Research Article

Design and Control of IoT Based Automatic Watering Devices for Vegetable Plants

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Abstract: This research aims to design and develop an Internet of Things (IoT)--based automatic watering device for vegetable crops, especially water spinach and bok choy. The IoT technology used allows users to monitor and control the watering process remotely through an Android-based mobile application. The device is equipped with a soil moisture and temperature sensor (DHT22), which automatically controls the water pump and fan according to the needs of the plants. System testing was conducted to ensure the functionality of the sensors and that the automatic watering system operates effectively. The test results show that the device works efficiently in maintaining soil moisture and plant temperature, thereby improving the maintenance of vegetable crops. With this system, watering is done promptly and according to the needs of the plants, thereby reducing water and energy wastage. This research offers a practical solution for farmers or plant enthusiasts to monitor and care for plants automatically and efficiently.

Keywords: Internet of Things, automatic watering, moisture sensor, DHT22, Android, vegetable plants

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1. Introduction

Regular watering ensures that plants receive optimal nutrients for their growth and development. Water is an essential component in the photosynthesis process, which is how plants produce food. Farmers often water plants manually according to a set schedule, but this is inefficient as it requires excessive time and energy. Additionally, plant owners must always be present to avoid water shortages that can lead to wilting and plant death. (Effendi et al., 2022).

Efforts to ensure regular watering are an essential routine in the growth and development of plants. This routine task can be carried out more efficiently by utilizing sensor technology and IoT to monitor and control watering remotely. This issue has been addressed by previous researchers (Tullah et al., 2019), who proposed a solution titled, "*Automatic Plant Watering System Based on Arduino Uno Microcontroller at Yopi Ornamental Plant Store*." This study explored the development of an automatic watering system using an Arduino microcontroller and its supporting modules. The system was designed to help improve the efficiency and effectiveness of plant cultivation activities at the store, especially in terms of watering.

Therefore, to prevent delays in watering due to other commitments, a device with a specialized system that enables remote plant maintenance and control using IoT is needed. This system can monitor the temperature inside the greenhouse and the soil moisture of the cultivated area. Based on the issues discussed, the researcher proposes a solution entitled "*Design and Development of an IoT-Based Automatic Watering Device for Vegetable Plants*."

In addition, the selection of water spinach (*Ipomoea aquatica*) and bok choy(*Brassica rapa subsp. chinensis*) as the focus of this study is based on several considerations. Water spinach has a fast growth cycle, allowing the results of the automatic watering system to be observed in a short period. This plant also requires consistent watering for optimal growth, making it ideal for testing an IoT-based automatic watering system. Moreover, water spinach is a popular and widely cultivated plant in Indonesia, making the study highly relevant and beneficial for many farmers and gardening enthusiasts.

Meanwhile, bok choy is known for its tolerance to various environmental conditions, although it still requires regular and precise watering. It is also a type of leafy green vegetable with high economic value and significant market demand. Additionally, as a nutritious leafy vegetable, bok choy offers numerous health benefits, which can positively impact public health promotion. Thus, the selection of water spinach and bok choy as research objects is expected to provide significant and practical results in developing IoT-based automatic watering technology for vegetable plants.

2. Method

The research and development (R&D) method is a highly practical approach. R&D is not only about discovering new knowledge but also about directly producing solutions in the form of new products or improvements to existing products. Due to its applicative nature, R&D is well-suited for academic research, such as undergraduate theses, master's theses, or dissertations. Researchers can use R&D to test the performance of a product, develop better products, or even create completely new and innovative products. R&D is a mixed research method that adopts a sequential approach.

This study will be conducted over three months, from September to November 2023, at the Faculty of Engineering campus in Makassar, South Sulawesi. Further testing and data collection will be carried out at the Informatics and Computer Engineering Laboratory. Based on the stages of the R&D waterfall model, the research is formulated as follows in Figure 1.

