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Implementation of Smart Aquarium System Supporting Remote Monitoring and Controlling of Functions using Internet of Things

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Junaid Khan[1], Onib-Ur-Rehman[1], Zafran Jalil[1], Sikandar Ali[1], Abdul Samad Danish[2,*]

[1] Department of Electrical Engineering, HITEC University, Cantt, Taxila, Rawalpindi, Punjab, 47080, Pakistan.
[2] Department of School of Electrical Engineering and Computer Science, NUST, Islamabad, 44000, Pakistan.

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ABSTRACT

IoT Based fish aquarium is a fully automated and remotely monitored aquarium, fully capable of operating without human intervention or interaction. Major features of this research project are the mechanical feed design, fish feeding over the internet and remote monitoring of all the parameters. The parameters include feed level, water temperature, pH and water level. They can be accessed through a website on a computer or through the app on phone. This task is achieved using Node MCU v1.0, Cayenne and Arduino mega2560 for the implementation of IoT. This is supposed to reduce human efforts and errors in owning an aquarium full of aquatic animals.

1. Introduction

As the trend of keeping pets increases, people are keeping all sorts of animals at home and it is not a new concept in any way. The strong connection between pets and their owners is evident from a report by Micheal Gross [1]. All of these animals require special care and sometimes humans cannot attend to their needs and these days there are many people fighting to protect the ethical rights of animals like PETA [2]. Out of these animals, fish require the utmost care because their environment is completely different from land animals, so they need specific conditions like a temperature range, pH, suitable oxygen and CO_2 levels. Normally aquariums have oxygen pumps, heaters, and filters. This is not enough or equivalent to the natural habitat. Many scientists have worked on the effects of meteorological and hydrological diversity with respect to the spatiotemporal scales [3]. Maintaining these conditions is very hard manually, so automating this process will greatly reduce the fish death rate and will create great convenience for the owners.

*Corresponding author.
E-mail address: Abdul Samad (abdulsamaddanish66@yahoo.com)

The main cause of death for fish in aquariums and fish farms is the inability to take care. This is not only true for this project but in fact automation is one of the most productive way of doing things with ease [4]. This project is designed to decrease the labor time and can be controlled from anywhere, such as a mobile phone or PC etc. IoT is the technology that enables communication between devices; this minimizes human interaction with the machine, automates normal or routine tasks and even makes them faster as the machine can also communicate with the other machines it is dependent upon. This makes an entire network of smart machines that are independent of human beings and this will also monitor the breakdown of the product or mistakes that happen as the IoT based machines are constantly monitoring through sensors. Internet of things is a blend of many concepts that are put together to make an autonomous product that is easy to use and is diverse enough to perform the end task [5]. IoT is helping manufacturers make better products and diagnose problems much more easily. The manufacturers can even shut down the machine or replaces a part before it fails. This will create great convenience for the user as well, because he will get the things he needs ahead of time and without having to worry about the things that are less important.

2. literature review

There is an application called Louis COETZEE et al. Introduced the concept of Internet of Things. It is about the advancement in IoT from computers, to people and now to things, this will allow many applications and services. Numerous fields are using the concept of IoT for their area of interest and they are providing guidance for using IoT concepts. With advancements achieved in IoT the globalization will take place in every technical field. Progress of IoT will make it very important for communication. By the ongoing progress of IoT in every technical field the future of IoT seems to be on the bright side. This milestone can only be achieved by increasing urge to work on the IoT field and also globalization of internet will make IoT automatically the top field. Compare this with the progress of the TCP/IP which provides a medium of communication between server and user. It is like Imagining your clock alarm giving a signal to your geyser to turn on so you will have warm water before you get up. On leaving the house, all appliances are signal to be turned off automatically for power saving. This can only be achieved by using IoT [6]. A research at Beihang University defined IoT as a cloud computing unit. Instead of server, a cloud can be used as a data monitoring and controlling unit. Cloud manufacturing a technique can be used for IoT base networks. Cloud manufacturing (CMfg) is an intelligent service-related area which is of highest attention for people throughout the world. In order to maintain the best way of the implementation of CMfg, manufacturer should understand the manufacturing resources intelligently by grasping what is the best and most accessible. For the purpose of solving the issue of finding and grasping the manufacturing resources intelligently, a light is shed on the uses of IoT in CMfg. The definition of resources and its uses, and also the link between them, are shown as five-layer integrated system. Five-layered system have perception layer, resource layer, service layer, application layer and network layer. Asset astute recognition and access framework dependent on IoT is planned and exhibited [7]. A research in UK performed a subjective longitudinal analysis of the public opinions and suggestions about the multiple pros and cons that are related to IoT, by using social media platform Twitter. To present their results they used modeling algorithm LDA to identify the six main concerns of the people in

handling technology like IoT. Among the six topics they considered the most of them are related to the Big data and Security. This gives us a prediction of what IoT has to change in order to secure data and handle every need of their users. In spite of the business intrigue that the IoT presents for huge information investigation, the difficulties looked by the restricted security of the present IoT gadgets is the real worry for the overall population [8]. So as to offer advantages to the two individuals and the things in IoT, information mining innovations are incorporated with IoT advancements for enhancement of framework and expanding basic decision-making capacities. Data mining includes extraction of helpful information for finding new methods and possibly valuable examples from information and to make new calculations for the extraction of concealed data [9]. It is anticipated that the accessibility of web is all over the place and online for every one of the general populations. With the progressions in numerous highlights to non-critical failure and viable power utilization of hubs and handset, IoT has encouraged internetwork, diverse gadgets and accessibility of information from anyplace.

In Lee et al [10]. The depiction is that there is yet an opportunity to get better in the field of IoT. This makes it very hard going after for associations to choose decisions in the light of IoT determination/utilization. It is perceived that there are three characterizations of IoT applications: watching and control, gigantic data and business assessment, and, information sharing and joint exertion. IoT can be utilized to show adventure openings and theory evaluation with NPV and real options. An exploration was directed in USA that analyzed five challenges in realizing IoT applications for different endeavors [11]. We are living in a time of gigantic data and advances around us. An age portrayed by brisk gathering of universal data. Huge data joins boundless proportions of information. In various ventures, it is creating, giving an approach to improve and streamline business. Various fields and divisions, running from money related and business activities to open associations, from national security to sensible research in various zones, are locked in with huge data issues. Enormous information has changed the world to the extent envisioning customers direction [12]. When the expression "Web of Things" (IoT) was first presented, the basic request could be what is considered as "Things". Till continuous years, social occasions of examiners and affiliations strived to explain the importance of IoT. Haller proposed an importance of IOT with a presence where physical things are faultlessly consolidated into the information association, and where the physical articles can wind up powerful individuals in business process [13].

