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A Novel Approach of Marine Ecosystem Monitoring System with Multi-Sensory Submarine on Robotic Platform for Visualizing the Climate Change Effect over Oceanic Environment

Sheekar Banerjee* **and Aminun Nahar Jhumur**

Department of Computer Science and Engineering, International University of Business Agriculture and Technology, Dhaka 1230, Bangladesh

(*Corresponding author's e-mail: 16203084@iubat.edu)

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Abstract

It is obvious that the whole world is so much concerned about the terrifying escalation of climate change in the recent time period. This climate change effect can be visible in the land, atmospheric and oceanic area simultaneously. Though there have been multiple attempts of proposing solutions concerning the protection for the land area environmental balance, monitoring and surveillance. But unfortunately there have been a very handful of research work which predominantly concerns about the protection upon the environmental state of marine biological species and its ecosystem. So, the following research study proposes a solution which appears to be a full-fledged Bluetooth controlled Submarine prototype with a sensory chipboard attached inside its endo-skeleton which contains multiple sensors like DHT11 temperature-humidity, dust, CO_2 and YL69 pH sensors. The sensory data provides the information of underwater whether the naval environment is habitable for the marine biological species or not, under the terrible effect of global climate change. The submarine prototype is fully functional in the surface and underwater scenario which contains a very unique mechanical design and circuitry with an exceptional sensor data streaming capability which can be used by marine biological researchers and oceanographers professionally as a full-fledged marine ecosystem monitoring device.

Keywords: Underwater surveillance, Marine ecosystem, Sensor data streaming, Precision control, Navigation

Introduction

Climate change is undeniably a true fact and phenomena which is quite noticeable in the recent outcome though the nature. The climate change includes both the global warming driven by human emissions of greenhouse gases. This havoc or obliteration is resulting large-scale shifts in weather pattern. There have been several periods of climate change previously since the mid-20th century. Humans have had unprecedented impact on Earth's climate system and caused change on a global stage. The largest catalyst of this warming is the emission of greenhouse gases, of which more than 90 % are carbon dioxide (CO_2) and methane. The fossil fuel burning for energy consumption is the main source of these emissions alongside the other contributions from agriculture, deforestation and rigorous industrial processes [1]. Deserts are quite expanding and heat waves and wildfires are quite common because land surfaces heat faster than the ocean surfaces. But it is high time that we must realize that the transfer of heat is not anymore limited to the land surface area. Rather the heating process in expanding in the oceanic area as well where the habitat destruction and imbalance effect in the marine ecosystem are being noticed significantly by the notable researchers affiliated with marine biology and oceanography [1,2].

Marine ecosystems are the largest of Earth's aquatic ecosystems and are distinguished by waters that have a high salt content while the ecosystems contrast with fresh water ecosystems. The fresh water ecosystem has a lower level of salt content. The most moving fact is that the marine waters cover more than 70 % of the surface of the Earth and account for more than 97 % of Earth's water supply and 90 % of habitable space on Earth [1]. The marine ecosystems include nearshore systems, such as the salt marshes, seagrass meadows, mangroves, mudflats, rocky intertidal systems and coral reefs. They also extend outwards form the coast to include offshore systems, such as the surface ocean, pelagic ocean waters, the deep sea, oceanic hydrothermal vents and the sea floor [2]. These huge marine ecosystems have a very important influence over the planet which is getting affected dastardly because of global warming and climate change. The recent days of ocean acidification are containing the significant evidence of this affects. The ocean acidification is the ongoing decrease of pH of Earth's oceans, caused by the uptake of carbon dioxide (CO_2) from the atmosphere [3]. The burning fossil fuels play the role to be the reason of it. Seawater is slightly basic (meaning pH > 7) and ocean acidification involves a shift towards pH-neutral conditions rather than a transition to acidic conditions (pH < 7) [4].

In the verge of this catastrophe, we are sincerely trying to strive upon the finest technological support through our utmost innovative minds [5,6]. Our proposed naval ecosystem monitoring system with multiple sensor based Bluetooth controlled submarine focuses on the proper collection data form the oceanic environment through multiple highly precision controlled and tuned sensors. The utility sensors are namely DHT11, YL69 pH, dust module and CO_2 sensors. According to our proposed system, we tried to gain sensory data of temperature and humidity from the DHT11 model. According to the temperature and humidity data, it would be very comfortable to compare the data with the normal index of oceanic temperature and humidity and the marine ecosystem. The continuous increase of sensory temperature data in the oceanic environment shows the clear result of climate change and global warming resulting to the rising of sea level. The imbalance of underwater humidity also determines the imbalance of the environment for the marine ecosystems.

The YL69 model of pH sensor in the proposed system plays a very vital role in determining the acidification of oceanic environment. Whenever the pH value displayed less than 7 (pH < 7), the navigated underwater and surface area of the submarine prototype seemed to be acidic. Theoretically, if the pH level showed up less than 4 (pH < 4), particular underwater area could be declared as catastrophic and life threatening for the marine biological species and its ecosystems. Similarly, the dust sensor module from the submarine showed up the amount of marine pollution comprising with the industrial waste, spread of invasive organisms, agricultural, residential waste and so on. The pollution of marine environment is determined through the dust sensor value indexed by ounce-per-L. If the ounce-per-L value increases, the real time numerical data of evidence can be showed which proves the existence of marine ecosystem pollution and its catastrophic devastation. Following the work flow, the CO_2 sensor value displays the real time amount of carbon dioxide in the marine ecosystem. While the CO_2 sensor module from the proposed submarine showed its capability of continuous and uninterrupted sensory data streaming capability which reassures the proper way of marine ecosystems monitoring and its most accurate level of real time implementation and execution. CO_2 should not be crossing the range of its amount to keep pace with the habitability of marine species underwater. If CO_2 value crosses the limit, another catastrophe for the marine ecosystems can be estimated unarguably. CO_2 sensor module from the submarine prototype would be reliable enough to inform us about the ups and downs of CO_2 value in the environment of marine ecosystems.

