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Hand washing system based on internet of things

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ABSTRACT

In December 2019, the first case of mysterious pneumonia was reported in Wuhan, Hubei Province. The source of transmission of this case is still unknown, but the first case was linked to a fish market in Wuhan. According to Packham in his research entitled Hand Hygiene for Infection Prevention Against COVID-19, there are two main approaches to hand decontamination, the first is to remove the virus, and the second is to inactivate the virus so that even if the virus is transferred it will not cause harm. Water is a vital resource for life. Water is used for activities such as drinking, bathing, cooking, and washing. Therefore, the availability of sufficient water is highly prioritized in both urban and rural areas. This research aims to create a handwashing warning system based on the Internet of Things (IoT) as a preventive measure against the spread of COVID-19 which is controlled and monitored for use through an Android device.

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1. INTRODUCTION

In the era of globalization, the level of mobility of people and goods is very high and fast. This condition can be a threat when viewed from the point of view of disease transmission from one place to another. The more disease transmission, the more health problems. One of the health problems that are currently of global concern is the emergence of infectious diseases. Emerging infectious diseases are diseases that reappear sporadically in a region, country, and sometimes globally over time (Mukherjee, 2017).

In December 2019, cases of mysterious pneumonia were first reported in Wuhan, Hubei Province. The source of the transmission of this case is still uncertain, but the first case was linked to a fish market in Wuhan (Rothan & Byrareddy, 2020). Ren et al stated that from December 18 to December 29, 2019, there were five patients treated with Acute Respiratory Distress Syndrome (ARDS) (Ren et al., 2020). From 31 December 2019 to 3 January 2020, this case increased rapidly, marked by the reporting of 44 cases. In less than a month, the disease has spread to various other provinces in China, Thailand, Japan, and South Korea (Huang et al., 2020).

According to the World Health Organization, initially, the disease was temporarily named 2019 novel coronavirus (2019-nCoV), then WHO announced a new name on February 11, 2020, namely Coronavirus Disease (COVID-19) caused by a severe virus. Acute Respiratory Syndrome Coronavirus Virus-2 (SARS-CoV-2) (World Health Organization, 2020).

According to Packham in his research entitled "Hand hygiene for infection prevention against COVID-19", there are two main approaches to hand decontamination, the first is eliminating the virus, and the second is virus inactivation so that even if the virus is transferred it will not be harmful. There is no exclusive hand hygiene method. However, because damage to the skin is highly undesirable, hand washing should be limited to situations where sanitation using alcohol is not suitable, as alcohol is not effective against certain microorganisms. When washing hands, it is important to reduce skin damage by using a moisturizer every time your hands are washed (Packham, 2020).

A study by Nisreen Alwan highlights that handwashing with soap is one of the most effective ways to reduce the spread of the novel coronavirus by deactivating the virus, which is translocated from contaminated surfaces (Alwan et al., 2024).

Additionally, research in JMIR mHealth and uHealth discusses how behavior change interventions addressing hand hygiene can support adherence to public health recommendations, thereby preventing the spread of COVID-19 (Baretta et al., 2023).

The increased frequency of handwashing, especially during health crises like the COVID-19 pandemic, has led to a rise in water consumption in Indonesia. A study published in the journal Water examined the impact of the pandemic on hygiene practices and water usage in the country. The findings indicated that heightened hand hygiene practices, aligned with health protocols, resulted in increased water and hygiene product usage. This surge in water consumption raises concerns about domestic pollution and wastewater management during and after the pandemic (Komarulzaman et al., 2023).

Numerous studies from different regions, such as the India, Italy, Morocco, and Indonesia, during the early phases of the pandemic, have documented variations in water quality due to decreased industrial, transportation, and tourism activities (Adwibowo, 2020; Cherif et al., 2020; Mishra & Viral, 2021; Niroumand-Jadidi et al., 2020). In contrast, the shift to remote work and school closures led to an uptick in domestic water consumption (Abu-Bakar et al., 2021; Lüdtke et al., 2021; Rizvi et al., 2021) and adjustments in daily water usage patterns(Dzimińska et al., 2021; Lüdtke et al., 2021). Additionally, heightened personal hygiene practices, including frequent handwashing and increased use of cleaning agents, have contributed to greater water usage (Koksoy Vayisoglu & Oncu, 2021; Toussaint et al., 2020).

