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Design and construction of smart IoT-based aquaponics powered by PV cells

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Abstract
An aquaponic is a system that combines aquaculture with hydroponic to form a bio-integrated structure that aims at achieving a symbiotic environment for both aqualife and crops growth. Fish excretions in fish tanks contains ammonia which is poisonous and is considered very dangerous on fish survival. However, ammonia can be converted by the action of the nitrifying bacteria into Nitrites and then to Nitrates which can be used as nutrients for the plants, hence the symbiotic relationship between the two. The aim of this project is to monitor and control aquaponics by using Internet of Things (IoT) technology by recording various parameters in real time settings. Our proposed system consists of sensors that measure pH, temperature, Oxygen and ammonia levels. In turn, these sensors are connected to a remote database over the internet to enable users to get the values of these sensors. We used NodeMcu to acquire sensors data and deliver them to a web server. The low power consumption of the system has resulted in the possibility of powering it by solar power. We have registered levels of ammonia without the action of aquaculture part between 0.05 to 0.4 mg/L over a period of one week. These values have since risen to a dangerous level of 0.5mg/L leading fish deaths. However, a stable range of 0.02 to 0.04 mg/L were registered with the integration of the aquaculture part. In addition, a normal pH level of 6.5 to 8 were recorded and the temperature was between (23-25.57) C°. these results are considered acceptable for a healthy growth of both aqualife and hydroplants.

Keywords: Aquaponics; Internet of things; NodeMcu; Environmental parameters.

1. Introduction
Aquaponics is a term used to describe a system that combines aquaculture and hydroponics operating in a symbiotic relationship. An aquaculture is considered more suitable option than traditional agriculture in cases where both space and water, among other resources, are limiting factors [1]. The shared water resource between the plants and fish could achieve an optimum environment for the nourishment of both parties while keeping water consumption at minimum. Ammonia is a by-product of fish, which although very poisonous to fish, is converted by the nitrifying bacteria into Nitrites and then to Nitrates. Nitrates can be used as nutrients for plants. However, aquaponics requires continuous monitoring and the presence of man-power should the balance between the two environment is lost. This could result in a higher operation cost than traditional agriculture. Nevertheless, in this research, we proposed IoT, to

enable remote monitoring and management of aquaponics. Hence, they can be deployed in cheap rural areas and monitored remotely resulting in further reduction in operating cost.
Internet of Things (IoT) is a technology that can be used to connect physical devices to the internet to store and exchange information [2]. Ma'arif and Wijaya [3] have proposed a system for aquaponics automation. Their design can measure the level of pH and electro-conductivity of the water. They have used TCP protocol and a web server for user access. Others such as in reference [4], have designed a so-called: growbox. A growbox is a small-scale environment where the values of the humidity, temperature soil moisture are automatically monitored to perform some corrective measure with actuators such as a fan and water replenishment system. Their design had two modes: automatic mode and manual mode. Kretzinger [5] designed an aquaponics-control system implementation with an Arduino microcontroller. It provided precise control of cycle times, and collects sensor data for user to know what is taking place in the growing environment. In 2018, One researcher proposed the use of Raspberry Pi microcomputer and (IoT) instead of an Arduino implementation [1]. The main objective of the proposed design is to control and monitor aquaponics by (IoT) such as measuring the pH level, temperature, Oxygen, Ammonia level, etc.
Although much effort has been done on ways to monitor and control an aquaponics from various standpoints, less has been done to measure the actual values that really effect the survival of aqualife and nourishments of plants such as Ammonia. Without knowing how these factors interact and evolve over time, the thresholds that define the corrective actions of a typical control-software remains arbitrary. The user of such systems would carry the burden of defining such levels. We aim at studying these governing factors while implementing a small-scale IoT system. These result would serve as a pilot plant for future system expansion and scaling.
The rest of this paper is divided into four sections: section two will give details of our method and design. Section three will report the result obtained while section four will conclude the paper. An appendix showing images of our system is attached in section five.

