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Design and Implementation of an Automated Aquaponics System using Internet of Things

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Abstract

Agriculture is one of India's most vital industries. Everyone's basic need is food. Traditional farming, on the other hand, has the disadvantage of being reliant on soil quality, climate, chemical fertilizers, pesticides, and water. There is a technique called Aquaponics, combination of aquaculture and hydroponics. It might be utilized to solve the issues of traditional farming. Aquaculture is concerned with the expansion of fish, while hydroponics is concerned because of the rise in soilless plants by giving necessary nutrients. Aquaponics technology that will supply the country with natural food. Because this method reuses water, it takes up less space and provides natural food to the user. We're using an Arduino to control fish feeder that runs on its own with a servo motor and a timer. It'll provide food for the fish every 12 hours. Because we're using a real-time clock, we can schedule it whenever we choose. Aquaponics can be managed and controlled automatically by making use of the Internet of Things and sensors such as pH, temperature, and humidity, water flow, water temperature. Operating sensors on microcontrollers such as NodeMCU and Arduino UNO, the results of which is readily available via the Bevywise application for monitoring purposes. This method may be used to create both an indoor and outdoor system.

Keywords: NodeMCU, Aquaponics, Aquaculture, Hydroponics, Internet of Things, Bevywise, Fish feeder, Real Time Clock

Introduction

Agriculture has provided natural food to the majority of the world's population, but in recent years, the use of pesticides to accelerate crop growth has increased, causing harm to human health and increasing soil problems [1]. Aquaponics is a term used to describe a method that combines aquaculture (fish farming) and hydroponics (growing plants) (generation of plants in the absence of soil). The nitrifying bacteria turn ammonia-containing fish excretions into nitrites, which are then transformed to nitrates, it is suitable for usage as plant nutrients [2]. We've built a system for aquaponics that addresses both soil and natural food challenges. It's good for areas where fertile soil is scarce, water, or even available land [3]. The objective is to show that this system is with the aid of the IoT domain, we can keep track of everything. It continuously monitors and shows factors like as pH, water level, humidity, temperature, water flow etc., to the user [4]. The physical elements that collect and communicate data are known as sensors. By just observing things, the configuration effective methods for plant growth, significant advancement in the globe of agriculture is a viable option brought about using IoT in Aquaponics systems [5]. NodeMCUs are used in a number of ways Wi-Fi enabled the system should be able to obtain access to the internet, where the data server system variables were saved in parameters such as water flow, temperature, and humidity in a database and gave the information to the server, where the information was available through the Bevywise dashboard and in graphical format [6]. The system's specifications and their values and information can be shown on the web server through Bevywise dashboard continually using the Internet of Things in the

Aquaponics Monitoring system [7]. The sensors are employed to collect data that will tell us whether or not the system is operating normally. That information is going to be transmitted to the cloud, which will store the readings and transmit them to the Bevywise dashboard. Sensors, Arduino, and the cloud are utilized to collect data and show it [8]. The feeding of fish is necessary to do on time, and it should be computerized in order to set a specific length of time for feeding fish. When the setup is fully automated, it will eliminate the majority of farming's human labor and aid in plant development that is more natural [9]. The lack of natural food in today's environment has resulted in a slew of health complications. Also, for faster plant growth, artificial fertilizers and chemicals are utilized, causing the soil to lose its natural state, which takes years to reclaim. Farmers have no choice except to grow plants artificially using pesticides and fertilizers [10]. The following are advantages of combining Aquaponics and IoT:

i. Fertilizers are not necessary since the fish offer abundant nutrients to the plants.

ii. Because there is no soil in aquaponics, we won't be exposed to soil-borne infections.

iii. Aquaponics is a technique for simultaneously growing fish and vegetables. We provide food for the fish, and the fish, in turn, provide food for our plants through their waste.

iv. Water is used more efficiently since it is reused. Farmers no longer need to rely on precipitation for irrigation.

v. Plants and fish can be grown in a climate-controlled environment.

This study focuses entirely on current developments in soilless farming, specifically aquaponics, which has made it possible for individuals to farm or even farmers to use.

Literature Review

The aquaponics system using a diverse set of components, including a pH sensor, temperature sensor, grow bed, and nodeMCU. With the help of thingspeak and nodeMCU, water conditions such as pH and temperature are relayed to the pocketIOT app [11]. Authors explained based on the Arduino microcontroller, developed an aquaponics garden All of the functions needed for a stand-alone aquaponics garden can be handled by a simple timer [12]. Authors proposed the architecture of an IoT-based water quality monitoring technology that continually examines the nature of water. This system includes a number of sensors that monitor water quality criterion such as pH, turbidity [13]. Smart Grow box is a smart box design with many features as an environmental engineering supporter with various sensors and actuators that help to optimize agricultural goods through the use of technology [14]. The paper Automatic Controlling Feeding in Dense Aquaculture fish tanks describes an effective visual signal processing method to regulate the feeding of fish in an aquaculture tank on a continuous basis [15]. The suggested system can continually monitor and adjust water quality and fish feed; convey early warnings via email, SMS, and push notification; and correct system abnormalities that don't need the use of human intervention. The Intelligent Voice Control System (IVCS) of the IoT was proposed to alleviate the problem of farmers who are unable to use information interfaces. IVCS can lower the barrier to entry for partners interested in the development of science and technology agriculture, inspiring more diversified applications to successfully increase agricultural, fishing, and plantation production efficiency [16]. presented an aquaponics automation system. Their design can detect the water's pH and electro-conductivity. For user access, they employed TCP protocol and a web server. In addition, fuzzy logic is used in this study to increase productivity and precision of decision-making in the control system. Experiments with bok choy and lettuce show that the device detects nutritional value and pH automatically according to the timer [17]. The successfully constructed prototype unit is being tested and operated at the departmental level. The aquaponics system has produced a good output of vegetables. Illustrated the burst location and confinement plot for water distribution networks, which combines lightweight pressure and inconsistency detection with diagram topology analysis [18]. It controls cycle times precisely and collects sensor data to show what's happening in the growing environment. Through the implementation of the Internet of Things, we can receive text messages, stream and log data, and much more [19].