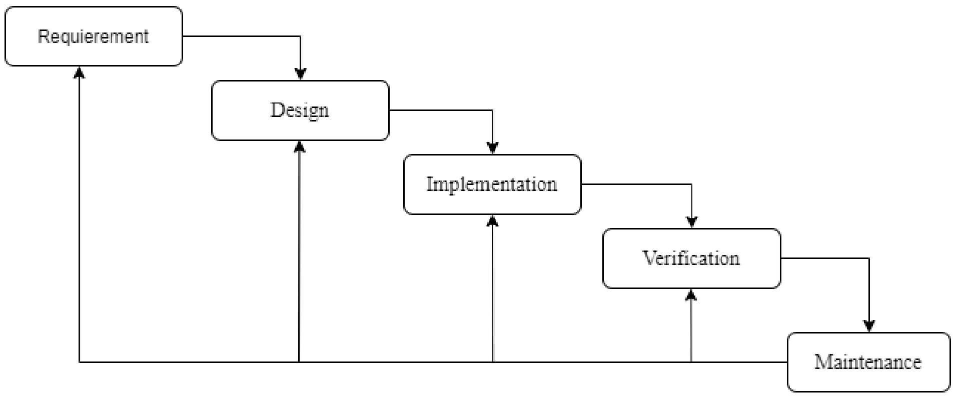

Figure 1. Research Procedure

The following is a breakdown of the R&D waterfall method procedure as illustrated in Figure 2. Some of the essential points in this research are as follows:

2.1 Requirement Analysis

Requirement analysis is the process of collecting data to serve as a reference for producing a product that addresses existing problems and can be used effectively. For data collection requirements, the researcher uses observation as the data analysis technique.

Furthermore, in this stage, the researcher analyzes and identifies the problems that arise to create a solution in the form of an IoT-based automatic watering device for vegetable plants. This stage involves analyzing the system designed to operate the watering device and control the temperature and humidity of vegetable plants.

2.2 Design

The system design development method in this study is carried out through the following stages:

2.2.1 Design and Control System (Hardware)

In this design stage, a circuit is created for the automatic plant watering system and the control of temperature and humidity for vegetable plants, which is managed by the ESP32.

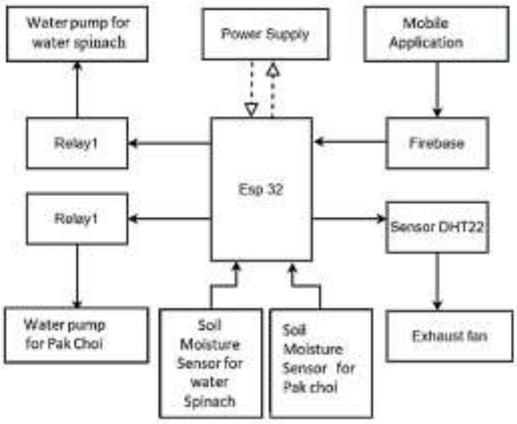

Figure 2. Block Diagram System

In Figure 2, There are two main power sources:

- Power Supply: Functions as the power source to provide energy to the ESP32.
- ESP32: Acts as the microcontroller to control the system's operations. Next, several sensors provide input to the ESP32.
- Soil Moisture Sensor for Water Spinach: Provides input to the ESP32. If the soil moisture is below 75%, the pump will water the plant.
- Soil Moisture Sensor for Bok choy: Provides input to the ESP32. If the soil moisture is below 75%, the pump will operate.
- DHT22 Sensor (Temperature and Humidity Sensor): Provides input to the ESP32. If the temperature exceeds 32°C, the exhaust fan will activate to regulate the temperature inside the greenhouse.

2.3 Software Development

The steps for developing the software are carried out using the Arduino IDE application and are linked to the program created in the Arduino IDE. Once the program is completed, it is uploaded to the ESP32 to control the automatic watering device and the temperature and humidity control system for vegetable plants that have been designed. Next, the Flowchart can be seen in Figure 3.

