reliable navigation system is needed to support optimal robot performance. Robots were created to make it easier for humans to solve problems, such as extinguishing fires [3]. Many people can feel technological developments, including in the fields of electronics and computer science, for the use of industry, government, and education [4].

A robot is a collection of electronic or mechanical devices that are connected to an electric current with the principle of doing work like humans [5]. Fire is one of the disasters that can cause significant losses, both in terms of material, environment, and human life. The firefighting process often presents high risks for firefighters, especially in areas that are difficult to reach or have the potential for additional hazards such as chemical leaks or explosions. Firefighting is the process of containing a fire's progress and extinguishing it. It is seen as a risky task for firefighters working in hazardous conditions. Attempting to rescue individuals who are enveloped in flames presents additional difficulties for firefighters [6].

The risks borne by the firefighting team are very high. Therefore, an innovative solution is needed to minimize these risks and increase the effectiveness of the extinguishing process, namely creating a firefighting robot to assist humans in this work. One of the efforts to improve their safety is the development of robots to handle such situations. These robots assist firefighters by mitigating risks and enhancing the effectiveness of fire extinguishing tasks. With the use of these robots, the risk to firefighting personnel can be significantly reduced.

Related research on fire extinguishing robots has been carried out by the results of this study [7]. A robot that functions to find the source point of the fire and then extinguish it using a fan using the L9110 fan motor drive module was designed and built. Infrared sensors and HC-SR04 ultrasonic, the process of finding the point of the fire source utilizes ultraviolet light emitted by the fire. Research on firefighting robots has also been carried out in designing and implementing fire detection and extinguishing systems using dual-axis mechanics [8]. Previous research has been conducted on the application of IoT in the design of a miniature robot fire extinguishing system to assist the pre-evacuation evaluation process [9]. This research aims to develop a miniature wheeled IoT (Internet of Things) robot that can monitor visual conditions using an esp32-cam and retrieve data from the necessary sensors such as gas, fire, temperature, and distance sensors.

This study builds upon prior research by integrating IoT-based technologies with hardware components such as Arduino Mega 2560, Node MCU ESP8266, and the L298N motor driver. The system also utilizes Android applications to provide a user-friendly robot control interface. Previous research highlights the efficacy of IoT and Arduino in

robotics, and the Fire Detection and Water Release Activity for Fire Fighting Robots using IoT is one of the foundations for developing this research [10].

Previous studies highlight the efficacy of IoT and Arduino in robotics, illustrating an IoT-based fire detection robot capable of real-time response, providing a foundation for this research. IoT is part of today's technological developments that can connect the Internet from a device and provide sustainable benefits [11]. IoT can connect embedded hardware through the internet network [12]. The Arduino Microcontroller Board is the robot controller used in this research [13]. Specifically, the Arduino Mega 2560 microcontroller, based on the ATMEGA 2560, is utilized, and it features 54 input pins [14].

Fires pose significant threats to both human safety and property. Current firefighting methods rely heavily on manual operations, which can endanger the lives of firefighters. Moreover, these methods may not effectively address fire outbreaks in inaccessible or high-risk areas. Despite advancements in robotics, existing fire extinguishing robots often face limitations in range, control precision, and operational adaptability. Thus, there is a critical need for a more efficient and safer solution to mitigate these challenges.

The Arduino Mega 2560 is used as the microcontroller board in this firefighting robot. The 2560 control board offers multi-channel digital input and output, making it better suited for tracking car projects that require extensive IO interface design. The automobile can receive more signals with 16 digital inputs and outputs, while a 12 MHz crystal oscillator provides clock synchronization for the main board [15]. Researchers widely use Arduino Mega 2560 as a microcontroller to control embedded materials and to carry out programmed instructions [16]. This research results in a prototype firefighting robot with Arduino Mega 2560-based programming [17], using Internet of Things technology controlled by the Android application.

The Internet of Things (IoT) is a recent technological development capable of transferring large amounts of data through an Internet network that is connected to the destination source [18]. In recent years, the Internet of Things has become a prominent research topic [19]. IoT typically integrates software and hardware components, often provided by IT companies [20]. Today, IoT technology plays a significant role in human life, where each object is uniquely identifiable, equipped with sensors, and connects in real-time to the Internet [21].

