Internet of Things-Based Surveillance and Feeding System for Aquaculture Applications

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Abstract. In both developed and developing countries, the agricultural sector is playing a significant role in driving economic growth. In Nigeria, there has been an increased push to diversify the economy through agriculture, and aquaculture has been identified as a key sector to aid in this effort. However, the sector faces various challenges, such as poor water quality, feeding-related issues, pest control, disease, and predator control, resulting in reduced output and lower incomes. Previous research has aimed to provide solutions to these challenges, but some works only focus on monitoring water quality, disease, or surveillance against predators or theft, without considering feeding rates. Therefore, a monitoring and surveillance system is required to minimize death rates caused by hunger and increase productivity. This work presents the use of IoT to enable real-time monitoring in aquaculture. The system successfully initiated and terminated the feeding process in the pond within a 3-second timeframe and provided a live feed of the pond's activities to the farm remotely and in real-time. The system achieved a performance of 90% and 88.8% for accuracy and precision, respectively.

Keywords: IoT, Aquaculture, Fish-Feeding, Surveillance.

1 Introduction

Fish are an essential source of animal protein and a crucial part of the diet in most households in Nigeria. In 2015, aquaculture contributed 31% of the total fish production in the country [1]. Aquaculture involves the farming and cultivation of aquatic plants, animals, and fish in fresh, brackish, or saltwater. Some examples of aquatic animals include aquatic plants, algae, and fish [2]. However, the mortality

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rate of fish rearing is a critical issue for individuals who raise fish for business and domestic consumption, and unmonitored conditions in ponds contribute to this problem [3]. Monitoring involves observing individuals, groups of people, objects, or things, and can be achieved through various means, such as humans, animals, or different systems, including alarm systems or closed-circuit television systems. These monitoring systems can be utilized in various settings, including homes, offices, industries, workshops, malls, and farms. In today's technological age, the aquaculture sector requires a monitoring system that enables farmers to monitor their fish from anywhere and at any time [4].

A number of efforts through research have aimed to improve the productivity level of aquaculture by addressing the challenges faced by farmers in maintaining this livestock [2]. The use of a network of sensors and Internet of Things (IoT) technology has been introduced to detect and report parameters in fish ponds, especially water quality, and to collect, transmit, and process data from these ponds [3, 5]. In this work, the concept of IoT is employed to design and develop a surveillance system that enables farmers to monitor and feed their fish at the appropriate time.

The remaining sector of this paper is organized into the following sections. Section 2 focuses on the review of related past works, while Section 3 presented the methodology adopted in the development of the proposed system. In Section 4, the results of the performance evaluation are presented and Section 5, Concludes the work with the direction toward future research.

2 Literature Review

In the areas of development of IoT-based system for the monitoring and surveillance of aqua-culture systems, there exist a number of related works. In [6] the development of a smart wireless sensor network monitoring system for aquaculture environments with the aim of enabling remote monitoring of fish farm environmental data and allowing prompt control over various environmental factors was presented. The system utilized four sensing modules, including temperature, dissolved oxygen, PH value, and water level, as well as an MCU processor for capturing physical sensing signals and a ZigBee wireless sensor network for transmitting data to the central processing core. Results indicated that the system was more secure and less expensive when using a UPS, consumed low energy, and was easy to operate with a high degree of freedom.

Similarly, [7] developed a smart field monitoring system using IoT for the agriculture sector, presenting an e-Agriculture application comprising KM knowledge and monitoring modules. The study outlined the benefits of ICT in the Indian agricultural sector and developed a proto-type monitoring unit using various sensors for which inputs were fed from a knowledge base. TI CC3200 Launchpad and Arduino

UNO board with Ethernet Shield were used for the prototype's development. An analysis of the system's effectiveness showed that it efficiently utilized water resources and helped reduce labor costs, overcoming the drawbacks of traditional agricultural monitoring systems. The design of an IoT-based smart aquaculture system for cloud environments that provides functionalities such as water quality check, environmental monitoring, power monitoring, and a web surveillance platform was developed by [8]. Experimental results showed that the system reduced carbon emissions and energy consumption [8].

Furthermore, [9] utilized wireless sensors and an android application to implement an efficient aquarium management system. The study employed four sets of water quality parameter sensors, namely pH, temperature, conductivity, and dissolved oxygen, which was integrated into the pond using a buoy. The measured data were transmitted by an Xbee wireless transmitter to a fixed monitoring system. Through a web server established with the aid of the internet, the android application retrieved the measured data, allowing users to remotely monitor the aquaculture. The mobile phone also enabled graphical analysis of water quality. The system was observed to reduce the electricity operational cost due to its automatic aeration characteristics. However, the Xbee wireless transmitter had a short range and low data speed, which could be improved with the use of another transmitter. Similarly, [10] developed an aquarium-based environmental monitoring system aimed at improving the breeding environment and reducing farm lab our intensity by strengthening the real-time monitoring and management system of aquaculture. The system comprised sensor nodes, base stations, microcon-trollers, routing, and mobile phones. Through field testing, the system was observed to be stable, easy to control, simple, small, and cheap. The simulation results showed an accuracy of 98%.