3. Methodology

3.1. Tools

Some of the tools used to make this application are:

- Arduino Mega 2560
- Ultrasonic Sensor
- ESP8266
- LCD 20x4
- PH Sensor
- Temperature Sensor

- Water Pump Motor
- Servo Motor
- Four Channel Relay Module
- Water Heater
- Fan

3.1.1. Arduino Mega 2560

Arduino mega 2560 is a microcontroller with 16 analog inputs pins and 54 digital input/output pins 15 of which can be used as PWM (pulse width modulation).It has a crystal oscillator of 16MHz frequency and a USB port is fixed on the board which helps the users to connect the board with computer and transfer the code from computer. An external DC power jack is also available on the board which can be used to power the board with operating voltage 9v-12v. For programming the Arduino and uploading the code from the computer ICSP header is integrated with the board. Arduino mega 2560 comes with more memory space as compared to other Arduino family as we mentioned above it makes AT mega 2560 more feasible and suitable to deal with complex circuitry projects.

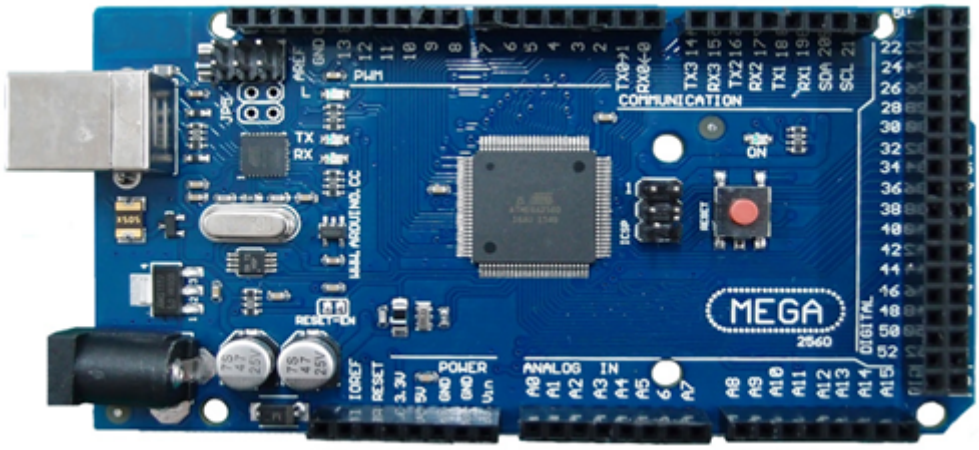

Fig. 1. Arduino mega 2560

3.1.2. Ultrasonic Sensor

Ultrasonic Sensor HC - SR04 provides a distant, non-contact measurement function. Its range is from 2cm up to 400cm. It works on the principle of echo. It has a transmitter and receiver and also a control circuit. Ultrasonic sensor needs 5V to operate. The transmitter transmits the wave and receiver gets it by reflection from object or surface, the distance can be calculated by measuring the time of transmitting and receiving pulse. It is widely used for measuring distance or water level.

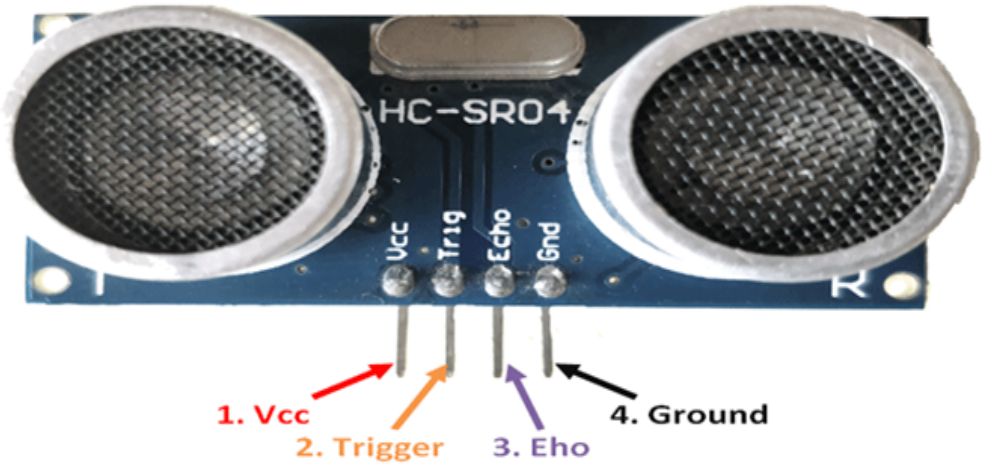

Fig. 2. HCR04 Ultrasonic Sensor

3.1.3. ESP8266

The ESP8266 Wi-Fi Module is an independent SOC (system on chip) that can helps any microcontroller to connect to the Internet. The ESP8266 is able to do either facilitating an application or offloading all Wi-Fi organizing capacities from one application processor to another application processor. Each ESP8266 module comes pre-modified with an AT direction set firmware, which means, you can essentially attach this to your Arduino gadget and get about as much Wi-Fi-capacity as a Wi-Fi Shield offers. The ESP8266 underpins allows APSD for VoIP applications and Bluetooth coexistence interface. It contains a self-adjusted RF, enabling it to work under every working condition, and requires no outer RF parts. ESP8266 helps in many projects to connect over with Wi-Fi and Internet.

