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A Technology Trend on IoT Based Fish Aquaculture Sensor: A Comprehensive Review

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ABSTRACT

A system known as aquaponics combines hydroponics with conventional aquaculture (the method of growing plants in water i.e. soilless farming of crops). It combines these two technologies in such a way that the plant consumes fish waste as food while simultaneously filtering the water for instant re-use by the fish. This aids in resolving the issue of frequent water changes. The end result is this reviewed literature, which is extracted from the database. The review is concentrated on three themes: (1) the internet of things and current technological trends, (2) water quality monitoring, which is a crucial component of fish farming, and (3) sensors that are integrated into the system. For fish breeders who support the IR4.0 system connected online and mobile apps that also support modern agriculture, this review is important in order to effectively minimise the feed residual, monitor the growth of fish, and raise fish survival rate, consequently raising the feed conversion rate.

1. Introduction

In recent decades, Malaysia and the rest of the world have experienced labor shortages in agriculture, which will have an impact on aquaculture productivity due to low young adult labor participation rates and an ageing agricultural population [1-3]. By creating a smart IoT-based fish monitoring and control system with various IoT devices to enable real-time data collection, the IOT BASED FISH AQUACULTURE system is primarily intended to address the issues faced by the aquaculture farming sector in Malaysia. This allows fishpond water-quality conditions and other system parameters to be easily monitored, adjusted, and evaluated from a distance.

Given the enormous number of fish farms already in operation and the rising global demand, aquaponics health is crucial in the food sector. Aquatic organisms are raised in controlled, natural marine and freshwater settings through the practice of aquaculture. In fish farming, real-time monitoring of aquatic environmental parameters is crucial. Real-time monitoring can greatly benefit from the Internet of Things (IoT) [4,5].

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Because of the inherent ability to assign tasks created by a user or to communicate agriculture data received through sensors to producers for examination on various terminal devices, Internet of Things (IoT) has opened up a new dimension for smart farming and agriculture. Aquaponics is a cutting-edge, clever, and sustainable agriculture method that combines hydroponics and aquaculture (fish farming) to grow vegetable crops symbiotically. Aquaponics, when used properly, can produce nutritious organic foods while using little water and chemical fertilizer. There have been numerous research initiatives aimed at adopting this technology as a new precision technology and making it feasible and reliable to use at large commercial scales. Use of the Internet of Things (IoT) and smart sensing systems is urgently required for monitoring and managing all activities associated with aquaponics systems in order to improve the management of such technology [6-8].

Every fish farmer in the aquaculture sector deals with the issues of sluggish fish growth and fish fatalities in fisheries. When cultivating any aquatic organism, water quality is an important component that must be monitored; unfortunately, most fish farmers do not take this into account because water tests and water sensors are expensive and difficult to use. In aquaculture production systems, the most important factor determining fish health and performance is water quality. The majority of a fish's demands are met by the water in which it lives. As a result, it's critical to comprehend the fish's needs in terms of water quality. For a large fish breeder, keeping and raising fish in a pond is an essential responsibility. Pond management, such as fish food production and pond water quality maintenance, are the key concerns for fish breeders. To ensure that aquaponic breeders receive the highest possible return on their investment while preserving fish, a dynamic or technological breeding system has been developed [9-11].

The article concentrates on the technological trend on IOT-based fish aquaculture sensors is the key finding of this study, which is important because it reviews the technology trend employed in applied IOT-based fish aquaculture.

2. Literature Review

2.1 Internet of Things and Technology Trend

The process of developing an innovative aquaponics health monitoring system that integrates high-tech back-end innovation sensors to examine fish and crop health and a data analytics framework with a low-tech front-end approach to feedback actions to farmers has received renewed interest in recent developments in the field of aquaculture. Administrators can monitor the water quality in a fish farm using mobile devices thanks to the integrated data being supplied to them via the Internet of Things. It takes time and resources to transport the instrument to each fish farm for testing at a set time because the existing pH sensors cannot be submerged in the liquid for extended periods of time for measurements [12-14].

For automatic data gathering, an Internet of Things (IoT) system was created that uses an ESP-32 microcontroller to manage water quality sensors in aquaponics fish ponds. Temperature, pH, dissolved oxygen, turbidity, ammonia, and nitrate sensors are among the available sensors. The Internet of Things technology reads water quality data and instantly uploads it to the cloud. For data analytics and decision-making, the dataset is downloaded and viewed in the cloud. This study discusses the use of fishery intelligent equipment, IoT, edge computing, 5G, and AI algorithms in contemporary aquaculture and assesses the current issues and potential for future growth. Meanwhile, design frameworks for crucial functional elements in the development of an intelligent fish farm are suggested depending on various business requirements [14-16] .

