Journal of Ubiquitous Computing and Communication Technologies (ISSN: 2582-337X)
www.irojournals.com/jucct/

Unveiling the Internet of Things (IoT) Applications in Aquaculture: A Survey and Prototype Design with ThingSpeak Analytics

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Abstract

The study examines the potential impact of IoT in aquaculture, and its role in enhancing water quality monitoring as well as the disease prevention. It highlights the transformative power of IoT technology in providing real-time data on water parameters and enabling proactive measures against diseases. The study emphasizes the significance of adopting IoT solutions to optimize water conditions, mitigate disease risks, and enhance fish health. It also explores recent advancements, key challenges, and future directions in IoT applications for aquaculture, including water quality monitoring, feed automation systems, environmental control systems, fish tracking and monitoring systems, remote monitoring and control systems, smart harvesting systems, and disease detection and prevention systems. Based on a comprehensive literature survey, this paper introduces a research proposal focusing on water quality monitoring and disease prevention in fish. The progress thus far encompasses the selection of hardware components, sensor testing, and ongoing activities in programming and debugging.

Keywords: IoT, Aquaculture, Sustainability, Water Quality Monitoring, Disease Prevention, Real-Time Data, Proactive Measures, Fish Farming, ThingSpeak, Embedded Solutions

DOI: https://doi.org/10.36548/jucct.2023.2.004
Received: 02.05.2023, received in revised form: 02.06.2023, accepted: 17.06.2023, published: 27.06.2023

1. Introduction

Aquaculture is the practice of cultivating aquatic organisms such as fish, shellfish, and plants in controlled environments. It plays a significant role as an additional activity to conventional farming, providing diversification and additional income opportunities for farmers. Aquaculture not only contributes to food production but also offers social and economic benefits to farmers by generating employment, improving livelihoods, and promoting sustainable development in rural communities [1]-[3]. In recent times, aquaculture practices face several critical problems that can have a detrimental impact on the rural economy. One major issue is the outbreak of diseases in fish farms, which can lead to significant economic losses and even the collapse of entire farming operations. Another challenge is the degradation of water quality due to pollution and improper waste management, affecting the health and growth of farmed aquatic organisms. Insufficient access to finance and credit, limited market opportunities, and inadequate infrastructure for transportation and storage also hinder the growth and profitability of aquaculture ventures. These problems collectively pose a risk to the sustainability and viability of rural economies that heavily rely on aquaculture as a primary source of income and livelihood for local communities [4]-[7]. Sustaining aquaculture is crucial to ensure a consistent supply of fish for food production and support the livelihoods of communities dependent on this industry. It can be achieved by implementing effective resource management practices, such as proper water quality monitoring, responsible feed usage, and disease prevention measures. Additionally, promoting sustainable aquaculture through certification programs, regulatory frameworks, and public awareness campaigns can help minimize environmental impacts and ensure the long-term viability of this essential sector [8]-[12]. IoT should be considered for designing smart aquaculture systems to enable real-time monitoring, optimize resource utilization, and improve overall productivity and sustainability.

2. A Survey of Internet of Things Applications in Aquaculture Systems

Section 2 is a literature survey on the role of the Internet of Things for improving aquaculture systems. IoT's role in aquaculture is critical as it enables real-time monitoring of water quality, fish health, and environmental conditions in fish farms. By leveraging sensors, connectivity, and data analytics, IoT solutions optimize aquaculture operations, enhancing productivity and mitigating disease risks. With automation, remote control capabilities, and intelligent decision-making, IoT empowers the industry to adopt sustainable and efficient practices, ensuring the well-being of aquatic organisms and the long-term viability of aquaculture systemsThrough IoT integration, fish farming has witnessed enhanced operational efficiency, optimized resource utilization, and increased yields, ultimately transforming the industry into a more sustainable and profitable venture.Fig. 1 shows the IoT applications in aquaculture.

