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Smart Aquaponics: Challenges and Opportunities

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Abstract

IoT in agriculture is rapidly emerging as the need for the production of food increases globally. Smart agriculture with the use of sophisticated machines and prediction tools helps agriculture in the vital production of food more sustainably and ecologically. Aquaponics is a system in which a mixture is bounded by aquaculture as it requires growing fish in a tank and hydroponics involves growing plants with water and nutrients. The use of smart device sensors and computers to analyze the productivity in agriculture also helps aquaponics to improve and yield productivity with more features. However, even after the advancement of technology and researches, the challenges confronted in aquaponics are numerous. Challenges to sustainability revolve around balancing the aquaponics system environment for optimum growth in maximizing production outputs and minimizing effluent discharges to the environment and many more which will be listed in this paper. Aquaponics when combined with a control smart environment can be done anywhere. It allows the profitable growth of large food materials and fish anywhere in the world. This paper specifies about the antiquity of Aquaponics, also interprets the significance of smart aquaponics and their challenges and opportunities in the world of agriculture.

Keyword: Internet of Things, Smart Agriculture, Smart Aquaponics system, Aquaponics, Hydroponics, Raspberry pi , Arduino.

I. INTRODUCTION

Agriculture is the most crucial sector around the world. As the population increases the supply of food production and commodities has also risen from past years. Aquaponics is an organic farming system that incorporates aquaculture also known as aquafarming for the breading of fishes, aquatic plants, and other organisms in a controlled condition or system, and hydroponics for plant cultivation with nutrient-rich water that is supplied from the fish tank, together they produce a high-quality food material more efficiently and productively in the modern world of agriculture. This system was primarily used in china for the cultivation of rice plants where the use of fish excrete and growing food was used. Aquaponics is often hailed as the future mass food production systems. Apart from conventional methods of farming aquaponics systems utilize only 2 to 10 % of the water required in traditional vegetables or crop production and have the potential to produce 10 times the output without the use of harmful chemicals, pesticides. Also, these systems provide organic

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fertilizers which are environment friendly as well as most aquaponics frameworks catch generally 70% of the supplement contribution in the form of fish food and the remaining solid waste is relatively simple to manage. These systems are space-efficient as they can be altered according to the business and day-to-day needs. They are easy to maintain and affordable for installation.

