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Aquaponics Environment and Water Quality Parameter Analysis

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Abstract: This work develops a distributed environmental monitoring system for aquaponics based on the internet of things technology, which mainly includes the information IoT device layer, the information transmission layer and the system architecture. The system has employed multiple sensors terminal to real-time acquisition, including air and water temperatures, dissolved oxygen, ammonia, etc. Modbus-RTU RS485 protocol is suitable for sending big data and the 4G data logger was employed to collect data and send to the cloud platform. JavaScript is used for background applications, to access cloud platforms and local data processing. Based on the collection and processing of environmental data and cloud service platform, Grafana dashboard have been developed to control the environment and visualize. It has been implemented and tested in Unisel, Basteri Jaya for 3 months in 2022. The results showed the proposed monitoring system stability for overall operation and accuracy data transmission, which can support the actual aquaponics production management. After analysis of monitoring data collected from the developed monitoring system, indoor air temperature and indoor light have the strong negative correlation with humidity (-0.97 and -0.81) and finally, total dissolved solids and water salinity have a substantial correlation with electrical conductivity (1.0 and 1.0) respectively.

Keywords: Aquaponics, Greenhouse Environment, Internet of Thing, Monitoring System

1. Introduction

Traditional aquaculture has encountered resource consumption and environmental pollution problems (Bergland et al., 2020), thus many researchers have investigated the mechanisms of aquaponics restoration, as well as the continuous improvement of the breeding model focused on water quality (Pedersen & Wik, 2020). Cleaner aquaponics (Taha et al., 2022) in greenhouses are becoming increasingly common in modern agriculture. Because the stability of the environment has a direct impact on production, it is necessary to investigate a stable monitoring system in order to observe the breeding environment.

Due to the deployment of modern information and communication technologies, high intelligent monitoring technology has been obtained in agricultural systems in recent years. ZigBee has indicated the integration of communication capabilities to sensors (Zhang et al., 2022), allowing them to track environmental conditions in real time. To determine the water quality parameters, (Vasdravanidis et al., 2022) used a multi-point sample device and an Internet of Things sensor system. Detailed research of the temporal and spatial changes in light intensity and feeding amount of dissolved oxygen in the aquaponics system, with an emphasis on the dissolved oxygen parameter, is being conducted. (Cruz et al., 2019) created a sophisticated water quality assessment and control system to meet the low automation and complex management of aquaponics. However, no other environmental parameter is involved in this investigation. (Wu et al., 2022), for example, emphasised on the advancement of agricultural Internet of Things technologies in aquaponics. (Herrmann et al., 2020) created an intelligent aquaponics system that includes automatic data collecting, recording, analysis, and control.

For hydroponics (Lee & Wang, 2020), an IoT monitoring system based on the cloud was proposed, which could measure water temperature, water level, dissolved oxygen, and water temperature. Furthermore, three infrared distance sensors of varying heights are put on the tank glass to monitor fish group behaviours. (Witzel et al., 2019) suggested a management execution system (MES) solution for integrated hydroponic production system control and regulation.

(Tolentino et al., 2019) demonstrated an Internet of Things (IoT)-based monitoring and automatic correction system for a hydroponic system built in a temperature-controlled greenhouse. The system primarily collects real-time data monitoring from the light intensity sensor as well as the air temperature and humidity sensor. The pH and temperature of the system's circulating water and plant canopy were monitored. The pH and TDS levels in fish water will alter as the fish grows. (Riansyah et al., 2020) developed a monitoring system to detect them and achieve automatic feeding based on fish demand and time scheduling. (Menon, 2020), in order to tackle the mentioned challenges in traditional hydroponics, proposed a technology solution that employs wire-less sensors and a communication network with GUI applications.