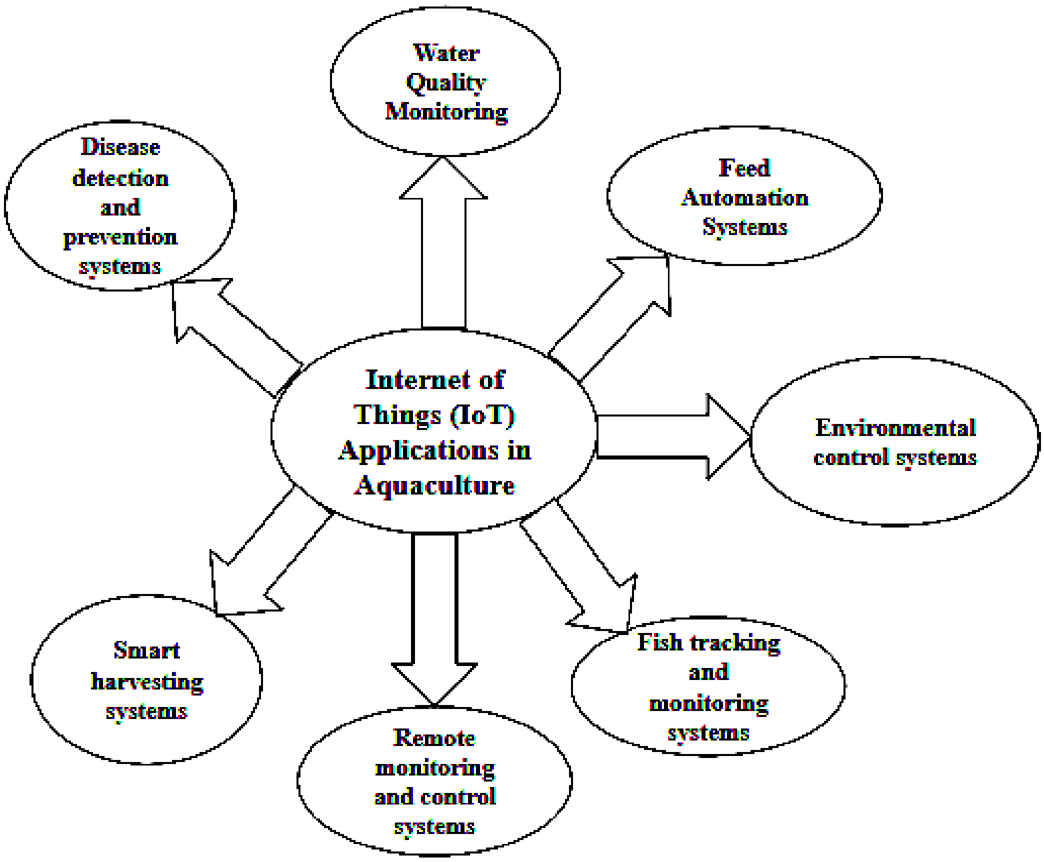

Figure 1. Applications of IoT in Aquaculture

2.1 Water Quality Monitoring Systems

[13] introduces an IoT system for real-time monitoring and control of water parameters in aquaculture, leading to proactive actions and compatibility with diverse systems. [14] proposes anNarrowBand-Internet of Things(NB-IoT)-based water quality monitoring system for aquaculture ponds, enabling remote data collection, intelligent control, and centralized management to support sustainable production. [15] presents an IoT-based smart aquaculture system (ISAS) that detects water quality and automates aeration, significantly improving shrimp survival rates. [16] contributes a standalone photovoltaic /-battery energy storage (PV/BES)-powered water quality monitoring system based on NB-IoT, optimizing energy and enabling real-time monitoring for early warnings. [17] presents Hybrid Aerial/Underwater

RobotiC System (HAUCS), an IoT framework utilizing unmanned aerial vehicles and underwater devices for water quality monitoring in aquaculture farms, with a promising HAUCS Path Planning Algorithm for large-scale farms. Future research should focus on AI-based analytics, edge computing, and integrating IoT with emerging technologies like blockchain for enhanced security and transparency while addressing challenges related to data accuracy, interoperability, and cybersecurity concerns.

2.2 Fish Feed Automation Systems

The research presented in [18] introduces an automated feeding control system for aquaculture tanks, optimizing feed amount based on continuous fish consumption and accurate detection of excess feed on the water surface. The study in [19] proposes a pH and TDS monitoring system integrated with an Android application for aquaponics, achieving real-time measurements and precise feeding schedules with minimal errors. In [20], existing methods for identifying fish feeding behavior in aquaculture are reviewed, emphasizing the need for improved recognition accuracy and suggesting the use of data fusion and deep learning techniques. [21] provides an overview of precision aquaculture engineering innovations, highlighting the significance of monitoring and controlling the production process for enhanced fish production and welfare. The paper proposes a two-stage approach utilizing optical flow neural networks and 3D convolution neural networks to evaluate fish feeding intensity accurately. Future research directions involve advancements in data fusion, machine learning, and AI algorithms to optimize feeding strategies and explore the potential of wearable sensors and underwater drones for comprehensive data collection and precise control mechanisms.

2.3 Environment Control Systems

These IoT-integrated systems optimize environmental factors in aquaculture by monitoring and controlling temperature, humidity, and lighting [22]. They improve fish growth and reproduction, reducing reliance on time-consuming lab testing methods. The research [22] developed a smart aquaculture system with six sensors, enabling real-time monitoring for improved accuracy and timely alerts. [23] demonstrates an IoT-based system for fish farming, showcasing superior performance over traditional methods. Continuous water quality monitoring in aquaculture through IoT technology enables real-time data transfer, optimizing productivity [24]. Future research aims to integrate AI and machine learning for intelligent decision-making and adaptive control strategies, enhancing sustainable and optimized aquaculture production.

2.4 Remote Monitoring and Control System

The research in [25] presents an IoT-based remote monitoring system for aquaculture, achieving high accuracy in measurements and control parameters while being cost-effective and user-friendly for multiple smartphone users. İn [26] the study proposes a real-time monitoring system for offshore fish farms using IoT and LoRaWAN technology, enabling remote control and optimization of fish farming processes with reliable communication up to 8.33 km offshore. İn [27] the study combines GIS and IoT technology to develop an integrated water quality monitoring system for industrialized aquaculture, facilitating effective control of the aquaculture environment. İn [28] the study leads to a design on a a low-cost buoy prototype for remote water quality monitoring in fish farming, providing an affordable and automated solution. Future research directions include advancements in sensor technology, AI integration, and the expansion of IoT infrastructure for enhanced scalability and interoperability across industries.