In 2023, an Arduino-controlled wireless fire extinguishing robot designed for residential areas was produced by L. Wasu. et al. [22] This robot offers an alternative to fighting fires in enclosed areas, buildings, and residential areas. By remotely operating the robot outside the disaster area, the spread of fire and property damage can be stopped before further help arrives. IoT Technology-Based Firefighter Robot The robot is operated using a remote desktop application. The connection between the robot and the application (authority) is done through the Internet. This paper introduces how the concept of the Internet of Things (IoT) is introduced to robots. The IoT-based automatic fire detection and extinguishing robot addresses these challenges by combining advanced sensor technology, robotics, and IoT [23] to provide autonomous and real-time solutions. The robot is equipped with fire and temperature sensors that can detect fires at an early stage.

This study uses the ESP8266 MCU Node as an additional device to connect to wifi. ESP8266 is a wifi module with a System on Chip on TCP/IP and has to control the microcontroller [17]. A robot is designed using Node MCU (ESP8266), which is easy to program [24].In this research, a prototype robot will be designed that can be used to extinguish fire remotely using control from an Android app.

The novelty of this study lies in integrating IoT technology with an Android-based control system to create a user-friendly interface for firefighting robots. Unlike previous designs, this prototype focuses on real-time control and operational efficiency within a defined range, as demonstrated through rigorous testing. Using the L9110 fan to extinguish fires and implement a user-centric Android application provides unique contributions to existing solutions. In conclusion, this research aims to enhance firefighting operations by addressing existing limitations and providing a safer, more efficient solution by integrating advanced technologies and innovative design.

This article is written using the structure of introduction, materials and methods, results and discussion, conclusion, and references.

MATERIALS AND METHODS

This research uses a prototype method to help work as humans do. In this study, the prototype was used for the initial stage of testing and experimentation. The researcher adopts the research and development and development method, explicitly focusing on firefighting robots through 5 five-cycle processes: Analysis, Prototype

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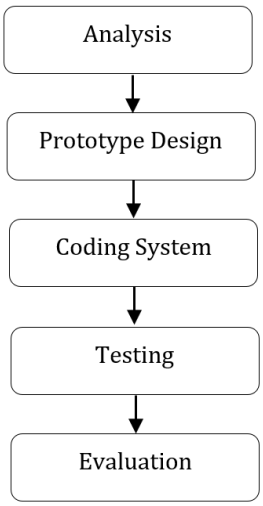
Design, Coding System, Testing, and Implementation.

This process can be seen in Figure 1, illustrating the development of the Android-based prototype firefighting robot [25] :



Source: (Research Results, 2024)

Figure 1. Proposed Research Method

Analysis

During this step, the research objectives and resource requirements are assessed. This research intends to improve robotics skills by creating a prototype firefighting robot with Arduino Mega 2560 and Android-based Internet of Things (IoT) technologies. The end product of this step acts as an input for the following phase, the design stage.

Prototype Design

At this stage, An intelligent firefighting robot is designed using the Arduino Mega 2560 and Android-based IoT technology. The design process employs Fritzing software to create the entire prototype circuit of the robot schematically. The firefighting robot is designed to resemble a car, equipped with wheels for movement and fans to extinguish fires. This step serves as a reference for the development stage [26].

Coding System

In this cycle, the researcher ensures that all designs have been completed and operated according to the research objectives. This involves creating hardware circuits and interconnecting components, such as the Arduino Mega 2560, Node MCU ESP 8266, L298N Module, Servo Motor, Power Supply, etc. This stage is known as the development stage [27].

Testing

The implementation step follows the development stage. After constructing the robot components, the following step is to create a set of commands in the programming language using standard Arduino syntax to control the microcontroller's performance in the device. Additionally, I developed an Android application to control the firefighting robot when connected to the Internet.

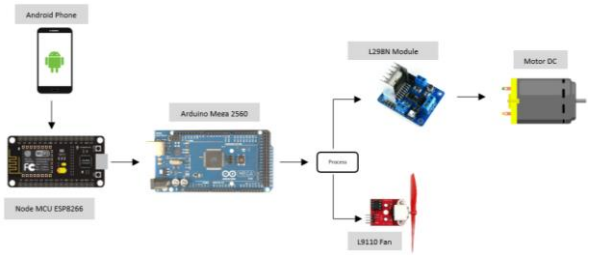
Evaluation

Evaluation is the final stage of this research method to reveal the work's effectiveness [28]. In this stage, a series of tests is conducted on the firefighting robots to identify any functional errors or deviations from the research objectives. If errors are found, they will be corrected, and if the robot functions as intended, further development will be pursued. Ultimately, the robot prototype is created and tested according to the experimental design [29].

RESULTS AND DISCUSSION

Block Diagram

The hardware made as a design is a collection of several modules to form a system to make it functional [30]. In system development, it begins with the implementation stage [31]. The design of a Smart Firefighting Robot Using Arduino Mega 2560 and Android-based IoT Technology is depicted in the block diagram as shown in Figure 2.



