AI and IOT in Aquaculture: An Overview

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ABSTRACT

Aquaculture defines as the culture of Aquatic organisms in the controlled conditions like stable Water quality, Feed Management, Disease Management and other activities. Aquaculture plays a major role in National and Global economy and also it plays a vital role in food and nutrition. It is one of the fastest growing food sectors, to maintain the sustainability AI and IOT are used in the proper manner. Increasing in demand for the culture of fishes and organism's paves way for the technological integration. Now we see about the integration of technology and its impacts in aquaculture in various point of views.

INTRODUCTION

Importance of Aquaculture

Aquaculture is one of the major food sources around the world. It is the cheapest protein source and widely available source too. Aquaculture also helps to diversify the organisms and its sustainability. Aquaculture plays a major role in livelihood of people by employment of poor people both male and female, around the world from Marine and Inland sectors. It contributes top level in the economy of the nation. Now the scenarios have been changing rapidly from the capture fisheries to culture fisheries in recent years. In terms of farmed species, the proportion of freshwater fish was the greatest, followed by crustaceans and diadromous fish. Among finfish produced worldwide in 2018, in terms of volume, various types of carp accounted for 48.5%, followed by tilapia (10.2%), catfish (7.5%), and salmon (4.5%) (A Suzuki 2021).

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Artificial Intelligence (AI)

Artificial Intelligence (AI) is the capability of a computer system or machine to mimic human cognitive functions such as learning, reasoning, problem-solving, perception, and decision-making. It involves the development of algorithms and models, often based on machine learning, to process data and act in ways that typically require human intelligence. AI is rapidly being adopted across virtually every industry today, driving efficiency, innovation, and enhanced decision-making, for examples they used in Health care, Cybersecurity, Transportation, Education, etc. But in point of Aquaculture the AI used in various forms like Increasing culture efficiency, Reducing the Environmental impact, Improving the fish health and product quality.

Internet of Things (IoT)

The Internet of Things (IoT) is a network of interconnected physical objects—"things"—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet or a communication network. This allows for seamless data collection, remote monitoring, and automation without constant human intervention. In aquaculture, IoT forms the foundational physical network that collects essential data from the aquatic environment, enabling real-time visibility and remote control over farm operations.

Integration of AI and IOT in Aquaculture

The integration of Artificial Intelligence (AI) and the Internet of Things (IoT), often referred to as AIoT, is revolutionizing aquaculture by replacing several labor-intensive, error-prone, or time-consuming manual tasks. This shift enables higher productivity, better fish health, and reduced operational costs. The key areas of manual labor and human decision-making that are being replaced or heavily augmented by AI and IoT systems are:

1. Water Quality Monitoring and Adjustment

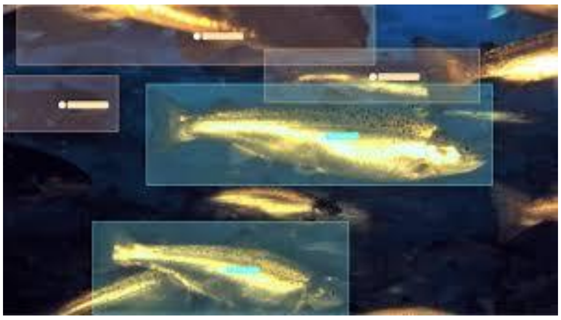
Traditionally we use the Manual Sampling and Testing for the water quality monitoring but by replacement of IoT Sensors & Actuators: Deploying a network of smart buoys and submersible sensors to continuously and remotely monitor parameters (pH, Dissolved Oxygen (DO), Temperature, Ammonia, etc.) in real-time. Replaces: Daily trips and physical water sample collection/testing. Benefit: Provides 24/7 data and instant alerts, reducing labor and preventing catastrophic failures from sudden water changes.

2. Feeding Management

Before introduction of AI and IOT the Scheduled Manual Feeding will be operated in Culture farms, but now the Technology uses Smart/Automated Feeders (IoT): Automated systems dispense precise feed amounts at programmed times. Replaces: Labor for physically distributing feed. Benefit: Consistent feeding regardless of staff availability. Estimating Fish Appetite using AI Computer Vision & Acoustic Sensors: Underwater cameras and acoustic sensors (listening for feeding noises) feed real-time data to an AI model. The AI determines the fish's actual appetite and adjusts the IoT feeder to dispense feed only when necessary. Replaces: Experienced farmer manually observing fish behavior to judge hunger. Benefit: Optimizes feed conversion ratio (FCR), drastically reducing feed waste and preventing water pollution from uneaten food.