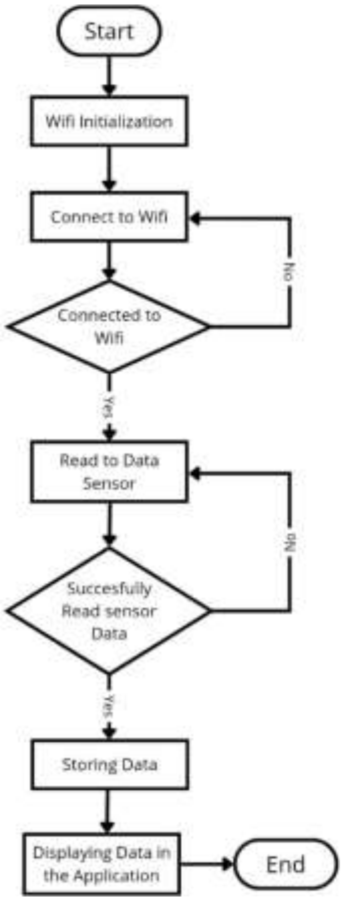

Figure 3. Flowchart System

- *Initialization WiFi:* Activate and configure the WiFi connection on the microcontroller.
- *Connect to the Internet Network:* Attempt to connect to the Internet via WiFi; if unsuccessful, retry the connection process.
- *Read Sensor Data:* Collect data from the sensors or other modules connected to the microcontroller.
- *Store and Display Data*: The successfully collected data will be stored and can be displayed through the application.

The data collection stages in this research are carried out in several steps, as outlined below:

1. *Literature Study*
   This stage is the initial phase where we need to search for references from various sources related to the design and research being conducted. The stages are as follows:
   - Conduct direct observation of water spinach and bok choy plants.
   - Study the characteristics of the automatic plant watering device and temperature and humidity control systems.
   - Collect references related to the ESP32 used as the microcontroller that connects the sensors being used.

2. *Research Instruments*
   The sensor testing scenario is a series of situations or scenarios specifically designed to test the performance and accuracy of the sensors. The goal is to ensure that the sensors operate optimally and provide accurate and consistent results under various conditions that may occur during use. Several testing scenario tables can be implemented to ensure the performance of the design and development of the automatic watering device for vegetable plants.

3. Result and Discussion

This research creates a prototype system model by applying machine learning technology to an IoT platform that uses Arduino and developing an application created with Android Studio to monitor plant watering. The steps in this research include dataset processing, creating a machine learning model, developing an API for the machine learning model, building the system prototype, and testing the entire system.

3.1 Hardware

Hardware in plant watering consists of physical components used to support plant growth and enable remote monitoring of the plants.

3.1.1 Plant Pots 1 and 2

Plant Pot 1 for growing water spinach can vary depending on preferences and growing conditions. However, in general, water spinach can be planted in containers such as pots, plastic trays, buckets, or even stacked used tires filled with soil or fertile planting media. Plant Pot 2 for growing bok choy can also vary depending on preferences and growing conditions. It is important to choose a container with an appropriate size to allow the bok choy roots enough space to grow and develop well. Additionally, make sure the container has adequate drainage holes to prevent water from accumulating inside.

3.1.2 Box Controller

The Box Controller is a hardware device used to control and manage components in the system. It serves as the brain or control center of the system, which consists of various components.

3.1.3 Hose

The water flow hose is a flexible tube used to carry water from the water source to the plant containers or watering areas. This hose is typically made from rubber or plastic materials that can withstand water pressure and have holes to allow water to flow smoothly. The water flow hose is crucial in plant watering because it enables precise water distribution to each plant in the garden or container.

3.1.4 Exhaust Fan

An exhaust fan is a device used to expel air from a room to the outside. It is typically installed in walls or ceilings to remove hot, humid, or odorous air. The exhaust fan works by pulling air from inside the room and directing it outside through an air duct or ventilation system. This function helps maintain clean and fresh air inside the room by removing polluted or contaminated air, while also helping regulate temperature and humidity levels to ensure a comfortable environment.

3.2 Application

The application in this research is used to monitor the growing environment conditions of the plants, such as humidity levels, temperature, nutrients, and soil moisture content. Below are the results from the application interface, which was built using Android Studio and utilized in this research.

Moreover, the splash screen is the initial interface when the application starts, displaying a logo, name, or brief message with engaging animations or graphics. The goal is to provide an initial experience for the user and leave a good impression before the application fully loads. Dashboard Display ditunjukkan pada Figure 4.

