Smart Automation Aquaponics Monitoring System

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Abstract—**Modern agriculture, such as aquaponics, has become a well-known solution nowadays for farming, especially in Asia countries. It provides an alternative to support food demands and maintain environmental sustainability. However, it requires manpower and time to maintain and monitor the system. This research proposes a smart automation aquaponic monitoring system that helps users maintain and monitor the system through smartphone applications. The system uses DHT11 to record temperature and humidity, HC-SR04 for water level, and FC-28 to maintain soil moisture. The sensors are integrated with WeMos D1 Wi-Fi Uno based ESP8266 microcontroller to process the data. The data collected is stored in the cloud and retrieved via the Blynk application, which also performs as an actuator and allows users to control the parameters involved. The application helps to monitor the humidity, temperature, and water level in the fish tank and control the actuator for feeding fish. The system also sends a notification to the user for any activities performed, such as watering plants, feeding fish, and abnormality of temperature in the surroundings. The performance of the system was evaluated using regression modeling. The result indicates positive growth for both plants and fish during the monitoring duration, suggesting the proposed system's effectiveness. Overall, this solution helps to reduce manpower and operation costs as well as alternatives for food demand and stabilize environmental sustainability, especially in the urban residency.**

Keywords— **Monitoring system; automation; aquaponics; IoT.**

I. INTRODUCTION

Food security and supply have been a global concern in urban and rural development areas. Researchers worldwide have begun discussing different aspects of food security issues [1]–[4]. The agricultural land supplies have decreased as the growth population increased [5]. In Malaysia, the decrease in the economy in several agriculture sectors has affected the performance of Malaysia's Gross Domestic Product (GDP) performance, resulting in a decrease of 5.6% in 2020 [6]. The growing concern for a healthy and reliable food supply requires the need for new methods of agriculture. Conventional farming methods require field area, long term, and manpower to harvest the crops [7]. Automated agriculture system has been widely promoted to overcome the limitation of conventional farming [8]–[12]. Aquaponics is one of the famous urban farming systems for plants' growth and aqua lives [13]–[16]. The use of aquaponics can be seen as one of the appropriate options for better food safety and biodiversity [17], [18].

Aquaponic can be defined as a mix of the aquatic environment and the agriculture of plants, and a fish and a plant can be positioned in an iterative process which would then produce a symbiotic relationship between them [19]. The connection in the system is important as components of the system such as water, aquatic species, bacteria, nitrogen cycles, and plants that thrive together throughout the rivers can be found not only in the environment but also in nature.

The main factor in the process is to draw on the advantages and eliminate the complexity of both the two substances in aquaculture and hydroponics. The faces produced by the fish become nutrients for the plants after nitrification [20]. Fig. 1 shows the diagram of an aquaponics system. Many aquaponics monitoring systems were built for smart agriculture for plantations, excluding fish farming. The nutrient film technique is a famous method implemented in aquaponics systems [21]. However, for IoT-based systems, the notification alert to the farmers is still lacking. It is designed to control and monitor the automation of the system, which requires minimal space to be developed inside a building or on the rooftop.
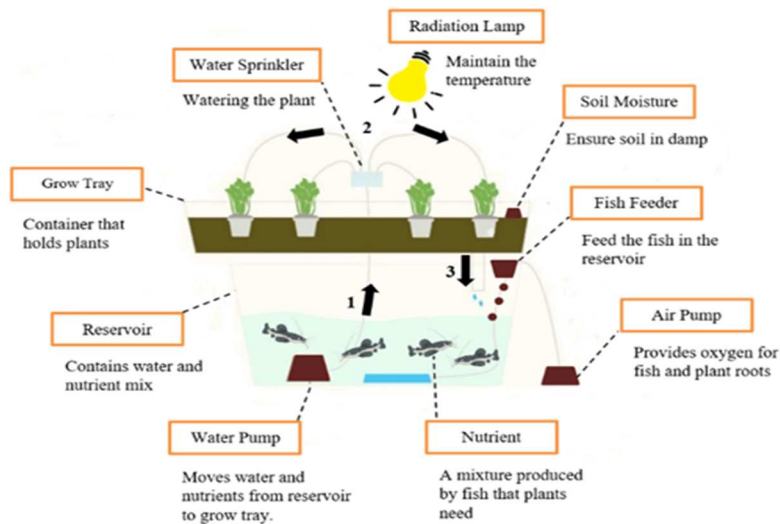
Fig. 1 Aquaponic system

An aquaponic system uses a microcontroller for receiving and sending data from integrated sensor devices. Internet of Things (IoT) application for aquaponic creates automatic self-control systems integrated with wireless sensor networks (WSN) [22]. By developing an IoT-based monitoring system, the smartphone communicates with the system as a device to acknowledge the farmer or user based on IoT. This method has proven effective in other domains that require urgent feedback or notification [23], [24]. Hence, the aquaponic system's automation integrated with smartphones can help farmers make prompt and precise decisions.