Water is an essential resource for human life, integral to activities such as drinking, bathing, cooking, and washing. Poor water usage and management can significantly impact the water availability, which is crucial for both urban and rural communities. A study published in the International Journal of Biomedical Materials Research highlights that limited water reservoirs, high population growth, and inadequate infrastructure contribute to water scarcity, making it challenging for communities to meet their basic daily needs (Abie Fetene, 2021).

One effort to assist water management is through the use of technology that allows users to control and monitor water usage remotely and record water consumption in real-time. The technology that can be utilized is Internet of Things (IoT), which is controlled via an Android application.

The use of Internet of Things (IoT) has been applied in various aspects of management, one of which is water and energy management. A study conducted by Muhammad Yusri in 2024 discusses the development of an IoT-based water quality monitoring system using ESP32 and sensors for pH, TDS, and turbidity. This system is designed to monitor water quality parameters in real-time, which can help in the management of water resources in urban environments (Yusri et al., 2024).

In the context of energy management, a study by Amirul Fadly Ragali discusses an IoT-based electrical energy management system using occupancy sensors. This research method involves surveying energy needs, designing an IoT-based system, developing hardware, and testing the system implementation (Ragali et al., 2024).

Android applications have become integral in controlling Internet of Things (IoT) devices, offering users seamless interaction with various smart technologies. These applications enable functionalities such as remote monitoring, device management, and automation, enhancing user experience and system efficiency.

The application of IoT technology in water and energy management demonstrates significant potential in improving the efficiency and effectiveness of resource management, which can ultimately contribute to environmental sustainability and cost savings in operations.

A study by Md Redwanul Islam in 2020 discusses an Android application can be use to control an IoT-based real-time smart energy meter monitoring system to reduce manual efforts in measuring electricity usage and to raise user awareness about excessive consumption (Islam et al., 2020). Therefore, there is a need for a water usage management system using the Internet of Things, controlled through an Android application.

This research makes a significant contribution to the field of science by demonstrating the application of Internet of Things (IoT) technology to improve public health practices, particularly handwashing habits during the COVID-19 pandemic. This research successfully developed an IoT-based handwashing alert system integrated with real-time Android applications and adds to the literature on IoT technology that focuses on efficient resource management and its application in the context of public health.

2. RESEARCH METHOD

The methodology used in this study is a research and development method. This method has stages that will become a reference in research. This stage includes system analysis, system design, the manufacture of a handwashing warning module, the manufacture of an automatic faucet module, the manufacture of a water discharge calculator module, the manufacture of a soap percentage calculator module, and application development.

Problem Fomulation

The formalization problem is the basis of this research. Problem formulation defines and formulates problems that occur based on the method taken. The problem formulation explains to the reader about the research problem and the objectives to be addressed.

Source Collection

At this stage, the search for relevant and reliable sources related to the research carried out is carried out. These sources are used to strengthen the problems defined in the previous stage, make hypotheses about the solution to the problems outlined in the research objectives, and estimate the benefits that will be obtained from this research. In this study the authors took sources from various literacy such as books, scientific articles, and articles on the internet.

Literature Review

Prior to conducting this research, a literature review was conducted which aims to collect the information needed to conduct research. Furthermore, studies were carried out from various sources that had been obtained in the previous stage, namely regarding the industrial revolution 4.0, Internet of Things (IoT), ESP8266, waterflow sensors, Passive Infra Red (PIR) sensors, buzzers, load cell weight sensors, Dart programming language, Flutter Framework, as well as similar studies that have been done before.

System Analysis

At this stage an analysis of the system requirements to be built is carried out. These requirements include functional requirements for IoT devices and functional requirements for Android applications. Functional requirements are essential in system analysis, as they define the specific behaviors and functions a system must perform to meet user needs. A study published by Levlanov discusses methods for analyzing functional requirements to ensure consistency and logical coherence in information systems (Ievlanov et al., 2018).

