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A Framework for an AI-IoT Based System for Improving Fish Production in a Smart Pond

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Abstract:- Nigeria still depends largely on imports to bridge the overwhelming demand for fish despite efforts to enhance local production in order to meet the nutritional value requirements of the citizens. Leveraging on technology, a solution can avail an average house-hold to own smart pond which they can monitor and manage from wherever they may be. Our proposed research, therefore, is to develop a framework for a smart pond. The fundamental principle is the interlinking of Internet of Thing (IoT) devices that is smartly driven by Artificial Intelligence (AI) algorithms and powered by a cloud resource. This will enable the learning of some behavioural dynamics of the fishes in the pond from generated data by the sensors. This behavioural understanding can adequately enable adaptation of certain devices for increased production over time. Creating an AI-IoT based system to enhance fish production in a smart pond requires a well-thought-out framework that integrates various technologies and components. This paper is mainly focusing on the design of the framework which, if properly achieved will serve as the basement for the completion of the research which will see the design of the prototype and final implementation. Prototype smart pond that will be achieved in the subsequent research can be implemented based on the framework and the data generated will be analysed and compared with similar data from conventional fish pond.

Keywords:- *Cloud Computing, IoT, Machine Learning, Smart-Pond*.

I. INTRODUCTION

Adequate food and optimal nutritional status are the foundation blocks for the building of healthy, secure lives and thus form the basis for development in any nation (Ministry of Budget and National Planning, 2016). The world needs about 50% more food by 2030 and Nigeria with a population of nearly 200 million has up until now depends on importation of foods and proteins. Fish production is especially amongst the most highly imported products to meet the demand gap. This is because the fishery products is central to food security and nutritional strategies at all stages of human development (Wang et al., 2021).

The global fish production in 2018 was estimated to about 179 million tons, of which aquaculture takes a fair share of 82 million tons. From 1961 to 2017, the average annual growth rate of global consumption of fish for food was 3.1%, which was almost twice the average annual growth rate of the world population during the same period, the rate was also higher than that of other animal protein foods (meat, dairy products, milk, etc.) with an annual growth rate of 2.1% (FAO, 2009). Because of the high quality and cheap protein present in fish, it is likely to have the great potential to become an important substitute for livestock and poultry protein (Ogubdari & Awokuse, 2016).

Nigeria through the federal and local agencies have introduced measures to encourage local fish production by providing training and gadgets to set up ponds even at homes. However, fish farming requires absolute monitoring which only a full-time farmer who solely commit to farming activities can achieve. The full-time fish farmers are aging and their methods can't cope with the increasing population and demands. Therefore, the vast majority of populace especially the working class who may be interested in fish production at family level can be encouraged into it by leveraging on technology-controlled fish farming.

The research in the recent fields of Artificial Intelligence (AI), Cloud Computing, and Internet of Things (IoT) are touching every aspect of human endeavours. AI algorithms are becoming more robust and reliable hence being implemented in different domains to solve complex problems (Mohan et al., 2017). The pervasiveness of the AI technologies is strengthened by the social-aware component focusing on behavioural adaptation of social beings. IoT is the new revolution enabling communication between devices, people and processes to exchange useful information and knowledge that create value for humans. IOT technologies have revolutionized fish farming processes using sensor networks to measure values such as pH, temperature and other parameters. Fish farm management can be automated to be easily and remotely monitored from other location saving time and money-making aquaculture operations more efficient and even eco-friendly.

Cloud technology and development in telecommunication occasioned by high speed and low latency expectation of 5G technology further open research on IoT for improving human production capacity. Combining the features of AI and IoT via cloud technology for a smarter system described as Artificial Intelligence Internet of Things (AIoT), depicted in Figure 1, can be designed and implemented to realize a smart pond that will yield quality products.

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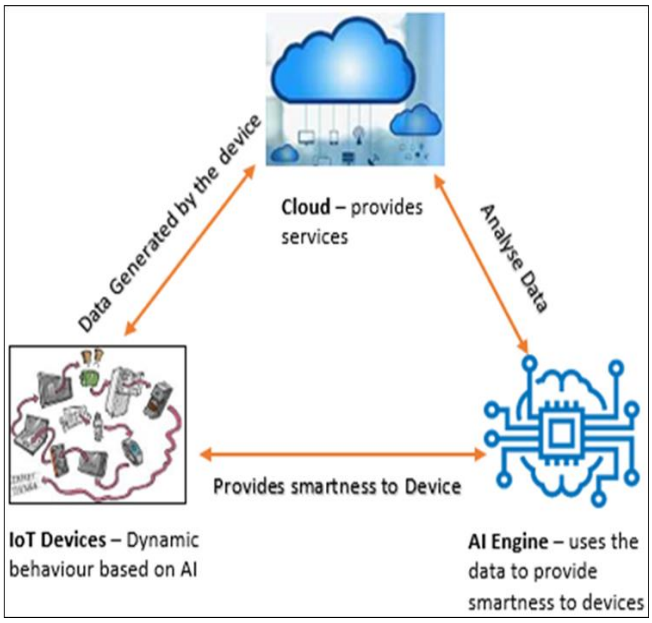