2.5 Fish Tracking and Monitoring

The study in [29] presents an IoT-based intelligent fish farming and tracking control system in China, ensuring automatic water quality management and traceability of freshwater fish. The proposed forecasting method effectively predicts water quality indicators, enhancing revenue for fish farmers while safeguarding food safety. İn [30] the study designs a multilink gliding fish robot for underwater information collection in the IoUT, demonstrating flexible swimming and energy-efficient gliding through mechatronics and behavioral control. İn [31] the study introduces the BeFAQT system, a Blockchain-enabled solution for fish provenance and quality tracking, achieving real-time, trusted fish tracking and quality assessment with IoT and AI technologies. In [32] the research work combines deep learning, fish tracking, and DTW to detect anomalous behavior in underwater fish, supporting disease investigation and precision breeding in a smart aquaculture system integrated with IoT sensors. Future research aims to enhance fish tracking accuracy, real-time data analysis, and interoperability through advancements in sensor technology, edge computing, machine learning, and standardized protocols, enabling comprehensive monitoring.

2.6 Disease Detection and Prevention System

The work in [33] utilizes image processing and machine learning to identify salmon fish diseases in aquaculture with high accuracy, enabling timely prevention and ensuring food security. [34] presents an automated IoT and AI-based system for real-time monitoring of water quality in fish farming, facilitating disease detection and knowledge sharing among fish farmers. AquaScanner in [35] offers an innovative product for remote monitoring and management of aquarium tanks, including fish disease detection and automated feeding. [36] proposes a status monitoring system for fish farms using PLC and ICT, addressing power failures and enabling convenient observation and management. Future research aims to improve sensor technologies, refine disease detection algorithms, and enhance data analytics to develop more effective and reliable IoT-based solutions for fish disease prevention and detection, while addressing challenges related to sensor accuracy, algorithm robustness, and data security. The disease detection and prevention system in aquaculture using IoT focuses on developing advanced sensor networks and machine learning algorithms to monitor water quality parameters, detect disease outbreaks, and enable real-time decision-making for efficient disease management in aquaculture.

2.7 Fish Harvesting System

The integration of Blockchain and IoT in fish supply chain systems enables secure traceability and fraud detection [37]. [38] explores transforming commercial aquaponic systems into home/urban setups, achieving self-sustainability and increased plant harvest. [39] emphasizes the importance of interoperable IoT platforms for seafood traceability, enabling transparency and value generation. A cost-effective method using fish fin waste to generate electrical energy through a triboelectric nanogenerator is proposed [40]. Current research focuses on optimizing sensor technologies, data management, and analytics for smart fish harvesting using IoT, while future directions involve advancing AI algorithms, enhancing IoT connectivity, and implementing automated harvesting techniques for improved efficiency and sustainability.

2.8 Summary of Literature Survey

The key points from the survey of the Literature are summarized below.

i. The literature survey highlights the growing research in aquaculture leveraging IoT technologies for water quality monitoring, fish feed automation, environment control, remote monitoring, fish tracking, disease detection, and fish harvesting.

ii. IoT-based solutions enable real-time monitoring and control of water parameters, improving accuracy, timely alerts, and aquaculture production optimization.

iii. Continuous water quality monitoring and IoT sensor integration support preventive measures and optimize productivity in aquaculture.

iv. Current research focuses on enhancing automation, data analytics, and connectivity in IoT-based environment control systems to optimize water quality and improve efficiency.

v. Future directions involve integrating AI and machine learning, advancing sensors, and expanding IoT infrastructure for intelligent decision-making, predictive analytics, and sustainable aquaculture production.

vi. The literature survey also highlights the importance of IoT in enabling precise feeding strategies and improving feed efficiency in aquaculture. By integrating IoT technologies with feed automation systems, precise feeding schedules and portion control can be achieved, reducing feed wastage and optimizing growth rates.

vii. By using advanced tracking technologies such as RFID or acoustic tags, fish movements, behavior, and growth can be monitored and analyzed, allowing for better understanding of fish health, population dynamics, and optimizing stocking densities.

3. Problem Statement and Objectives of Work

3.1 Problem Statement

The project aims to utilize IoT and wireless sensors for real-time monitoring of temperature, pH, dissolved oxygen, and disease prevention in fish. The collected data will be transmitted through a real-time application and the ThingSpeak cloud server, enabling access to the information via GSM devices.

ISSN: 2582-337X

3.2 Research Gaps

Research gaps in the field of IoT-enabled aquaculture systems include:

i. Limited studies on the integration of advanced AI and Machine Learning algorithms to enable intelligent decision-making and predictive analytics based on the collected data.

ii. Lack of comprehensive investigation into the optimal frequency and duration for monitoring water parameters, which can help determine the most effective preventive measures and early detection of abnormalities.

iii. Limited exploration of the long-term impact and scalability of IoT-based aquaculture systems, including their ability to adapt to different fish species, environmental conditions, and production scales.

iv. The absence of effective disease prevention and alert systems in prawn farming leads to devastating losses and potential bankruptcy, highlighting the need for integrated communication platforms and timely information sharing to improve disease management and farm sustainability. The presence of birds in aquaculture can pose significant challenges, including predation and potential disease transmission, affecting the overall health and productivity of fish populations. Aquaculture faces challenges in integrating advanced AI, optimizing monitoring frequency, assessing long-term impact, and implementing effective disease prevention and bird management measures.

3.3 Objectives of the Work

i. Implement IoT and wireless sensors to continuously monitor pH, temperature, and dissolved oxygen levels in a timely manner.

ii. Develop a real-time application for data transmission and storage on the ThingSpeak cloud server.

iii. Enable accessibility of the monitored data through GSM devices, ensuring easy and widespread availability.

iv. Establish predefined intervals for monitoring the water parameters to ensure prompt detection of any abnormalities.

v. Employ preventive measures to avoid cross-transfusion and promote the well-being of the birds.

vi. Ensure the accuracy and reliability of the collected data by utilizing robust sensor technology.

vii. Optimize the system's efficiency to minimize resource consumption and maintenance requirements.

viii. Contribute to the overall improvement of bird health and safety in aquaculture environments through effective monitoring and preventive measures.