System Design

At this stage, the design of the system that will be built in this study is made based on the results of the analysis that has been carried out in the previous stage. The design includes system functionality workflow design using use case diagram.

A use case diagram is a graphical representation that illustrates the interaction between actors (users or other systems) and the developed system, highlighting the functionalities provided by the system. According to an article written by Andrianto in 2022, a use case diagram models the behavior of the information system to be developed, with two main components: actors and use cases (Andrianto, 2022).

IoT Modules Manufacture

This IoT modules manufacture stage is the stage where IoT modules are made. The stages are divided into 3 stages. The first stage, namely the printing of the circuit board. The second stage, namely adding the program to the circuit board. The author first conducted a study on the human detection algorithm with a PIR sensor, an automatic faucet algorithm using an Infra Red Barrier and relay, an algorithm for calculating water flow using a water flow sensor, and an algorithm for calculating the percentage of soap using a weight sensor, namely a load cell sensor. Then from the sources obtained, the author added some changes to the algorithm to make it more eficient and run according to the needs of the IoT module. The third stage is packaging, which is the stage where the author makes sure all the components work well, then wraps it in a container that will make the tool easier to use.

Android Application Development

At this stage, Android application development is carried out based on system requirements and the results of the designs that have been made. The author first conducted a study of the algorithms needed in the development of this Android application. Then from various sources obtained, the author made several changes to adjust to the needs of the system to be built. Then the author makes source code based on the algorithm so that the Android application can run. After the application is completed, it is tested using the Black Box Testing method to check whether the Android application has been running properly and has the functionality required by the system.

Integration

At this stage, the IoT modules are integrated with the Android application that has been developed. This process is bridged by the Antares platform. This platform is a platform under the auspices of PT. Indonesian Telecommunications. The Antares platform is used as an intermediary for connectivity between IoT modules and android applications and is a place where data obtained from IoT modules is stored.

System Testing

At this stage, testing of the handwashing warning system based on ESP8266 using IoT is carried out. Tests are carried out to wash the performance of the system that has been built by installing the tool on a faucet, then simulating hand washing and data changes that occur on the platform and displayed on the Android application.

3. RESULTS AND DISCUSSIONS

Functional Requirements

These functional requirements are divided into functional requirements for IoT devices and functional requirements for Android applications. The functions required by IoT devices include function to detect the presence of the user, function to alert hand washing, function to detect the hand in front of the faucet automatically, function to turn the faucet on and off automatically, function to calculate water discharge, function to calculate the percentage of soap. While the functions required by android applications include function to display the water flow used by the automatic faucet, function to display the remaining soap percentage, function to display water usage reports, function to display soap usage reports, function to export water consumption data into a spreadsheet file, function to export soap usage data into spreadsheet file.

System Functionality Workflow

After obtaining the functional requirements as above, a use case diagram can be made to describe these functions, the interactions between actors that occur and the behavior of the system to be created. The use case diagram of the handwashing warning system using iot can be seen in Figure 1.

Based on the use case diagram in Figure 1, in this system there are 7 actors, namely users who use automatic faucets, admins who operate and control android applications, databases on the Antares platform, and also 4 sensors, namely PIR sensors, infrared barrier sensors, water flow sensors, load cell sensors.

The function is to detect the presence of the user interacting with the user and the PIR sensor. If the function detects the presence of the user, the system will give a warning. The function to detect the hand in front of the faucet automatically interacts with the user and the infrared barrier sensor. If the function detects the presence of the user's hand, the system will control the faucet automatically by turning the faucet on or off. The function to calculate the water flow interacts with the water flow sensor and the results of the calculation will be updated into the database. The function to calculate the percentage of soap interacts with the load cell sensor and the result of the calculation will be updated into the database. The function is to display the water flow used by the automatic faucet, the function is to display the percentage of soap, the function is to display the water usage report, and the function is to display the soap usage report using the data in the database and interact with the admin.

