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Design and Implementation of Smart Aquaculture Monitoring and Control System for Fish Pond.

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Abstract

The aquaculture industry is pivotal in meeting the global demand for seafood, yet it faces challenges related to water quality management, disease control, and resource optimization. Sustaining ideal conditions for fish health and output is a difficulty for aquaculture. Conventional approaches to water quality monitoring are time-consuming and labour-intensive, which may result in lost productivity. This paper presents a design system which comprises of an array of sensors for monitoring critical water parameters such as temperature, pH, dissolved oxygen, and water levels. These sensors communicate data to a central processing unit, which utilizes machine learning models to predict optimal feeding schedules, detect anomalies, and initiate automatic corrective actions. The system aims to enhance fish health, improve yield, and reduce operational costs by providing aquaculture farmers with actionable insights and automated control mechanisms. Field tests conducted on a pilot fish pond demonstrated significant improvements in water quality stability, fish growth rates, and resource utilization efficiency. This technology encourages lucrative and sustainable fish farming by integrating sensors and automation to deliver real-time insights into important water quality metrics.

Keywords: Aquaculture, Smart, sensors, Metrics.

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1. Introduction

Aquaculture has become an essential component of the global food system, contributing to food security and economic development [1]. However, traditional aquaculture practices often suffer from inefficiencies and challenges related to water quality management, disease outbreaks, and environmental impacts [2]. These issues necessitate the development of advanced monitoring and control systems that can ensure optimal conditions for fish growth and health.

Fish farming, a vital source of protein for a growing global population, faces significant challenges in maintaining optimal conditions for fish health and productivity. Traditional methods of monitoring water quality in fish ponds are often laborious and time-consuming [3], hindering efficient management and leading to potential losses due to disease or environmental fluctuations [4]. Research has shown that keeping the pond's vital parameters within acceptable bounds and continuously monitoring them can significantly increase both the yield and health of the fish [5]. This continuous monitoring allows for timely intervention, ensuring optimal conditions for fish growth and reducing the risk of disease outbreaks. As temperature is the second-most critical water quality parameter after dissolved oxygen, the system will be particularly attentive to maintaining the optimal temperature range for tropical fish, which prefer temperatures between 25°C and 32°C [6]. This paper focuses on the design and implementation of a smart aquaculture monitoring and control system specifically for fish ponds.

2. Literature Review

Recent advancements in IoT and smart farming technologies have paved the way for significant improvements in agricultural practices. IoT-based systems have been successfully implemented in various fields, including precision agriculture, livestock monitoring, and greenhouse automation. However, the application of these technologies in aquaculture remains underexplored.

Existing studies primarily focus on isolated aspects of monitoring or control, lacking an integrated approach that combines real-time data analytics with automated management actions. This paper builds on previous research by integrating sensor networks, machine learning, and automation to create a comprehensive Smart Aquaculture Monitoring and Control System (SAMCS) for fish ponds

[7] offers small-scale farmers an affordable smart monitoring device for managing water quality in fish and shrimp ponds. It automates the monitoring of pH, temperature, and water level by integrating sensors, a microcontroller, and cloud connectivity. However, further work is required, including field testing, dissolved oxygen monitoring, and resolving security issues.

[8] discusses the challenges of open water aquaculture using submersible fish cages, highlighting the need for automation and optimization. It proposes a "Smart Aquaculture System" using IoT and AI to minimize manual labour and feed waste, enabling remote feeding, continuous monitoring, and AI-driven feeding optimization. This aligns with the industry's push for more efficient and sustainable practices.

Examining smart aquaculture techniques, [9] emphasises how these approaches may be used for risk management, prediction, and real-time monitoring. It talks on how the Internet of Things, computer vision, and artificial intelligence can help to enable this, as well as the drawbacks of conventional methods. In addition to examining automated fish morphological measuring and behaviour identification approaches, the review contrasts conventional and cutting-edge methodologies.
The aquaculture system includes a fish tank and underwater life support system. A smart aquaculture system uses an Arduino acquisition board with an atmega328p microcontroller to monitor and control the system. Four sensors monitor water temperature, PH level, and transparency. Four liquid pumps control temperature, water level, and PH levels. A water heater provides hot water when low, and a buzzer alert when abnormalities occur. A servo motor auto feeds fish based on time.

