Monitoring And Controlling System Based on Internet of Things (IoT) for Ornamental Chrysanthemum Plants

Roihan Noval
Department of Computer Engineering, Universitas Wiralodra, Indonesia
Indri Yanti
Department of Computer Engineering, Universitas Wiralodra, Indonesia
Muh Pauzan
Department of Computer Engineering, Universitas Wiralodra, Indonesia

Abstract: Monitoring and controlling system based on Internet of Things has been developed for ornamental chrysanthemum plants. User interface of the system is a website application created using PHP programming language and MySQL as Database Management Systems. The IoT system built are the result of literature review of chrysanthemum plants, such as an ideal soil moisture for chrysanthemum plants is in the range of 40% to 60%, the average plant water requirement is 16.05 ml/day, it is also recommended to apply liquid fertilizer with a high N content of 2g per litre of water every week. This knowledge then applied in the IoT system. Research findings indicated that the device could be controlled through the website and was capable of transmitting real-time soil moisture data. This system not only triggers watering when the soil humidity falls below 41%RH and stops it when reaching 60%RH but also incorporates scheduled fertilizer according to predetermined schedules, meeting the anticipated outcomes. Water and fertilizer pumps produced volumetric flow rate that changed as the level of liquid in the storage tank decreases. The lower the height, the smaller the volumetric flow rate produced, this is due to the influence of hydrostatic pressure.

Keywords: Internet of Things, ornamental chrysanthemum plants, NodeMCU ESP8266, soil moisture, website application.

Introduction

Automatic watering of plants have been carried out in previous studies, the first part is just an embedded system which is do automatic watering, in this case soil moisture sensors are used as input that provide soil moisture values by (Asriya & Yusfi, 2016; Hasan, 2017; Husdi, 2018;

Correspondents Author:
Muh Pauzan, Department of Computer Engineering, Universitas Wiralodra, Indonesia
Email : muhpauzan.ft@unwir.ac.id

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Nurdiana, 2021; Prayama et al., 2018; Rahardjo, 2022). Some other research add the sensors for automatic watering, such as temperature and humidity sensors (Daifiria et al., 2019; Huda et al., 2023; Kumar et al., 2023; Mudholkar et al., 2022). The second part of previous studies are monitoring and automatic watering based on an IoT system (Dwi Sasmita et al., 2021; Hasan, 2017; Nadzif et al., 2019; Setyawan et al., 2018). One of the research is an IoT technology to control and monitor plants, chili plants in a green box is used for case study. Input value from soil moisture or soil PH sensor are to perform automation watering by means of X and Y axed-robot. The accuracy of prototype was 95.53%, 99.15% for x and y axis respectively (Ukar et al., 2022). Other study made the same IoT technology for premium sun chocolate covered cherry plant. Besides soil moisture sensor, light-dependent resistor sensor is added for capturing light intensity (Capili et al., 2023). Rai et al also used IoT-based plantation based on light intensity, the research aim is to prevent harmful consequence of excessive or insufficient light from sun of plants (Rai & Patidar, 2023). Tsang et al made the same IoT system for plants but with different experimental setup. The plants are put indoor and outdoor, automatic watering based on input value from soil moisture sensor between them were compared (Tsang et al., 2022). Research for monitoring nutritional deficiency in plants based on IoT was conducted by (Albert et al., 2023; Andrianto et al., 2023; Purwalaksana et al., 2022). Soniya et al (Soniya et al., 2023) and Nayagam et al (Nayagam et al., 2023) conducted an IoT-based research for both feeding pets and watering plants, Blynk platform are used to control the prototype (Soniya et al., 2023). While Soniya et al. employed mobile application, Katoch et al used website application for monitoring plants, the research aim is to detect plant disease (Katoch et al., 2023).

Previous studies show that an IoT system have been implemented in various plant types, IoT systems were implemented for monitoring soil moisture, temperature, light intensity, humidity and nutrition of plants. The next IoT implementation is both monitoring and controlling plants, the latter is done with the aim of maintaining stable plant conditions, such as prototype pours water and fertilizer for plants. User interface applications for IoT that have been used are mobile and website application.