Related work

The area of the naval environment monitoring and underwater surveillance is already a well-researched field where we can easily notify the significant studies and findings based on underwater and naval robotics as well [3-6]. The research of underwater robot with electro-active polymer pectoral fins, market-based task allocation framework for autonomous underwater robots, the Proportional Integral Derivative (PID) controller station systems for underwater robots, disturbance rejection control for accurate positioning for underwater robots, optical underwater robots are very influential in this field [7]. The Periodic Auction Distributive Algorithm (PADA) algorithm makes the market based task allocation approach very unique where the update of allocation table, urgency factor and position assets are initialized. The PADA was also improvised through ResolveAuction() function so that the "check relocation task" could be remodified with better accuracy [8]. The approaches of Brushless Direct Current (BLDC) Motor, Low Pass Filter (LPF) and Sliding Motor Control (SMC) can be notified for the PID controlled research work [9]. They are all especially concerned about the proper way for navigation, stability and preciseness of the directional movement of their specific robots [7-10].

The optical underwater robots with some wireless sensors are applied to create a new exceptional genre of naval robotics for execution of the purpose of surveillance, reconnaissance and military operational activities. It featured a testbed for the subsystems that later would be segregated into different modules. Basically, their proposed systems were a modular system composed of a set of stackable, cylindrical modules with different functions. The trivial self-configuration feature seemed to be the most intellectual implementation in this research which almost entirely relied upon the mechanical advancement of the underwater robot [11].

The task allocation framework to manage cooperation, can be seen in the autonomous underwater robot research where the authors tried to extend the PADA with the process of better task allocation process. PADA works by using periodic negotiations among neighboring robots and requires only local communication. Particular attention was paid to make the auction scheme robust to intermittent the communications of the submarine rover [12].

The autonomous underwater surveillance robot showed the precise structural manifestation of an autonomous naval robot where the authors exploited their vision of implementation though the actual interfacing of Arduino ATMega2560 and its pins of layout. They were mostly concerned about the full functionality of their robots navigation and underwater movement with a cost effective manner. But with the proper way of surveillance, which sort of multi-dimensional approach could be done, was not specified [13].

Data muling over underwater wireless sensor networks using a submarine considered a system comprising an Autonomous Underwater Vehicle (AUV) and many static underwater sensor nodes (USN) networked together optically and acoustically. The AUV could locate the static nodes using vision and hover above the static nodes of data upload. Undoubted authors focused on the data mining strategy coming from multiple sensor nodes and exploited the data to reconstructs a model of sensory data management, training and testing. But their data did not even remotely concern about the marine ecosystem monitoring and their hazards resulting from the climate change [14,15].

Distributed Information Fusion in multi-static sensor networks for underwater surveillance focused over the anti-submarine warfare (ASW) tactics and ultrasonic sensory deployment mechanism for naval warships detection and reconnaissance. The authors considered two types of distributed sensory systems. The 1st diffusion scheme contacts were combined at each node using the optimal Bayesian-tracking based on the random finite set (RFS) formulation. The 2nd diffusion scheme tracks were combined using the track to track (T2T) fusion [16].

HYDROBOT focused on some specific tasks to be carried out like detecting and mapping submerged wrecks, rocks and obstructions that could be intervened the navigation systems. The structure was made up of polyvinyl chloride pipes and was balanced by the principle of center of gravity. The structure was capable of rotating in 360^{o} as well as the changing depth according to the user. Only for the surveillance purpose, some sensors were used such as accelerometer, hall-effect and temperature sensors [17].

Almost in all research works in the previous days, the 1st and foremost objectives of most of the underwater robots or vehicles are implied as surveillance for security purpose, military tactics for the cause of underwater operations, diving, demolition and salvage [18-20]. But after all of them, we started to notice that the genre of underwater robotics was approaching towards the betterment of humanity through the diving operations of the robots though recuing purpose which can be seen in [19]. The uses of multi-dimensional high precision wireless sensors are also seen tremendously with some higher sophistication in the latter time [20,21]. But unfortunately all of the previous studies have always leaned to the purpose of surveillance, rescue and military operational manners. There was almost no mention of proper surveillance and monitoring over the naval biological species and marine ecosystems with the same mechanism of wireless sensors and underwater robotics navigation so that oceanographic researchers could identify the effect of climate change in the seawater and marine biological scenario. Through the naval bot namely a submarine, a very exponential load of success could be achieved with the proper assembly of necessary environmental sensors and proper approach of testing. In all of the previous cases, the collected sensory data was not significant enough to show the real existential scenario of the underwater environment. The live streaming of sensory data should have been collected, compared with different situations, made up with an environmental simulation and mathematical statistics by which we could make the statistical comparison of sensory data and understand the habitability of marine life in the seawater. Concerning the overlooked purpose of the previous research activities, our proposed work as Multi-Sensory Bluetooth Submarine is trying to step down the footstep with a very higher level of accuracy for climate data collection and evaluation from sensors. The noble intention and the unique approach of our proposed research work are successfully implied to show the evidence of novelty which no other researchers could show previously at all. The following methodology and result analysis would be carrying the manifestation of proper implementation and novelty with marine ecosystems climate data collection, visualization, statistical data analysis and evaluation.

