Development of an IoT-based Aquaponics Monitoring and Correction System with Temperature-Controlled Greenhouse

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Development of an IoT-based Aquaponics Monitoring and Correction System with Temperature-Controlled Greenhouse

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Abstract—This paper presents a monitoring and automatic correction system for an aquaponics set-up in a temperature-controlled greenhouse using an Android device through Internet of Things (IoT). The system involves the acquiring of real time data detected by the light intensity sensor, and air temperature and humidity sensor. It also includes the monitoring of the pH level and temperature of the recirculating water of the system and the canopy area of the plant. If the acquired data is not within the threshold range, the correcting devices, namely grow lights, exhaust and inlet fans, evaporative cooler, aerator, and peristaltic buffer device were automatically triggered by the system to correct and achieve its normal status. The Internet remote access includes the effective wireless transmission and reception of data report between the system and an Android unit with the Android application in real-time.

Keywords—aquaponics, Android, IoT, Image processing, Smart farming,

I. INTRODUCTION

Aquaponics is one of the methods in implementing urban farming. It is the combination of aquaculture, breeding and raising of aquatic organisms such as fish, shrimps, crabs in a controlled environment; and hydroponics, production of plant in a soilless medium, in a mutually beneficial environment [1-2]. There are some aquaponics monitoring and correction systems in the literature such as in [3] and [4] but have not considered monitoring of pH level, light intensity, water and air temperature, and indirect measuring of plant's canopy area through image processing, as well as remote monitoring through Internet of Things (IoT), to be integrated all together. The general objective of this paper is to develop a monitoring and correction system for aquaponics through Android IoT application to optimize its crop growth. The proposed system is designed based on Arduino Mega (for water/air temperature sensors, light intensity sensor, ISFET pH sensor, and control for cooler, buffer pump, aerator, grow lights, and feeder) and Raspberry Pi (with a WLAN server, stepper motor, and a camera module with a linear actuator).

II. SYSTEM DESIGN

The aquaponics system is composed of five sections namely the water parameter detection and correction, environment parameter detection and correction, automated feeding, plant growth monitoring system, and internet remote access. The block diagram of the proposed aquaponics system is shown in Fig. 1. The aquaponics setup is shown in Figs. 2 and 3.

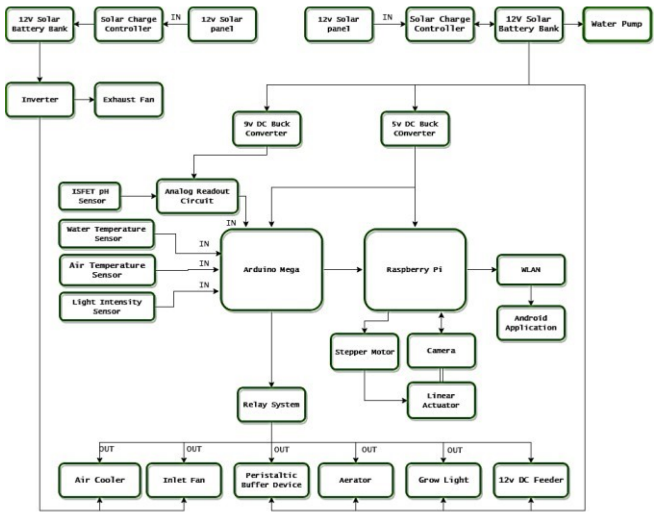

Fig. 1. Block diagram

For the water parameter detection and correction, the water parameters of the aquaponics system such as pH level (through the Winsense ISFET pH sensor) and water temperature (through DS18B20 digital thermometer) were monitored and controlled to achieve optimum growth of the plants in the grow bed and fishes in the tank. The threshold range for the pH level for the system was set within 6 to 8 pH level. If the pH < 6, the peristaltic buffer pump device automatically released calcium carbonate ($CaCO_3$) to add base and increase the pH slowly until the readings return at the normal pH range. For this study, the water temperature, T_{water}, was set at 25°C which is in the middle of the optimal temperature range of tilapia. If the $T_{water} > 25°C$, the aerator was automatically turned on to supply oxygen to the fish.

