E-agriculture of hydroponic farming with nutrient film technique (NFT) using internet of thing

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Abstract. Agriculture is one of the activities to produce food. Nowadays, farming is not only done on the ground on open land but can be done with the hydroponic method. Hydroponic technique is a technique of planting with water media that is given nutrients. One of the hydroponic techniques is Nutrient Film Technique. A key challenge in hydroponic farming is the continuous monitoring of environmental factors that affect plant growth. This will make it difficult for farmers because it is very dependent on human labor, especially large-scale hydroponic gardens. Therefore, hydroponic plant management requires a monitoring system that can help hydroponic farmers in their cultivation. This research develops an automated monitoring system using Internet of Things (IoT) technology to track temperature, light intensity, humidity, and water usage. This system aims to reduce manual labor and optimize plant growth conditions. If there are conditions that are not ideal, the system can give feedback to drive actuators such as fans, lights and water pumps. The devices used are sensors, arduino microcontroller, wifi modules and internet networks. The research employs a prototype model, utilizing UML for system design. The backend is developed using PHP with the Laravel framework, while MySQL is used for database management. The system is anticipated to enhance efficiency in hydroponic farming by automating environmental monitoring and control, thereby reducing reliance on manual labor and improving plant growth conditions. Additionally, the system features CCTV camera monitoring for real-time observation, as well as tools for generating harvest reports, tool usage reports, and nutritional data.

1 Introduction

With the world population projected to reach 9.1 billion by 2050, food production will need to increase by 25% to 70% to meet rising demand. This requires a change from traditional farming methods to modern farming by utilizing technology and information (ICT). ICT enhances farm management across various stages, from soil preparation and planting to pest control, irrigation, and harvesting, ultimately boosting agricultural productivity [1- 3]. ICT in agriculture or e-agriculture is a subset of agricultural technology that focuses on improving information and communication processes. According to definition of FAO, E-agriculture is emerging field in the intersection of agricultural informatics, agricultural development and entrepreneurship, referring to agricultural services, technology dissemination, and information delivered or enhanced through the Internet and related technologies [1].

Conventional farming using soil media is affected by land availability, weather changes, natural disasters, water availability, and soil fertility which is decreasing due to the use of chemicals such as fertilizers and pesticides. Hydroponic planting is one type of planting other than conventional methods with soil. Hydroponic planting does not use soil media but by utilizing water [4] [5] The important thing in hydroponics is the fulfillment of nutritional mineral needs from water. Based on research conducted by Emergen Research in 2022 the global hydroponics market size was valued at $2.56 billion in 2021 and is expected to expand at a compounded annual growth rate (CAGR) of 19.2% from 2022 to 2030. Meanwhile, in Indonesia, according to knowledge sourcing intelligence, Indonesia indoor farming (hydroponic, aeroponic, soil based, hybrid) market is estimated to grow at a CAGR of 6.40% to reach US$71.399 million in 2028 from US$46.247 million in 2021.

Hydroponic systems offer several advantages, including faster crop growth, year-round production, reduced disease and pest incidence, and minimal weeding [6] . They also provide better temperature control, reduced water loss, and protection from weather fluctuations [7] . Notably, hydroponic systems can save up to 70–80% of water [8]. Because it does not use soil media, this method can reduce soil-borne diseases. Some of the disadvantages of hydroponic systems are the continuous monitoring of temperature and water, dependence on electrical power, and the need to keep the system running [9] and higher costs especially if large-scale.

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There are several hydroponic growing techniques, namely drip system, Ebb and flow, nutrient film technique (NFT), deep water culture, aeroponic, and wick system [10]. In addition, hydroponic systems can also be a combination of several techniques. The basic principle of the NFT hydroponic system is to flow nutrients to plant roots with a shallow and circulating nutrient layer so that plants get enough water, nutrients, and oxygen. The advantages of hydroponics with the NFT system are edequate water system, the use of nutrients becomes more optimal and accurate because nutrient volumes are calculated periodically [11]. Schematic diagram of NFT hydroponic is shown in Fig 1.