Fig 1 Symbolic Relation between IoT , Cloud Technicalogies and AI

With right investment in research to aid technology in agriculture, the small farmers, who are in the majority, can earn a better living and provide enough nutritious food for our growing population and build pathways to sustain future growth.

Modern agriculture and value chain are essential to attaining food security. On the other hand, good nutrition is highly significant for the lives of people as it affects health, education, and productivity. Nigerian economy is dominated by labour intensive, low value-adding technologies in a mono-product fueled economic setting. Fish farming has been encouraged to complement the protein needs but the practice is still conventional fishing methods. Research on the application of IOT for smart pond is at infancy and emphases on AI to boost such research efforts is sketchy. Most works are on web-based monitoring of aquatic, automatic feeder (Atoum et al., 2015), and most recently on water control and managements (Jha et al., 2020; Ramya et al., 2019). Most of these studies concentrated on the front-end device communication with little or no efforts to leverage AI techniques to dynamically manage the IOT devices based on generated data. This gap is the basis of this research concept.

As the first step to achieving this more inclusive and robust smart pond system, a framework is proposed in this research that presents the IoT devices' connectivity and communication as powered by cloud resources. The framework includes the definition of appropriate AI model that enables the study of the behavior of the aquaculture with a view to making smart decisions and taking autonomous actions. A prototype smart pond is proposed using the framework where study will be conducted to compare processes and products with that obtainable from conventional pond.

II. RELATED WORK

The study on a framework for an AI-IoT based system for improving fish production in a smart pond requires an exploration of existing research and developments in the fields of artificial intelligence (AI), the Internet of Things (IoT), and aquaculture with a focus on how these technologies can be integrated to enhance fish farming. The key concepts, challenges, and potential benefits associated with the framework is the main highlight in this context.

Ma et al. (2012) proposed the prototype of an 'Aquaculture Information System' based on Internet of things E-nose. The Architecture consists of an on-site sense and control platform which senses various pond water quality parameters and controls the actuators to adjust the parameters accordingly. They highlighted the role of sensors and actuators in collecting data from aquaculture ponds. For the use of AI to detect fish disease and diagnosis, Ahmed et al. (2022) used image-based machine learning approach namely SVM with kernel function on salmon fishes. Their model has achieved respectively 91.42% (with augmentation) and 94.12% (without augmentation) accuracy.

Chiu et al., 2022) Proposed a smart IoT-based fish monitoring and control system equipped with different IoT devices to enable real-time data collection; so that fishpond water-quality conditions and other system parameters can be readily monitored, adjusted, and assessed remotely. The study develops a deep learning model (DL) that correlates the different parameters of the smart aquaculture system primarily to predict the growth of the California Bass fish.

Bidossessi (2021) studied the technology for the integration of AI and IoT for monitoring and controlling aquaculture systems. They discussed how AI can analyze IoT data to make informed decisions, optimize feeding, and manage resources efficiently. Ubina et al. (2023) explored smart farming systems, including aquaculture, and the role of AI and IoT in optimizing resource utilization. They highlighted the importance of data analytics in improving fish farming practices.

In the area of fish behaviour monitoring, Xia et al. (2018) used computer vision and deep learning to conduct aquatic toxic analysis by monitoring fish behavior. Their model had successfully gathered sufficient detailed behavioral data for toxicity prediction of the fish-enclosed system. Water quality is crucial for fish health. Several studies, such as the work by (Vijayakumar & Ramya, 2015), have focused on IoT sensors for real-time water quality monitoring in aquaculture ponds. Integrating AI can help in proactive quality management and early issue detection. While the potential benefits are evident, challenges like data security, scalability, and the high initial costs of implementing such systems should be considered. AI-IoT systems can also have a significant economic and environmental impact. Research by Yang et al. (2020) addresses the economic feasibility and sustainability of AI-IoT integrated systems in aquaculture.

Examining case studies of AI-IoT integrated systems in aquaculture, such as those implemented by commercial fish farms, can provide practical insights into the real-world benefits and challenges.