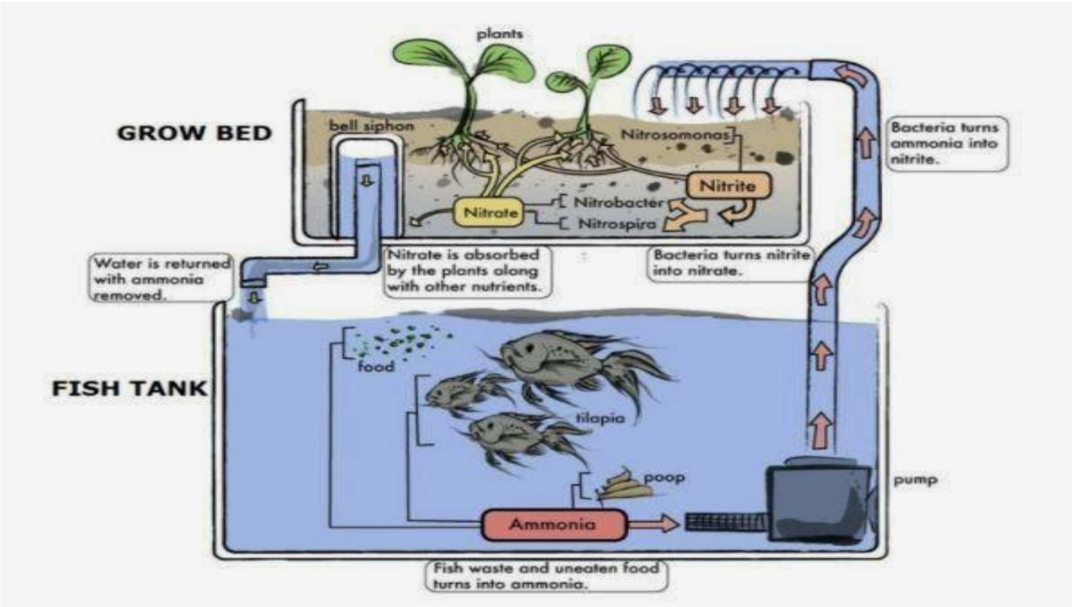

Fig.1 Aquaponics system

In the era of the internet and connected devices Internet of Things plays a vital role in all industries. Having said that, it is anticipated that by the next 30 years the population of the world will exceed 6 billion and the incremental throughput needed to produce food for this population is 70%. IoT-based smart agriculture systems are essential to cope up with this need. IoT enhances the production by real-time crop monitoring that enable farmers to get real-time data of resource utilization and to optimize them, analyze the data and create an efficient automated decision making, life stock smart tracking and management, and smart waste management

II Related work

Smart aquaponics has been introduced so that the conventional method of farming in with soil and water also with the use of conventional methods and energy to produce crop did not get a yield according to the rising population. People have invested time and researches has been done to maximize the yield and decrease the use of water and land.

Sharad R. Surnar et al. [1] a study of the innovative organic farming aquaculture where water is recirculated using motor , the water streams through the bed and back to the tank. This study helps to understand the basic working of aaquaponics system in use and also helps to make it innovative sytem. The study mentions about nutrient requirement , crop selection.

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HarryW. Palm et al.[2] explains about the different aquaponics system designs and constructions that are in use with the different levels of uses they are the open and pond ,domestic ,small scale and large scale or commercial designs.

Christopher Somerville et al.[3] elaborates about the conventional small scale aquaponics system architecture and design also records the design layout, probable cost and estimated project costs.

Peng Chen et al.[4] work such as theirs will help to elucidate the difference between the life cycle assessment of hydroponics and aquaponics in Midwestern countries. Both the systems have an identical design structure with the same yield of production in both the systems.thus coming into a result that the aquaponics system uses less water than hydroponics system. While hydroponics uses nutrient concentration for the plant growth and the ph value in the system will be constant , in aquaponics $KOH/Ca(OH)_2$ were used to maintain the ph in water , as the ph rapidly increases in the aquaponics system due to nitrification. This study clearly explains the advantages and the disadvantages of the systems for farming making both organic farming techniques unique in their own way.

Thu Ya Kyaw et al. [5] demonstrates a full fledged smart aquaponics system with data acquisition unit, alarm unit, system rectification unit, central processing unit, web application, mobile application, and cloud server. The system introduced in this paper works perfectly and can be monitored.

Brandon Yep et al. [8] details about the trends and the challenges of aquaponics system. The article clearly specifies the different trends in plant, animal, microbial organisms and system designs that help aquaponics in a much efficient and promiseing way.

Shafeena T [16] traces out the different challenges and the opportuinities of the smart aquaponics system. Also points out some of the challenges and opportunities of the smart aquaponics system in use. Also describes about the future work that has to be conducted for the smart aquaponics system .

Wanda Vernandhes et al. [18] Smart Aquaponic with Monitoring and Control System Based On IoT by has depicted a system that monitors the light temperature a system that is appropriate for indoor farming. With the help of Arduino , wifi modules and sensors that sends data back to the user.

III Proposed Algorithm

Smart aquaponics is the next step for urban farming. These systems are designed with smart devices that talk to each other to provide information that also triggers the sensors and actuators that serve to optimize agricultural products with the application of technology in it. Hardware components are connected to run the control and monitoring process. The system hardware consists of sensors actuators, relays, Arduino, and raspberry pi. A similarly designed system for urban farming has been mentioned in the paper Fig2. This system helps to monitor, maintain the system efficiently and in a productive manner to produce a good result.

