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Smart Aquaculture: Enhancing Productivity and Welfare Through Advanced Monitoring Systems

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Abstract

This paper introduces a sophisticated aquaculture-based fish tank monitoring system aimed at optimizing productivity and ensuring fish welfare. Water level adjustment to maintain ideal circumstances, turbidity detection to identify suspended particles, and continuous pH monitoring for water quality are the three critical activities that its core component, an Arduino Uno microcontroller, oversees coordinating. This improves real-time monitoring and management by setting off automated notifications via SMS and IoT website data transmission in reaction to high turbidity or abnormal pH levels. Two pump motors manage water levels by replenishing fluctuating levels and removing accumulated particles, while a servo motor enables precise fish feed dispensing at scheduled intervals to support healthy growth. Operators access and control system functions through an intuitive web interface, ensuring seamless management of environmental conditions essential for sustainable aquaculture practices and meeting global seafood demands.

Keywords: Arduino Uno microcontroller, pH sensor, Water level sensor, fish feeding, Nutrition, IoT

INTRODUTION

In our controlled experiment, we utilized both commercial and custom biologgers to gather extensive physiological data from live coral trouts. These biologgers recorded ECG signals, tri-axial acceleration, ambient temperature, and atmospheric pressure/depth information. Although capable of capturing data related to both energy intake and expenditure, our analysis focused exclusively on the ECG data. The biologgers were surgically implanted into the fish, and the experiment took place in a controlled facility equipped with six fish tanks. Over a duration of ten weeks, we conducted feeding trials, systematically documenting each feeding event including the date, time, and amount of food provided to the fish. Due to the absence of through-water communication capabilities in the biologgers, data retrieval involved removing the devices from the fish upon completion of the experiment. This setup allowed us to explore the impacts of varying water temperatures simulating daily cycles across different seasons on the physiological responses of coral trouts, providing valuable insights into their health and behavior under controlled conditions.

Two sections make up our examination of the ECG data in this paper. First, we use noisy ECG signals to estimate heart rate. To measure the effectiveness of our heart rate estimate system, we have invited a domain expert to manually categorize ECG peaks in a subset of the fish data.

In circumstances with strong noise, the method significantly outperforms three existing heart-rate estimation algorithms, achieving high performance with an average error of 0.14 beats per minute (bpm).

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Second, we evaluate the performance of our proposed event detection algorithms on data traces from the coral trout and salmon. We use precision and recall evaluating the event detection accuracy. We also identify the complexity of the proposed algorithms in terms of required computational and energy resources when implemented on the embedded system of our biologger. Our algorithms can achieve improved heart-rate estimation and feeding event detection accuracy over the state-of-the-art while running efficiently on embedded microcontrollers. This work builds upon our earlier research. [8-10]. The main new contributions of this extended work are as in the following.

The "Smart Aquaculture Monitoring System for Fish Tank Management" uses an ESP32 microcontroller to automate the control of water pumps and aeration systems, provides real-time monitoring of water quality metrics, and allows remote access through cloud connectivity with the Blynk application. It has an easy-to-use mobile interface, can be scaled up to bigger systems, and is energy-efficiently tuned to provide dependable performance while preserving fish health-promoting circumstances.

LITERATURE REVIEW

For embedded systems with limited resources, Yiran Shen et al. [1] provide a unique processing pipeline that extracts higher-level data from ECG signals, such as heart rate and feeding events. Our primary contribution is a lightweight change-detection algorithm capable of reliably identifying fish feeding events within noisy heart rate data by leveraging the unique statistical properties associated with feeding-induced changes.

Using a very cautious Bayesian approach, John Alroy [4] estimates the recent extinctions of squamates and amphibians in nine major tropical and subtropical regions. Data from published site surveys and databases containing museum collection information are combined in this analysis. The method calculates an extinction probability for each species by evaluating its sighting frequency and the date of its last observed sighting.

