Hydroponic Plants Monitoring System based on Single Board Computing in Order to Increase Food Security in Bali

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Abstract. To optimize agricultural yields on increasingly shrinking agricultural land in Bali, hydroponic cultivation is the solution. Compared to conventional planting, hydroponic planting uses different methods. This method causes one disadvantage in hydroponic planting. The weakness is the skill of farmers in monitoring their crops. To help farmers monitor their hydroponic plants, a system is needed. The system should be able to monitor and inform farmers about the condition of their crops. This study designed and built a hydroponic plant maintenance system using a single board computer, microcontroller, sensor, and actuator. The microcontroller is used to collect data from sensors. Next, the data is forwarded to a single board computer to be processed into information. The information will be forwarded and stored into the server, and then continued to the farmers concerned through smartphone devices which are connected to the internet. Then, the farmers make decisions according to the information. On this system, a single board computer, microcontroller, sensor, and actuator are in a local connection. Single board computer that is connected to the internet in such a way, that it is able to transmit data to the farmers' smartphone devices. The communication between single board computer and microcontroller is using web services based on JSON-RPC, and from the single board computer to the farmer’s devices is using web services with the REST architecture. The conclusions from this study are the system built is able to monitor the hydroponic plants and inform the farmers using their smartphone.

1. Introduction

Urban Farming is one of the farming activities carried out in urban areas. This technique adapts pre-existing techniques and is applied in households, especially urban areas that have a limited area. The urban farming technique used is the hydroponic technique.

In hydroponic planting, many techniques are developed, one of which is the Ebb and Flow technique, also known as tidal techniques. The tidal technique is one of the most used hydroponic techniques. This system works by filling the growth media with nutrient solutions and nutrient solutions that are not absorbed back into the reservoir [1]. This tidal technique is an easy technique to do but requires expertise and thoroughness from farmers. Often farmers are late in flowing water that contains nutrients, so the plants become nutrient deficient and production results are not optimal.
In addition to obtaining optimal crop yields, data on cultivated crops and harvests obtained are often not available. This primary data can be used by policymakers to make decisions, such as pricing. As an example, the price of fluctuating chilli often rises, but sometimes prices also fall due to abundant harvests in various places. This can actually be overcome with the right decisions from policymakers, supported by the right data. To get data accurately, we need technology that can run in real time and online. The technology that can be used for this is the Internet of Things (IoT) technology.

The study aims to design an Internet of Things (IoT) tool to collect data about plants, regulate watering or plant nutrition automatically, regulate the light intensity and room humidity, as well as remote monitoring of hydroponic plants through an online control system and time. This research will be tested on a hydroponic greenhouse used for green mustard and “pok-chai” plants.

2. Literature Review

2.1. Internet of Things

Internet of Things (IoT) can be explained as a set of things connected to each other via the internet. Things here can be tags, sensors, humans, or other devices. IoT functions to collect data and information from the physical environment, these data will then processed so that the meaning can be understood. The ability of IoT to communicate with each other makes IoT possible applied in all fields [2]. In the health sector [3], IoT sensors can be used to monitor the patient’s condition, so that the patient’s condition remains monitored for 24 hours. In agriculture, IoT can be used as a sensor to monitor soil conditions, temperature and humidity that are important for plants.

2.2. Nutrient Film Hydroponic Technique

The Nutrient Film Technique or also known as NFT is a high technology crop production system and requires both skill and experience from its users if the best results are to be obtained [1,4]. NFT was developed in the mid-1920s in China by Dr. Alan Zhang Jr. In an ideal system, the depth of the recirculating stream is very shallow, little more than a film of water, hence the name 'nutrient film'. This ensures that the thick root mat, which develops in the bottom of the channel, has an upper surface, which, although moist, is in the air. Subsequent to this, an abundant supply of oxygen is provided to the roots of the plants.

The NFT technique shown in Figure 1. The tank provides the nutrient solution for the plants. The nutrient solution is water mixed with dissolved plant nutrition [5]. The water pump lifts the nutrient solution to the pipe below the plants. The plants is grown on the pot filled with the rockwool media. The rockwool media will absorb the flowing nutrient solution and save it for the plants. The excess of the nutrient solution will pour back into the nutrient solution tank. The aerator dispenses oxygen into the nutrient solution.

3. Objectives

The aim of this research is to design and build an Internet of Things (IoT) based system to collect plant data, remote monitoring and automatic mechanical treatment of hydroponic plants. From these objectives, the specific objective to be achieved in this study is how to build a prototype system based on the Internet of Things and hydroponic plant maintenance mechanism using a single board computer, microcontroller and sensor, where the system can help policymakers get executive ranks data about plants, as well as assisting farmers in maintaining and monitoring hydroponic plants on a planting area. The plantation method in question is a greenhouse.

Meanwhile, with the existence of this system, the benefits obtained by farmers are the reduced risk of plants dying due to the delay in giving treatment measures, such as watering, opening vents or closing the blazing light. So that in the end it will be accompanied by an increase in their production and also improve the standard of living of the farmers.