2. Methodology

2.1 Block diagram of the system

The main objective of the proposing system is to develop an IoT based aquaponics monitoring system which measures and displays parameters like pH level, oxygen level, temperature, etc. continuously to users. Real time monitoring of water quality in the aquarium tank should be done for the optimal growth and survival of the fish as well as plants, see Figure 1.

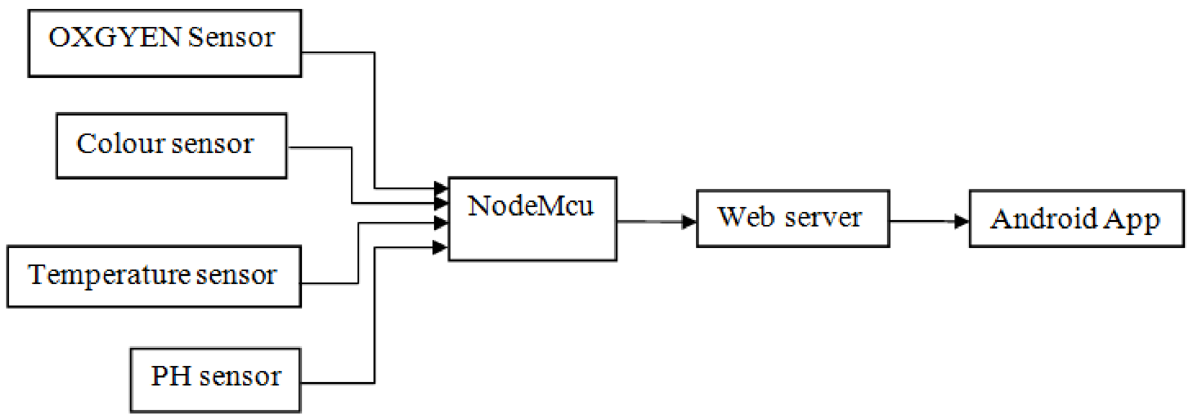

Figure 1. Block diagram of the proposing system.

Our design is comprised of a dissolved-oxygen (DO) sensor which is used in aquaculture ensure sufficient amount if DO is present. Otherwise, fish may suffocate. The ideal level of is (DO > 5), a TCS2300 colour sensor is used to detect the colour a test strips for Ammonia thereby assessing its level which should be ideally less than 1(mg/L), a DS18B20 temperature sensor and a pH sensor. It is of value to note that the temperature and pH level for optimum fish growth should be between (18-30) degrees Celsius and a pH of (6-8) [6]. Sensors measurements are acquired using NodeMcu microcontroller, the data is then uploaded to database. Users can access these information from anywhere in the world [7].

We have built a simple Android app using remoteXY to perform all mentioned processing and to help connect the system to the web and to display information to the user in a convenient way.

2.2 Flow diagram of the system

Our design is simple and straightforward, see Figure 2. We believe that having less hardware translate to less maintenance and cost. All sensors sent their values simultaneously. These values are then checked against specific conditions for the optimal growth of plants and fish and warnings are sent accordingly. Real-time values for each parameter are sent and displayed on the smart phone app.

