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The Implementation of Internet of Things (IoT) for Aquaponic Cultivation

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Abstract. *Aquaponic is a plant cultivation technique that is widely used by farmers and today's communities due to its efficiency and ability to increase the agricultural productivity. The aquaponic cultivation in general still uses simple systems, such as manually feeding the fish by spreading the feed at predetermined times, monitoring water pH using a pH meter and monitoring water height or level through measurements, requiring farmers to spend time and special labor to care for and maintain plants and fish. Therefore, a solution is needed in the form of a system that can monitor and control plants and fish conditions automatically and continuously for 24 hours. The system should have the ability to control and monitor feeding activities, water pH, water and environmental temperature, water level and environmental humidity. The system in question is the internet of things (IoT) system that can be used as a tool for automatic control and monitoring through an application. The IoT system consists of several sensors that are connected to a microcontroller which can measure water pH, temperature, water level and environmental humidity. The data obtained by the sensor will be sent to a server via Wi-Fi protocol and stored in a database. The system is equipped with a web application that can be accessed through a computer device. The application provides a visual display of data: time, water pH, temperature, water level and environmental humidity, making it easier for farmers to monitor aquaponic conditions from a distance without having to come to the land. Through the implementation of IoT in aquaponic cultivation, farmers can increase efficiency and agricultural productivity by reducing the time, labor and costs required for control and monitoring.*

Keywords: *Aquaponic Cultivation, Internet of Things, Sensors*

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INTRODUCTION

The Indonesian government is paying attention to food security and studying it carefully. In 2006, the Food Security Council was established to help the government maintain national food security (Regulation of the President of the Republic of Indonesia Number 83 of 2006 concerning the Food Security Council). Food security is defined as a situation where food meets household needs in sufficient quantity, safe, high quality, equitable and affordable (Law No. 7 of 1996 concerning Food). Food security is a condition where everyone's nutritional needs are met in quantity and quality so that they can live an active and healthy life in a sustainable manner in accordance with local culture [1]. Increasing population, decreasing agricultural land area, and food availability are associated with many factors that influence food security [2].

In urban areas, various agricultural methods have been used to overcome limited land and meet food needs, especially for daily needs in the fields of animal husbandry, freshwater fisheries, and horticulture [4], [5]. The term urban farming refers to agricultural practices in urban areas and covers the entire food production system [4], [5]. The urban farming method has proven to be effective. Aquaponic, which combines farming and cultivating freshwater fish, is one of the urban farming methods with great potential [8], [9]. Aquaponic can be applied to limited land, such as the yard. Therefore, it is very suitable for use in urban areas. Cultivators use the aquaponic cultivation method by combining various types of plants and freshwater fish. These include catfish and kale [10], gourami with mustard greens and kale [2], and gourami with salad [9]. Some of the advantages of the aquaponic method include greater production, less land and nutrient use, easier pest, and disease control, and because the food is organic the vegetables and fish are healthier. Compared to farming using soil or water, aquaponic cultivation really requires a controlled

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environment and requires more maintenance. To get optimal harvest results, feed must be given regularly, and control the pH, environmental temperature, water level and humidity.

Therefore, the solution needed is a system that can automatically and continuously monitor the condition of plants and fish throughout the day. This system must have the ability to control and monitor feeding activities, water pH, temperature, water level and environmental humidity. Internet of Things (IoT) systems are systems that are connected to each other through internet network connectivity, software, embedded sensors, and other electronic devices needed to collect and transmit data to objects around them [10]. IoT has been used in various sectors of life, such as health [11], [12], [13], [14], agriculture and agribusiness [10], [15], [16], [17], [18], [19], [20], [21], field of agriculture [22], [23] , field of education [9] .

The main objective of this research is to design IoT for aquaponic cultivation which can control and monitor the condition of plants and fish automatically. The IoT system consists of several sensors connected to a microcontroller, including pH sensors, temperature sensors, sensors for measuring water levels, and environmental humidity sensors. The data obtained by the sensor will be sent to a server via Wi-Fi protocol and stored in a database. The system is equipped with a web application that can be accessed via a computer device. The application provides a visual display of data: clock, water pH, temperature, water level and environmental humidity, making it easier for farmers to monitor aquaponic conditions remotely without having to come to the field. Through the implementation of IoT in aquaponic cultivation, farmers can increase agricultural efficiency and productivity by reducing the time, labour and costs required for control and monitoring.

