Journal of Theoretical and Applied Information Technology
30th April 2023. Vol.101. No 8

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

INTERNET OF THINGS DESIGN ARCHITECTURE DEVELOPMENT FOR CONTROLLING AND MONITORING HYDROPONIC PLANTS

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ABSTRACT

This research focuses on creating an Internet of Things (IoT) system that can monitor temperature, pH, humidity, and water flow in and out, increase flow strength, and measure the intake of nutrient solutions in the nutrient intake system in hydroponic systems. There are many problems found by researchers, such as 1) the difficulty of monitoring plant nutrition when not on the farm; 2) not being able to know whether the water level in hydroponic plants is normal or not; 3) when the water flow is abnormal, it cannot be controlled remotely; 4) not being able to monitor the temperature in hydroponic plants. To overcome these problems, we can utilize the Internet of Things (IoT) for control and monitoring in smart agriculture. IoT has proven to be very influential in the agricultural sector. by using the design thinking method and an object-oriented approach and creating a unified modeling language. An initial design was produced in the form of a smart farming system to control and monitor hydroponic plants using the Internet of Things (IoT). Hydroponic plants can be controlled and monitored with a mobile application to record the nutritional conditions of plants by measuring the pH of the water, the temperature of the plants, and the normal status of water flow. Hopefully, this technology will help advance hydroponic farmers while also attracting a large number of people to agriculture.
Keywords— *Hydroponics, Smart Farming, Internet of Things, Systems Design, Mobile apps.*

1. INTRODUCTION

The focus of this research is to create an Internet of Things (IoT) system that can regulate temperature, pH, humidity, water inflow and outflow, and absorption of nutrient solution in a nutrient absorption system in a hydroponic system. WHO (World Health Organization) recommends a daily intake of 400 grams of vegetables and fruits per person to maintain a healthy life[1]. Reports from the World Health Organization and the Food and Agriculture Organization of the United Nations recommend that adults eat at least five servings of fruits and vegetables a day, excluding starchy vegetables[2]. However, citing BPS data, analysis results show that the average vegetable consumption of the Indonesian population is 70.0 grams per person per day, while fruit consumption is 38.8 grams per person per day. The average vegetable and fruit consumption of the Indonesian population is 108.8 g/person/day[3].

The 2020 agricultural production index increased by 5.12 points compared to 2019, from 162.43 (fixed figure) in 2019 to 167.55 (provisional figure) in 2020. This is due to an increase in the production index of horticulture, plantations and livestock. The agriculture sector's contribution to Gross Domestic Product (GDP) at current prices in 2020 was 13.70%, an increase of 0.99% from the previous year. The order of the largest contributions to GDP in 2020 in the agriculture subcategories is as follows: Plantation (3.63%), food crops (3.07%), fisheries (2.80%), livestock (1.69%), horticulture (1.62%), forestry (0.70%), agricultural services (0.20%) [4].

Government efforts in the implementation of development are inseparable from the development

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

of the agricultural sector, including hydroponics crop agriculture, as a form of effort to improve the welfare of the people who are still mostly engaged in the hydroponics agricultural sector. Objective, reliable, and relevant indicators in planning, monitoring, and evaluating the implementation of agricultural development indicators in light of the actual situation are needed[5].

However, when researchers conducted a survey at the locations of hydroponic farmers, there were several problems faced by farms in the farming they did, including: 1) the difficulty of monitoring plant nutrition when they were not on the farm; 2) the inability to know whether the water level in hydroponic plants was normal or not; 3) the inability to control the water flow remotely when it was abnormal; and 4) the inability to monitor the temperature in hydroponic plants. In this context, technology can play an important role in improving efficiency and leading to smart farming on farms.

To solve these problems, we can utilize the Internet of Things (IoT) for controlling and monitoring smart agriculture. IoT has proven to be very influential in the agricultural sector. One example is the success of the study.[6]. It was mentioned in the study that IoT can turn manual farming into smart farming. The benefits of implementing IoT-based smart agriculture include the ability to control things needed for plants more easily for quality improvement, the ability to remotely monitor plant growth in order to maintain plants, the ability to obtain nutrients more easily from plants, and the avoidance of unwanted things[7].

By utilizing IoT technology, we can build a system for farmers to able to build an IoT-based system for controlling and monitoring nutrition and pH in hydrophonic plants, can determine the time to turn on the nutrition and pH pumps, and provide a control system to control nutrition and pH and other things as well for this plant[8]. The new knowledge in the study to support hydroponics farming in addition to those already mentioned is to create a system to monitor and control the normal level of water flow in plants both directly and remotely in case of sudden problems. This research will focus on creating an agricultural system architecture. The scope of this research is related to smart farming for hydroponics crop farming, by limiting the system created as mentioned above. The research for making this system will be an IoT-based system to control, monitor, and automate hydroponic plants through an application[9].

2. LITERATURE REVIEW

2.1 Smart Farming

Smart farming is an agricultural concept based on precision agriculture that utilizes technological automation supported by big data management, machine learning or artificial intelligence, and the Internet of Things (IoT) to improve the quality and quantity of production in order to optimize land resources, cultivation technology, human resources, and other production resources[10].