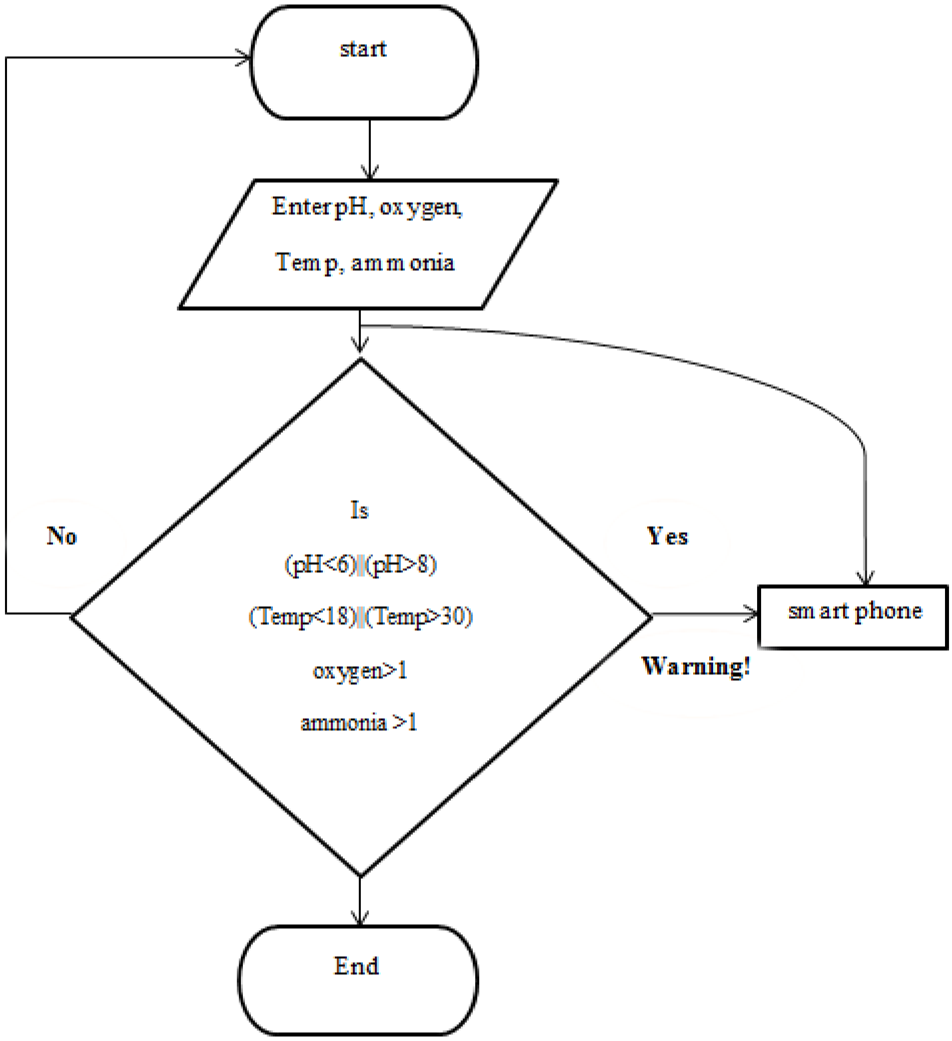

Figure 2. Flow diagram of the proposing system.

3. Result and discussion

3.1 Setup of the system

An aquarium tank was built from scratch with dimensions of (80cm * 40cm* 40cm). We have added double outlet air-pump for both the aquarium and aquaculture parts. The aquaculture system was erected above the aquarium tank (Figure 3) and consisted of PVC pipes. Crops were planted inside sponge-filled cups. The sponges have two advantages of providing mechanical support for the crops and rich media for bacteria growth. The tank was cycled for 24 hours before Carp fish were added. The water is rotated continuously throughout the PVC pipes then back to the tank. Observations were recorded everyday through a period of one week.

Figure 3. Setup of the proposing system.

3.2 Monitoring section of the system

Figure 4 shows the NodeMCU microcontroller connected to the sensors used in the system during design and prototyping.

