ISBN 978-9937-0-4872-9
September 27, 2018

IOT BASED AQUAPONICS MONITORING SYSTEM

Abhay Dutta
Department of Computer and Electronics & Communication
Kathford International College of Engineering & Management, Tribhuvan University
Balkumari, Lalitpur
abbynuts2@gmail.com

Prayukti Dahal
Department of Computer and Electronics & Communication
Kathford International College of Engineering & Management, Tribhuvan University
Balkumari, Lalitpur
pray4dahal@gmail.com

Rabina Prajapati
Department of Computer and Electronics & Communication
Kathford International College of Engineering & Management, Tribhuvan University
Balkumari, Lalitpur
rabinaprajapati2@gmail.com

Pawan Tamang
Department of Computer and Electronics & Communication
Kathford International College of Engineering & Management, Tribhuvan University
Balkumari, Lalitpur
tamangtara19@gmail.com

Er. Saban Kumar K.C.
Research and Development Co-ordinator
Kathford International College of Engineering & Management, Tribhuvan University
Balkumari, Lalitpur
er.saban@kathford.edu.np

***Abstract*— Aquaponics is a food production method that combines the traditional hydroponics with aquaculture in a symbiotic relationship that facilitates a sustainable system with necessary input as all the water and nutrients within are re-circulated in order to grow terrestrial plants and aquatic life. This technique of agriculture can possibly replace other traditional methods if brought in use effectually. And when traditional Aquaponics meets the technology, remarkable outcomes could become visible. The IoT based Aquaponics Monitoring system features to monitor pH value, temperature and humidity level, water level using the specific sensors has been done and then after perceiving those values from the sensors, the values were displayed through a 16*2 Liquid Crystal Display as well as on the web by the application of Internet of Things. A new technology, Internet of Things has been introduced that bridges the gap between the physical world and the digital world and that starts with things. To connect the sensors with the internet, the database server and application server can be managed so as to display the information regarding the sensors. In order to introduce technology to the traditional aquaponics system, use of Raspberry Pi microcomputer and Internet of Things in the system has been done.**

Keywords— Aquaponics, Aquaculture, Raspberry Pi, Internet of Things.

I. Introduction

Aquaponics refers to the system that supports the dual combination of the aquaculture (fish rearing) and the hydroponics (production of the plants without soil). The excretions of the fish containing ammonia are converted by the nitrifying bacteria into nitrites and then to nitrates which can be used as nutrients for the plants. As compared to the traditional methods of farming, aquaponics is favorable for the place where there is no fertile soil, or lack of water or even lack of free land/soil.

The main objective of this system is to develop an Internet of Things based aquaponics monitoring system which measures and displays parameters like pH level, water level, humidity, temperature, etc. on continuously to the user. Sensors are the hardware components that are used for acquiring information to and from Internet of Things technology. With the application of Internet of Things in Aquaponics system, remarkable changes can be brought in the field of agriculture by simply monitoring and maintaining the system parameters for effective growth of the plants. The use of Wi-Fi of Raspberry helped to connect the system to the web where in the data server stored the values of system parameters like pH value, temperature and humidity in the database and provided the information to the web server where the user can access the data in JavaScript Object Notation format and in graphical format as well. With the application of Internet of Things in the Aquaponics Monitoring system, the values of the system parameters and information can be displayed on the web server continuously.

II. Literature review

The first aquaponics research was held in Canada. It was a small scale system added on to existing aquaculture research at a research station in Lethbridge, Alberta. Aquaponics naturally evolved from aquaculture in an effort to eliminate fish waste. The research made in Alberta has largely been driven by the industry itself as those in the greenhouse strive to perfect models and methods. In the mid-1990s, a number of fish growers in Alberta began the transition into aquaponics by building greenhouses and growing vegetables. The development of modern Aquaponics is often attributed to the various works of the New Alchemy Institute and the works of Dr. Mark McMurtry at the North Carolina State University. Dr. James Rakocy and his colleagues started researches in 1979 at the University of the Virgin Islands and developed the use of deep water culture hydroponic grow beds in a large-scale Aquaponics system. A set up was developed in a greenhouse at Brooks, Alberta where they made findings on rapid root growth in Aquaponics systems and also the system run well at a low PH level favored by the plants [1].