Materials and methods

This particular section details the 3 main components of the Multi-sensor Submarine proposal and they are: Submarine Navigation, Sensory Connections and the Real Time Data Transmission procedure. The schematic diagram of the submarine system is given in **Figure 1** which shows the working procedure of each and every block and element of its hardware. The submarine navigation relates to the proper manipulation of the data collection structure of frame upon the subject environment. The precise hardware assembly, connection and act of scrutinizing are the prime factors in this section. The sensory connection signifies the prime existence of multiple sensors to dignify the objective of collecting multi-dimensional data from the surface and underwater environment through the sensors. Primarily, the prototype endo-skeleton was associated with 4 sensors. Rather, we kept options of modifying the sensor panel to be engaged with 'n' numbers of sensors. If the 1^{st} DHT11 sensor symbolizes as S_1, dust sensor module as S_2, gradually the finalized merge of the sensory values are synchronized with summation of series formula with ad-hoc mechanism, $S_T = S_1 + S_2 + S_3 + S_4 + \ldots\ldots.. S_{n-1} + S_n$. On the other side, the real time data transmission refers to the live sensory data transmission procedure through an output monitor alongside the Arduino IDE simulation dashboard. Following each of the components will be detailed below.

In **Figure 2**, the diagram of the navigation circuitry is represented with its essential components. Submarine navigation is generally dependent upon the following electro-mechanical equipment with TX-RX transmission-receiving protocol. Multiple A2212 1400KV BLDC motors' regulation with maximum current 6-12A, 16A/60S of current capacity, compatible to 2S and 3S Lithium Polymer power sources and almost precise electric impulses and calibration. 1100 GPH 12V Submersible Marine Hydraulic Pump Motors speculate for proper diving mechanism with 1100 gallons per hour flow rate, 1 - 1/8" tubing (29 mm) size, bearing a height of 107 and 60 mm diameter. TowerPro MG995 full metal Servo Motors manipulation system is used for most accuracy of direction controls in both surface and under water scenario. It features analog modulation, 10.00 kg-cm torque, 0.20 s/60 ºC speed of liver movement, coreless motor type and dual bearings rotation support. The direction control of our proposed submarine frame prototype will generate the solution of the navigation barrier according to the laws of hydrodynamics mechanism. The efficient way of multiple servo motors connection through the D1-D13 digital pins assembly and execution plays the most important part in those cases so far. PWM ports are associated to improvise the servo rotation speed through the frequency control with digitalRead() function in actionable programs.

Sensory connections are the most soulful part of in this proposed research work which is represented with a circuit diagram in **Figure 3**. Multiple sensors are planned to be attached within single chipboard where the process and streaming of the sensory data escalates through a microcontroller, preferably Arduino Uno R3 alongside Arduino ATMega2050. The sensory input data has been stored and processed within a single microcontroller but it can also be multiple according to the need of time and environment. The process can be improvised through Raspberry Pi3B or 4B but extended program written in Python with Python 3.9 interpreter will be needed for better performance with specific RaspbianOS (Dedicated virtualized operating system for Raspberry Pi).

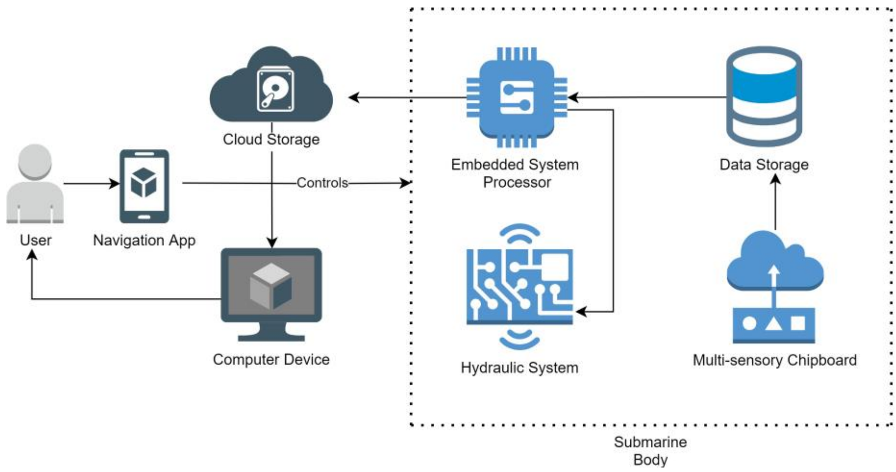


Figure 1 Schematic diagram of the multi-sensor submarine prototype.

The sensors which are proposed to be used in this work are DHT11 temperature sensor, CO_2 sensor, dust sensor and YL69 pH sensor which are all shown in **Figure 3**. Real Time Data Transmission procedure is the object oriented manifestation of the entire proposal by which the real data will be live streamed through the microcontroller attached with wireless communication hardware methodology. The output of the real time data is observed through a single com-serial board which is represented in **Figure 4**. Those collected data escalated the further research work upon the surface and underwater environmental surveillance. Alongside the com-serial board the excel data streamer can be apply for further machine analytics and demonstration.