4. System Overview, Block Diagram and Operation

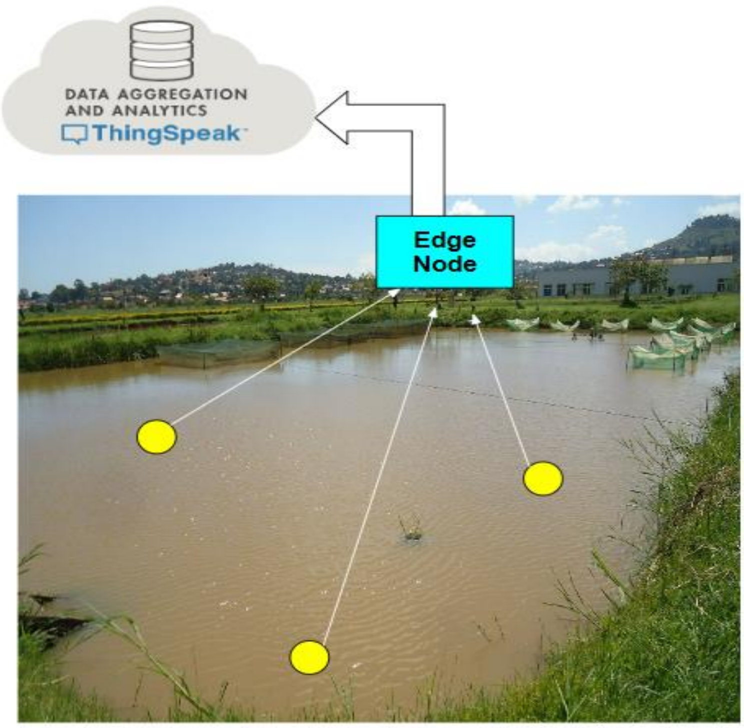

Figure 2. System Overview ([41],[42])

Fig. 2 shows a schematic representation of how the system would look in real time. As seen in Fig.2, wireless sensor nodes are deployed in the fishing area. The number of monitoring nodes to be deployed depends on the size of the reservoir. These sensor nodes are designed to continuously sense water parameters such as pH, temperature, and dissolved oxygen, which impact the fish life. The sensed parameters are transmitted to the Edge Node using a short-range wireless protocol like ZigBee. Additionally, if the parameters exceed the threshold value, an SMS alert will be sent to the farm manager through a GSM modem. Since data from multiple nodes needs to be sent to the cloud simultaneously for analysis, edge computing is required. An edge node, which is a device or computing resource situated at the network edge, closer to the endpoints or users, facilitates local connection, aggregation, and processing of data generated by connected devices or sensors. Deploying edge nodes in edge computing architectures reduces latency, bandwidth usage, and dependence on centralized data centers, resulting in faster and more efficient data analysis and decision-making.

The key parameters to monitor and control in aquaculture systems are temperature, dissolved oxygen, and pH, as they directly impact the health, growth, and carrying capacities of aquatic animals. Temperature influences fish feeding patterns and growth, with stress and disease risks increasing at extreme or fluctuating temperatures. Dissolved oxygen is vital for fish and is affected by water temperature, with warmer water holding less oxygen. Salinity is also crucial, as high levels can cause stress, poor appetite, slow growth, and disease outbreaks in fish. The threshold values depend on the type of fish (Table. I).

Table 1. Temperature, pH, Dissolved Oxygen for fish [43]

Fishes	**Temperature**	**pH**	**Dissolved Oxygen**
Catfish	24–30 ^{0}C (75	86°F) 6.5	9.0 >5.0ppm
Tilapia 28	30°C (82	86°F) 7.5	7.8 >5.0ppm
Carp 23	30°C (73–86°F) 7.5	8 >5.0ppm	Carp 23
Barramundi 26	30 ^{0}C (78	86°F) 7.2	8 4
Eel	28 ^{0}C(7382°F) 7	9 >5.0ppm	28 ^{0}C(7782°F) 7
Salmon 25	28 ^{0}c(7782°F) 7	9 >8.5ppm	Salmon 25

Table 1 provides essential information about the temperature, pH, and dissolved oxygen requirements for various fish species. Each species has specific environmental needs to thrive and remain healthy. For example, catfish prefers temperatures ranging from 24 to 30°C (75-86°F) with a pH level between 6.5 and 9.0, and a minimum dissolved oxygen level of 5.0ppm. Tilapia, on the other hand, thrives in a slightly higher temperature range of 28 to 30°C (82-86°F) with a pH level between 7.5 and 7.8, and a similar minimum dissolved oxygen level.

Carp can tolerate temperatures between 23 and 30°C (73-86°F) with a pH level of 7.5 to 8, and a minimum dissolved oxygen level of 5.0ppm. Understanding and maintaining these parameters is crucial for ensuring the optimal health, growth, and overall well-being of the fish in aquaculture systems. The tolerable conditions for aquaculture include a temperature range of 29-31°C, pH levels of 6.5-6.8, dissolved oxygen levels above 5ppm, and salinity ranging from 8-20 psu. Maintaining the appropriate temperature, pH, and dissolved oxygen levels according to the specific requirements of different fish species, such as catfish, tilapia, and carp, is essential for their optimal health and growth in aquaculture systems. These environmental parameters play a vital role in ensuring the overall well-being and successful production of fish. Adequate monitoring and control of these factors are crucial to create favorable conditions and support sustainable aquaculture practices.