Based on previous research, no one has yet created an IoT system for certain plants, even though each plant requires different care according to needs, such as the chrysanthemum ornamental plant. Based on literature review, this plant requires soil moisture in the range of 40% to 60%, the average plant water requirement is 16.05 ml/day, it is also recommended to apply liquid fertilizer with a high N content of 2g per litre of water every week. Therefore, an IoT system was created to meet the needs of these plants. Due to this need, scheduled fertilization was added, this fertilization was not carried out in previous research. So, we can carry out scheduled fertilization every week as it's needed by the plant. RTC (Real-Time Clock) added to the system, RTC would act as an accurate timer, allowing users to set the right fertilizer schedule according to plant needs. With this system, ornamental chrysanthemum plants would receive optimal nutrition at the right time, so that their growth and development will be better. Apart from that, in this research a manual control function was added, user can pour water and fertilizer onto the plants at any time via the website application. Manual and automatic control (based on sensor input) in this research was not found in previous studies, they usually do an automatic control in their system.

Research Method

Flowchart of IoT System

IoT system are built of both hardware and software, there are three modes for the operation such as monitoring the soil moisture, administering liquid fertilizer on weekly basis and control (turn on and off) both water and fertilizer pump manually from application. The flow of all these processes can be seen as in Figure 1.

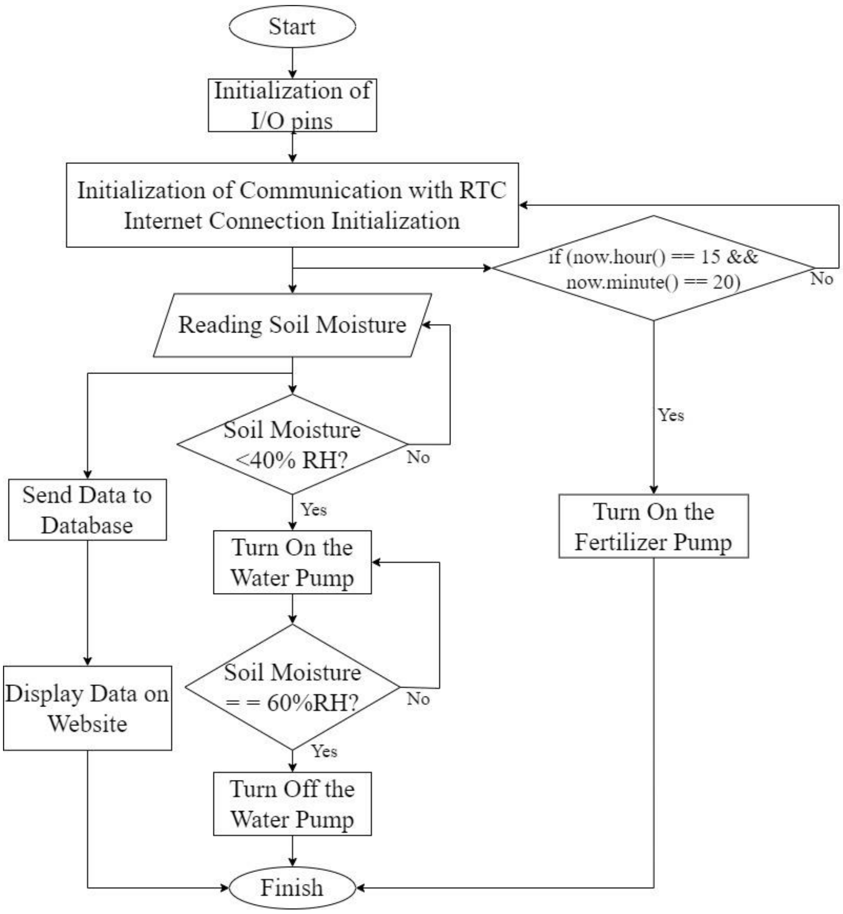


Figure 1 Flowchart of IoT systems

Based on Figure 1, the tool first checks the time in the form of hours and days. If the time is match with the water and fertilizer watering schedule, the tool would do watering and fertilizer automatically. If it is not match then the tool will read the value from the soil moisture sensor. If the humidity value is below 40%RH then water is sprinkled, watering continues until the value becomes 60%RH. However, if the humidity is above 40%RH then the water pump will not be turned on, but the tool will send humidity data to the database. The stored values are then displayed on the monitoring page on the website application.

Hardware Design

After determining the IoT concept, the next step is to design and build monitoring and controlling device. The circuit schematic can be seen in Figure 2. Fritzing application was used as a tool to illustrate the connection for each component.