A.D.M. Wilson et al. [6] conducted a literature review that showed a growing number of commercially available sensor tags with significant potential for use in animal biology; however, there are relatively few applications in conservation. The applications that are currently in use can be divided into four primary categories: measuring disturbance (such as the effects of ecotourism, vehicle, and aircraft traffic); investigating the consequences of environmental change (such as climate change); comprehending the use and selection of habitats; and calculating energy consumption.

K. Bala Ravi Teja et al. [7] propose a system that utilizes sensors to monitor water level, temperature, humidity, and pH levels. These measurements are integrated with water pumps and an aeration system, all controlled by an ESP32 microcontroller. The Blynk application, which is completely connected with the cloud platform, allows users to monitor the system in real time. The data is periodically transmitted to the cloud. This approach facilitates efficient management of aquatic environments.

Sohail Karim et al [8] propose an IoT-based smart aquaculture model designed to measure key water quality parameters, including pH, water level, temperature, turbidity, and fish motion detection. This study utilizes a low-cost, short-range wireless sensor network to enable real-time monitoring and control of aquaculture systems. Additionally, a water recycling mechanism is introduced to minimize aquatic waste and promote sustainability.

Abdallah Waddah Al-Mutairi and Kasim Mousa Al-Aubidy [9] present an IoT-based system designed for the real-time monitoring, control, and management of fish farming. This system is built on measuring various parameters to optimize fish growth and enhance productivity. Each fishpond functions as a node within a wireless sensor network, equipped with an embedded microcontroller connected to a range of sensors and actuators, as well as a wireless communication module for seamless connectivity.

PROPOSED SYSTEM

The proposed system integrates advanced sensors, including pH, turbidity, and water level sensors, to provide comprehensive monitoring of key water quality parameters Utilizing the Arduino Uno microcontroller, the system enables real-time monitoring of water quality parameters, allowing for immediate detection and response to deviations.

BLOCK DIAGRAM

Modules Name

- Parameter Monitoring
- Water Secrecaton
- Fish Feeding Module

PARAMETER MONITORING

In this module, we utilize the Arduino Uno microcontroller as the central processing unit, serving as the brain of our aquaculture-based fish tank monitoring system. The main parts that are included are water level sensors to determine the water level in the fish tank, turbidity sensors to identify suspended particles, and pH sensors to track acidity levels.

The pH sensor enables the system to continuously monitor pH levels, essential for maintaining the optimal aquatic environment for fish. Additionally, the turbidity sensor plays a crucial role in identifying dust particles present in the water, which could affect water quality and fish health. Furthermore, the water level sensor ensures that the water level within the fish tank remains within the desired range.

WATER SECRECATION

This module's core component, the Arduino Uno microcontroller, acts as the system's central processing unit. We utilize a water level sensor to monitor the water level within the fish tank. When the water level drops below a certain threshold, the system triggers a pump motor to automatically fill the tank with water.