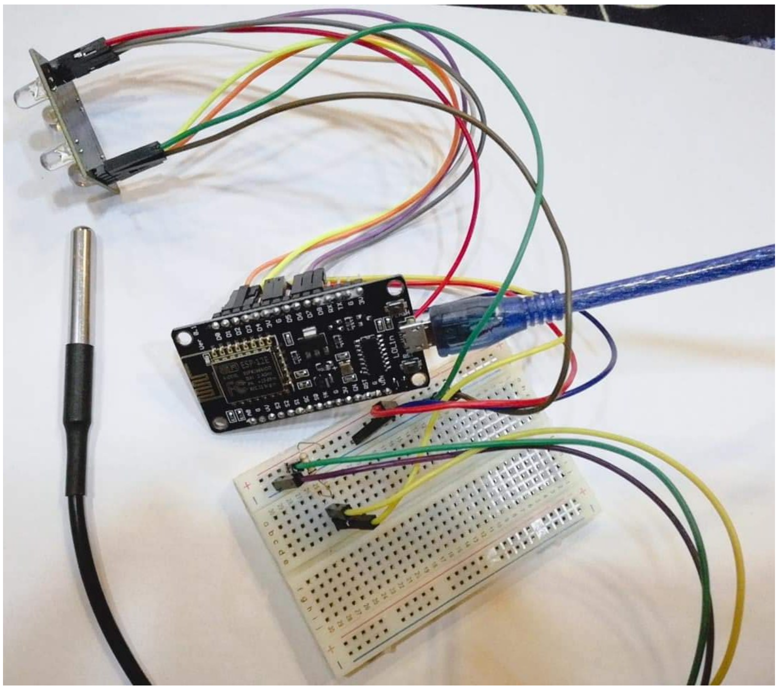

Figure 4. Monitoring section of the system.

Readings of sensors over one week of running the aquaponic have shown some interesting results. Firstly, Temperature values over one week of running the system were between 18-30 °C which is well-within the ideal range of (18-30) °C, see Figure 5.
As mentioned before, the suitable pH range for the growth and survival of plants and fish in the system is in between (6.5-8). Our results showed varied between (6 - 7.4) as shown in Figure 6.

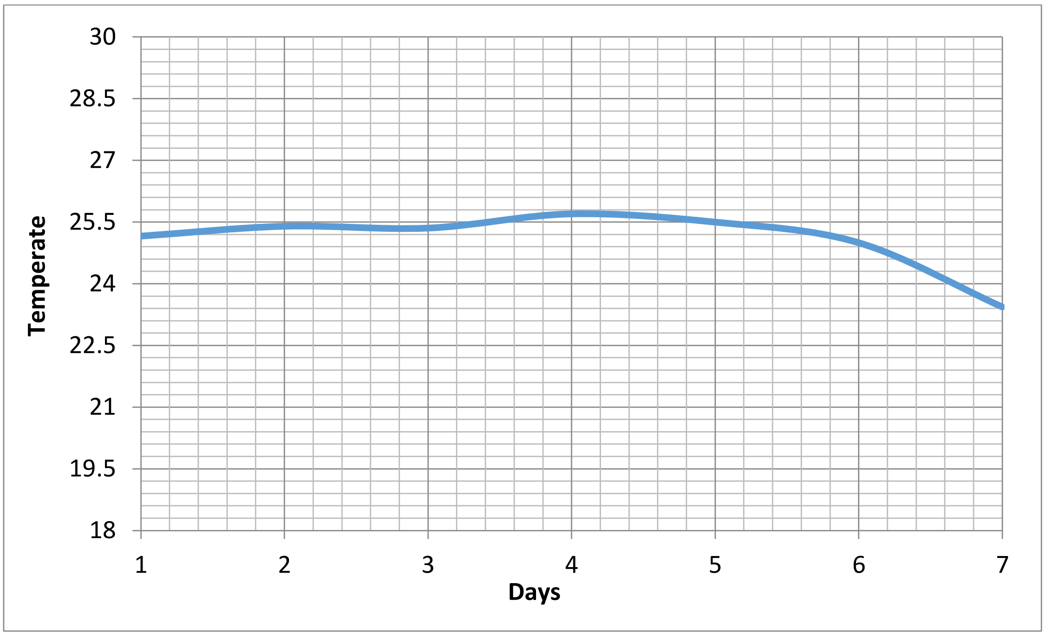

Figure 5. Graph showing temperature of the system.

