PLC-based Automated Aqua-Hydroponics System

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Abstract. Aquaponics refers to the growth of fish and plants in a single platform. As the demand for land increases due to urbanization, the growing of crops and other vegetables with less soil area is needed. Growing plants and aquatic animals in the same environment will save the usage of soil and the consumption of water levels will also be minimized. To automate the Aquaponics environment and to monitor the plant growth from the seed level to the fruiting level, a system is designed. This proposed method will help the user to monitor the water quality parameters like pH, humidity, and temperature and intimates the user about the current level, and alarms the user for any overshooting. The proposed system is designed, fabricated, and tested in laboratory conditions. The plant growth is monitored from the starting seed stage to the final fruiting stage. The essential nutrients required for plant growth are monitored and the discrepancy is satisfied accordingly. The bacteria and the microorganisms present in the soil decompose the plant waste into food that aquatic animals consume. The remains and excreta of the aquatic animals are sediments and given to plants as nutrition. Due to proper plumbing, water consumption is reduced. Different plants require different nutrient levels for their growth. The nutrient levels are listed and the test values are loaded into the microprocessor according to the plant selected. Here spinach is selected. The pH level, temperature level, and humidity levels of the soil and the water are monitored and the values are updated to the user using the web interface. From the web page, the user can get the parameter values and a comparison can be made accordingly.

1. Introduction

Aquaponics was coined in the early 1970s and became famous over the years. It was first adopted in countries where the land space is not sufficient to progress in cultivation. Aquaponics is a combination of aquaculture and hydroponics. Aquaculture refers to the growing of aquatic animals and harvesting them. Hydroponics is the technique of growing plants in soil-less conditions but rich in nutrients. In recent years hydroponics has gained the most popular due to the non-availability of land. We have to search for new agricultural techniques to serve the overpopulated world [12]. In order to feed the unnourished and poor people all over the world, the techniques like hydroponics are implemented. In general, Aquaponics is a technique to grow aquatic animals like fish and do agriculture at the same time. Agriculture means we can grow paddy as well as vegetables on our rooftops. The cost of Aquaponics is very less as we serve only the fish and the remains of fish are served as the input for agriculture. The fish excreta is rich in nutrients. This avoids the usage of fertilizers for our plants. The water usage and land usage in Aquaponics are very less when compared to aquaculture and agriculture separately. As we have avoided pesticides and other harmful fertilizers, the yield from the plants gives us healthier and organic foods. The measurement of soil quality parameters is also very important in agriculture. The yield will be more when the suitable plantation is done according to the type of soil. The soil quality is analyzed with various methods. Earlier, it was done

directly by the farmers by visiting the lands and inspecting them. But this method is not accurate. Then the physical method is used to find the soil depth and the types of pores. The biological method is used to find the microorganisms and bacteria present in the soil. Currently, we are using chemical methods to find the soil pH, salt content, chemicals, and composition present in the soil. This chemical method provides accurate results and it is a commonly used method [8].
The main components of Aquaponics are a rearing tank. This tank holds the fish. Here the fish is grown. Below the tank, there will be a settling bin for collecting the excreta from the fish and other fine materials. Then bio filter portion will help in converting ammonia into nitrates which the plants consume. The sump system helps to collect the cleaned water from the plants and then drive them back to the fish tanks. The water pumping and draining are taken care of by the DC motors. All the tanks are connected internally with the help of a plumbing system. The pipe materials are selected according to cost and quality. PVC pipes are commonly used because they are easily available and have moderate quality. The vinyl is of low quality but it is very cheaper. The steel and copper pipes are of high quality but it is very costly [4,6]. The comparison between hydroponics, Aeroponics, and Aquaponics shows that the saving of water, soil, and fertilizers are very less in Aquaponics. Aeroponics is the technique of growing plants in the air. The comparison is listed in the table and illustrated as a graph [3].

Table 1: Comparison of different techniques

Parameters	Hydroponics	Aeroponics	Aquaponics
Water Consumption savings	80	85	90
Fertilizer savings	55	85	90
Production	75	100	125

The comparison shows the advantages of Aquaponics when compared with Aeroponics and Hydroponics. Water consumption is more in Aquaponics and the usage of fertilizers is also less. Productivity shows a drastic improvement in terms of quantity and quality. The output is fertilizer and pesticide free.