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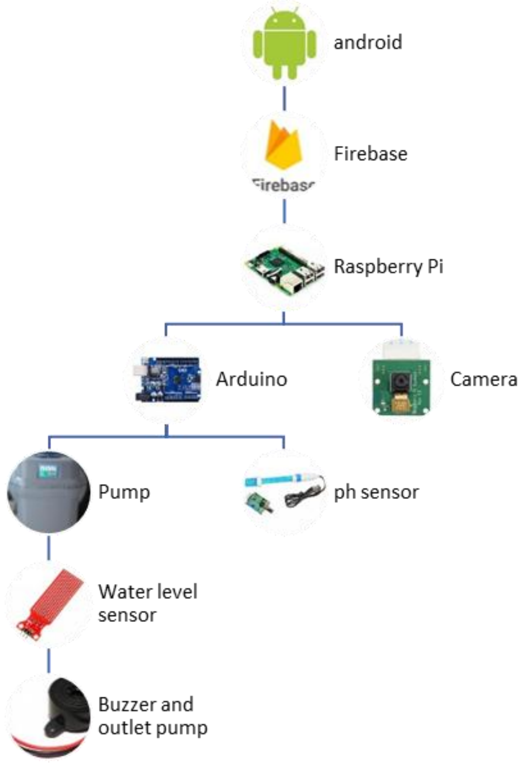

Fig 2. The architecture of a smart aquaponics

This is a system architecture of Smart Aquaponics system for urban residential farming. This system mainly specifies the urban residential area farming where water and space are limited for use. A full-fledged smart aquaponics system is cited [5] by Thu Ya Kyaw, Andrew Keong Ng. In this paper as per Fig 2 mentioned above, the architecture of the system works in a 3 three-layered manner. 1)Application layer 2) Data processing and transaction layer 3) Physical or the network layer

1. Application layer:

   This layer accounts for the Android application that the user uses to control the system. Which is build for the user to monitor and analyze the system for the efficient growth of both the living organisms.
2. Data layer:

   This layer processes the data the is transmitted through the Firebase as the real-time database. In real-time, the data is passed through the hardware to the firebase and at last to the end-user.
3. Physical layer:

   All the necessary connections, sensors, actuators, and all the physical hardware that automates the system works synchronized to make the process much efficient and easy to manage