Source: (Research Results, 2024)

Figure 2. Block Diagram Design

Figure 2 explains a Block Diagram that serves as a reference for connecting all components [32]. This electronic manufacturer's design makes extensive use of Arduino for data processing. A well-structured research design is required to meet the research objectives.

Robot Design

Figure 3 explains that this firefighting robot uses an Arduino Mega 2560 as a microcontroller and several other supporting hardware to ensure that the robot system works according to the research objectives. The hardware components in this firefighting robot are the Arduino Mega 2560, Node MCU ESP 8266, L298N Module, Servo Motor, Power Supply, and FAN L9110. In addition, an Android was also developed as supporting software to control the robot in extinguishing fires remotely.

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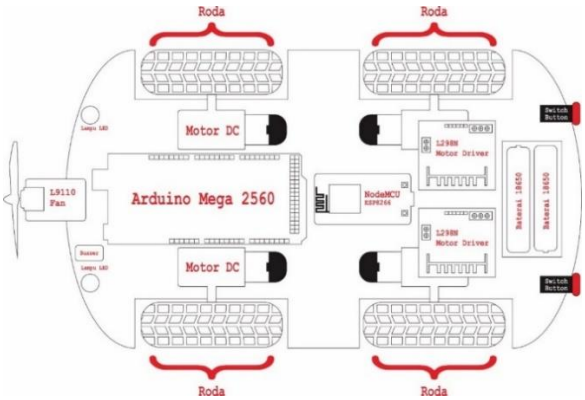
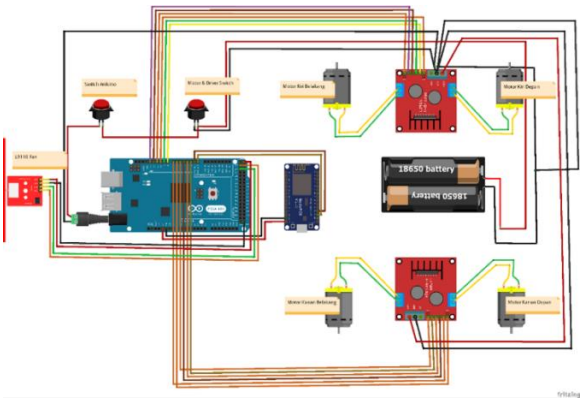
The following is the design of the research methodology, as illustrated in Figure 3.



Source: (Research Results, 2024)
Figure 3. Hardware Design

Wiring Design

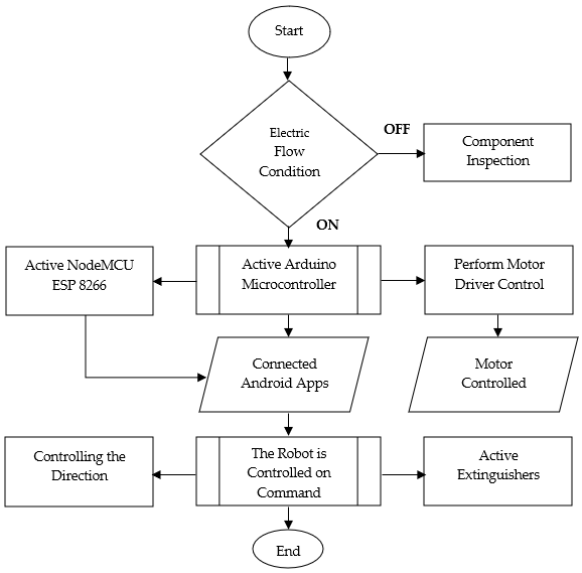
Implementation is one of the activities in the system development section [33]. At this stage, the activity involves placing a prototype of a firefighting robot that is a functional part of the developed system. The design of the wiring diagram is shown in Figure 4.



Source: (Research Results, 2024)
Figure 4. Wiring Design

Flow Diagram

Figure 5 is a Flow Diagram Design. When the Arduino component is electrified, the microcontroller will be in control and provide instructions to the ESP 8266 MCU Node and L298N Motor Driver. Once both components are activated, the MCU ESP 8266 Node will connect to the Android application, while the L298N will control the driver motor. Through the Android application, the firefighting robot can be controlled under two conditions. Firstly, it can change the robot's direction of movement, and secondly, it can activate the fan to extinguish fires. The design of the flow diagram is shown in Figure 5.