3. System Architecture

The proposed model predominantly centres on continuous observing the water quality factors at all time in order to take preventive steps early to harm for water animals. The proposed architecture has four parts, namely: power module, sensor network (sensor module), the central processing unit (controlled module) and the control mechanisms (output module) as shown below in figure 1.

3.1 System Features

The design is concerned with three major issues; Effective measurement of water quality parameters, Monitoring, Control and Ease of access.

(I) **Effective measurement of water quality parameters:** This work has the sensor module includes a few sensors, for example, pH sensor, LDR, Ultrasonic sensor and temperature sensor. These sensors are fixed on microcontroller and are used for detecting the water parameters all the time.
(II) **Monitoring**: The sensor data has been monitored using the thingSpeak cloud.
(III) **Contro**l: Based on the sensor data and threshold values the aqua pond can be controlled.
(IV) **Ease of access**: the data can be effectively accessed using the cloud and its can be observed and controlled using the mobile application

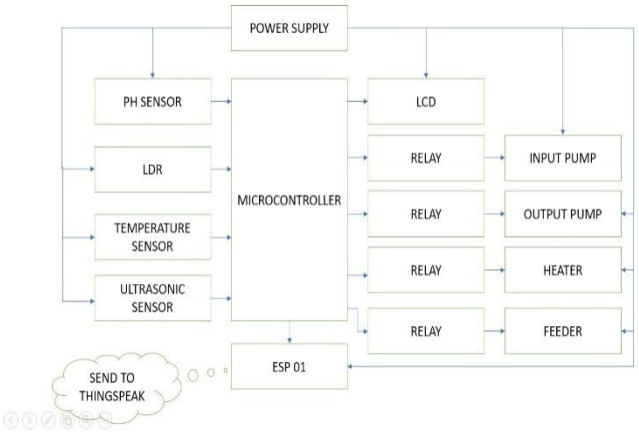


Figure 1 System Block Diagra

3.2 Block Diagram Description

3.2.1 Power module: The power module has a DC-DC converter, charge controller, battery. The battery is predominantly used to supply control in the night as water quality parameters for the most part changes at night. A DC-DC converter is thee to give the capacity to scale controller module which will work at 5V. A DC-DC converter is mainly used to provide an invariable voltage.

3.2.2 Sensor Network: A variety of sensors are deployed to continuously monitor key water parameters, including temperature, pH, dissolved oxygen and ammonia levels. These sensors are connected to microcontrollers that transmit data wirelessly to the central processing unit.

3.2.3 Central Processing Unit: The core of the system, this unit collects sensor data and processes it using machine learning algorithms. The algorithms analyse historical and real-time data to predict optimal feeding times, detect anomalies, and recommend or execute corrective actions.

3.2.4 Control Mechanisms: Automated devices such as feeders, aerators, and water pumps are controlled by the central processing unit based on the insights generated from data analysis. These mechanisms ensure that the pond conditions remain within optimal ranges, thus promoting fish health and growth.

4. IMPLEMENTATION

The implementation of the entire system is categorized in terms of hardware and software. Once the hardware part is assembled, that is sensor nodes with raspberry pi, comes the software part. Implementation is done mainly three different domains; python, cloud and android. Thingspeak is used for implementing cloud operations. Android app is developed using android studio. Raspberry pi uses raspbian as an Operating System (OS) and python IDLE is used for writing python codes. In addition to this, you can use putty and vncserver to access the raspberry pi terminal from a laptop without having to connect the pi to a monitor or an external keyboard and mouse. The SPI or 12C protocol serves as the foundation for the communication mechanism between various nodes. SPI (Serial Peripheral Interface) is a connectivity protocol for the machine- to - machine (M2M) communication. It was designed as transportation of extremely lightweight messaging and publishing. It

is beneficial for remote location interconnections where a small code footprint is required and there is limited network bandwidth. The system uses thingSpeak API as a key with URL to send the data from python IDLE. It can post messages after a thingSpeak client is connected to a broker. ThingSpeak has a topic - based clarification of the broker's messages, so each message needs to contain a particular subject that the broker will use to send the message to active clients. Normally, each message has a payload containing the actual data to be transmitted in byte format. ThingSpeak is data-agnostic and the structure of the payload depends entirely on the use case. If you want to send binary data, textual data or even full-fledged XML or JSON or CSV, it is completely up to the sender. The Sensor hub, Cloud and end User Device all comes into picture while acknowledging in a consecutive way. Most importantly, information caught by the sensor hub is sent to the cloud and furthermore the end User. Information retrieval is managed and various tasks carried out in the cloud are all explained by flowcharts as seen in figure 2 below.