METHODS

In general, the research stages related to the design and construction of IoT-based aquaponic cultivation systems are as follows:

2.1 Needs Analysis

At the needs analysis stage, the action taken is to collect data through literature research. The aim is to collect basic theories, general references, and specific references, as well as additional information about how to create and implement Internet of Things systems that meet farmers' needs. Requirements analysis consists of functional and non-functional requirements analysis. Functional requirements analysis analyzes the functions that an IoT system can perform. Non-functional requirements analysis analyzes things that are not related to system function, such as choosing the software and hardware used.

2.2 IoT System Design

The IoT system design stage is formulated:

1. Overall system hardware design, which includes the IoT system architecture, each subsystem is designed thoroughly including the microcontroller and control system.
2. Software design for monitoring applications.

2.3 IoT System Implementation

The IoT system implementation process consists of hardware and software implementation stages. The hardware implementation stage includes sensor and microcontroller circuit design. The software implementation stage includes database design, flow diagrams, interface design, and program logic design that will be used to run the IoT monitoring system on the computer.

2.4 Testing

To ensure that each series of sensors works well, the testing stage is carried out through modular and complete circuit testing. Each circuit will be tested separately before combining software and hardware to form the desired IoT system. After that, system performance will be tested again.

RESULT AND DISCUSSION

3.1 Needs Analysis

At this stage, what is done is to formulate the needs for IoT system development, namely functional needs, and non-functional needs. Functional requirements analysis is an analysis of the functions that can be performed by an IoT system. The results of the analysis of the functional requirements of the IoT system are presented in Table 1.

Table 1. Functional Requirements

No	Functional Requirements
1	capable of displaying environmental temperature
2	capable of displaying humidity
3	able to display the water level
4	able to display the pH of water
5	able to display air temperature
6	capable of displaying sensor time
7	IoT system performance is running well
8	The system can store and send sensor data
9	The system can communicate between the microcontroller and the web
10	The system can connect to the internet

Meanwhile, non-functional requirements analysis is analysis that is not related to system function, such as selecting the hardware and software used. In Table 2 the equipment used is presented.

Table 2. Research Tools

No	Tools	No	Tools
1	Arduino uno	11	Power cable
2	16x2 lcd module	12	Rainbow jumper cables
3	RTC 1302	13	1K Ohm resistor
4	Transformer 2A	14	PCB
5	Diodes 1A	15	Potentio
6	6 IC 7812	16	Tin
7	Transistors 2N2055	17	Bolt
8	12V relays	18	Box
9	Transistors D313	19	Water pump
10	Switch	20	Computers

3.2 IoT System Design

At the design stage, an IoT system architecture design is produced, a design for how the hardware works, and a design for how the software works.

3.2.1 IoT System Architecture

In Figure 1, the IoT system architecture design is presented. Based on the IoT architecture in Figure 1, it can be explained how the system works as follows:

The IoT system works using 5 sensors, namely the DHT11 sensor, Vernier pH sensor, RTC DS3231 sensor, water level sensor and DS18B20 water temperature sensor. The dht11 sensor is used to measure the temperature and humidity of the air around the aquaponic growing room. The data produced by the dht11 sensor is in the form of analog data, namely data in the form of voltage. The voltage obtained will be processed and processed by the Arduino Uno microcontroller so that the data can be displayed in the form of temperature and humidity. Vernier pH sensors are used to detect the pH value of the water contained in the pool. The data produced by the pH sensor is in the form of voltage, then the data is processed and processed by the Arduino Uno microcontroller so that the data is displayed in the form of a pH value. If the detected pH is less than the pH standard determined for the plant, the Arduino will instruct the relay to turn on the pump to add liquid so that the pH condition is stable. The RTC sensor is used as a sensor to detect real time and will be used as a time indicator for scheduling hydroponic plant irrigation. If the scheduled time matches real time, Arduino will instruct you to turn on the relay to water. The water level sensor is used to detect water level based on the voltage polarization produced. This data will be sent to the Arduino microcontroller for processing. The ds18b20 sensor is used as a sensor to detect the temperature in the water. The data generated from the sensor is in the form of voltage which will then be processed by the Arduino Uno microcontroller to be displayed as finished data in the form of temperature data. All data generated by each sensor will be processed and processed by the Arduino Uno microcontroller so that valid data is obtained, then the existing data will be sent to a database that has been hosted via an ethernet shield that has been connected to an access point that has internet access, so that the data can be accessed. from wherever and whenever.

