System Design for Internet of Things Assisted Urban Aquaponics Farming

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***Abstract*—Since Taiwan is a small and overcrowded island, the advance of ICT technology promotes the development of quality agriculture. In this paper, we transfer the commercial aquaponic system to the home / urban one. That is, this paper not only adjusts the ratio of fish and plants, but also reduces food miles and carbon emission. The main goal is keeping self-sustaining. According to our experimental results, the number of fish can be reduced from 30 to 15, and the number of planted plants is increased from 20 to 30. The plant harvest has a 50% increment.**

Keywords—Aquaponics, Internet of Things (IoT)

I. Introduction

The upward trend in population increases food demand. However, due to the food safety crisis in Taiwan, people worry about whether the crop cultivation is affected by chemical nutrients or pesticides or not. Hence, the recirculating farming systems are popular to provide a new opportunity for economical and health food source. Aquaponics, which is the combination of aquaculture and hydroponics, gains great attention recently. The basics of aquaponics is the co-raising of fish and plants in recirculating water as a closed-loop ecosystem. First, fish in a tank eat and excrete in the water. Next, the fish waste has ammonia which can be converted into nitrite (NO_2) and then nitrate (NO_3) by bacteria. The ammonia and NO_2 are toxic to fish, but NO_3 is relatively harmless for plants. Plants use the fish waste as nutrients, keep growing hydroponically and purify the water. Therefore, water plays the vital roles of biological filtration and recirculation. If the water recirculation can be set up to achieve the optimal condition, the aquaponic system can have high productivity both in the fish and plant units.

Internet of Things (IoT) is able to interconnect the cyber world and physical environment. Now, IoT is popular to applied into different business areas, including agriculture [1]. Two main goals of this paper are (1) scaling the commercial-scale aquaponic system down to the home / urban one based on the Taiwan condition, and (2) establishing the IoT assisted aquaponic monitoring subsystem for water recirculation. According to our observation, small or medium scale aquaponics in Taiwan may operate by the past experience. That is, the ratio of fish and plants depends on the past experience. The fish feeding amount and the adjustment of water quality also depends on the past experience. This paper utilizes the IoT monitoring technique to record the scaling-down process in order to learn the transition of water quality and then develop one automatic and intelligent aquaponic system in the future. This paper is organized as follows. Section II introduces our proposed IoT assisted urban aquaponic system. Section III evaluates our work and presents the experimental results. Finally, Section IV concludes this paper.