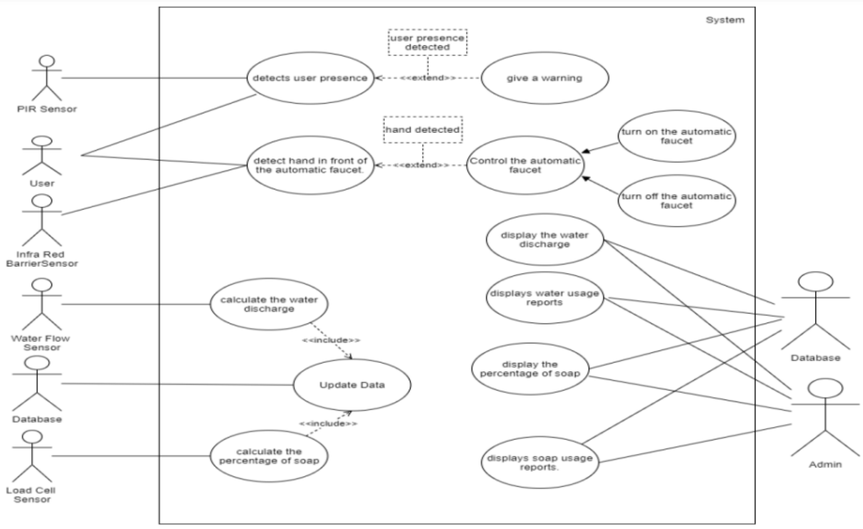

Figure 1. Use case diagram

Iot Module Working Principle

a. Working Principle of Human Presence Sensor Device, this human presence detection device runs using a PIR sensor to detect the presence of humans passing in front of the sensor. If the PIR detects a human presence, the device will turn on a buzzer that produces a sound as a warning to wash hands immediately.

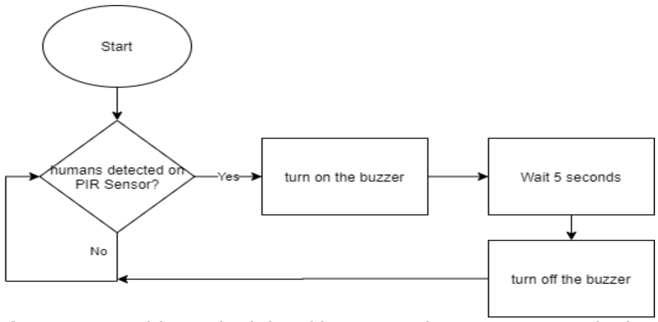

Figure 2. Working principle of human existence sensor device

This human presence detector uses an interrupt function as a trigger to turn on the buzzer so that the buzzer emits a sound that can remind the user in front of the sensor to wash their hands. This function is a function to trigger another program line externally or internally.

In the first part of the program line are the settings to define the pins used by the sensor and their functions. In this section, the author defines the PIR sensor as input and the buzzer sensor as output. Then the PIR sensor is defined as a pin that uses the interrupt function with RISING mode so that when there is a logic change from low to high, the program lines written will be executed.

In the second part, the program line will be executed when the interrupt function occurs. In this section, the author writes a program to turn on the buzzer and record the time when the interrupt function is executed.

Furthermore, the program line will run continuously or loop. In this section, there is a command to turn off the buzzer if a certain time has passed since the last interrupt function was executed.

b. Automatic Faucet Working Principle, this automatic faucet device works by using a sensor that detects the user's hand. If the sensor detects a hand in front of the sensor, the device will activate the relay module which makes the solenoid valve open so that water can flow through the faucet.