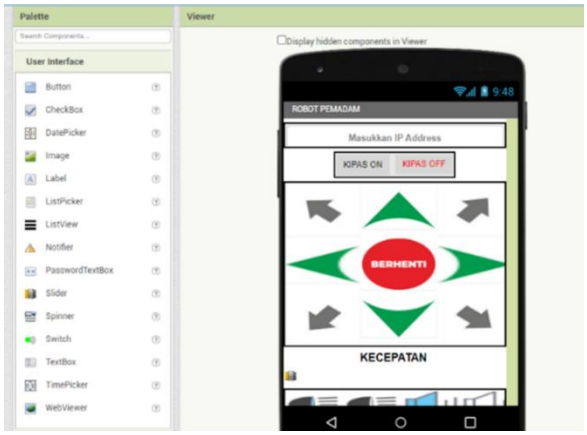
Source: (Research Results, 2024)
Figure 5. Flow Diagram

Program Code

At this stage, commands in the programming language are commands to control the microcontroller's performance in the designed device. The programming language used is C ++, implemented through Arduino software. The program code is shown in this link: https://github.com/budysatria/Fire-Extinguisher-Robot/tree/master.

Application Design

To facilitate the control of the robot, android application software is needed as a remote control. The user interface layout is shown in Figure 6.



Source: (Research Results, 2024)
Figure 6. Application Interface

Prototype Robot

The prototype of the Fire Extinguisher Robot can be viewed from various perspectives. Figure 7

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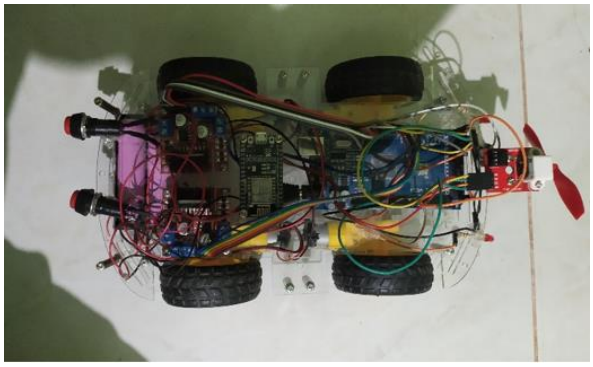
depicts the top view, while Figure 8 illustrates the side view perspective.



Source: (Research Results, 2024)
Figure 7. Top View

Source: (Research Results, 2024)
Figure 8. Side View

Functionality Test Result

Table 1 represents the results of functionality testing on all hardware components. Each component has been thoroughly tested and functions well-functioned based on the predetermined parameters and criteria. The functionality test result is shown in Table 1.

Table 1. Functionality Test Result

No	Component Name	Information	Result
1	Microcontroller Arduino Mega 2560	- Connectable to a computer and Connected to the Internet	100%
2	NodeMCU ESP8266	- Connected to an Android device	100%
3	L298N Motor Driver	- The wheels on the robot have moved	100%
4	Power supply	- Components have electricity	100%
5	L9110 Fan	- Spin when activated	100%
6	Android Application	- Controlling Fire Extinguisher Robot	100%

Source: (Research Results, 2024)

Prototype Robot Test Result

The tests in Table 2 were performed to assess the performance of the HC-SR 04 ultrasonic sensor, which serves as a robot protection system. The test was conducted 15 times at 1 cm up to 30 cm intervals. Protection system test results are shown in Table 2.

Table 2. Ultrasonic Sensor Test

Test	Distance Measured by Sensor	Result
1	2 cm	Has stopped
2	4 cm	Has stopped
3	6 cm	Has stopped
4	8 cm	Has stopped
5	10 cm	Has stopped
6	12 cm	Has stopped
7	14 cm	Work
8	16 cm	Work
9	18 cm	Work
10	20 cm	Work
11	22 cm	Work
12	24 cm	Work
13	26 cm	Work
14	28 cm	Work
15	30 cm	Work

Source: (Research Results, 2024)

Table 2 shows the results of tests that have been carried out at a distance of 2-12 cm; the robot will stop because it has been programmed that the robot must stop when it detects an object in front of it based on that distance. However, the robot will still move at a distance of 14-30 cm.

The next test involves testing the connectivity of robot control using an Android application against concrete obstacles, as shown in Table 3. The testing is conducted at a distance ranging from 1-20 meters. Based on the test results, It was obtained that robot navigation control through an Android application connected to the internet network functions appropriately within a range of 0-5 meters. Test results for Android applications are shown in Table 3.