Proposed Method

Recent developments in detection, technology, and the IoT have resulted in significant advancements in the applications of environmental monitoring. The major goal is to create an IoT-based aquaponics monitoring system that constantly monitors and shows data like as pH, water level, humidity and so on to the user. Real-time assessments of the water inside the aquarium tank may be made to make certain the fish and plants in the system thrive and survive in a healthy environment. We begin by connecting sensors to Arduino and interacting with it (pH, turbidity, temperature, dissolved oxygen, and electrical conductivity). ADC is the process of converting analogue sensor data to digital data (real-world data) (analog to digital converter). Arduino is used to manipulate the data. With a serial communication between Arduino and NodeMCU, all processed data is sent to NodeMCU. The systems parameters and information may be shown on the server through Bevywise dashboard constantly with the implementation of Internet of Things in the Aquaponics Monitoring system. The components indicated below are utilized in the operation of the aquaponics system, as are the sensors, which are used to manage worst-case circumstances. Sensors are the most frequently used component for the proper working of the system because if any abnormal conditions arise, the sensors will always provide readings for awareness. In this section we tend to discuss concerning many parts operating procedure.

Hardware

The hardware component is central to our proposed method, which consists of several elements.

1. **sensors**: Data collection and acquisition from the environment and water (pH, temperature, etc.) to assess the environmental conditions of fish and plants.

Temperature & Humidity Sensor: The suitable vary of temperature for the sake of growth and survival of plants and fishes within the system is in between (15 - 35) degree centigrade. The suitable humidness is in between (75 - 90) %. It is placed outside the carters to work out close temperature and humidness.

Water Level Sensor: It will keep an eye on the problem and take preventative measures of water from overflowing within 0.02 kg/L. If the sensor delivers a signal that the water level is dropping, the system will tell the pump to continue pumping water from the source until the target water level is attained.

Turbidity Sensor: The Turbidity Sensor detects the amount of turbidity in freshwater (0 – 4500mg/l). It determines the quality of water by measuring the quantity of turbidity in it.

pH Sensor: The pH sensor Module consists of a pH sensor (also known as a pH probe) and a signal conditioning board that produces an output proportional to the pH value and may be connected to any controller directly. It measures the pH of the water in the fish tank as well as the pH of the plants. The ideal pH range for plant and fish growth and survival within the system is between (6.5-8).