The block diagram of the system is shown in Fig. 3

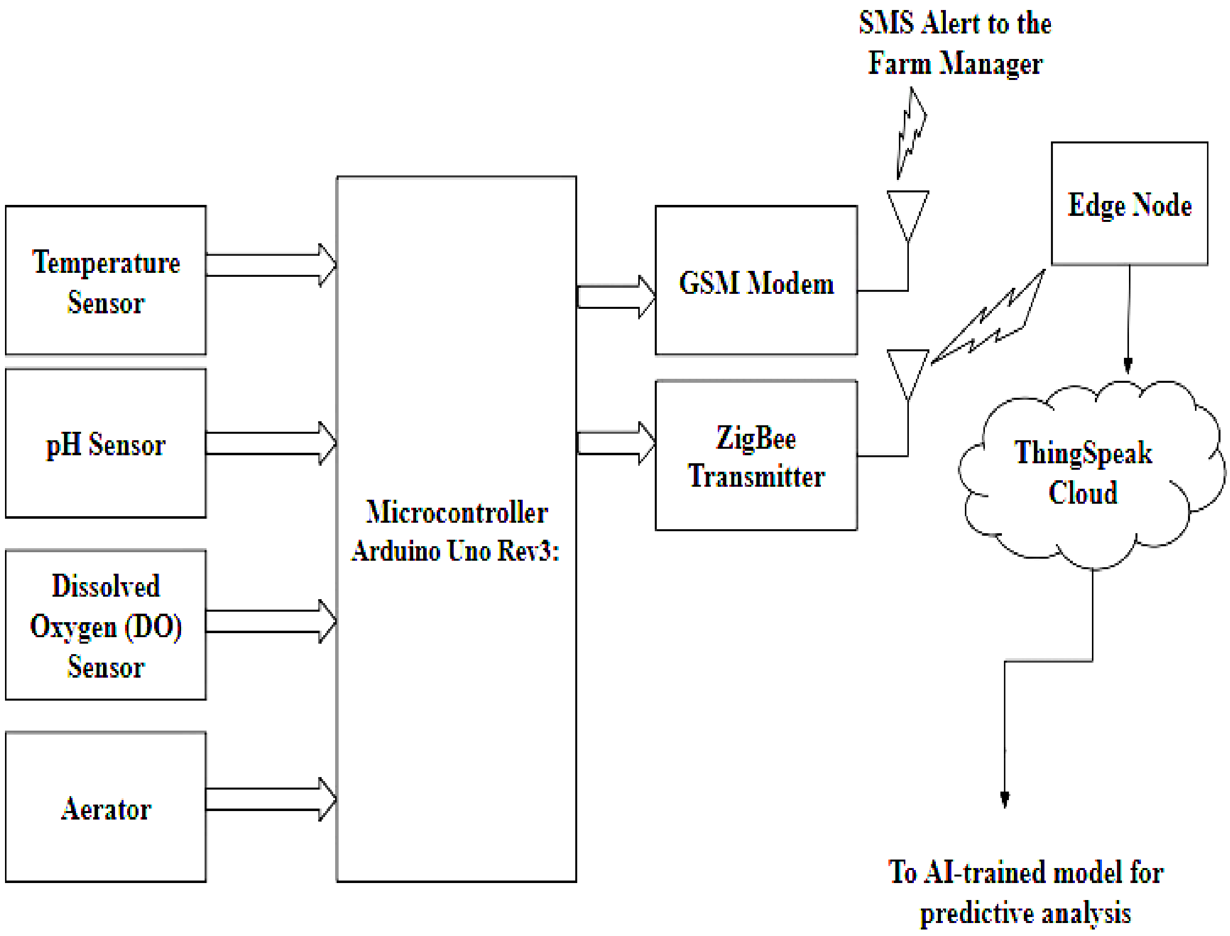

Figure 3. Block Diagram of the System

In Fig.3, multiple wireless sensor nodes, including temperature, pH, dissolved oxygen (DO) sensors, and an aerator, are deployed in a fishing pond. These sensor nodes collect data on important parameters affecting fish health and pond conditions. The data from these sensor nodes is transmitted wirelessly to an edge node, which serves as a local point of connection and processing. The edge node then sends the data to the ThingSpeak Cloud through the internet for storage and analysis. ThingSpeak empowers users with a cloud-based IoT analytics platform service, enabling them to aggregate, visualize, and analyze live data streams with ease. The edge node plays a crucial role in aggregating and forwarding the sensor data, reducing latency and bandwidth usage by processing the data locally before transmitting it to the cloud. Also, a SMS alert is sent to the farm manager if any of the parameters cross the threshold value. This architecture enables real-time monitoring and analysis of the fishing pond conditions, facilitating informed decision-making and predictive analysis using an AI-trained model.

4.1 Diseases due to Cross Transfusion by Birds in Fish and Prevention Measures

Birds can significantly impact fish health in aquaculture due to several reasons. Firstly, their droppings can introduce harmful pathogens and bacteria into the water, leading to diseases and infections among the fish. Secondly, birds often prey on fish in open fish farms, causing direct mortality and stress. Thirdly, their constant presence can disrupt the feeding patterns and behavior of fish, affecting their growth and development. Additionally, birds can damage netting and infrastructure, allowing fish to escape or be exposed to predators. Lastly, their disturbance and noise can induce stress responses in fish, compromising their immune system and overall well-being.