2.2 Hydroponics Plants

Hydroponic plants are plants whose growing medium is not soil. Hydroponic plants also do not require a lot of water, so there is no need to water them like plants grown on soil media. The hydroponic planting technique is an environmentally friendly farming technique. Vegetables grown with hydroponics are proven to be healthier and safer for consumption. Some people may still be very unfamiliar with hydroponic plants. However, there are many people who use this method of growing plants. The development of the hydroponic planting method has not been very rapid because some people are hesitant to apply it because they are worried about the quantity of the harvest. But actually, the harvest from hydroponic planting techniques has good quality and quantity. However, hydroponic growing techniques cannot be applied to all types of plants. Only a few are suitable and able to thrive with satisfactory results. The hydroponic planting technique itself is very suitable for those who have limited land[11].

Figure 1: Hydroponics Plants

2.3 Internet Of Things

IoT, or "the internet of things," is a concept in which different sensor devices are connected through the internet to collect and transmit data. These activities are performed without computer or human assistance. The goal is to enable technology or sensors to control, communicate, connect, and exchange data with other devices in everyday life as long as they are connected to the internet. IoT is playing a very important role in raising the standard of technology. enabled activities in the form of e-health, smart homes, and smart learning. For professionals, IoT finds its applications in automation, smart supply chain and transportation, remote monitoring, and logistics[12]

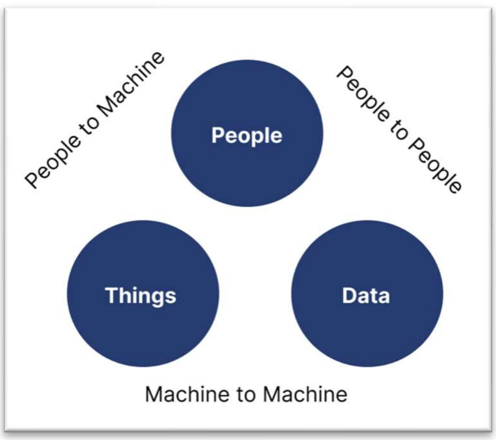

Figure 2 : Diagram of Internet of THings

2.4 Agriculture

Agriculture is a business activity that includes growing food crops, horticulture, plantations, ranching, fishing and forestry. It can be said to be a kind of production activity based on the growth process of plants and animals. Agriculture in a narrow sense is called small-scale farming. Agriculture in the broad sense includes agriculture in the narrow sense, forestry, animal husbandry, plantation cultivation, and fisheries. fishing. Broadly speaking, the definition of agriculture can be broken down into four indivisible elements. [13].

2.5 IT Protocols In Smart Farming

According to [14], The basic building blocks of a smart farming architecture are connected sensors, gateways, servers and, of course, the network. A network sensor is a collection of sensors placed in an agricultural field (a field of 1 1 meter or 2 2 meters) that stores data locally and communicates with a gateway that transmits it to the Internet on a predetermined schedule. Data is sent from the gateway to the server through a remote terminal unit (RTU).

2.6 System Design

Systems analysis and design are processes used in the development of information systems. In this process, there are activities that involve identifying problems in the company, proposing solutions in the form of information systems for one or more of the identified problems, and their design[15].

2.7 User Interface

According [16]. The interface of an interactive system, also known as the "user interface," is all the parts of the system that people physically, perceptually, and conceptually come into contact with:

A. Physically, we can interact with devices by pressing buttons or moving joysticks, and interactive devices can respond by pressing buttons or moving joysticks to provide feedback.

B. Perceptually, devices display things on a screen that we can see or make sounds that we can hear.

C. Conceptually, we interact with devices by trying to figure out what they are doing and what we should be doing. The device provides notifications and other indicators to help us do this.

2.8 User Experience

According[16], User Experience Design, commonly referred to as UX Design, is the process of increasing user satisfaction (among application users and website visitors) by improving the usability and enjoyment of interactions between users and products. User Experience focuses on a deep understanding of the user. B. What they need, what they appreciate, the skills they have, and their limitations. Furthermore, this knowledge is considered when determining the business goals and objectives of the group managed in a user experience project.The advantage of using user experience is that it improves the quality of user interaction and the perception of other related products and services.

2.9 Related Works

Table 1: Related Works Table

Author	Summarize
[17]M. A. Zamora-Izquierdo, J. Santa, J. A. Martínez,	This study of the EU DrainUse project framework has been fully utilized in a real prototype that makes hydroponics controllable via software for connected farmers.

