IoT Based Recirculating Aquaculture System

Md. Zafor Iqbal [1], FAHMIDA JAMILL [2], Redwan Rahman [3], Hasibul Haque [4], Hannan Ashrafy [5]
Dept. of Computer Science & Engineering
Independent University, Bangaladesh
{2111495, 2111288, 2221936, 2111498, 2130184}@iub.edu.bd

***Abstract*—Aquaculture systems are integrating Internet of Things (IoT) technologies due to the growing demand for sustainable fish production. The IoT-based Recirculating Aquaculture System presented in this research aims to optimize water quality management by means of real-time control and monitoring. The system uses temperature, turbidity, and pH sensors to gather water quality data. After processing, data is wirelessly sent to a device with Node-Red support for visualization. Nevertheless, throughout the development stage, issues with sensor accuracy and connectivity arose, which had an impact on the accuracy of turbidity measurements. The promise and difficulties of integrating IoT in aquaculture for efficient and sustainable fish production are highlighted by this study.**

I. Introduction

IoT technologies are being used more and more by aquaculture systems to improve sustainability and water quality control. The usefulness of IoT systems for real-time monitoring of vital water parameters like temperature, dissolved oxygen, pH, and ammonia has been shown in earlier researches [1]–[25]. Because of these developments, aquaculture management has improved to efficient data collecting and analysis. Nonetheless, issues with sensor calibration, accuracy, and connectivity continue to exist, making it more difficult for IoT-based systems to integrate and function properly.By offering an Internet of Things-based recirculating aquaculture system intended to maximize water quality management, this research seeks to address these issues. The system uses a Node-Red equipped device for data visualization and incorporates temperature, turbidity, and pH sensors to monitor water parameters. Even though IoT in aquaculture has a lot of promise, the study emphasizes the need for more research and development to get over current obstacles and guarantee consistent and sustainable fish production.

II. Literature Review

Aquaculture systems are using Internet of Things (IoT) technologies more and more to improve sustainability and water quality control. An Internet of Things (IoT) system with many sensors was introduced by [1] to monitor critical water parameters such as temperature, dissolved oxygen, pH, and ammonia. This system allows for real-time monitoring and control. [2] used a similar strategy, combining fog computing and Recirculating Aquaculture Systems (RAS) to improve aquaculture management through effective data collection and analysis. In [3], robust field-tested systems were showcased through an innovative mobile application that extended real-time monitoring and control.

[4] investigated ammonia conversion in closed RAS with a specific focus on water quality, illuminating the processes of nitrification and aerobic denitrification. The use of IoT in fish farming control was highlighted by [12], who described a system with several tanks and sensors in addition to a mobile application for remote monitoring and control. Furthermore, [22] introduced microsensors for conductivity and pH measurements, showcasing their cost, accuracy, and durability for monitoring water quality in real time.

[22] highlighted the potential of RAS in improving environmental sustainability and climate change adaptability, emphasizing their water-efficient and environmentally beneficial nature. However, issues including excessive energy use were identified, necessitating more study and development of technology. While addressing issues like disease management and high expenses, [6] and [5] both emphasized the need for sustainable fish production on a worldwide scale and the benefits of RAS in terms of effective water usage and site flexibility.

In order to fulfill the growing need for sustainable and effective fish production, these studies collectively show the growing interest in and developments in the use of IoT, fog computing, and novel sensor technologies to optimize water quality management in aquaculture systems.

III. Problem Statement

A. Sensor Related Issues

- pH sensor - Normally we do not require calibration for this sensor but we needed to calibrate it. The pH we were getting was in reverse direction, i.e. when we were supposed to get pH values greater than 7 we were getting pH values lower than 7 and vice-versa. In addition, we needed to use an offset value which varies from sensor to sensor to get the neutral pH value.
- Turbidity sensor - The first sensor was faulty because the readings we were getting would always be a constant value which should not have been the case.

B. Other Issues

- While reading the data from all of the 3 sensors at once from the Arduino Mega 2560, the ESP8266 portion of the board was getting disconnected continuously from the web socket connection.
- The first USB cable which is used to write code to the micro-controller, stopped working after using it only once.

IV. System Architecture

The following diagram shows the sensors collect the data from the liquid body and send the data to a micro-controller board, and the micro-controller is used to implement a wireless node by providing necessary power and control functions required to operate the wireless communication hardware. The wireless node sends the data to a Node-Red enabled device, which is responsible for aggregating all the sensor data and showing them into a dashboard containing charts and texts for visualization. The connection between the micro-controller board and the Node-Red enabled device is a Web Socket based connection. This ensures a reliable and efficient channel for the seamless transfer of data, facilitating the smooth operation of the entire system.