A considerable amount of literature has been published on automatic aquaponic systems. In 2020, a smart and sustainable home aquaponic system was developed to resolve the issue of food security that has been recurring for years in Singapore [25]. This project was designed for a home-based environment aquaponic system to encourage local citizens to produce their own food. This solution may help to reduce the food demand of the country. From the positive review, this farming method saves a lot of land space and encourages the citizen in economic support. Recent research has also reviewed hydroponic and aquaculture as integrated aquaponics systems in various aspects [26].

An aquaponic system can also be designed to be integrated with the web monitoring system. The hardware system can be synchronized with the web to visualize data from the system and store the data on internet cloud storage. This method allows basic data monitoring and possible future data performance analysis or aquaponic prediction as applied in other domains [27].

A previous study that implements ESP8266-based Arduino WeMos D1 Wi-Fi Uno microcontroller was carried out by Lee et al. The board was specially designed because it is computable with a Wi-Fi chip. This microcontroller's capability for constant two ways of communication. Information is fed to the microcontroller from the user interface, and the conditions are sent back to the user via an internet server under the name Blynk [28]. This research uses the report as a tool in the Blynk Apps. The report will save all the data of the inputs and outputs in the system. However, the system does not implement notification directly to the owner.

The designated users need to open the apps to know the operation of their aquaponics system.

This paper aims at the effect of IoT-based monitoring systems on plantation and fish farming effectiveness by continuously collecting data from various types of sensors implanted in the system. The suggested system could also alert the user if there is an abnormal condition in the circulation system. It can also present the designated data via mobile applications Blynk Apps. The IoT-based technology function is to send messages to the user a notification that the process is completely done. In addition, it also functions as a signal to the system to operate processes such as feeding the fish.

II. MATERIALS AND METHOD

This section outlines the detailed methods and components used in the study. The content is divided into four subsections, i.e., (a) system architecture to outline the research components and (b) system flowchart detailing each process.

A. System Architectures

The system architecture provides a brief description of the microcontroller, input, and output of the structure connection of the system. Fig. 2 shows the block diagram of the automated monitoring system for aquaponics.
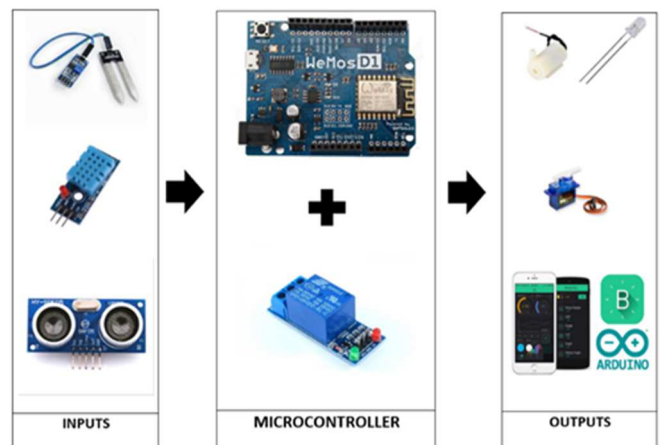

Fig. 2 System architecture

The automatic aquaponics monitoring system has been developed by combining several parts.

1) Input: The sensors are the inputs for the device, where the data will be constantly gathered from all the sensors. The temperature and humidity sensor (DHT11) measured the temperature and humidity of the surrounding environment. However, the soil moisture sensor (FC-28) was used to measure the dampness of the soil to enable the water pump as an actuator. An ultrasonic sensor (HC-SR04) was used to monitor the water level of the fish tank.

2) Microcontrollers: An ESP8266-based Arduino WeMos D1 Wi-Fi Uno consists of a Wi-Fi module. Arduino Wemos D1 with 11 digital input/output pins that act as the system's central processing where it is used to attach input and output sections. Furthermore, the relay board will allow Wemos D1 to operate the output components by turning the associated electronics components on and off. The ESP8266 Wi-Fi module, installed on Wemos D1, allows connectivity between the smartphone and Wemos D1 via the home router. Then, section 2 consists of a one-way relay which is a component to allow the switching circuit. The relay triggered 3.3V when the Wemos D1 sent a signal from digital input I/O to activate the relay for the switching circuit.

3) Output: This processing segment consists of 2 parts, the actuators and the mobile phone app (Blynk application). The first section is the actuator, where the operating system decides that the actuator can be enabled or disabled based on information acquired by the inputs. The lamp will serve as a warmer for the plant while there is a low temperature in the environment. LED deployed in the project as a Radiation lamp. The water pump functions to pump the water from the fish tank to the water sprinkler. Servo motor works as a fish feeder to consume the fish food. The second segment is the Blynk application which can be used because it is easy to install, user-friendly, and can view notifications in real-time. This application can be easily accessible by people of all ages and downloaded free of charge from the Playstore or the Appstore. This application may allow users to control the device quickly.

