pH Monitoring IOT Controlled Biomimetic Robotic Fish

R. Aylmer Britto, Shreya Sinha, Swastika Palit, Arockia Selvakumar*

Abstract--- Autonomous Underwater Vehicles (AUVs) find a wide range of applications in marine geosciences and are increasingly being used for search and rescue, health monitoring, data collection and naval surveillance. In this research, design, fabrication and IOT control of a pH level measuring robotic fish (Fanny) is proposed. The developed robotic fish has three parts body, abdomen and tail, apart from that two hinges are provided for the independent motions of the abdomen and tail. The developed robotic fish uses a gear train for motion transmission. The modelling of Fanny is done using 3D printing using ABS material. An IOT control system is developed with our own platform using HTTP protocol. To monitor the pH level of water a pH sensor SEN0161 is used. The Chemical nature of the water was observed and was constantly pushed to the cloud on a regular time interval. Based on IOT, the response time varies according to the behaviour of the water body and the degree of turn of robotic fish is found to be dependent on the efficiency of the design.

I. INTRODUCTION

Engineers are continuously finding faster, more efficient means of transportation especially in the area of underwater vehicles[1]. This has led a number of researchers to give attention to the power and maneuvering of swimming fish. Today under-water findings is mainly dominated by manned or unmanned submarine-type vehicles. The most successful in this respect is considered to be submarine, but lacks flexibility, ease of manoeuvrability and energy efficiency which makes the robotic fish better adapted ecologically in comparison to submarines. This lead to the development of a robotic fish. Biometric underwater robots have a lot of applications starting from surveillance to pipe inspection. Recently a lot of work has been reported in the field of robotic fishes. Most of the works are reported in the field of mechanism and dynamics of robotic fish[2-4]. Chen[5] has worked on application of Ionic Polymer Metal Composite fins to propel the fish. Much studies are reported in the field of fluid-body interaction that leads to good speed and good efficiency[6-7].Research works related to motion control algorithm has also been proposed[8]. Apart from Internet of things being used in smart cities, agriculture, health care monitoring, security it can also be extended for underwater technologies. The main challenges in the IoUT(Internet of underwater Things) were the transmission Radio signals are more prone to attenuation and also these signals being absorbed the medium on the way to the target node. Earlier control methods were making use of serial communication protocols like UART, I2C and SPI to exchange data and control. Later when wireless technologies evolved z Waves and GSM were used to transfer information. Acoustics waves were also used to receive and transfer information. Some studies are reported in which a Biomimetic fish robot controlling system by using acoustic signal has been realised [9]. The system consists of devise such as PC, MAC base board, underwater acoustic modem, and transducer. An interrupt driven mechanism has been used by underwater acoustic modem and MAC based board. Another work [10] focuses on overcoming the challenges in IoUT (Internet of Underwater things). A detailed investigation on cutting-edge routing techniques and routing protocols has been done along with a survey of multicast-tree-based routing protocols. Also, a comprehensive comparative study of the routing protocols has been included. An important aspect of underwater IoT system is power consumption. Nowadays, there is an increasing demand of battery operated IoT applications in underwater environment. Many researchers have been carried out for power saving in IoT devices. In this regard, a low power IoT underwater sensing architecture for applications such as AUVs, has been built and tested.[11] The proposed architecture is based on low-power Flash Micro-controller and a GPS for network synchronisation. A local server has been implemented on a Raspberry PI unit. One of the applications of AUVs is monitoring the quality of water. pH monitoring and sensing is very sensitive and important and also applicable in many aspects such as detection of bolus movement, nature of the refluxate and esophageal volume clearance after reflux. Power of hydrogen ions for a water body is one of the major solution quality parameters. This parameter of the given water body helps us determine if the given water is acidic or alkaline or neither of those. To measure the pH of the given water body the earlier methods mostly comprises of installing the sensor/transducer in a particular place and measuring the pH values at that particular time. Lately, many methods have been proposed for real time pH monitoring. In the paper[12], an arduino based system has been designed which connects a mobile app and a physical device using the internet. The user can view the changing values of the pH in the mobile app. Another mechanism used in recording pH values of water is via Cloud System Services.[13]The processing system can access the recorded pH by various PDA devices via internet network.