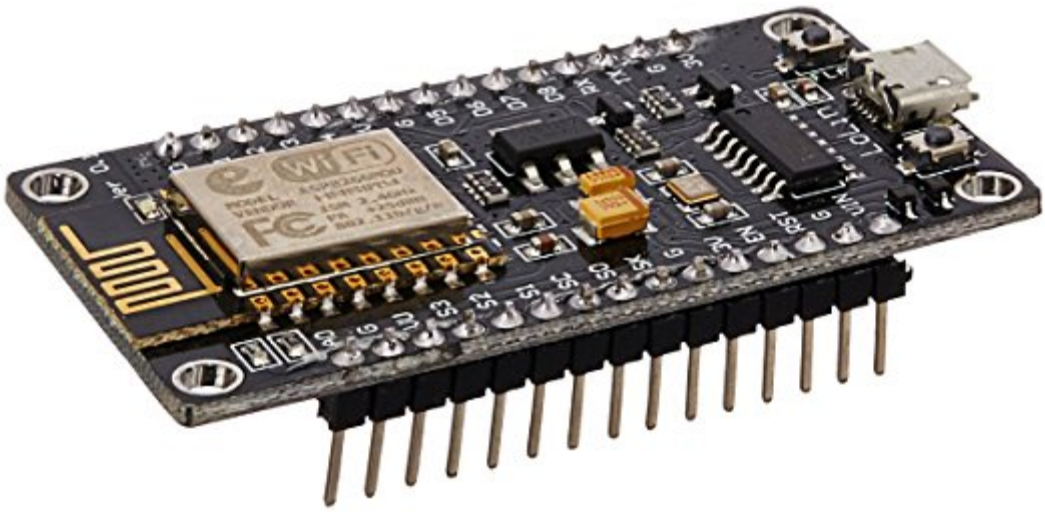

Fig. 3. ESP 8266 module

3.1.4. LCD 20x4

This LCD consists of 20 characters wide 4 rows with white text and blue background. It is used to display the results in digital form. It is usually connected with arduino and display output. Its Connection port is 0.1" pitch, single row for easy bread boarding and wiring. Single LED backlight with a resistor included and also a grounded resistor as well. You can power it directly from 5V. You can adjust it brightness by using variable resistor or PWM.

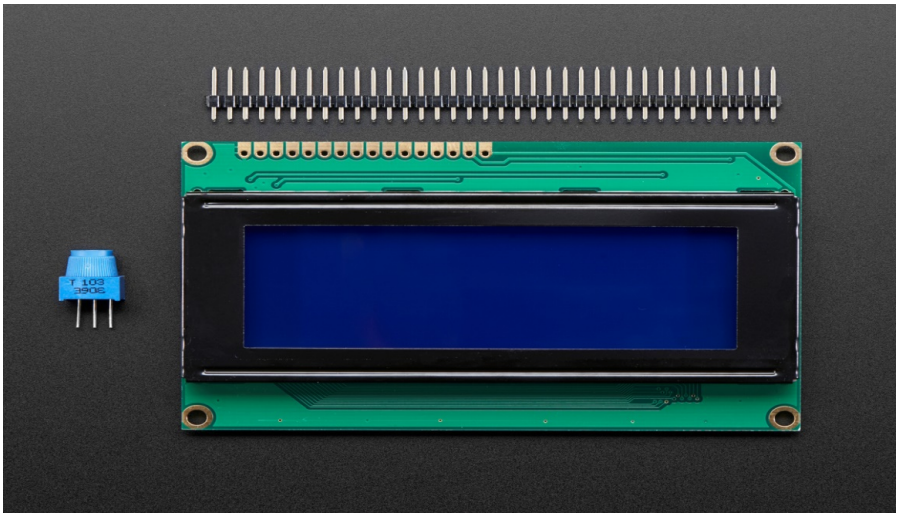

Fig. 4. LCD 20x4

3.1.5. pH Sensor

pH sensor is used to measure hydrogen ion concentration in a solution. Glass pH electrode is widely used in pH sensors. The electrode is main part of measuring the pH in a solution. It works on the principle of voltmeter and use potential difference to check solution voltages and compare them with existing ones. The ideal value for a solution should be pH=7 and if it is more than 7 it will a basic solution and if pH is less than 7 then solution will be acidic.

Fig. 5. pH Sensor

3.1.6. Temperature Sensor

Temperature sensor plays an important role in many applications like in case of fish aquarium it is necessary to check the temperature. Temperature sensors are usually thermocouple or RTD. We have used thermistor base temperature sensor which is capable of monitoring water temperature. It works on the inverse time characteristics phenomena. The resistance of thermistor decreases when temperature increases and gives the signal of rise in temperature.

Fig. 6. Temperature Sensor

3.1.7. DC Water Pump Motor

DC water pump motor consist of an inlet and an outlet. It is used for extraction or refilling of water in the tank or aquarium. It is operated on voltage between 6V to 12V DC supply. Its maximum rated

Fig. 7. DC Water Pump

current is 1.2A and maximum rated power is 16.8W. Its flow rate is 10 liters per minute. We have used two such motors, one extracts impure water from the aquarium and second motor refills the aquarium with fresh water.

3.1.8. Servo Motor

Servo motor works on the basis of the applied signal to the control pin. It works on the principle Pulse Width Modulation. The construction of servo motor consists of a dc motor and variable resistors with gear mechanism. Its movement can be 180 degree or 360-degree based on the adjustment. For high pulse its response is high and its motion is to and fro.

Fig. 8. DC Servo Motor

3.1.9. Four Channel Relay Module

The 4-Channel Relay Driver Module is load tripping mechanism used to derive load based on setting. It is widely used for the Arduino board. It can operate on 5V, this makes it compatible. 4-channel relay is an electro-mechanical relay operated on electrical signal provided to it. Switches inside the relay make it useful for quick switching of load.

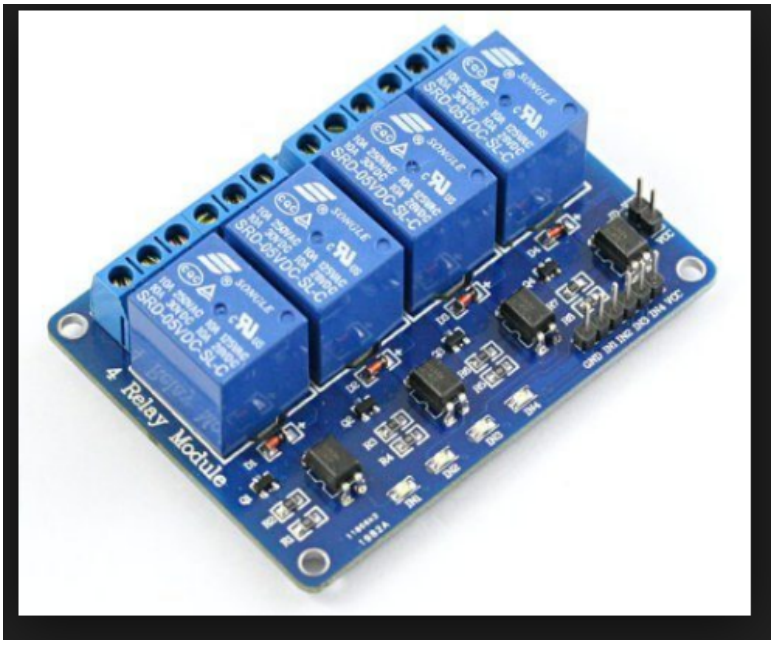

Fig. 9. Channel Relay Module

3.1.10. Water Heater

Heater is usually used to stabilize the temperature. In fish tank it is necessary to maintain certain temperature to keep fish alive. It consists of rod with spiral type resistive material. Through discharge of heat, water warms up. It is helpful for us to achieve the desired temperature for the aquarium.