An Internet of Things (IoT) and machine learning (ML)-based solution can be implemented to prevent the spread of diseases in fish caused by cross transfusion by birds [44]. This solution utilizes actuators such as speakers, motion devices, and visual deterrents, which are controlled through an IoT platform. Machine learning algorithms analyze sensor data to detect patterns and set thresholds, thus triggering appropriate bird deterrent methods . Remote monitoring and control are facilitated through a mobile app or web interface, allowing users to receive alerts, adjust settings, and assess the effectiveness of different deterrent methods.

Table 2. Summary of Deterrent Methods [45].

Type of Method		**Effectiveness/ Remarks**
Auditory	Gas cannons	Productivity can be enhanced by varying the timing and location of firing.
	Pyrotechnics	Effectiveness is achieved when a large gathering of birds occurs.
	Bio-acoustics	Recordings of bird alarm or distress calls are played, specifically those of gulls, herons, and corvids.
	Ultrasonic devices	Only few can hear in this range
	Sonic devices	For effective results, it is necessary to play a variety of sounds.
Visual	Raptor models	It becomes more useful when they are oscillating and moved around.
	Replica or real corpses	Mimicking dead or injured birds can deter other birds of the same species.
	Tapes	The effectiveness of warning tapes can be increased through their visual, auditory (wind-induced "hum" sound), and physical deterrent properties.
	Flags	The most effective type of deterrent against waterfowl are black flags made from simple and inexpensive sheets of plastic measuring 60x90cm.
	Scarecrows	While their effectiveness tends to diminish over time, dressing scarecrows in loose-fitting clothing with streamers that create noisy movements in the wind can enhance their efficacy.
	Nets	These deterrent methods can be employed to protect crops and aquaculture facilities, and they prove highly effective in preventing bird-related damage.
Physical Preventives	Anti-perching devices	Birds can be prevented from landing through the use of straightforward measures such as coils, wires, gels, or spikes.
	Wires	Achieving visual and physical impact through symmetrical spacing can make it a cost-effective and effective deterrent.

	Sward height	Reptiles of small size can utilize the sward as a shelter, whereas at a height of 20 cm, it can be disregarded or removed.
Habitat change	Water spray devices	Spraying water along the farm creates a visual distraction that hinders hunting activities. The application of water spray on small fishing lakes proves beneficial by obstructing the birds' view of fish in the water.
	Fish refuges and vegetation cover	Refuges are highly effective in safeguarding fish against predation. A straightforward stock-fencing cage filled with brushwood, old Christmas trees, and strategically shaded to attract fish serves as an excellent refuge. Additionally, water weeds, tree roots, and marginal vegetation offer valuable cover for fish.
	Food removal	Birds have the ability to relocate when food resources are scarce.
	Lethal shooting	Shooting can contribute to effective bird scaring when incorporated as a component of a comprehensive bird scaring program.
Lethal control	Egg destruction	The most effective technique involves substituting real eggs with artificial ones, and treating the removed eggs by chilling before placing them back in the nest. Oiling, on the other hand, is not completely reliable, as the oil can transfer onto the parents' feathers and needs to be reapplied three times throughout the incubation period to ensure effectiveness.

5. Progress of the Work to Date

The process of selecting the necessary components and modules for the hardware implementation based on the prototype requirements has been finished. Additionally, the sensors have been tested, and their output has been verified. Currently, the focus is on programming the system to read the sensor data and transmit it wirelessly via a ZigBee transmitter to the NodeMCU, which acts as the edge node. The steps for programming are given below:

i. Initialize the Arduino, Zigbee module, and WiFi connection.

ii. Enter the main loop.

iii. Read pH, dissolved oxygen, and temperature values from respective sensors.

iv. Print the sensor values to the Serial monitor.

v. Send the sensor data through the Zigbee module.

vi. Prepare a data string containing the sensor values.

vii. Send the data string to the Zigbee module.

viii. Connect to the NodeMCU via WiFi.

ix. Prepare an HTTP POST request with the data string.

x. Send the POST request to the NodeMCU.

xi. Wait for the response from the NodeMCU.

xii. Continue looping after a delay of 5 seconds.