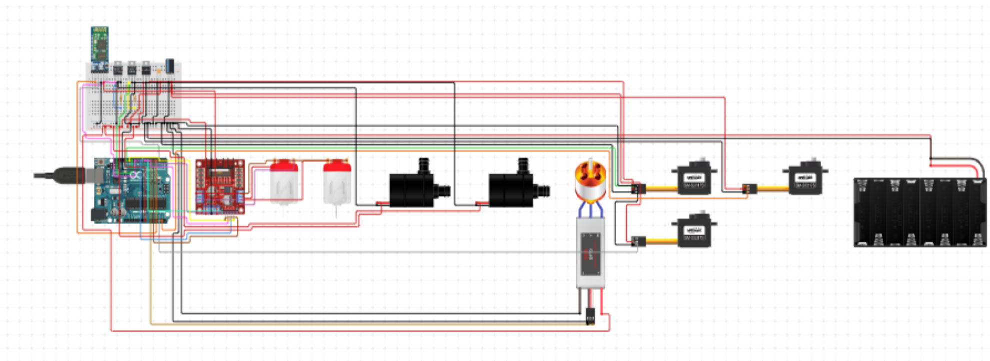


Figure 2 Circuit diagram of the navigation circuitry of the submarine prototype.

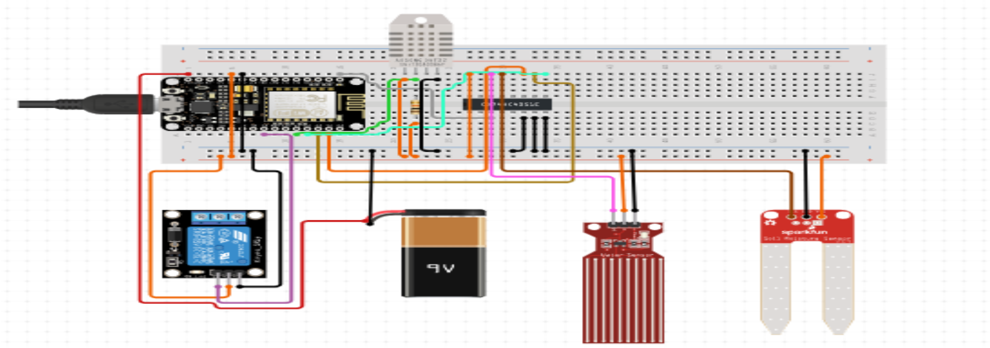
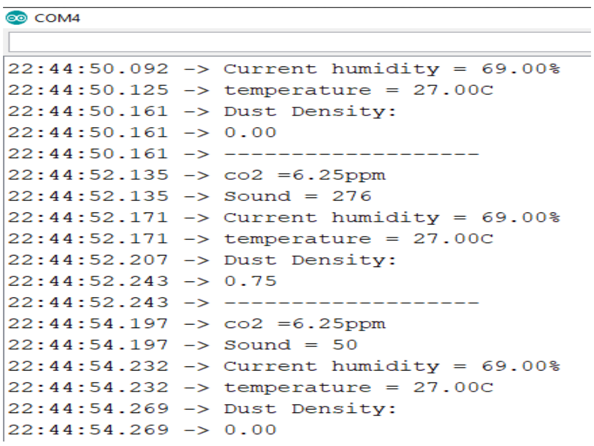


Figure 3 Circuit diagram of the sensory circuitry of the submarine prototype.



COM4

```
22:44:50.092 -> Current humidity = 69.00%
22:44:50.125 -> temperature = 27.00C
22:44:50.161 -> Dust Density:
22:44:50.161 -> 0.00
22:44:50.161 -> -------------------
22:44:52.135 -> co2 =6.25ppm
22:44:52.135 -> Sound = 276
22:44:52.171 -> Current humidity = 69.00%
22:44:52.171 -> temperature = 27.00C
22:44:52.207 -> Dust Density:
22:44:52.243 -> 0.75
22:44:52.243 -> -------------------
22:44:54.197 -> co2 =6.25ppm
22:44:54.197 -> Sound = 50
22:44:54.232 -> Current humidity = 69.00%
22:44:54.232 -> temperature = 27.00C
22:44:54.269 -> Dust Density:
22:44:54.269 -> 0.00
```

Figure 4 Output demonstration of multiple sensors’ values from the com-serial monitor.

The research upon multiple sensors Submarine is proposed generally for the monitoring of marine biological species for the future development. Although the proposal is approached by concerning the universal usage and implementable point of view, it generally concerns upon the hydro environmental nursery based on lakes, ponds and rivers as well. We can also approach for the sea level and oceanographic manifestation as well but for this implementation and testing, we would need the highest possible accuracy for the precision control over the sensors.

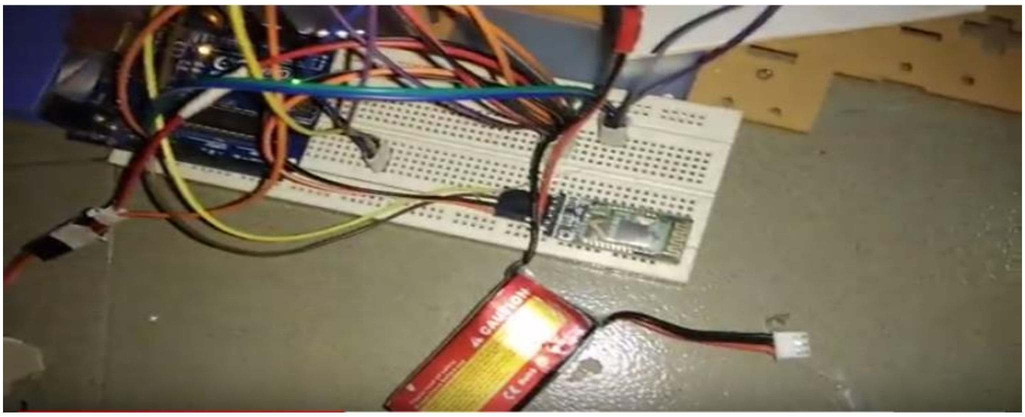


Figure 5 Real time assembly of the navigation circuitry of the submarine prototype.