In summary, a framework for an AI-IoT based system for improving fish production in a smart pond has the potential to revolutionize the aquaculture industry. By integrating AI for data analysis and decision-making with IoT for real-time data collection, fish farmers can optimize their operations, improve fish health, and enhance productivity. However, it is essential to address technical, economic, regulatory, and ethical considerations to ensure the successful adoption of such systems. Further research and practical implementations are needed to refine and validate these frameworks

III. METHODOLOGY

The general research involves four main steps. The first step which this paper centres on is the framework, which is the proposed blueprint for setting up the ideal AI-IoT smart pond. The framework defines the objectives and the requirements, hardware setup, data collections and integration, data analysis, automation procedures, communication proceedings, Artificial Intelligence and Machine Learning algorithms, and other connectivity protocols for setting up a typical smart pond.

The second stage of the research is the operability of IoT devices required for the system. The sensors and microcontrollers are defined in terms of scalability, lower power, adaptability and cost for an optimal performance. The third stage involves the exploration of a high-performance and scalable cloud (e.g., Microsoft Azure) platform to provide the hardware support, software needs and process services for the AI algorithms to suffice.

The final step is to test a prototype smart fish pond based on our AIoT framework. The dashboard interface control using mobile app and web app is implemented at this stage. This stage involves evaluating the prototype against a controlled fish pond and the outputs compared based on the quality and value of the final products.

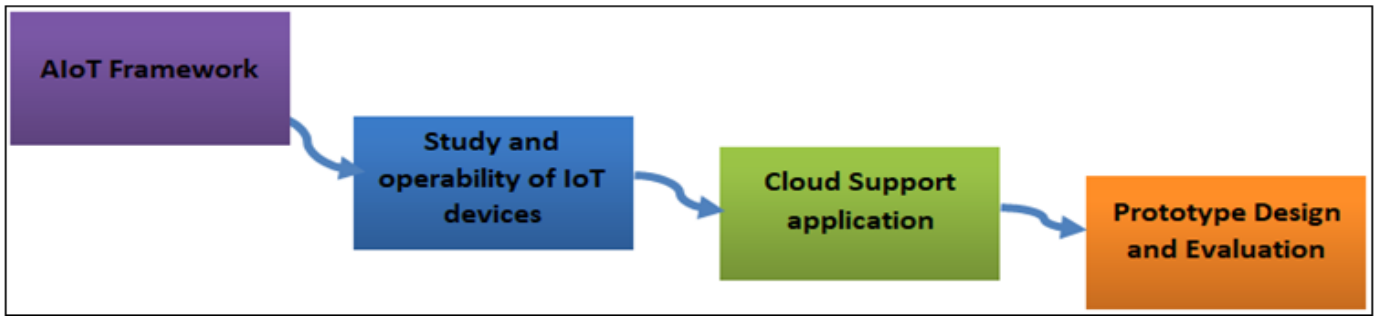

Fig 2 Proposed Research Process

This current research focuses only on the first step which is the designing of the framework that will serve as the basis for exploring and achieving the other three stages. The other three stages would be proposed separately.

IV. THE PROPOSED AIoT FRAMEWORK FOR A SMART POND

Creating an AI-IoT based system to enhance fish production in a smart pond requires a well-thought-out framework that integrates various technologies and components. The proposed get-start framework consists of 16 modules which are implementable in the chronological order of the table in order to achieve optimum results.

Table 1 AIoT Framework for Implementing Smart-Pond

1. Define Objectives and Requirements	• Clearly define the goals of your system, such as increasing fish yield, optimizing resource usage, and ensuring water quality • Identify the specific requirements, such as types of fish, pond size, and available
2. Hardware infrastructure	Implement a robust hardware infrastructure for your smart pond • IoT Sensors: Deploy various sensors for monitoring water quality parameters such as temperature, pH, dissolved oxygen, ammonia levels, turbidity, and salinity • Cameras: Install underwater cameras for real-time fish monitoring and image recognition • Automatic Feeder: Implement an automatic fish feeder that dispenses feed based on predefined schedules or AI-driven recommendations • Water Circulation System: Use pumps and aerators to control water circulation and oxygen levels • Water Quality Control Mechanisms: Employ systems for automatic water filtration, UV sterilization, and chemical dosing to maintain optimal water conditions
3. Data Collection and Integration	• Connect IoT sensors to a central data collection hub • Implement protocols for data transmission and storage, ensuring data integrity and security • Integrate data from various sources, including weather forecasts and water quality databases