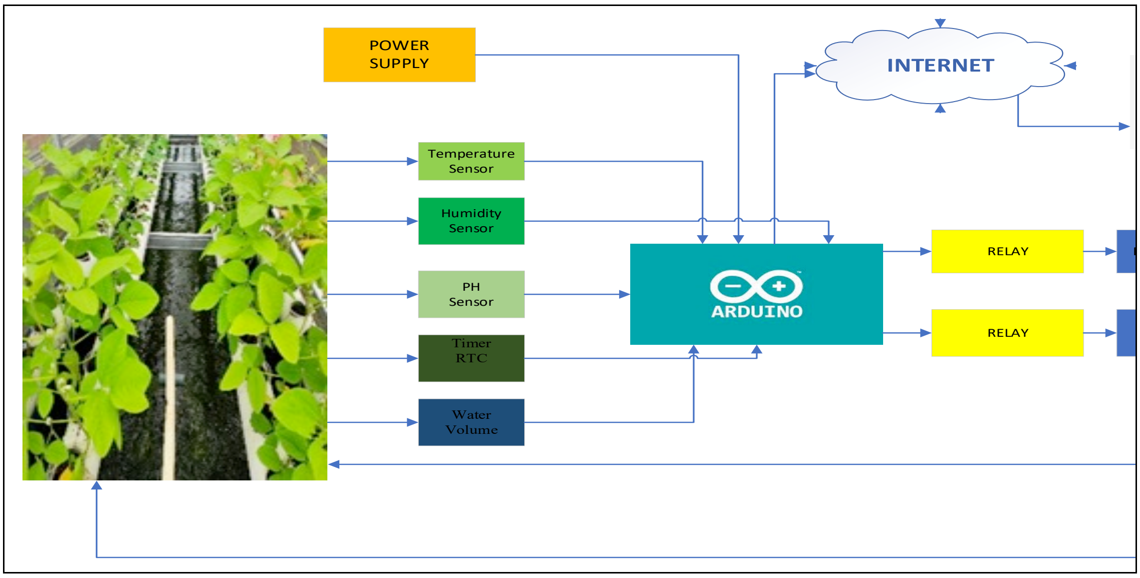

Figure 1. Aquaponic Cultivation IoT Architecture.

3.2.2 How the Software Works

Software device works is presented in Figure 2.

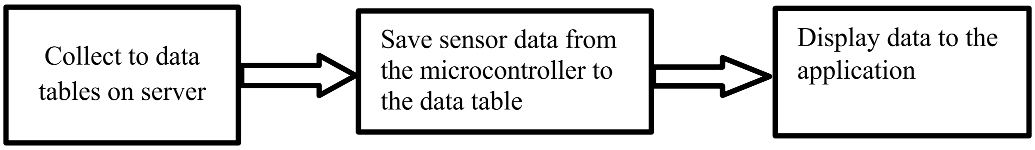

Figure 2. How Software Tools Work.

Software device works when connected to the internet, starting by connecting to a data table on the server. Next, the sensor data collected from the microcontroller device will be read and stored in the data table on the server. The data is then displayed in the application in real time.

3.2.3 How Hardware Devices Work

How the IoT system hardware devices work is presented in the form of a flowchart in Figure 3.