V. Martínez, and A. F. Skarmeta	
[18]J. Doshi, T. Patel, and S. K. Bharti	In this study, a smart farming solution using IoT was created to optimize the monitoring of agricultural conditions. It is also mentioned that the IoT sensor created is not only one but there are more than one sensor that can be monitored from the farmer's mobile. Which will allow farmers to manage their crops in the new era of agriculture.
[19]A. Nayyar	This study created an IoT-based agricultural solution for direct monitoring of soil temperature and moisture using Arduino, cloud computing, and solar technology. With the implementation of this solution, farmers can easily control their agriculture to increase crop yields.
[20]R. Dagar, S. Som, and S. K. Khatri	This study designs a simple architecture for IoT sensors applied to farms to make them smart farms. The IoT sensors will collect data and transmit it via the Wi-Fi network to the server. Then, the server can take action depending on the information.
[21]S. Kim, M. Lee, and C. Shin	This study develops a smart farming prediction system for strawberry diseases.strawberry is also included that can use hydroponic techniques. This research makes data transferable to any IoT device and communication for non-standard products possible.The results of this study show high communication strengths even in a poor communication environment. As a result, IoT-Hub ensures the technology's stability, particularly in agricultural environments.

3. RESEARCH METHODS

There are two methodologies applied in this research to support the success during the real implementation of this system, namely: design methodology by applying design thinking methodology, and system methodology by applying Object Oriented Approach by creating Unified Modeling Language.

3.1 Design Methodology

3.1.2Design thinking

Design methodology to implement the application or website needed in this research using design thinking. According[22]. Design thinking is an iterative process of understanding your users, challenging assumptions, redefining the problem, and identifying alternative strategies and solutions that may not be immediately apparent in your initial understanding. At the same time, design thinking offers a solution-oriented approach to solving problems. It is a compilation of ideas, ways of working, and methods of practice. Below are some stages of design thinking.

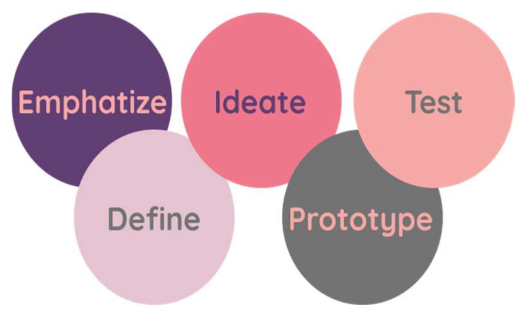

Figure 3 : Design Thinking Metode

3.1.2.1emphatize

This stage aims to gain an empathic understanding of the problem that the researcher is trying to solve. At this stage, it will directly involve hydroponics farmers and consulting experts to find out more about the problem and what the target users need. In this stage, it will be done in two ways, namely: 1. Distributing questionnaires 2. Conducting direct interviews so that, from the two ways above, the researcher will get the information needed to continue the research.

3.1.2.2 Define

During this phase, researchers collect information created and collected during the "empathy" phase. In this phase, researchers analyze and synthesize observations to identify the core issues identified. Similar to user personalities and problem statements, researchers attempt to identify problems in a human-centered way as problem statements.

3.1.2.3 Ideate

Ideate Stage The researcher begins to generate ideas from the problems discovered during the empathize and define stages. a strong background, the researcher does several things, such as: 1. What Are Our Options? 2. solution mapping to identify new solutions to the created problem statement

3.1.2.4 Prototype

Researchers will create prototypes using the Figma application according to the predefined solutions to identify the best solution for each problem identified during the previous three stages. The solutions are implemented in the prototype, and one by one they will be investigated and accepted, improved and re-examined, and rejected based on user experience.

3.1.2.5 Test

The last stage in design thinking is the Test. However, this stage can make researchers return to the previous stage if defects are found. Researchers will continue to the implementation stage if, at this stage, the results are good and acceptable.

3.2 System Methodology

3.2.1 object oriented approach

This study will use Object Oriented Approach. According[23] Using an object-oriented approach, the focus is on capturing the structure and behavior of an information system in small modules that combine data and processes. The main goal of object-oriented design (OOD) is to improve the quality and productivity of system analysis and system design by improving usability.

OOD models are useful in the following ways:
a. It helps change the system at low cost.
b. Encourage component reuse.
c.Simplifies the problem of integrating components to configure large systems.
d. Simplify the design of distributed systems.

3.2.2 unified modelling language (uml)

This study will use UML Diagram for design a systems. According [15], [24], Unified Modeling Language is an object-oriented system design tool. The emergence of UML was inspired by an existing concept, namely the concept of object-oriented modeling (OO), because the concept is analogous to a system, such as real life, which is object-oriented and has a very specific notation to describe or mark it, so OO has an independent standard process. The main purpose of UML diagrams is to help project development teams communicate, explore design potential, and validate software architecture designs or program creators.

4. RESULT AND DISCUSSION

4.1 Interview Finding

User interviews were generated from interviews conducted by researchers with hydroponics farmers. The table below shows the conclusions obtained after conducting interviews with hydroponics farmers. It can also be concluded from the results of this interview that most hydroponic farmers do not find it easy to farm because they cannot control and monitor hydroponic plants remotely.