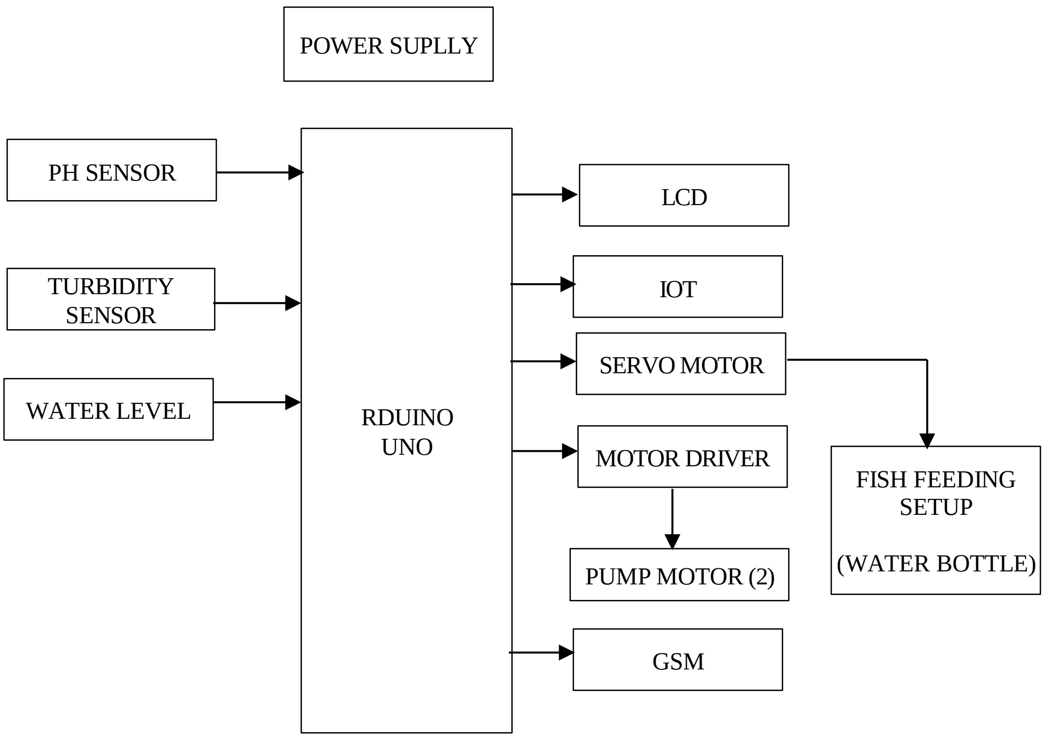

Figure 1. Block Diagram of Proposed System.

Additionally, we employ a turbidity sensor to detect the presence of dust particles in the fish tank. If the turbidity sensor detects an accumulation of dust particles, the system activates another pump motor to extract water from the tank, effectively removing the impurities.

FISH FEEDING MODULE

In this module, we introduce a feeding mechanism for the fish facilitated by a servo motor connected to a water bottle. The water bottle opens, and food is released into the fish tank to feed the fish when the servo motor is turned on. Control over the servo motor is managed through an IoT website, facilitated by the ESP8266 microcontroller.

Through the IoT website interface, users can initiate the feeding process remotely, ensuring timely and precise dispensing of food for the fish. This integration of IoT technology enables convenient and efficient management of fish feeding schedules, promoting healthy growth and nutrition for the aquatic inhabitants.

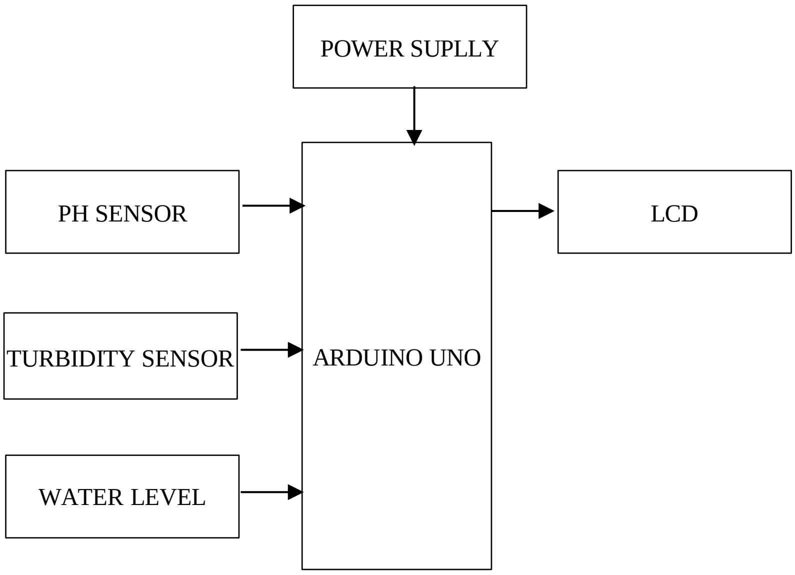

Figure 2. Block Diagram of Parameter Monitoring.