For the environment parameter detection and correction, the air temperature of the greenhouse (through the DHT11 sensor), T_{air}, was set at 25°C which is in between of the suitable temperature range for the lettuce and pak choi (pechay). If the $T_{air} > 25°C$, the evaporative air cooler was automatically turned on. If the $T_{air} < 25°C$, the inlet fan was automatically turned on which lets the cool air inside the greenhouse. The grow lights will be turned on when the light intensity (measured by the BH1750FVI light intensity sensor) is below 500 lx since the intensity of natural light during sunrise or sunset. Meanwhile, the automatic feeder was created for the operation of food dispensing to the fish. It was programmed with an initialized default time setting in the Arduino Mega that was turned on every 8 hours. The operation happens when the microcontroller sends a digital signal to the relay driver for feeder to dispense food. In the plant growth monitoring section, plants on their top view were captured by the camera connected to a linear actuator that was responsible for camera movement from first plant to next plant. The captured images underwent image enhancement, image segmentation, and dimension acquirement using a Python program in a Raspberry Pi module. The projected plant canopy area acquired from the image processing was transmitted to the database and to the Android application for data visualization. The internet remote access includes the transmission and reception of the outputs to the database (using TinyWebDB) Android application. These outputs (such as ISFET pH, temperature, and light intensity readings) are obtained from the parameter detection and its analysis by the Arduino Mega and the data (canopy/surface area) acquired from the plant growth monitoring system transmitted by the Raspberry Pi as shown in Fig. 4.

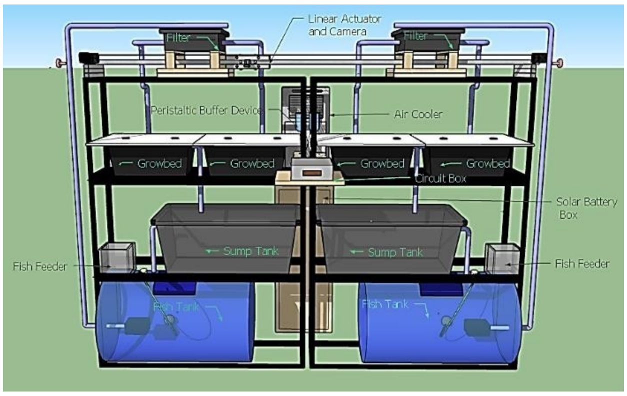

Fig. 2. Parts and sections of the aquaponics set-up

Fig. 3. The actual aquaponics set-up

Fig. 4. Android Application Retrieved Data User Interface

III. Experimental Results

The comparison diagram of the two experimental set-ups is shown in Fig. 5. The conventional farming set-up is composed of the plants grown with a soil medium in Styrofoam containers. The growth is monitored by the plant growth monitoring system. Table I shows the canopy areas of the lettuce planted in 2 set-ups.

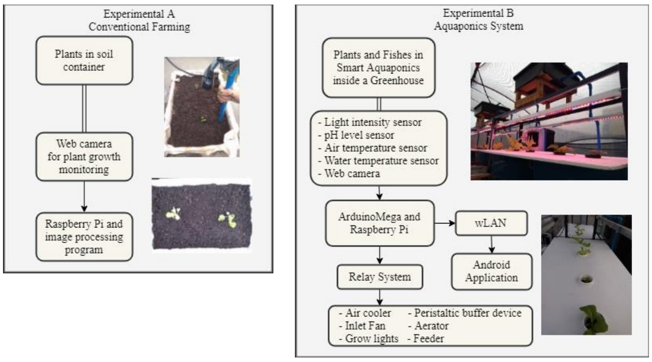

Fig. 5. Comparison diagram of 2 different experimental set-ups

TABLE I. Canopy Areas of the Lettuce Planted in 2 Set-ups

Days Lapsed	**Canopy Area (cm^2)**	
	Proposed Aquaponics Set-up	***Conventional Farming***
21	91.70	10.27
28	107.52	13.61
35	151.20	30.94

IV. Conclusion

We developed an IoT-based aquaponics monitoring and correction system with temperature-controlled greenhouse which yields a larger canopy area of the lettuce compared with the conventional farming. For future work, we can extend this study for growth monitoring of the fish tank using image processing.

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