AgriCos e-Newsletter
Open Access Multidisciplinary Monthly Online Magazine
ISSN: 2582-7049
Volume: 04 Issue: 07 July 2023 Article No: 19

An Overview of Smart Aquaponics System

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SUMMARY

Food security and sustainability is a major concern for population due to its rapid urbanization, land scarcity, and low local food productions of fish and leafy vegetables. This paper attempts to design and develop a smart Aquaponics system that can synergize fish farming and plant growing. Various sensors, actuators, microcontroller, and microprocessor were employed in the system to monitor and control water quality, light intensity, and fish feed. To ensure healthy growing environment for fish and plant, early warnings in form of email, short message service, and push notification are automatically sent to the user when the sensor detects any abnormal condition. Concurrently, the respective actuator will intervene and rectify the abnormal condition without human interference. Moreover, fish feed is dispensed at the user present timings of the day. All system activities and live sensor measurements are securely stored in cloud storage for data analysis. User-friendly web and mobile applications were also created to provide graphical user interfaces between the Aquaponics system and the user. Additionally, the user can monitor the Aquaponics facilities live from web application through a camera module of the system. As such, the proposed smart Aquaponics system has demonstrated to be a self-sustainable, cost-effective, and eco-friendly urban farming that can attract commercial farmers and home gardeners.

INTRODUCTION

Aquaponics is a combination of aquaculture (fish farming) and hydroponics (plant growing without soil). It is a closed-loop recycling fresh water system between fish and plant. Wastes generated by the fish become nutrients for the plants after nitrification process. The process, which acts as biofilters, cleans the water before recirculating it back to the fish tank. Although Aquaponics can address the issues of food security and sustainability, its operation can be challenging because constant monitoring of Aquaponics facilities for healthy growth of fish and plant is necessary.