4) Type of fish and plant: This project specifies and focuses on catfish as the prospect which is famous for the famous aquaculture in Malaysia. Catfish is commonly used for fish farming because it is fast-growing and suitable for a warm climate. Catfish only needed to be fed twice a day for the first month, and for the second month was once per day. Furthermore, catfish can survive in cloudy water for long period, and the farmers can change the water in the fish tank once in two weeks.

The most suitable plant for this project is a salad. The salad was chosen as a prospect because it has the best requirement to be planted. Salad can survive in warm temperatures and also has a fast-growing rate. Plus, salad is highly in demand in the market and is also the best vegetable in cooking. This project focuses on home farming which can be harvested by the owner and used salad and catfish as their food.

B. System Flowchart

A flowchart is a type of diagram that describes the mechanism or breakdown of the system. The flowchart may also describe a step-by-step guide to the challenge as a diagrammatic representation of an algorithm. In this segment, a separate process stage was seen in sequential order. This aquaponics automation monitoring system consists of two flowcharts of the system, a whole flowchart of the aquaponic monitoring system workflow and the other is a flowchart of the configuration process. The aquaponic flowchart monitoring system manages the aquaponics system ecosystem by monitoring and regulating temperature, humidity, water level, fish feeder, and plant watering pumps. The other flowchart is the Wemos D1 configuration method. Configuration processing illustrates a series of network connection processes.

1) Flowchart of the aquaponic monitoring system: All the sensors involved will detect the variables in an aquaponics system. The sensor that used in this project are DHT11, HC-SR04, and FC-28. These data which have been obtained from the sensors will be received by the WeMos D1 Wi-Fi Uno Based ESP8266, these data will be sent to the Blynk application directly. The data collected in the cloud can be reached by the designated user through their cell phone via the Blynk application. The user can control all parameters and outputs obtained from the sensors. In addition, the Blynk application can also operate the actuator.

If there are changes in the surroundings, the sensors will sense the abnormal status and send the data to Arduino Wemos D1, and Wemos D1 will send the information to enable the actuators to maintain the surrounding area automatically. To monitor the temperature and provide light for the plant to undergo photosynthesis, the mechanism can automatically monitor the Radiation lamp. Furthermore, it also consists of a controlling actuator, the servo motor. The servo motor act as a fish feeder. This mechanical part was created to help the user feed the fish while the user is away from home. The flowchart in Fig. 3 describes how the system workflow.

2) Configuration Processing Flowchart: This process runs for a configuration process that illustrates a series of network connection processes, where there is a Wi-Fi configuration from Wemos D1. These processes included the generated coding from IDE software (Arduino software). It is also required to install the Wi-Fi module in the software to activate the Wi-Fi module inside the board. When the Wemos D1 network configuration is successful, then the next step is configuring a connection to the router, where the router is already connected to a smartphone; if all configuration has been successful, then the system is automatically connected to the device. If the process configuration is not successful, it is necessary to do the configuration process from the beginning. Whenever the Wemos D1 is already successfully connected, it will connect automatically for the next setup. Fig. 4 describes how the system workflow.
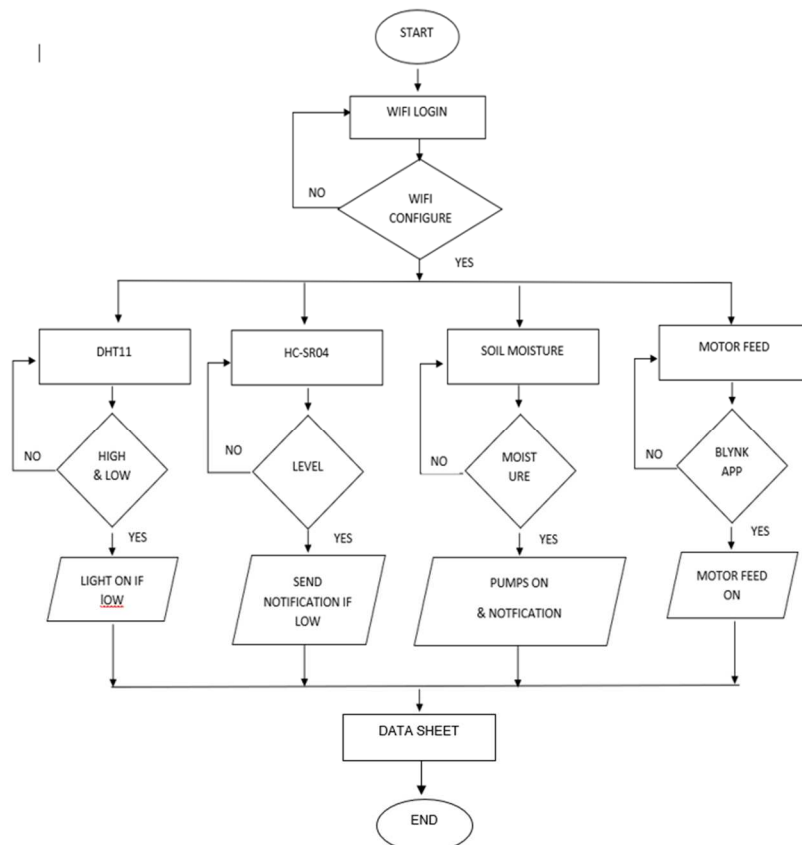
Fig. 3 Aquaponic monitoring flowchart

