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EMPOWERING STRAWBERRY CULTIVATION: HARNESSING THE POTENTIAL OF IOT-BASED TECHNOLOGY IN SMART FARMING

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Abstract— *Agro-tourism is a form of tourism that uses agricultural land or related facilities to attract tourists. One popular agro-tourism site in Rasau Jaya Tiga is the Inspirasi Strawberry Park. Until now, the manual watering has been a common practice for strawberry plants. The Problem in watering strawberry plants manually is that inconsistent watering schedules often lead to overwatering or underwatering, affecting plant health and yield. Therefore, there is a necessity for an automated system to ensure precise and consistent watering, optimizing plant growth, water efficiency, and overall crop quality. By developing an Internet of Things (IoT) integrated irrigation system for strawberry plants, strawberry plants can be watered automatically and controlled through the Internet or mobile devices, using soil moisture sensors, air temperature, and intelligent decision-making. The results of this study indicate that the automatic watering system is able to accurately collect real-time data on temperature, humidity, time, and date of data collection. Additionally, the automatic scheduling system for watering plants and lighting system can operate as intended. With the implementation of an IoT-based automatic irrigation system for strawberry cultivation, labor costs are reduced, and crop yields are increased, contributing to enhanced agricultural productivity and economic sustainability.*

Keywords*: agro-tourism, automatic irrigation system, internet of things, smart irrigation system, strawberry*

Intisari— *Agro-wisata adalah bentuk pariwisata yang menggunakan lahan pertanian atau fasilitas untuk menarik wisatawan. Salah satu situs agro-wisata populer di Rasau Jaya Tiga adalah Taman Inspirasi Strawberry. Hingga saat ini, penyiraman manual telah menjadi praktik umum untuk tanaman stroberi. Masalah dalam penyiraman manual tanaman stroberi adalah jadwal penyiraman yang tidak konsisten seringkali mengakibatkan penyiraman berlebih atau kekurangan air, yang mempengaruhi kesehatan tanaman dan hasil panen. Oleh karena itu, diperlukan sistem otomatis untuk memastikan penyiraman yang tepat dan konsisten, mengoptimalkan pertumbuhan tanaman, efisiensi penggunaan air, dan kualitas keseluruhan panen. Tujuan dibuatnya sistem penyiraman tanaman strawberry berbasis IoT, tanaman stroberi dapat disiram secara otomatis dan dikendalikan melalui perangkat internet atau seluler, menggunakan sensor kelembaban tanah, suhu udara, dan pengambilan keputusan cerdas. Hasil dari penelitian ini menunjukkan bahwa sistem penyiraman otomatis mampu dengan akurat mengumpulkan data suhu, kelembaban, waktu dan tanggal pengambilan data secara real-time dan untuk sistem penjadwalan otomatis untuk penyiraman tanaman dan sistem penerangan dapat beroperasi sesuai fungsinya. Dengan adanya penerapan sistem penyiraman otomatis berbasis IoT untuk budidaya stroberi mengurangi biaya tenaga kerja dan meningkatkan hasil panen, yang berkontribusi pada peningkatan produktivitas pertanian dan keberlanjutan ekonomi.*

Kata Kunci*: agro wisata, internet of thing, penyiraman otomatis, penyiraman pintar, strawberry.*

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INTRODUCTION

Strawberries are a high-value fruit with many benefits [1] [2], such as containing vitamin C that can lower the risk of digestive tract cancer, reducing blood pressure, preventing diabetes, act as an antioxidant, and preventing cataracts not only that, consuming strawberries may have positive effects on serum cholesterol, lipid peroxidation, and other health parameters[3][4]. Due to these benefits, the demand for strawberries is high[5]. They are typically grown in high-altitude areas, but as such land becomes increasingly limited, production has expanded to medium-altitude areas[6]. The factors that determine strawberry production are the availability of land and proper plant care [7], [8]. In Kubu Raya Regency, Kalimantan Barat, there is a strawberry agro-tourism site called Taman Inspirasi Strawberry owned by Mr. Sucipto. This site is frequented by tourists interested in strawberry plants from both Kalimantan Barat and other regions. The site is not just a tourist attraction, but can also be used for student internships, plant and land observation, and research.