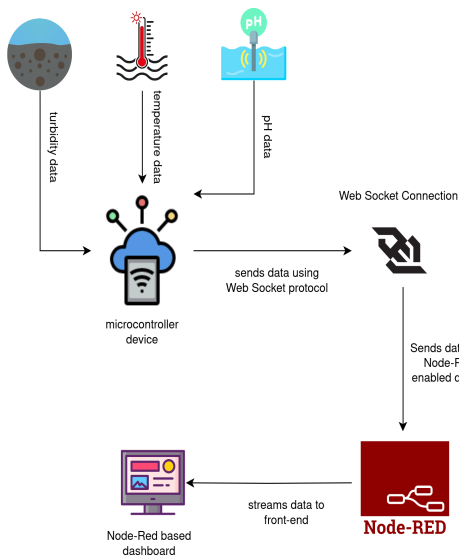

Fig. 1. System Architecture

V. Methodology

The development of the IoT based Recirculating Aquaculture System is divided into three sections. To power up all the sensors and the micro-controller board a common power source is built which is connected to a 9V 2A AC/DC power adapter.

A. Integration of Sensors

Implementing this IoT based project requires three types of data which are pH, turbidity, and temperature.

1) pH Sensor: To measure the pH of the water, an Analog pH Sensor is used. It measures the Hydrogen ion concentration in the water body and outputs an analog signal. An acidic solution has far more positively charged hydrogen ions in it than an alkaline one, so it has greater potential to produce an electric current in a certain situation. in other words, it's a bit like a battery that can produce a greater voltage. The pH meter takes advantage of this and works like a voltmeter: it measures the voltage (electrical potential) produced by the solution whose acidity we're interested in, compares it with the voltage of a known solution, and uses the difference in voltage (the "potential difference") between them to deduce the difference in pH. It operates on 5V inside a (0 - 60)°C environment. The analog output wire of the sensor is connected to the A0(Analog 0) pin of the Arduino Mega 2560 micro-controller which has a accuracy of ± 0.1pH (25 °C).

2) Turbidity Sensor: Turbidity is a measurement of solid matter being suspended in water, rather than dissolved into it. If water is turbid it appears to be cloudy, so is a visual guide to water quality. This sensor uses Nephelometric technique in accordance with ISO 7027, which uses Formazin as a reference standard. We measure turbidity in Nephelometric Turbidity Units (NTU) which are nominally equivalent to Formazin Turbidity Units (FTU). Turbidity sensor is designed to give a measure of suspended particles in a sample of water. It achieves this by emitting infra-red light into the sample and measuring the incident light scattered at right angles from the particles in the sample. The operating voltage of this sensor is 5V and a (-20 - 90)°C environment. This sensor also outputs an analog signal. A1 pin of the micro-controller board is used to get the turbidity data.

3) Temperature Sensor: The DS18B20 which is used in the development of the project is a small temperature sensor with a built in 12bit ADC. It can be easily connected to an Arduino digital input. The sensor communicates over a one-wire bus and requires little in the way of additional components. The data output is a 3-state or open-drain port (DQ pin 2) and requires a 4.7K pull-up resistor. It operates on (3.0 - 5.5)V within a temperature range of (-55 - 125)°C. The data line is connected to to the PWM 8 pin of the micro-controller board.

B. Data Flow

Collecting the data from the sensors to sending it over a web socket connection, there are two steps.

1) Data Acquisition and Processing: Starting from the pH sensor, on average after every 5 seconds a total of 10 readings are taken from the pH sensor. In order to eliminate the anomalies, average of the readings is taken. At the same time the data is being scaled down to a (0 - 5)V range. Afterwards an offset is added to get a meaningful pH value. Moving on to the turbidity sensor, the analog output signal is being mapped in between (0 - 300) ntu. The ntu less than 10 refers to a clean water body, higher than 10 but less than 30 refers to a little cloudy water and higher than 30 refers to a dirty water. Lastly, the temperature sensor outputs a digital signal which is already in Celsius(°C) without any type of conversions. After