For the assembly of the multiple sensors within a single processor hub, an iterative preciseness has been checked quite often. As the entire proposed research is relying on the perfection of the data streaming of sensor values, the temperature, dust, water depth, pH and CO_2 sensors are connected with extra care. Concerning the unexpected corruption of data among the sensors, we constructed thin layers of foiled partitions between the physical out-layers of those sensors. The real time navigation circuitry can be seen in **Figure 5** while the real time assembly of the sensors can be seen in **Figure 6**.

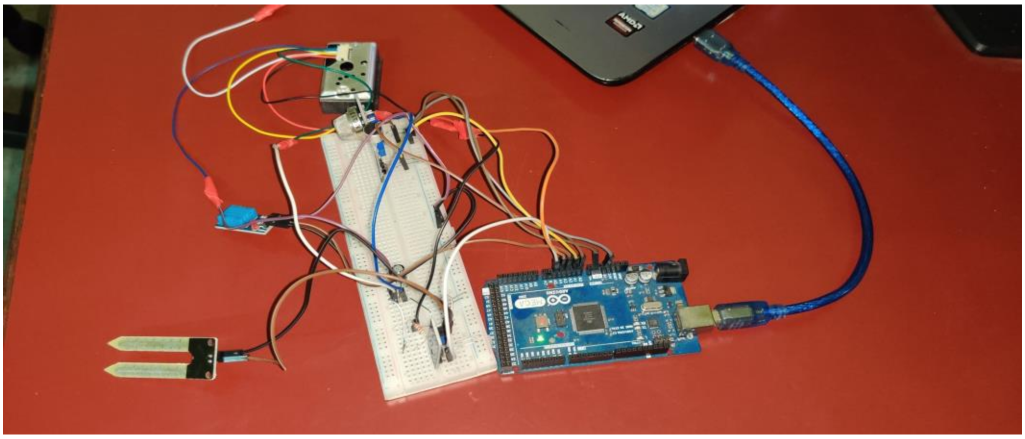


Figure 6 Real time assembly of the sensory circuitry of the submarine prototype.

The navigation control, direction control and diving hydro-mechanisms controlling the hydraulic motors are expected to maintain with a full functional Multi-Senor Submarine Navigation App which is noticeable in **Figure 7**.

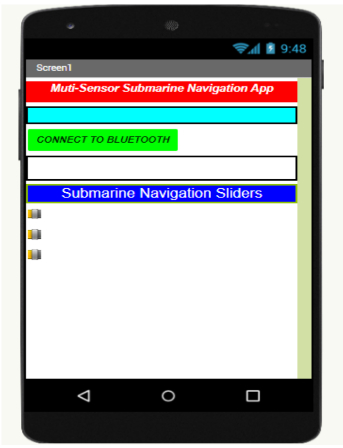


Figure 7 Layout of the multi-sensor submarine navigation smart phone application.

Algorithm: Submarine motor control and navigation

```
begin
deployment: Submarine is deployed to the naval environment
SETUP Process
setup ()
    starting Bluetooth communication system with Serial.read() function
    initializing servo motors with declaration of variables sm1, sm2 and sm3
    initializing bit-per-second baud-rate with Serial.begin(9600), transferring impulse as 9600 bits/s
end setup
LOOP Process
loop ()
    if (bluetooth.available()>=2) then
        measure servo motor position in smartphone app slider
        calculate: realservo = (servopos1 * 256) + servopos
            if(realservo>=1000 && realservo<=1180)
                move servo by 180 degrees
                display Servo1 is "ON"
                display 10 milliseconds
            end if
    end if
end loop
```

These conditional statements go for the same manner of the multiple parameters of the multiple servo motors just like sm1 starts its loop from 1000 to 1180, sm2 will start from 2000 to 2180 and sm3 will start from 3000 to 3180. This prototype coding mechanism can be plotted for n-times if we approach for the manifestation of n-numbers of servo motors.

Table 1 Pin configuration between CO_2 sensor and the micro-controller.

MQ135	Arduino	Description
A0	A0	Analog Input Pin
D0	D0	Digital Output Pin
Vcc	5V	Connection to positive of power source
GND	GND	Connection to negative of power source

Table 2 Pin configuration between pH sensor and the micro-controller.

pH Sensor	Arduino	Description
+	5V	Connection to positive of power source
-	GND	Connection to negative of power source
D+	4	Data Pin

Table 3 Pin configuration between temperature-humidity sensor and the micro-controller.

DHT11	Arduino	Description
Vcc	5V	Connection to positive of power source
GND	GND	Connection to negative of power source
Signal	6	Data Pin

The pin configurations between the Arduino Microcontroller and the other sensors namely CO_2 sensor, pH sensor and temperature-humidity sensor are described in **Tables 1 - 3** respectively. Only for CO_2 sensor, analog pin of Arduino has been used so that analog data signal can be passed. But for the other sensors, digital data signal has been passed through digital pins of the Arduino which are shown in **Tables 1 - 3**.

Results and discussion

Approaching the main segments of the real time testing, we divided the entire mechanism into 2 stages. They were expected to be like: Hydro-dynamics navigation, real time sensor data streaming with graphical representation. We tested continuously for 15 days and found out some negligible error upon our proposed mechanism. We corrected that with proper and precise manner. We showed a nature of iterative testing into various kinds of scenarios and situations. The precise navigation can be seen in **Figure 8**. We debugged the communication jamming problems which sometimes cut off the sensor impulses in the functional period. After 7 days of testing, we tried the tuning mechanism for the sensors so that we could get the sensory output with the highest possible accuracy.