The Internet of Things (IoT) is a technology that emerged during the Fourth Industrial Revolution[9]. This technology works by using the internet to communicate data or connecting users with the value of a measuring device's data[10], [11]. Typically, a device like a sensor is needed to obtain data values, whether they are analog or digital. Innovative technologies, such as automatic irrigation systems based on the Internet of Things, have been developed in the food sector to increase crop production[12], [13] Automatic watering for strawberry plants can be monitored and controlled using the internet or mobile devices. These devices can work automatically using soil moisture and air temperature sensors. With this technology, it is hoped that managing Taman Inspirasi Strawberry in Rasau Jaya Tiga will be easier by allowing watering at the appropriate times[14], [15].

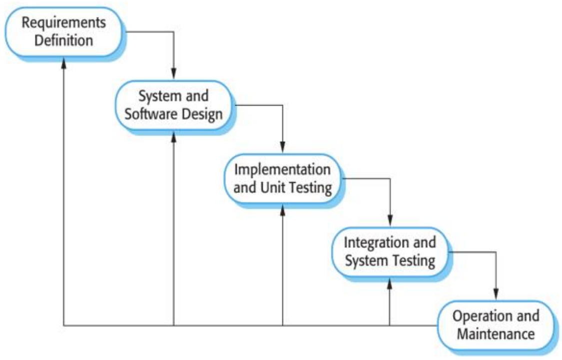
The issues facing Rasau Jaya Tiga's economy in terms of agriculture and industry. While the potential for agriculture is high, much of it is still managed individually, resulting in suboptimal yields. The strawberry agro-tourism site, for example, has good potential, but the land for strawberry farming needs to be expanded to increase production. Watering and monitoring of strawberry plants have been done manually, which is time-consuming, laborious, and requires the owner's attention. One solution is to create an automatic watering system using IoT technology to make it easier for site management to monitor plant conditions and schedule watering times[16], thereby maximizing crop yields[17], [18].

Previous research on plant irrigation has been conducted before[19], [20], but some challenges need to be addressed, such as water usage efficiency and inaccurate monitoring[21]. Therefore, the author attempts to create an innovation in the form of a smart irrigation system development that utilizes advanced sensor technology to improve water usage efficiency and provide more accurate monitoring of plant needs. By using an automatic irrigation system, the plants can receive the right amount of water at the right time, thereby improving plant growth and saving time and human effort in manually providing water[22].

MATERIALS AND METHODS

A. System in General.

In this system, there are several sensor nodes to collect data from several sensors taken from the real environment. Sensors are connected to the local gateway on the client side, reporting values obtained from all sensors continuously and or according to the pre-arranged time, and then the data is sent to the cloud platform. The gateway on the system is responsible for managing IoT devices, receiving sensor data, and then using the data. The cloud platform is responsible for storing device data using a service interface provided by the gateway so that users can use the data as a prediction in machine learning.



Source: (Sommerville, I [23], 2024)
Figure 1. Waterfall Method

The method used in developing this application is the waterfall method [24]. This method describes a systematic and sequential approach to software development, starting with requirements specification, design, implementation, verification, and maintenance.

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a. Requirement Analysis:

The first step is analyzing the system requirements. The researcher determines the requirements needed to build the SIMORI web application. The Simori web application is being built through Android Studio, XAMPP, Sublime, and others. At this stage, an analysis of the minimum device requirements is recommended for building the system. This study used several supporting equipment consisting of hardware and software. Table 1 describes the general requirements for the software:

Table 1. General Requirements for Software

No	Component Name	Function
1	Mac OS X	OS at running Client
2	Ubuntu Server	OS at server
3	Raspbian	OS at Raspberry Pi
4	Phyton	Language Programming
5	Arduino IDE 1.8.2	Arduino Compiler
6	Firebase, JS	Cloud Server
7	Android	OS at Smartphone
8	Hotspot Manager	(HotSpot App.) Getting the IP

Source: (Research Results, 2024)

This research uses the hardware for the client side and hardware for the server, while the details of the hardware requirements needed in this study are as follows:

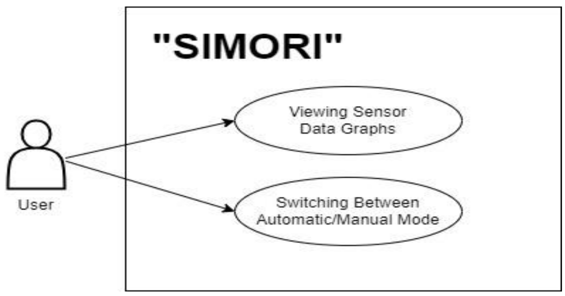
Table 2. General Requirements for Hardware