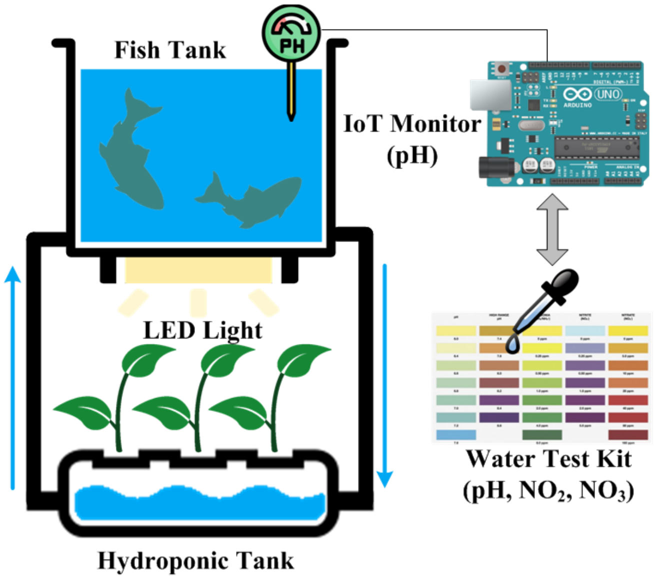

Fig 1. The IoT assisted urban aquaponic system

II. System Design

According to our goals, Fig. 1 depicts our proposed IoT assisted urban aquaponics system. We adopt raft hydroponics to plant lettuces and breed goldfish in our system. The size of our fish tank is 60 cm (L) * 30 cm (W) * 25 cm (H) with 45 L water. On the other hand, the size of hydroponic tank is 75 cm (L) * 30 cm (W) *25 cm (H) with 45 L water. One water pump is configured for water recirculation. Although most existing system puts the hydroponic tank above the fish tank, after considering the indoor light, this paper lets the fish tank be above the hydroponic tank and configure extra LED light under the fish tank. Blue and red light can help the progress of photosynthesis. We add the blue, red and white light with the ratio of 4:1:1. The illuminance is another important issue. Hence, The distance between LED and plant is 21 cm with an illuminance of 15,776 lux. Furthermore, we utilize the Arduino UNO board to connect one pH sensor. In order to make sure the data collected from the Arduino board, we also utilize the water test kit on the market, which can show not only the pH value but also the values of NO_2 and NO_3.

In this paper, we focus on the ratio of fish and plants. If the ratio is optimal, greater output of either hydroponic produce or fish protein can be rewarded. Modern aquaponic systems are highly successful because they have intensive control and management. Hence, our goal is to scale down one commercial-scale and famous aquaponic system developed by the University of the Virgin Islands (UVI) [2]. First, based on the UVI system design, each fish tank has 7800 L water and 231 fish whose total weight is 15153.6 g. Since our fish tank has 45 L, we need about 90 g. All goldfish we have are about 3 cm and have 2.5 g ~ 3.7 g. Thus, we decide to feed about 30

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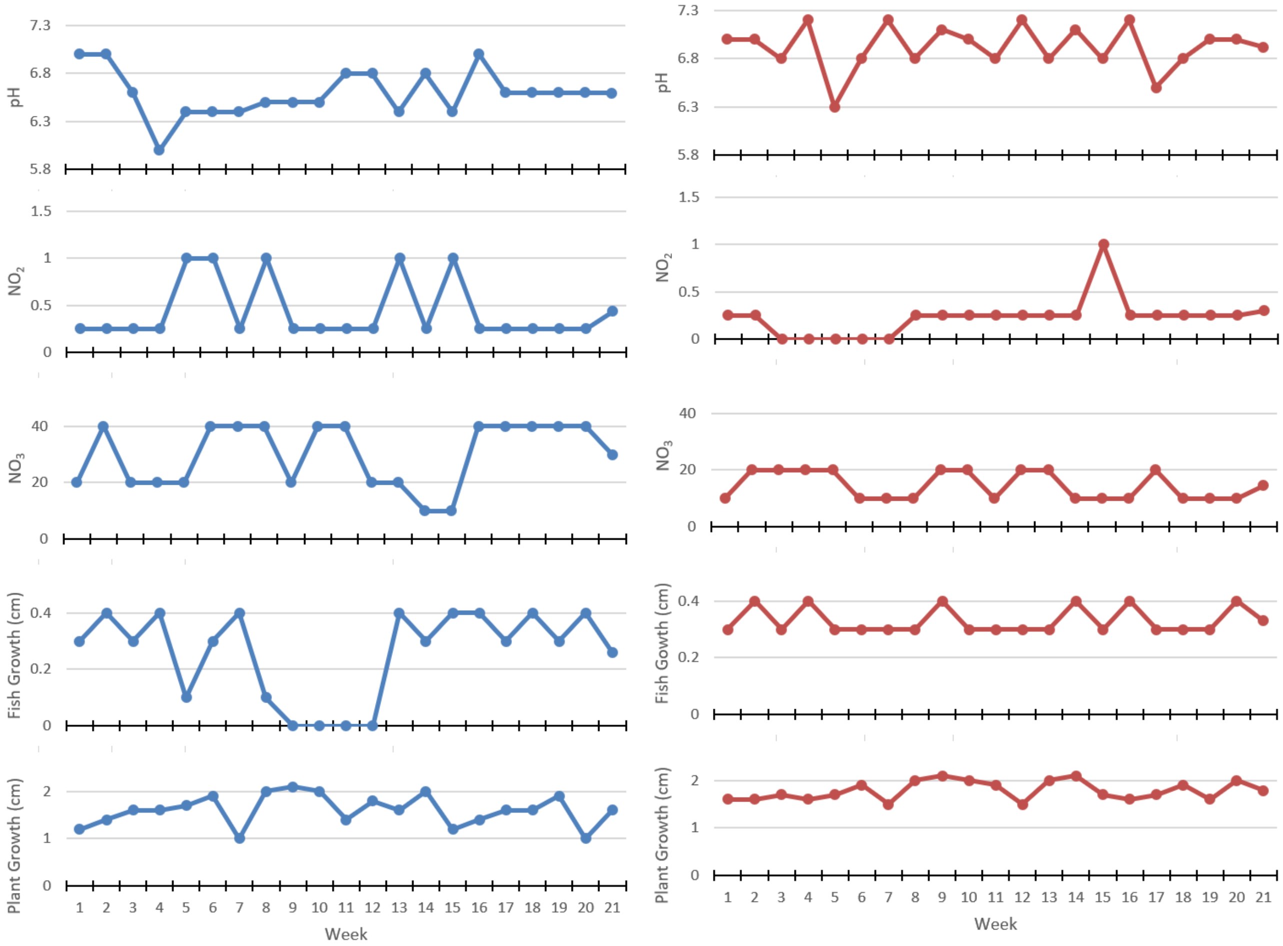