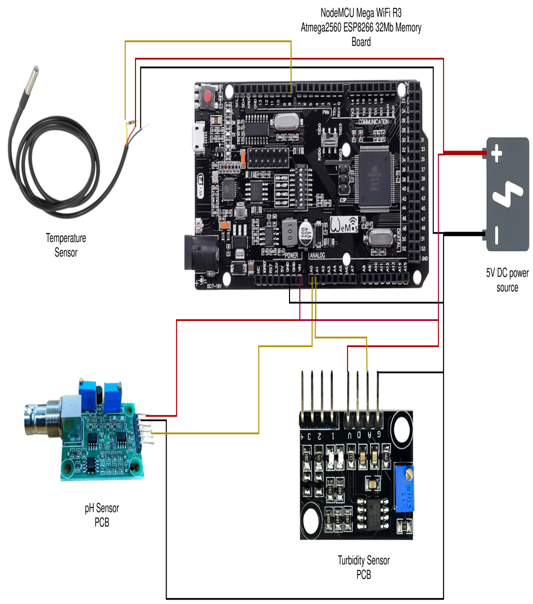

Fig. 2. Circuit Diagram

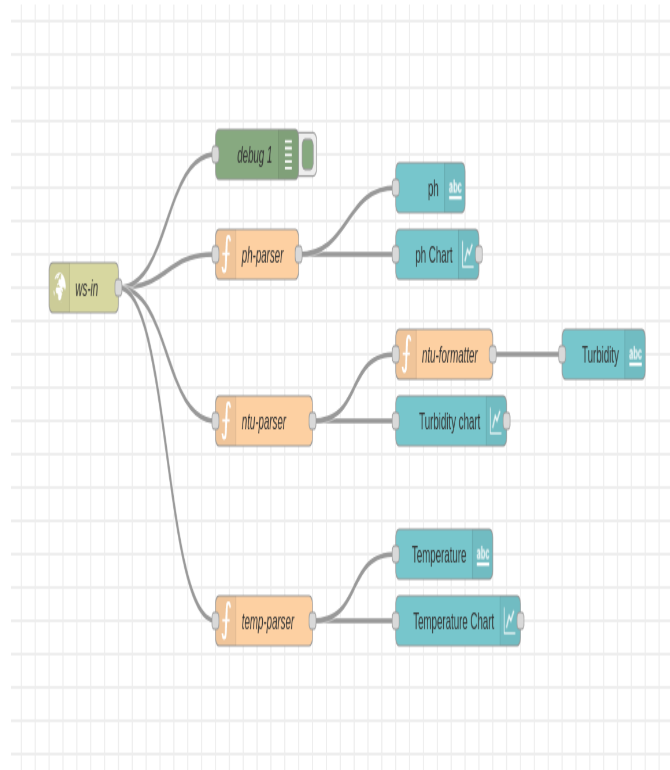

Fig. 3. Node-Red Flow

acquiring all the sensor data, they are aggregated in a string value separated using commas. Later on this string data is written to the third serial port of the Arduino Mega 2560 at a baud rate of 115200 bits per second.

2) Web Socket Transmission: Initially the ESP8266 gets connected to a LAN(Local Area Network) via a built-in wireless module. After making a successful wireless connection, the ESP8266 board connects to a Node-Red enabled device through web socket protocol. On average after every seconds this board reads the sensor data from the serial port one by one for each sensors respectively pH, Turbidity, and Temperature and sends the data formatted as a json string ({"indetifier": data}) to the Node-Red enabled device.

C. Data Visualization

To get the data through web socket, a web socket node(ws-in) is used which listens on the path '/ws/ras'. Then the data gets forwarded to three functions for three sensors to parse the string data into a json object. This parsed data then visualized using chart and label nodes from the 'node-red-dashboard' palette.

D. User Interface

The user interface for this project is created using Node-RED, which is a flow-based, low-code development tool for visual programming developed originally by IBM for wiring together hardware devices, APIs and online services as part of the Internet of things. Node-RED provides a web browser-based flow editor, which can be used to create JavaScript functions. The minimalist ui shows real-time sensors data in separate graphs. It also provides text based labels describing what the data is about.

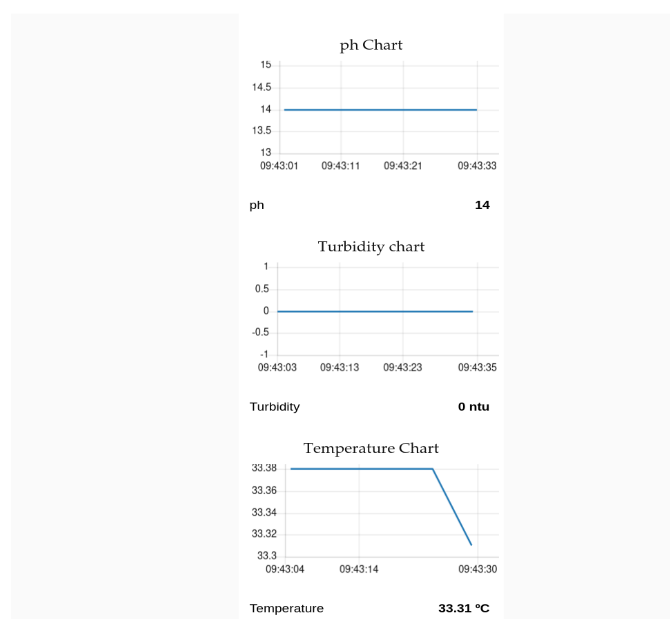

Fig. 4. User Interface

VI. Result Analysis

The graphs shows the values of pH, temperature and turbidity against time. The data for the turbidity sensor is wrong as we are getting a value of 0 no matter what type of water we are supplying.