Table 2: Interview Finding Table

Background	Results
Name: Eliana Experience: 1.5 Years Job: Hydroponics Farmer	"It has been 1.5 years since I became a hydroponics plant farmer. I still have a lot to learn so that my farming results are satisfactory. "Especially since I also work as a housewife, sometimes I can't always control or see my plants. In this sophisticated era, I would love to be able to easily see the ph of the water to measure the nutrition of my plants."
Name: Eka Yuliana Experience: 1 Years Job: Hydroponics Farmer	"For the past year, I have been active as a hydroponics plant farmer, following my friends. It feels good to be able to farm with this method. However, just like other farmers in my group, to get good results, of course, you have to be able to measure the nutrients in it. That's what has been difficult until now. Hopefully, there are tools that facilitate our problems."
Name: Nina Marlina Experience: 2 Years Job: Hydroponics Farmer	"I'm Nina; I've been a farmer for two years now, and I'm the senior farmer among the women here. I like farming because, in addition to strengthening bonds with each other, sometimes farming can

	release stress. The difficulty I feel as a hydroponic plant farmer is the difficulty of monitoring plants from home. We can't always be here. Hopefully there is a tool that makes my plants monitorable and, if possible, controllable from home."

4.2 Problem Statement

Based on the information gathered in the previous phase, we identified three main problems facing farmers in Indonesia, namely:

4.2.1 Unable to monitor plants remotely

This is a problem experienced by almost all hydroponics farmers who cannot monitor their plants from home or remotely include temperature and flow water to plants.

4.2.2 Difficult to view plant water ph information from home

hydpronics plants need ph to be measured to be able to decide whether it needs more or less on the plant. this problem is felt by farmers because they cannot see the water ph of their plants.

4.2.3 Difficult to measure plant nutrition

then each plant will be looked at for nutrients to match what is expected. However, the nutrients cannot be seen by the farmer. so they do not know what the content is.

4.3 Howmightwe & Solution Mapping

4.3.1 Howmightwe

Based on the problems and needs defined in the previous phase, I conducted iterative brainstorming sessions to come up with new solutions. We proposed a solution, which is a smart farming mobile application platform that aims to provide farmers with the ability to monitor and control the pH of the water of hydroponic plants through smartphones in order to be able to measure the nutrition of the plants. Smart farming will be implemented on one type of platform for farmers: Mobile Application: The mobile application platform will be used by farmers to control and monitor the pH of water to measure the nutrition of hydroponic plants. The reason for choosing this platform is because the target farmers want a platform that can be easily carried anywhere and accessed at any time. Therefore, I think the mobile application platform can be used to solve the farmers' problems.

4.3.2 Solution mapping

The solution mapping in Figure 4 illustrates better, adjusting to the method used, that there are three main problems experienced by farmers. The main solution based on the existing problems is to create something to be able to control and monitor hydroponic plants. Not only that, the authors argue that there are some good things to add to adjust to this problem, namely those listed in the improvement section.

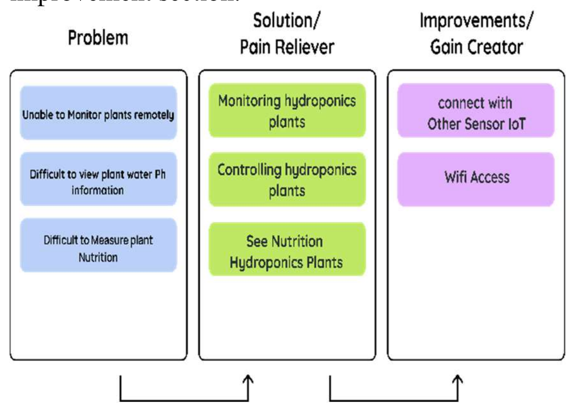

Figure 4 : Solution Mapping

4.4 Activity Diagram

Based on Figure 5, the farmer can enter the application and connect the device to the plant on the mobile phone. and after that, the farmer can control and monitor the plant and the device. such as viewing water PH, flow status, nutrients, and plant temperature, as well as controlling and adding hardware.