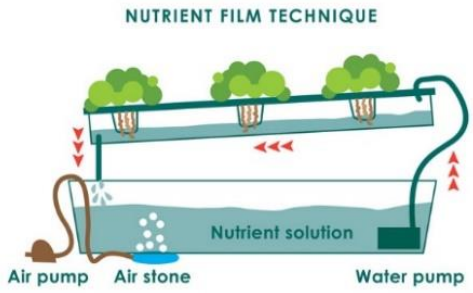

Fig. 1. Schematic diagram of NFT hydroponic.

Conventional farming generally uses open land. The use of open land requires good soil quality, rich in nutrients and free from pests that must always be maintained from planting to harvesting. But with the occurrence of environmental changes or unpredictable weather changes will affect the results of agricultural production. To overcome these problems, one of them can use a greenhouse. A greenhouse is a building where plants are grown that has a translucent roof and wall structure. Greenhouse are usually made of glass or plastic. In a greenhouse, environmental factors such as temperature, light intensity and humidity can be controlled or manipulated to produce optimal factors for planting. Managing greenhouse properly will result in faster and more production [12] In addition, it requires less land compared to conventional agriculture, is suitable for resource-constrained areas and is not affected by climate change because it is indoors, uses less water and resources, has less environmental impact due to excessive use of fertilizers and pesticides.

In the cultivation of NFT hydroponic plants in greenhouses, there are monitoring problems, especially if there is no tool as a monitoring media to control environmental factors that affect plant growth in greenhouses. The traditional monitoring system for greenhouse is labor intensive and time consuming [13]. Monitoring of plants, temperature, water, nutrients, and light intensity, will make it difficult for hydroponic plant farmers if it is still done by human labor manually controlling these factors [14]. If there is an error or delay in monitoring, it will disrupt the quality of the plants which can result in crop failure. This will certainly be detrimental to farmers. Therefore, quick and accurate information is needed about the environmental conditions in the greenhouse to avoid unwanted things such as lack of water or nutrients. Slow information makes decision-making inappropriate. Hydroponic plant management requires a monitoring system that can help hydroponic farmers in carrying out their cultivation, one of the technologies currently developing is using the Internet of Things (IoT).

The Internet of Things (IoT) refers to a network of interconnected devices, including sensors and electronic devices, that communicate independently through the internet. Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals. The goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path/network and any service [15]. IOT can be applied to various fields such as manufacturing, transportation, retail, health, agriculture and others [16] . IoT in agriculture and farming focus is on automating all the aspects of farming and agricultural methods to make the process more efficient and effective [17] , lead the quality improvement of corps dan increasing productivity [18]. Some research on the utilization of IoT for hydroponic plants is monitoring PH, flow rate, nutrient concentration [19-20] and temperature [21-23] The use of an IoT monitoring system in hydroponic farming showed a growth rate effectiveness [24] and grow better [19],[22] than traditional method.

The research contribution is to develop an e-agriculture solution for hydroponic vegetable cultivation using the Nutrient Film Technique (NFT) and IoT technology. With the use of IoT, it can facilitate the monitoring of temperature, humidity, water usage and lighting continuously and automatically. In addition, the system made can be used to record plants, the use of nutrients and crop yields and facilitate the process of monitoring planting blocks so that it becomes more effective and efficient.

2 Research method

The development method used in this research is the prototype method according to Pressman [25]. Protoype model is shown in Fig 2.

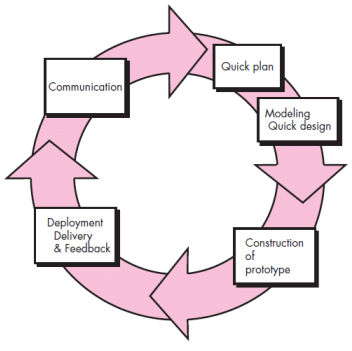

Fig. 2. Prototype model [25].