The aquaponics monitoring system has been extensively researched, with key studies focusing on numerous environmental parameters. Taking into account the lack of research on multi-environment parameter systems in aquaponics greenhouses, this work designed and implemented an aquaponics monitoring system based on a distributed environmental monitoring system, collecting data from sensors embedded in the water and indoor climate and sending it to a database via RS485-Modbus-RTU to achieve real-time monitoring. Unlike current designs of aquaponics monitoring systems, the suggested system with many sensors has been successfully applied in production.

This article is arranged as follows. Materials and methods were first presented; then, the proposed monitoring system verification and stability test was presented; subsequently the proposed monitoring system management and maintenance were described; finally, the investigation of aquaponics environment performance in this article was carried out; and finally, conclusions were drawn.

2. Materials and Methods

2.1 Establishment of efficient real-time monitoring and control system for aquaponics in greenhouse

The aquaponics management system is primarily concerned with real-time monitoring and management. The Internet of Things technology was used to improve the performance of the management system, including real-time environmental monitoring, remote control, over-limit alarm, video monitoring, and other functions for planting, which greatly reduced labour intensity, saved management costs, and improved production efficiency.

Plant growth environment, fish growth, water quality, and indoor climate are all examples of demonstration sites. The monitoring system must maintain the three sections' dependability, practicability, and accuracy. The aquaponics system was installed at Unisel, Basteri Jaya Campus, and it included a fish tank symbiosis system and a vertical plant symbiosis system. Figure 1 shows the layout of the site.

Figure 1. Aquaponics in Unisel, Basteri Jaya Campus (Selangor Center of Research on Sustainable Agriculture - SCORSA)