III. Result And Discussion

This section explains the outcomes and the actions to reach the goals.

A. Automation Aquaponic Monitoring System

The proposed automation aquaponic monitoring system, which is assisted with effective IoT inputs, outputs, and microprocessors for real-time monitoring, analyzing, and reporting catfish and salad in the aquaponic system, is shown in Fig. 5.

Once the device has been installed, and the system has been supplied with electricity, users can control the system using their mobile phone via an application called Blynk. Before the results and data were obtained from the Blynk application, this system was tested manually. To evaluate the performance of the smart automation aquaponic monitoring system, the system was operated for 31 days. The parameters shown in the Blynk application are the time and date, temperature reading, the water level in the fish tank, and the watering plant when the water pump starts watering grow tray containing plants. These measurements communicate between hardware servers and user interactions between the application interfaces. These components are running well with no errors in electrical conductivity. Through the physical measurements, the sensors are placed in the right position for measurements. Fig. 6 shows the hardware of the temperature and humidity sensor/module (DHT 11) that has been used for the prototype.
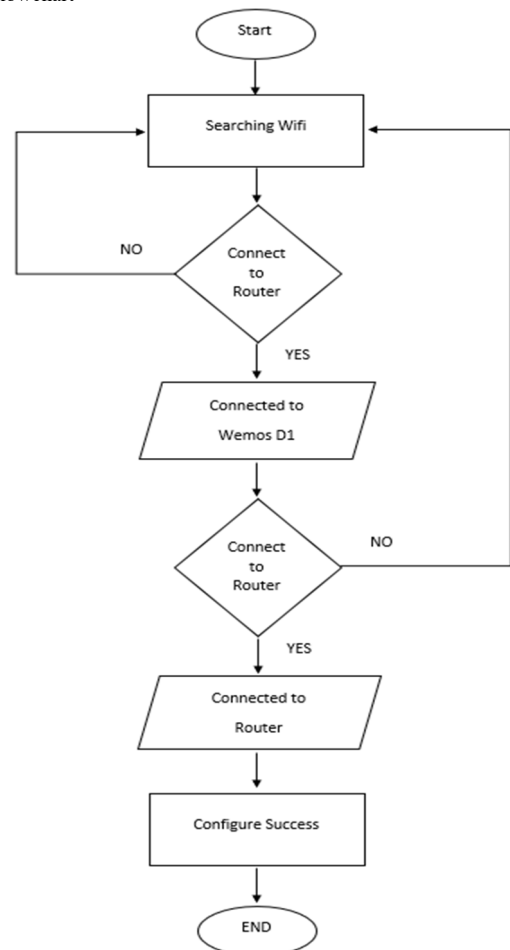

Fig. 4 Configuration processing flowchart

259

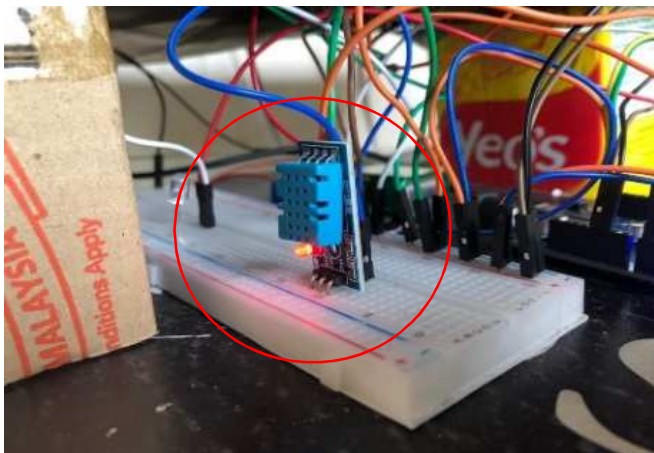Fig. 5 Prototype of the smart automation aquaponic monitoring system

Fig. 6 Temperature and humidity sensor/module (DHT 11)

The sensor that is applied to detect temperature and humidity is DHT11, where this sensor can detect both parameters in the system. The DHT11 sensor relates to Arduino Wemos D1 which is acts as a brain in the system, and the microprocessor will control the radiation lamp whether to switch on or off based on the data collected by the DHT11 sensor. Diode-led is used as a Radiation lamp. Table 1 shows the value of temperature and humidity of the surrounding aquaponic system.