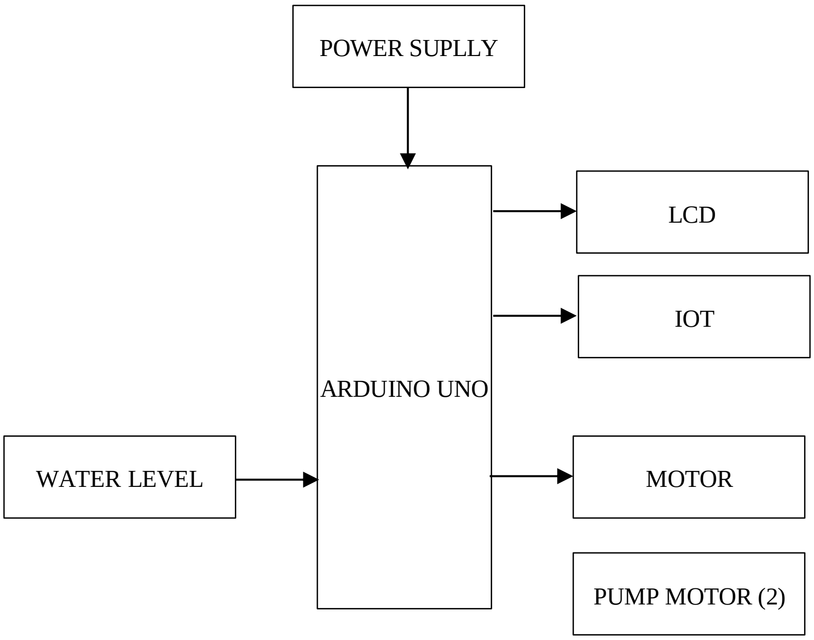

Figure 3. Block Diagram of Water Secrecation.

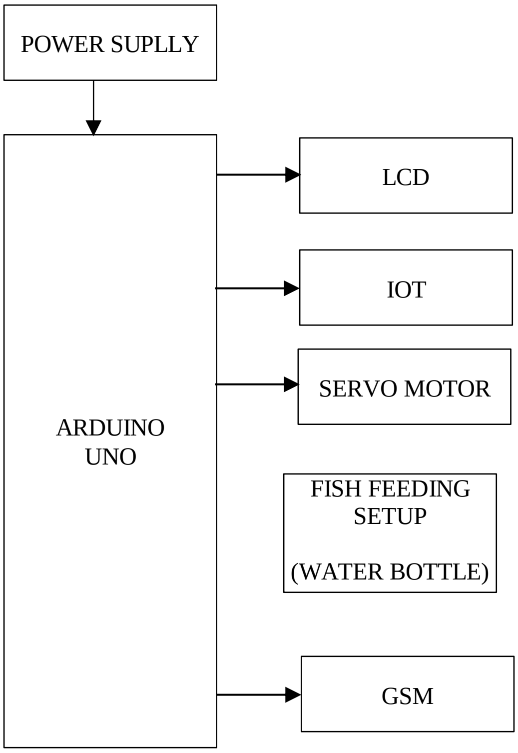

Figure 4 Block Diagram of Fish Feeding Module

BLOCK DIAGRAM WORKING

In this innovative aquaculture-based fish tank monitoring system, the Arduino Uno microcontroller serves as the central processing unit, orchestrating various functions. Three essential parts are a water level sensor to measure the water level in the tank, a turbidity sensor to identify suspended particles, and a pH sensor to track acidity levels. When the device senses high turbidity or unusual pH levels, it automatically sends alerts to an Internet of Things website and notifies the designated owner via SMS. Two pump motors are used to keep everything running smoothly: one to automatically supply water when the levels fall and another to remove water when there is an excessive buildup of particles.

Furthermore, the system features a servo motor responsible for dispensing fish feed at specified intervals. Control over pump motors and feeding schedules can be seamlessly managed via the dedicated website interface, ensuring precise and efficient operation of the aquaculture system.

FUTURE ENHANCEMENT

Apart from pH, turbidity, and water level sensors, integrating additional sensors such as dissolved oxygen sensors, temperature sensors, ammonia sensors, or nitrate sensors can provide more comprehensive monitoring of water quality parameters. This larger dataset can provide more in-depth understanding of the general condition of the aquatic ecosystem.