The Figure 1 Block diagram of Automated Aquaponics System

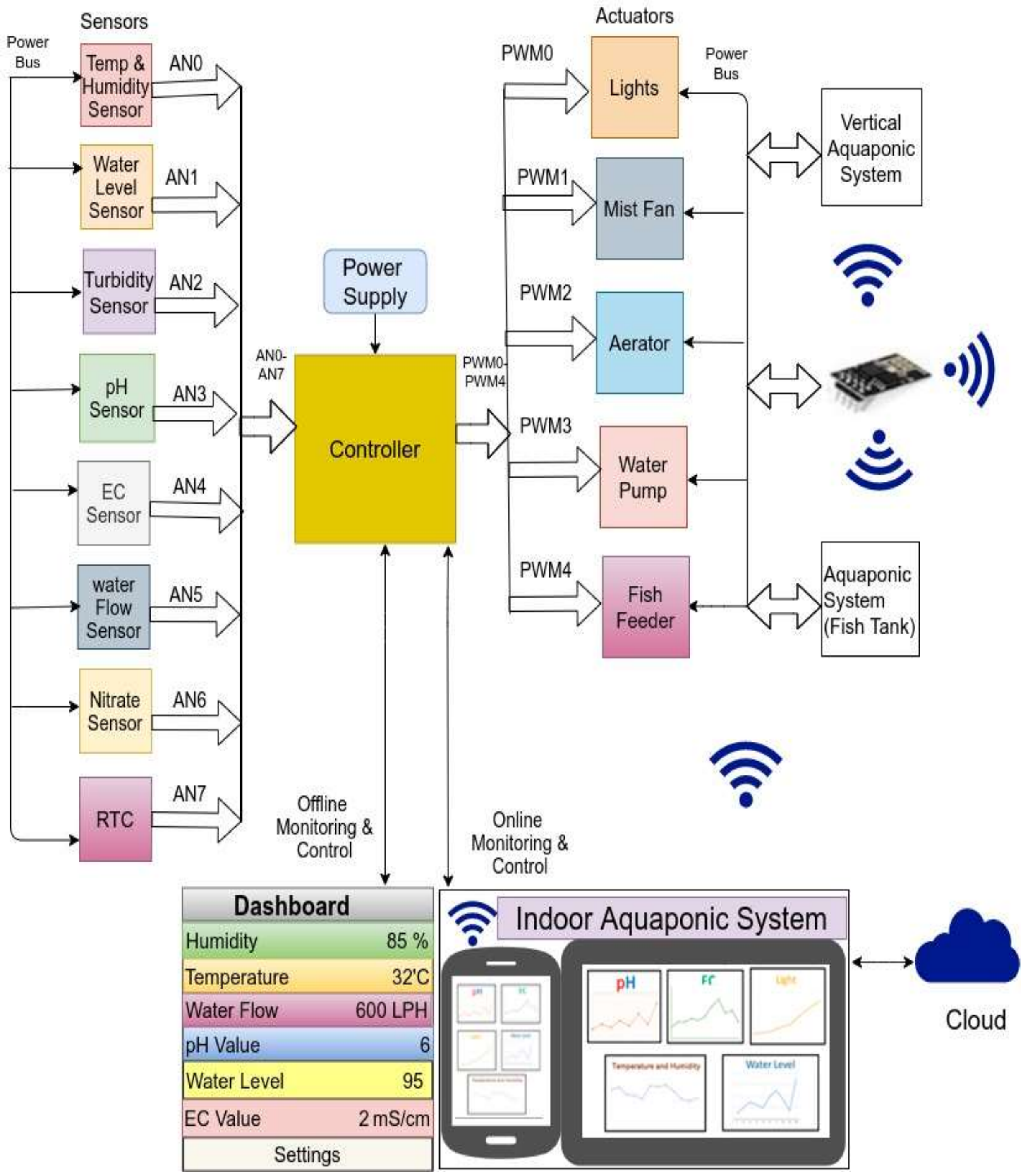


Fig 1: Block Diagram of the Automated Aquaponics System

EC Sensor: The concentration of dissolved salt has an effect on water's electrical conductivity. A solution's ability to conduct an electric current is improved by adding salts. As a result, a high EC value denotes a high amount of salinity (100 – 2000 µS/cm). When water has a high salinity content, it is salty. The conductivity increases as the salinity increases.

Water Flow Sensor: It monitors the flow of water from the fish tank to the plant grow beds at a rate of 1 to 2 litres per minute.

Nitrate Sensor: The ammonium ion concentration in the fish tank is detected using an ammonia ion a sensor capable of identifying concentrations ranging from 0.09 mg/L to 9000 mg/L. Nitrite is a hazardous intermediate form of nitrogen in the nitrification process. The Nitrite Ion sensor can detect nitrite concentrations ranging from 2.5 to 1000 mg/L. The nitrification process produces nitrate, the ultimate form of nitrogen. The Nitrate Ion sensor can detect nitrate concentrations ranging from 0.6 to 31,000 mg/L.

Water Temperature: The water temperature range for aquaponics is 68°- 86°F (20-30°C). The bacteria, plants and fish thrive in this range. It is essential to choose a combination of fish species and plants that are appropriate for our area and environmental conditions to avoid problems and lower our maintenance costs.

2**. Central Control System**: This category includes all of the supporting devices that are required to make the circuit design fully functional. ESP8266 was configured as central control unit for entire system. We can monitor sensors data offline in serial monitor of Arduino IDE.

Node MCU: It is an open-source development board with GPIO, PWM, I2C, 1-Wire, and ADC interfaces based on the ESP8266 microcontroller. It connects to the internet through Wi-Fi. A 3V battery system powers this microcontroller for online monitoring of sensors data.

Bevywise Web Application: To provide a user interface in graphical form for the system, the Bevywise web application was created and hosted on an ESP8266. The user interface compares and displays real-time and historical sensor values, as well as records system events. It also allows the user to keep track of the aquaponics facilities and control the actuators from afar.

Mobile Application: Android was used to develop the mobile application. It shows real-time sensor readings and allows users to control actuators from afar via cloud-based services. It also allows users to change the threshold settings for each sensor in real time.

Cloud Server: The central control unit and the mobile application communicate through the cloud server.

The primary purpose of the cloud server is to retain the data gathered by the data acquisition unit and to relay actions from the mobile application to the central control unit in real-time.

3. **Actuators**: Actuators are used to manage numerous environmental characteristics like as light, humidity, electrical conductivity, ammonia, CO2, and temperature, all of which have an impact on the

growth of plants and fish.

Water Pump: This DC 3-6 V Mini Micro Submersible Water Pump is inexpensive. A small size Pump for Submergence Powered motor by a 2.5 ~ 6V power supply.

Real Time Clock: To set time, such as date, month, year, and clock, use the RTC DS3231 component. It is crucial since it is necessary to schedule the feeding of the fish.

Servo Motor for Fish Feeder: The servo works in this series to move an actuator in a fish-eating location so that it can work automatically when feeding the fish according to predefined requirements.