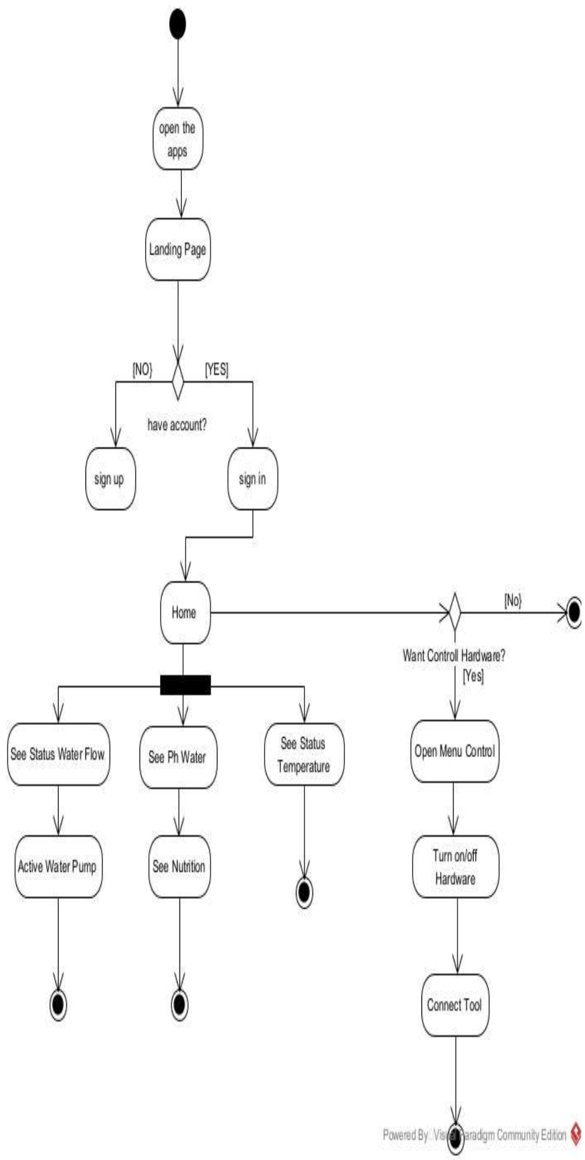

Figure 5 : Activity Diagram

4.5 Use Case Diagram

Based on figure 6. this application will have one main actor is farmer and seven main use cases for farmers, namely: register, connect the plant tool to the mobile phone, control hardware, view water ph and view plant nutrients, see temperature of hidroponik plant, and then can see the status of flow water at the farm.

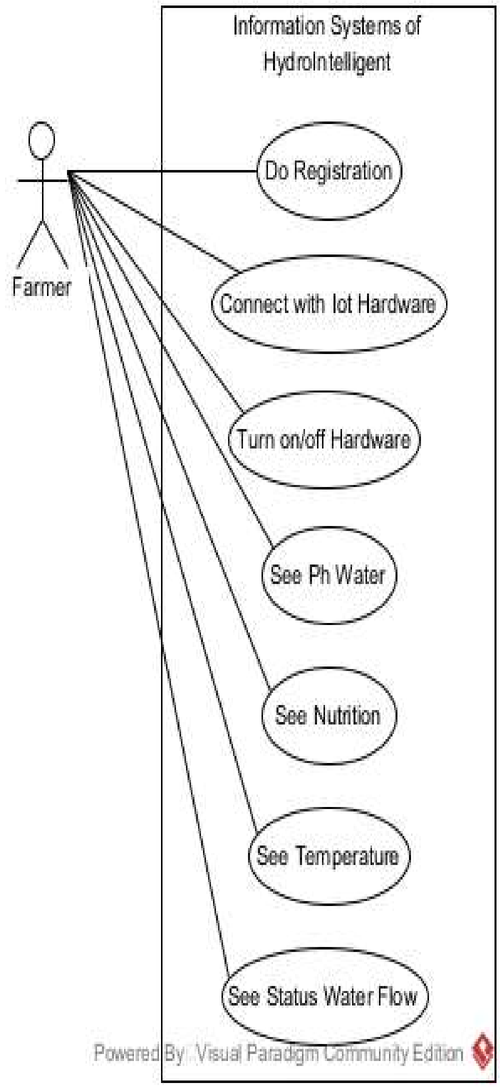

Figure 6 : Use Case Diagram

4.6 Class Diagram

Based on Figure 7, this application will have nine objects and need to know the relationship between one object and another to run. The conclusion that can be drawn from the objects below is that farmers can connect more than one IoT device with this application. and the IoT device will store data in the database, such as the temperature at the plant site, the strength of the water flow to the plant, the ph of the water from the plant, and the nutrition of the hydroponic plant. After that, the data will also be displayed in the application. Each IoT device will be associated with hydroponic plants because each hydroponic plant has different PH water and nutrition levels. The data will be entered by the administrator.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

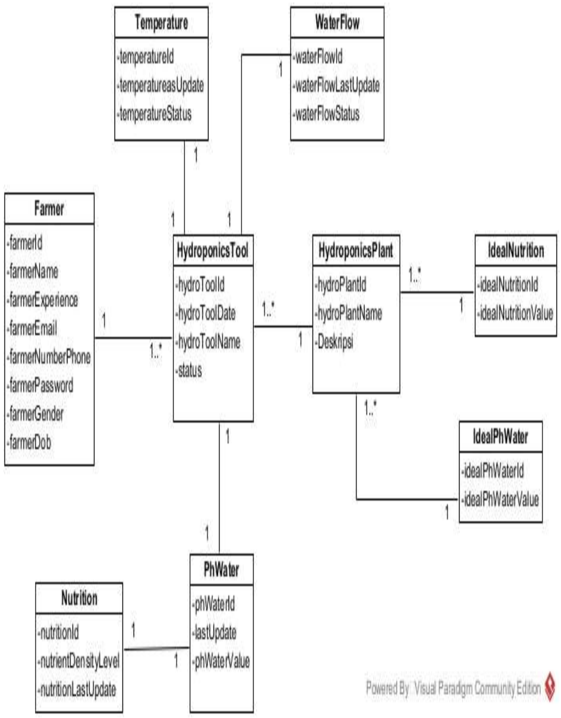

Figure 7 : Domain Class Diagram

4.7 User Interface

Based on Figure 8, It can be seen that when the farmer finishes downloading the application and opens the application, the first page that will be seen by the farmer is a splash screen that brings up the logo and also the name of the application. then the farmer will see a landing page that shows images that change every day and the motto of the application, and there are two buttons that can be selected by the farmer: wanting to create an account or directly logging into the application. If the farmer clicks the "create account" button, the application will display the "register" page, where the farmer can enter their email address and password or use a gmail account to register in the application. Registration initially only requires an email and password, but the farmer can fill in more data on the edit profile page. If the farmer chooses the log in button, he can enter the email and password that have been registered or enter via a gmail account, and then the farmer will be able to enter the application, which will display the home page.