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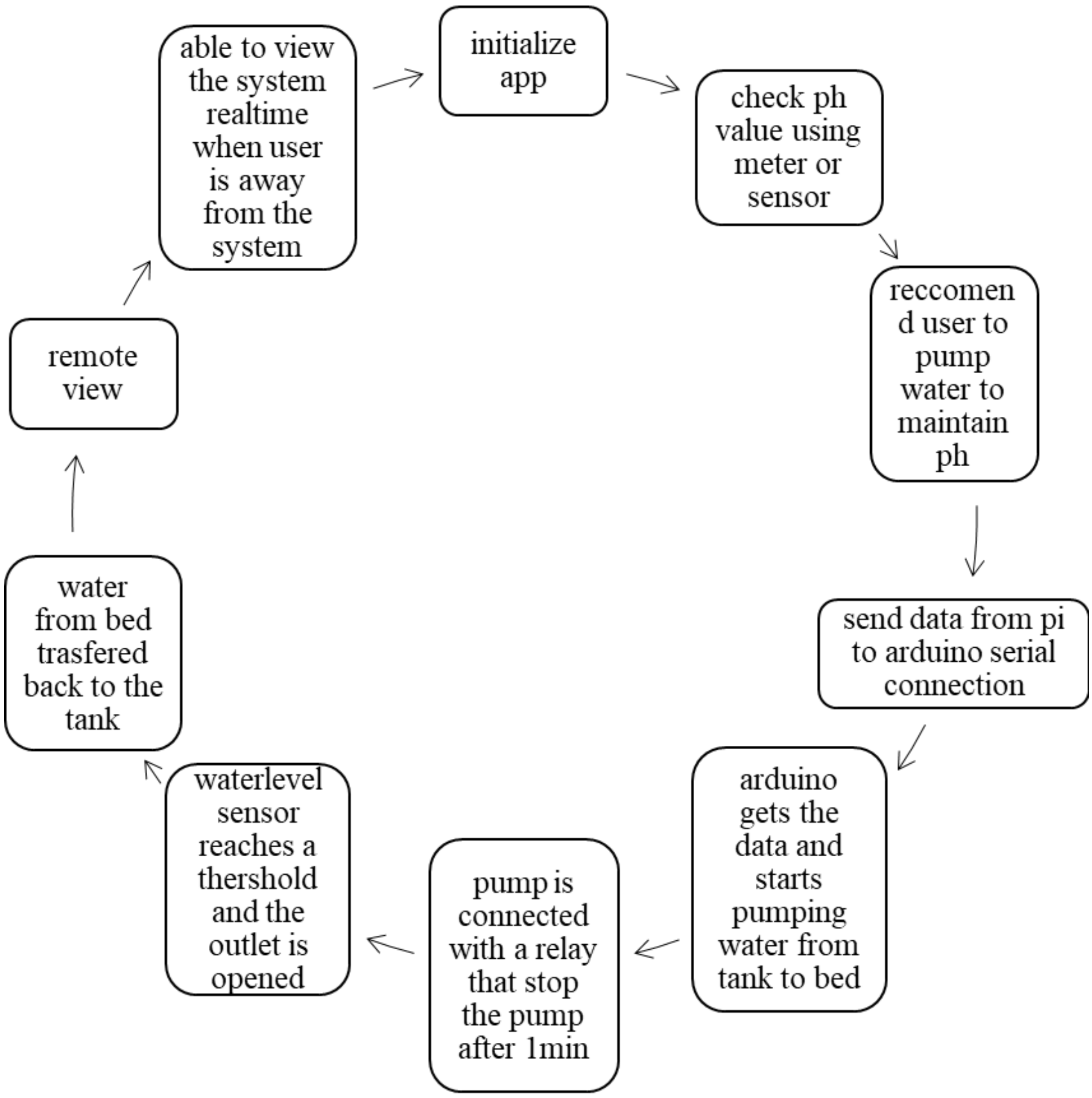

Fig 3 Process diagram of a smart aquaponics system

To begin aquaponics a fish tank that holds fishes rearing and a rock media bed is needed. The ph level in the system is monitored by the ph sensor. Ammonification refers to the ammonia that the fishes excrete while fed. High concentrations of ammonia are toxic to the fishes. Controlling and maintaining a steady range of ph is an important part of aquaculture and aquaponics. Ph control in aquaponics maintenance is in setting a ph level that caters to all the three kinds of living organisms the plant, the fish, and the bacteria in water at the same time. The ph level should range between 6.8 and 7.2, the fish waste in the water can turn the ph level of water acidic. The result of the ph measured by the ph sensor is sent to the user and recommended to pump the water to the bed to maintain the ph level. Therefore a pump removes the fish waste from the tank and cycles the ammonia and water to the grow bed. Beneficial bacteria which inhabits the grow media or bed breaks down the ammonia and converts it to nitrites which are known as nitrification. Further, the bacteria convert the nitrites to nitrates. The converted nitrates are absorbed by the plant roots as their food source known as assimilation. The water level sensor in the bed is programmed with a threshold for the amount of water that needs to be in the bed and the instruction is given to the outlet pump and the buzzer if the water reaches the threshold value of the sensor the water is pumped back to the tank for the fish with maintained ph and oxygenated. Thus the grow media or the bed acts as biofiltration. The camera is installed when to remotely view the system in real-time if water shortage or the quality of the water turned bad.

III. Experiment and Result

Although aquaponics can solve the problems of food security. However, under this study, the challenges and the opportunities are investigated for the betterment of the system and also for future research works that need to be carried out.