Manuscript received February 01, 2019
R. Aylmer Britto, SENSE, Vellore Institute of Technology, Chennai, Tamil Nadu, India.
Shreya Sinha, SENSE, Vellore Institute of Technology, Chennai, Tamil Nadu, India.
Swastika Palit, SMBS, Vellore Institute of Technology, Chennai, Tamil Nadu, India.
Dr. Arockia Selvakumar*, SMBS, Vellore Institute of Technology, Chennai, Tamil Nadu, India. (e-mail: arockia.selvakumar@vit.ac.in)

II. THEORIES

Currently, there doesn't exist any AUV model which uses IoT technology for locomotion and pH monitoring.

In this paper a preliminary attempt is made to propose an IOT controlled Robotic Fish named FANNY which is used for the pH level monitoring purpose. It uses a gear train mechanism formation transmission. Fabrication of the prototype has been done using 3D printing of the material ABS. IOT control system has been developed with our own platform using HTTP protocol. Wi-Fi technology of IEEE standards 802.11 used, operating at 2.4GHz, proved more efficient with less latency rate at significant depths and distances. Internet based cloud computing vendor services has been avoided and a private-configured local server was implemented. This comes with advantages such as adapting to whatever edge computing that has to be added and reducing the latency rates compared to the servers which are Internet dependent. Sensor SEN0161 has been used to measure the pH level of water. Usually, in places of bigger tanks, more than one sensing units are installed for measuring the instant pH at various places and correlative analysis of all the instances are done to come to a conclusion. Synchronization of sensor data at different instant is a big issue. But in our proposed system, the method of measurement is dynamic where the fish traverses to various places as requested by the user and then uploads the sensor/transducer data to the local server which reduces time and cost , edge computing complexity and also brings a reasonable solution for the synchronization problem.

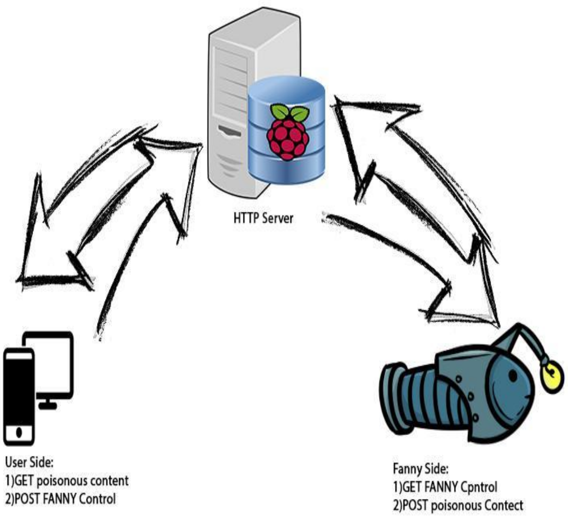

Fig. 1: Block Diagram

III. DESIGN AND FABRICATION

The mathematical model of the biomimetic fish consists of the geometry for an underwater vehicle which consists of three parts one is the main body, abdomen part, and the tail. The length of fish is 30cm, width is 15cm and thickness is 2.5cm (Fig 1). The prototype is fabricated using 3-D printing using Acrylonitrile Butadiene Styrene material (ABS material).FANNY has three parts main body, abdomen, and tail. It was designed using CATIA. The three parts of FANNY are detachable from the rest. Two hinges are provided

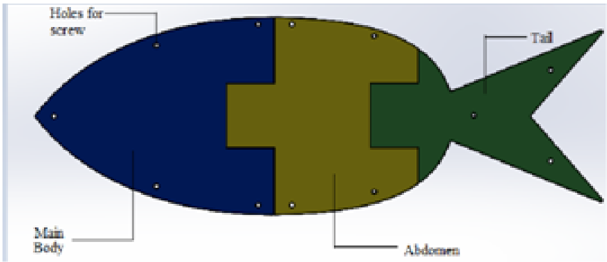

Fig. 2: View of Fish

Table 1: Hardware components

Component	Number Count
nodeMCU	1
SEN0161(pH)	1
servo (mg-995)	2
Gear train sets	2
Power Supply(AAA Batteries)	4
Battery Holder	
General purpose Board	

for the independent motions of the abdomen and tail. Screws with diameter 4mm are provided at different strategic points. The main part consists of the controller, power supply, pH sensor followed by gears and servo motor. Abdomen part also houses a gear system and one servo motor. The flapping mechanism is made from servo motors with gear drive to suit the purpose(Fig2). The motion is given by two separate motors, one for the tail and the other for the abdomen. The gear train is used for motion transmission.