The Dashboard Display is an interface that presents a summary of important information visually, typically in the form of graphs, tables, or widgets. The purpose is to provide a quick understanding of the performance or data related to a process or system as a whole. The integration results between the plant watering system prototype and Firebase allow data to be sent directly every time there is a change using the Realtime method to sort data by keys (ID).

Furthermore, with this method, the application can retrieve the most up-to-date data based on the continuously updated ID. The data is then fetched from the real-time database to the application, which monitors sensor parameters and displays the information in the application interface.

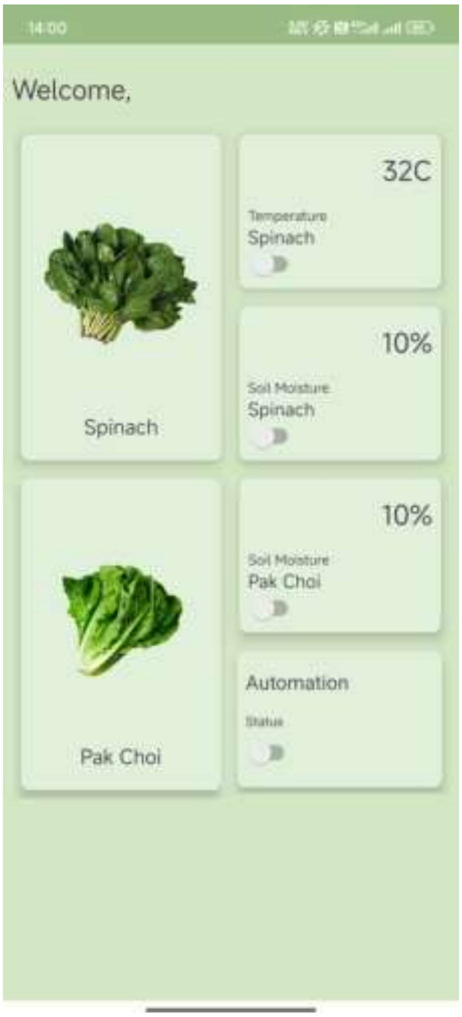

Figure 4. Dashboard Display

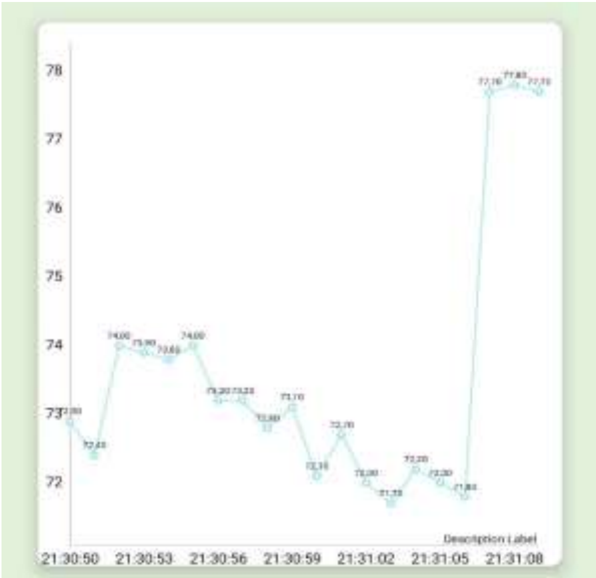

Figure 5. Graphics Display

The graphical display of the application refers to the part of the user interface that presents information in the form of graphs or charts, such as bar charts, line graphs, pie charts, or scatter plots. These graphs help users understand and analyze data visually, facilitate decision-making, and provide deeper insights into the information presented by the application.

3.3 Overall System Testing Results

The results of the overall system testing represent a comprehensive evaluation of the system's performance to ensure that all components and features function according to the specifications. The ultimate goal of this testing is to verify the system's alignment with user needs and requirements.