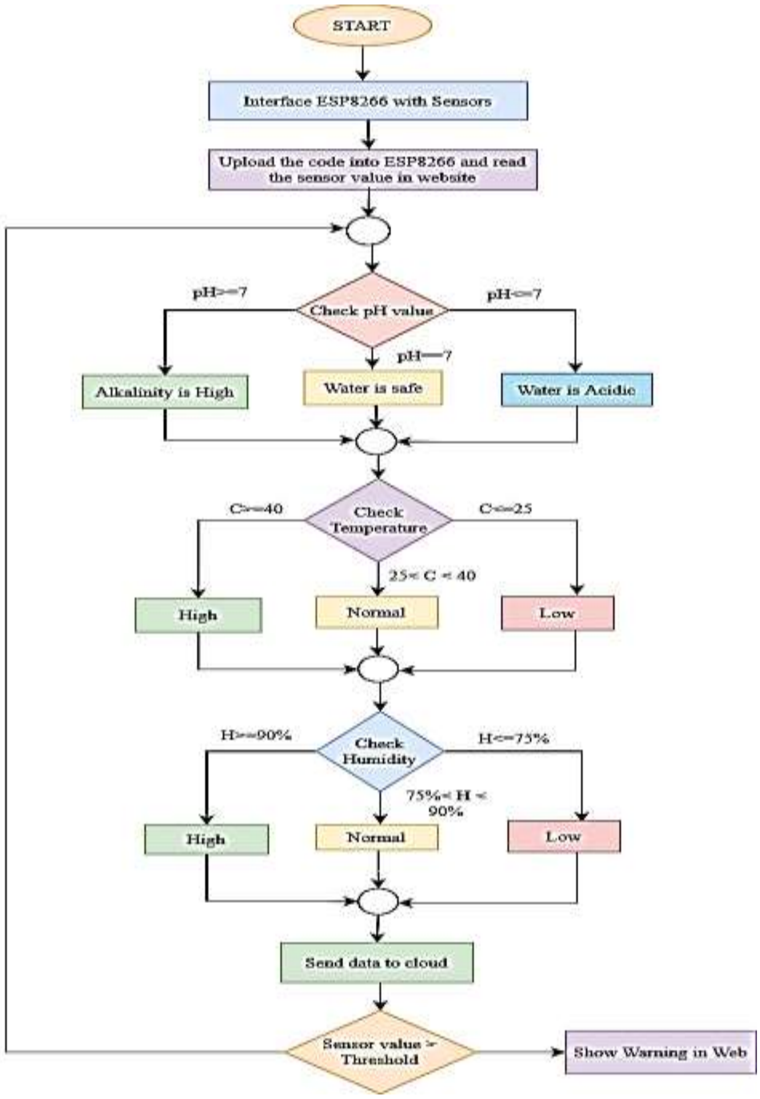
Light: When the brightness of the surrounding light is high level, it is used to encourage plant growth.

Aerator: It will provide a constant flow of air to the water tank. It would be necessary because fish in fast-moving water require more oxygen.

Mist Fan: It sprays water into the air on a regular basis, which helps to chill the air as it evaporates.

3.2 Dataflow Diagram

The fig 2 Data flow diagram refers to the procedures used in a system to move data from the input to file storage and report output. Data flows displaying a quick summary of the sort of information transferred between entities and the system.



We can indicate a range of potential values for the parameter shown in Table 1. A range helps us to verify that the parameter value falls inside a particular range of values. There is a predetermined min and max value within this range.

Table 1. Parameters range for aquaponics system:

Sl. No	Parameters	Aquaponic
1.	pH	6.5 – 8.0
2.	Water Temperature	17oC – 30oC
3.	Water Level	0.02kg/L
4.	Electro-Conductivity	100 - 2000µS/cm
5.	Total Ammonia-Nitrogen	<2 mg/L

6.	Nitrites	<1 mg/L
7.	Nitrates	50ppm-100 ppm
8.	Water Flow	1-2 Litres/min
9.	Air Temperature	15oC – 35oC
10.	Humidity	75% - 90%

3.3. Software Application

To create a software application that will allow the user to see the aquaponic data. We evaluated a number of factors, including the technology we would employ and how we would apply it.

Implementation using Bevywise IoT Platform

As a service, Bevywise offers a real-time data and backend. The service provides an API for application developers that allows data to be synchronized among clients and saved in the cloud. MQTT uses a publish-subscribe paradigm to send messages to one or more customers. IoT apps enable energy monitoring by gathering energy data and using it to make intelligent business choices on how to enhance energy efficiency. With the IoT Dashboard, we can activate and monitor our electricity generation, distribution, and consumption. Managing the information and gadgets that customers have on their premises is one of the most difficult challenges that every company organization faces. This will raise the expense of maintenance and development, as well as make it difficult to track. To address this, providers can install our Bevywise IoT platform on a cloud server and grant each customer access or login. The IoT platform's Device Manager allows each user to generate unique web access and assists consumers in monitoring the device or resource separately. It is less expensive and takes less time. Bevywise IoT platform offers an attractive and clear dashboard that monitors device and data without any complication.

Bevywise Dashboard

we implemented the software application on Web, Mobile or Laptop. The key factor that influenced this selection was convenience of use. Another important element we examined while selecting a software strategy was accessibility. When a user enters the application, it checks to see if he or she has already been authenticated. Users can sign up or sign in to this site to authenticate themselves. The email address and password are entered into two fields on this page. After successfully signing in or creating an account, the user will be directed to the application's home screen. The application's home screen presents a summary of one of the user's previously registered systems. The summary comprises the system's name, status, the last time the information was updated, system warnings, and a list of all sensors and their measured values. The sensor chart, aquaponic system settings, and user settings screens are all accessible to the user. The user can change the sensors they want to examine, as well as the time during which the measurements were obtained. New measures are retrieved from the bevy wise backend, and the graph is updated anytime the user selects a sensor to see or alters the time range. we can monitor the sensors data both Online and Offline mode. Online is through Bevywise Dashboard and Offline is through serial monitor of Arduino IDE.

A flowchart is a sort of diagram used to depict a workflow or process. Following flowchart may alternatively be described as a diagrammatic depiction of an algorithm, or a step-by-step procedure for completing a task.