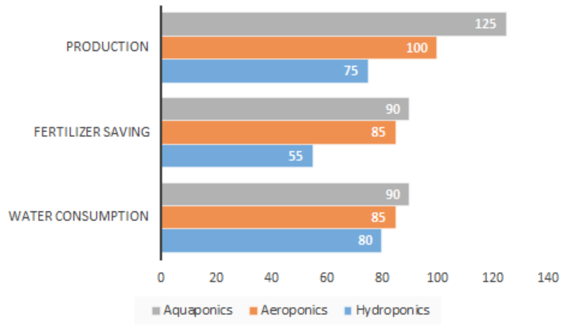

Figure 1: Comparison of different agriculture methods

The plants and fishes that are commonly grown in Aquaponics environments are listed. The common fish grown is Tilapia. This fish is inexpensive and do not have great taste. This fish needs less maintenance and it is consumed by more people. Any leafy vegetables like lettuce, and cauliflower and herbs like basil can be grown in the Aquaponics environment [7,10].
We have worked on this research paper in the following way. The introduction about Aquaponics and the importance of soil are discussed in the introduction part. The advancements in the research area are studied by conducting a detailed literature review and the difficulties of most of the authors faced are summarized. The proposed methodology is studied and the extensions are implemented. The hardware components are handpicked and the test circuit is drawn and simulated. The threshold values of the different parameters used are fixed after studying the soil parameters. Then the test circuit is transferred as a proposed model with hardware implementation along with the software programming. The interaction between the hardware and the web is carried out and the user is alerted to the values present as a graphical representation.

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2. Literature Survey

Slamet W [15] has developed a system to monitor the radial growth of guava fruit using IoT. A reflective tape is wound on the guava fruit. The optoelectronic sensor senses the changes in the bar code of the reflective tape. The data collected is monitored and real-time analysis is done. The developed system can measure the radial growth of the fruit with a 2mm error and the success rate is 97.54% Mi-Hwa Song [11] has developed a smart gardening system that is able to auto-monitor the humidity and temperature of surroundings, air quality, and soil moisture. He has used Node MCU in the IoT platform to collect the data from the sensor. By analyzing the data the system is capable of initializing automatic irrigation of the soil when the soil moisture is low.

Ranjit Raut [13] has analyzed the specific relationship between Physio-chemical parameters, soil micronutrients, cropping patterns, and pH. From the analysis, he has found that the pH will affect the physical and chemical properties of the soil. So continuous irrigation, canal water, and the use of fertilizer have an adverse effect on the soil parameters. Shahana Firdous et.al [14] have analyzed 10 soil parameters statistically. Analysis of variance (ANOVA), cluster analysis (CA), and principal component analysis (PCA) was performed to evaluate correlation in soil quality parameters on spatiotemporal and vertical scales. This analysis has greatly reduced the sampling sites and helped in water management also.

A B Kalinin [1] has developed a system to eliminate soil compaction. He used digital measurement of parameters so that the soil state is monitored up to the depth of 60cm. The data obtained are used to select rational settings for sub-soil to fulfill the required indicators of the quality of tillage while minimizing energy consumption. Jason J. Danaher [9] examined the growth of plants and other aquatic animals by monitoring the water quality parameters. Abigail J. Lynch & Cooke S.J [2,5] informed the importance of fisheries in social and other related areas. He posted that the conservation of resources in the aquaculture field will yield good results.

3. Proposed Methodology

Due to overpopulation and the non-availability of the land surface for agriculture, the proposed model is fabricated. This proposed model is tested on the rooftop and the results are satisfactory. This model can be extended to any land area and the system will adapt accordingly. The monitoring of soil parameters and the service accordingly will help the user to get detained from the system.

3.1. Problem Identification

As the earth is insufficient of land due to buildings, industries, and residential complexes, an optimal solution to grow plants without soil and conservation of water, land, and fertilizers is proposed. Since Aquaponics is an emerging solution for the above-said issues, advancement in the proposed area is required. Moreover, the monitoring of soil parameters along with seed growth monitoring is not available in the market.

3.2. Proposed Model

The model has two modules. The first one is the control side, which has a processor along with the sensors. The sensor values along with the programming control the processor. The other side is the plant/fish side, where the parameters of the soil and water are monitored using sensors fixed. The whole setup values can be monitored by updating the values in the website using the Internet of Things.

3.2.1 Essential components of the proposed Method

The essential components are classified into two categories. Living and nonliving components. The living components consist of plants, fish, and bacteria. The other components are sensors, processors, connecting wires, pipes, fish tanks, and a soil bed. The living components are classified as fish and plants.