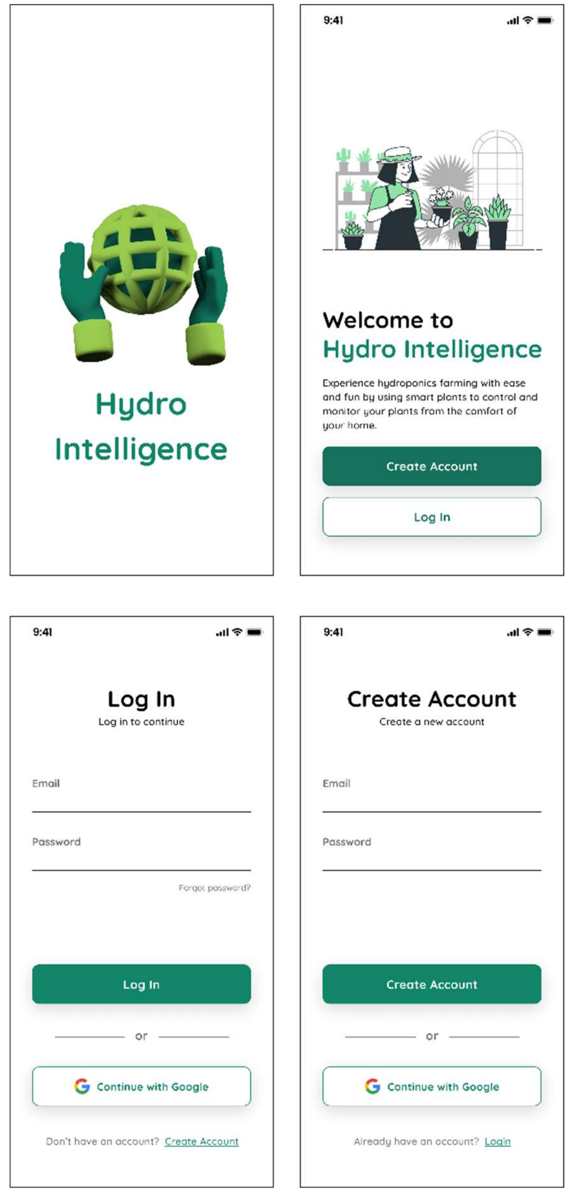

Figure 8 : User Interface one

Based on Figure 9, when the farmer enters the application, the home page will appear by presenting three main pieces of information, such as the ph of the water from the connected device; if clicked, the farmer will be directed to the nutrition page to be able to see the ph of the water and the nutrients in the hydroponic plant; and there is also the ideal value of the plant. Then there is also information on the temperature of the hydroponic plant, as well as on the flow status of the hydroponic plant, whether normal or abnormal. Then there is also information on the temperature of hydroponic plants as well as the flow status of hydroponic plants, whether normal or abnormal. Then there is a Control menu to control the hardware that has been

Journal of Theoretical and Applied Information Technology
30th April 2023. Vol.101. No 8

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

connected to the application; the tool can be activated or deactivated through the application from this menu. only that, but on this page there is also a hardware connect button for farmers to connect their IoT devices with the application.