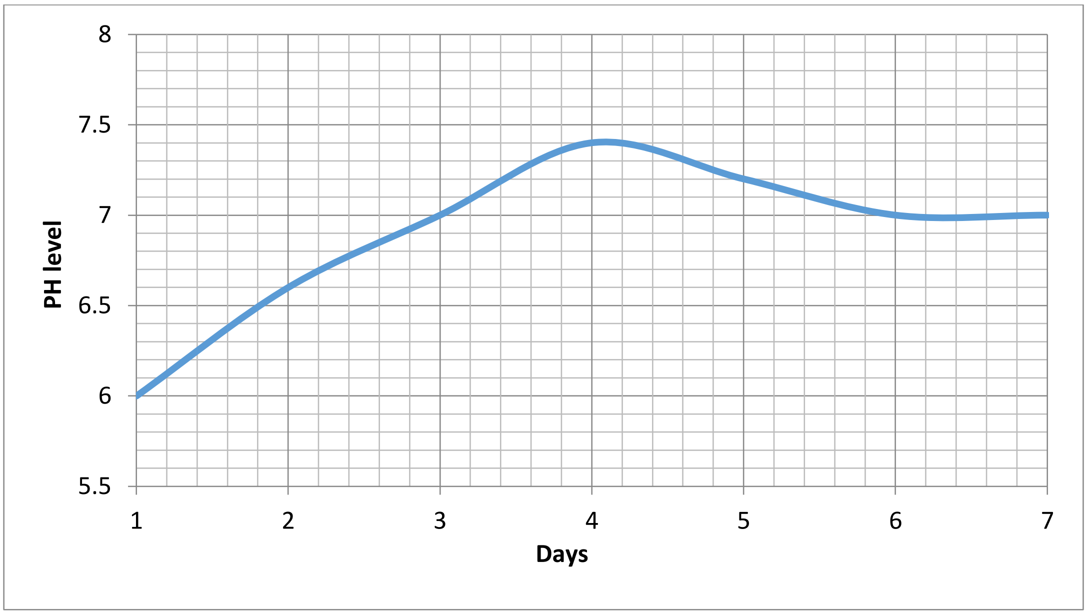

Figure 6. Graph showing PH level of the system.

We have registered levels of ammonia between 0.05 to 0.4 mg/L over a period of one week. Eventually, when the level reached 0.5mg/L, it led to fish fatality (Figure 7). However, the integration of the hydroponics, have kept the value of the Ammonia within good range of 0.02 to 0.04 mg/L over a period of one week. Figure 8 shows a snapshot of a carp fish living inside the tank. These results are considered acceptable for a healthy growth of plants and fish.