No	Client	Server
1	NodeMCU – ESP32	
2	Sensors:	Macbook
	DHT11	
	Soil Moisture Sensor	
	Relay Module	Wifi

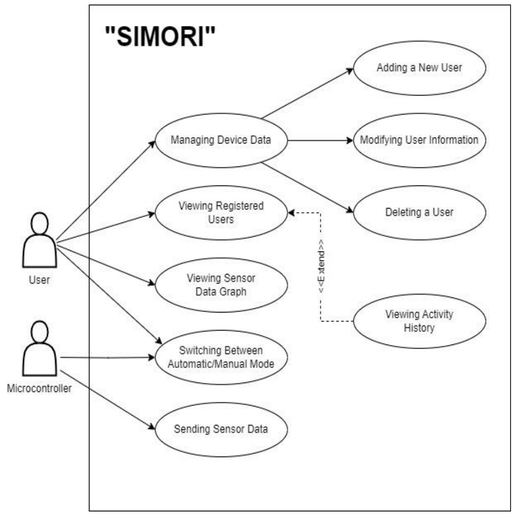
Source: (Research Results, 2024)

b. System Design:

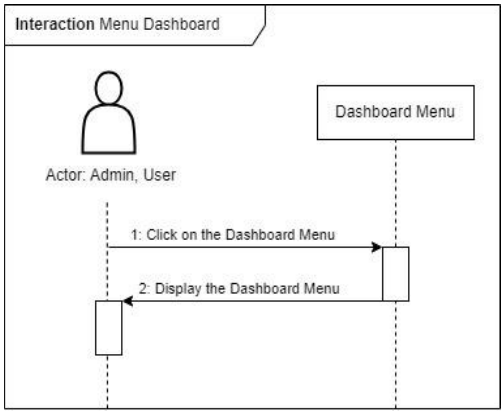
In this section, it details the design and structure of the system, which includes some of: Use Case Diagrams, Activity Diagrams, Sequence diagrams, and Interface Design. Figure 2 shows the use case diagram for user, while figure 3 shows the use case diagram for admin.



Source: (Research Results, 2024)
Figure 2. Use Case Diagram for User

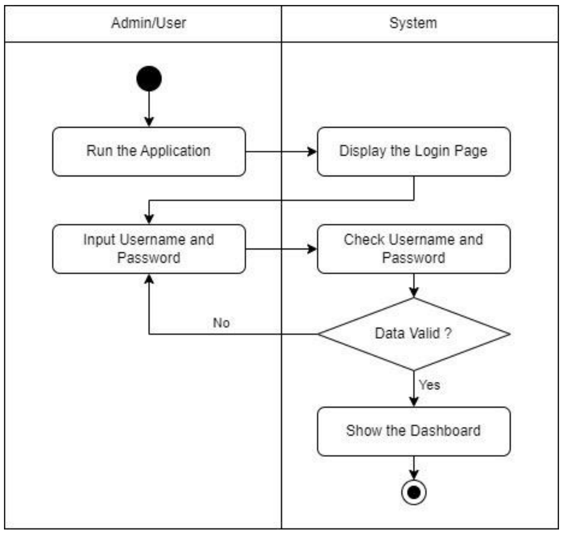


Source: (Research Results, 2024)
Figure 3. Use Case Diagram for Admin



Source: (Research Results, 2024)
Figure 4. Sequence Diagram for Admin and User

Figure 5, 6, and 7 shows the activity diagram for Admin or User from the "SIMORI" The Monitoring and Automatic Watering System.