3. Fish Health and Growth Assessment

Traditionally we use the mathematical formula and technical ways as Manual Biomass Estimation to estimate the biomass and adjust the other management techniques but now in presence of AIoT impact is AI Computer Vision: Underwater 3D cameras and machine learning algorithms non-invasively scan fish as they swim to calculate their length, weight, and overall population size (biomass). Replaces: Physically netting, handling, and weighing a sample of fish, which causes stress and potential injury. Benefit: Accurate, stress-free growth tracking for better harvesting and stock management.



Visual Disease/Stress Detection it changed as AI Vision Analysis: AI models are trained to recognize subtle changes in fish behavior (e.g., Erratic swimming, Lethargy) or physical signs (e.g., Wounds, Sea lice) from camera footage. Replaces: Farmer's periodic visual inspection, which can miss early signs. Benefit: Early disease detection and classification allow for immediate, targeted treatment, preventing mass outbreaks and reducing the need for broad-spectrum antibiotics. These all changes impact the Total management and Operational cost of the culture by preventing the economic loss and energy.

4. Physical Inspection and Maintenance

In general, we use the Catwalk and other ways to Cage/Net Inspection but now Unmanned Underwater Vehicles (UUVs) and Drones: Robotic systems (IoT) equipped with cameras and sensors autonomously patrol net pens and structures to inspect for holes, biofouling, or structural damage. Replaces: Hazardous and time-consuming work by human divers or manual Remote Operated Vehicle (ROV) piloting. Benefit: Increased worker safety and more frequent, high-precision structural checks.

AI used in specific purpose:

AI, specifically using computer vision and machine learning, is revolutionizing aquaculture by enabling automated, data-driven decisions that improve efficiency, sustainability, and productivity.

Fish Species and Biomass Identification

AI-powered systems, often integrating IoT sensors and underwater cameras, can automatically detect, recognize, and count fish. Common aquaculture practices involve measuring fish biometrics at different growth stages, which is crucial for feeding regime management and for improving farmed fish welfare. Fish measurements are usually carried out manually on individual fish. However, this process is laborious, time consuming, and stressful to the fish.

Therefore, the development of fast, precise, low cost and indirect measurement would be of great interest to the aquaculture sector. In this study, we explore a promising way to take fish measurements in a non-invasive approach through computer vision. Images captured by a stereoscopic camera are used by Artificial Intelligence algorithms in conjunction with computer vision to automatically obtain an accurate estimation of the characteristics of fish, such as body length and weight.

We describe the development of a computer vision system for automated recognition of body traits through image processing and linear models for the measurement of fish length and prediction of body weight. The measurements are obtained through a relatively low-cost prototype consisting of a smart buoy equipped with stereo cameras, tested in a commercial mariculture cage in the Mediterranean Sea (N. Tonachella *et.al* 2022).

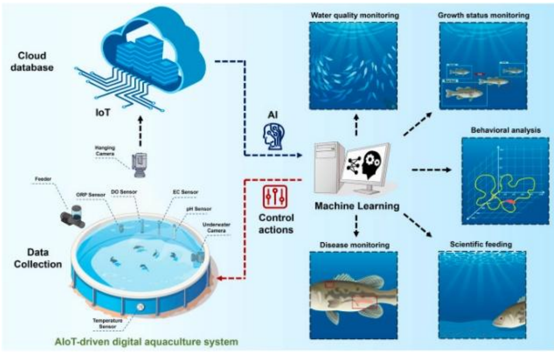
They do this by analyzing images and video footage to identify physical characteristics like size, shape, and color. This automated process is used for:

- **Species identification and classification** to monitor biodiversity and conservation efforts.
- **Counting aquaculture organisms** for accurate stock management and health monitoring.
- **Estimating fish biomass**, or the total weight of the fish population, to optimize feeding schedules and predict growth rates.
- **Tracking individual fish** to monitor their health and behavior over time.

AI in Disease Detection

Accurate classification of fish diseases is crucial in the aquaculture industry, particularly in India, where seafood farming plays a vital role in the national economy. Traditional disease detection methods primarily depend on manual inspection by aquaculture experts through visual observation. These conventional approaches often suffer from limitations such as time consumption, subjectivity, and reliance on experiential knowledge, which can result in inconsistent and delayed diagnoses (R. Pavan *et.al*. 2025). The integration of image-processing and computer vision technology intelligently allows the diagnosis of fish diseases (D. Li. *et.al*. 2022).