A modular, Internet of Things-connected gadget to address this issue has been developed. Local fish farmers may use it with our application on their smartphones for real-time monitoring, device setup, and data archiving. The modular gadget is made up of many water sensors, including pH, dissolved oxygen, total dissolved solids, temperature, turbidity, and oxidation-reduction potential. These sensors, along with various actuators like an aerator, a water filter, a peristaltic pump, a water pump, a fish feeder, and a heater, will aid in detecting and addressing any anomalies in the aquatic environment [17].

An Internet of Things (IoT)-based system with integration of an enhanced decision machine learning algorithm since a new conservative approach is required for monitoring fish feed. The development of system on chip technologies has made it possible to monitor crucial factors including water quality, pump range, velocity, and flow. If all the parameters are properly tracked, fish will live longer. As a result, a sensor-based technology that is simple to attach and affordable has been used to monitor the required parameters [18]. This system also discusses the creation of a smartphone application for the Internet of Things-based integrated control and real-time monitoring of smart fish farms (IoT). This project's crucial function is to regulate the water processing in an intelligent, recirculating fish farm. Two water tanks, a balancing tank, and a recirculating aquaculture system make up the planned smart fish farm. The proportional integral derivative (PID) controller, water-level ultrasonic sensors, water-temperature sensors, and dissolved oxygen (DO) and potential hydrogen (pH) sensors are all used in this aquaculture to manage the water flow process. Message Queue Telemetry Transport (MQTT) is used for real-time monitoring and remote control, while lab servers are used to store the collected huge data. The developed aquaculture system can be used to operate manually, automatically, or remotely using a mobile device [19,20].

Extending to the agricultural context, in this setting, various technologies are being used to reduce those environmental hazards, giving rise to the concept of precision agriculture and aquaculture, which is a form of management based on observing, measuring, and reacting to the spatial and temporal variability of productions. Precision aquaculture's goal is to improve monitoring, management, and documentation of biological processes in fish farms by applying control-engineering principles to production. Even though most of them are not specifically addressed in the precision aquaculture framework, the goal of this review is to provide an overview of the precision aquaculture engineering innovations, with examples of commercial systems, in terms of: computer vision for animal monitoring, environmental monitoring tools, and sensor networks (i.e., wireless sensor networks, and long-range), robotics, and finally data interpretation and decision-making (i.e., algorithms, Internet of Things, and Decision Support Systems). Cyber-physical systems communicate and collaborate with one another and with people in real-time across the Internet of Things, both within and between organizational services provided and used by value chain players. Monitoring and controlling the production process is becoming ever more crucial in order to boost output, improve the quality of fish products, and address concerns about animal welfare [21,22].

2.2 Monitoring and water quality

In order to transfer the temperature, pH level, dissolved oxygen, water level, and life expectancy of the sensor in the fish farm to the server, we used wireless transmission technology with a variety of sensors as in Figure 1. Administrators can monitor the water quality in a fish farm using mobile devices thanks to the integrated data being supplied to them via the Internet of Things. It takes time and resources to transport the instrument to each fish farm for testing at a set time because the existing pH sensors cannot be submerged in the liquid for extended periods of time for measurements. In order to do automatic measurement and maintenance tasks, a robotic arm was created. This arm was created using an embedded system, a single chip with a wireless transmission module, and a programmable logic controller. Control, measurement, server, and mobility make up this system [13].

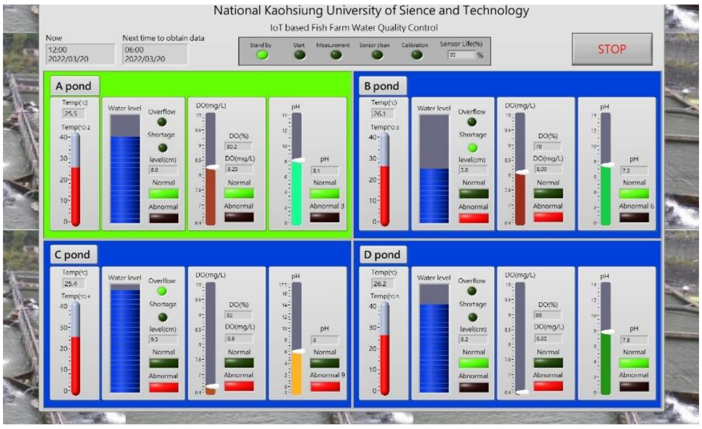

Fig. 1. Human–machine interface of intelligent fish farm measurement system [13]

This work also creates a deep learning model (DL) that correlates the many aspects of the smart aquaculture system in order to forecast the growth of the California Bass fish. In order to obtain the best DL model configuration for the given experimental data set, Bayesian optimization-based hyper-parameter tweaking was used. An R2 score of 0.94 and a mean square error of 0.0015 produced by the best model show that it may be used to predict the intended outcome. Based on the findings of the trials, the autonomous feeding system can incorporate the DL model to cut down on the amount of wasted feed [23].