3.1 Challenges in a smart aquaponics system

As with conventional farming, aquaponics has a lot of benefits, but it also comes with numerous downsides too. Aquaponics is a modern organic farming method that practices recirculating aquaculture systems. The water that is used for this kind of farming is reused for the plants to grow which in turn, turns out to be not used for fishes. As the dissolved nitrate are harmful to the fishes after so much use of the water.

Excess nitrate dissolved in water in a system can cause overstimulation and mutation to an aquatic organism. In an ideal freshwater aquarium, the level of nitrates in the water should be below 25ppm and not certainly above 50ppm. As to restrict the growth of algae the nitrate level should below 10ppm.

As evaporation is an essential rule of nature the water evaporated by the system can vary according to the size and the use of the system. In a typical aquaponic system water loss is only 1.5% while in a smart aquaponics system this percentile increases as the use of smart devices and sensors connected to the system produce heat and energy. As a result, the water level decreases faster, and the use of water in the system increases.

System contamination is a very big threat in aquaponics as the same water recirculates to the above bed and the fish tank, contamination of the system is not controllable and can spread quickly. The organism that is living in the system needs to be monitored for the healthy growth of plants and fishes. The ideal parameter for an aquaponics system can be considered with a temperature range of 18-30^{o}C, a ph range of 6-7. Some studies help to detect the disease in a plant using Artificial Intelligence, but there is less number of studies that can precisely detect the diseases that occur in aquaculture.

One important challenges in aquaponics system is water choice when encountering Indian agriculture in terms of groundwater and surfacewater quality.

3.2 Opportunities in aquaponics systems

Agriculture in areas of Europe and parts of the world with less water becomes easier and food will be viable to all the people around the world. Thus this way of Organic farming with less water helps the small farmer and commercial agriculture. The opportunities of aquaponics are very large and can support all farming methods. Aquaponics is a promising practise for aquaculture and hydroponics. Aquaponics are now incorporated in build for green building , vertical farming aeroponics and many other methods to cultivate and grow plants have developed. People growing their own small food materials in the their own homes are common now. Thus making agriculture viable for everyone in the world.

IV CONCLUSION

The technique is sustainable and mimics the natural ecosystem and that makes it environmentally friendly as well. This report describes the implementation of a physical IoT aquaponics system. The system monitors, maintain the water quality, recycle water automatically, send a notification to the user, controls light intensity without human intervention. The advantage of the system is that the system does not recycle as in the bell siphon, where it works under hydrostatic pressure. The fish eat the food and excrete waste, which is converted by beneficial bacteria to nutrients that the plants can use. In consuming these nutrients, the plants help to purify the water. You cannot use herbicides, pesticides, or other harsh chemicals in an aquaponics system, making the fish and plants healthful and safe to eat. This smart aquaponics system is designed into three levels application, data, and the physical layer. Future works for the proposed system can be 1) sensor to detect oxygen and nitrate level 2) machine learning techniques for the production increase 3)solar panel for the system to have energy supply 4) provide video streaming 5)automatics feed control