Fig. 10. 50w Water Heater

3.1.11. Fan

The fan consists of rotating arrangements of blades in a way that it can control the flow of air between its blades by compressing it. It gets the cool air from outside and throw it inside using the blades. It cools down temperature. We have used the fan such that if temperature of water rises fan will turn on and will try to balance the optimum temperature inside the tank.

Fig. 11. Cooling Fan

3.2. Hardware Calculations

3.2.1. pH calculations

To calculate pH value, we took the average of 6 samples and then multiplied the average value with transfer function. Then we added a correction factors to get the accurate value of pH. This has been written in code with loops.

pH= avgValue*5.0/1024/6
phValue = -5.70 * pHValue + 21.34
phValue=phValue-5

3.2.2. Ultrasonic Sensor Calculation

In an ultrasonic sensor a pulse is transmitted from trigger and after reflection from the surface it comes back to the sensor through echo pin. We calculated the time taken by the pulse and dividing it by 2 so that we get the time for the pulse to reach the surface of water. As we know that the speed of sound at sea level so we found the distance by simple formula:

S = v * T/2
At sea level Speed of sound= v = 34300 cm/s
S = 17150 * Time (unit cm)
3.2.3 Fish Feed Calculations

We have designed the fish feeder in which the servo motor pulls the tray outward and feed is dropped through the hole into the aquarium. The hole was of 1cm diameter so that the fish are not over fed. The rotation angle was adjusted according to the tray and hole. It was calibrated by repeated testing.

3.2.3. Wiring Layout Explanation

Arduino Mega 2560 microcontroller is controlling all the central functions of the project. It sends the data to Esp8266 module which sends it to internet.

3.2.4. Temperature Sensor

Temperature Sensor has three pins Vcc, ground and data. We have connected the data pin to Arduino at pin A0 for sensing and connected the rest of the two pins with Vcc and Ground respectively.

3.2.5. Ultrasonic sensors

We have used two ultrasonic sensors HCSR-04 for measurement of feed level and water level of aquarium. It has 4 pins Vcc, Trigger, Echo and Ground. We have connected Vcc, and ground of the Sensors by the external Vcc and ground. We have connected trigger and echo pins of water-level ultrasonic sensor with digital pin number 4 and 5 of Arduino and we have connected the trigger and echo pins of feed-level ultrasonic sensor with digital pin number 2 and 3 of Arduino.

3.2.6. pH sensor

We have connected pH sensor with pH module. Its module has 3 pins which are Vcc, Ground and Data pin . We have connected data pin with A1 of Arduino and rest of the pins with Vcc and ground.

3.2.7. Four Relay module

We have used 4-relay module for switching according to our requirements. It has 4 inlets, Vcc and ground. We have connected four inlets with Arduino at digital pin number 22, 23, 25 &24 for controlling motor m1, motor m2, fan and heater respectively. Then at the outlet we have four relays, each relay has 3 pins normally open, normally closed and common point. We joined all the common points of relays. Then we connected motor m1, motor m2, fan, and heater with normally open points of relays 1, 2, 3 &4 respectively. Then we connected the common points of fan, heater and motors with common terminal and connected it to ground Pin. Pin configuration is shown in the table.

Table. 1. Explanation of 4-relay module connections

	Relays Pin	Connected with	Reason
Input Pins	IN1	D25 of Arduino	To send a signal from Arduino to Relay 1.
	IN2	D24 of Arduino	To send a signal from Arduino to Relay 2.
	IN3	D23 of Arduino	To send a signal from Arduino to Relay 3.
	IN4	D22 of Arduino	To send a signal from Arduino to Relay 4.
Output pins	Relay1 (NO)	Motor M1	To Turn ON/OFF motor m1.
	Relay2(NO)	Motor M2	To Turn ON/OFF motor m2.
	Relay3(NO)	Fan	To Turn ON/OFF Fan.
	Relay4(NO)	Heater	To Turn ON/OFF Heater.
	R1, R2, R3, R4 (Common)	With Common of Motor m1.m2, fan and heater.	To Complete the circuit.
Power Pins	Vcc	Vcc	To Enable Relay Module.
	Ground	Ground	To Complete the circuit.

3.2.8. Esp8266 Connection

We have used Esp8266 as a Wi-Fi device ,it will transmit and receive the data from internet .It has multiple data pins but we have used its data pins .We connected D1,D2,D3,D5 and D6 with digital pin number 6,7, 9,8 and 11 of arduino.D7 is used for output.

Table. 2. Explanation of ESP module connection with Arduino

Esp8266 Module		
ESP pins	**Connected To**	**Reason**
D1	D6 of Arduino	For transmitting Temperature sensor's processed data to internet through Esp8266.

D2	D7 of Arduino	For transmitting pH sensor's processed data to internet through Esp8266.
D3	D9 of Arduino	For transmitting processed data of water level sensor to internet through Esp8266.
D5	D8 of Arduino	For transmitting processed data from Feed level sensor to internet through Esp8266.
D6	D11ofArduino	For receiving command signal from the internet for the feeder.
D7	Output	To Activate the DC Servo Motor.
Vcc	Vcc	To Turn on Esp8266.
Ground	Ground	To complete the circuit.

To Display the results we have mounted an LCD on the front of the aquarium. To avoid the complexity, we have minimized the number of pins up to 4 pins by using I2C module. Now LCD has 4 pins which are VCC GND SCL SDA which are connected to Arduino as shown in the figure 12.

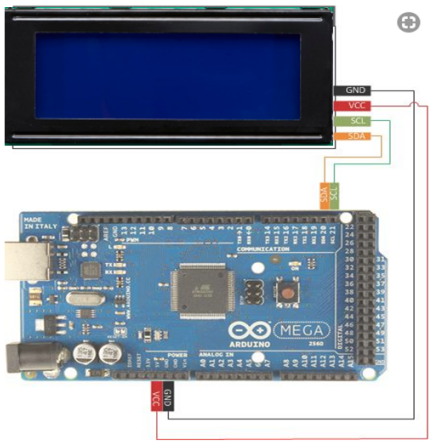

Fig. 12. LCD connections with Arduino

3.2.9. Mechanical Design of Fish Feeder

We have constructed mechanical fish feeder which we placed on the top of the aquarium. The Feeder is made up of aluminum. It has a capacity for storing feed in its box. The feeder has 3 layered design. In the figure given below bold rectangle shows the fixed support, narrow line shows the dimension of box which is also fixed on the support and narrow lines represents the movable tray. Each layer has hole in it. With the help of flexible wire, the tray is connected with DC servo motor which rotates 180 degree. We have adjusted its rotation according to our requirement. The tray is also connected with rubber band for recoil.