Fish diseases can be classified into bacterial, fungal, viral, and parasitic categories, each requiring specific diagnostic and treatment approaches. Bacterial infections like *Aeromoniasis* and Bacterial Gill Disease, along with parasitic and fungal infections, are prevalent in the region and cause significant harm to fish health. Recognizing these issues, this research aims to develop an automated fish disease classification system using deep learning techniques, particularly convolutional neural networks (CNNs). The system utilizes fish colour images as input and processes them through multiple neural layers to extract visual features such as lesions, color changes, and patterns, ultimately identifying the disease type with high accuracy. By automating the disease classification process, the proposed model minimizes dependency on human expertise, reduces diagnostic time, and ensures consistent and accurate predictions.



This research not only aims to enhance fish health management but also promotes sustainable aquaculture by enabling fish farmers— especially those managing small and microscale farms—with accessible tools for timely treatment and disease control (R. Pavan *et.al*. 2025). This early detection allows for timely intervention, preventing outbreaks, reducing economic losses, and minimizing the use of medications.

AI based Machine learning used in Aquaculture (disease detection)

In this research work, the authors focused on detecting diseases in **salmon fish**

aquaculture, which is one of the fastest-growing sectors in global food production, contributing about 70% (2.5 million tons) of the total market. The study aimed to identify infected salmon fish using a combination of image processing and machine learning techniques. The research was carried out in two main stages. In the first stage, the researchers performed image pre-processing and segmentation to enhance the image quality by reducing noise and highlighting important features of the fish. In the second stage, they extracted significant image features and used these to classify fish diseases through a Support Vector Machine (SVM) algorithm equipped with a kernel function. The pre-processed images from the first stage were input into the SVM model for training and testing. The study used a specially prepared salmon fish image dataset, which included both original and augmented images (to improve model robustness). Through experimental evaluation, the results showed that the proposed SVM-based approach achieved impressive accuracy levels — 91.42% for the dataset with image augmentation and 94.12% for the dataset without augmentation (M.S., Ahmed *et.al*. 2022)

AI based Machine learning used in Aquaculture (Automatic feeding system)

This study successfully designed and verified an AI-driven IoT-based smart feeding system for Nile tilapia farming in a desert environment. By combining real-time water quality monitoring with machine learning optimization via the XG-Boost algorithm, the system outperformed standard human feeding methods. The smart feeding system resulted in a 28% increase in final fish weight (200.33g vs 156.7g), a 30% improvement in feed conversion ratio (1.24 vs 1.76), and a 42% increase in protein efficiency ratio (2.7 vs 1.9), all while maintaining flawless survival rates. In conclusion, AI and IoT are poised to revolutionize aquaculture by enabling smarter, data-driven feeding systems. By optimizing feed delivery, reducing waste, and enhancing sustainability, these technologies address critical challenges in fish farming. This research contributes to the field by developing an integrated AI-IoT solution that balances productivity and environmental responsibility, paving the way for more efficient and scalable aquaculture practices worldwide.

This paper makes an important contribution to smart aquaculture technologies, especially for growing aquaculture economies such as Egypt, which produces 84% of Africa's tilapia. The shown increases in growth performance, feed efficiency, and environmental effect emphasize AI-IoT systems' transformative potential in contemporary aquaculture methods (H.M. Dorgham, *et.al*. 2025)

Other uses of AI in fisheries sector

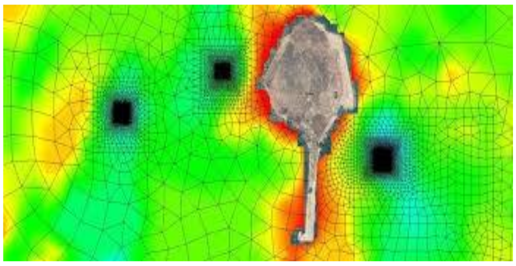
One of the key applications of AI in aquaculture is the development of smart monitoring systems. These systems employ various sensors, cameras, and data analytics tools to continuously collect real-time data on water quality, temperature, oxygen levels, and fish behavior.

- Kailash Bohara, *et al*. (2024), they proposed that the developments of technologies in **aqua medicine**, such as sequencing, biosensors and CRISPR, have enabled rapid disease detection within minutes.
- Yaxuan Zhao, *et al*. (2024), they proposed that the **Phenotypic and behavioural information** of fish, which can reflect fish growth and welfare status, play a crucial role in aquaculture management. Stereo vision technology, which simulates parallax perception of the human eye, can obtain the three-dimensional phenotypic characteristics and movement trajectories of fish through different types of sensors.

- Lim Leonard Whye Kit, *et al*. (2024), they proposed the **depletion of aquaculture lands and aquatic pollution** are some of the major worrying predicaments challenging the future of this industry. Sustainable growth strategies are the only way out, and they must come hand in hand with the implementation of artificial intelligence to achieve the desired outcome high throughput in short time periods. The intelligent fish farm and smart cage aquaculture management system are some of the fruits of this drive, and the system keeps improving to date.