Table 1. Testing Results

Plant Type	Temperature	Humidity	Fan	Pump	Mobile Notification
Water Spinach	20°C	50%	OFF	ON	- Plant 1 is dry - Current temperature is 20°C
	25°C	80%	OFF	OFF	- Plant 2 is moist - Current temperature is 25°C
	35°C	90%	ON	OFF	- Plant 1 is wet - Current temperature is 35°C
	40°C	100%	ON	OFF	- Plant 1 is wet - Current temperature is 40°C
Bok choy	20°C	50%	OFF	ON	- Plant 2 is dry - Current temperature is 20°C
	25°C	70%	OFF	ON	- Plant 2 is moist - Current temperature is 25°C
	35°C	90%	ON	OFF	- Plant 2 is wet - Current temperature is 35°C
	40°C	100%	ON	OFF	- Plant 2 is wet - Current temperature is 40°C

3.4 Discussion

The design of an IoT-based plant monitoring and automatic control system resulted in a system prototype that combines two technologies, namely Arduino and Android Studio. This research aims to assist farmers in managing plants in gardens or monitoring planting media using IoT technology. This system prototype also generates sensor data that can be used by the system itself.

The automatic watering prototype in this study is a system designed to manage plants in gardens or planting media with the help of IoT technology. The automatic plant watering prototype is equipped with a NodeMCU ESP32 microcontroller that is interconnected with temperature sensors and soil moisture sensors that collect environmental data. The data collected by these sensors is sent to the Firebase Realtime Database as a data storage server.

The IoT-based plant monitoring application is developed using Android Studio with Java programming language. Meanwhile, the application uses Firebase as its database system to store the values from the DHT22 sensor, soil moisture sensors, and the designed hardware components. The user interface of the application displays real-time clock values sourced from the Firebase Realtime Database. Real-time monitoring is achieved using the "get data" function, which connects to the application to display the DHT22 sensor and soil moisture data on the application interface. Additional features include real-time graphical displays, allowing users to view sensor history that automatically updates when new data is available.

The plant watering system prototype uses processed data to decide whether to water or not. If the soil moisture is below the minimum threshold, the sensor will send a signal to start watering. Conversely, if the soil moisture is above the maximum threshold, the sensor will send a signal to stop watering.

4. Conclusions

Based on the research conducted, the following conclusions can be made: [1] The result of the plant watering monitoring design using NodeMCU ESP32 is a system prototype that can monitor the environment of the plants in real time and perform automatic watering actions based on sensor parameters. [2] Based on the results of the hardware functionality testing, the connected sensors were tested by observing and analyzing the comparison of the values produced by the sensors with a reference testing device. The DHT22 sensor, when compared with a digital thermometer, showed an error of 0.02%, providing accurate temperature monitoring results even when the surrounding temperature fluctuates. The soil moisture sensor tested in wet, damp, and dry soil conditions produced data on the soil condition at various moisture levels. This information is then used to trigger automatic watering decisions based on the predefined threshold values.