But the developed systems till then were not found to be informative type. The design is based on software and hardware part. The software is required to simulate the circuit using Multisim software, Microchip MPLAB IDE software used to perform the interface to Peripheral Interface Controller (PIC18F4550) and develop the layout of a printed board circuit using the Proteus software. Large amounts of Random Access Memory for buffering and enhanced flash program memory make it ideal for embedded control and monitoring applications that require periodic connection with a personal computer via Universal Serial Bus for data upload or download and/or firmware updates [2].

Globally, there are now hundreds of small scale aquaponics initiatives and several larger scale commercial or near commercial enterprises – the latter mainly in the USA and in particular Hawaii. In parallel with research on aquaponics there has also been substantial research on integrated multi-trophic aquaculture in which fish and plants are grown in more open systems. The classic examples here are of growing caged salmon in close association with mussel and seaweed cultivation. Despite substantial pilot scale research for well over a decade however, these systems have not been adopted on a significant commercial scale, mainly because of the large quantity and low value of seaweed produced, reduced water circulation around the fish cages, and a range of other management issues[3].

One of researcher named Rik Kretzinger designed an aquaponics garden based on Arduino microcontroller. A simple timer performs all functions needed for a stand-alone aquaponics garden. An Arduino Uno microcontroller provides precise control of cycle times, and collects sensor data to show you what’s taking place in the growing environment. An Arduino microcontroller lets you control your garden anywhere in the world. Receive text messages, do data streaming and logging, and more through the implementation of Internet of Things [4].

The use of Internet of Things technology to configure and deploy smart water-quality sensors that provide remote, continuous, and real-time information of indicators related to water quality, on a graphical user interface (GUI) was done in Seattle University by Shiny Abraham, Armand Shahbazian, Kevin Dao, Han Tran. A sensing system comprising of a Raspberry Pi and commercial sensor circuits and probes that measure Dissolved Oxygen, pH, and water temperature was deployed in an aquaponics facility in a town called Manchay, near Lima, Peru. Data acquired from the sensor system is uploaded to ThingSpeak, an Internet of Things analytics platform service that provides real-time data visualization and analysis. Continuous monitoring of this data, and making necessary adjustments, will facilitate the maintenance of a healthy ecosystem that is conducive to the growth of fish and plants, while utilizing about 90% less water than traditional farming [5].

When compared with the traditional farming methods, aquaponics can be taken as the best alternative to it. It has got some really impressive features that can overtake the traditional methods of farming in near future. Aquaponics uses 90% less water than traditional farming. With the aquaponics system, plants can grow any time of year, in any weather, anywhere on the planet because aquaponics recycles the water in the system. For the commercial farmer, aquaponics produces two streams of income, fish and vegetables, rather than just one. In between Aquaponics and Hydroponics, Aquaponics can be considered to be the best option. In Hydroponics, continuous change of water supply is needed because the nutrient solution builds up salts and chemicals in the water. Not only is this wasting more water than aquaponics, it is also polluting the water resources. Nutrient solutions needed for hydroponics are super expensive, where the fish in aquaponics can be fed worms, bugs, etc. Hydroponics revolves around a sterile environment, whereas Aquaponics embraces all micro-organism as they each play an important part in the growing process. Aquaponics tends to have less diseases and pest problems. But for hydroponics, fish culture is impossible. Hydroponic growers can use toxic chemicals to control pests while Aquaponics is completely organic form of farming.

The system based on microcontrollers are seen much more efficient and effective in the field of agriculture. In this project, some modifications has been brought in comparison to the previous systems that were based on microcontrollers like ATMega328, Arduino, etc. In this aquaponics system, Raspberry Pi has been used to replace the previously used microcontrollers. Raspberry Pi has got some extra features which would be much more appropriate for implementation in the project. As seen in the context of Nepal, microcontrollers has not been implemented in aquaponics. Microcontroller based system is obviously going to be more effective than the traditional systems. And in case of Raspberry-Pi, we have an extra feature of Wi-Fi which allows the use of Internet of Things as well. By means of Internet of Things, certainly remarkable changes can be brought to the existing systems.