Ongoing projects of AI integration in Aquaculture

1 **The Dalma Fish Project**, refers to the United Arab Emirates' marine aquaculture project on Dalma Island, which uses AI-driven technology to sustainably raise native fish species in a marine cage-farming system.



Technology:

➢ Utilizes Artificial Intelligence (AI) and modern scientific tools to manage and improve fish farming operations.

Goal:

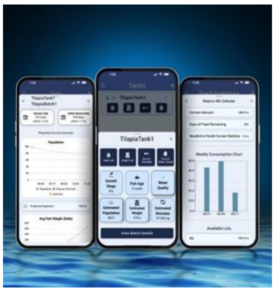
➢ The goal is to produce 100 tonnes of local fish species annually (Safi, Shaari, Qabit, Hamour, etc.).

2 **The BiOceanOr startup,** a French technology startup that provides AI-powered water quality forecasting and monitoring services for the aquaculture industry and environmental management.

Technology:

➢ BiOceanOr uses connected devices (IoT sensors) to measure over 15 physicochemical parameters in real-time (such as dissolved oxygen, temperature, salinity, and pH). This data is then analyzed using machine learning and biological models to provide 48-hour rolling forecasts and actionable recommendations for fish farmers.

3 **Sightline Systems' AQUA Sightline 2.0**, is a company based in the United States, it is an aquaculture management app that uses AI for predictive analytics, including more accurate growth models and feed inventory management. It allows for "right on time" inventory, which reduces waste and improves feed conversion ratios.



Goal:

➢ Better estimates for mortality.

➢ Calculate cost per unit (e.g. pound) of fish growth via feed conversion ratio; helps optimise feeding costs.

4 **Aquaconnect**, an Indian aquaculture technology startup, offers the FarmMOJO

mobile app, a project that utilizes AI and satellite remote sensing to assist fish and shrimp farmers with everything from predicting diseases and improving water quality to securing financing and connecting to markets.

Key Schemes & Financial Benefits for Farmers of AI in Aquaculture in India:

The Indian government is not running a scheme named "AI in Aquaculture." Instead, it integrates financial and technical support for AI and other modern technologies into its larger, comprehensive plans for the fisheries sector. Key Schemes & Financial Benefits for Farmers,

1. **Pradhan Mantri Matsya Sampada Yojana (PMMSY):** The main government program to modernize India's fisheries sector. It provides financial aid and subsidies for new equipment, infrastructure, and technology that can include AI-based systems like automated feeding machines, water quality sensors, and smart monitoring tools.

Credits & Subsidies:

General Farmers: Get up to a **40% subsidy** on the cost of the project.

SC/ST/Women: Get up to a **60% subsidy** on the project cost.

2. **Pradhan Mantri Matsya Kisan Samridhi Sah-Yojana (PM-MKSSY):** A sub-scheme of PMMSY focused on making the fisheries sector more formal and tech-friendly. It promotes digital tools and platforms like the National Fisheries Digital Platform (NFDP), which helps farmers get a digital identity. This makes it easier to access government benefits, insurance, and bank loans.

Credits & Subsidies:

- It provides one-time incentives for farmers to get **aquaculture insurance**, which can protect against losses that AI systems help to prevent.
- It also gives **performance grants** to small businesses and groups that adopt new technology for better safety and quality.

3. **Kisan Credit Card (KCC) for Fisheries:** A special credit card for farmers to meet their daily expenses. Farmers can use this for a working capital loan to buy small AI-enabled devices or pay for data services.

Credits & Subsidies:

- Loans up to ₹2 lakh are **collateral-free**.
- The effective interest rate can be as low as **4%** for those who repay their loans on time, thanks to interest subsidies from the government.

CONCLUSION

The integration of AI into aquaculture represents a significant leap forward, offering a suite of improved culture techniques that directly contribute to sustainable growth. By leveraging AI-powered systems for tasks like real-time water quality monitoring, automated feeding, and early disease detection, farmers can optimize their operations. This leads to reduced waste, lower operational costs, and healthier fish populations.

Furthermore, AI's ability to analyze vast datasets provides a predictive capability that was previously unavailable. This allows for proactive management of environmental variables and health risks, ensuring a more stable and resilient farming environment. Ultimately, the adoption of AI in aquaculture not only boosts productivity but also aligns with the global imperative for sustainable food production by minimizing environmental impact and promoting responsible resource management. The future of aquaculture is inextricably linked with AI, promising a more efficient, ethical, and sustainable industry.

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