In a related manner, similar works have also been conducted in the aspect of fishing in aqua-culture systems using improved techniques and methodologies. In [11], an automated feed monitoring system using a mobile application was designed to solve the problem of short manpower and inadequate data on fish pellets monthly consumption. The study utilized the agile method for smart feed monitoring, with Arduino UNO as the main component for de-signing the hardware and firebase for the system database. Results showed that the automated feeding system was more efficient than the manual method of feeding, achieving higher efficiency and reducing electricity usage for farmers.

Similarly, [12] designed a smart system for feeding remotely using smartphones, which utilized the Internet of Things and Artificial Intelligence to continuously monitor the condition of the fish, timing and amount of feed, and other factors. [13] designed an IOT-based automated fish feeding system for aquariums, with an analysis of feeding algorithms and their parameters. The system's precision and recall time decreased with an increase in the number of fish species. Furthermore, [14] designed an intelligent fish-feeding system using fish behavioral vibration analysis and artificial neural networks, which achieved an accuracy of 100% for predicting fish behavioral activities. Also, [15] designed a two-level feeding system for koi fish ponds using IoT, which was able to effectively monitor and control feeding activity re-motely and send notifications to farmers.

Based on the aforementioned review, this works proposes the development of an IoT-based system for the surveillance and feeding of fishes in a typical recirculatory aquaculture system, this is with the view of reducing the challenges farmers by small and medium-scale farmers practicing subsistence farming.

3 Material and methods

In this work, a simplified architecture for the development of the surveillance and feeding system has been proposed and depicted in Figure 1. This proposed methodology is inspired by the conventional IoT platform architecture where the camera and actuator incorporated with the Raspberry Pi and its wifi connection form a complete IoT device. The camera pro-vides sensory feeds (for the surveillance) from the aquaculture system, while the actuator receives commands to control the feeding trough to either dispense or not dispense fish feeds. Furthermore, the Rasp-berry Pi serves the duo function of being a controller and a gateway for the IoT system. As a controller, the Pi controls the activities of the camera and actuators, while as a gateway to the platform, the Pi works in bidirectional mode with the wifi module to send events to the IoT Cloud platform. It also receives Commands from the Cloud, which are passed to the IoT devices.

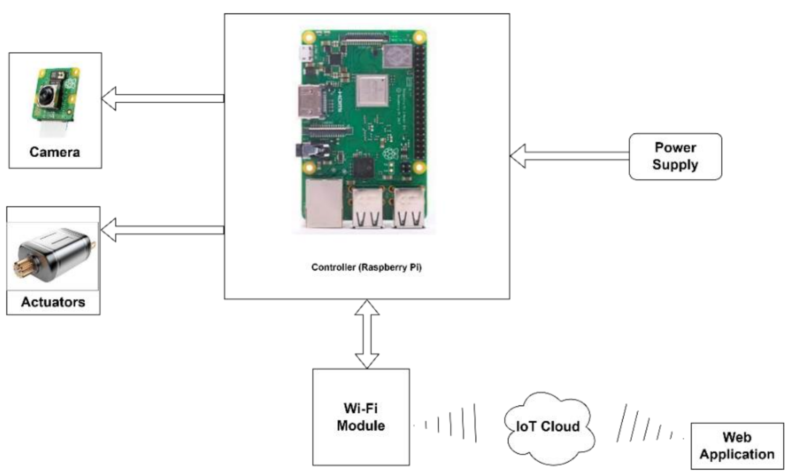

Fig. 1 The Proposed IoT Architecture

The sensory operation of the camera is controlled by an image processing algorithm developed using the OpenCV platform, which is also resident on the controller. The Wifi-Module of the IoT platform communicates with the IoT cloud using the Hypertext Transfer Protocol (HTTP). Also, the web application which interfaces with the cloud also uses the same protocol. To actualize the web application interface for the analytics of the surveillance, an application was built using the python Programming Language. Table 1 shows the technical information of the hardware design considerations for the proposed system. The information highlights the major hardware as well as their specifications.

Table 1. The Hardware Specification of the Proposed System

Components Description	Rating/ Specifications
775 DC Motor	12V 24RPM
HQ Pi Camera	5MP
Raspberry Pi 3 Controller	Model B 1GB, 1.2GHZ Quad Core
Wifi Module	802.11b/g/n

The operation of the proposed system is such that the Raspberry Pi controller houses the program codes and controls the activities of the sensor (Camera) and actuators (DC motor). The controller in turn communicates via the Wifi module for enhanced communication and internet connectivity. The data from the sensor are transferred to the cloud via the wifi module. The sensors also receive instructions for the cloud via the wifi connectivity. Furthermore, the web application interfaces with the cloud to obtain data and display the requisite information for users.