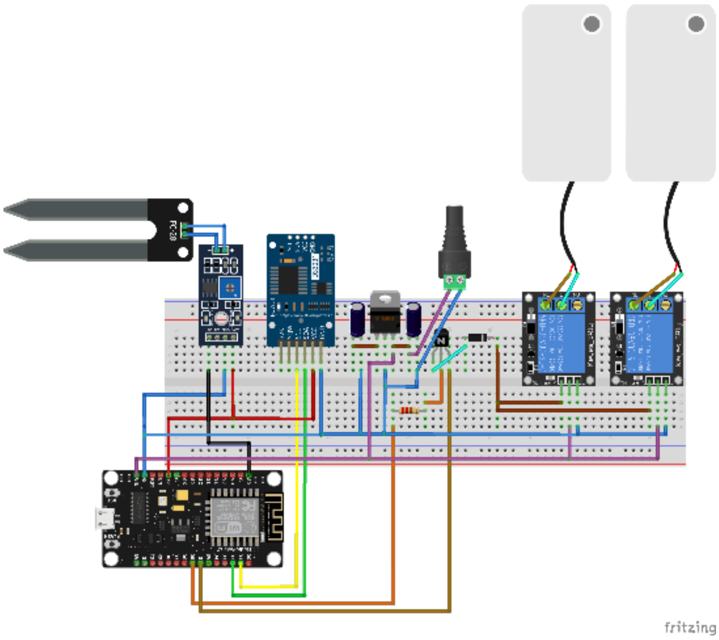


Figure 2 Circuit schematic for monitoring and controlling device(Lal et al., 2022)

According to Figure 2, the ESP32 is used as a control center for the device, such as for monitoring and controlling. The soil moisture sensor provides input in the form of an analog signal to the ESP32, with the ADC feature, ESP32 can convert it into a digital value. Then the data is sent to database. Watering (activating water pump) can be done at any time if the conditions are met, namely when the soil moisture value is below 40%RH, if this is met then ESP32 will activate the fertilizer pump and will turn it off until the value is at least 60%RH. RTC DS3231 with ESP32 communicates using the SPI concept, ESP32 uses time as input. If the time received from the RTC is the same as the time set for fertilization, the ESP32 will activate the fertilizer pump for 10 seconds.

Database Design

Class diagram from this research can be seen in figure 3. There are three main classes can be identified, namely `users`, `sensors`, and `control`. The linkages between these classes are established through one-on-one associations. The `users` class plays a central role with typical attributes such as `id`, `username`, `email`, and `password`, along with `login()` and `register()` functionality. A direct one-to-one connection with the `sensor` class indicates a clear connection between the user and the sensor. Meanwhile, the `control` class is also connected one-to-one with the `sensor` class, showing a similar correlation. Thus, through this structure, information related to users, sensors and controls is arranged in an orderly manner, where each class has its own role and responsibility in the system it represents.

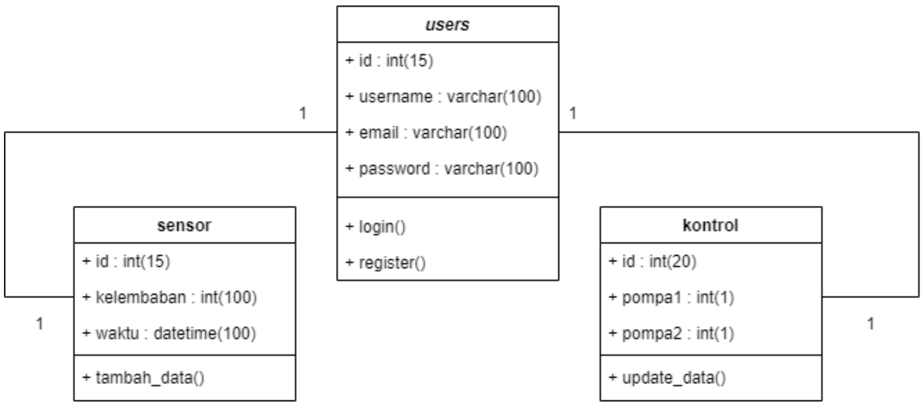


Figure 3 Class diagram of IoT system

Result and Discussion

The IoT system has successfully created for ornamental chrysanthemum plants which is needed specific treatment. The result is divided into hardware and software (website application). Hardware is the tool employed to control and monitor the plant. The consumption energy of the tool is relatively low, namely 1,2 watts. This indicates that the IoT system could use solar cell as it's energy source, this study needs to be implemented in the future. In software aspect, black box testing was executed to know the performance of the application. Details about both hardware and software results are explained below.