Figure 8 Real time navigation of the multi-sensor submarine prototype.

After precise tuning of those sensors, we got the proper data streaming value at a very regular basis with the passage of time at every 2 s each. We could undertake the entire process of navigation and sensor data streaming with an accuracy rate of 96.56 %. The data live streaming in excel sheet can be noticed over the **Figure 9**.

Temperature (Celcius)	21.98	22.98	23.98	26.04
Water Depth (Meter)	20	50	15	40
pH (No unit)	7.1	5.67	4.72	4.17
Dust (Ounce/Liter)	27.67	28.56	32.67	34.98
CO2 (Milliliter)	3.21	3.45	3.72	3.33

Figure 9 Real time live streaming of multiple sensory data from the submarine prototype within an excel sheet representation.

In the **Figure 10**, we demonstrated the real time live streaming of sensory data. Namely, the DHT11 temperature sensor kept streaming the values nearly 27, 24, 23, 19, 22, 29, 27 ºC with the index of degree centigrade which could have been converted to Fahrenheit as well with the re-modification of sensor programs. Through the screenshot of the dashboard, we could see the XY based 2 dimensional graphical representations of sensor values where the X- axis was symbolizing the real sensor value and the Y- axis was determining the time interval between the streaming of continuous data in seconds. Humidity value was floating around 62 to 69 unit, CO_2 sensor was showing the optimal percentages of CO_2 in the particular area of submarine navigation. Dust sensor was showing values around 4.15, 5.89, …… , 9.37 ounce-per-L signifying the high rate of dust and pollution in the area of marine ecosystem. With the specific time interval the pH sensor was also showing the pH value of the seawater area such as 7, 6.98, 6.77, …….., 4.08 unit. Though those pH value, we could significantly determine the oceanic acidification because quite frequently the pH sensor was showing the pH values very close to 4 unit. This scenario definitely proofs the undeniable acidification of seawater. We significantly tested our proposed system in the shore of Bay of Bengal and we got almost the same values of pH which testifies the evidence of acidification of the great Bay of Bengal. If we check some background of the industrial growth of Bangladesh, we can identify the higher frequency of industrial development in the shore area of Bay of Bengal. It would be a very wise estimation if we could say that the off-shore industrial waste materials are being the reasons for the acidification of the great Bay of Bengal. Meanwhile, our proposed multi-sensory submarine was able to proof its full-functionality and novelty by showing the proper water area submarine robot navigation and error-free sensory data transmission by which we could make proper decisions of the effect of climate change in the seawaters and marine ecosystems.

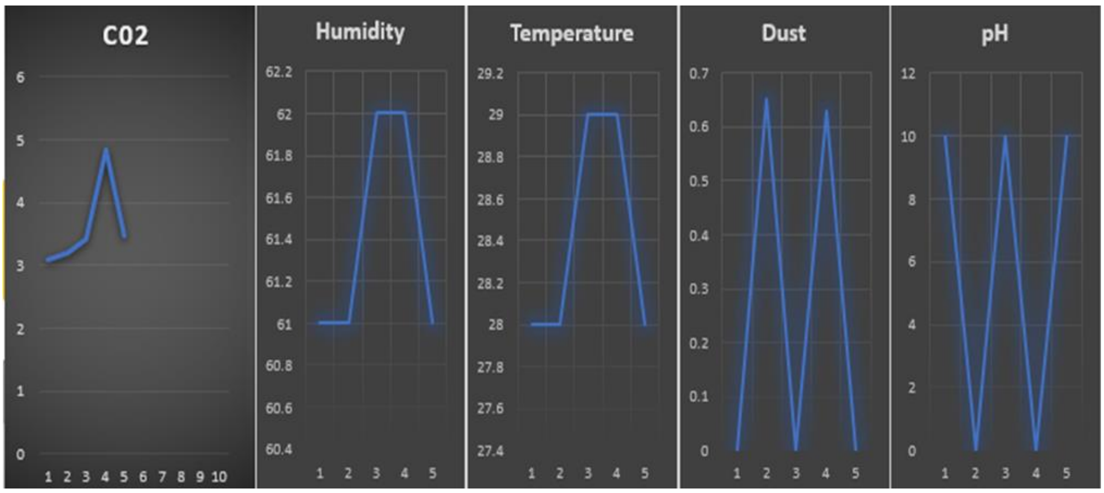
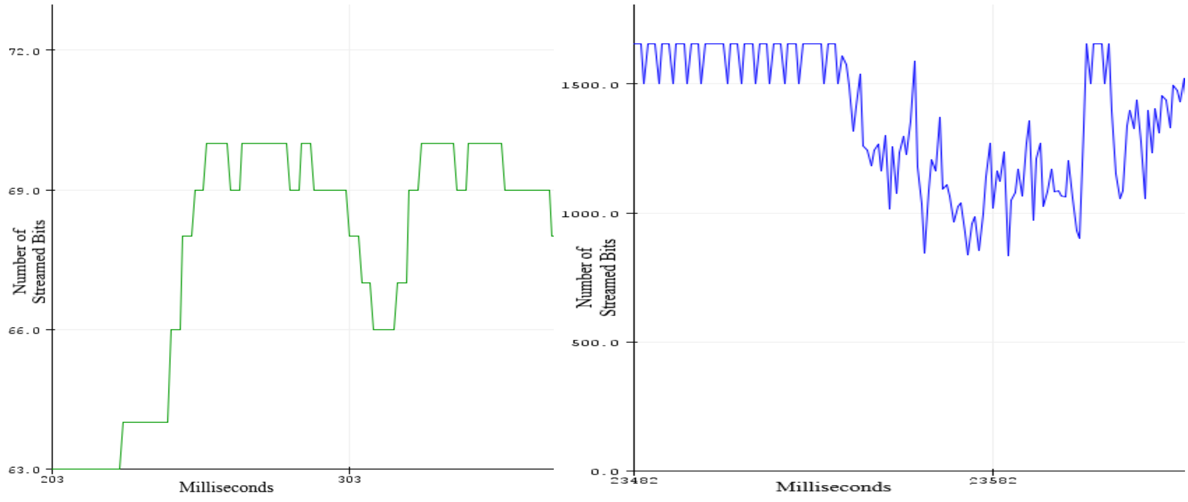
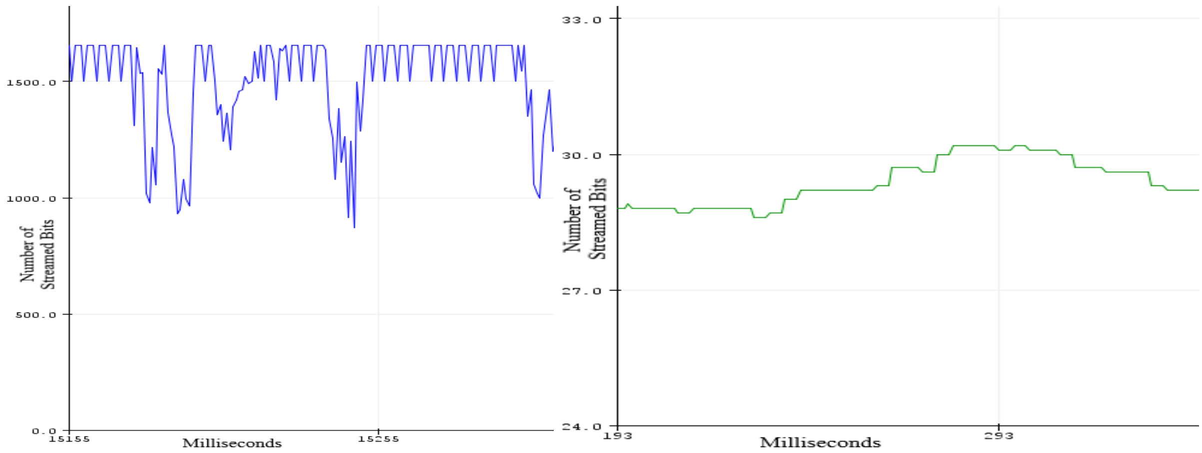