The fishes like Tilapia are commonly grown in the Aquaponics environment. It is a freshwater fish and it is commonly found in rivers, lakes, streams, and ponds. The reason for growing this particular fish is that it can tolerate any pH change, temperature change, and levels like ammonia and oxygen. Even if the levels are either up or down, this fish will grow for about 9 months and no harm will occur. The commonly grown plants in the Aquaponics environment are creepers (Watermelon, Cucumber, Bitter Gourd, and Ridge Gourd), Underground (Radish, Garlic Chives, and Carrot), Herbs (Celery, Rosemary, Parsley, Oregano, Thyme, and Sage) and plants (Brinjal, Capsicum, Green Chilli, Lady’s Finger and Tomato) The specifications of the materials used are presented in Table 2.

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Table 2: Specifications of the components

Components	Specifications	Remarks
Plastic Tray	51 x 27 cm	Rectangle
Piping	3 mm x 5 mm	Silicone
Fish Tank	48x21x28 cm	Glass
Layers	Clay, coco, net, Foodgrade	Growing area
Nutrition tank	Nitrogen, Phosphorous, and Potassium	
Processor	Supporting NodeMCU	
Sensors	Soil moisture, pH, Humidity	
Relays	4 channel	
motor	DC submersible	

3.2.2 Proposed model Block diagram and specifications

The proposed work is divided into two blocks. The main block is the control side which has sensors, processors, motors, light control, and IoT display interfacing. The raw seeds before germination are kept in coco-peat cups. These cups are used in gardening as a medium alternative to soil. It is produced from coconut fibers. The waiting period will be started until the seeds start germination. Once the waiting period got over, the germinated seeds are planted in the grow bed. The second block in our proposed system is the continuous monitoring of the germinated seeds. The seeds need enough water and nutrients for their growth. The water level needed is monitored by the moisture sensor and the nutrient levels are monitored by the pH sensor.

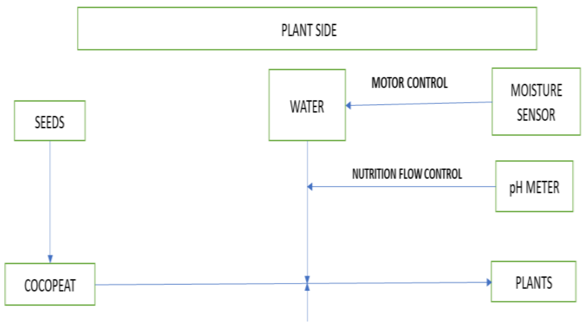

Figure 2: Block diagram – Plant Side

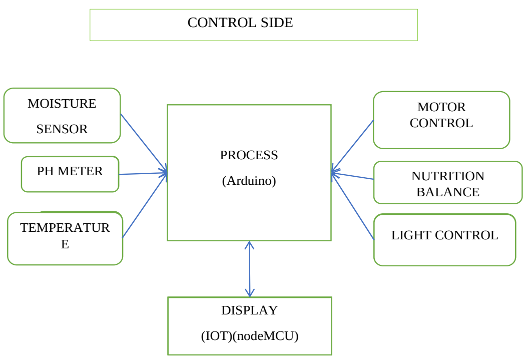

Figure 3: Block diagram – Control Side

This cycle of monitoring the temperature, pH, and humidity will be continuous and the measurements are transferred to the user through IoT. The proposed model is implemented by carrying out the workflow. Initially, the process is studied in detail. Then the necessary materials are collected and the specifications are noted. Next, the designing happened in two dimensional. Since the proposed model has both aquaculture and hydroponics, the fish tank and plant growing bed are fabricated using the materials collected. Then the connections are provided. PVC connections and the electronics side connections to the processor are done. Finally, the observations are noted and the analysis is done on the calculated values. The necessary parameters are displayed in the display device with the help of IoT.

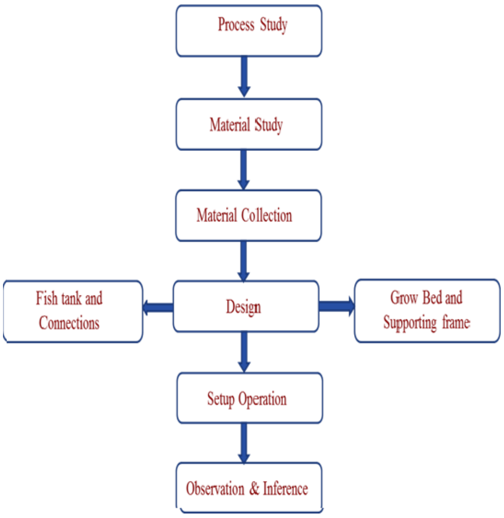

Figure 4: Workflow diagram of the proposed model

3.2.3 Hardware and Software design

The parameter measuring sensors used are pH sensor, Humidity sensor and moisture sensor. The processor used is Arduino Mega and fan is used as a temperature controller. Four subimersible motors are connected to the processor using the 8 channel relay module. The relay circuit helps in connecting the interfaces like motors, bulbs to the processor and the interfaces can be controlled by the processor through the relays.