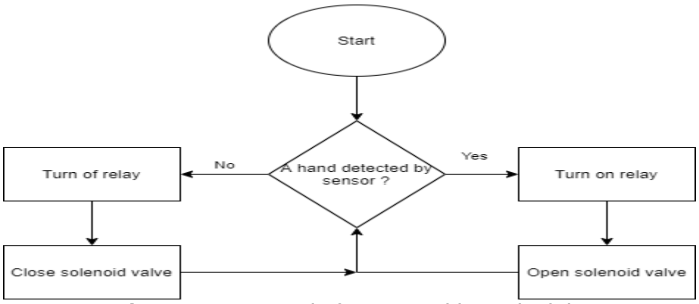

Figure 3. Automatic faucet working principle

In the source code for this automatic faucet, it starts with the command line, which is setup, namely the definition of the pins used and their respective functions. In this section, the author defines the infrared sensor pin as input and the relay pin as output. Next, the program line will run continuously or in a loop. In this section, the author writes a command to read the input received by the infrared sensor. If the reading is 0 or an obstacle is detected, electricity will flow through the relay, while if the reading is other than 0, it will cut off electricity through the relay.

c. Working Principle of Water Discharge Counter, the water discharge calculating device works by using a water flow sensor that has a turbine in it. The water that passes through this sensor will rotate the turbine and this rotation is used to calculate the flow of water that passes through the sensor or is used in automatic faucets.

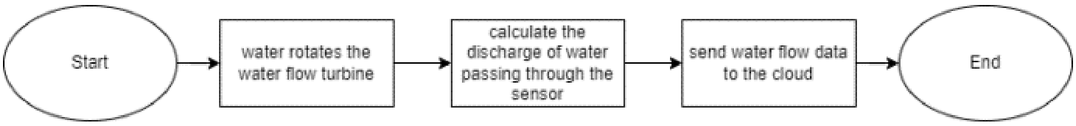

Figure 4. Water discharge counter working principle

In the first part, the command line is in the form of a setup or commands that will be executed when the device is turned on. The setup is in the form of defining a water flow sensor pin using the interrupt function, connecting to a registered wifi, connecting to the Antares platform, and setting the NTP or Network Time Protocol to get the time and date the program is running. Furthermore, the program line is a program line that will be executed if the interrupt function occurs. In this section, the program calculates the water frequency for further calculations. In the last part, a program will run in a loop. In this section, the command to update the time, then record the time will be executed. If the date is the 1st, at 00:00:00, the program will reset the calculated water volume value. Meanwhile, if it is other than that date and the water flow is detected on the sensor, the program will calculate the flow rate per minute and calculate the volume of water that has passed through the sensor. After getting the calculated data, the program will send the data to the Antares platform to be stored and displayed on the Android application.

d. Working Principle of Soap Percentage Counter, the soap percentage calculator works by calculating the percentage of soap using a load cell sensor and then the data from the calculation is sent to the cloud for use in the Android application. If the percentage of soap is less than 5%, the device will turn on the buzzer as a sign to immediately replace or refill the soap. In the source code of this soap percentage calculator, the code starts with a setting or command that will be executed when the device is turned on. The settings consist of determining the pin used for the load cell sensor, determining the pin used as the output to turn on the buzzer, setting the weight reading by the load cell sensor, connecting to registered wifi, and connecting to the Antares platform.

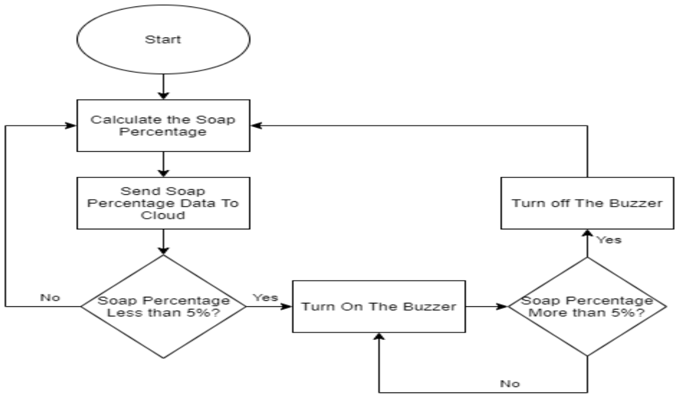

Figure 5. Soap percentage counter working principle

Then the program will run continuously or in a loop. In this section, the author writes an order to read the weight placed above the sensor in the form of a soapy water container containing the soap itself and then calculates the percentage of soap remaining with the formula:

$$percentage = \frac{current\ weight}{maximum\ weight}\ x100\% \quad \text{...(1)}$$

If the calculation result is between 0% and 5%, then the program will turn on the buzzer to warn the user to refill the soap. Then the program will send the reading results to the Antares platform to be displayed on the Android application.