TABLE I
VALUE OF TEMPERATURE, HUMIDITY, AND ACTION OF RADIATION LAMP

Parameter	Parameter Value						
Temperature (ºC)	28	29	30	31	32	33	34
Humidity (%)	70	65	60	50	55	50	45
Action of the Actuator	LED turn ON				LED turn OFF		

The actuator, which is the radiation light, is turned on and off to stabilize the temperature and humidity of the surrounding environment in a good state for plant growth. The

most suitable temperature for plant growth is between 31ºC and 34ºC, and the suitable humidity for vegetable growth is between 55% and 70%. However, adequate humidity between 50% and 60% is required for flowering development. The LED is turned on when the temperature is below 31ºC, or the humidity of the surrounding area is above 70%, and the LED is switched off when the temperature and humidity of the surrounding area are between 31 ºC and 34ºC and the humidity range is between 60% and 70%. Based on Fig. 7, the actuator can stabilize the temperature and humidity of the surrounding for the plant to grow healthy. Limit lines are shown for both parameters, which is the actuator start function. Plus, the Wemos D1 also generates a signal to send notification of time and date to the phone through the Blynk application as shown in Fig. 8.
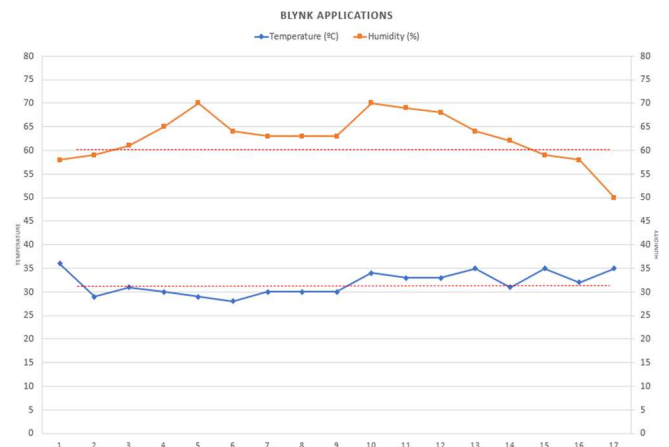

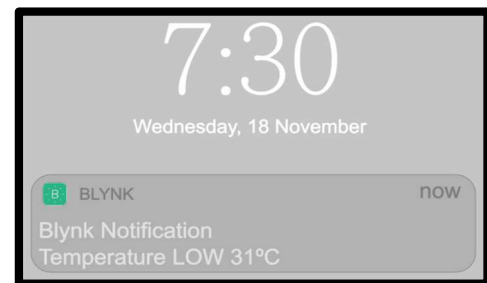Fig. 7 Temperature and humidity in Blynk application

Fig. 8 Notification for temperature

The next parameter for the aquaponics system is soil moisture sensors (FC-28) which it is set up at the grow tray to detect most of the soil. The moisture of the soil is measured by the reading received from the soil moisture sensor. The same method is applied to the soil moisture sensor, which functions as a soil detector and the water pump's actuator. Table 2 shows the soil reading and the actuator's action.

TABLE II
SENSOR READING AND SOIL CONDITION AND ACTION OF THE WATER PUMP

Parameter	Parameter Value and Condition		
Sensor Reading	0-610	610-970	971-1024
Soil Condition	Dry soil	Moist soil	Wet soil
Action of the Actuator	Water pump ON		Water pump OFF

The actuator is the water pump, a sink in the fish tank. The water pump started to pump the water to the water sprinkler when the value of FC-28 was lower than 1000. If the value exceeded 1000, the water pump would turn OFF to avoid the

plant overwatering. This measurement ensures the plant receives enough water and nutrients from the fish tank to keep the soil moist. All the watering activities were recorded, as shown in Fig. 9. The red line on the graph was performed to declare the growth of salad in this project for 31 days. The user also sent the notification when the aquaponic system started to water the plant, as shown in Fig. 10.
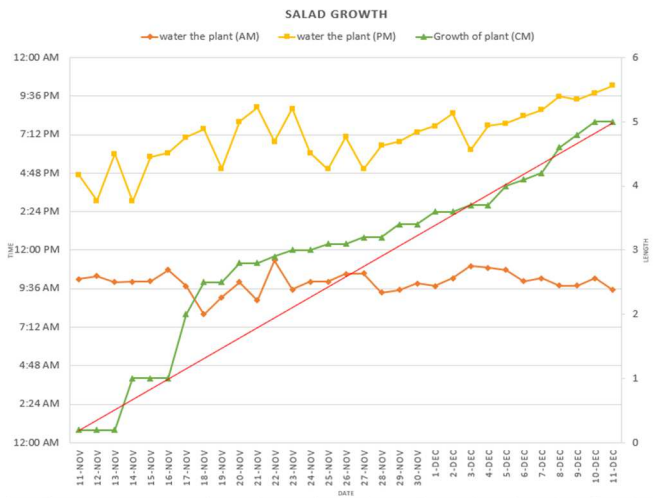