Source: (Research Results, 2024)
Figure 5. Login Activity Diagram for Admin/User

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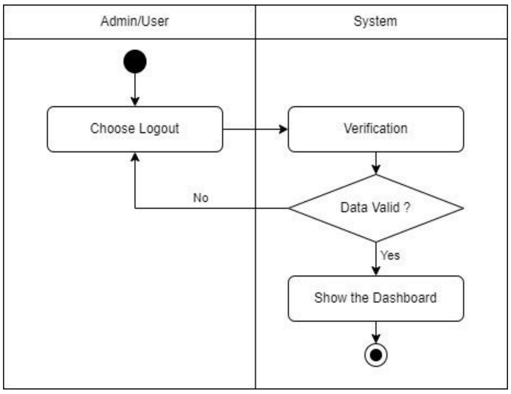
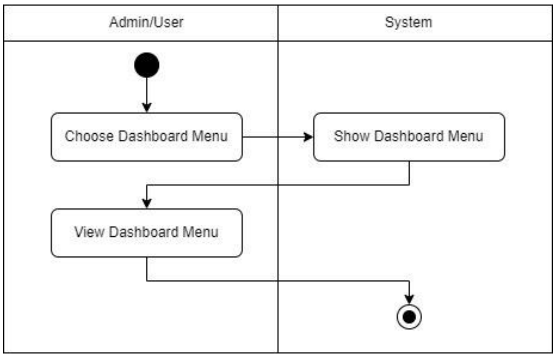
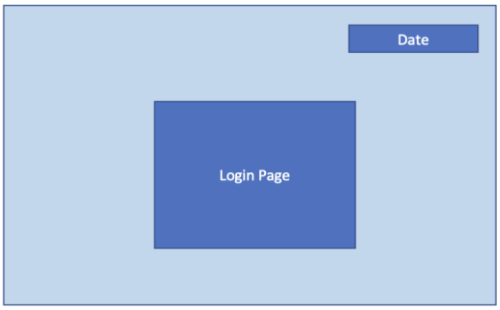


Source: (Research Results, 2024)
Figure 6. Logout Activity diagram for Admin/user

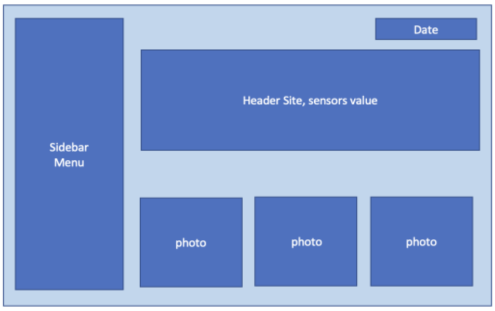


Source: (Research Results, 2024)
Figure 7. Dashboard Activity Diagram for Admin/User

Figure 8 shows the interface system design such as (a) login page, (b) Home page, (c) Monitoring data page, and (d) automatic Control schedule page.

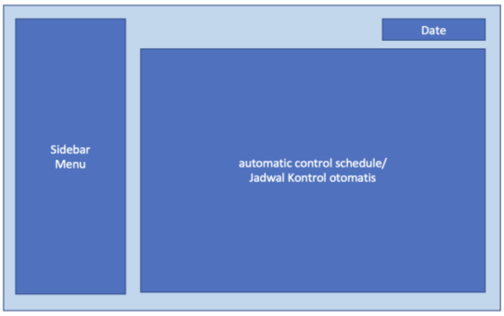


(a)



(b)

(c)



(d)

Source: (Research Results, 2024)
Figure 8. (a)(b)(c)(d) The system Interface design

c. Implementation:

The development of this application is implemented using the Java programming language in Android Studio with the Android SDK (Software Development Kit) and using PHP on the website, as well as additional tools to help create the application and a smartphone for testing (debugging) during application development. Figure 9 shows the system implementation on hardware configuration.

Source: (Research Results, 2024)
Figure 9. Implementation on Hardware Configuration

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d. Verification:

At this stage, testing is carried out using a functional testing techniques, which focus on the functional requirements of the application based on the requirements specification.

e. Maintenance:

The final stage is the waterfall model. The software that has been completed is run and maintained. Maintenance includes fixing errors not found in previous stages, improving system implementation units, and improving system services as new needs arise.

RESULTS AND DISCUSSION

The assessment of the proposed method for automatic irrigation in strawberry plants, which leverages Internet of Things (IoT) technology, is of paramount importance. This innovative approach seeks to optimize the irrigation process by integrating sensor data, weather conditions, and plant needs to ensure precise and efficient water delivery. Evaluating the method's performance is crucial to determine its effectiveness in conserving water resources while maintaining optimal growth conditions for the strawberry plants. By analyzing the real-time data and comparing it with traditional irrigation methods, it is possible to assess the potential benefits and improvements achieved through this IoT-based approach. The results of this evaluation will provide valuable insights into the practicality and efficiency of automated irrigation in strawberry cultivation, contributing to sustainable and technology-driven agriculture.