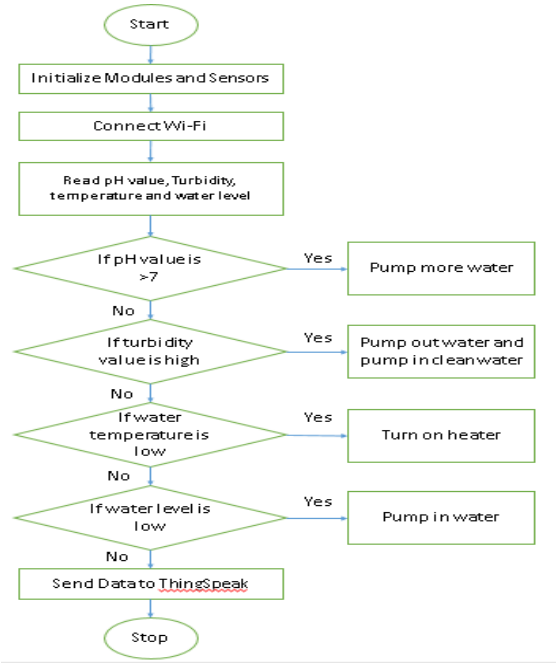


Figure 2. System Flowchart

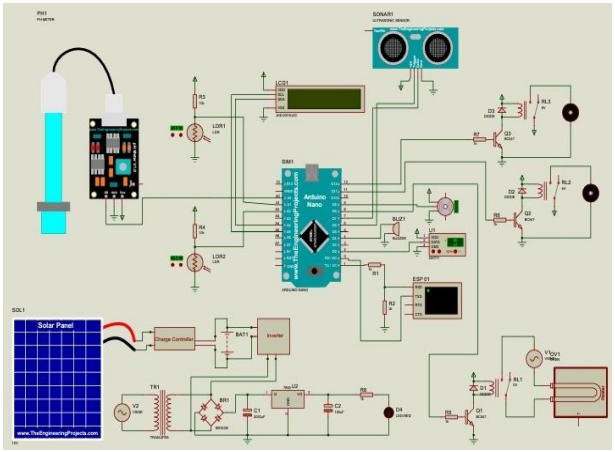


Figure 3 System Circuit Diagram

5. Measurements and Testing

The components used for the implementation of this project were tested on breadboard for better performance, and were later transferred to the Vero board and soldered. The heat applied during soldering was just moderate to avoid damage of the Vero and the components since most of the components have low heat resistance. The test equipment includes;

- Breadboard-To assemble and test individual components
- Digital multi meter to measure voltage, current, resistance and check for continuity
- proteus simulation software
- Biofilter

The use of biofilter is crucial as it helps in maintaining water quality in the pond. The figure 4 below shows the components of the biofilter design for this project.

This filter media in biofilter provides a large surface area for the growth of beneficial nitrifying bacteria. Common media include bio balls, ceramic rings. The inlet is the part where pump and water flow are attached to ensures that water continuously flows through the biofilter, bringing ammonia and nitrite into contact with the bacteria.