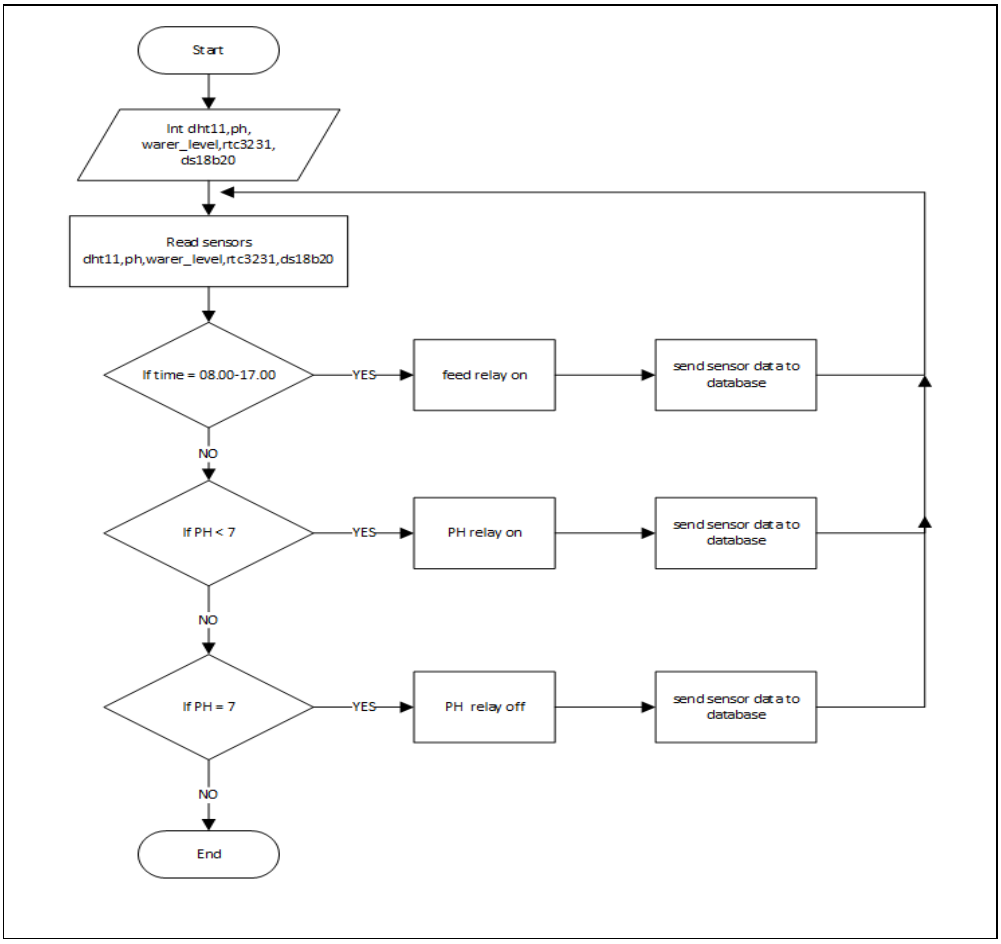

Figure 3. Flowchart of How Hardware Devices Work.

The flowchart explanation for how hardware devices work is:

1. Start the program.
2. Initialize the ports used by Arduino.
3. Read data from dht11, pH, water level, RTC, and ds18b20 sensors.
4. Enter the first condition, namely if the time shows 08.00 or 17.00 then relay1 will be ON and the fish feeding pump will turn on.
5. If the pH value is <7 then relay2 will be ON and the pH pump will turn on to add liquid to increase the pH of the water stable.
6. If pH = 7 then relay2 will be OFF so the pH pump will stop.
7. Data from each sensor will be sent to a hosted database.
8. Instructions will always loop or repeat.
9. Finish.

3.3 IoT System Implementation

IoT system implementation consists of implementing a series of hardware and software. The following is the explanation.

3.3.1 Hardware Circuit

Hardware circuit consists of a series of pH sensors, water temperature sensors, environmental temperature sensors, humidity sensors, and water level sensors.

3.3.1.1 pH Sensor Circuit

In Figure 4, a pH sensor circuit is presented.