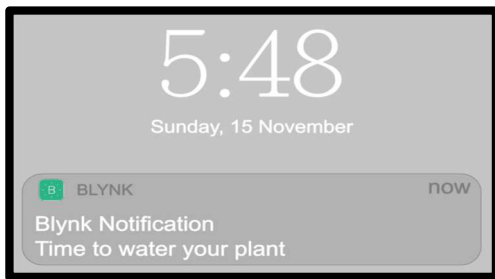Fig. 9 Watering activities for plant growth

Fig. 10 Notification for the watering plant

This prototype also uses the water level sensor (HC-SR04), an ultrasonic sensor, to detect the water depth in the fish tank. The sensor was placed at the top of the fish tank and faced directly to the water's surface. The sensor is set to 10cm long to trigger the Wemos D1. HC-SR04 functioned to trigger the signal when it did not detect the water surface in the range of 10cm. Then, it will send the signal to Wemos D1 and send a notification to the user through the Blynk Application. Fig. 11 shows the hardware of the ultrasonic sensor that has been used in the prototype. The notification is also sent to the user to alert them that the water level in the fish tank is low whenever the HC-SR04, as shown in Fig. 12.
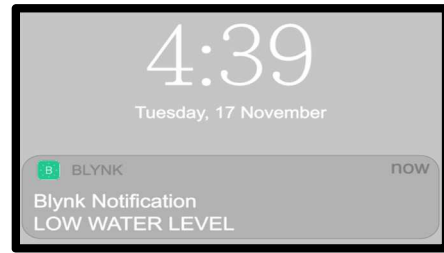

Fig. 11 Ultrasonic sensor/module (HC-SR04)

Fig. 12 Notification for low water level

The fish food was provided by a food feeder designed with a 5V servo motor and some other mechanical parts. The fish feeder is controlled by the user using the Blynk Application. It was designed with a control button in Blynk with a range of 0º to 180º. To feed the fish, the user needs to turn the button between 0º to 180º. The valve opens and closes depending on the angle of the servo motor turn. The fish food is given also depends on the user's angle needed. A larger angle will provide more food to the fish. All the feeding activities were recorded, as shown in Fig. 13. The red line on the graph was performed to declare catfish growth in this project for 31 days.
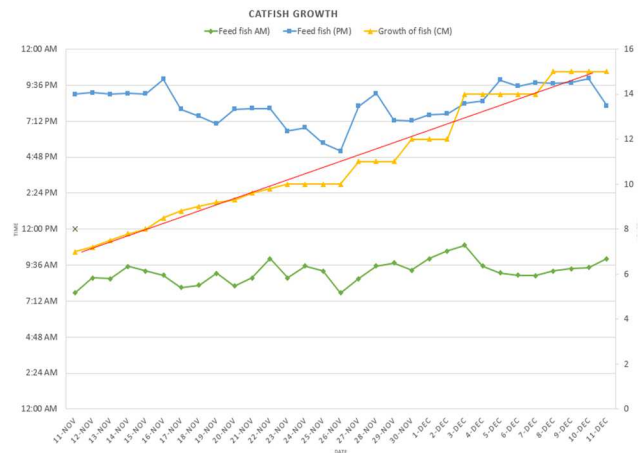

Fig. 13 Feeding activities for fish growth

The system's performance has been analyzed by measuring the growth correlation of the fish and salad with a given time. This evaluation method has also been used to measure another system's performance [29]. The growth of the catfish and the salads were recorded and showed that the aquaponic circulation grew well.

Linear regression analysis was performed to conduct and model the fish length(cm) and plant height(cm) over time, as shown in Fig. 14 and Fig. 15, respectively. The regression equation for fish growth is $YC= 0.2813x - 12409$, where YC signifies the length of the fish and x signifies the number of days with an R^2 completeness value of 0.9685. For plant growth, the regression equation is $YS = 0.1439x - 6352.3$, where YS denotes the plant height, and x denotes the number of days, with an R^2 value of 0.9087. R^2 values were explicitly similar to 1, which implies a strong match. To forecast fish and plant growth in the planned aquaponics method, these models may thus be implemented.
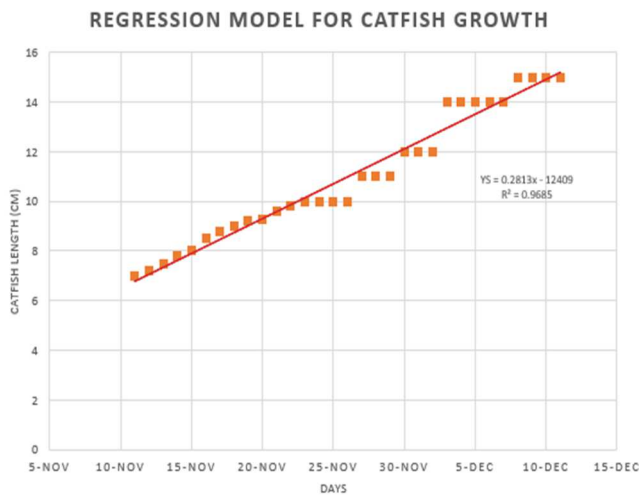
Fig. 14 Regression analysis model for catfish growth

