REVOLUTIONIZING AQUACULTURE: IOTs role in enhancing water - quality parameters and nutrition in fisheries

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Abstract

Internet of Things (IoT) technology revolutionizes aquaculture by enabling real-time monitoring of water quality, fish health, and feeding processes. This integration of IoT and aquaculture offers improved productivity, sustainability, and reduced losses. Monitoring nodes continuously collect data on critical parameters, transmitting it to cloud platforms for analysis and alerts to farmers. Key IoT applications in aquaculture include water quality monitoring, fish tracking, and automated feeding systems. However, challenges such as data volume and energy-efficient data transmission remain. The future holds promise for further advancements in IoT and AI integration to enhance decision-making and sustainable aquaculture production.

1. Introduction

In addition to conventional farming, aquaculture the food industry with the greatest growth rate plays a vital role as a complementary activity, offering farmers chances for income diversification and social and economic benefits. Several criteria, including environmental conditions, production factors like water quality, and biotic factors, must be continuously checked to avoid yield losses and boost efficiency. Precision aquaculture employs cutting-edge technologies, including artificial intelligence (AI) and the Internet of Things (IoT), to ensure profitability, sustainability, and environmental protection. IoT solutions used in aquaculture often use a local server and save the enormous amount of generated data in an Excel file or a database. It's conceivable to argue that aquaculture has reached the digitalization phase due to the Internet of Things (IoT) ability to provide real-time monitoring solutions remotely and with little or no human intervention (Fig. 1).

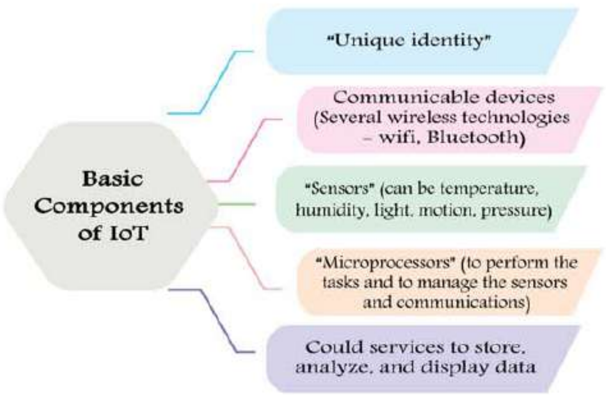

Fig. 1. Various components of Internet of things

The network of physical objects is known as the Internet of Things (IoT). Its rapid growth set it apart from the present Internet, which is mostly a network of computers, including mobile devices like phones and tablets. People, animals, plants, household appliances, machinery, products, buildings, and cars can all be considered "things" in the IoT. All physical devices are connected through the Internet of Things (IoT) and can exchange data without the need for human interaction. Remote access and control are both possible for them. This has completely transformed our lives, a truly revolutionary concept. Linking several devices is not a novel idea. The first gadget connected to the Internet was a Coke machine at Carnegie Mellon University in 1982. British businessman Kevin Ashton coined the phrase "Internet of Things" in a 1999 presentation to Procter & Gamble. Radio-frequency identification, or RFID, formed the foundation for the Internet of Things. Due to the combination of numerous supporting technologies, such as embedded systems, wireless communications, microcontrollers, sensors, and micro-electromechanical systems (MEMS), subsequently evolved and gained popularity. The Internet of Things is currently viewed as the future and the next big thing. IoT will spread exponentially in the same way that the Internet did about 20 years ago.

IoT is employed in the aquaculture industry for various purposes, including environmental monitoring, animal tracking, industrial management, precision agriculture, and other areas. A significant amount of data has been gathered using automated controllable systems and networked sensors. This optimizes productivity. Additionally, the productivity of fisheries is increased by reliable data from the Internet of Things, particularly in complex and risky routine activities. Many relevant new technologies are also used to support several sensors and cover a broad region, such as low-power, long-distance wireless communication. These data-driven strategies improve aquaculture operations' effectiveness, sustainability, and productivity.