III. METHODOLOGY

A. Block diagram of the system

The main objective of this system is to develop an Internet of Things based aquaponics monitoring system which measures and displays parameters like pH level, water level, humidity, temperature, etc. on continuously to the user. Real time observations of the water inside the aquarium tank can be done for the favorable growth and survival of the fishes as well as the plants related to the complete system.

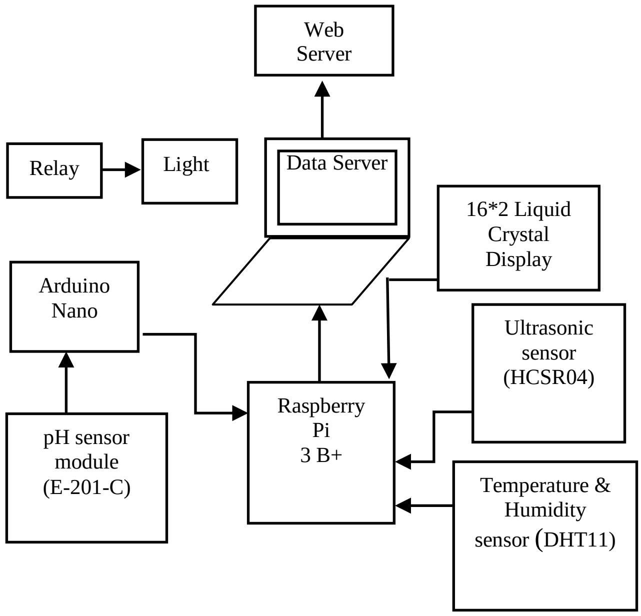

Figure 1: Block diagram of the system

All the system parameters are measured after interfacing of the respective sensors gets done and then are displayed in the 16*2 Liquid Crystal Dispaly which helps in monitoring when the user is around. To perform all these interfacing and processing, Raspberry Pi has been used. But the pH sensor we used happened to be incompatible to the microcomputer thus leading to the use of Arduino microcontroller which converted the analog value coming from the sensor to digital and then the intended tasks were performed through serial communication between the microcontrollers. After that, a relay has been used for the control of light needed for the system. A Printed Circuit Board was designed for the proper placement of the electronic components used in the system. The actual purpose of using Raspberry Pi was not only because of its high speed, low power consumption, etc. but also to use the feature of Wi-Fi in order to implement Internet of Things in our system. The use of Wi-Fi of Raspberry helped to connect the system to the web where in the data server stored the values of system parameters like pH value, temperature and humidity in the database and provided the information to the web server where the user can access the data in JavaScript Object Notation format and in graphical format as well. With the application of Internet of Things in the Aquaponics Monitoring system, the values of the system parameters and information can be displayed on the web server continuously.

B. Flow diagram of the system

With the help of this logic flow, the system has been designed and implemented in order to meet the favorable conditions required by the plants and fishes within the aquaponics system. The system parameters have to be well maintained so that the aim of monitoring the system gets effective.