Fig. 15 Regression analysis model for salad growth

B. Comparison with Previous Works

A few improvements have been done to produce an efficient and systematic system for aquaponics from the previous work studies. Table 3 compares with recent studies to make changes more reliable.

TABLE III
TABLE OF COMPARISON OF PREVIOUS STUDY

Previous Work	Improvements
[25] Using an automatic food dispenser for fish feeding can cause overfeeding the fish and wastage of consuming the food.	Using automation on BLYNK application which is can control manually through smartphones. More efficient and also can avoid overfeeding the fish.
[30] Using Web application to monitor the aquaponics. Needed to set up a computer and Internet for real-time monitoring.	Using BLYNK application which is flexible time monitoring using smartphones. Notifications of actuator and sensors activities directly to the designated user.

IV. CONCLUSION

An automated aquaponic monitoring system has been developed with an integration of multiple sensors, microcontrollers, actuators, and smartphone devices. The integration ensures consistent plant growth, water fish tank measurement, automatic ambient temperature management, and continuous tracking. The solution facilitates the user monitoring operations of the aquaponic system in real-time.

The proposed system helps to overcome the issues of food shortages. In the future, the system can be improved by monitoring the water in the fish tank with pH value. The pH value in the fish tank can ensure that the fish are healthy, hence increasing the monitoring factors to the aquaponics system. Adding a solar module to supply AC electricity to the water pump for bigger scale aquaponic farming would also provide energy sustainability to the solution.

REFERENCES

[1] Panasenko, N. A. (2022). Food security of Kuzbass: state, problems, and prospects. IOP Conference Series: Earth and Environmental Science, Vol. 949, No. 1, p. 012015.

[2] Xu, Y., Li, X., Zeng, X., Cao, J., & Jiang, W. (2022). Application of blockchain technology in food safety control: Current trends and future prospects. Critical Reviews in Food Science and Nutrition, 62(10), 2800-2819.

[3] Chernyavskaya, S. A., Sidorenko, T. N., Ovcharenko, N. A., Udovik, E. E., & Glushchenko, T. E. (2022). Food Subsystem: Innovative Technologies and Prospects for Rural Development. In Sustainable Agriculture (pp. 93-100). Springer, Singapore.

[4] Opiyo, A., & Githeng'u, S. (2022, April). Rapid Multiplication Techniques in Seed Potato Production: Prospects, Opportunities and Challenges. In Egerton University International Conference.

[5] P. Munguia-Fragozo et al., "Perspective for Aquaponic Systems: 'omic' Technologies for Microbial Community Analysis," Biomed Res. Int., vol. 2015, 2015.

[6] Department of Statistics Malaysia (DOSM), "Selected Agricultural Indicators, Malaysia, 2021," dosm.gov.my. https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=72&bul_id=TDV1YU4yc1Z0dUVyZ0xPV0ptRlhWQT09&menu_id=Z0VTZGU1UHBUT1VJMFlpaXRRR0xpdz09 (accessed: May. 27, 2021)

[7] Department of Agriculture (DOA), "Vegetables and Cash Crops Statistic Malaysia 2017," doa.gov.my. http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/perangkaan_sayur_tnmn_ladang_2017.pdf ((accessed: May. 28, 2021)

[8] Vedulla, T., Reddy, Y. M., Kalyan, A., & Jenila, R. (2021). VLSI Architecture for Smart and Precision Agriculture Using Sensors. International Journal of Advanced Science Computing and Engineering, 3(1), 18-27.

[9] Quy, V. K., Hau, N. V., Anh, D. V., Quy, N. M., Ban, N. T., Lanza, S., Randazzo, G. & Muzirafuti, A. (2022). IoT-Enabled Smart Agriculture: Architecture, Applications, and Challenges. Applied Sciences, 12(7), 3396.

[10] Ramachandran, V., Ramalakshmi, R., Kavin, B. P., Hussain, I., Almaliki, A. H., Almaliki, A. A., Elnaggar, A. Y. & Hussein, E. E. (2022). Exploiting IoT and Its Enabled Technologies for Irrigation Needs in Agriculture. Water, 14(5), 719.

[11] Sinha, B. B., & Dhanalakshmi, R. (2022). Recent advancements and challenges of Internet of Things in smart agriculture: A survey. Future Generation Computer Systems, 126, 169-184.