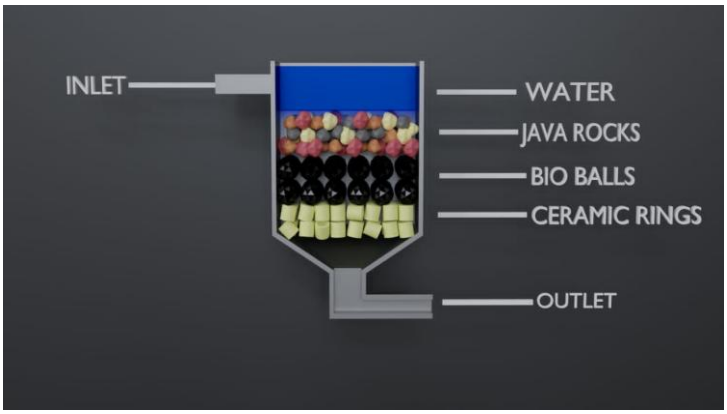


Figure 4: Components of Biofilter





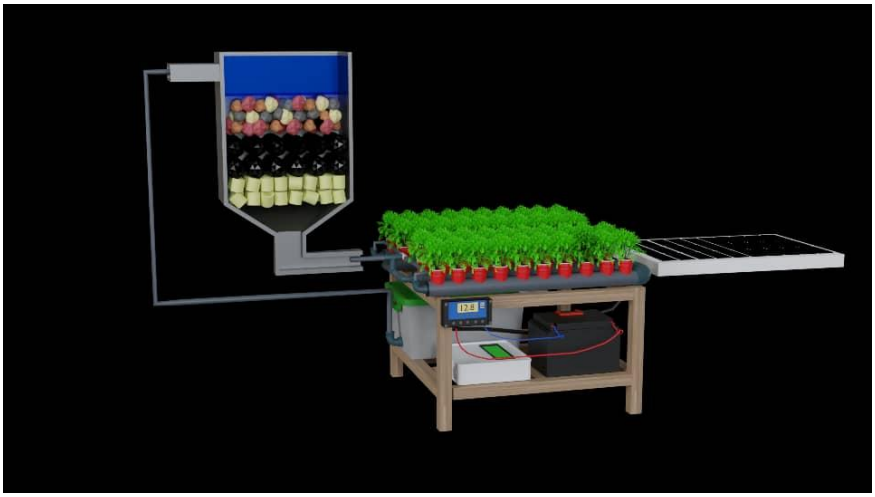


Figure 4: Biofiltration in an Aqua-Pond Design

6. RESULT

In an aqua-pond, the proposed system was implemented and results were obtained using different sensors for one week. Results were obtained with time for varying parameters of water quality, temperature and pH as seen in Table1 below. Figure 6 shows the plot of the variations in pH, water temperature, and water level over the specified period. The pH is plotted in red, the water temperature in blue, and the water level in green.

Table 1: Daily Monitoring Schedule for a 50cl Aquarium for one week

Date	Time	pH	Water Temperature (°C)	Water Level (ml)
2024-06-15	8 AM	7.0	28.2	500
	2 PM	6.9	32.1	495
	6 PM	7.1	29.8	490
	10 PM	6.8	28.5	495
2024-06-16	8 AM	7.1	28.3	498
	2 PM	6.9	32.3	493
	6 PM	7.0	30.0	489
	10 PM	6.8	28.6	494
2024-06-17	8 AM	7.0	28.1	497
	2 PM	7.0	32.2	492
	6 PM	7.1	29.9	488
	10 PM	6.9	28.4	493
2024-06-18	8 AM	7.1	28.2	496
	2 PM	6.8	32.0	491
	6 PM	7.0	29.7	487
	10 PM	6.8	28.5	492
2024-06-19	8 AM	7.0	28.3	495
	2 PM	6.9	32.1	490
	6 PM	7.1	29.8	486
	10 PM	6.8	28.6	491
2024-06-20	8 AM	7.0	28.2	494
	2 PM	6.9	32.3	489
	6 PM	7.0	30.0	485
	10 PM	6.8	28.5	490
2024-06-21	8 AM	7.1	28.1	493
	2 PM	6.8	32.2	488
	6 PM	7.0	29.9	484
	10 PM	6.9	28.4	489
2024-06-22	8 AM	7.0	28.2	492
	2 PM	6.9	32.1	487
	6 PM	7.1	29.8	483
	10 PM	6.8	28.5	488

Notes:

1. **pH Readings**: Variations of ±0.1 are normal and acceptable.
2. **Water Temperature**: The slight daily temperature variations reflect changes in ambient conditions.
3. **Water Level**: A drop of 5 ml by the afternoon due to evaporation is typical; topping up in the evening ensures stability.