There are five stages in the method, namely:

a. Communication

In the Communication stage, issues in hydroponic management are identified through interviews, discussions, and observations. This stage aims to thoroughly understand the needs and challenges faced by hydroponic farmers to ensure that the final product addresses these requirements effectively.

b. Quick plan

During the Quick Plan stage, the system's functional and non-functional requirements are collected and analyzed. This includes identifying necessary hardware (e.g., sensors and microcontrollers), software components, and user requirements. A detailed plan is created to guide the development process.

c. Modeling quick design

In the Modeling Quick Design stage, rapid creation of analysis and design models occurs. This involves developing system diagrams and UML models (such as use cases, activity diagrams, class diagrams, and deployment diagrams) to ensure a unified understanding of the system's architecture and functionalities. Architectural design, database schema, and user interface design are also developed during this stage.

d. Construction of prototype

In the Construction of Prototype stage, the monitoring system prototype is developed based on the design models from the previous stage. The system is implemented using PHP and Laravel framework for backend development, and XAMPP for managing the PHP and MySQL database.

e. Deployment, delivery and feedback

During the Deployment, Delivery, and Feedback stage, the prototype undergoes rigorous testing and evaluation to ensure it meets the specified requirements. Feedback from users is collected to identify any issues or areas for improvement. If necessary, iterations are made based on feedback to refine the system. Once the system is deemed satisfactory, it is finalized and deployed as a complete product.

3 Result and discussion

3.1 System modeling

3.1.1 Use case diagram

The use case diagram illustrates the interactions between different actors and the system. The primary actors are the user (e.g., greenhouse manager) and the Arduino microcontroller. The diagram outlines the various functions each actor performs, such as monitoring and managing the greenhouse. Users can monitor the greenhouse, manage crops, do reporting and monitor security cameras. Meanwhile, the microcontroller monitors humidity, temperature, light intensity and water volume in the reservoir. The use case diagram of the system to be created is shown in Fig 3.

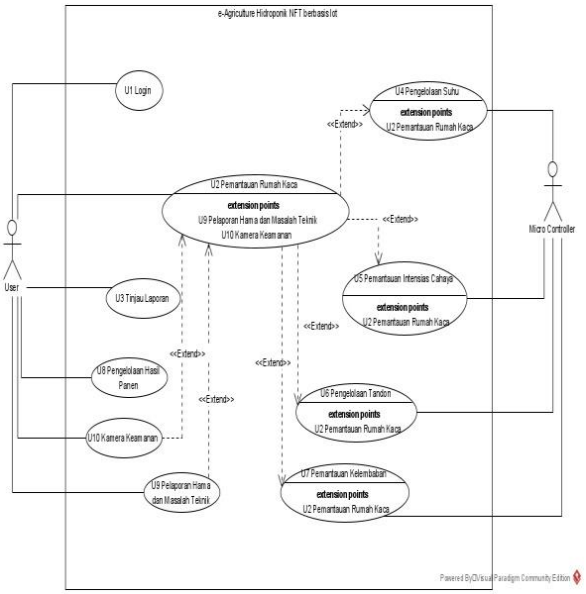

Fig. 3. Use case diagram.

3.1.2 Swimlane diagram

The swimlane diagram in Fig. 4 details the processes involved in greenhouse monitoring. It shows the responsibilities of the person in charge, including activating or deactivating the greenhouse and managing multiple greenhouses. The diagram helps in understanding the workflow and interactions within the system.

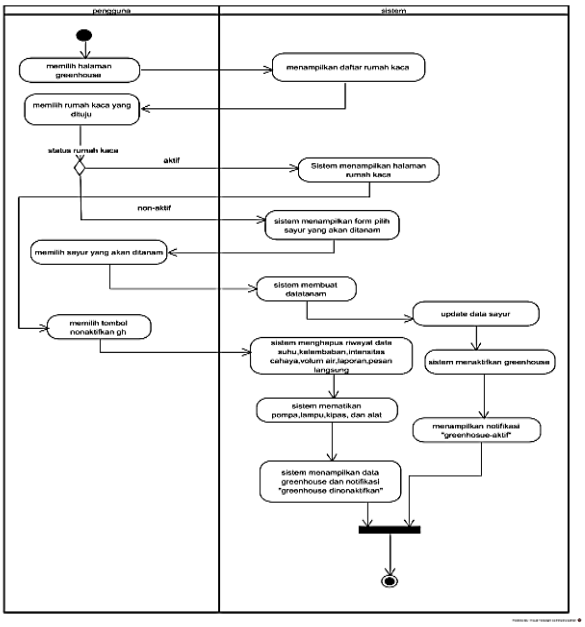

Fig. 4. Greenhouse monitoring swimlane diagram.