[12] Akhtar, N., Ilyas, N., Meraj, T. A., Pour-Aboughadareh, A., Sayyed, R. Z., Mashwani, Z. U. R., & Poczai, P. (2022). Improvement of Plant Responses by Nanobiofertilizer: A Step towards Sustainable Agriculture. Nanomaterials, 12(6), 965.

[13] Colt, J., Schuur, A. M., Weaver, D., & Semmens, K. (2022). Engineering design of aquaponics systems. Reviews in Fisheries Science & Aquaculture, 30(1), 33-80.

[14] Romano, N., Powell, A., Islam, S., Fischer, H., Renukdas, N., Sinha, A. K., & Francis, S. (2022). Supplementing aquaponics with black soldier fly (Hermetia illucens) larvae frass tea: Effects on the

production and composition of sweetpotato slips and sweet banana peppers. Aquaculture, 555, 738160.

[15] Braglia, R., Costa, P., Di Marco, G., D'Agostino, A., Redi, E. L., Scuderi, F., Gismondi, A. & Canini, A. (2022). Phytochemicals and quality level of food plants grown in an aquaponics system. Journal of the Science of Food and Agriculture, 102(2), 844-850.

[16] Zhang, Y., Zhang, Y. K., & Li, Z. (2022). A new and improved aquaponics system model for food production patterns for urban architecture. Journal of Cleaner Production, 342, 130867.

[17] R. Barbosa, S. I. S. Hassen and L. Nagowah, "Smart Aquaponics with Disease Detection," 2nd Int. Conf. Next Gener. Comput. Appl., pp. 1–6, 2019.

[18] David, L. H., Pinho, S. M., Agostinho, F., Costa, J. I., Portella, M. C., Keesman, K. J., & Garcia, F. (2022). Sustainability of urban aquaponics farms: An emergy point of view. Journal of Cleaner Production, 331, 129896.

[19] W. Vernandhes, N. S. Salahuddin, A. Kowanda, and S. P. Sari, "Smart aquaponic with monitoring and control system based on IoT," 2nd Int. Conf. Informatics Comput., pp. 1–6, 2018.

[20] C. Nicolae, F. Dumitrache, D. Mocuţa, and E. Elia, "Low-Tech Aquaponic System Based on an Ornamental Aquarium," 2015.

[21] A. Bittsánszky et al., "Nutrient supply of plants in aquaponic systems," Eco cycles, vol. 2, no. 2, pp. 17–20, 2016.

[22] S. Sansiri, W. Y. Hwang, and T. Srikhumpa, "Design and implementation of the smart small aquaponics system," 12th Int. Conf. Ubi-Media Comput., pp. 323–327, 2019.

[23] Yani, N. A. A., & Zolkipli, M. F. (2021). Computerized Senior Citizen Health Monitoring using Mobile Application. International Journal of Advanced Science Computing and Engineering, 3(3), 140-152.

[24] Abdullah, H., Taa, A., & Mohammed, F. (2021). Remote Patient Health Monitoring System Using Mobile and Wireless Body Area Network in Yemen. Int. J. Adv. Sci. Eng. Inf. Technol, 11(1), 43-50.

[25] Ramachandran, V., Ramalakshmi, R., Kavin, B. P., Hussain, I., Almaliki, A. H., Almaliki, A. A., Elnaggar, A. Y. & Hussein, E. E. (2022). Exploiting IoT and its enabled technologies for irrigation needs in agriculture. Water, 14(5), 719.

[26] Sinha, B. B., & Dhanalakshmi, R. (2022). Recent advancements and challenges of Internet of Things in smart agriculture: A survey. Future Generation Computer Systems, 126, 169-184.

[27] Hassan, R., Jabar, H. I. A., Hasan, M. K., Lam, M. C., & Hussain, W. M. H. W. Cloud Based Performance Data Analysis and Monitoring System for Express Bus in Malaysia. International Journal on Advanced Science, Engineering and Information Technology, 1959-1967.

[28] Y. Lee, J. Jiang, G. Underwood, A. Sanders, and M. Osborne, "Smart Power-Strip: Home automation by bringing outlets into the IoT," IEEE 8th Annu. Ubiquitous Comput. Electron. Mob. Commun. Conf., pp. 127–130, 2017.

[29] Iriany, A. The Correlation Model between Microclimates and Potato Plant Growth. International Journal on Advanced Science, Engineering and Information Technology, Vol. 11 (2021) No. 1, pages: 223-228.

[30] Mulyono, Sri, Muhammad Qomaruddin, and Muhammad Syaiful Anwar. "Penggunaan Node-RED pada sistem monitoring dan kontrol greenhouse berbasis protokol MQTT." TRANSISTOR Elektro Dan Informatika 3.1 (2018): 31-44.