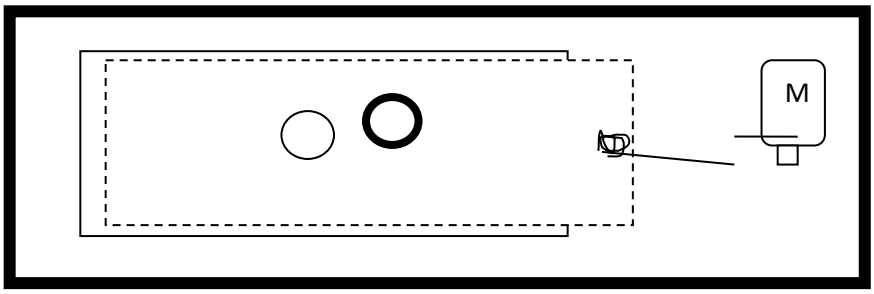

Fig. 13. Fish feeder design

In normal position, the hole of box and tray are exactly in same symmetry and feed is stored in the hole of tray as shown in figure.

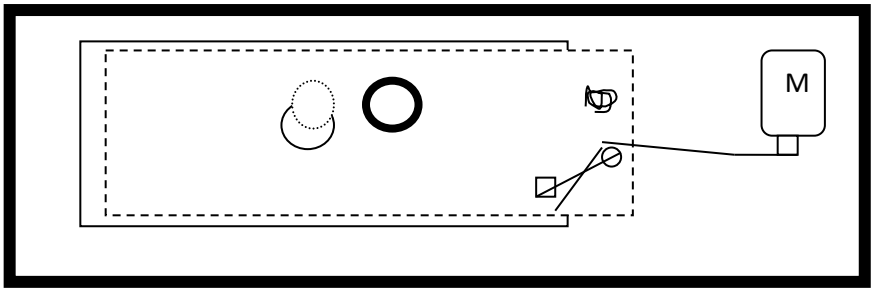

Fig. 14. Fish feeder design at normal position

Whenever we want to feed the fish, we will press the button 'Feed it' on Cayenne then servo motor will pull the tray outward, such that the hole of tray and fixed support are in same symmetry as shown in figure and feed will fall into the aquarium.

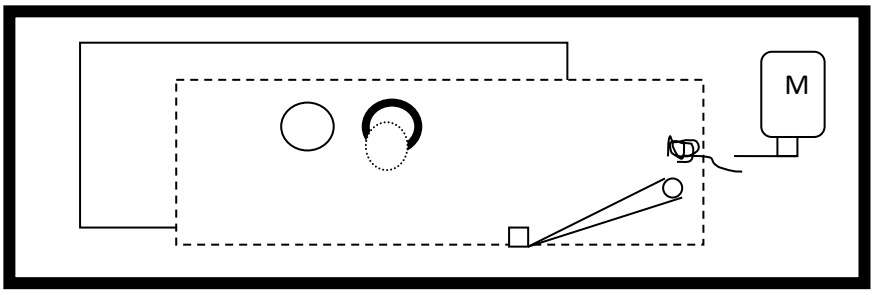

Fig. 15. Fish feeder design when button is pressed

Then rubber band will pull the tray back to its original position because the motor will relax the string after rotating -90 degrees.