Farmers gauge the overall quality of the water using time-consuming, outdated procedures. Farmers can't act quickly enough to stop the fish from worsening since they don't get enough alerts. To achieve this goal, efforts have been undertaken to design the architecture of an IoT framework that will assist aquaculture farms in determining the water quality and inform the farmers to take the necessary steps to prevent losses due to fish mortality.

However, there are still a lot of difficulties in aquaculture that need to be resolved. One of the key issues that precision aquaculture could solve is maximizing the yield through effective resource use. This article mainly highlights the importance of IOT in aquaculture, its basic components, workflows, major applications and the various constraints while developing it in fisheries sectors.

2. Importance

Commercial aquaculture is facing several difficulties due to sudden changes in climatic conditions that affect the criteria governing water quality. Aqua farmers currently employ manual check procedures to determine the water's parameters. This will take longer and be inaccurate because water quality parameters may change over time. Aquaculture should innovate to increase potency and reduce losses by monitoring water quality parameters to prevent this drawback. Secondly, the major importance and achievement of IOT in aquaculture is Automated Feeder. Correct feeding is vital at a scheduled period, and aqua-farmers still do this by hand. Therefore, the invention of automated feeding equipment has proven to be a gift for farmers because it eliminates the need for human labour and lessens the problems associated with overfeeding and other issues, for which overfeeding is the primary reason.

IoT-based solutions enable monitoring and adjusting water parameters in real-time, boosting accuracy, prompt notifications, and optimizing aquaculture production. IoT in aquaculture enables accurate feeding methods and enhances feed efficiency. Precision feeding schedules and portion control can be achieved by integrating IoT technologies with feed automation systems, decreasing feed waste and optimizing growth rates. Fish movements, behaviour, and growth can be tracked and analyzed using cutting-edge tracking technology like RFID or acoustic tags, providing a greater understanding of fish health, population dynamics, and stocking density optimization.

3. Workflow

The size of the water bodies (ponds, reservoirs, tanks, etc.) will determine the number of monitoring nodes to be deployed. These sensor nodes continuously detect and record water parameters such as pH, temperature, and dissolved oxygen, which impact the fish's life and are key parameters as they directly impact aquatic animals' health, growth, and carrying capacities. These multiple wireless sensor nodes are deployed in a fishing pond. These sensor nodes gather information on important factors influencing fish health and pond conditions. These sensor nodes wirelessly transfer their data to an edge node, a regional hub for communication and processing. The data is subsequently transmitted from the edge node to the cloud platforms through the Internet for storage and analysis (**Fig. 2**).