VII. Challenges Faced

The main challenge we faced was getting sensors that works perfectly in low cost, we had to buy same type of components multiple times as some sensors were either faulty from the get-go or very fragile.

VIII. Conclusion

Increasing sustainability and managing water quality are two potential benefits of integrating IoT technologies into aquaculture operations. In this work, a real-time temperature, turbidity, and pH monitoring system for recirculating aquaculture based on the Internet of Things was described. Despite the system's effective data gathering and transmission capabilities, during the development phase, issues with sensor accuracy, calibration, and connectivity arose. The turbidity sensor in particular showed irregular readings, which compromised the accuracy of the water quality measurement.These difficulties highlight how crucial it is to choose trustworthy and precise sensors for Internet of Things-based aquaculture systems. Notwithstanding these difficulties, the paper emphasizes how IoT may optimize aquaculture management and urges more study and development to overcome current obstacles and guarantee the effective application of IoT technology in sustainable fish production.

References

[1] M. M. T. Abinaya, J. Ishwarya, "A novel methodology for monitoring and controlling of water quality in aquaculture using internet of things (iot)." IEEE Conference Publication, 2019. [Online]. Available: https://ieeexplore.ieee.org/document/8821988

[2] S. M. Z. P. L. E. K. Z. A. A. Muhamad Asmi Romli, Shuhaizar Daud, "Automatic ras data acquisition and processing system using fog computing." IEEE Conference Publication, 2017. [Online]. Available: https://ieeexplore.ieee.org/document/8311764

[3] T. T. K. j. S. Junchan Lee, Amarnathvarma Angani, "Realization of water process control for smart fish farm." IEEE Conference Publication, 2020. [Online]. Available: https://ieeexplore.ieee.org/document/9051285

[4] F. M. L. C. W.-G. L. J. G. Guang-Yu Wang, Jixian Yang, "Ammonia conversion characteristics in a closed recirculating aquaculture system." IEEE Conference Publication, 2009. [Online]. Available: https://ieeexplore.ieee.org/document/5162304

[5] B. K. K. S. Yuhwan Kim, Namgu Lee, "Realization of iot based fish farm control using mobile app." IEEE Conference Publication, 2018. [Online]. Available: https://ieeexplore.ieee.org/document/8644854

[6] L. G. Shadrack Amponsah, "Promoting domestic production of fish using recirculating aquaculture system (ras)." ResearchGate, 2021. [Online]. Available: https://www.researchgate.net/publication/354759898_Promoting_Domestic_Production_of_Fish_Using_Recirculating_Aquaculture_System_RAS

[7] M. Isla, "Water quality in recirculating aquaculture systems (ras) for arctic charr (salvelinus alpinus l.) culture." ResearchGate, 2008. [Online]. Available: https://www.researchgate.net/publication/277123551_Water_quality_in_recirculating_aquaculture_systems_ras_for_arctic_charr_salvelinus_alpinus_L_culture

[8] L. G. Shadrack Amponsah, "Production of lumpfish in ras with distinct water treatments: Effects on fish survival, growth, gill health and microbial communities in rearing water and biofilm." ResearchGate, 2020. [Online]. Available: https://www.researchgate.net/publication/339126659_Production_of_lumpfish_in_RAS_with_distinct_water_treatments_Effects_on_fish_survival_growth_gill_health_and_microbial_communities_in_rearing_water_and_biofilm

[9] J. A. P. Elena Villar-Navarro, Carmen Garrido-Pérez, "The potential of different marine microalgae species to recycle nutrients from recirculating aquaculture systems (ras) fish farms and produce feed additives." ResearchGate, 2021. [Online]. Available: https://www.researchgate.net/publication/353257150_The_potential_of_different_marine_microalgae_species_to_recycle_nutrients_from_recirculating_aquaculture_systems_RAS_fish_farms_and_produce_feed_additives