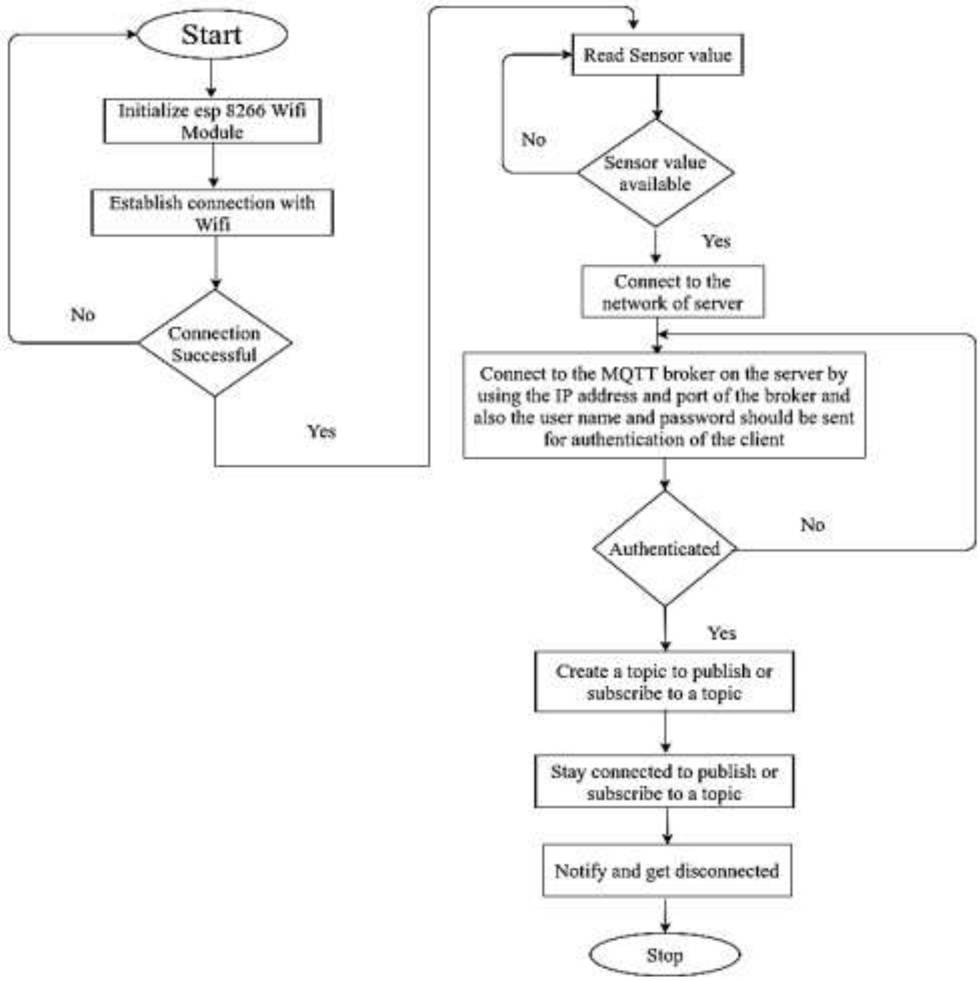


Fig 3: User case Diagram

Experimental Setup

For a period of 7 days, the implemented prototype automated aquaponics system was put to the test. Here we tested with some sensors like Water temperature, Water flow rate, Humidity, pH level, Air Temperature were all measured. Additionally, for data analysis, physical measurements of plant height were taken as shown in table 2.

Table 2: Data Analysis of Plant Height

Day	1 & 2	3	4	5	6	7
Plant Height (cm)	Soaking seeds	Baby Sprouted seeds	1.27	2.54	3.81	5.08

4.1 Automated Aquaponics Predefined Model

The fish tank built with dimensions of (575x420x185mm). The fish is fed with fish food in tank to leave the extract as we are giving automatic fish feeder through servo motor and real time clock. It'll feed the fish every 12 hours. The fish extract will be pumped into the sump tank via the fish tank's valve. With the aid of the sump tank's motor, fish extract from the sump tank will be transferred to the Grow bed. The stand which we are using for grow bed is height 5 feet and width 6 feet. To detect the water temperature, a DS18b20 sensor is mounted within the sump tank. Furthermore, the plants in the Grow bed will collect fish water from the sump tank through pipe where it sprinkles water and begin to grow. The DHT11 Sensor is put outside the Grow bed to measure the temperature and humidity. A plant bed is in the shape of rectangle tray with dimensions of (35cmx18cmx14cm). Jowar, Paddy, Bazra and wheat plant can grow fast easily. It necessitates nutrients that are already present in fish extract. Holes of 0.5 width are dig to Plant bed to send purified water back to fish tank through outlet. Murrel fish is also known as snakehead because it has the appearance of a snake. The murrel has a suprabranchial auxiliary respiratory organ in its head, making it one of the indigenous air-breathing fish. Murrels can even thrive in low-oxygen environments. The fish extract is high in nitrates and nitrites, which are needed by plants. The carters are set side by side and have holes that are fitted with pipes to carter.

The following figure 4 is the entire Aquaponic system setup, including the fish tank, hardware connections, Automatic Fish feeder and plant development.

Fig 4: Implemented Prototype Aquaponic System

The below figure 5 is the Aquaponics system's hardware configuration, via which we can obtain temperature, water flow data, etc. Arduino is used to create an automated fish feeder with a timer and servo motor. Every 12 hours, it'll feed the fish. Because we are utilizing a real-time clock, we can set whatever time we choose.