The web interface was developed for the surveillance and feeding system using HTML, CSS, JavaScript and PHP Web Scripting Languages. The goal of this interface is the provide a graphical user interface for the visualization of the status of the aquaculture system in terms of surveillance and feed requirements. Users can also send commands to the Sensor and actuator via the web interface. The process of realizing the system is as depicted in Figure 2.

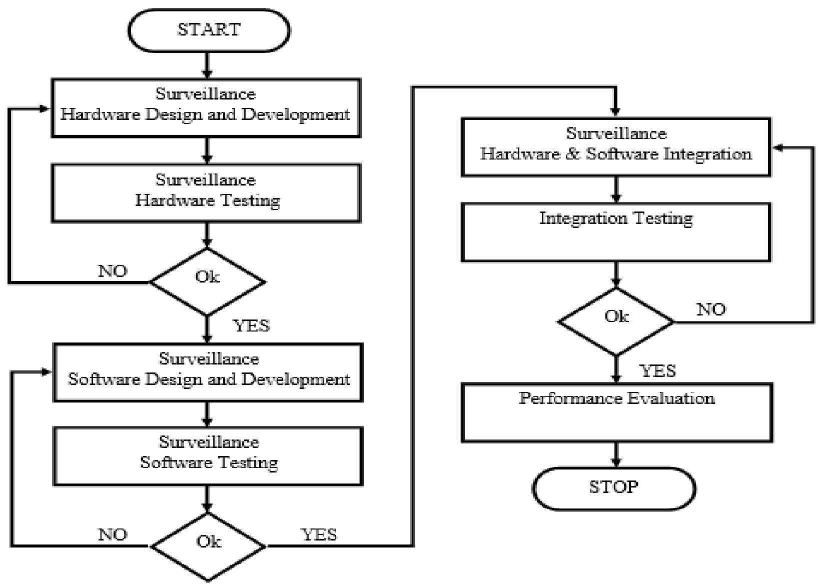

Fig. 2 The flowchart for the development

4 Results and discussion

In accordance with the implementation flow of the proposed system, as depicted in Figure 2, the physical realization of the prototype surveillance and feeding system was achieved. The physical realization of the proposed surveillance and feeding system is depicted in Figure 4, showing the sensor (camera)and the actuator (motor)position over the pond system. The operating sequence of the developed is as depicted in Figure 5, wherein the feed received from the camera sensor determines the actuator operations of whether or not to release feeds into the pond.