As a result, the goal of this article is to comprehensively highlight research initiatives devoted to the use of automated, fully operated aquaponic systems. To do this, it will discuss all relevant aquaponic parameters aligned with smart automation scenarios and IoT, supported by some examples and research findings. Additionally, an effort was made to identify any gaps in the existing research and prospective future contributions relevant to automated aquaponics [14].

In accordance with the designed system, information from the farmed field is sent to Ocean Cloud's data platform. All acquired data and analytical findings can then be used to the cage culture field. Results: This management system is used in cage culture and successfully combines AI and IoT technology. This paper demonstrates how the system merges AI and IoT into a workable framework that can continuously capture information about the health status of fish, survival rate of fish, as well as the feed residuals. Examples include underwater biological analysis photos and AI feeding [15,24,25].

This study evaluates the available sensors to measure the important water parameters for fisheries, including temperature, pH, nitrate, phosphate, calcium, and dissolved oxygen (DO). Additionally, this research makes a future suggestion for smart fisheries that will assist in monitoring variables affecting water quality, making choices based on the information gathered, and responding more swiftly to changing conditions Using Arduino and Raspberry Pi 3B+ via LoRaWAN IoT Protocol, this paper presents a water quality monitoring system with automatic correction to monitor and maintain vital water quality parameters necessary for fish growth, such as temperature, potential hydrogen (pH) level, oxidation-reduction potential, turbidity, salinity, and dissolved oxygen to achieve maximum yield. A web application, an aquarium heater, a motor for distributing sodium bicarbonate, a solenoid valve, and a water pump are used by the system to collect and monitor data for six distinct water quality metrics. These parameters are maintained at a desired level that is best for fish growth. Two intensive aquaculture installations, a controlled setup and a traditional setup, were observed by the proponents in order to gauge the system's effectiveness and dependability [26,27].

Furthermore, the dynamic fish feeder is set up to dispense food in areas where sensors have identified fish. The created hardware is programmed for the NodeMCU ESP8266 microcontroller board. Based on sensors that are attached, the controller manages the feeding and feedback process. The controller is programmed with an ultrasonic sensor to measure the amount of food, and a waterproof ultrasonic to measure the presence of fish. In order to regulate the food's freshness, the humidity in the container was measured by the humidity sensor. The waterproof sensor was moved by two servo motors in order to draw the fish and administer food to the fish when it was present. The outcome shows four measured levels: container temperature, food quality based on measured humidity, fish detection counter, and quantity of fish food in the container. On the ThingSpeak platform, data analytics on all the measured levels were displayed utilising data collects from all sensors obtained via Blynk [16,28].

This article provides an Internet of Things (IoT)-based system with integration of an enhanced decision machine learning algorithm since a new conservative approach is required for monitoring fish feed. The development of system on chip technologies has made it possible to monitor crucial factors including water quality, pump range, velocity, and flow. If all the parameters are properly tracked, fish will live longer. As a result, a sensor-based technology that is simple to attach and affordable has been used to monitor the required parameters [17,18,29,30].

We can control the water quality and thus gather both quality and quantity in fish raising by monitoring the real-time sensor data indicators (such as indicators of salinity, temperature, pH, and dissolved oxygen-DO) and predicting them to acquire early warning. We address the use of wireless sensor network (WSN) technology to communicate data about the temperature, humidity, and water quality of the area [22].

2.3 Sensors

This research looks at the process of creating an innovative aquaponics health monitoring system that combines low-tech front-end feedback mechanisms with a data analytics framework to assess the health of the crops and fish [1].

Administrators can monitor the water quality in a fish farm using mobile devices thanks to the integrated data being supplied to them via the Internet of Things. It takes time and resources to transport the instrument to each fish farm for testing at a set time because the existing pH sensors cannot be submerged in the liquid for extended periods of time for measurements. In order to do automatic measurement and maintenance tasks, a robotic arm was created. This arm was created using an embedded system, a single chip with a wireless transmission module, and a programmable logic controller. Control, measurement, server, and mobility make up this system [2].

Over the course of a year, three commercial aquaponic farms in Southeast Texas provided the input data for our model on a weekly basis. Because there were so few data points, highly correlated predictors were eliminated using dimensionality reduction approaches such pairwise correlation matrices. The characteristics were ranked according to their relative value using feature selection methods like the XGBoost classifier and Recursive Feature Elimination with ExtraTreesClassifier. The two most important nutrients to predict were ammonium and calcium. Based on the months in which lettuce was grown, the median value of these nutrients in the historical dataset served as the ideal concentration to be kept in the aquaponic solution to support healthy growth of tilapia fish and lettuce plants in a coupled setup. To do this, nutrient values were measured using Vernier sensors, and actuator systems were created to discharge the right nutrition into the environment through a closed loop [25].