Android Application Workflow

The android application workflow describes the two main workflows performed by the android application, namely retrieving the latest data and all data from the Antares platform. This data is the data displayed in the Android application. The data is displayed in the form of diagrams and the form of text. The last data is displayed in real-time and in text form because if you retrieve all the data it will take time so it can cause the data to not be displayed in real time. While the data obtained from the process of taking all data will be displayed in the form of a diagram.

a. Last Data Retrieval Workflow, the process carried out is to access the Antares platform by using the HTTP features in the Flutter framework using the Dart programming language. This HTTP feature is used according to the type of data required. In accordance with the documentation on the Antares platform website, the parameters used in collecting this data must match the accounts, applications, and devices that have been registered on the Antares platform.

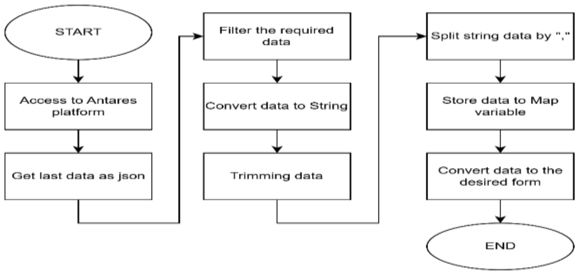

Figure 6. Last data retrieval workflow

After receiving a response from the Antares platform, the next step is to filter the data obtained so that it only takes the data that is needed. The data taken is the data in the “con” tag which contains data with their respective keys and values. Then the data is converted into a string to make it easier for the next step. If the data is empty, it will not proceed to the next stage. Meanwhile, if the “con” tag contains the required data, then the next step is to remove unnecessary characters such as quotation marks, open curly braces, and closed curly braces.

Furthermore, the string data is separated by a separator, namely a comma (,) to get each key with its respective value. Then, all the results of the separation are separated again between the key and its value and stored in the Map variable so that it can be mapped between the key and its respective value. The last stage is to define the data stored in the Map variable into each of the required variables.

b. All Data Retrieval Workflow, he process carried out is almost the same as the latest data retrieval, namely using the HTTP feature, but accessing the Antares platform is done twice for each purpose. The first data retrieval aims to retrieve all Data-IDs that refer to each data.

After getting a response from the Antares platform, the data that was previously in the form of JSON is filtered so that it only takes data that is in the "m2m:uril" tag. Then the data is converted into Map form and repeated as many values as in the data. In the repeater, the second Antares platform is accessed by referring to the value of the previously retrieved Data-ID.

After receiving a response from the Antares platform, the next step is to filter the data obtained so that it only takes the data that is needed. The data taken is the data in the “con” tag which contains data with their respective keys and values.

Then the data is converted into a string to make it easier for the next step. If the data is empty, it will not proceed to the next stage. Meanwhile, if the “con” tag contains the required data, then the next step is to remove unnecessary characters such as quotation marks, open curly braces, and closed curly braces. Furthermore, the string data is separated by a separator, namely a comma (,) to get each key with its respective value. Then, all the results of the separation are separated again between the key and its value and stored in the Map variable so that it can be mapped between the key and its respective value.