In addition, another benefit that can be felt by farmers is being able to monitor a lot of planting land from afar, with farmers being able to use their mobile phones. Notifications or warnings will be sent via short message service (short message service/SMS). If something happens to the plant that requires further action, it can be dealt with as soon as possible. So that it can improve the efficiency of farmers in managing large areas and lots [6].
4. Methodology
The system design steps to be carried out in this study are:
1. Conduct a literature study
2. Analysis of system requirements
3. Create a system design
4. System implementation
5. System testing

4.1. Literature Study
The literature study was conducted to gather library resources that support the design of this mechanical system. The literature sought is literature on Internet-of-Things (IoT), single board computer programming, microcontrollers, sensor literature, the literature on microcontroller supporting modules, and literature on techniques for planting hydroponic plants [7,8].

4.2. Analysis of System requirements
System requirements analysis is carried out to analyze the needs needed to build the system in this study. These requirements include the need for hardware and the need for software.

4.3. System Design
In order to be suitable for the purpose of this research, a stage is needed to describe the design work plan of the system to be created [9]. We can see the system design chart in Figure 2. There is a set of microcontrollers (A) that are the brains of all these systems. Sensors (E, F, G) are placed around the planting media to be able to monitor any changes, whether temperature, light or humidity. A water pump (C) is used to drain water and nutrients to plants through pipes. The planting media is arranged in such a way that excess water and nutrients can flow back into the reservoir (B). There are also electric motors (H) and (I) that are used to open windows and blinds to regulate the air and light ventilation windows, and a sprinkler (K) and an exhaust (J) which function to regulate humidity.
5. Results and Discussion
The result of this study will be separated into 5 (five) parts, i.e.: hardware design (Figure 3), software design, testing scenarios, implementation (Figure 5 and 6), and testing results.
5.1. Hardware Design

Figure 3. Hardware Design and Connectivity

5.2. Software Design

The detail of data communication of the software can be seen in Figure 4. Data from the single board computer will be transferred into the cloud server using an HTTP protocol [10]. Next, the result of the processed data will be carried out to the user smartphone using HTTP protocol and formatted with JSON.

Figure 4. Design of Software Data Communication
5.3. Testing Scenarios

To testing the built system, we used the black-box testing method. The testing conducted based on the default functions of the system. Table 1 listed the default functions of the system which is tested using the Black-box method.

| Function                  | Description                                      |
|---------------------------|--------------------------------------------------|
| Get the soil humidity     | Get the soil humidity from the sensors           |
| Get the room temperature  | Get the room temperature from the sensors        |
| Get the light intensity   | Get the light intensity from the sensors         |
| Get the pH                | Get the pH from the nutrient solution            |
| Turn the exhaust on       | Turn on the exhaust fan to flow out the air      |
| Turn the exhaust off      | Turn off the exhaust fan to stop the air flow    |
| Turn the water pump on    | Turn on the water pump to watering the plantation media |
| Turn the water pump off   | Turn off the water pump                          |
| Send notification to the smartphone | Send notification to the smartphone using web services |

5.4. Implementation

![Air humidity sensor connectivity](image1)

**Figure 5.** Air humidity sensor connectivity

![Light intensity sensor connects to the microcontroller](image2)

**Figure 6.** Light intensity sensor connects to the microcontroller
5.5. Testing Results

Using the black-box testing, Table 2 shown the result.

| Function                  | Description                                      | Result     |
|---------------------------|--------------------------------------------------|------------|
| Get the soil humidity    | Get the soil humidity from the sensors           | Succeed    |
| Get the room temperature | Get the room temperature from the sensors        | Succeed    |
| Get the lights           | Get the light intensity from the sensors         | Succeed    |
| Get the pH               | Get the pH from the nutrient solution            | Succeed    |
| Turn the exhaust on      | Turn on the exhaust fan to flow out the air      | Succeed    |
| Turn the exhaust off     | Turn off the exhaust fan to stop the air flow    | Succeed    |
| Turn the water pump on   | Turn on the water pump to watering the plantation media | Succeed |
| Turn the water pump off  | Turn off the water pump                          | Succeed    |
| Send notification to     | Send notification to the smartphone using web services | Succeed |
| the smartphone           |                                                  |            |

6. Conclusions

The urban farming monitoring plants designed and built in the form of prototypes can be used to monitor the remote location of hydroponic plants. The web services system designed to provide early information to the farmers with the condition of hydroponic plants in the event of a critical situation.

7. Acknowledgment

This article was presented at the 2nd International Conference on Smart City INNOVATION (ICSCI) 2019, jointly held by Universitas Indonesia and Universitas Diponegoro. ICSCI conferences have been supported by the United States Agency for International Development (USAID) through the Sustainable Higher Education Research Alliance (SHERA) Project for Universitas Indonesia’s Scientific Modelling, Application, Research, and Training for City-centered Innovation and Technology (SMART CITY) Center for Collaborative Research, administered through Grant #AID-497-A-1600004, Sub Grant #IIE-00000078-UI-1

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