The temperature sensor will detect the temperature of the green house room and then send it to the monitoring system through the Ardui The system will compare whether the temperature exceeds the limit. If it exceeds the set temperature limit, the system sends data back to the arduino to drive the fan. Temperature management swimlane diagram shown in Fig 5.

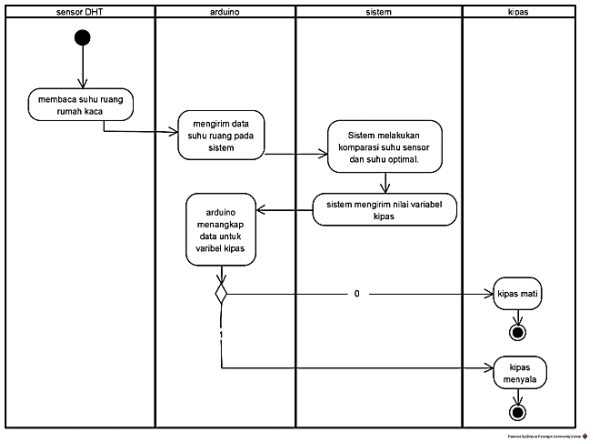

Fig. 5. Temperature management swimlane diagram.

3.1.3 Class diagram

The Class Diagram as shown in Fig. 6 visually represents the various classes within the E-Agriculture Hydroponic NFT IoT system. It includes 21 interconnected classes, each with specific attributes and methods. This diagram serves as a blueprint for translating the system model into programming code, ensuring that all components interact as intended.

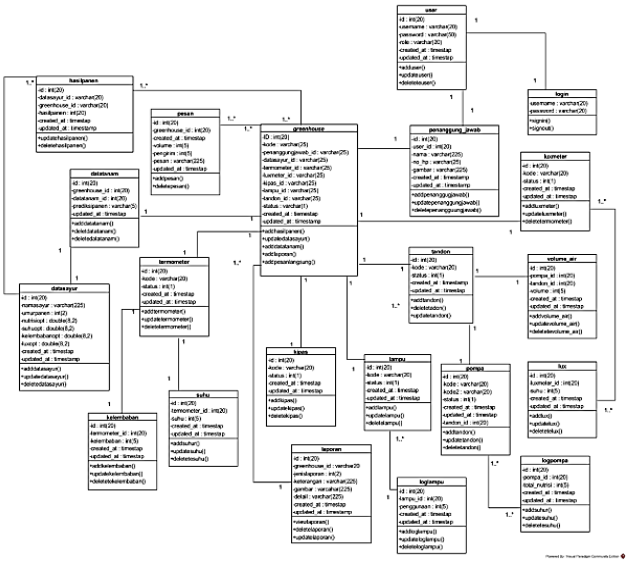

Fig. 6. Class diagram.

3.1.4 Deployment diagram

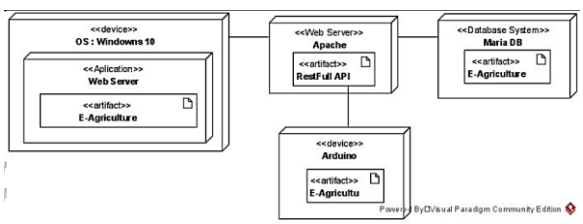

Fig.7. Deployment diagram.

The Deployment Diagram as shown in Fig. 7 depicts the infrastructure components of the e-agriculture system, including web servers, database systems, and various devices. This diagram is crucial for understanding how different elements of the system are distributed and interact within the network.