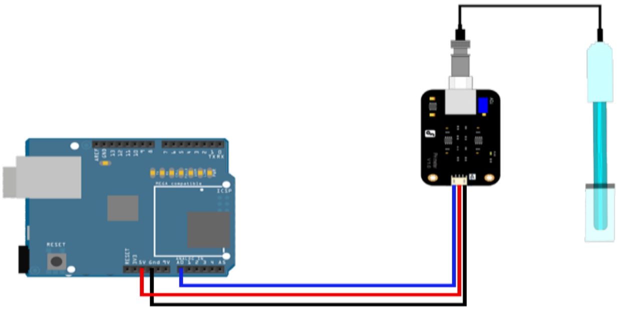

Figure 4. pH Sensor Circuit.

3.3.1.2 Water Temperature Sensor Circuit and Environmental Temperature Sensor

In Figure 5, a water temperature sensor circuit is presented.

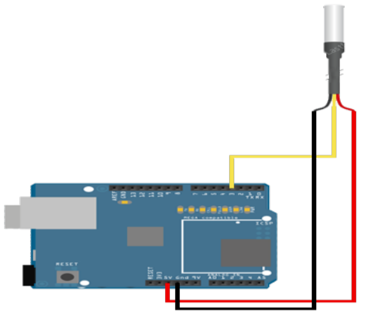

Figure 5. Water Temperature Sensor Circuit.

3.3.1.3 Humidity Sensor Circuit

In Figure 6 a humidity sensor circuit is presented.

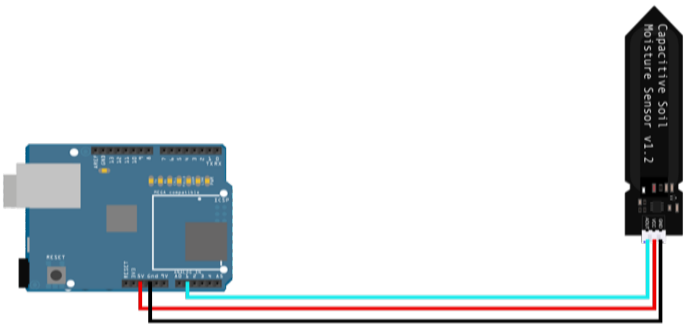

Figure 6. Humidity Sensor Circuit.

3.3.1.4 Water Level Sensor Circuit

In Figure 7, a water level sensor circuit is presented.

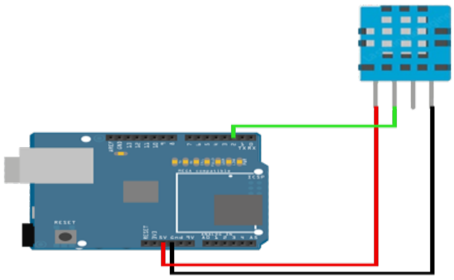

Figure 7. Water Level Sensor Circuit.

3.3.1.5 Overall Circuit

In Figure 8 the entire sensor circuit is presented.

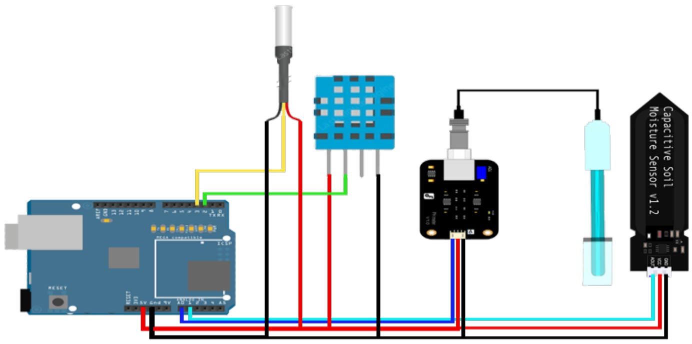

Figure 8. Overall Circuit.

3.3.1.6 Overall Hardware Set

In Figure 9, the overall circuit that has been produced is presented.