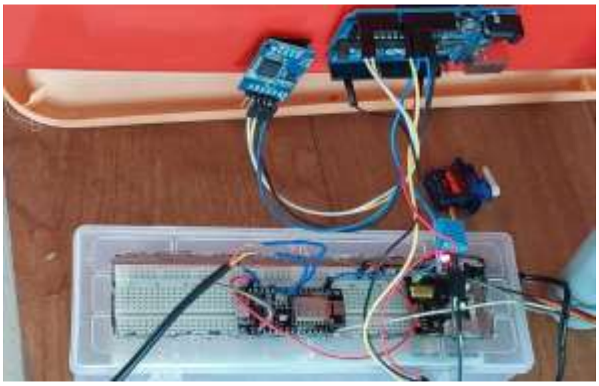


Fig 5: Hardware Setup for Aquaponic System

Results & Discussions

Online Monitoring Data

Here sensors data can be monitored online through Bevywise users dashboard

Water Temperature Sensor: The below figure 6 represents the measurement of water temperature in the fish tank with respect to time. Water Temperature sensor is used to monitor the temperature. In this figure the level of the temperature is 30 o C normal for the growth of both fishes and plants.

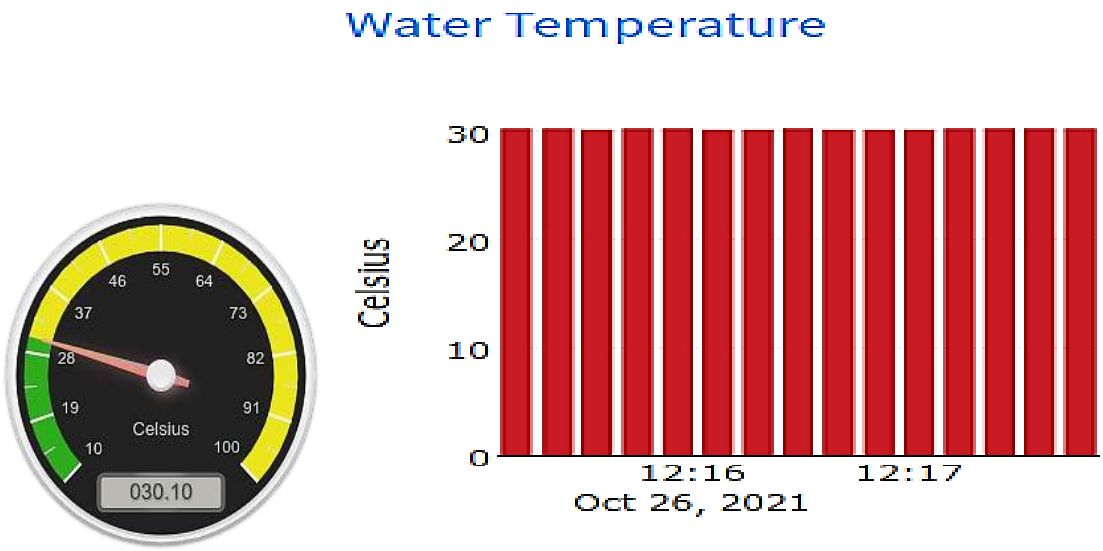


Fig 6: screenshot and graph showing the Water Temperature data on Bevywise dashboard.

Air Temperature & Humidity Sensor: The below figures 7 & 8 represents the measurement of air temperature and humidity with respect to time. This are placed outside the carters. Air Temperature sensor is used to monitor the temperature and Humidity sensor is used to determine the surrounding humidity. In this figures the air temperature 31.6 o C and humidity 83 % are normal for the growth of both fishes and plants.

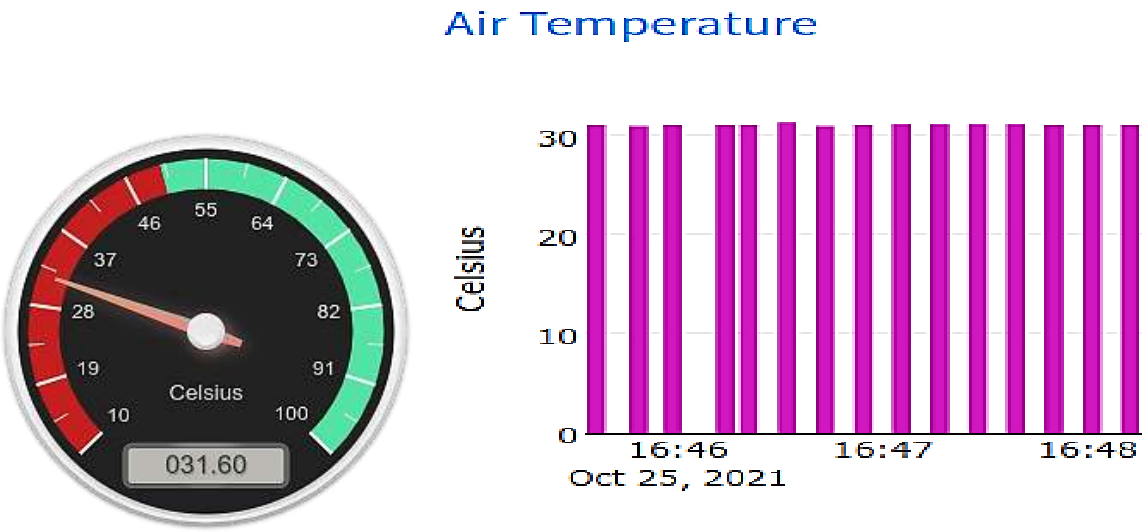


Fig 7: screenshot and graph showing the Air Temperature data on Bevywise dashboard.