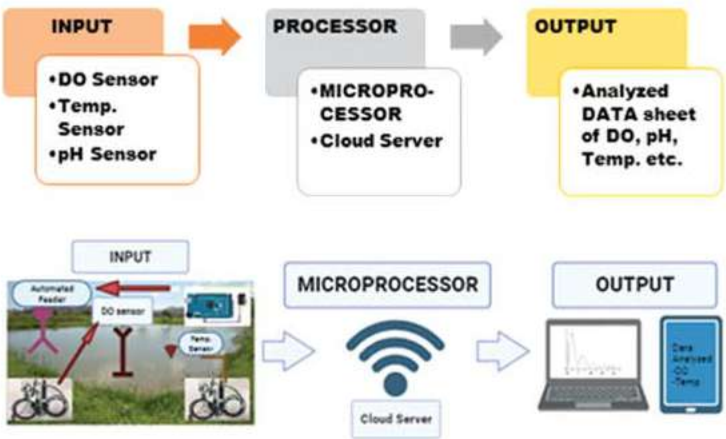

Fig. 2. Workflow of IOT in Fisheries Ponds

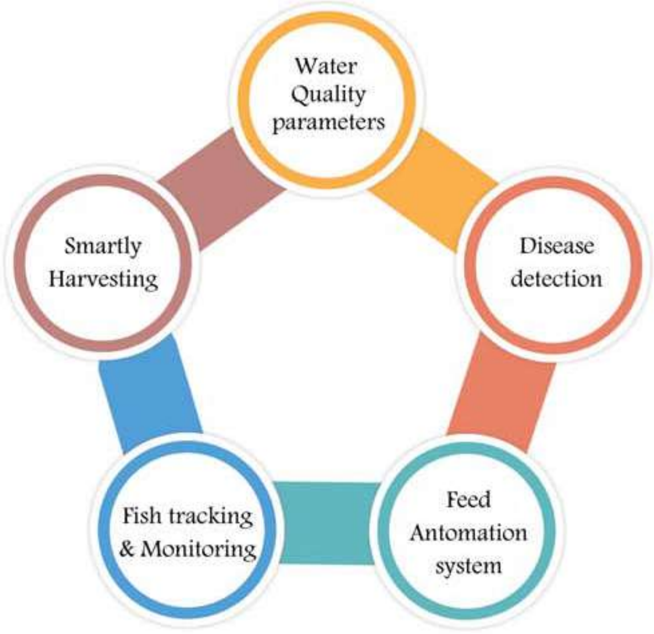

Fig. 3. Applications of IOT in Aquaculture

This cloud platform service enables them to easily aggregate, visualize, and analyze live data streams. An SMS alert is sent to the farm manager if any parameters cross the threshold value. The main three basic pathways are- Input, Microcontrollers and Output. Sensor nodes deployed in the water bodies will act as Input components. The various cloud platforms used are the microprocessor, and as an Output, water parameters data will be displayed on the connected device's screen via SMS or emails. 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. Based on the alert, steps will be taken to boost productivity and lessen the effects of fish loss. The user is automatically notified through email and text messages when a parameter surpasses a specific critical value for the farm. This system enables speedy response by initiating a problem-solving action.

4. Applications of IoT in aquaculture

The Internet of Things (IoT) is essential to aquaculture because it makes it possible to monitor water quality, fish health, and environmental factors in fish farms in real time (**Fig. 3**). IoT technologies optimize aquaculture operations by utilizing sensors, connectivity, and data analytics, boosting productivity and reducing disease risks. IoT enables the sector to adopt sustainable and effective practices, assuring the welfare of aquatic animals and the long-term survival of aquaculture systems. These capabilities include automation, remote control, and intelligent decision-making. Fish farming has seen improved operational effectiveness, optimized resource utilization, and better yields thanks to IoT integration, which has turned the sector into a more sustainable and lucrative business.

Aqua farmers use manual measurements to evaluate the state of the water's various parameters. Manual measurements take a long time and produce inaccurate findings since the factors that gauge water quality constantly change. Therefore, if automatic monitoring is possible, it will be better. Aquaculture uses cutting-edge technology like the Internet of Things (IoT), Computer Vision, and Machine Learning to overcome the challenge of measuring water parameters.

Better regulation of the many chemical, physical, and biological aspects of the water in fish ponds is unquestionably necessary for achieving maximum fish output. Therefore, for effective fish pond management, it is important to understand the water quality, which is controlled by several factors, including temperature, turbidity, water colour, pH, carbon dioxide, alkalinity, electrical conductivity, total dissolved solids (TDS), unionized ammonia, nitrate, and nitrite. Users can use an Android app from anywhere worldwide to monitor the water quality utilizing Wi-Fi and the Internet.

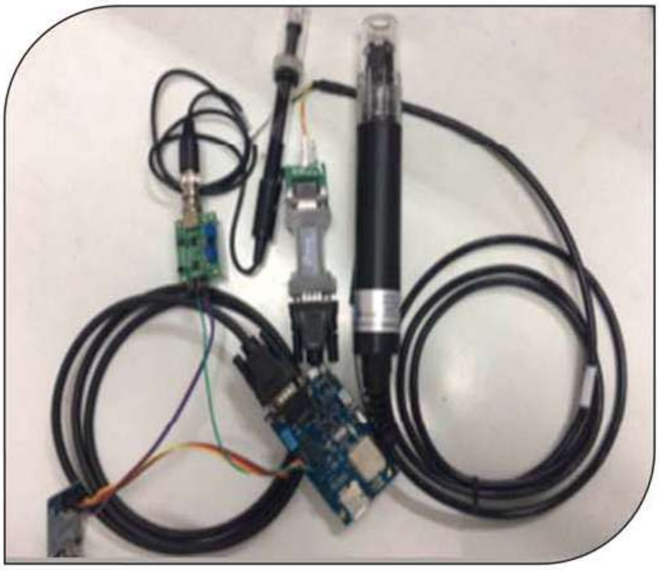

Fig. 4. Sensor measuring DO, Temperature & pH (Courtesy : Huan et al., 2020)