Regular monitoring with accurate equipment helps maintain optimal conditions for the catfish, ensuring their health and well-being.

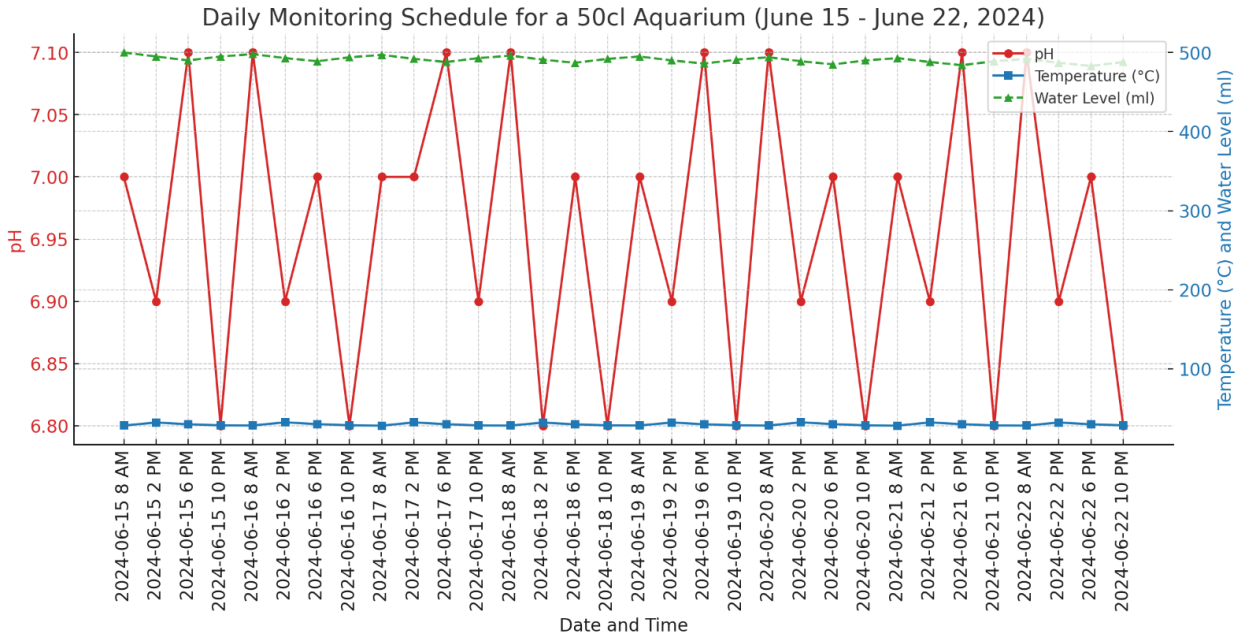


Figure 5: Variations in pH, water temperature, and water level over the specified period.

Here is the graph illustrating the daily monitoring schedule for the 50cl aquarium from June 15 to June 22, 2024. It shows the variations in pH, water temperature, and water level over the specified period. The pH is plotted in red, the water temperature in blue, and the water level in green. This provides a clear visual representation of the data, making it easier to monitor and analyse the tank conditions.

Table 2: Power Supply Unit Result

	SOURCE VOLTAGE (V)	STEP DOWN VOLTAGE (V)	RECTIFIED VOLTAGE (V)	REGULATED VOLTAGE (V)
THEORITICAL	240	15	21.21	5
MEASURED	235	14.7	19	5.02