3.2.10. Flow Chart

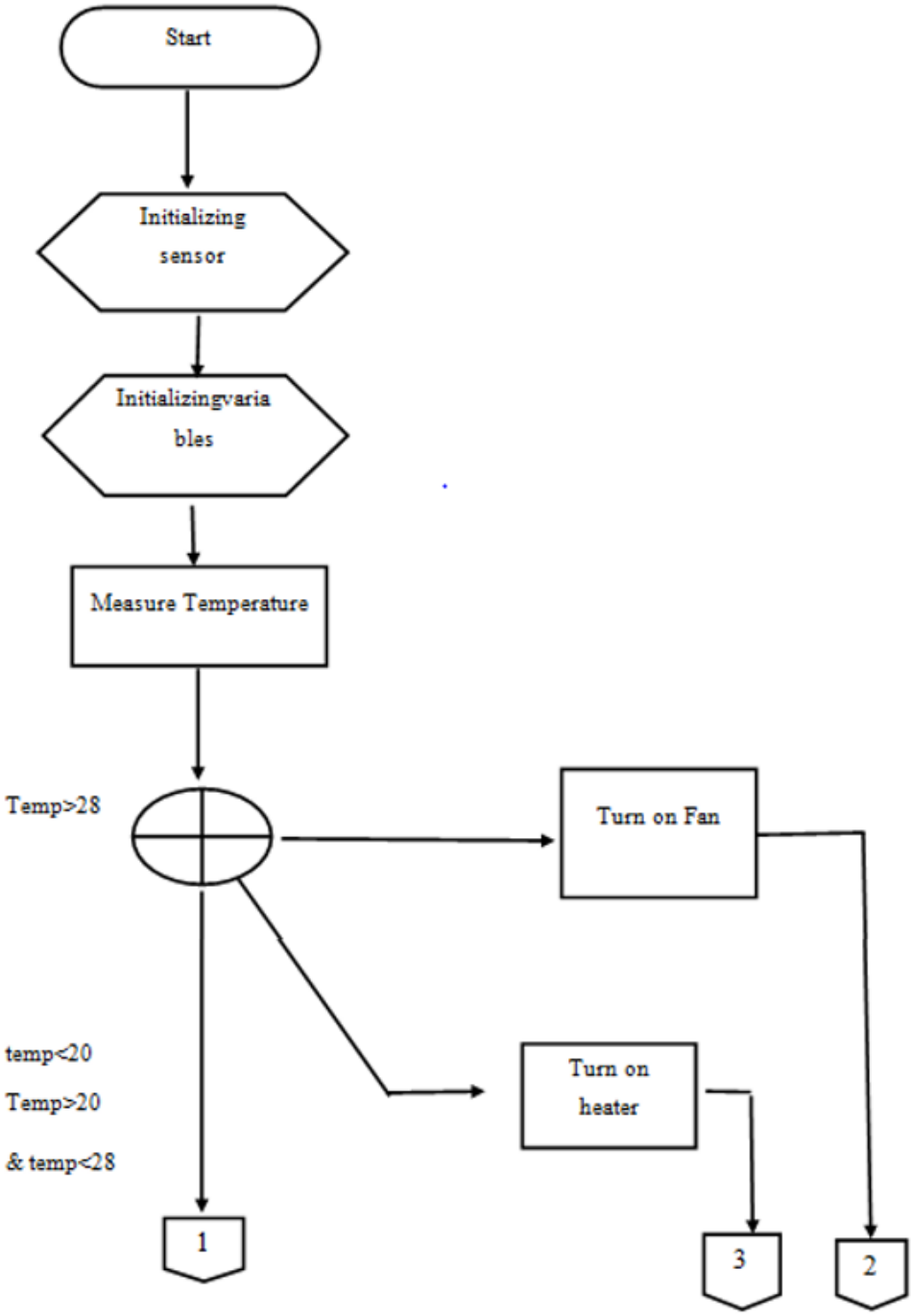

Fig. 16. Flow Chart for sensor control

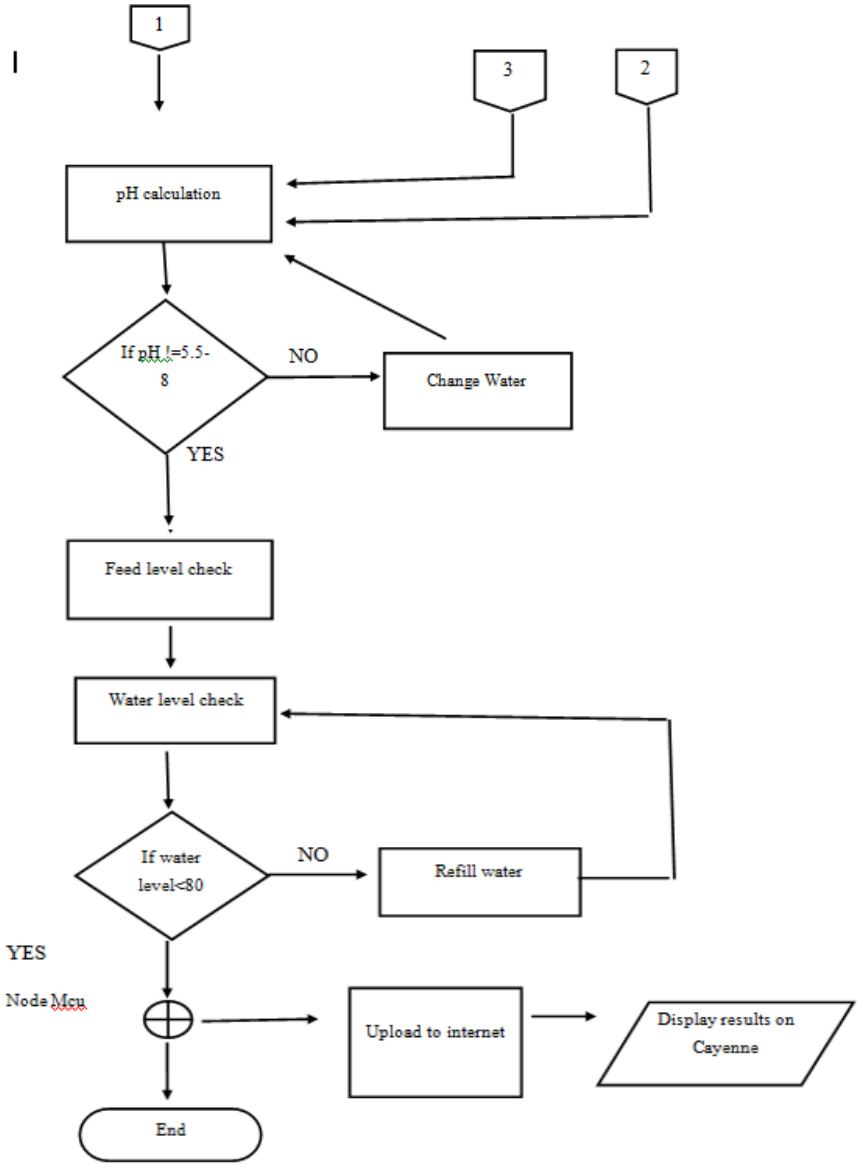

Fig. 17. Flow Chart for sensor control

The complete flow diagram of our project represents the overall working of the software. Oval represents the start or end of the project. Rectangle represents the processes while diamond sign shows the condition .We have used the arduino software. The program starts with initialllizing sensors. Then process of sensing temperature starts. Thermistor senses the temperature of water and sends the signal to the arduino.In our code, we applied a condition that if temperature of water is in range between 20 to 28 degrees celcius. If Yes then it means that the temperature of water is in its optimum range and will move to the next step. But if temperature is not in this range then it will check the next condition.If the temperature is greater than 28 degree celcius then it will turn ON the fan until temperature of water reaches the optimum range.If the condition fails it means that temperature is less than 20 degree celcius then it will turn ON the heater so that temperature rises to its optimum range. Then the pH sensor will start the process of sensing the pH of water. We have applied a condition that if the pH of water is in range between 5.5 to 8 or not? If yes then it will move

to the next step,if this condition is false then arduino will start the motors m1 and m2 for extracting impure water and refilling of pure water .This process will continue until the condition is satisfied. Then it will check the feed level and display it. It will go to the next stage and check the water level , if the water level is above 80 percent it will display the water level and upload the data of sensors to the internet. If the condition is false it will refill the aquarium.

The Arduino controls the relays, sensors, motors and it is connected to the Esp8266. The main purpose of the Arduino is to perform calculations, take data from sensors, operate the motors and pumps through relays, it also sends the data to the Esp8266 which acts as an interface between cayenne and Arduino. Esp8266 forwards the data of sensor to Cayenne website. It also sends the instruction to operate the servo motor to feed. Esp8266 also acts as a Wi-Fi Module and provides internet connectivity to the whole circuit. We used wire.h library in Arduino to enable the use of I2C adapter. We downloaded LiquidCrystal_PCF8574.h library to use 20x4 LCD with I2C adapter. For Esp8266 we downloaded and installed Esp8266 board libraries. In libraries we downloaded and installed “CayenneMQTTESP8266.h” library from sketch. To operate the servo motor, we included “servo.h” library and made an object called “my servo” to use the servo motor. By using this library, the use of cayenne is pretty straight forward it is like displaying data on an LCD or serial monitor. The control of the feeding system is like interfacing the motor with Arduino. On cayenne we have to make a widget and define a function for the button or widget and then link it by an MQTT pass key.