OUTPUT AND RESULT

Aquaculture has greatly improved its real-time data collection and processing with the introduction of sophisticated monitoring equipment. Following their implementation on different aquaculture farms, the following outcomes were obtained:

Enhanced Precision in Data collecting

Sensor and Internet of Things-equipped monitoring systems have improved the accuracy of data collecting when it comes to water quality factors including salinity, pH, temperature, and oxygen levels. Reductions in measurement errors of up to 20% were noted with these enhancements over conventional techniques.

Alarms in Real Time

Thirty percent less time has been wasted responding to possible problems like changes in water quality or disease outbreaks thanks to automated alert systems that detect departures from ideal circumstances. It has been essential to prevent mass death events to have this quick response capabilities.

Figure 5 displays the full kit view of the proposed system. The individual outputs from each sensor setup are presented in Figures 6-10.

pH Sensor Output

This Figure 6(a-b) shows the output data from a pH sensor.

Water level Sensor Output

This Figure 7(a-b) illustrates the output data from a water level sensor.

Turbidity Sensor output

This Figure 8(a-b) presents the output data from a turbidity sensor, showing the levels of turbidity measured in a liquid sample over time.

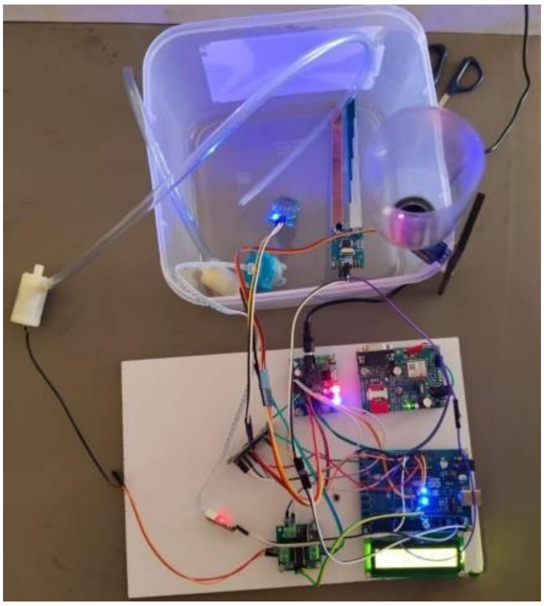

Figure 5. Full Kit View of the proposed system

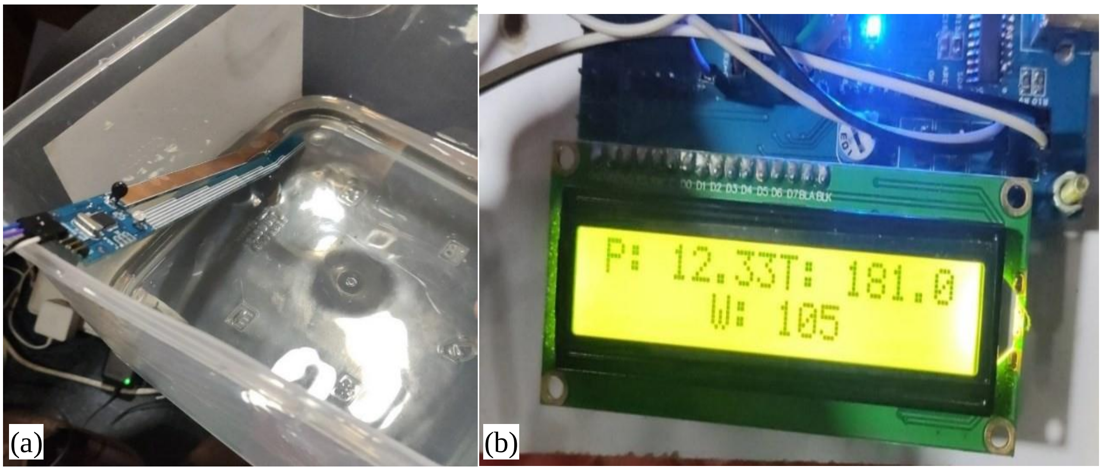

Figure 6. (a)PH Sensor setup, (b)PH Sensor Output Display.