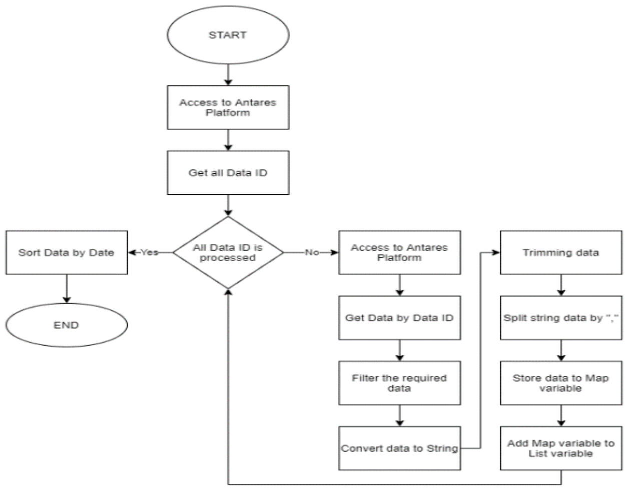

Figure 7. All data retrieval workflow

Internet of Things Module Testing

After the source code for each device has been generated and uploaded to each device, the next step is to test the functionality of each device to determine if the device runs properly. The results of these tests can be seen in table 1.

Table 1. Iot modules testing results

Function	Result Obtained	Result obtained
Function to detect the presence of the user	The user in front of the sensor is detected	The user in front of the sensor is detected
Function to alert hand washing	The buzzer is turned on when a user is detected	The buzzer is turned on when a user is detected
The function to detect the hand in front of the automatic faucet	The hand in front of the sensor is detected	The hand in front of the sensor is detected

Function	Result Obtained	Result obtained
Function to turn the faucet on and automatically	The faucet is turned on when a hand is detected	The faucet is turned on when a hand is detected
	The faucet is turned on if the hand is not detected	The faucet is turned on if the hand is not detected
Function to calculate water discharge	The water debit has been calculated and successfully sent to the Antares platform	The water debit has been calculated and successfully sent to the Antares platform
	The volume of water has been calculated and successfully delivered to the Antares platform	The volume of water has been calculated and successfully delivered to the Antares platform
Function to calculate the percentage of soap	The percentage of soap was successfully calculated and successfully sent to the Antares platform	The percentage of soap was successfully calculated and successfully sent to the Antares platform

Android Application Testing

At this stage, testing of the Android application that has been developed is carried out. The tests carried out are black box testing or functionality testing, namely software testing methods used to test software without knowing the internal structure of the code or program. In this test, the functional requirements have been made at the system analysis stage. The results of black box testing carried out on the Android IoT-Based Hand Washing Alert System application can be seen in Table 2.

Table 2. Android application testing result

Function	Expected Results	Results Obtained
Function to display the water flow used by the automatic faucet	Water discharge displayed on the Android app	Water discharge displayed on the Android app
Function to display the remaining soap percentage	Soap percentage displayed on android app	Soap percentage displayed on android app
Function to display water usage reports	Water usage is displayed in the form of a chart on the Android application	Water usage is displayed in the form of a chart on the Android application
Function to display soap usage reports	The use of soap is displayed in the form of a chart on the Android application	The use of soap is displayed in the form of a chart on the Android application
Function to export water usage data into a spreadsheet file	Water usage data can be exported into a spreadsheet file	Water usage data can be exported into a spreadsheet file
Function to export soap usage data into a spreadsheet file	Soap usage data can be exported into a spreadsheet file	Soap usage data can be exported into a spreadsheet file

4. CONCLUSION

From the results of the research that has been done, it can be concluded that the Flutter Framework can be an option for building Android applications that have integration with IoT devices. The IoT-based handwashing warning system can work well and can be used as a tool to help reduce infectious diseases, which in this case is Covid-19. This system can also be used as a decision-making tool in terms of the use of water and soap during the Covid-19 pandemic.

With the development of an IoT-based handwashing warning system, it is hoped that it can help reduce the spread of infectious diseases, especially Covid-19, and assist in decision-making regarding the use of water and soap during the Covid-19 pandemic in terms of using water and soap. This research enriches the literature on IoT applications in public health by providing a case study on the integration of IoT with mobile platforms to encourage hygiene habits and provides a replicable framework for developing other IoT-based systems in public health, such as monitoring sanitation facilities in schools or healthcare centers. The scope of the study was limited to a controlled environment, with no field testing in areas with limited water access or culturally different hygiene practices so future research could conduct field tests in various environments, including rural areas with limited water and urban areas with high water demand, to evaluate the adaptability of the system.

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