Source: (Research Results, 2024)

Figure 10. Execution of Hardware Configuration

The Execution of Hardware Configuration can be seen in Figure 10 which shows the circuit board, hardware modules, and sensors that have been connected with an adapter to form a complete system. This Automatic irrigation system is designed to provide water automatically to strawberry plants by regulating the timing and amount of water needed. Here's a description of how the automatic irrigation system works:

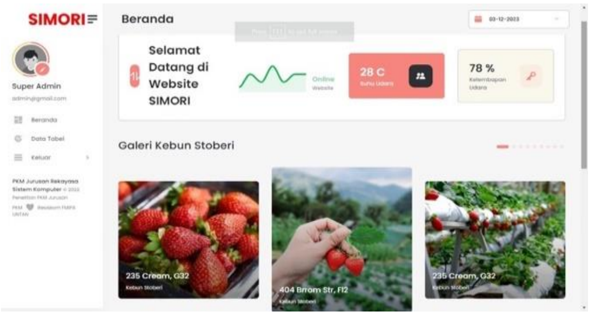
a. Soil Moisture Sensor: The automatic irrigation system is equipped with a soil moisture sensor that determines when water should be given to the plants. When the sensor detects that the soil is dry, the system will provide water to the plants.
b. Water Pump: After the soil moisture sensor gives a signal that the soil is dry, the water pump will be activated to flow water to the plants.
c. Watering Time: The automatic irrigation system has a timer that can be adjusted according to the needs of the plants. This timer will give a signal to the water pump to provide water at the designated time.
d. Water Amount Setting: The automatic irrigation system is also equipped with a setting for the amount of water given to the plants. The amount of water can be adjusted according to the type of plant and its water needs.
e. Energy Use: The automatic irrigation system also uses electric power or battery energy to operate the water pump and soil moisture sensor.

Figure 11. shows the location of “Taman Inspirasi Strawberry” with the automatic irrigation system implemented.

Source: (Research Results, 2024)

Figure 11. Location of “Taman Inspirasi Strawberry”

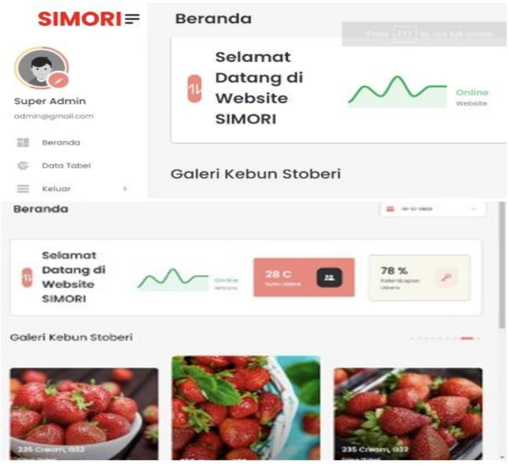
Operating the automatic plant watering tool is facilitated through the SIMORI web application. The user interface of the automatic watering application provides a user-friendly display, allowing users to efficiently manage and control the watering system with ease. This integration of technology through the SIMORI web application enhances the convenience and accessibility of the automatic plant watering tool, offering a seamless and user-centric experience for efficient plant care. can be seen in Figure 12.



Source: (Research Results, 2024)

Figure 12. The display of " SIMORI APP" - The Monitoring and Automatic Watering System.

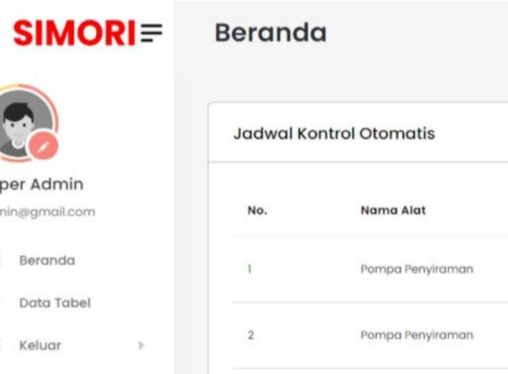
This site shows the menus in the interface, such as the homepage, data table, and sign-out menu. This homepage shows the graph of data, date and time, data sensor value, and the photo gallery of strawberries.



Source: (Research Results, 2024)