References

1. Sharad R. Surnar, O. P. Sharma, V.P. Saini. **Aquaponics: Innovative farming.** ISSN: 2347-5129 International Journal 2015; 2(4): 261-263 2015 IJFAS www.fisheriesjournal.com
2. HarryW. Palm & Ulrich Knaus & Samuel Appelbaum&Simon Goddek & Sebastian M. Strauch &Tycho Vermeulen & M. Haïssam Jijakli & Benz Kotzen. **Towards commercial aquaponics: a review of systems, designs, scales and nomenclature** https://doi.org/10.1007/s10499-018-0249-z Springer International Publishing AG, part of Springer Nature 2018.
3. Christopher Somerville, Moti Cohen, Edoardo Pantanella, Austin Stankus, and Alessandro Lovatelli, 2014. **Small-scale aquaponic food production – Integrated fish and plant farming**. FAO Fisheries and Aquaculture Technical Paper 589, 2014, pp 288
4. Peng Chen, Gaotian Zhu, Hye-Ji Kim, Paul B. Brown, Jen-Yi Huang. **Comparative life cycle assessment of aquaponics and hydroponics in the Midwestern United States** https://doi.org/10.1016/j.jclepro.2020.122888.
5. Thu Ya Kyaw, Andrew Keong Ng . **Smart Aquaponics System for Urban Farming** Energy Procedia,Volume 143,2017,Pages 342-347,ISSN 1876-6102, https://doi.org/10.1016/j.egypro.2017.12.694 .
6. The aquaponics association. **2020 Statement on the Organic Certification of Aquaponic Crops** 284 15th Street, SE #402 Washington, DC 20003 www.aquaponicsassociation.org
7. Barosa, R., Hassen, S. I. S., & Nagowah, L. (2019). **Smart Aquaponics with Disease Detection**. 2019 Conference on Next Generation Computing Applications (NextComp). doi:10.1109/nextcomp.2019.8883437
8. Yep, B., & Zheng, Y. (2019). **Aquaponic trends and challenges – A review**. Journal of Cleaner Production. doi:10.1016/j.jclepro.2019.04.290

9. C. K. Cheong, A. M. K. Iskandar, A. S. Azhar, *W. A. F. W. Othman, **Smart Aquaponics System: Design and Implementation using Arduino Microcontroller , International Journal of Research ,** https://edupediapublications.org/journals ,p-ISSN: 2348-6848 , e-ISSN: 2348-795X, Volume 05 Issue 21, October 2018.
10. Daniela Pantazi, Serenella Dinu, Sanda Voinea, **The smart aquaponics greenhouse –An Interdisciplinary educational labotatory**, Article no. 902
11. Sandy C. Lauguico, Ronnie S. Concepcion II, Jonnel D. Alejandrino, Rogelio Ruzcko Tobias, Dailyne D. Macasaet, and Elmer P. Dadios , **A Comparative Analysis of Machine Learning Algorithms Modeled from Machine Vision-Based Lettuce Growth Stage Classification in Smart Aquaponics ,** International Journal of Environmental Science and Development, Vol. 11, No. 9, September 2020
12. Sana A.A. Abusin, Brian W. Mandikiana , **Towards sustainable food production systems in Qatar: Assessment of the viability of aquaponics ,** www.elsevier.com/locate/gfs The Social and Economic Survey Research Institute, Qatar University, P.O. Box 2713, Doha, Qatar
13. Zala Schmautz , Carlos A. Espinal , Theo H.M. Smits , Emmanuel Frossard , Ranka Junge , **Nitrogen transformations across compartments of an aquaponic system ,** www.elsevier.com/locate/aque
14. Lars-Flemming Pedersen , Karin I. Suhr , Johanne Dalsgaard , Per B. Pedersen , Erik Arvin **Effects of feed loading on nitrogen balances and fish performance in replicated recirculating aquaculture systems**, www.elsevier.com/locate/aqua-online
15. Moeid M. Elsokah , Malek sakah **Next Generation of Smart Aquaponics with Internet of Things Solutions,** 2019 19th international conference on Sciences and Techniques of Automatic control & computer engineering (STA), Sousse, Tunisia, March 24-26, 2019
16. Shafeena T **, Smart Aquaponics System: Challenges and Opportunities ,** European Journal of Advances in Engineering and Technology, 2016, 3(2): 52-55
17. Daniela Pantazi , Serenella Dinu , Sanda Voinea , **THE SMART AQUAPONICS GREENHOUSE –AN INTERDISCIPLINARY EDUCATIONAL LABORATORY** Romanian Reports in Physics **71**, 902 (2019)
18. Wanda Vernandhes, N.S Salahuddin, A. Kowanda, Sri Poernomo Sari, **Smart Aquaponic with Monitoring and Control System Based On IoT** Computer System, Faculty of Computer Science andInformation Technology, Faculty of IndustrialTechnology, Gunadarma University, Jakarta, Indonesia.