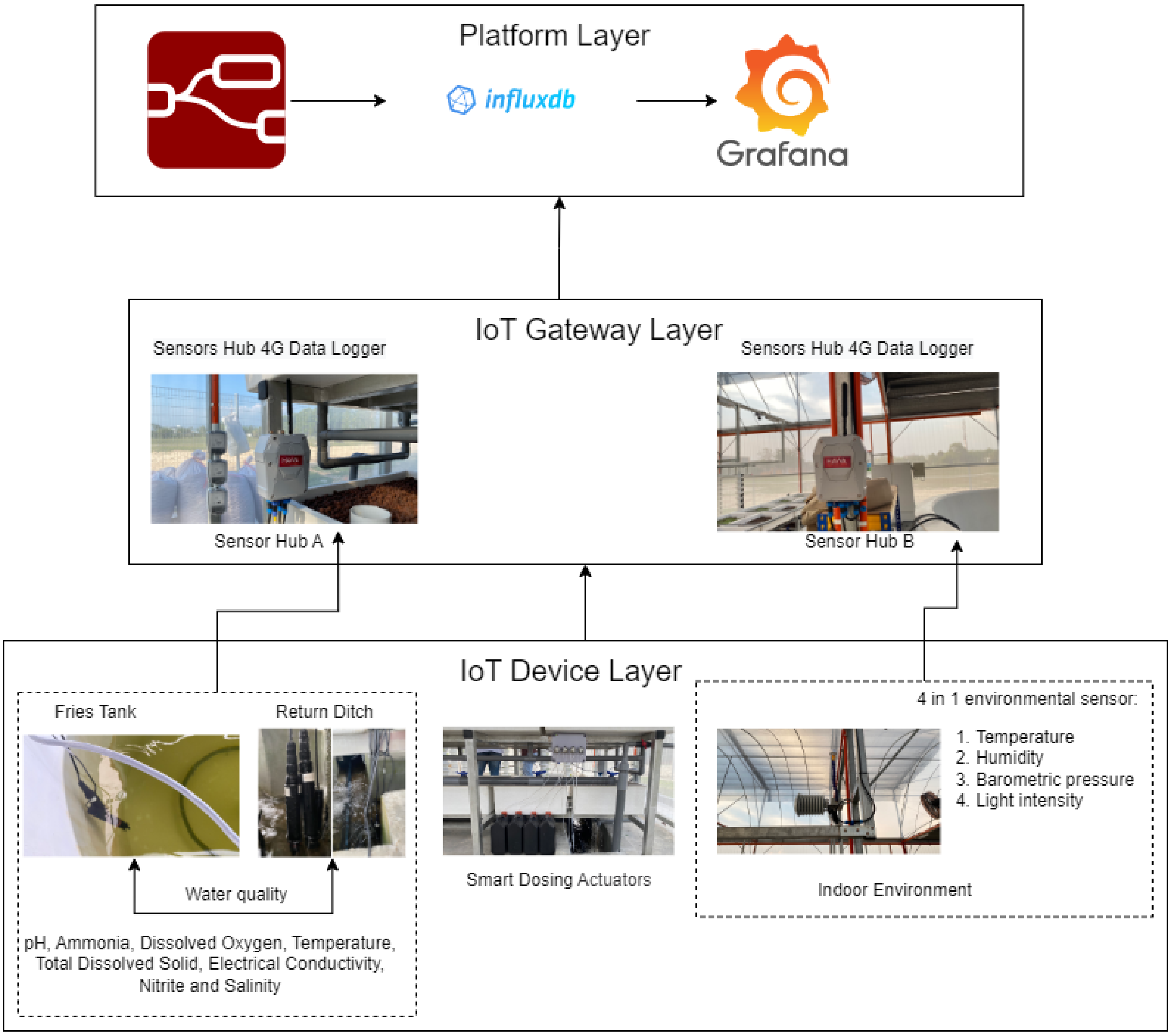

Figure 2. Monitoring system for aquaponics in greenhouse

Given the variety of environmental elements, it is required to establish an appropriate system for implementing changes in the growth environment of fish and vegetables. The aquaponics environmental monitoring system was divided into three sections: fish and vegetable monitoring, greenhouse microclimate monitoring, and outdoor monitoring. Meanwhile, as indicated in Fig. 2, the monitoring system was divided into three layers: device layer, gateway layer, and platform layer. The specifics are as follows:

IoT Device Layer: It mainly includes water quality monitoring sensors, weather monitoring sensors and on-site sensor networks. The Realtime data collected on-site is transmitted upwards through the use of RS485 and Modbus-RTU communication methods.

IoT Gateway Layer: the data from the first layer, which will be sent to cloud platform though the 4G network, MQTT was employed to send the data to the cloud. Meanwhile the date from the IoT Device Layer was also shown on the Grafana dashboard.

Platform Layer: the function of application layer is data pre-processing and forward it to user. It could not only monitor the data on the platform but complete data storage and dynamic display.

The functions of the monitoring system include:

1. Real-time monitoring the water quality in aquaponics system such as Dissolved oxygen and water temperature and so on monitoring sensors.
2. Real-time monitoring the indoor temperature, humidity, light intensity and barometric pressure.

2.2 Hardware platform and IoT architecture

2.2.1 Hardware equipment selection

As the frame, the solution presented in this paper of the monitoring system hardware equipment, from bottom to top, mainly covers on-site water quality monitoring parameters, weather monitoring parameters and Modbus-RTU network equipment. IoT communication technologies are employed to connect sensors and server. The investment cost of the system is completely within the scope of farmers' acceptance, according to the requirements of hardware equipment for product durability, simple operation principle, reasonable price, and convenient purchase, the system uses as many general equipment as possible. Table 1 Brief introduction of sensor component parameters.

Table 1. Brief introduction of sensor component parameters.