Figure 13. The display of " SIMORI APP" Homepage

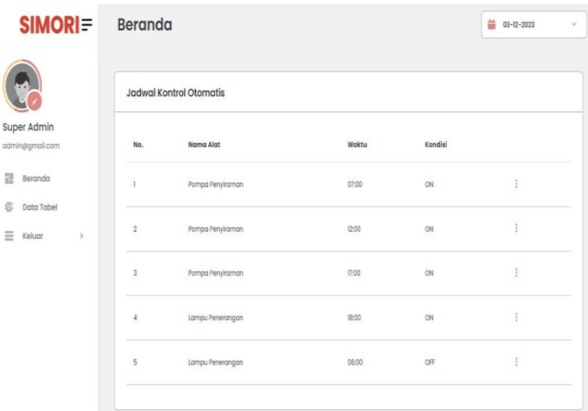
Within the SIMORI web application's homepage, users have access to a comprehensive tab featuring table data encompassing temperature and humidity control parameters. This tab also includes data related to the irrigation pump and the schedule for automatic lighting control. Additionally, the homepage hosts a gallery menu dedicated to the strawberry garden, showcasing a diverse collection of photographs capturing various aspects of the garden's development and growth. This multifaceted interface not only provides detailed insights into the essential environmental conditions for plant cultivation but also offers an engaging visual representation of the strawberry garden's progress through a curated gallery of images. Figure 14 shows the "SIMORI" Application display, and showing the data table.



Source: (Research Results, 2024)

Figure 14. "SIMORI" APP display – The Monitoring and Automatic Watering System

Within the control schedule menu of the SIMORI web application, users can find a control mechanism that extends to both the watering pump and lighting systems, allowing them to set specific timings for activation and deactivation of these devices. This menu not only facilitates the customization of schedules but also provides a clear display indicating the current status of the watering pump and lighting—whether they are in the active (ON) or inactive (OFF) state. This comprehensive feature enhances user control by offering a detailed overview of the operational status of essential components, ensuring precise management of the watering and lighting systems based on individual preferences and the specific needs of the strawberry garden.



Source: (Research Results, 2024)

Figure 15. The "SIMORI" APP display -The Monitoring and Automatic Watering System

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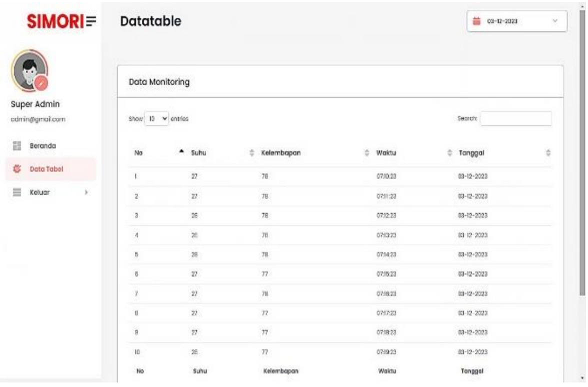

Source: (Research Results, 2024)

Figure 16. “SIMORI” APP. Display – Data Table

In the monitoring section, the application displays temperature and humidity data at specific times. To view previous data, it can be done by accessing the calendar menu in the upper right corner of the SIMORI application interface, it will display the date and time selection data, and then show it on the application interface.

SYSTEM TESTING

The research conducts black box testing to verify the operational integrity of the website, ensuring alignment with its predetermined design. This method entails scrutinizing each implemented feature on the site. The detailed findings of the black box testing are outlined in Table 3.

Table 3. The Result of Black Box Testing

No.	Testing Page	Testing Scenario	The expected outcomes.	Result
1.	Regis-tration	Username, email, and password are correct.	Registration successful, proceed to the login page.	Success
		Username, email, and password are correct.	Registration failed, return to the regis-tration page.	Success
2.	Login	Username and password are correct.	Login successful, entering the dashboard.	Success
		Username and password are incorrect.	Login failed, returning to the login page.	Success
3.	Logout	Click the "log out" menu.	The system revokes user access and will return to the dashboard login page.	Success
4.	Landing Page	Access the "Device data management" menu.	Show Device data management menu	Success
		Viewing registered user	Show activity history	Success
		Viewing Sensor data graphs	Show sensor data graphs	Success
		Switching between “automatic/ manual watering mode	Show watering mode	Success
		Sending Sensor data	Sending sensor data	Success
5.	Manage Device Data	Adding a new user	Adding a new user to access the application	Success
		Modifying user information	Modifying user information	Success
		Deleting a user	Deleting a user who can access the application	Succes

Source: (Research Results, 2024)

CONCLUSION

In conclusion, the application testing results affirm the successful implementation of the automatic monitoring and watering system for strawberry plants. The black box testing indicates that the system effectively maintains conformity between input and output displays, ensuring its suitability for intended functions. Moving forward, further research should prioritize advancements in sensor technology and the expansion of system implementation across broader geographical regions. It is imperative to consider the cost and maintenance aspects of these systems while emphasizing the development of robust sensor technologies to address scalability concerns. Additionally, exploring sustainable energy sources for powering these systems will be crucial for their long-term viability and effectiveness.

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