Fig. 2 Experimental results of 21 weeks. (Blue-Left) the UVI ratio. (Red-Right) our proposed ratio.

goldfish in our tank. In the same way, we calculate that we need to plant 20 lettuces. Then, we try three times with different ratio values every 50 days. Initially, we observe the UVI ratio, i.e., 30 goldfish and 20 lettuces during 50 days. After 50 days, 17 goldfish are dead. We reduce the number of goldfish to 25, but only 8 goldfish are still dead. Hence, we reduce the number of goldfish to 20 again and, at the same time, increase the number of lettuces to 30. In this time, only 3 goldfish are dead. Finally, we try to reduce the number of goldfish to 15 and increase the number of lettuces to 40. No goldfish is dead but the growth of lettuces is not better than the previous experiment. Based on the aforementioned experiments, we decide to propose 15 goldfish and 30 lettuces in our aquaponic system.

III. Experiments and Evaluations

In order to evaluate our proposed aquaponic system, we compare the original UVI ratio, i.e., 30 goldfish and 20 lettuces, and our new ratio, i.e., 15 goldfish and 30 lettuces in 21 weeks and collect the corresponding values of water quality, e.g., pH, NO_2, and NO_3. We also record the growth of goldfish and lettuces. Fig. 2 depicts the experimental results of 21 weeks. First, the average pH value of the UVI ratio is 6.6. The values of NO_2 and NO_3 are 0.44 ppm and 30 ppm. Thus, according our observation, it induced that 17 goldfish are dead in Weeks 9 – 12. The average growth of lettuces is 1.6 cm. The average growth of goldfish is 0.3 cm. On the other hand, the average pH value of our proposed ratio is 6.9. The value of NO_2 and NO_3 are 0.263 ppm and 14.5 ppm. Although the pH and NO_3 are much stable, 3 goldfish are still dead in our experiment. The average growth of lettuces is 1.8 cm. The average growth of goldfish is 0.3 cm.

IV. Conclusion

Regarding the Taiwan urban conditions and food requirements, this paper studied and implemented one apuaponic system with IoT assisted monitoring. In this paper, we concentrated on the ratio of fish and plants and then determined whether the water recirculation can become balance for fish and plants or not. According to our experimental results, 15 goldfish and 30 lettuces are the optimal combination in our system. Since this ratio may change with different kinds of fish and plants, we utilizes IoT techniques to record all experimental data. In the future, we will try to learn and analyze these data and then build one intelligent IoT automation aquaponic system.

Acknowledgment

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