Hardware Result

The process of making the device went well because it followed a design that had been prepared previously using the Fritzing application. All components that have been prepared are carefully assembled on the PCB then soldered, then placed into the case that has been made and put it in the box. After making some measurement and testing, the device specifications are obtained, for more detail can be seen in table 1. The complete setup of the device together with ornamental chrysanthemum plants can be seen in figure 4.

Table 1 Device specification

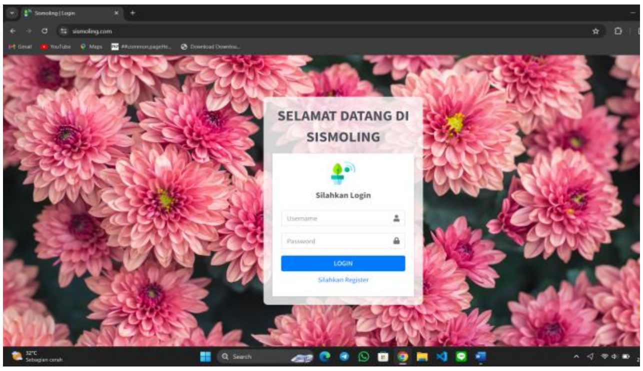
Spesification	Information
Dimension	12,5 cm x 8,5 cm x 5 cm
Dimension of storage tank	20 cm x 15 cm x 10 cm
System on Chip	ESP-12E
Flash Memory	4 Mb
Protocol WiFi Support	IEEE 802.11 b/g/n
Frequency	2.4 GHz - 22.5 Ghz
Current	240 mA
Operational voltage	12 V
Power consumption	1,2 watt
Hose	100 cm x ¼ inci

Figure 4 Complete setup of the device and ornamental chrysanthemum plants

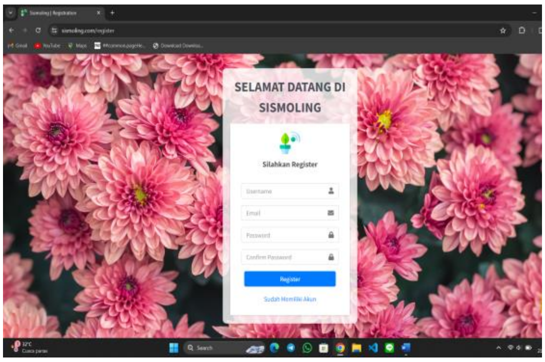
Website Application

The website that has been made using the CodeIgniter 4 framework has been assigned a domain called sismoling.com and has been uploaded. This site features two main functions, namely Monitoring and Controlling. Monitoring Menu: In this menu, users can view soil moisture percentage data in visualization form, which is presented in the form of graphs and in tables. This information will help users to monitor the condition of the soil and determine the appropriate soil moisture level for plants. Control Menu: This feature allows users to control the fertilizer and water pump on ornamental plants. By using the interface provided by the website, users can activate or deactivate both pumps remotely, making it easy to manage ornamental plants automatically.

This allows houseplant owners to practically control the watering and fertilizer of their plants via a provided web interface, ensuring that their houseplants receive appropriate care remotely. All of these features are designed to provide easy accessibility and control for users in monitoring and managing agricultural conditions efficiently through the web interface that has been built. For more detail about the website interface can be seen in figure 5a, 5b, 5c and Figure 5. (a)login interface, (b)register interface, (c)monitoring interface, and (d)controlling interface



(a)



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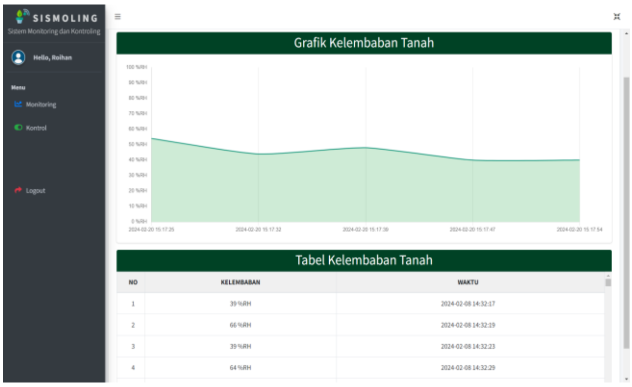

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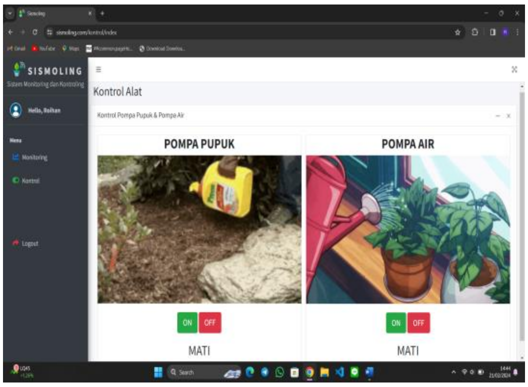