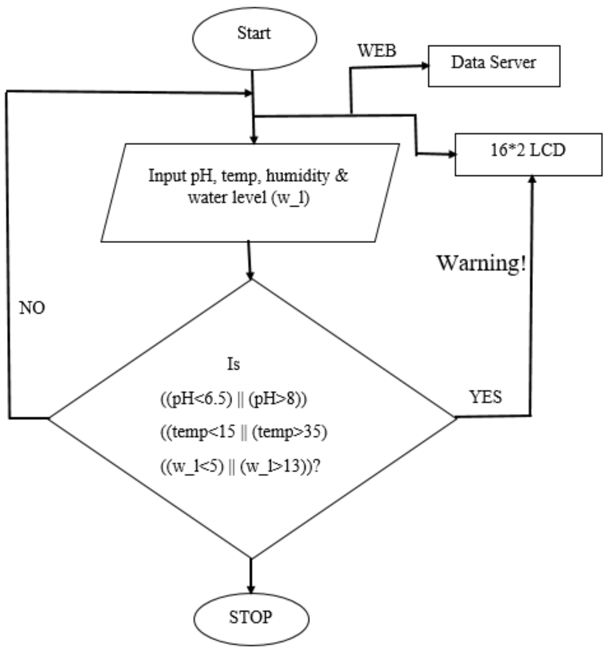

Figure 2: Flow diagram of the system

First of all, the system is initialized. All the sensors start their functioning and then send their values. After that the conditions defined for the growth of plants and fishes are checked. Real time values for each system parameter is displayed on the Liquid Crystal Display and web server. In case of mismatch in defined range for each sensor, the warning message is displayed on Liquid Crystal Display as well as in the web server through Internet of Things. If the data is matched then, no changes to the system has to be made and vice-versa.

IV. RESULTS AND DISCUSSION

A. *Aquaponics system system*

Figure 1: Aquarium setup of the system

The aquarium tank required for the system was built of dimension (30 inch *15 inch *15 inch) with minimal cost and expenses. After that preparation of frame out of the PVC pipes in order to create a space for the plants to grow into the system. Then after that, the proper setup of the tank along with the frame was done by fixing upon a table. The water was filled and the tank was left as it is for some days. When the cycle got ready, 2 pairs of Koi-Carp fishes were kept into the tank for a few weeks. And when the system seemed suitable for use, the frame built earlier was filled with the grow bed (lava rocks). The water was circulated throughout the frame and then back to the tank. 4 more pairs of the same fish was added into the tank for better results. Then, the germinated seeds of coriander and tomato were kept inside the holding cups which had grow bed within them. The observations were done for a couple of weeks without introducing the system to the electronics part.

B. *Monitoring section of the system*

Figure 2: Monitoring section of the system

The monitoring section have been designed and developed in order to detect and measure the system parameters of the aquaponics system. The technologies used to develop this section has made things easier to percept about the favorable conditions required for the fishes and plants to grow within a same combined system. Different sensors have showed different types of readings when compared for a week, the data that has been acquired through the used sensors have been showed below:

- Data from DHT11 sensor:

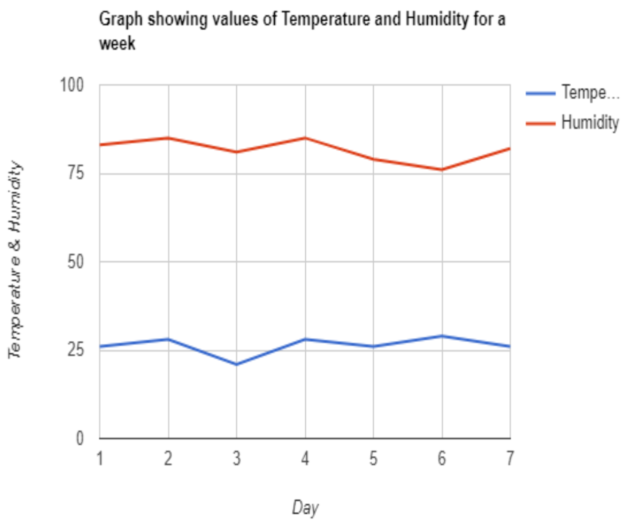

Figure 3: Graph showing Temperature & Humidity of the system

The suitable range of temperature for the growth and survival of plants and fishes inside the system is in between (15-35) degree Celsius. The readings were taken for a week and the system was seen very favorable in the development of a healthy system.

The suitable humidity for the growth and survival of plants and fishes inside the system is in between (75-90) %. The readings were taken for a week and the system was seen very favorable in the development of a healthy system.