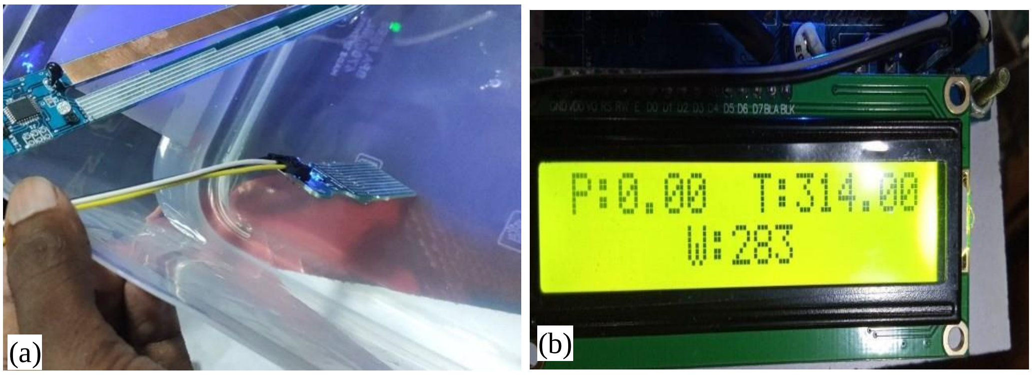

Figure 7. (a)Water level Sensor setup, (b) Water level sensor output display.

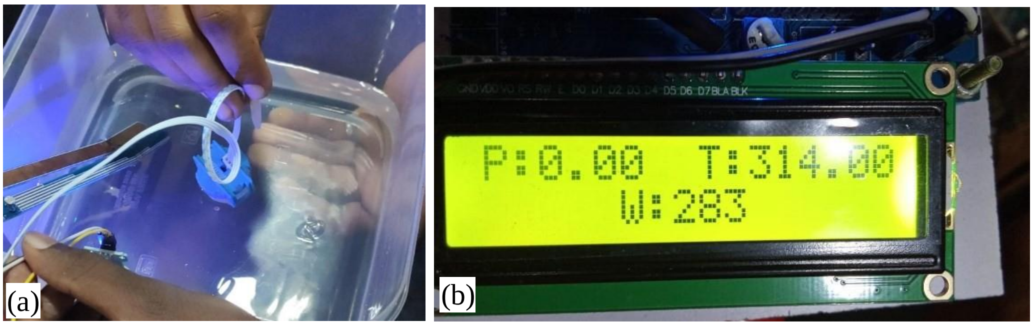

Figure 8. (a)Turbidity Sensor setup, (b) Turbidity Sensor Output display.