Figure 10 Real-time live streaming of sensory data from the submarine prototype with line graph perception.

In **Figure 11**, the number of streaming bits per s can be seen for the sensors namely dust sensor, pH sensor, temperature-humidity sensor and CO_2 sensor. We manipulated the rate of sensory data streaming by improvising the baud rate of data streaming in Arduino IDE Serial Monitor so that we could control the frequency of data streaming for every sensor.



(a) Dust sensor. (b) pH sensor.



(c) Temperature sensor. (d) CO_2 sensor.

Figure 11 Precision controlled iterative value of multiple sensory data streaming bits from the submarine prototype during underwater navigation.

The DHT11 temperature sensor reading was taken with time interval of 3 s at first. Then it was tested iteratively for continuous data streaming with 2 s, 1 s, 500, 300, 200 and 100 milliseconds of time interval respectively. The Bits/s was initialized though the Baud-rate of serial monitor dashboard console. The Baud-rate was improvised from 9600, 19200 to the 115200 Bits/s for the better accuracy in different situations. The program was debugged according to the Baud-rate though the Serial.begin() function.

Eventually the same Baud-rate improvisations were implemented for the other sensors namely YL69 pH sensor, CO2 sensor and Dust sensor. With all of these sensory technical mechanism, a marine biologist or an oceanographer could monitor a particular seawater area very easily and compare the sensory data to the ideal climate data excel sheet. By the comparative analysis and evaluation though the sensory and climate statistical data, the oceanographer could formulate far more better understanding of climate changing effect in the marine ecosystems, all of which would be possible due our novel proposed research work.