Table 3. Application Test Result

Test	Distance	Android Application	Signal
1	1 m	Work	Good
2	2 m	Work	Good
3	4 m	Work	Good
4	8 m	Work	Good
5	10 m	Does not work	Bad
6	12 m	Does not work	Bad
7	14 m	Does not work	Bad
8	16 m	Does not work	Bad
9	18 m	Does not work	Bad
10	20 m	Does not work	Bad

Source: (Research Results, 2024)

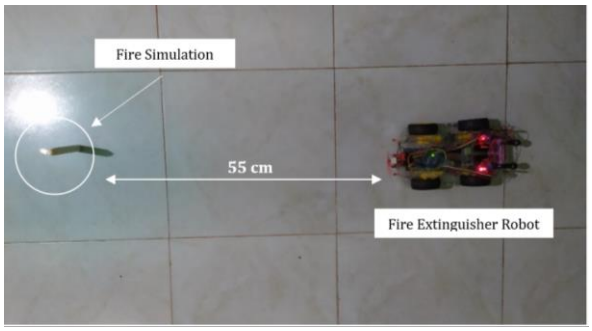
Table 3 can be concluded that testing the Android application at a distance of 1 - 8 meters will get good signal quality, but if it is at a distance of 10-

20 meters, what happens is that the Android application does not work, and the signal quality is terrible. Next is testing the fire extinguishing robot. The tests carried out started with setting the distance between the robot and the fire, the amount of time to extinguish the fire, and the test results, which can be seen in Table 4 below.

Table 4. Fire Extinguishing Robot

Test	Distance	Duration	Fire Condition
1	5 cm	2 second	Off
2	10 cm	2 second	Off
3	15cm	3 second	Off
4	20 cm	3 second	Off
5	25 cm	4 second	Off
6	30 cm	4 second	Off
7	35 cm	5 second	Off
8	40 cm	6 second	Off
9	45 cm	7 second	Off
10	50 cm	10 second	Off

Source: (Research Results, 2024)



Source: (Research Results, 2024)

Figure 9. Robot a Distance of 55 Cm

L911 fan performance test results are shown in Table 5.

Table 5. L9110 Fan Performance Test Results

Test	Distance	Android Application	Fan Result
1	1 cm	Work	Spin
2	2 cm	Work	Spin
3	8 cm	Work	Spin
4	14 cm	Work	Spin
5	16 cm	Work	Spin
6	18 cm	Work	Spin
7	20 cm	Work	Spin
8	22 cm	Work	Spin
9	24 cm	Work	Spin
10	28 cm	Work	Spin

Source: (Research Results, 2024)

Table 5 shows that the test results were carried out to determine the state of the fan on the L9110 Fan when with distances ranging from 1 to 28 cm. The result is that the fan can be turned on and rotated appropriately according to its function.

CONCLUSION

The prototype of a Fire Extinguishing Robot with Android Application control has been successfully implemented. The results indicated that the robot stopped at a distance of 2-12 cm but functioned adequately at a distance of 14-30 cm. In addition, testing was carried out on the Android application, which is used for robot control in extinguishing fires within a range of 1-20 meters. The test results showed that the Android application worked properly and had good signal quality at a distance of 1-8 meters. However, the application stopped working at distances of 8-20 meters. The test was also conducted on the L9110 fan component. Test results showed that the fan operated very well within a distance of 1-28 cm, fulfilling its intended function. Moreover, the Android application also functioned optimally within this range, successfully allowing the fan to extinguish the simulated fire source. The results of this study obtained a new approach to autonomous fire detection and extinguishing using IoT and robotic technology. In addition, it is able to integrate an Android-based IoT controller to enable remote control with real-time monitoring to overcome problems in previous research. The use of wifi communication with an Android app for dual-mode (manual and automatic) operation is a notable enhancement in usability and accessibility. The use of servo-controlled FAN L9110 improves firefighting efficiency. Cost-effective design for multiple applications, such as using the Arduino Mega 2560 microcontroller and ESP8266 MCU Node, which integrates wifi capabilities and achieves functionality without significantly increasing costs, making it suitable for residential, commercial, and industrial applications. This research has successfully designed and developed an innovative IoT-based firefighting robot prototype. The use of Arduino Mega 2560 microcontroller, ESP8266 MCU Node, L298N Motor Driver, L9110 Fan, and the use of IoT platform and Android application provides flexibility and convenience in monitoring and controlling the robot. This research makes a significant contribution to the field of robotics and intelligent systems. This research makes a significant contribution to the field of robotics and intelligent systems. This research opens up new opportunities to develop more advanced fire safety systems in the future, namely Explore AI-based fire detection and alternative network solutions.

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