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References

1. Agung, M., Nikmah, N., & Nur, M. I. (2021). Development executive summary sistem informasi kepegawaian berbasis android untuk pimpinan UNM. Journal of Embedded Systems, Security and Intelligent Systems, 2(2), 61.
2. Ariyanto, P., Iskandar, A., & Darusalam, U. (2021). Rancang Bangun internet of things (IoT) pengaturan kelembaban tanah untuk tanaman berbasis mikrokontroler. Jurnal JTIK (Jurnal Teknologi Informasi dan Komunikasi), 5(2), 4.
3. B, M. F., Lestary, F. D., Fakhri, M. M., Agung, M., Surianto, F., & Hidayat, A. (2023). Sistem kontrol pintu irigasi tambak otomatis berbasis mikrokontroler atmega16 dan sms gateway. Jurnal Teknik Informatika (JUTIF).
4. Devinta, S., Fahrudi, A., & Primaswara, R. (2022). Prototype monitoring dan kontrol alat penyiraman tanaman kangkung menggunakan arduino berbasis website. Jati (Jurnal Mahasiswa Teknik Informatika), 6(1), 4.
5. Effendi, N., Ramadhani, W., & Farida, F. (2022). Perancangan sistem penyiraman tanaman otomatis menggunakan sensor kelembapan tanah berbasis IoT. Jurnal CoSciTech (Computer Science and Information Technology), 3(2), 91–98.
6. Febrianti, V. P., Permata, T. A., Humairoh, M., Putri, O. M., Amelia, L., Fatimah, S., & Khastini, R. O. (2021). Analisis pengaruh perkembangan teknologi pertanian di era revolusi industri 4.0 terhadap hasil produksi padi. Jurnal Pengolahan Pangan, 6(2), 2.
7. Firdausi, F. A., & Ramadhani, S. (2020). pengembangan aplikasi online public access catalog (opac) perpustakaan berbasis mobile pada Stai Auliaurrasyidin. 4, 5.
8. Firebase | Google's Mobile and Web App Development Platform. (t.t.). Diambil 21 November 2023, dari https://firebase.google.com/?hl=id
9. Ginting, D. B., & Wangsa, O. A. (2021). Perancangan dan pembuatan prototype lampu jalan otomatis berbasis arduino uno r3 menggunakan sensor inframerah dan ldr. Fakultas Sains dan Teknologi, Universitas Buddhi Dharma, 2.
10. Hasan, F., & Pakaya, N. (2020). Perbedaan jenis komposisi media tanam terhadap pertumbuhan dan produksi kangkung darat (ipomea reptans poir) dalam polibag. Jurnal Agercolere, 2(1), 17–23.
11. Ismail, F. (2021). Perancangan dan implementasi iot platform untuk pemantauan tanaman pakcoy pada tahap penyemaian. e-Proceeding of Engineering, 8(2), 1530-1539.
12. N, N., & Jaya, A. (2022). Rancang bangun smart home berbasis internet of things menggunakan firebase real time database dan aplikasi android. Jurnal Logitech: Logika Technology.
13. Putri, A. R. (2019). Perancangan alat penyiram tanaman otomatis pada miniatur greenhouse berbasis IoT. Seminar Nasional Inovasi dan Aplikasi Teknologi di Industri.
14. Ridarmin, R., & Pertiwi, Z. P. (2018). Prototype penyiram tanaman hias dengan soil moisture sensor berbasis arduino. Informatika, 10(1), 3.
15. Roihan, A., Mardiansyah, A., Pratama, A., & Pangestu, A. A. (2021). Simulasi pendeteksi kelembaban pada tanah menggunakan sensor dht22 dengan proteus. Methodika: Jurnal Teknik Informatika dan Sistem Informasi, 7(1), 25–30.
16. Saputra, F., Suchendra, D. R., & Sani, M. I. (2020). Implementasi sistem sensor dht22 untuk menstabilkan suhu dan kelembapan berbasis mikrokontroler nodemcu esp32 pada ruangan. e- Proceeding of Applied Science, 6(2), 1977- 1984.
17. Surya Ramadhan, I., Martias, M., Sastra, R., & Iqbal, M. (2023). Alat penyiram tanaman otomatis berbasis arduino uno dan nodemcu. INSANTEK, 4(1), 12– 17.
18. Syah, I. F., & Thoriq, A. (2023). Analisis kelayakan budidaya sayuran kangkung organik (ipotema aquatica). Seminar Nasional LPPM Universitas Muhammadiyah Mataram, 2, 207-215.
19. Syam, M. W. S., Latifa, U., & Nurpulaela, L. (2023). Perancangan kontrol aktuator berbasis nodemcu esp32 pada smart agriculture. Aisyah Journal Of Informatics and Electrical Engineering (A.J.I.E.E), 5(2), 141–151.
20. Tullah, R., Sutarman, S., & Setyawan, A. H. (2019). Sistem penyiraman tanaman otomatis berbasis mikrokontroler arduino uno pada toko tanaman hias yopi. Jurnal Sisfotek Global, 9(1).
21. Wahid, H. A., Maulindar, J., & Pradana, A. I. (2023). Rancang bangun sistem penyiraman tanaman otomatis aglonema berbasis iot menggunakan blynk dan nodemcu 32. JournalOfSocialScienceResearch.
22. Wulandari, P. A., Rahima, P., & Hadi, S. (2020). Rancang bangun sistem penyiraman otomatis berbasis internet of things pada tanaman hias sirih gading. Jurnal Bumigora Information Technology (BITe), 2(2), 2.