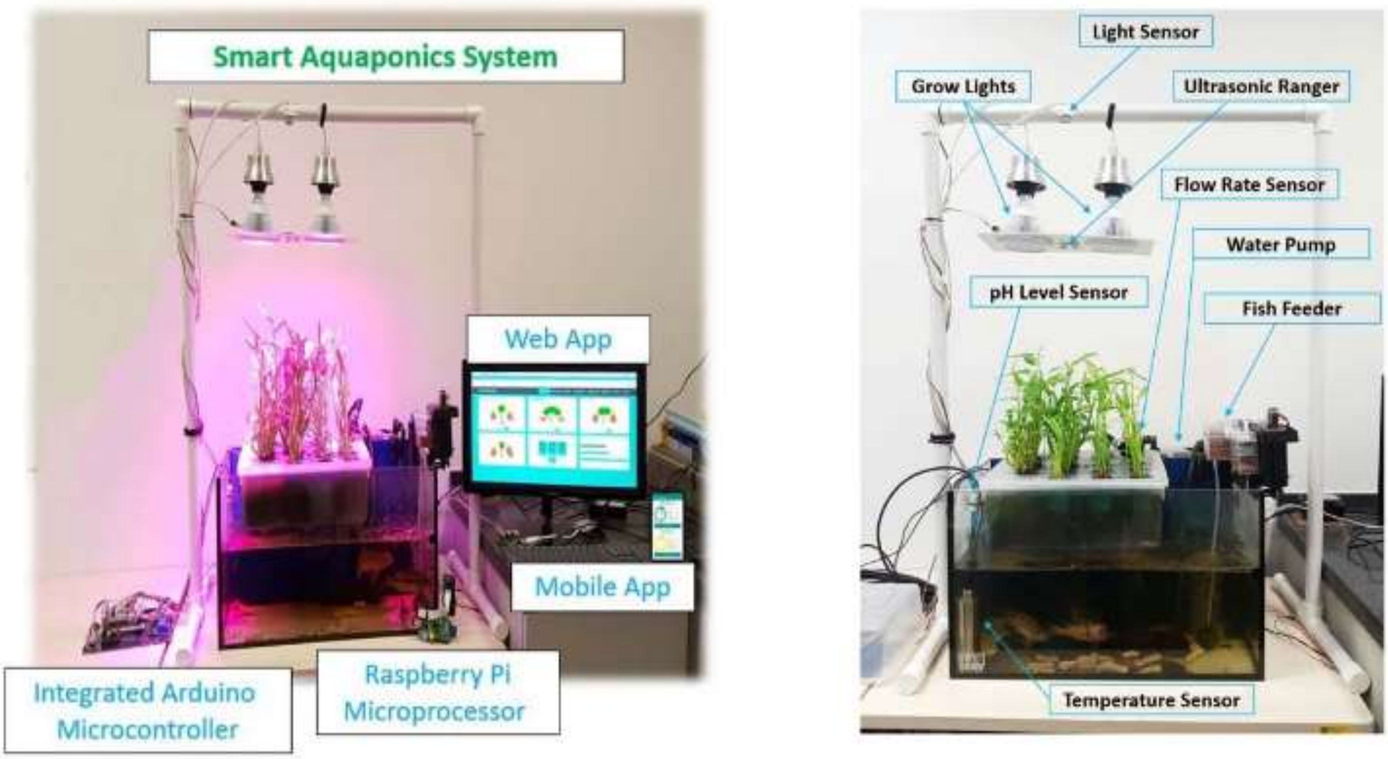

Fig. 1. Smart Aquaponics System

Smart Aquaponics System

A smart Aquaponics system was designed and developed by integrating data acquisition unit, alarm unit, system rectification unit, central processing unit, web application, mobile application, and cloud server, as presented in Fig.1. The proposed system can continuously monitor and control water quality, light intensity, and fish feed; automatically send early warnings in form of email, SMS, and push notification; and rectify system abnormality without human interference. Future work includes adding a dissolved oxygen sensor and a nitrate sensor to detect oxygen level and nitrate concentration level in the water respectively, incorporating solar panels to hardness solar energy to power the actuators, and providing live video streaming of the Aquaponics system using the mobile application. With a large-scale implementation, the proposed system can significantly reduce labour and operating costs, while increasing livestock production and profitability, which contributes towards sustainable and liveable cities. The smart Aquaponics system was developed by integrating seven modules: data acquisition unit, alarm unit, system rectification unit, central processing unit, web application, mobile application, and cloud server

Data acquisition unit

The data acquisition unit continuously collects data using five sensors. Water temperature sensor gathers water temperature of the fish tank. Water flow rate sensor measures water flow rate from the fish tank to plant grow beds. Digital light sensor quantifies light intensity of the environment. pH level sensor detects water pH level in the fish tank. Ultrasonic ranger measures the plant height.

Alarm unit

The alarm unit consists of a green LED light, a red LED light, and a buzzer. This unit displays green light when the system is healthy, but displays red light with buzzing sound to alert the user when the system is unhealthy.

System rectification unit

The system rectification unit automatically intervenes and rectifies the system abnormality by activating respective actuator. Decision to activate or deactivate the actuators is determined by the central processing unit based on the collected data and user present values. This unit comprises four actuators. Water heater provides additional heat source when the water temperature falls below a healthy range. Secondary water pump ensures water flow from the fish tank to plant grow beds in the event of primary pump failure. LED grow light supplies stable blue and red light to boost plant growth when the ambient light intensity enters into an unhealthy range. Fish feeder dispenses fish feeds at the user present timings of the day to increase fish growth.

Central processing unit

The central processing unit has two sections. The first section contains an Arduino Mega, a Grove-Mega shield, and a relay board. Arduino Mega, with 54 input/output pins, is used to communicate with the sensors and actuators from the data acquisition unit and system rectification unit. Grove Mega Shield was mounted on Arduino Mega to reduce the number of connections on the breadboard. Relay board enables Arduino to control the actuators by switching on and off the respective electric circuits. The second section consists of a Raspberry Pi 3 model B and a camera module. Raspberry Pi was configured as a central control unit for the entire system because it has a fast processor, as well as built-in Bluetooth and Wi-Fi modules. Moreover, it has a high-definition multimedia interface port that can be connected to visual display devices. Camera module v2 enables live streaming feature for Raspberry Pi. This camera module was chosen because it is easy to use and can record high-definition video after integrating with Raspberry Pi.

Web application

The web application was developed and hosted on Raspberry Pi to provide GUI for the system. The GUI displays and compares live and historical sensor values, as well as records system events. It also allows the user to timely monitor the Aquaponics facilities and remotely control the actuators.

Mobile application

The mobile application was created on Android platform. It displays live sensor values and enables user to remotely control the actuators by using services from the cloud server. Moreover, it permits the user to modify the threshold values for each sensor with real-time latency.

Cloud server

The cloud server is used to establish communication between the central processing unit and mobile application. The main goal for the cloud server is to store the collected data from the data acquisition unit, and to redirect actions, such as activating water heater, from the mobile application to the central processing unit in real-time.

System implementation

Each component was carefully inspected and tested before the integration. Subsequently, the implemented system was evaluated by simulating different possible scenarios. For example, when the water temperature falls into an unhealthy range, the system should trigger the alarm unit to alert the user, and activate the system rectification unit to rectify the problem by turning on the water heater. Simultaneously, the system should send out alert notifications, such as email, short message service (SMS), and push notification, as well as record the faulty event in the database. When the water temperature returns normal, the system should automatically turn off the water heater and buzzer, notify the user with updated system information, and record the recovery event in the database.

CONCLUSION

Due to rapid urbanization, a land resource for agriculture has been decreasing. Rapid growth of human population has also increased the demand for food. Traditional agriculture methods for growing plants require huge land space, time, and manpower. Consequently, there is an increasing concern for safe and sustainable food sources, which leads to the need for new agriculture methods. A possible solution to food security and sustainability is the use of Aquaponics.

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