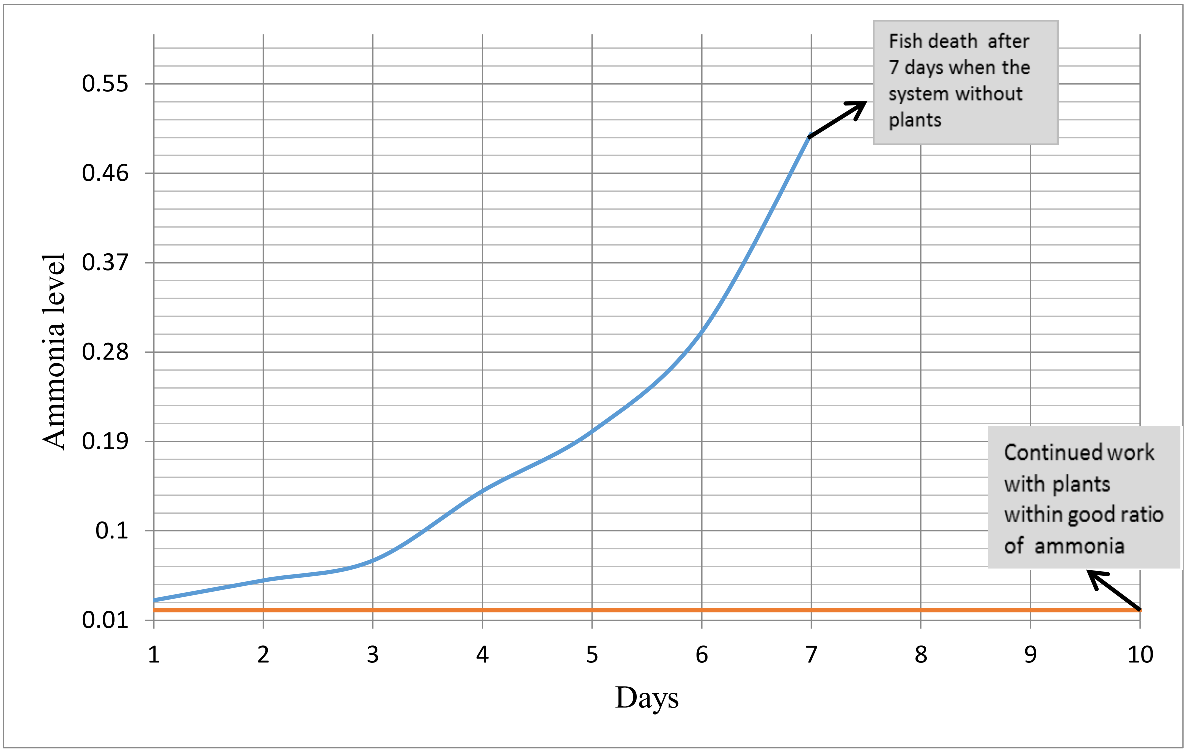

Figure 7. Graph showing ammonia level of the system.

Figure 8. Photograph of dead fish.

In addition, we registered reading of Ammonia levels twice a day over a period of two days. We observe during the night that the level of ammonia increased a little probably because the activity of the bacteria is higher throughout daytime, see Figure 9.

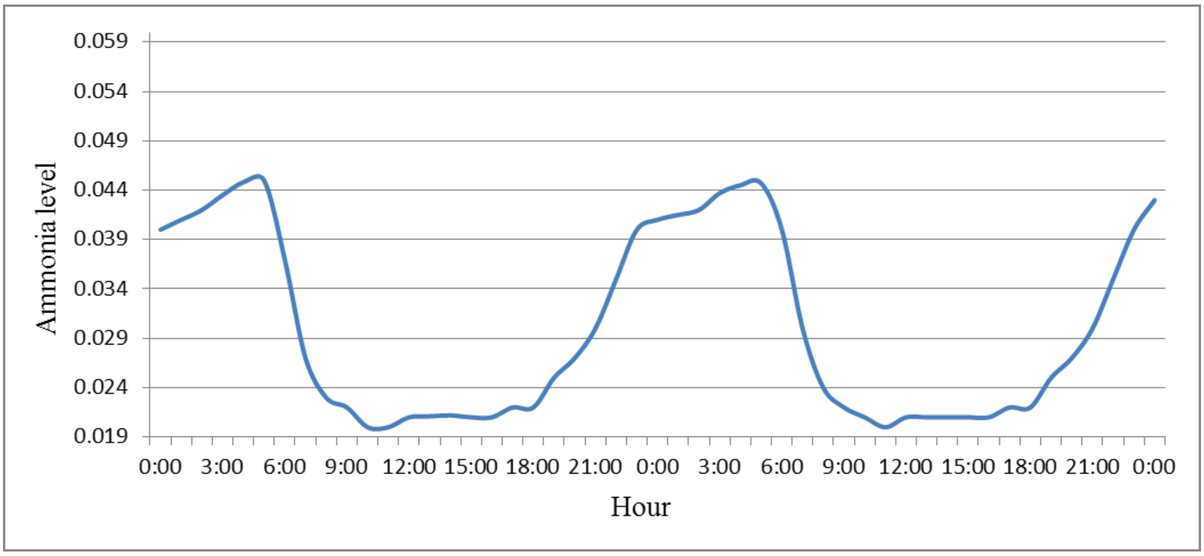

Figure 9. Graph showing ammonia level of the system during the night and day.

4. Conclusion

In the project, we designed an IoT based aquaponics system. It has been made up of a fish tank and a grow bed for plants. A monitoring sub-system was implemented to detect pH, temperature, ammonia and oxygen levels in the aquaponics system using cheap over-the-shelf sensors. All these sensors were interfaced to NodeMcu. Then finally the system parameters were displayed over a smart phone app. We have registered levels of ammonia between 0.05 to 0.4 mg/L over a period of one week and a pH of 6.5 to 8. The temperature was between (23-25.57) C°. These results are considered acceptable for a healthy growth of plants and fish. By the application of Internet of Things in this system, it has been possible to view the readings from anywhere in the world. Thus enabling remote management of aquaponics in rural areas.

Acknowledgements

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Appendix

Growth of plants in one month