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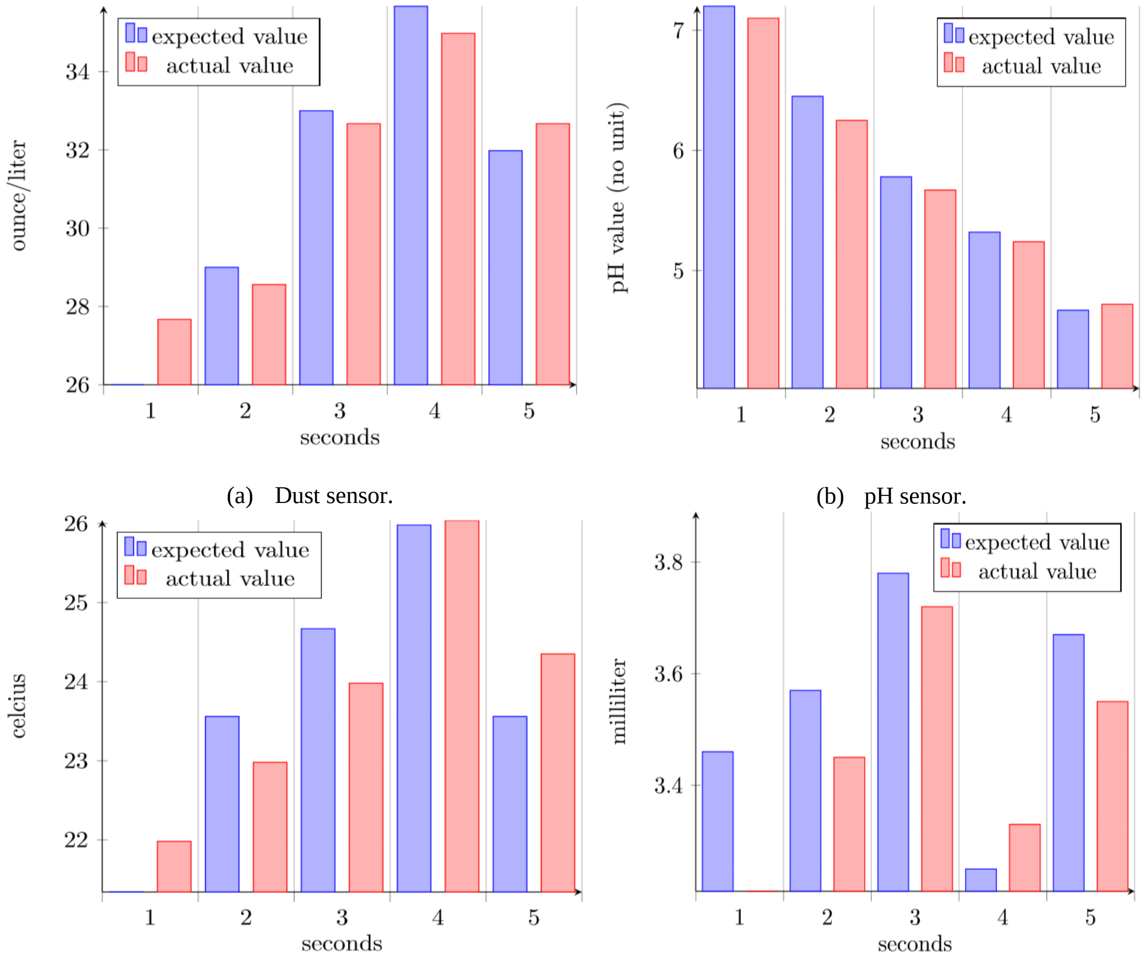

(a) Dust sensor. (b) pH sensor.

(c) Temperature sensor. (d) CO_2 sensor.

Figure 12 Accuracy presentations of dust, pH, temperature-humidity and CO_2 sensors with expected and actual data comparison bar graph.

Table 4 Sensory data from dust sensor with the accuracy comparison.

Time (s)	Expected Dust Value (Ounce/L)	Actual Dust Value (Ounce/L)	Accuracy
1	26	27.67	93.96 %
2	29	28.56	98.48 %
3	33	32.67	99 %
4	35.67	34.98	98.07 %

Table 5 Sensory data from pH sensor with the accuracy comparison.

Time (s)	Expected pH Value (no unit)	Actual pH Value (no unit)	Accuracy
1	7.2	7.1	98.61 %
2	5.78	5.67	98.09 %
3	4.67	4.72	98.94 %
4	4.02	4.17	96.40 %

Table 6 Sensory data from temperature sensor with the accuracy comparison.

Time (s)	Expected Temperature Value (°C)	Actual Temperature Value (°C)	Accuracy
1	21.34	21.98	97.09 %
2	23.56	22.98	97.54 %
3	24.67	23.98	97.20 %
4	25.98	26.04	99.77 %

Table 7 Sensory data from CO_2 sensor with the accuracy comparison.

Time (s)	Expected CO_2 Value (mm)	Actual CO_2 Value (mm)	Accuracy
1	3.46	3.21	92.77 %
2	3.57	3.45	96.64 %
3	3.78	3.72	98.41 %
4	3.25	3.33	97.59 %

In **Figure 12**, the graphical representation of the sensory data and their accuracy can be notified. The accuracy calculation and the numerical representation of their percentage has been explained through **Tables 4** - **6** and **8**.

To the best of our knowledge, the present proposed paper is the very 1st attempt to describe a system which demonstrates the thorough physical implementation of almost error-free navigation of a Bluetooth controlled submarine prototype with full functional data streaming of multiple utility sensors like DHT11 temperature-humidity, YL69 pH, CO_2 and dust. This sensory chipboard can be remodified over time by replacing other utility sensors for different types of sensory data exploration concerning the future of further oceanographic research and marine biological survival monitoring in verge of severe effect of climate change. In the previous era of underwater UAV research, no particular study was remotely concerned about the survival of marine biological species due to climate change [3-17]. But we successfully surpassed all of the previous research work of UAV by our proposed work's electro-mechanical and programming uniqueness with the proper implementation of multi-sensor algorithmic approach, precise submarine motor multi-directional navigation through the precise amalgamation of IoT, underwater robotics and marine biological environment exploration.

Conclusions

The principal concern of this work is to apply the newer development and improvement in the IoT area, within the smart naval environment monitoring context. The sensory data will be able to urge us determine that the marine ecosystems are safe from the climate change disaster or not. This precious novel research work manifests the last steps to reach a complete solution that included almost every part in the real data workflow (design, implement, transmission, analyze and graphically visualize). For the persistent manner of modification, the present day usage of particular microcontrollers can be replaced by higher level microprocessors or Nano-technological microcomputers. Clusters can also be used for the higher level of data storage and analysis if we are heading towards the big data handling for the streamed sensor value of climate data. In the future, there is always a moderate way to revise and modify the method in order to get more accuracy in the sensor reading and analyze the data with further more technicalities which can be helpful for the new genre of interaction between machine learning, data science, modern robotics, IoT, underwater robotics and marine ecosystem exploration for the evaluation of the effect of climate change in the seawaters.

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