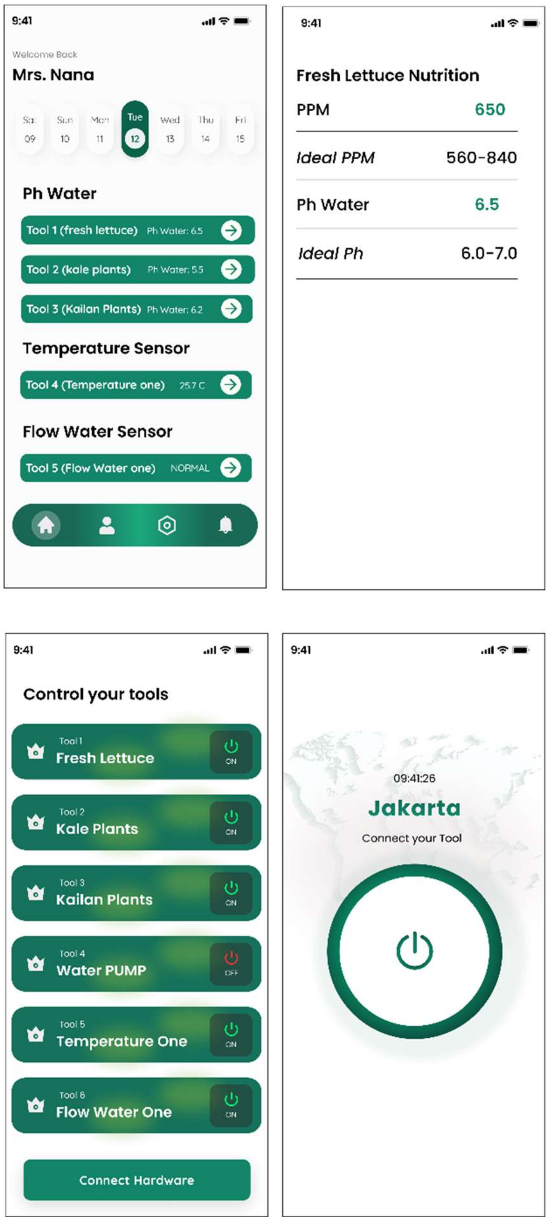

Figure 9 : User Interface two

4.8 Hardware Design

Three designs of IoT tools for controlling and monitoring hydroponic plants are shown below the author's description.consisting of a ph water sensor, which is the first and main tool in this design. Next is the water flow and pump design to detect water flow and control it if there is a problem with the flow of water. and the last is a tool to monitor the temperature of hydroponic plants. The main tool for hardware design is the Arduino Uno for IoT management.

4.8.1 ph detection sensor design

Based on figure 10, it can be seen that for the ph detection sensor, the Arduino Uno is connected to the ph detection sensor to be arranged in its function of measuring the ph of water from hydroponic plants, and later the results will appear in the LCD display ph water to be seen by the farmer. And not only that, the pH water measurement results will also be stored in the database and displayed in the application.

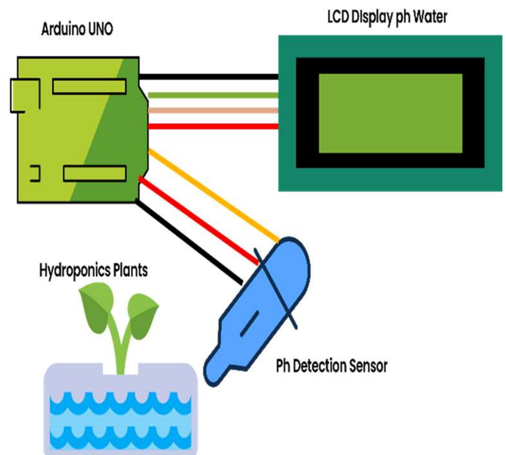

Figure 10 : Ph Water Design

4.8.2 water flow & water pump design

Based on Figure 11, the second tool that the author will make aims to detect the strength of the water flow that carries nutrients into hydroponic plants, whether it is normal or abnormal. If it is abnormal, the water flow sensor will provide a warning signal directly or through the application to be known by farmers. Furthermore, farmers can activate the power water pump through the application to make the pump work harder so that the flow strength returns to normal.

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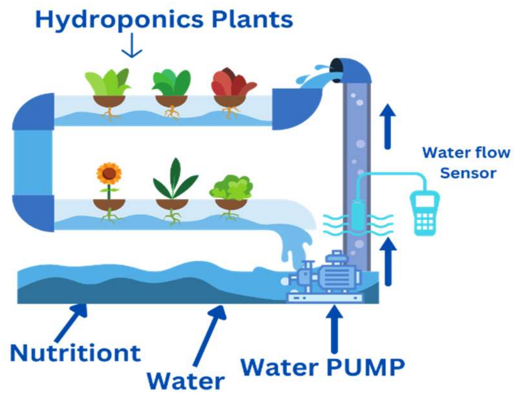

Figure 11 : Ph Water Flow & Water Pump

4.8.3 temperature sensor design

Based on Figure 12, in this design, the author will also make a sensor tool to measure the temperature in hydroponic plants as needed by farmers to implement sustainable farming. The temperature measurement sensor will be installed near the hydroponic plants and will automatically measure the temperature where it is located. The device will send the temperature data to the database, and farmers can view the temperature on the device or on the application on their mobile phones. This will help farmers monitor their hydroponic plants more effectively and efficiently.

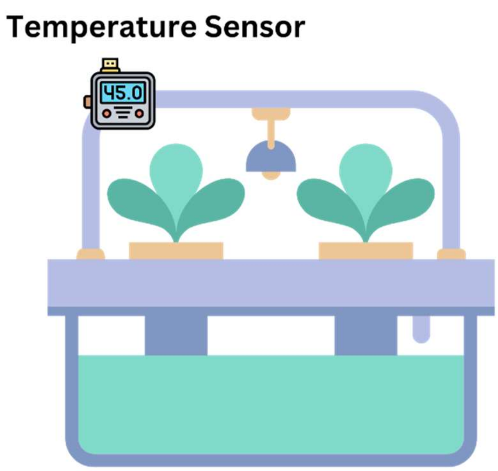

Figure 12 : Temperature Sensor

4.9 Other Design

After making the hardware design, the author also made several additional designs to be able to help him in the real application of making IoT-based sensor devices that will be connected to the farmers' mobile phones, which consist of architecture design, block diagram design, and system architecture.

4.9.1 architecture design

The architectural design shown in Figure 13 aims to transform the information model created during analysis into a model consistent with the technology used to implement the system. In general, IoT applications can be divided into three tiers: sensor layer, transport layer and application layer. The system architecture of this system design is based on this design because it is very clean and flexible for a surveillance system.