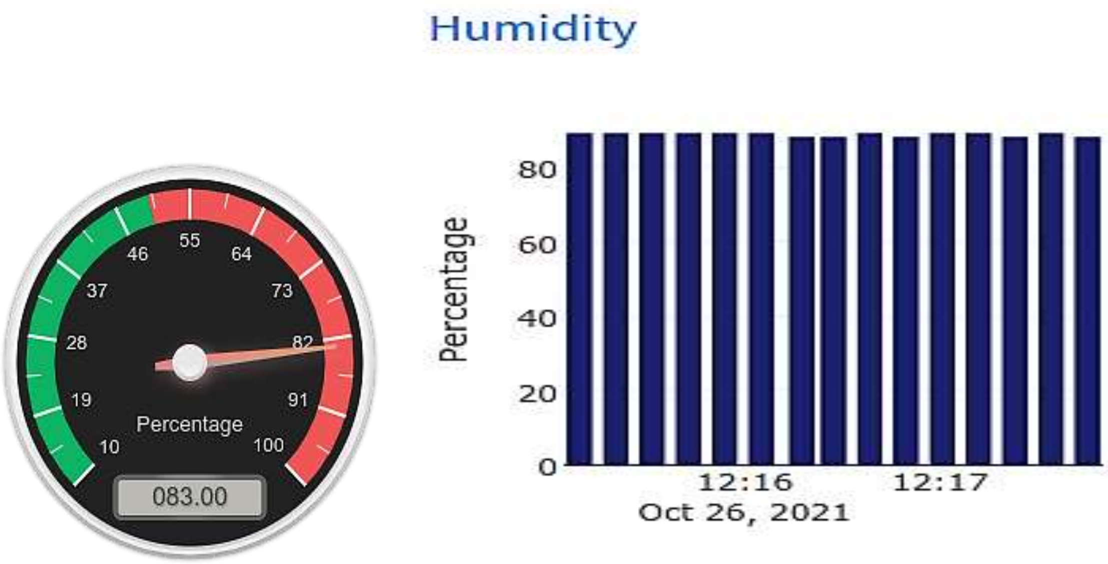


Fig 8: screenshot and graph showing the Humidity data on Bevywise dashboard.

Water Flow Sensor: The below figure 9 represents the measurement of water flow with respect to time. It measures water flow rate from the fish tank to plant grow beds. It is a gadget that can measure how much water is flowing through a pipe. The water flow rate is 1L/min.

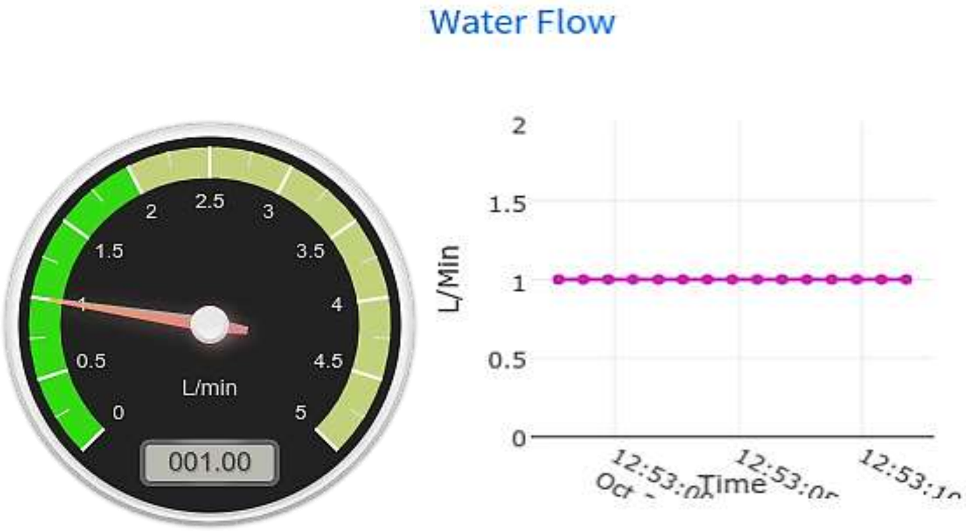


Fig 9: screenshot and graph showing the Waterflow data on Bevywise dashboard.

pH Sensor: The below figure 10 represents the measurement of pH of water with respect to time. It detects water pH level in the fish tank. In this figure 10 the pH is 7 which is neutral and good for the growth of both fishes and plants. It determines the amount of hydrogen in liquids as well as the activity of the hydrogen ion.