3.2 System block diagram

The System Block Diagram as shown in Fig. 8 illustrates the architecture of the IoT system for NFT hydroponics, divided into three main blocks: input, process, and output. The input block includes sensors for measuring humidity, temperature, light intensity, and water volume. Data from these sensors are processed by the microcontroller in the process block. Based on the data, actuators are activated to maintain optimal conditions. The processed information is then stored in a database and presented through the monitoring system in the output block. Table 1 outlines the ideal conditions for the greenhouse, specifying the value limits for temperature, light intensity, water volume, and humidity. The table also indicates the status and corresponding actuator actions required to maintain these conditions. The information or data will also be sent via the internet network to be stored in the database and then the information is presented in the monitoring system in the output block.

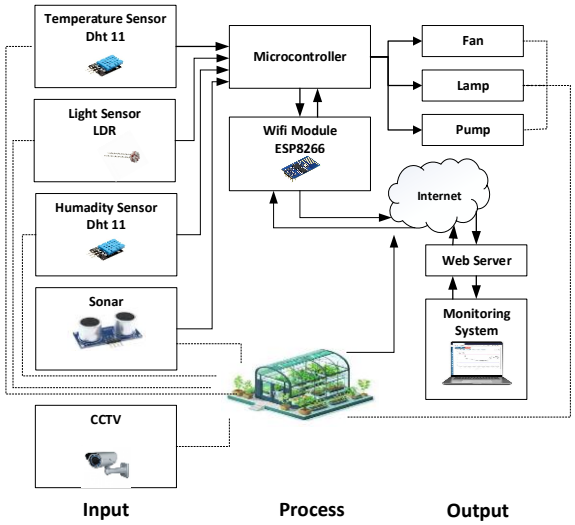

Fig. 8. The block diagram for the IoT system for NFT hydroponics.

Table 1. Scenario monitoring for green house.

Element	Value limit	Status	Actuator
Temperature	< 34 ºC	enough	fan off
	≥ 34 ºC	too hot	fan on
Light intensity	> 87 lux	enough	lamp off
	≤ 87 lux	less light	lamp on
Volume water	100%	optimal	pump off
	< 100%	not optimal	pump on
Humidity	≥ 89%	optimal	
	<89%	not optimal	

3.3 Interface implementation

The Interface Implementation section provides screenshots and descriptions of the system's user interface. Fig. 9 shows the dashboard page, which appears upon user login and includes menu options for greenhouse management, CCTV, reports, and master data. Subsequent figures (Figs. 10-15) display various pages such as the greenhouse list page, detail condition page, temperature details page, fan usage page, and harvest page. Each page is designed to provide specific information and facilitate efficient management of the greenhouse.

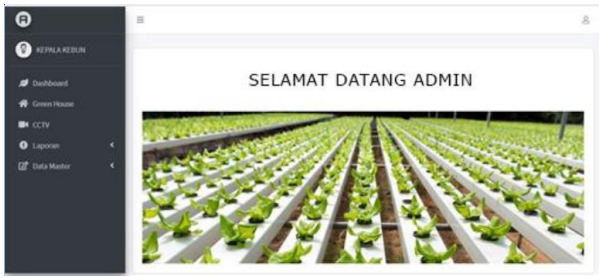

Fig. 9. Dashbord page.

On the greenhouse list page, several greenhouses are displayed. If the green house is active or is being planted with vegetables, the display is green while if the green house is not active, it is red as shown in Fig 10.

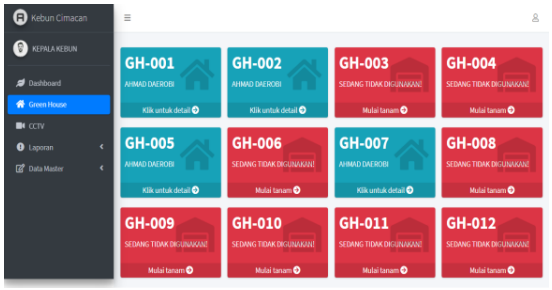

Fig. 10. Greenhouses list page.

The greenhouse detail condition page is the page that is displayed when the user selects the active greenhouse. This page is shown in Fig 11. Information will be displayed about temperature, humidity, reservoir volume, light intensity, fan and lamp status, types of vegetables grown and planting predictions. In addition, a video from CCTV is displayed.