(d)

Figure 5 (a)login interface, (b)register interface, (c)monitoring interface, and (d)controlling interface

Water and Fertilizer Pump Testing

In this test, the water and fertilizer pump was tested using a hose with a diameter of ¼ inch and a length of 100 cm to drain the water or fertilizer. The various parameters measured include not only the volume and flow rate of water, but also the pressure and efficiency of water flow through the hose. Although only the water flow rate is the focus of the discussion, this information provides an idea of the performance of the water pump in conveying water through the hose, which is relevant for evaluating the pump's ability to flow water and its possible use over a certain distance. The water pump test results can be seen in figure 7a which is show the volumetric flow rate.

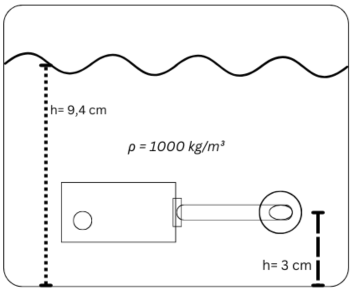

Figure 6 Hydrostatic Pressure affects the pump's performance

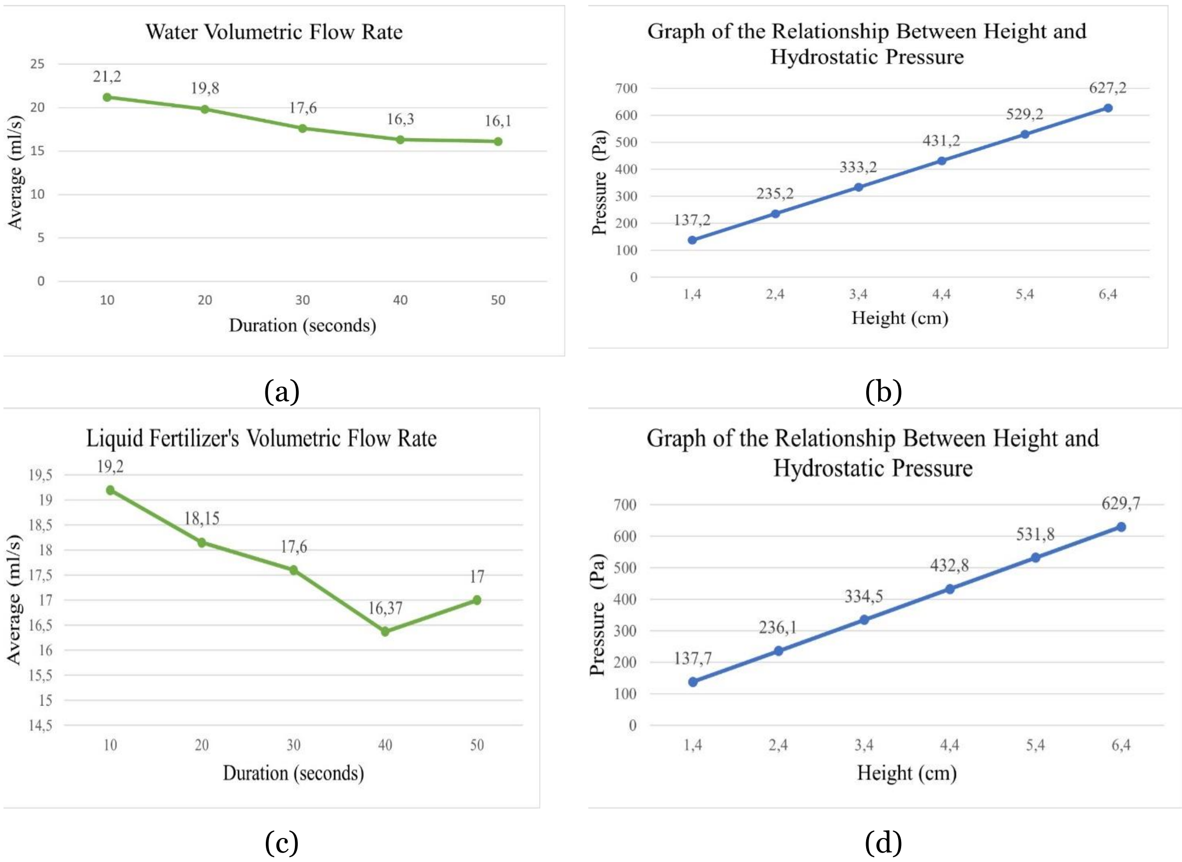

Figure 7 volumetric flow rate of (a)water and (c)fertilizer, relationship between height and hydrostatic pressure on (b)water and (d)fertilizer's box