Below is a provided partial Arduino sketch for programming the system.

```
#include <SoftwareSerial.h>

#include <ESP8266WiFi.h>

#include <ESP8266HTTPClient.h>

// Define the pins for the sensors

const int pH_Pin = A0;

const int dissolvedOxygen_Pin = A1;

const int temperature_Pin = A2;

// Define the pins for the Zigbee module

const int zigbee_RX_Pin = 2;   // Zigbee RX pin

const int zigbee_TX_Pin = 3;   // Zigbee TX pin

// WiFi credentials

const char* ssid = "your_wifi_ssid";
```

```
const char* password = "your_wifi_password";
SoftwareSerial zigbeeSerial(zigbee_RX_Pin, zigbee_TX_Pin);
void setup()
 {
  Serial.begin(9600);
  zigbeeSerial.begin(9600);
  // Connect to WiFi
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED)
 {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");
}
      void loop()
      {
  // Read sensor values
  float pHValue = readpH();
  float dissolvedOxygenValue = readDissolvedOxygen();
  float temperatureValue = readTemperature();
  // Print sensor values to Serial monitor
  Serial.print("pH: ");
```

```
  Serial.println(pHValue);
  Serial.print("Dissolved Oxygen: ");
  Serial.println(dissolvedOxygenValue);
  Serial.print("Temperature: ");
  Serial.println(temperatureValue);
  // Send sensor data through Zigbee
  sendData(pHValue, dissolvedOxygenValue, temperatureValue);
  delay(5000); // Wait for 5 seconds before taking readings again
}
float readpH()
{
  // Code to read pH sensor value
  // Replace with your pH sensor code
  // Return the pH value as a float
}
float readDissolvedOxygen()
{
  // Code to read dissolved oxygen sensor value
  // Replace with your dissolved oxygen sensor code
  // Return the dissolved oxygen value as a float
}
float readTemperature()
 {
```

```
  // Code to read temperature sensor value
  // Replace with your temperature sensor code
  // Return the temperature value as a float
}
void sendData(float pHValue, float dissolvedOxygenValue, float temperatureValue)
{
  // Prepare the data string
  String dataString = String(pHValue) + "," + String(dissolvedOxygenValue) + "," +
String(temperatureValue);
  // Send data to Zigbee module
  zigbeeSerial.println(dataString);
  // Send data to NodeMCU via HTTP POST
  WiFiClient client;
  // Replace the IP address and port with your NodeMCU's IP address and port
  const char* serverIP = "192.168.1.100";
  const int serverPort = 80;
  if (client.connect(serverIP, serverPort))
{
    // Prepare the HTTP POST request
    String url = "/data";
    String postData = "data=" + dataString;
    // Send the POST request
    client.println("POST " + url + " HTTP/1.1");
    client.println("Host: " + String(serverIP));
```

```
client.println("Content-Type: application/x-www-form-urlencoded");
client.println("Content-Length: " + String(postData.length()));
client.println();
client.println(postData);
client.println();
// Wait for the response
while (client.connected()) {
  if (client.available()) {
    String response = client.readStringUntil('\r');}}
```

The provided Arduino code includes the necessary libraries and definitions for sensors, Zigbee module, and WiFi credentials. It establishes a WiFi connection, reads sensor values, and sends the data through Zigbee while also transmitting it to a NodeMCU via HTTP POST request

6. Conclusion

This study explores the potential impact of IoT in aquaculture, focusing on water quality monitoring and disease prevention to enhance sustainability. It discusses various IoT applications in aquaculture, including water quality monitoring, feed automation systems, environmental control systems, fish tracking and monitoring systems, remote monitoring and control systems, smart harvesting systems, and disease detection and prevention systems. The research also presents a prototype IoT system implemented using with ThingSpeak and discusses disease prevention methods integrated into embedded IoT solutions. The research emphasizes the significance of adopting IoT solutions to optimize water conditions, mitigate disease risks, and improve fish health in aquaculture.

References

[1] Swann, LaDon. "A basic overview of aquaculture." (1900).

[2] Landau, Matthew. *Introduction to aquaculture*. Wiley, 1992.

[3] Ackefors, Hans, Jay Huner, and Mark Konikoff. *Introduction to the general principles of aquaculture*. CRC Press, 1994.

[4] Young, Nathan, et al. "Limitations to growth: Social-ecological challenges to aquaculture development in five wealthy nations." *Marine Policy* 104 (2019): 216-224.

[5] Martos-Sitcha, Juan Antonio, et al. "Welfare and stressors in fish: Challenges facing aquaculture." *Frontiers in physiology* 11 (2020): 162.

[6] Boyd, Claude E., et al. "Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges." *Journal of the World Aquaculture Society* 51.3 (2020): 578-633.

[7] Folke, Carl, and Nils Kautsky. "Aquaculture with its environment: prospects for sustainability." *Ocean & coastal management* 17.1 (1992): 5-24.

[8] Jana, B. B., and Santana Jana. "The potential and sustainability of aquaculture in India." *Journal of Applied Aquaculture* 13.3-4 (2003): 283-316.

[9] Pullin, Roger SV, Rainer Froese, and Daniel Pauly. "Indicators for the sustainability of aquaculture." *Ecological and genetic implications of aquaculture activities* (2007): 53-72.

[10] Osmundsen, Tonje C., et al. "The operationalisation of sustainability: Sustainable aquaculture production as defined by certification schemes." *Global Environmental Change* 60 (2020): 102025.

[11] Nobile, Andre B., et al. "Status and recommendations for sustainable freshwater aquaculture in Brazil." *Reviews in Aquaculture* 12.3 (2020): 1495-1517.

[12] Abinaya, T., J. Ishwarya, and M. Maheswari. "A novel methodology for monitoring and controlling of water quality in aquaculture using Internet of Things (IoT)." *2019 International Conference on Computer Communication and Informatics (ICCCI)*. IEEE, 2019.

[13] Huan, Juan, et al. "Design of water quality monitoring system for aquaculture ponds based on NB-IoT." *Aquacultural Engineering* 90 (2020): 102088.

[14] Tsai, Kun-Lin, et al. "IoT based smart aquaculture system with automatic aerating and water quality monitoring." *Journal of Internet Technology* 23.1 (2022): 177-184.

[15] Davis, Anthony, et al. "Developing and Field Testing Path Planning for Robotic Aquaculture Water Quality Monitoring." *Applied Sciences* 13.5 (2023): 2805.

[16] Atoum, Yousef, Steven Srivastava, and Xiaoming Liu. "Automatic feeding control for dense aquaculture fish tanks." *IEEE Signal Processing Letters* 22.8 (2014): 1089-1093.

[17] Chen, Jui-Ho, Wen-Tsai Sung, and Guo-Yan Lin. "Automated monitoring system for the fish farm aquaculture environment." *2015 IEEE International Conference on Systems, Man, and Cybernetics*. IEEE, 2015.