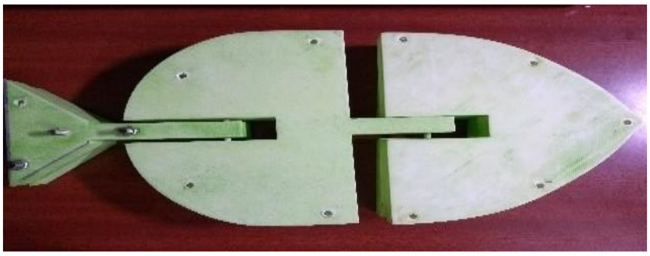

Fig. 3: 3-D Printed Model

IV. CONTROL SYSTEMS

A. Hardware Architecture: Locomotion and pH

Our Fish basically has three parts body, the tail part and abdomen part. The tail is responsible for the actual locomotion i.e. to drive the fish in the forward direction whereas the abdomen part is responsible for the navigation i.e. the left and right motion. The client side micro-controller is programmed in such a way that it keeps on pinging the server configured for the direction. If chosen to move forward the tail is made to sweep with a frequency of 2.5 which is enough to drive the fish in still water with no drag. The pinging which is done uses a normal GET request. The server returns a character based on the user response. Switch block is included in the code to respond according to the character received.

Despite there are many varieties of controllers nodeMCU was used. NodeMCU is an eLua based firmware for the ESP8266 Wi-Fi SOC.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

It has a Tensilica L106 32-bit processor. The clock speed is 80 160MHz. It also has a 10- bit analog to digital which means 1 input with 1024 step resolution. The received signal strength index of the inbuilt esp8266 is +19.5dBm output power in 802.11b mode. It supports communication protocols like UART/SDIO/SPI/I2C/I2S/IR Remote Control. A remote HTTP server is setup using a Raspberry pi 3 model B using the Django framework. Two independent URLs are made to control and moni-tor the fish response. A string is passed as message element to the server from the user side and this character would be by-passed to the fish at an interval of 1.5s. This makes the response time of the fish to be 1.5s. For the locomotion of the fish, two servo motors are used. One in the abdomen part and the other one in the tail part. The servo motor being used is mg-995. The stall torque of the motor is 8.5 kgfcm (4.8 V), 10 kgfcm (6 V). The operating speed is 0.2 s/60º (4.8 V), 0.16 s/60º (6 V).

To analyze the pH of the given water body SEN0161 sensor was used. The transducer was connected to a break out board. The breakout comprised of the Vcc, Gnd and the data pin. 3.3V is sufficient to operate the sensor. The data pin (i/p) is connected to an input pin. The data pin return values in millivolts in reference to the ground.

B. Software Architecture: Server Side

A local server based on python was hosted on raspberry pi3 Model B system. It runs on a Unix based operating system which makes the functions