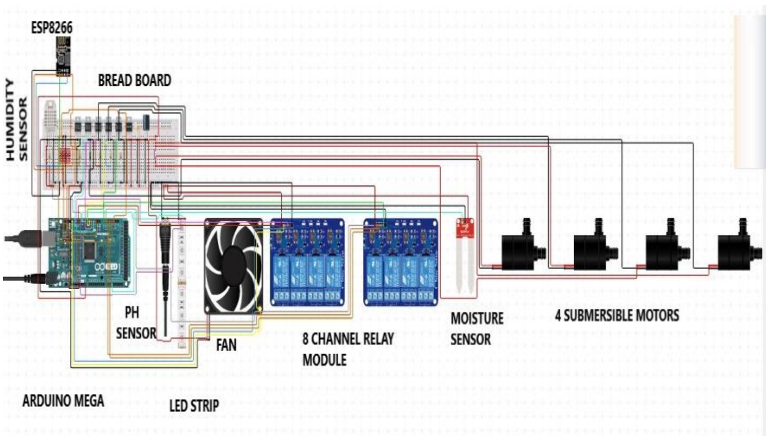

Figure 5: The hardware design of the proposed model

The other components like the fish tank and the plant growth bed are designed as per requirements. The Delta PLC programming software is used for the simulation of the proposed system. This software is preferred as it can be used for large-scale applications. The PLC ladder diagram is drawn for easy understanding of the process.

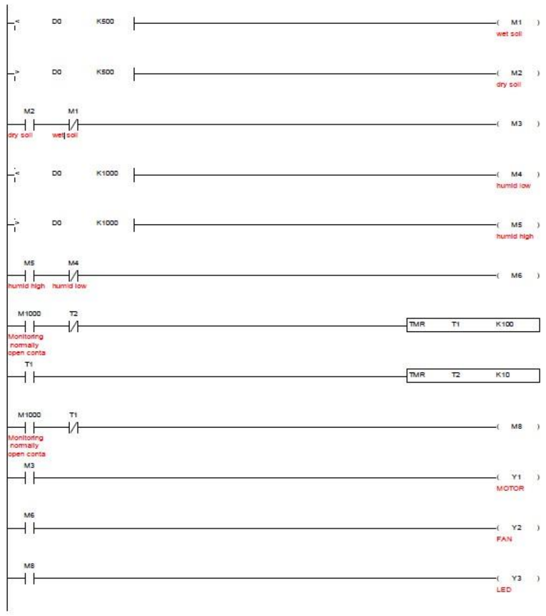

Figure 6: PLC Ladder Logic Program

3.2.4 Target values of the parameters

The water quality parameters mainly monitored in Aquaponics are dissolved oxygen, pH, temperature, hardness, and the dissolved nitrogen components. The growing cycle of any plant has five phases. The amount of water and other nutrient requirements will vary accordingly. The five phases of the plant life cycle are germination to a sapling (P1), vegetative growth beginning (P2), advanced stage of growth (P3), flowering stage (P4), and fruit formation (P5).

Table 3: Nutrient level requirements

Plant Varieties	pH Zone	Nutrient level for each growth stage NPK (ml/L)				
		P1	P2	P3	P4	P5
Coriander	6.0-7.0	0.5	1	1.5	2	2.5
Mint	5.5-6.5	0.5	1	2	2.5	3
Sprouts	6.0-7.0	1	2	3	4	5
Ladies Finger	6.0-7.0	0.5	1	2	2.5	3
Tomato	5.5-6.5	1	2	3	4	5.5
Spinach	**6.0-7.0**	**0.5**	**1**	**1.5**	**2**	**3**
Peppers	5.5-6.5	0.5	1	2	2.5	3
Onions	6.0-7.0	0.5	1	1.5	2	2.5
Capsicum	6.0-7.0	0.5	1	2	2.5	3
Beans	5.5-6.5	1	2	3	4	5.5

The pH levels and the requirement of nutrient levels will vary for plant varieties. We have used spinach as the plant variety for the proposed model. The ph value must be maintained from 6-7 and the nutrient level increases for different phases. Growing tomato in an Aquaponics environment is difficult because the nutrient requirements are very high. The fixed target values are monitored by the sensors and the deviation is corrected and intimated to the user by the web interface.