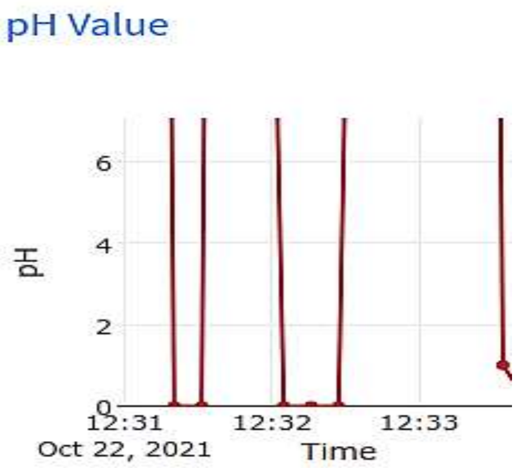
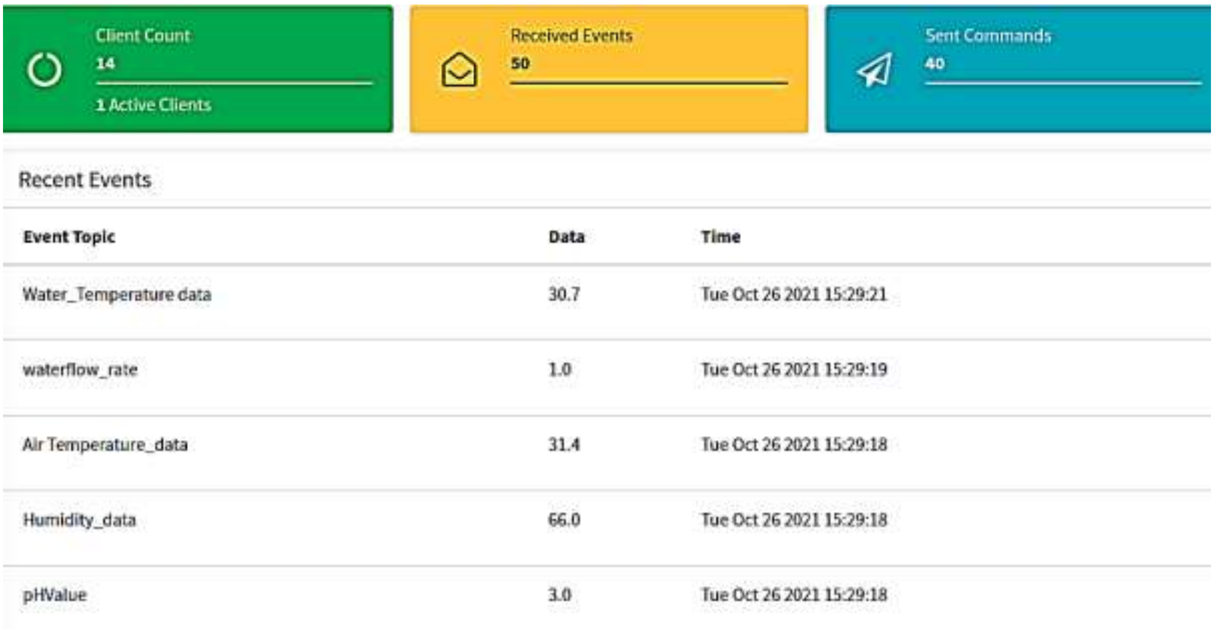


Fig 10: screenshot shows the graph of pH data on Bevywise dashboard.

The following screenshot 11 shows the Bevywise User Dashboard. Here The IoT Platform is a device management solution that allows you to manage IoT devices as well as gather and store data. Each user has their own interactive and distinct dashboard where they can see and control their sensors.



Event Topic	Data	Time
Water_Temperature data	30.7	Tue Oct 26 2021 15:29:21
waterflow_rate	1.0	Tue Oct 26 2021 15:29:19
Air Temperature_data	31.4	Tue Oct 26 2021 15:29:18
Humidity_data	66.0	Tue Oct 26 2021 15:29:18
pHValue	3.0	Tue Oct 26 2021 15:29:18

Fig 11: Bevywise User Dashboard

Offline Monitoring data:

If there is a network problem with the device's connectivity and not getting Wifi. Here sensors data can also be monitored offline through Serial monitor.

```
pHValue = 7.45
humidity: 83.00
temperature(c): 32.20
Water Temperature: 31.00ºC
31.00ºC
ºF
pHValue = 7.66
humidity: 83.00
temperature(c): 32.10
Water Temperature: 30.94ºC
30.94ºC
```

Fig 12: screenshot shows the all-sensors data

Arduino is used to create an automated fish feeder with a timer. It will feed the fish every 12 hours. Because we are utilizing a real-time clock, we can set whatever time we choose. When the time is synchronized with this time, the servo will rotate from 45 degrees to zero degrees. Then return to 45 degrees. This will happen twice more. As time passes, a certain point in time is reached. The pellet is rotated by the servo and fed into the tank. Here timer set for 14 hrs.0 mins. 28 secs. Servo motor will start rotate and automatically motor stops once the timer reached to 14hrs.4mins.10secs.

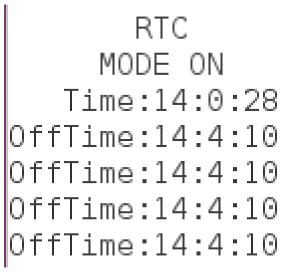


Fig 13: Screenshot shows the RTC timer for servo motor to start and stop

Conclusion

This approach was created to eliminate the usage of artificial fertilizers and chemicals in crop production and will help farmers who are having difficulty in cultivating natural foods. The fish extract employed here is a natural fertilizer for plant development. Data collection unit, Central control unit, Online, Offline & mobile application, and cloud server were all integrated to create a smart aquaponics system. Without human intervention, the implemented prototype aquaponics system can continually monitor and adjust water quality, fish feed, plant grow and correct system anomalies. With a large-scale application, the prototype can drastically cut labor and operational expenses while improving livestock output and profitability, contributing to the development of sustainable and livable communities.

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