Equipment	Quantity	Description
4G sensor hub	2	Modbus-RTU RS485
4 In 1 Environmental Sensor	1	Solid Performance: High reliability, superior stability, and ultra-low power consumption
pH Sensor	2	Operating Temperature: -40 °C ~ 85 °C IP Rating: IP65 Device Weight: 400g Range: 0 ~ 14 pH Accuracy ± 0.1 pH Resolution 0.01 pH
EC & TDS Sensor	1	Temperature Measurement: Range: -40~80°C Resolution: 0.1°C Accuracy: ±0.5°C
Ammonia Sensor	1	Range: 0~1000mg/L

		Accuracy: ±10% or ±2mg/L whichever is greater Resolution: 0.1mg/L
Dissolved Oxygen Sensor	1	Device Weight: 400g Measurement Method: Fluorescence Range: 0~20.00mg/L(0~200%, 25°C) Accuracy: ±2%F.S., ±0.3°C Resolution: 0.01mg/L, 0.1°C
Nitrite Sensor	1	Operating Temperature: 0 °C ~ 40 °C IP Rating: IP68 Device Weight: 400g Range: 0.02~1000mg/L Accuracy: ±2% 25°C Resolution: 0.01mg/L

3. Result and Discussion

Water quality parameters and environment parameters were monitored based on the data collected. The sensor collected data every 2 min, and the period of September 2022 to November 2022 data is selected as the sample to analyse the continuity of the system. As showed in the Fig. 3, the data did not fluctuate abnormally. During stage of production, the system can maintain continuity. Namely, sensors and communication devices could not experience instability such as disconnection.

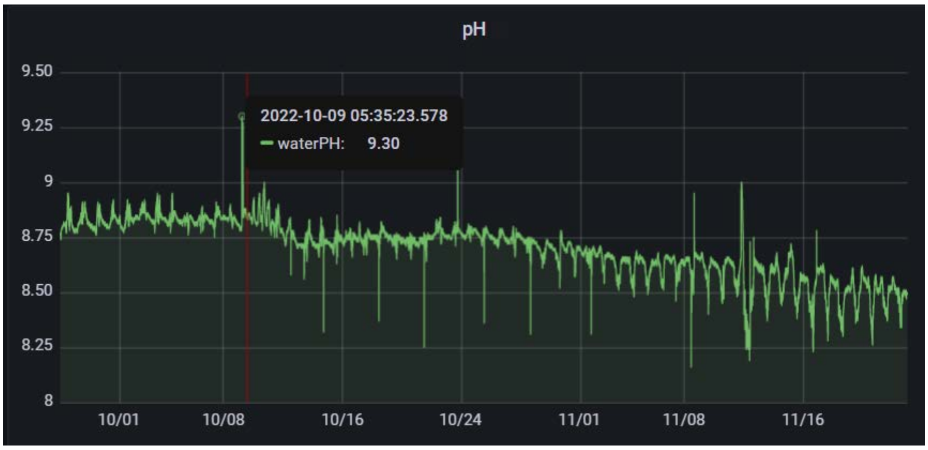

Figure 3. pH monitoring collection from September 2022 to November 2022

3.1 Investigation of aquaponics environment and water quality parameters

Energy has become increasingly valuable in greenhouse production, limiting the development of aquaponics in greenhouses, and temperature is a major influence in actuator energy use. The behaviour of microbes, fish, and plants in the system is directly affected by water and air temperature. We examine interior air temperature and water temperature using historical data collected during system operation (see Fig. 4). The above temperature metrics have comparable trends and seasonality. Indoor air temperature drops more slowly. Furthermore, the aquaponics water temperature has persistence when compared to the indoor air temperature.

Similarly, in Fig. 5, indoor air humidity is compared to air temperature, light intensity, as well as other factors. A direct correlation between these characteristics can be discovered. As seen in Fig. 6, indoor air humidity has a negative correlation with light (-0.81) and air temperature (-0.97). Meanwhile, total dissolved solids (1.0) and water salinity (1.0) have a substantial correlation with electrical conductivity. It means that multivariate historical data can be utilised to model and predict future air or water temperatures, among many other things. It could also guide smarter thermal environment control, thermal energy storage, and energy-saving measures. Furthermore, based on the aforementioned results, a novel growth comfort index as a function of combining indoor air temperature and humidity, Ammonia level in water was proposed and used to evaluate the plant crop growth level for this project. It is a comprehensive indicator used to determine whether the existing environment can create a comfortable microclimate for greenhouse crops. It also fluctuates according to the various crop growth environment requirements.