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4. Data Processing and Analysis	• Use machine learning models to predict fish behavior, growth patterns, and health status • Monitor the environmental conditions and adjust parameters (e.g., oxygen levels, temperature) accordingly • Cloud Platform: Utilize cloud-based services for data storage and processing. • AI and Machine Learning: Implement AI algorithms for predictive analytics, anomaly detection, and image recognition to monitor fish health and behavior. • Data Fusion: Combine data from multiple sources to gain insights into the overall pond environment.
5. Control and Automation	• Use AI-driven decision-making to control feed dispensers, aeration systems, and water quality maintenance systems • Ensure remote control and monitoring capabilities for ease of management • Remote Control: Allow remote monitoring and control of the pond system through a mobile app or web interface.
6. User Interface and Dashboard	• Develop a user-friendly dashboard for fish farmers to access real-time data and make informed decisions • Include features for setting preferences, receiving alerts, and adjusting parameters remotely
7. Communication and Alerts Module	• Setup alert mechanisms to notify farmers of critical events or deviations from optimal conditions • Enable SMS or email notifications for urgent matters • Mobile App: Develop a mobile application for farmers to monitor and control the pond remotely.
8. AI and Machine Learning and AI Models	Train machine learning models to: • Predict fish growth and health based on historical data. • Optimize feeding schedules and quantities. • Detect anomalies in water quality and fish behavior.
9. Security and Privacy	• Implement robust security measures to protect data and control systems from cyber threats. • Ensure compliance with data privacy regulations.
10. Scalability and Future-Proofing	• Design the system to be scalable to accommodate larger ponds or additional ponds in the future. • Stay updated with emerging technologies and incorporate them as needed.
11. Monitoring and Maintenance	• Set up a regular maintenance schedule for sensors, actuators, and other components. • Monitor system performance and conduct periodic system audits.
12. Data Backup and Redundancy	• Implement data backup and redundancy mechanisms to prevent data loss.
13. Training and Support	• Provide training to farmers on how to use the system effectively. • Offer customer support for troubleshooting and addressing issues.
14. Monitoring and Evaluation	• Continuously monitor the system's performance and fish production outcomes. • Use feedback to improve the AI algorithms and system efficiency over time.
15. 8. Cost Analysis and ROI Evaluation	• Calculate the return on investment (ROI) by comparing the system's cost to increased fish production and reduced operational expenses.
16. Regulatory Compliance	• Ensure that the system complies with local regulations and environmental standards.
17. Integration with External Systems	• Weather Data: Integrate weather forecasting data to make proactive decisions regarding pond management. • Market Data: Link to market information to optimize fish harvesting and sales strategies.
18. Scalability and Future Enhancements	• Design the system with scalability in mind to accommodate larger ponds or additional features. • Plan for future enhancements and updates to the AI models and software.

Building an AI-IoT system for smart fish farming involves a multidisciplinary approach, combining expertise in aquaculture, IoT, AI, and software development. It can significantly enhance fish production efficiency and sustainability while reducing manual labor and environmental impact. By following this framework, you can design an AI-IoT system that not only improves fish production but also enhances the overall efficiency and sustainability of your smart pond operation.

V. THE EXPECTED OUTPUTS

➢ *A framework for connecting scalable sensors at the pond (front-end), communicating via a local network with high-performing cloud (back-end) which also manages the device data for AI algorithms. The basic things to consider for the framework are*

- Pond Management System – Dashboard and mobile app designs
- IoT Platforms – Installed sensors for water levels, pH, humidity, ultrasonic, oxygen and other parameters

- Gateway for monitoring and controls - Microcontroller (RaspberryPi) interfaced the sensors to collect and send data through to the cloud.
- Machine Learning Algorithms to study the behavioural dynamics of the fishes
- Network and power integration – For ensuring adequate and uninterrupted energy source as well as communication network

➢ *A prototype smart fish pond that responds to behavioural dynamics of the fishes in the pond for optimal production.*

Fig 3 Expected Basic Device Connectivity

VI. CONCLUSION

In order to make fish rearing interesting and practicable by a vast majority of the increasing population of Nigeria, a means to domesticate the fish rearing operation is the way. Therefore, the implementation of the framework will make an easier for not only the commercial fish farmers but individual and working class to mount smart fish pond in their homes which they can monitor and control remotely. The inclusion of AI algorithms is to ensure the understanding of the fundamental behavioural dynamics of the pond for enriching the knowledge base of the system. This will trigger certain autonomous actions like changing of water and feeding without the intervention of the pond owner using the IoT devices and the communication between the devices is enhanced with the power of cloud resources. With this, operation could be done at the right time hence ensuring quality product, less stress and more yield as less fatality will be recorded due to errors of omissions or commissions.

The success of the project and the implementation amongst the targeted elites will not only ensure increase in the quality protein intake of average family, it will have a ripple positive effect such as the reduction in demands at local market hence resulting in price stability.

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