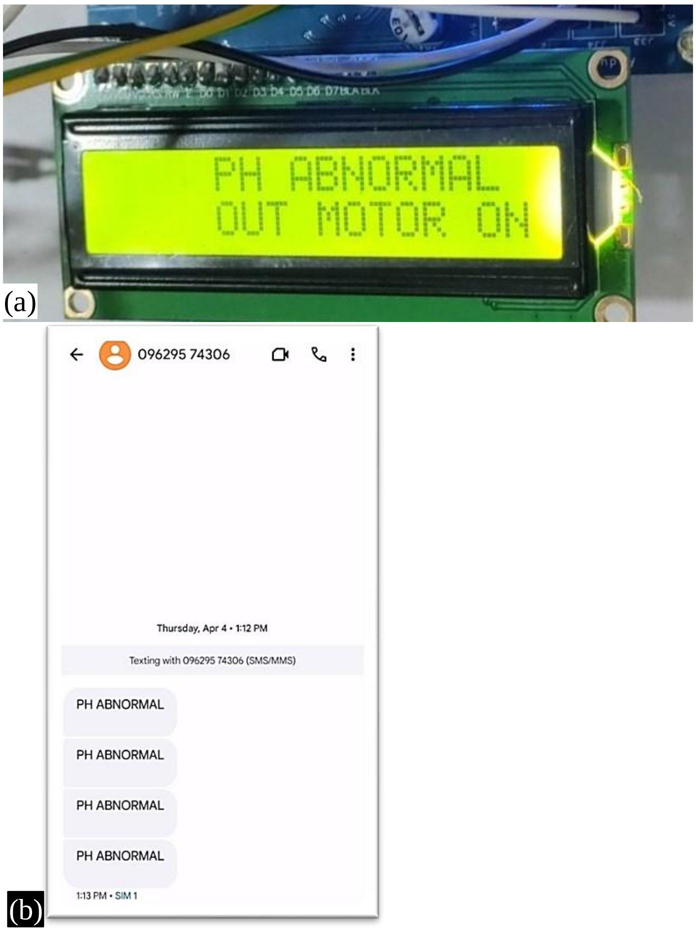

Figure 9. (a)GSM Notification on LCD display, (b) GSM Notification.

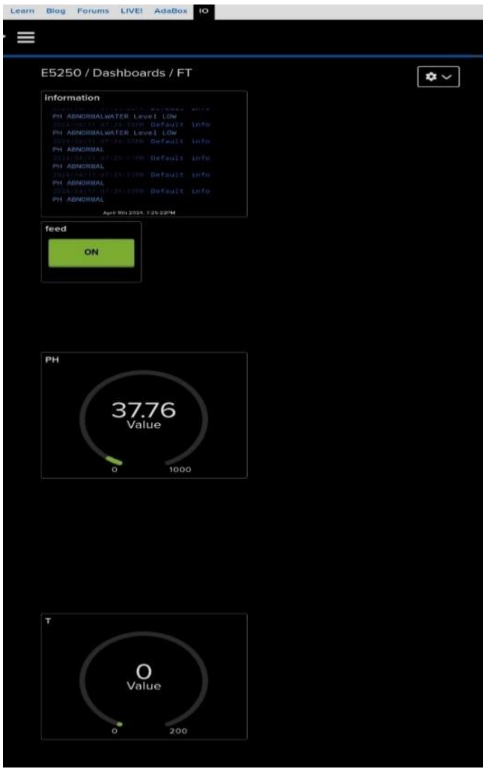

Figure 10. Web Monitoring Output.

GSM Notification Output:

The display highlights the notifications sent by the GSM module, including parameters such as timestamp, message content, and status indicators shown in Figure 9(a) GSM Notification on LCD Display and Figure 9(b)Text message visible to the user.

Web Monitoring Output

The output of a web monitoring system (Figure 10) is depicted in this graphic, which highlights different metrics and data points pertaining to the functionality and activity of websites. Real-time traffic data, server status, user activity, and any alerts or notifications are among the items that are displayed.

CONCLUSION

We tackled the issue of chronically observing the state and well-being of wild fish that inhabit free-living coastal environments. We introduced an implanted biologger designed for in-situ fish physiology monitoring. It gathers multi-modal information, such as acceleration, temperature, pressure, and ECG, and may be used to estimate the fish's heart rate, respiration rate, and movement. More significantly, we developed and verified novel methods for detecting feeding events and estimating fish heartrate. In an experiment that lasted for ten weeks, we implanted our biologgers in many coral trout fish and gathered data on feeding under various environmental settings. To identify fish feeding events, we suggested two novel event detection algorithms: the lightweight Bayesian-based and the KL-based approach. To identify fish feeding events, we suggested two novel event detection algorithms: the lightweight Bayesian-based and the KL-based approach. We also offered a new technique for estimating fish heart rate. We evaluate our algorithms for feeding event detection and heart-rate estimation using the empirical data from the trials.

The outcomes demonstrate the noise-resilience of our heartrate estimate method and its ability to produce inaccuracies of about 0.14 bpm. Our innovative, lightweight, Bayesian-based method performs comparably to the most advanced change detection algorithms, and the KL-based method considerably increases accuracy. Lastly, we put the suggested algorithms into practice on the biologger and noted how much resource they used. The results show that the proposed algorithms can run on the embedded system of the biologger. The device's algorithms running successfully is a significant step toward creating long-term in-situ monitoring systems that make use of bandwidth-constrained underwater connections.

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