[18] Riansyah, Akbar, et al. "Fish feeding automation and aquaponics monitoring system base on IoT." *2020 6th International Conference on Wireless and Telematics (ICWT)*. IEEE, 2020.

[19] Antonucci, Francesca, and Corrado Costa. "Precision aquaculture: a short review on engineering innovations." *Aquaculture International* 28.1 (2020): 41-57.

[20] Ubina, Naomi, et al. "Evaluating fish feeding intensity in aquaculture with convolutional neural networks." *Aquacultural Engineering* 94 (2021): 102178.

[21] Rosaline, Nikitha, and S. Sathyalakshimi. "IoT based aquaculture monitoring and control system." *Journal of Physics: Conference Series*. Vol. 1362. No. 1. IOP Publishing, 2019.

[22] Al-Mutairi, Abdallah Waddah, and Kasim Mousa Al-Aubidy. "IoT-based smart monitoring and management system for fish farming." *Bulletin of Electrical Engineering and Informatics* 12.3 (2023): 1435-1446.

[23] Chavan, M. S., et al. "Design and implementation of IOT based real time monitoring system for aquaculture using raspberry pi." *International Journal on Recent and Innovation Trends in Computing and Communication* 6.3 (2018): 159-161.

[24] Li, Hui, et al. "Aquiculture remote monitoring system based on IOT Android platform." *Transactions of the Chinese Society of Agricultural Engineering* 29.13 (2013): 175-181.

[25] Parri, Lorenzo, et al. "A LoRaWAN network infrastructure for the remote monitoring of offshore sea farms." *2020 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*. IEEE, 2020.

[26] P. Sun and Y. Chen, "Aquiculture Remote Monitoring System Based on Internet of Things," 2019 International Conference on Robots & Intelligent System (ICRIS), Haikou, China, 2019, pp. 187-190, doi: 10.1109/ICRIS.2019.00056.

[27] Medina, Juan D., et al. "Open-source low-cost design of a buoy for remote water quality monitoring in fish farming." *Plos one* 17.6 (2022): e0270202.

[28] Gao, Guandong, Ke Xiao, and Miaomiao Chen. "An intelligent IoT-based control and traceability system to forecast and maintain water quality in freshwater fish farms." *Computers and Electronics in Agriculture* 166 (2019): 105013.

[29] Wang, Chengcai, et al. "Design, modeling, control, and experiments for a fish-robot-based IoT platform to enable smart ocean." *IEEE Internet of Things Journal* 8.11 (2021): 9317-9329.

[30] Wang, Xu, et al. "Blockchain-enabled fish provenance and quality tracking system." *IEEE Internet of Things Journal* 9.11 (2021): 8130-8142.

[31] Wang, Jung-Hua, et al. "Anomalous behaviors detection for underwater fish using ai techniques." *IEEE access* 8 (2020): 224372-224382.

[32] Ahmed, Md Shoaib, Tanjim Taharat Aurpa, and Md Abul Kalam Azad. "Fish disease detection using image based machine learning technique in aquaculture." *Journal of King Saud University-Computer and Information Sciences* 34.8 (2022): 5170-5182.

[33] Agossou, B. Emmanuel, and Takahara Toshiro. "IoT & AI based system for fish farming: case study of Benin." *Proceedings of the Conference on Information Technology for Social Good*. 2021.

[34] Ranaweera, I. U., et al. "Image Processing and IoT-based Fish Diseases Identification and Fish Tank Monitoring System." *2022 4th International Conference on Advancements in Computing (ICAC)*. IEEE, 2022.

[35] Huh, Jun-Ho. "PLC-based design of monitoring system for ICT-integrated vertical fish farm." *Human-centric Computing and Information Sciences*.

[36] Ismail, Shereen, et al. "Toward an Intelligent Blockchain IoT-Enabled Fish Supply Chain: A Review and Conceptual Framework." *Sensors* 23.11 (2023): 5136.

[37] Lee, Chao-Hsien, and Jhih-Hao Jhang. "System design for internet of things assisted urban aquaponics farming." *2019 IEEE 8th Global Conference on Consumer Electronics (GCCE)*. IEEE, 2019.

[38] Jæger, Bjørn, and Alok Mishra. "IoT platform for seafood farmers and consumers." *Sensors* 20.15 (2020): 4230.

[39] Singh, Harminder, et al. "Generation of Electrical Energy Using Fish Market Waste Fish Fin from Mechanical Motion for Battery-Less Self—Powered Wearable Sensors and IoT Devices." *Electronic Materials Letters* (2023): 1-12.

[40] "https://en.wikipedia.org/wiki/File:Pond_for_breeding_young_fish_Aquaculture_Research_and_Development_Centre,_Kajjansi.JPG." *File: Pond for Breeding Young Fish Aquaculture Research and Development Centre, Kajjansi.JPG*. Accessed 8 June 2023.

[41] Available: https://thingspeak.com/pages/learn_more, last accessed 8 June 2023.

[42] Neetha K et.al, 'IoT based Smart Aquaculture' *Global Research and Development Journal for Engineering | National Conference on Emerging Research Trend in Electrical and Electronics Engineering (ERTE'19) | May 2019*

[43] Goud, Chalamala Srinivas, et al. "Wireless sensor network (wsn) model for shrimp culture monitoring using open source iot." *2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA)*. IEEE, 2020.

[44] Bishop, J., et al. "Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives." *Food and rural affairs, London* (2003): 1-53.