Based on Figure 7a, it can be concluded that the hydrostatic pressure has an effect on the amount of water pumped from the container to the plants, as illustrated in Figure 6. The initial condition at each interval, from 10 to 50 seconds, is when the water reaches its maximum height. For example, in the first 10 seconds, the water is full, and after pumping for 10 seconds, the average flow is 21.2 ml/s. The 20 second test starts from the same maximum water level, without utilizing the remaining water level from the previous 10 second test. Therefore, water from full condition is pumped for 20 seconds, resulting in a decrease in flow to 19.8 ml/s. A similar process occurs at intervals of 30 to 50 seconds. When the container is filled with water, the water level reaches a peak, causing the water level in the pump hole to reach its maximum point and producing the highest pressure. This refers to the hydrostatic pressure equation shown by equation 1.

$$P = \rho g h \tag{1}$$

where P is hydrostatic pressure, ρ is density of liquid, g is gravitational acceleration and h is fluid level(height).

According to equation 1, the pressure at the pump hole is in the larget level when the water is full, because pressure is directly proportional to height. However, when water is pumped, the water level in the container continues to decrease over time. This decrease in height causes a decrease in pressure in the pump hole, which then results in a decrease in the flow of water pumped by the pump. Figure 7a illustrates this phenomenon through the concept of hydrostatic pressure. The relationship between height and hydrostatic pressure can be seen in Figure 7b. The phenomena for pump's performance in water are founded same pattern for pump's performance in pour liquid feltilizer for plants as can be seen in figure 7c and 7d.

Black Box Testing

Testing to change the on/off condition of the water control is carried out by pressing the On and Off buttons to then check what the system reaction is like. Tests for changing water control on/off conditions can be seen in table 2.

Table 2. Black box testing

Input	Desired Output	Output	Conclusion
"ON" button clicked	• Show message "NYALA" • Water pump on	• Show message "NYALA" • Water pump on	Valid
"OFF" button clicked	• Show message "MATI" • Water pump off	• Show message "MATI" • Water pump off	Valid

Based on table 2, the system shows a response according to the user's expected action and controls the water pump appropriately. Meanwhile, in test cases with incorrect data, the system provides appropriate warnings when the user enters inappropriate data. The test results confirm the reliability of the system in responding to users consistently, whether the data entered is correct or incorrect.

Control testing

The IoT system implementation is not only designed to monitor and automate devices, but also provides control capabilities over the fertilization and watering processes. Therefore, in the sismoling.com website interface, control buttons are included that allow users to manage the device, including turning on or off the water pump and liquid fertilizer pump functions. The results of tool control testing can be seen in table 3

Table 3. Testing in website's button for controlling the pumps

No	Button				Output
	Water pump		Fertilizer pump		
	On	Off	On	Off	
1	√	-	-	-	Water pump on
2	-	√	-	-	Water pump off
3	-	-	√	-	Fertilizer pump on
4	-	-	-	√	Fertilizer pump off

Based on data from table 3, the results of control testing show that the function of the control buttons on the sismoling.com interface has been successfully implemented as expected. In water pump control testing, use of the "On" button resulted in activation of the water pump, while use of the "Off" button resulted in shutdown of the water pump. The same test was also applied to the fertilizer pump, where the "On" button turned the fertilizer pump on, and the "Off" button turned it off. From these results, it can be concluded that the implementation of tool control in the system has been successful and can be relied on to regulate the fertilization and watering process for ornamental chrysanthemum plants.

Conclusions

An IoT system has successfully created for ornamental chrysanthemum plants which is needs specific treatment. Monitoring humidity of the plants via website is work as expected, tool do watering when the humidity below 40%RH and stop it when humidity reach 60%RH. The fertilizer could be operated by the tool every week to the plants. Water pump and fertilizer pump produce water discharge that changes as the level of water/liquid fertilizer in the storage tank decreases. The lower the altitude, the smaller the discharge produced, this is due to the influence of hydrostatic pressure. Black Box testing results show the system is responsive and reliable. Even though there are variations in delay testing, the system is able to transmit data between the web application and hardware adequately.

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