- Data from E-201-C sensor:

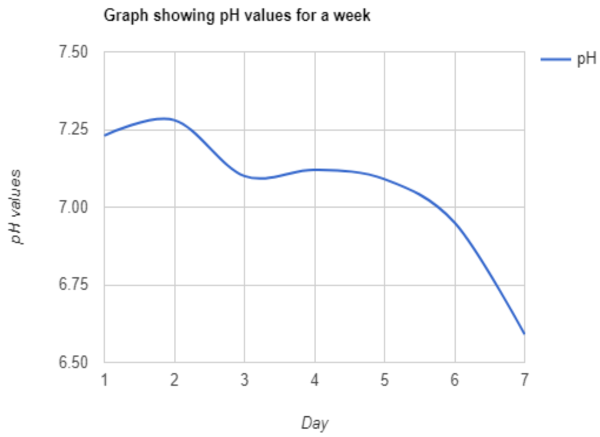

Figure 4: Graph showing pH values

The suitable pH range for the growth and survival of plants and fishes inside the system is in between (6.5-8). The readings were taken for a week and the system was made favorable in the development of a healthy system.

C. *Graphical representation of system through Internet of Things*

Figure 5: Graph showing system parameters

The acquired values from the Temperature & Humidity sensor and the pH sensor module was sent to the data server which firstly stored the values of the three parameters in MySQL database and finally the information concerning the sensor values were shown in the web portal continuously in JavaScript Object Notation format until the system components and server were on running condition. The figure above shows all the system parameters in the graphical form. It shows how the values differ within a certain interval of time and what changes are seen in the system when the values deviate from the specified range. Also, the growth of tomato plants and coriander plants have been presented through by the help of pictures below:

(Growth of tomato plants in 12 days)

(Growth of coriander plants in 12 days)

D. *Discussion*

As per the objective specified, IoT Based Aquaponics Monitoring system was developed with the use of Raspberry Pi as the main controller and Internet of Things as the exclusive feature in the system. This system can monitor the values of system parameters like pH value, temperature & humidity of the room, water level in the tank, etc. in real time basis. Monitoring the basic parameters in the system has really helped in the growth of plants and fishes well. Also, to maintain the light in the system, a relay has been employed which is programmed in such a way that light is automatically switched on/off in a specified interval of time. In the system, if there happened to be deviation from the specified range then, suitable changes were made in order to make the system stable and effective. The observations and readings were taken in order monitor the actual growth of plants in the standard conditions for each parameter. This system was able to give the output as per the research done comparing different other projects and papers. It is found through the result that this system can become the best alternative for traditional farming as well as hydroponics. By the use of Internet of Things in this system, system parameters can be viewed anywhere in the world. Though Internet of Things has been already implemented in the field of Aquaponics in some other parts of the world, Nepal still lags behind in this field of agriculture. And through this project, the requirement of plants were maintained and monitored. This has helped in achieving the suitable conditions when technology got introduced to a kind of traditionally working system. So, the Internet of Things and microcontroller based aquaponics can bring revolution in the field of agriculture.

V. CONCLUSION

The existing problems seen in the traditional aquaponics system can be detached by the introduction of electronic approach in the system. And this can encourage people to produce organic and healthy plants for daily use or consumption in their own household. For this project, the setup of an aquaponics system consisting of fish tank and grow bed for plants was done. Then, a monitoring section was established in order to detect the water level, pH value, temperature and humidity of aquaponics system by the use of Ultrasonic sensor, pH sensor module and Temperature and Humidity sensor (DHT11) respectively. All these sensors were interfaced to the Raspberry Pi microcontroller. Then finally the system parameters were displayed through Liquid Crystal Display and Internet of Things successfully. Also, a relay has been used for light controlling feature. Raspberry Pi has allowed the system to be Internet of Things based. By the application of Internet of Things in this system, it has been possible to view the readings from anywhere in the world and also it provided the graphical and analytical view of the system parameters which define the IoT Based Aquaponics Monitoring System.

ACKNOWLEDGMENT

It gives us great pleasure in presenting this project titled: “IoT Based Aquaponics Monitoring System”. We would like to deeply express our gratitude to our respected principal Dr. Madhu Sudan Kayastha and the management of Kathford International College of Engineering and Management for providing us an ideal atmosphere here to build up this project with well-equipped store and library with all the utmost necessary reference materials. Also, our parents who supported us every time during this project. We are extremely thankful to the faculty members and the seniors of the college who provided us all the facilities, resources and knowledge required for this project.

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