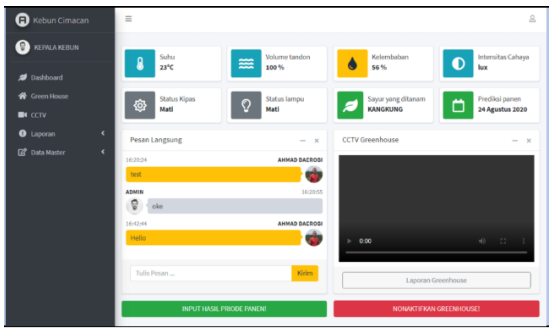

Fig. 11. Greenhouse detail condition page.

On the temperature details page, the temperature status during the green house is displayed as shown in Fig 12.

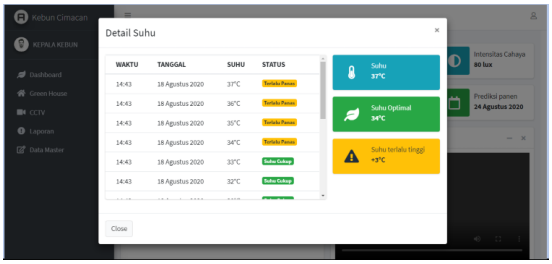

Fig. 12. Greenhouse detail temperature page.

The fan usage page displays the time and duration of fan usage when active, as shown in Fig 13.

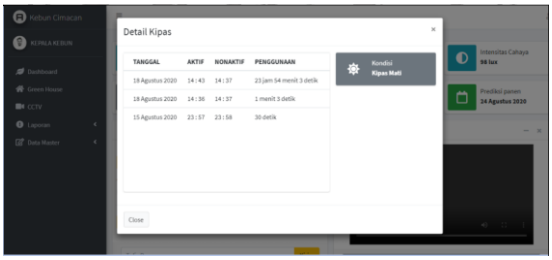

Fig. 13. Greenhouse fan usage page.

The harvest page displays the harvested vegetables from the green house. Harvest page is shown in Fig 14.

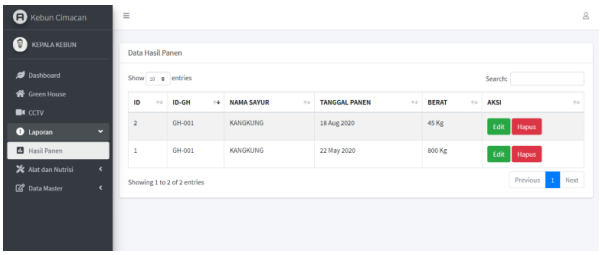

Fig. 14. Harvest page.

To find out the total lamp usage for each month, can be seen on the lamp usage report page. Fan usage report page is shown in Fig 15.

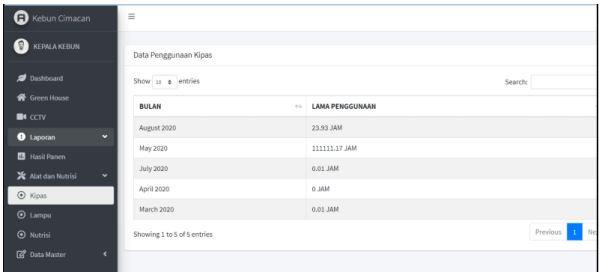

Fig. 15. Fan usage report page.

4 Conclusion

IoT-based NFT Hydroponic E-Agriculture is an application used for greenhouse monitoring and control. The IoT-based NFT Hydroponic E-Agriculture system streamlines the monitoring and control of temperature,

humidity, light intensity, and water volume within the greenhouse. Automation of these processes enhances efficiency and accuracy. In addition, this system can determine the condition of plants, the use of nutrients and data collection of crop yields. This system significantly accelerates the monitoring of planting blocks, improves efficiency, and reduces the likelihood of errors. By automating these processes, it supports more precise and reliable management of greenhouse conditions.

While the system offers substantial improvements in greenhouse management, future research could explore potential limitations, such as system scalability, integration with other agricultural technologies, and cost-effectiveness. Additionally, ongoing development could focus on enhancing system adaptability to various types of crops and environmental conditions.

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