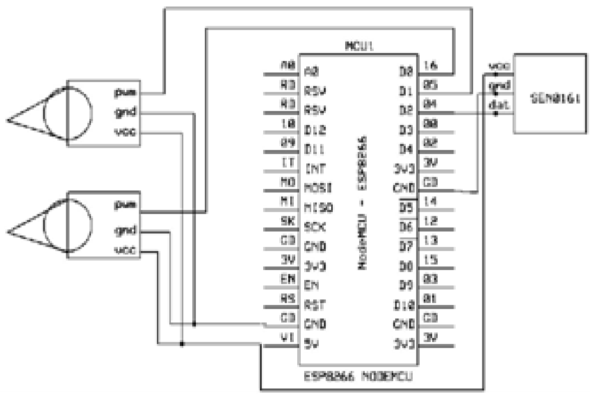

Fig. 4: Electrical Schematic of Control System

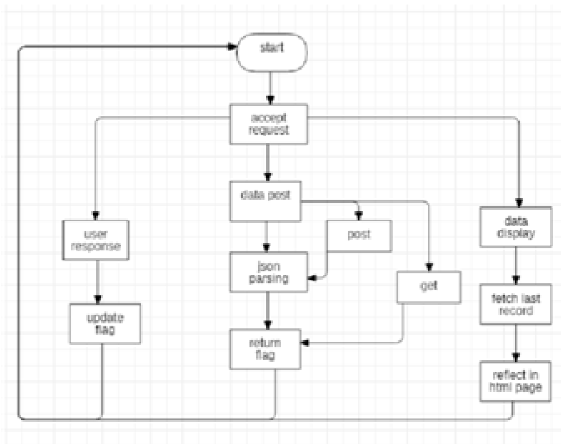

Fig. 5: Server Software Architecture

and programs flow smooth. The whole server was configured using the Django framework. It is light and can handle as many URLs/services the user wants without minimal lags. REST APIs were created to service the requests for both the sides i.e. FANNY side and the user side (website) to control the locomotion and visualize the pH instances of the water body. To keep in track of the pH content of the water body and to study the trend, the values are stored in sqllite3 model. In server side architecture we have services for two different targets. The different services are DataPost, DataDisplay and userResponse. DataPost url is meant for servicing FANNY side requests. UserResponse is for user sending user controls for the fish’s locomotion. DataDiplay for rendering the HTML page to dis-play the real Time values of pH sensor and controls for accessing User Response URL. For the FANNY side the API is configured to handle POST request regarding poisonous value and handle GET request for the locomotion part. The POST request handler here gets input of the pH sensor value and id tag in JSON format, parses it and updates it in the row having the particular id. The user check flag is updated based on the user requests from the user. The service is defined in such a way that for every POST request the user Check Flag is returned as an HTTP response. In the user side, a service has been made to handle the POST requests to update the user check flag which controls the locomotion fish. Also another URL service to handle GET requests return the instant pH value of the given water body.

C. Software Architecture: Client Side

Here, we have two target clients. One of the user end and the other one for the FANNY side. For the user side, it has two services one to upload the locomotion control and the other one to read pH instances. And its vice versa for the FANNY side architecture.

V. RESULTS AND DISCUSSION

A. Experimental Studies

FANNY was tested in a closed environment in a pool of freshwater. The Django framework server was deployed, and it starts servicing the requests that are already defined. FANNY makes a POST request which contains the pH instance of the water at that instant. The service returns a character which will give the details as an HTTP message. A switch conditional block was defined and the locomotions were switched accordingly. The initial position of the fish is A that is x=0 at time t=0s and final position of the fish is B that is x=0.2 m at time t=3s(Fig 10a and 10b). So, it has moved a distance of 0.2 m in 3 sec. From this, we observe that the velocity with which FANNY is moving is 0.07 m/sec. It is moving with the periodic oscillation of the abdomen and tail.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

B. pH Analysis

To monitor the amount of deviant contents in the water an at mega controller friendly sensor

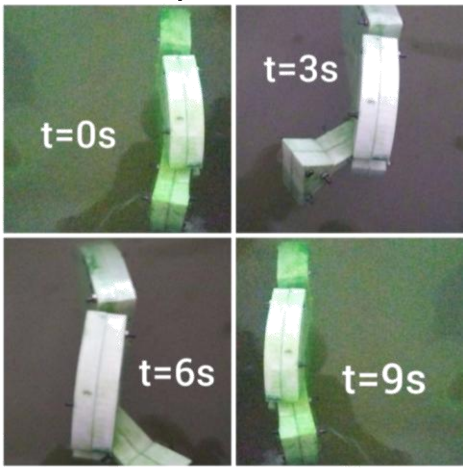

Fig. 6: FANNY Moving Straight, Right Turn, Left Turn, Straight

SEN0161 was used. The measuring range of pH is from 0 to 14. The operating voltage of the module is 5V. The nominal temperature at which the paper would operate is 00 C 600 C. The breakout board comes with an inbuilt gain potentiometer to tune output in the entailed format. From the datasheet, we could learn about the characteristic of water at room temperature. Based on the reference values on the chart, the analog voltages are being mapped from 0v to 5v with 10-bit precision. The voltage to pH conversion factor is being fixed this way.

While calibrating the sensor when the probe is put in a distilled water the ADC returns the values around 512. Based on the observation the most acidic solution would have the ADC value returned as 0 and for the most basic solution, it would be 14. So these ADC returned values are linearly mapped from 0-14. To display the fetched pH instances an HTML page is also rendered. It is also made to refresh this page by itself every 5 seconds.

VI. CONCLUSION

A bio-inspired robotic fish, FANNY, was pro-posed, designed, fabricated and tested for pH monitoring. Based on the observations made the following conclusions were drawn:

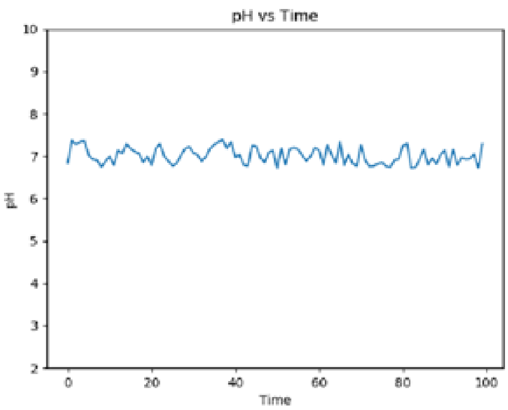

Fig. 7: pH instances after Calibrating it in Distilled water

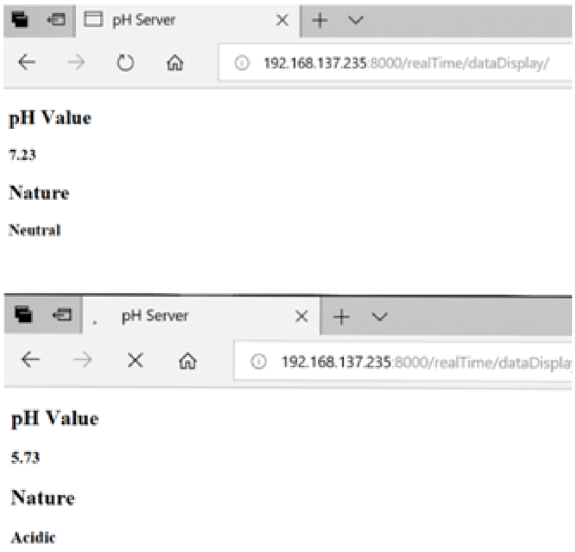

Fig. 8: pH values Rendered at HTML web page

FANNY was made to swim through the water body at the user desired paths by giving commands using the services handled by the dedicated server. It has almost achieved the desired velocity of 0.07m/s A HTTP based local server for IOT was deployed and this proved to be efficient by handling all the requests with very small la-tency rate. pH values were instantly rendered and real time monitoring of pH of the water body was made at desired spots.

The pH of water in the testing environ-ment was observed to be between 6.63 and 7.28.

REFERENCES

1. Techet A H, Triantafyllou M S. Boundary layer relaminariza-tion in swimming fish. Proceedings of the Ninth International Offshore and Polar Engineering Conference, Brest, France, 1999
2. Lighthill, M. (1960). Note on the swimming of slender fish J. Fluid Mech., 305-317.
3. Hu, H. (2006). Biologically inspired design of autonomous robotic fish at Essex. Proceedings of the IEEE SMC UK-RI, 1-8
4. Yu, J., Wang, S., and Tan, M. (2005). A simplified propulsive model of bio-mimetic robot fish and its realization. Robotica, 23(1), 101-107
5. Chen, Z., Shatara, S., and Tan, X. (2010). Modeling of biomimetic robotic fish propelled by an ionic polymermetal composite caudal fin. Mechatronics, IEEE/ASME Transac-tions on, 15(3), 448-459.
6. Kelly, S., and Murray, R. (2000). Modeling efficient pisciform swimming for control. International Journal of Robust and Nonlinear Control, 10(4), 217-241.
7. Hong, C., and Chang-an, Z. (2005). Modeling the dynamics of biomimetic underwater robot fish. Robotics and Biomimetics (ROBIO). 2005 IEEE International Conference on, 478-483.
8. Shang, L., Wang, S., Tan, M., and Dong, X. (2009). Motion control for an underwater robotic fish with two undulating long-fins. Decision and Control, 2009., 6478- 6483.

9. Sardorbek Muminov, Nam-Yeol Yun, Seung-Won Shin, Soo-Hyun Park, Jun-Ho Jeon, Chang-Gi Hong, Sung-Joon Park, Chang-Hwa Kim, Gi-Hun Yang, Young-Sun Ryuh . (2012).Biomimetic Fish Robot Controlling System by using Underwater Acoustic Signal. 2012 9th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON)
10. En-Cheng Liou, Chien-Chi Kao, Ching-Hao Chang, Yi-Shan Lin, Chun-Ju Huang. (2018). Internet of Underwater Things: Challenges and Routing Protocols. Proceedings of IEEE International Conference on Applied System Innovation 2018 IEEE ICASI 2018- Meen, Prior and Lam (Eds)
11. Redouane Es-sadaoui, Lahoucine Azergui, Youssef Ghanam, Jamal Khallaayoune.(2017). Design and experimentation of a low-power IoT embedded system for wireless underwater sensing.
12. Asma Fatani, Ahmed Bensenouci, SIEEE, Tayeb Brahimi, Hedaih Alshami, Mohamed-Amine Bensenouci. (2018.)Dual pH Level Monitoring and Control using IoT Application.
13. Thongchai Photsathian, Thitiporn Suttikul, Worapong Tangsrirat (2018). Design and Improvement of Wireless Crayfish Breeding System by Controlling Water Temperature and Monitoring pH via Cloud System Services.