[10] F. M. Y. J. A. V. Norulhuda Ramli, Christos Giatsis, "Resistance and resilience of small-scale recirculating aquaculture systems (ras) with or without algae to ph perturbation." ResearchGate, 2018. [Online]. Available: https://www.researchgate.net/publication/324551777_Resistance_and_resilience_of_small-scale_recirculating_aquaculture_systems_RAS_with_or_without_algae_to_pH_perturbation

[11] P. N. Sibasish Dutta, Dhrubajyoti Sarma, "Ground and river water quality monitoring using a smartphone-based ph sensor." AIP Publishing, 2015. [Online]. Available: https://pubs.aip.org/aip/adv/article/5/5/057151/979645

[12] W. J. W. Y. S. H.-L. K. Chen Jie, Sun Yingying, "Intelligent control and management system for recirculating aquaculture." IEEE Conference Publication, 2019. [Online]. Available: https://ieeexplore.ieee.org/document/9058567

[13] R. S. S. A. I. M. J. R. M. H. Muinul H. Banna, Homayoun Najjaran, "Miniaturized water quality monitoring ph and conductivity sensors." ScienceDirect, 2014. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0925400513014743

[14] A. J. H. M. C. M. R. R. B. E. P. A. Victoire M.C. Rérolle, Cedric F.A. Floquet, "Development of a colorimetric microfluidic ph sensor for autonomous seawater measurements." ScienceDirect, 2013. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0003267013006570

[15] M. M. R. Ngonidzashe A.G. Moyo, "A review of the factors affecting tilapia aquaculture production in southern africa." ScienceDirect, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S004484862100048X

[16] R. M. L. A. S. A. S. Arifa Ashrafy, Mst Khadiza Begum, "Economic feasibility of pabda and stinging catfish culture in recirculating aquaculture systems (ras) in bangladesh." ScienceDirect, 2022. [Online]. Available: https://www.researchgate.net/publication/356632898_Economic_feasibility_of_Pabda_and_stinging_catfish_culture_in_recirculating_aquaculture_systems_RAS_in_Bangladesh

[17] K. J. S. Seunghun Gong, Amarnathvarma Angani, "Realization of fluid flow control system for vertical recycling aquatic system (vras)." IEEE Conference Publication, 2018. [Online]. Available: https://ieeexplore.ieee.org/document/8644824

[18] R. R. T. J. A. Maria Gemel B Palconit, Ronnie Concepcion II, "Development of iot-based fish tank monitoring system." ResearchGate, 2021. [Online]. Available: https://www.researchgate.net/publication/359271847_Development_of_IoT-based_Fish_Tank_Monitoring_System

[19] N. T.-S. A. D. Bambang Yulianto, Sunaryo, "Survival and growth of mud crab (scylla serrata forsskål, 1775) reared in crab bucket recirculating aquaculture system." ResearchGate, 2019. [Online]. Available: https://www.researchgate.net/publication/335517956_Survival_and_Growth_of_mud_crab_Scylla_serrata_Forsskal_1775_reared_in_crab_bucket_recirculating_aquaculture_system

[20] I. I. J. A. Ricky Rahmat, Irfan Zidni, "Effect of difference filter media on recirculating aquaculture system (ras) on tilapia (oreochromis niloticus) production performance." ResearchGate, 2019. [Online]. Available: https://www.researchgate.net/publication/330906879_Effect_of_difference_filter_media_on_Recirculating_Aquaculture_System_RAS_on_tilapia_Oreochromis_niloticus_production_performance

[21] R. P. P. H. D. M. M. Badiola, O.C. Basurko, "Energy use in recirculating aquaculture systems (ras): A review." ScienceDirect, 2018. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0144860917302327

[22] G. M. T. Nesar Ahmed, "Recirculating aquaculture systems (ras): Environmental solution and climate change adaptation author links

open overlay panel." ScienceDirect, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0959652621008246

[23] W. Golz, "Biological treatment in recirculating aquaculture systems." ResearchGate, 1995. [Online]. Available: https://www.researchgate.net/publication/251766417_Biological_Treatment_in_Recirculating_Aquaculture_Systems

[24] N. T.-S. A. D. Bambang Yulianto, Sunaryo, "Survival and growth of mud crab (scylla serrata forsskål, 1775) reared in crab bucket recirculating aquaculture system." ResearchGate, 2019. [Online]. Available: https://www.researchgate.net/publication/335517956_Survival_and_Growth_of_mud_crab_Scylla_serrata_Forsskal_1775_reared_in_crab_bucket_recirculating_aquaculture_system

[25] M. M. R. Ngonidzashe A.G. Moyo, "A review of the factors affecting tilapia aquaculture production in southern africa." ScienceDirect, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S004484862100048X