4. Results

After constructing hardware and writing suitable software codes we have completed this project and obtained the results which are explained in this chapter. In this project we have monitored the water temperature, water level and water pH. We have made a remotely controlled feeding system using a button at Cayenne web app. We have displayed the results on LCD as well as on Cayenne web app. Some of the results of our project are described below.

4.1. LCD Based Results

4.1.1. Results on LCD

On LCD we displayed the results of water temperature, water level, pH and feed level which are shown in figure.

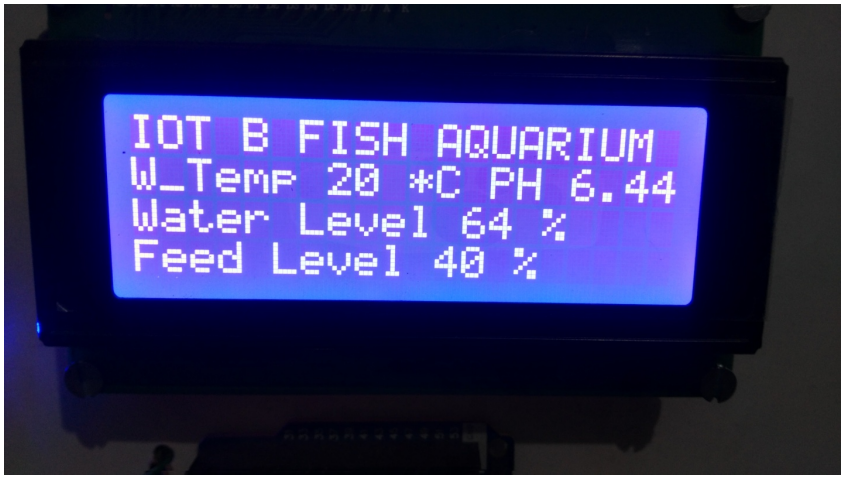

Fig. 18. Results on LCD

4.1.2. Results on Web Page

Cayenne my devices is a web app through which we have implemented our project. On this web app, we have displayed the results such as water temperature, water level, feed level and pH of water. We have displayed the graphs in real time. It also stores the previous data in graphical representation. We added a button 'feed it' which automatically feeds the fish whenever this button is pressed. We have obtained the following results of our project on Cayenne which are shown in the figure given below.

Fig. 19. Results on Cayenne Page

4.1.3. Feed Testing

To check the whether the feed level sensor is working properly or not we have tested it and obtained the results at no feed and putting some feed in it.
At no feed, we obtained the following results at as shown in figure.

Fig. 20. Feed Testing without Feed

Obtaining the results while feed is in the feeder.

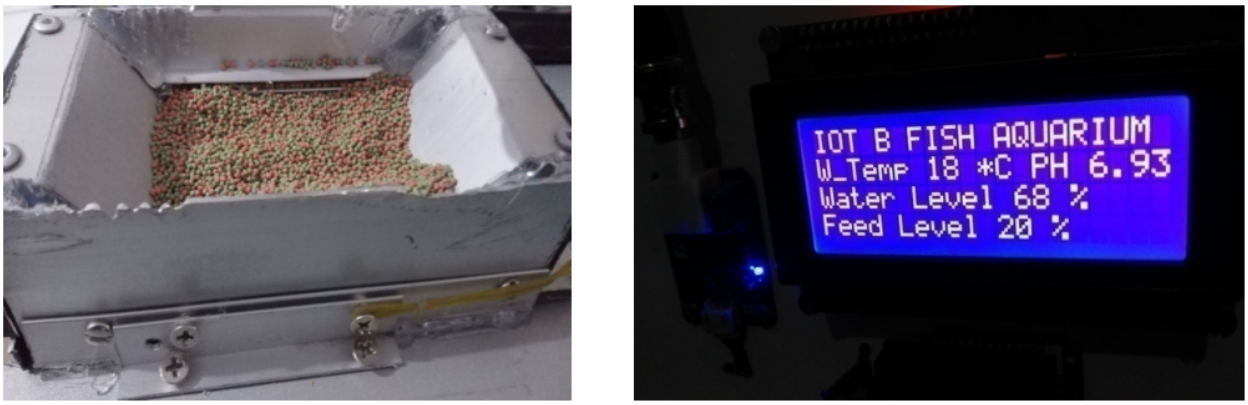

Fig. 21. Feed Testing with actual feed

4.2. Graph Based Results

We took several readings and obtained the following graphs with respect to time.

4.2.1. Feeding

We changed the feed many times and checked the feed level again and again. Sometimes the results were not in accordance to our requirement so we modified the codes through calibrations to get the desired results. The following figure shows the feed level of the feeder at different intervals.

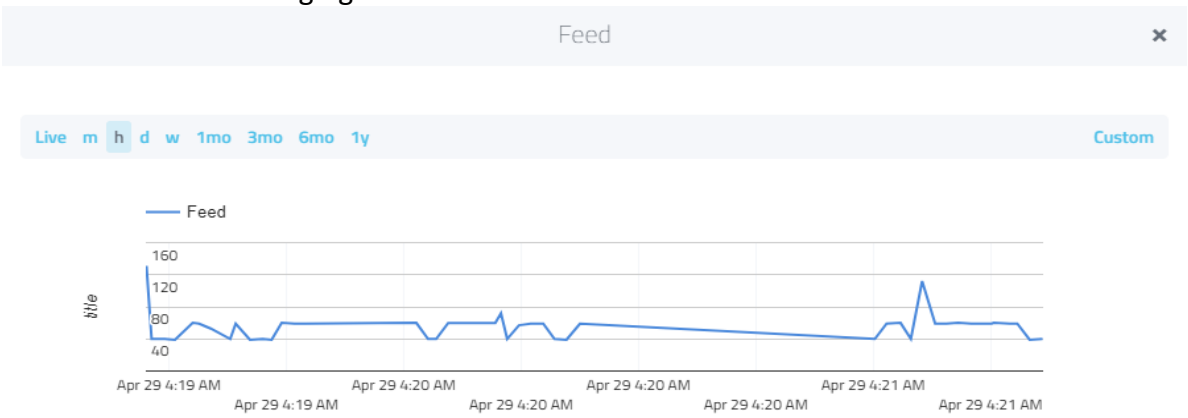

Fig. 22. Feed Level

4.2.2. Water Temperature

We have used thermistor which is senses the temperature of water continuously and displays the result on the LCD screen as well as on Cayenne Web app. The following figure shows the results obtained from temperature sensor.