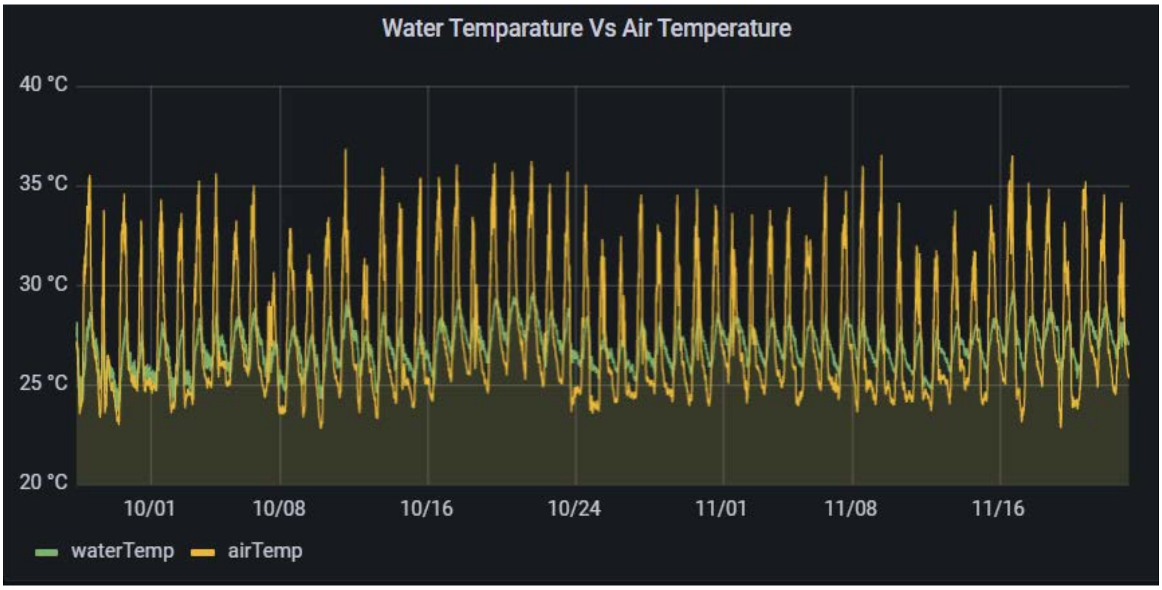

Figure 4. pH monitoring collection from September 2022 to November 2022

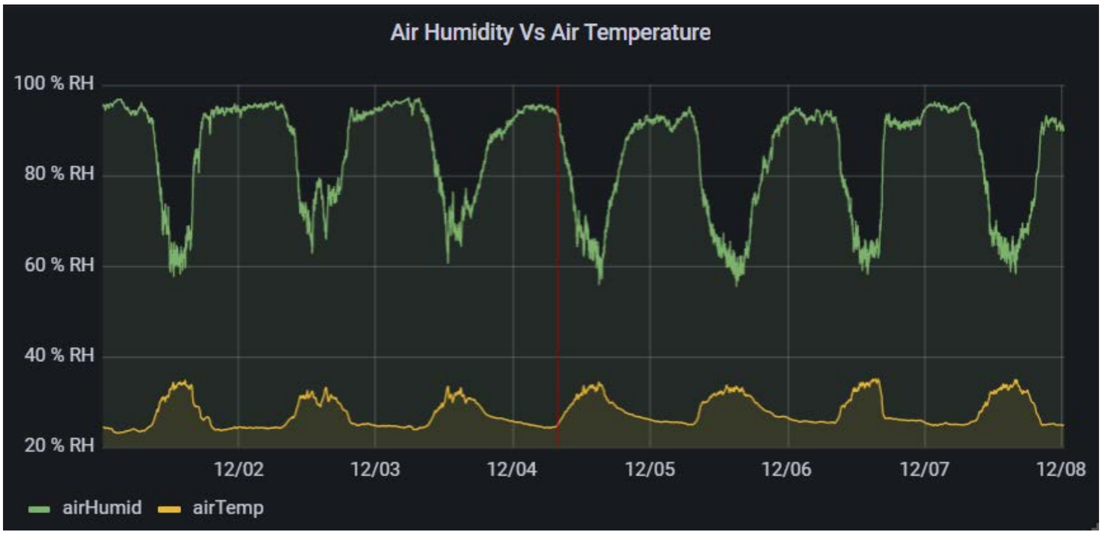

Figure 5. Comparison of indoor air humidity and temperature

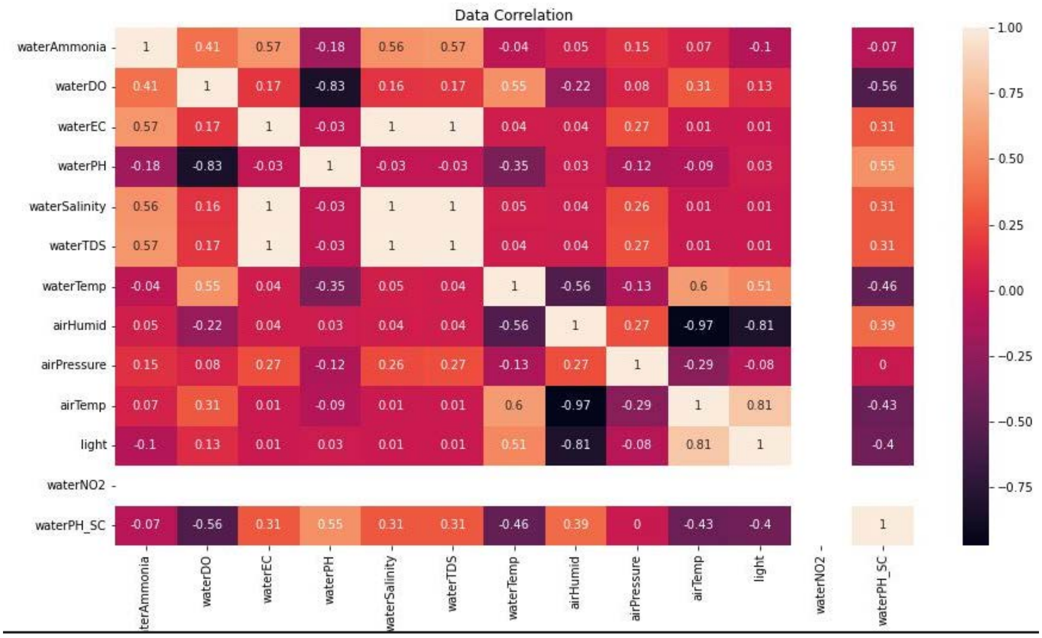

Figure 5. Heatmap correlation between water quality and indoor environment parameters

4. Conclusion

It is very significant to monitor the real-time environment of aquaponics due to fish and plant requiring the suitable growth environment. An environmental monitoring system was developed and implemented by the distributed sensor monitoring and wireless sensor networking which realizes the indoor environment and breeding all weather monitoring function of greenhouse environment and water environment. The system was helpful to continuously collect date from water quality environment, aquaponics environment. In addition, the historical database is constructed to help scientific management. The system has a simple operation interface and a high degree of visualization which uses Grafana as dashboard to understand the greenhouse environment in real time.

The proposed monitoring system could provide relevant technical support for aquaponics in greenhouse, which is conducive to the transformation and upgrading of the aquaculture and hydroponic industry. After analysis of monitoring data collected from the developed monitoring system, indoor air humid have the obvious correlation with air temperature (-0.97) and water salinity have strong correlation with water electric conductivity (1.0).

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