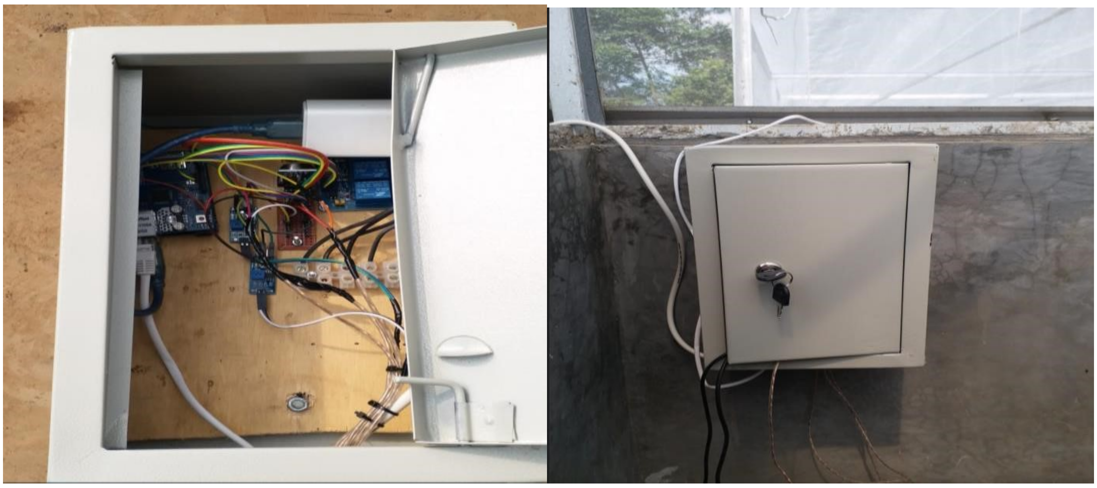

Figure 9. Physical Appearance of the Hardware Circuit.

3.3.2 Software Design

In Figure 10, the monitoring system software dashboard is presented.

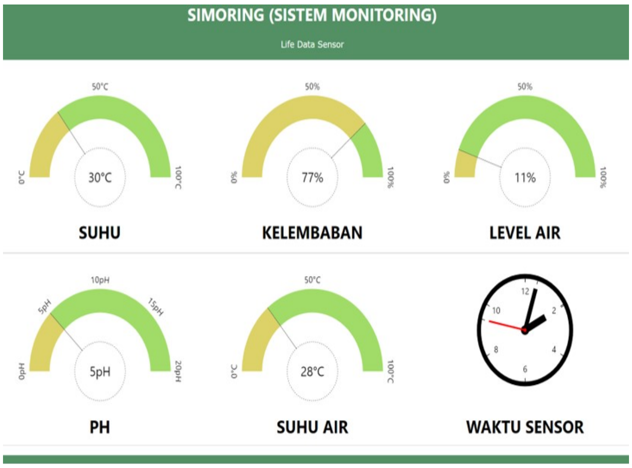

Figure 10. Dashboard Monitoring System.

3.4 Testing

IoT system testing is carried out on the hardware and software devices that have been produced. The hardware device is tested for connectivity to the internet. The results are presented in Table 3.

Table 3. Connectivity Testing Scenarios

No	Scenario	Results	Observation	Information
1	Connect	Can connect	Can respond to the Orders given	In accordance
2	Not connected	Not connected	Not responding orders given	In accordance

On software devices, testing is carried out using the black box testing method. The results are presented in Table 4.

Table 4. Monitoring System Test Scenario

No	Scenario	Observation	Information
1	The system can display environmental temperature values	Come on stage	Succeed
2	The system can display the humidity value	Come on stage	Succeed
3	The system can display the water level value	Come on stage	Succeed
4	The system can display pH temperature values	Come on stage	Succeed
5	The system can display time values	Come on stage	Succeed

CONCLUSION

Based on the research that has been carried out, it can be concluded that IoT has been successfully implemented for aquaponic cultivation. The IoT system can be used to collect data from various installed sensors such as pH sensors, environmental temperature and water temperature sensors, water level sensors, and humidity sensors. The collected sensor data can be displayed visually in the monitoring or Simoring application.

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