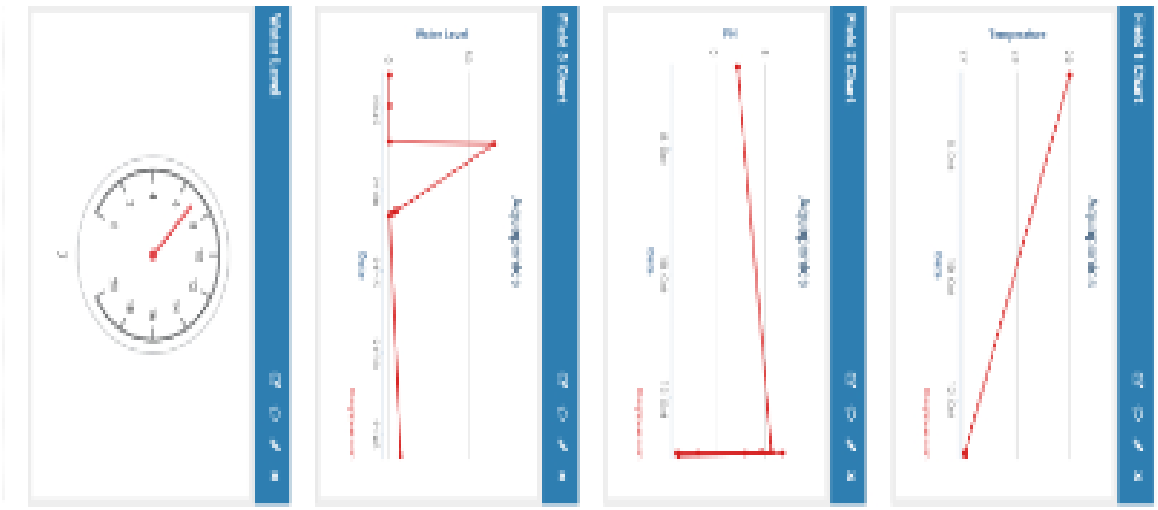


Figure 6: System Result on ThingSpeak

The table 2 shown above presents the results obtained from the tests carried out on power supply unit circuit. The test results are of two categories; theoretical voltage value test results and measured voltage value test results. It was found that the theoretical input voltage value of the transformer varies from its measured voltage value by 5V. It was also observed at the output that the theoretical output voltage value of the transformer varies from the measured output voltage by 0.6V.

CONCLUSION

After the design and implementation of the project, it is found that water quality management was attain due to the system automation according to the aim of the project. Hence the aims and objectives of the project were achieved.

RECOMMENDATION

- For further work on this topic, the following measures can be carried out to improve its functionality.
- Since the pond water is not self-maintained, therefore the pond water should be heated or cooled automatically
- Correction of system anomalies using the mobile application can be employed
- Addition of supplementary sensors, in order to detect the oxygen and nitrate concentration level in the water for more water quality management.

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Data availability: Data underlying the results presented in this paper are not publicly available at this time but may be obtained from the authors upon reasonable request.

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Kpelai Justin Akosuga, MNSE, NIEEE is currently a PhD student at Joseph Sarwuan Tarka University Makurdi. and Senior Lecturer in the Department of Electrical and Electronics Engineering, Benue State Polytechnic Ugbokolo, Benue State, Nigeria with over fourteen years (14) experience, outstanding communication and analytical skills, lecture room management and presentation skills using both ICT platforms and interactive means.

He has several academic laurels in his portfolio among which are B.Eng (Electrical and Electronics Engineering) from the Federal University of Agriculture Makurdi, Benue State, Nigeria (Now Joseph Sarwuan Tarka University Makurdi, Benue State). In his passion for attain higher academic attainments, he applied and got admission into University of Wolverhampton, United Kingdom in 2014 where he bagged an M.Sc Mobile and wireless System Engineering. With a burning zeal that continue to drive him higher, he enrolled for a PhD in Electrical and Electronics Engineering at Joseph Sarwuan Tarka University Makurdi Benue State, Nigeria in the area of **crop monitoring and management through 5G connectivity.**

The career path charted by Engr Kpelai Justin Akosuga was in line with his academic background. A background that is influenced by dedication, commitment and professional diligence. He began his career in the academic sector at Benue State Polytechnic Ugbokolo as Assistant Lecturer in 2010. His responsibilities in this position involves preparing course materials, assisting in preparing and conducting exams, supervision of students' projects, marking and computing of student's results and carrying out assigned tasks as directed by his Head of Department or Section. In this position it is also his responsibility to ensure that standards of teaching as well as developing further training and skills development for improved service delivery.



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Mr. Nasiru is a tech savvy who doubles as the founder and CEO of Nascomsoft Embedded. An enterprise with mind-blowing technological approaches to surmount human and environmental challenges.