Fig. 2. Biofloc Technology in Aquaculture [16]

The IoT framework for efficient monitoring and effective control of various aquatic environmental factors connected to water is presented in this study.

An Arduino and sensors are used to create the suggested system as an embedded system. The water of a farming pond has a variety of sensors, including pH, temperature, turbidity, and ultrasonic, all of which are connected to a single microcontroller board based on an Arduino Uno. Through the Arduino microcontroller, the sensors read the data from the water and save it as a CSV file in an IoT cloud called ThingSpeak. We gathered information from 5 ponds with different sizes and settings to validate the experiment. Only three of the five ponds were found to be ideal for fish farming after experimental examination, and these three ponds only met the requirements for pH (6.5-8.5), temperature (16–24 °C), turbidity (below 10 ntu), conductivity (970–1825 S/cm), and depth (1-4) metres. This research concludes with the presentation of a fully functional hardware implementation of the suggested IoT framework for a real-time aquatic environment monitoring system [26].

In this study, a smart automation aquaponic monitoring system is proposed. Users can utilise smartphone applications to maintain and watch over the system. HC-SR04 measures water level, FC-28 maintains soil moisture, and DHT11 records temperature and humidity. To process the data, the sensors are integrated with an ESP8266 microprocessor based on WeMos D1 Wi-Fi. The gathered data is saved in the cloud and accessible through the Blynk application, which serves as an actuator and lets users manage the associated parameters. The application aids in keeping track of the fish tank's humidity, temperature, and water level as well as controlling the actuator for fish feeding. Additionally, the system notifies the user of any actions taken, such as feeding fish, watering plants, or detecting an anomalous temperature in the area. Regression modelling was used to analyse the system's performance [27].

The goal of this study is to increase fish productivity and protect the aquatic ecosystem used for aquaculture in Bangladesh. This study outlines a method for monitoring aquaculture's fundamental requirements and assisting in the provision of fisheries-related necessities using Internet of Things (IoT)-based gadgets. These tools will be used to monitor various water properties to improve the living conditions for fish. These gadgets are made up of sensors that can monitor the water's temperature, the potential of hydrogen (pH), and two further portions where dissolved oxygen and ammonia levels, which are essential for successful fish farming in the right environment, may be measured. Additionally, a mobile application for Android has been created. In this system, users of an Android application will be farmers, fishermen, and those involved in aquaculture. Users will receive notifications regarding the amount of dissolved oxygen, ammonia level, pH level, and water body temperature via that application and with the aid of a device. Fish farmers will be able to prevent any disturbances in an aquatic environment with the use of this monitoring system. Despite the fact that Bangladesh is a riverine nation and fish farming has a significant economic influence here, maintaining excellent health is essential to producing an increasing amount of fish [28].

4. Conclusions

In order to create a sustainable system, the designed system enhances the state-of-the-art in terms of communication technology and metrics for tracking the aquaponics life cycle. The 24-hour operation of the intelligent measurement equipment developed in this study significantly decreases the losses brought on by human, material, and data errors. It is anticipated that the aquaponics system supported by smart control units will increase in profitability, intelligence, accuracy, and effectiveness within the purview of the research works discussed in this article.

The communities of agriculture, aquaculture, data science, and machine learning will all benefit greatly from this dataset. When this dataset is subjected to machine learning and data analytics, the insights it yields will be very helpful to fish farmers, giving them knowledge about feed conversion ratios, when to change the pond water, what stocking density to use, and how to predict the growth rate and patterns of their fish.

As a result of our study's findings, aquaculture owners and operators can more effectively decrease feed residual, track fish growth, and boost fish survival rates, all of which will raise the feed conversion rate. As a result, aquaculture based on artificial intelligence of things (AIOT) may help fish farmers intelligently handle and manage various fishpond equipment remotely as well as help aquaculture operators perform professionally, lowering the industry's entrance barrier and promoting aquaculture.

The controlled system significantly outperformed the conventional setup's yield quality, was significantly more efficient, required less work from fish farmers, and avoided fish fatalities, according to the data acquired. A mobile phone application can be used by the user to obtain information. This research has a wide range of possible uses, including monitoring water quality, preventing pollution, and lowering aquaculture mortality.

The outcome shows healthy growth for both plants and fish over the course of the monitoring period, indicating the success of the suggested approach. Overall, this solution helps to stabilise environmental sustainability, especially in urban areas, and reduce labour and operating expenses as well as options for meeting food demand.

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