3.2.5 Experimental setup of the proposed system

After the initial designing of hardware and software is completed, the experimental setup is fabricated accordingly. As the proposed system involves setting up the fish tank and the plant grow bed simultaneously, great care must be taken. The piping system is carefully designed and the water leakages must be checked as the leakage may damage the wiring connections.

Figure 7: Plant growth bed setup

Figure 8: Hydroponics Fish tank setup

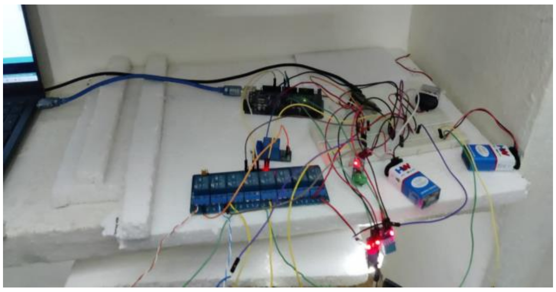

Figure 9: The hardware setup of the proposed system

The proposed system has three stages. The first stage is the preparation of the growth bed. The plant germination stage is monitored separately and the plants are shifted to the growth bed after germination. The growth bed is filled with clay pebbles. The second stage is hydroponics. The fish tank is taken for prototype and the parameters are monitored accordingly. The final stage is automation. The essential parameters are monitored using the sensors and the control of the parameter target values are done by the processor and the user will be provided with real-time values using the Internet of Things.

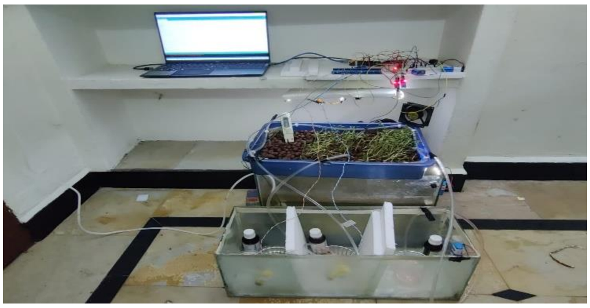

Figure 10: Final experimental prototype of the proposed system

4. Inferences from the results

The final prototype is designed and fabricated. The test values are loaded into the microprocessor using coding. The web interface is initiated and the values of pH and humidity will be plotted as a graph. The graph is provided with values on the y-axis and time on the x-axis. The target levels can be fixed and the user is alarmed by the faulty values. The target values of pH for our growing specimen is 6-7.

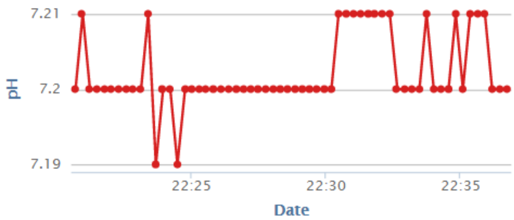

Figure 11: pH Measurement

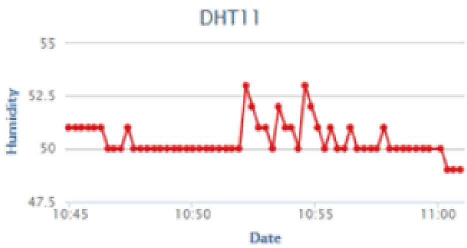

Figure 12: Humidity Measurement

5. Conclusion and future scope

The agenda of the designed system is to promote Aquaponics in an automated scheme. Since Aquaponics is an emerging area in the overpopulated world, automation and monitoring of the parameters which is necessary for the growth of plants and aquatic animals will provide good yields. The proposed work helps the user to monitor the growth of plants from the seed stage to the fruiting stage. Moreover, the main parameters of water like pH, temperature, and humidity are continuously monitored and displayed to the user through the web interface. The target values of the parameters can be updated in the microcontroller and the user will be alarmed when the values get overshot.

6. Acknowledgement

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7. Compliance with Ethical Standards

7.1 Funding

The authors declare that they have no conflicts of interest to report regarding the present study.

7.2 Ethical Conduct

This chapter does not contain any studies with human participants or animals performed by any of the authors

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