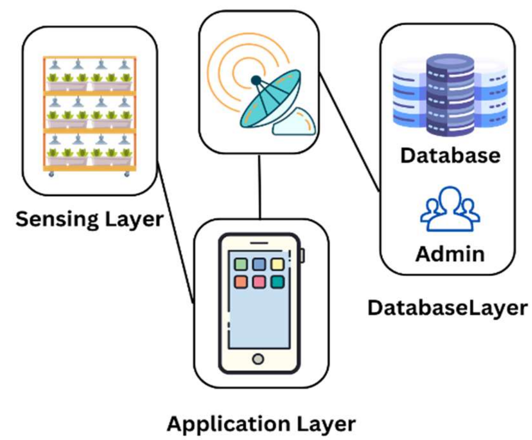

Figure 13 : Architecture Design of IoT based Hydroponics Farm

4.9.2 block diagram design

The block diagram design is shown in Figure 14. There are 3 sensors whose data is collected by the system. pH water detection sensor, temperature sensor, water flow sensor. In addition, the system sends the collected data to Wi-Fi, which uses his SIM card to send data over the network to the user's phone. Once the connection is established and the program is uploaded to the system, the system can work independently. The system requires no manual input during operation and can be used anytime, anywhere. By recording the water or nutrients of each hydroponic plant through sensors connected to the system, each hydroponic plant can be monitored and controlled anytime, anywhere. So having records in the database allows for quick and accurate identification of measures to effectively improve hydroponic nutrition. Therefore, with the availability of connected devices and a real-time connected database, hydroponic farmers can improve crop yields better and easier.

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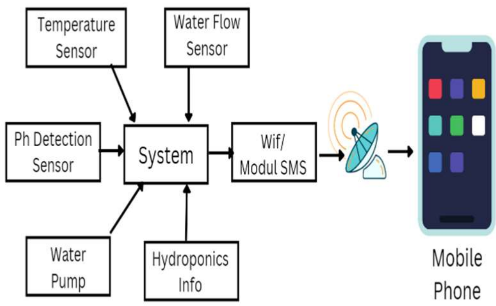

Figure 14 : Block Diagram of IoT based Hydroponics Farm

4.9.3 systems architecture

The system architecture, as found in Table 3, is a minimum description for device specifications by the client and also by the administrator to be able to operate this application. This will help researchers to be able to create applications according to the capabilities of farmers' devices through the research that has been done and make it easier when later socializing with farmers.

Table 3: System Architecture Table

Specification	Standard Client	Standard Application Server	Standard Database Server
Operating System	Android 9 iOS 9	Linux Mac OS	Linux
Special Software	App Store Play Store	Java	Oracle
Hardware	Snapdragon605 or Apple A11 Bionic 2GB RAM 16 GB Storage	64GB Memory 1 TB Disk Drive	64 GB Memory 4 TB Hotplug Disk Drive
Network	2Mbps Broadband 3G/4G	100 Mbps Ethernet	100 Mbps Ethernet

4.10 Discussion

The design of an iot-based system for controlling and monitoring hydroponics plants will be a reference in the real application of the system. There are no conflicting perspectives in the literature on this topic. The system design proposed in this study is able to handle the problem of hydroponic farmers to be able to monitor and control their plants remotely and from their devices using Wi-Fi or SMS Modules. This study is also able to contribute to farmers by informing farmers about the nutrition of hydroponic plants by measuring their water content. The water data received into the system will be processed according to the appropriate calculations, after which it will be able to display to farmers the level of plant nutrition. The purpose of this research with similar research can be said to be similar, namely supporting farmers in hydroponics farming by becoming smart farming using IoT technology..

The difference in the contribution of this research compared to similar research is that this research uses two methodologies, namely design methodology and systems. Namely, design thinking and also object oriented. Of course this will support its application and also support acceptance in the community.

5. CONCLUSION AND FUTURE WORK

Based on the results of the research conducted by the researchers, an initial design was obtained in the form of a smart farming system to control and monitor hydroponic plants using the Internet of Things (IoT). Hydroponic plants can be controlled and monitored with mobile applications to record plant nutritional conditions by measuring the pH of the water. It is possible to create more effective and efficient farming by applying IT to hydroponics farming. reducing some things to manual labor and replacing them with machines and systems to be able to measure hydroponic plant nutrition optimally. Thus, there will be a database that will store every record of the growth of hydroponic plant nutrition that can be seen from the farmers' mobile. And Every time something abnormal happens in the hydroponic plant, the farmer will get a notification through the application. Hopefully, this technology can facilitate and advance hydroponic farmers and attract many people to do agriculture.

The limitations contained in this study are only produces a design design related to monitoring and controlling in hydroponics plants. and has not entered the implementation stage. therefore, the next research that researchers will do to continue the current research is to implement all the results and designs of this research related to IoT sensors connected to the farmers' mobile phones. It is hoped that the design of this research will help farmers be able to create smart farming and make it easier for farmers to farm hydroponic plants.

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