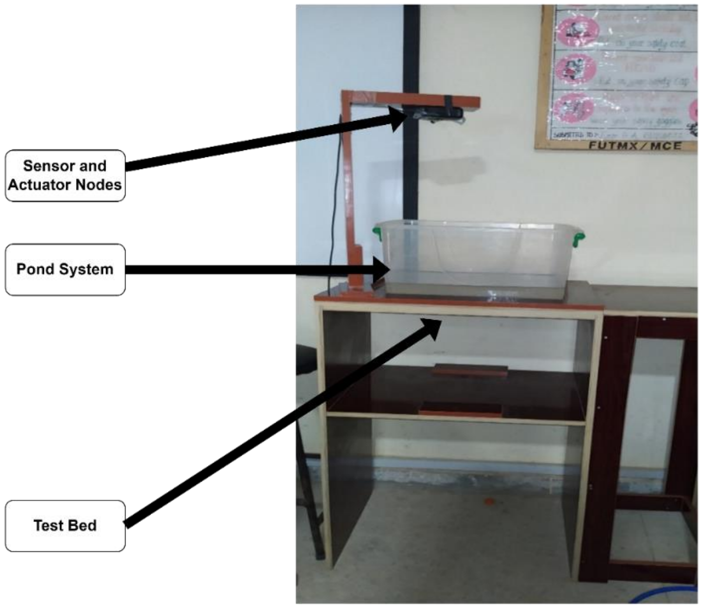

Fig. 3 The prototype of the proposed system

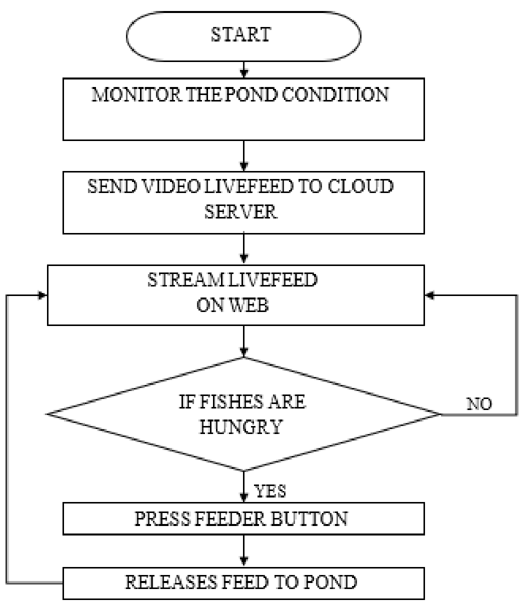

Fig. 4 The operating sequence of the developed system

Furthermore, the camera feed also provides a mechanism for surveillance, wherein the user (farm owner) can monitor the operations of the farm remotely. In Figure 5, shows the web-based user interface in idle mode with the features to on or off the actuators. Figure 6, depicts the monitoring mode, where in the live feed from the pond system is depicted on the monitoring interface. The user has the capability to activate the feeding mode based on the activities in the pond.

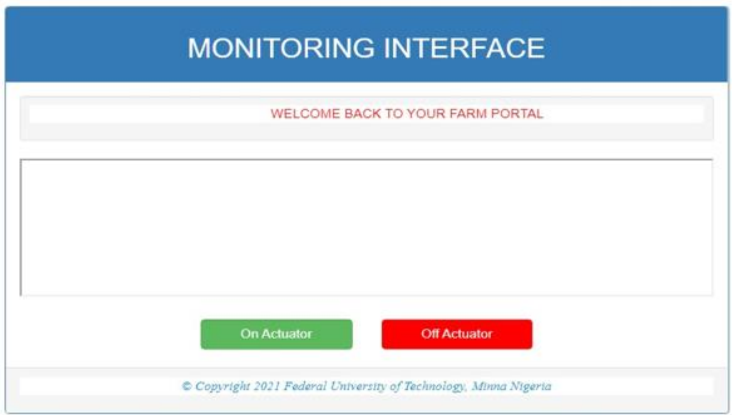

Fig. 5 The Web-based User Interface in Idle State

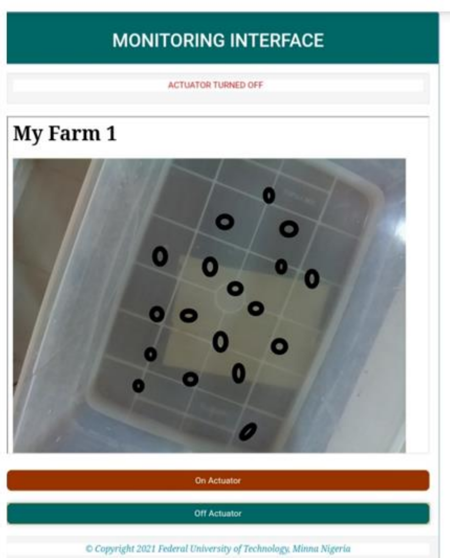

Fig. 5 The Web-based User Interface in monitor mode

Table 2. Confusion Matrix

N=10	Predicted: No	Predicted: Yes	
Actual: No	FN=0	FP=1	1
Actual: Yes	TN=1	TP=9	9
	1	9	

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} = \frac{8+1}{8+1+1+0} = \frac{9}{10} = 0.9 * 100 = 90\% \qquad (1)$$

$$\text{Precision} = \frac{TP}{TP+FP} = \frac{8}{8+1} = \frac{8}{9} = 0.88 * 100 = 88.8\% \qquad (2)$$

The results of trials as presented in the confusion matrix table and computed using (1) and (2) depicts an accuracy of 90% and a precision of 88.8%. The accuracy of 90% indicates that the model correctly classified 90% of the instances of where activities in detected in the pond. However, the precision of 88.8% suggests that when the model predicted a positive instance, it was correct only 88.8% of the time. This means that there were some instances where the model predicted a positive class label, but it was incorrect.

Thus, the confusion matrix with an accuracy of 90% and a precision of 88.8% provides a useful summary of the performance of the system. In addition, the results suggest that the system has achieved a high level of accuracy, but further analysis is needed to improve the precision of the model.

5 Conclusion

In the work, the practical application of the concept of IoT has demonstrated in the development of a prototype surveillance and feed system for a typical aquaculture system. The overall goals of the project are to improve the effectiveness and efficiency of small and subsistence farmers of aquaculture by enhancing to capability to automate basic operation sequences in the farming processes. Thereby increasing their profitability. The developed system offers features that allow users remotely monitor the activities of the pond via the web-based user interface powered by the IoT. In addition, it also offers the capability to remotely initiate the feeding process based on the activities surveyed in the pond. The performance of the developed system based on accuracy and precision shows promising and impressive results. However, future studies may be considered to feature other performance metrics as well as deployment of the system for longer durations in actual farms as compared with laboratory-scale demonstration.

Acknowledgements

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