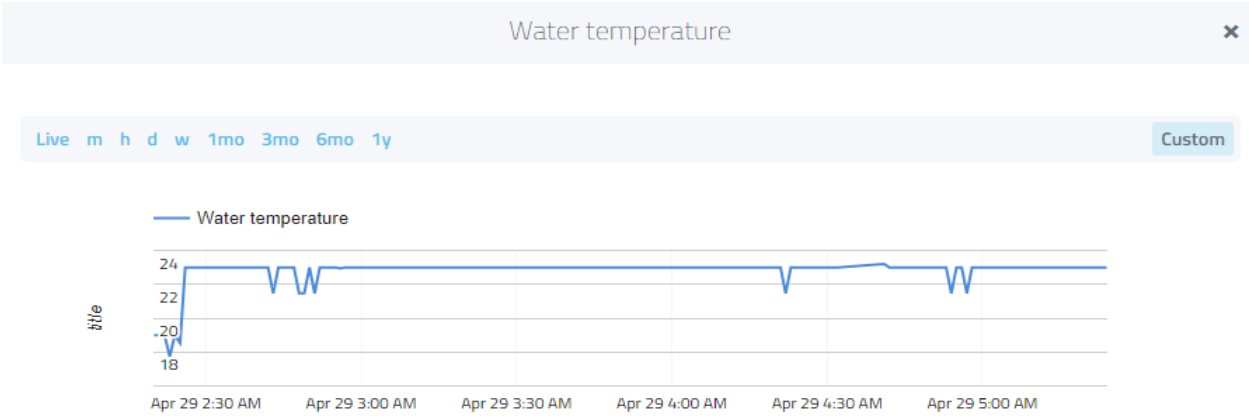

Fig. 23. Water Temperature

4.2.3. Water level

The following graph shows the water level at different intervals of time.

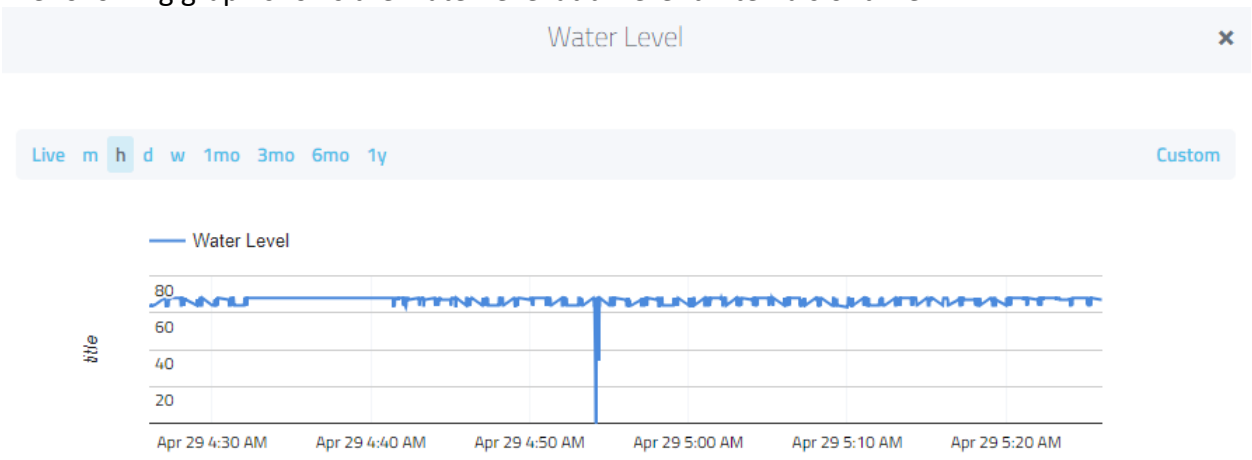

Fig. 24. Water Level

4.2.4. Water pH

As normal pH of water is 7, so during calibration of pH sensor we have obtained different values of pH. It gives the average values which are continuously changing between 6 and 7 with respect to time.

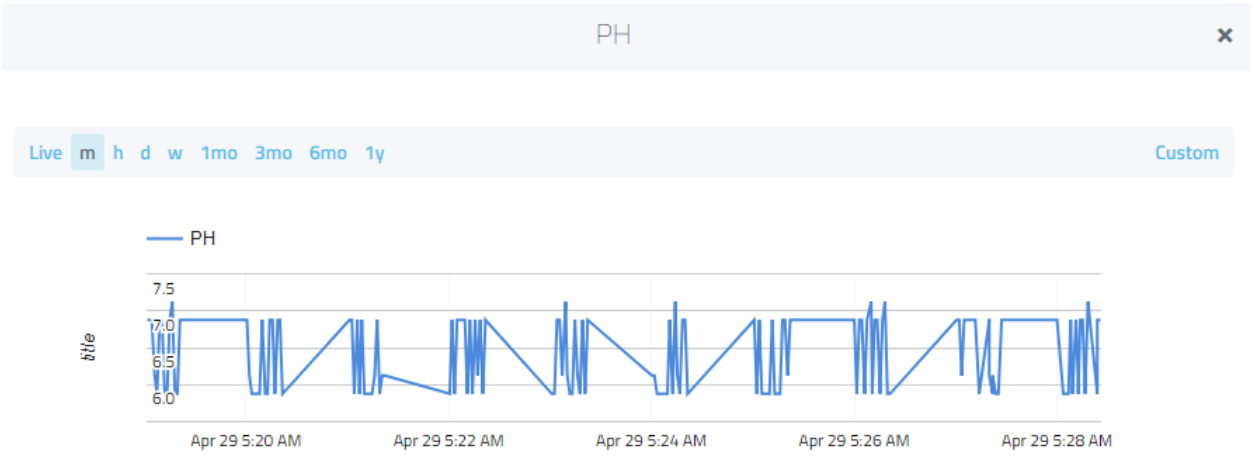

Fig. 25. Water pH

4. Conclusions

The project was inspired by an idea, to create a system that could automatically take care of the fish and the ability to be able to control these devices remotely over the cloud. Now most of the operations happen by themselves, maintaining steady pH, water level, temperature. By using an IoT platform, it can monitor these variables, visualize the data and even control some features manually, over the internet which is successfully implemented in this project. Another important feature was the mechanical design and implementation of the fish feeding system, which is an original design. It is a rather simple design, but it efficiently does the job, there are other designs but they are complicated, so this project achieves, simplicity, efficiency, time saving and cost saving. This project serves as a way to practically implement our skills to solve a very important management related problem and assist in achieving an ideal environment for fish in an aquarium.

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