Due to a lack of provenance and quality monitoring data, it is challenging to assess fish quality in practice accurately. Real-time and objective quality tracking with the newest Internet of Things (IoT) and Artificial Intelligence (AI) technologies may be possible. Recent advancements in embedded devices and sensor technology can offer a variety of views with previously unheard-of levels of information in the temporal, spatial, temperature, smell, and other environmental domains.

Fig. 5. IoT device under a coin (Courtesy: Wang et al., 2021)

IoT and AI technology made automated quality assessment and tracking possible. Small, water-resistant, and having a long battery life, IoT devices are. They are fastened to the containers fishermen use to transport and store fish across the state. Every IoT device has a Global Positioning System (GPS) sensor to track the box. Additionally, it is connected to an external temperature sensor, allowing Internet of Things devices to sense the temperature of the fish rather than the onboard temperature (**Fig. 4-6**).

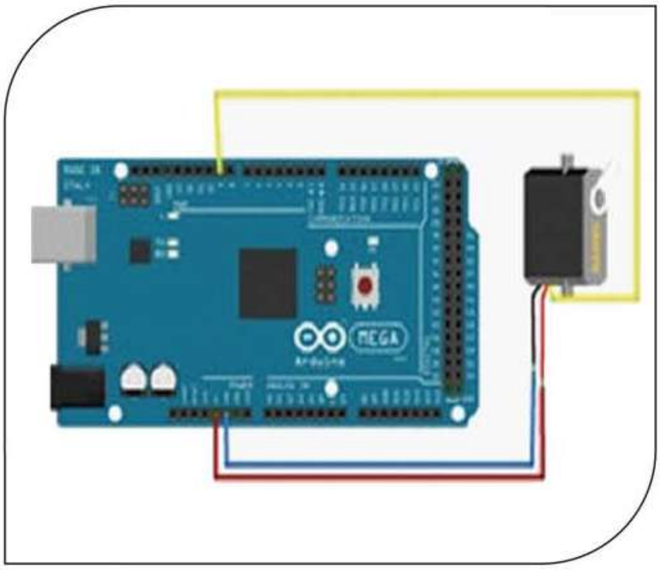

Fig. 6. The automation circuits of fish feeding systems
(Courtesy : Riansyah et al., 2020)

Even though fish must be fed on time, there are instances when this presents a problem while the owner is away from the fish pond. Furthermore, excessive feeding will make the feed deteriorate. The feed dose needs to be precise. The fish-feeding system in a mini aquarium is controlled online via a website, and the automatic fish-feeding system is through the Android application **(Table 1)**.

Table 1: IOTs in various Aquaculture Systems

S.No.	Aquaculture System	Parameters checked	Microprocessors	References
1.	Aquaponics System	pH, Temp., Turbidity, NH_3, NO_3^{2-}	Arduino	Udanor *et al.* (2022)
2.	Hydroponics with Aquaculture sytem	Temp., pH & Humidity	Arduino	Tamana *et al.* (2021)
3.	Recirculating Aquaculture System	Temp. & Water-level	Raspberry Pi	Al-Hussaini etal. (2018)
4.	Biofloc Technology	Temp., pH, DO & TDS	Arduino UNO	Rashid *et al.* (2022)

5. Major constraints

Requires more variables than we can currently monitor to obtain the most complete picture of what is happening in farms. Creating new probes to measure microbes, micropollutants, or other physicochemical properties makes this a technological challenge.

The capacity to transport a significant volume of data from the farm using the least amount of energy is another significant barrier to the IoT revolution in this industry. By examining their behaviour, activity, and potential diseases directly underwater, developing real-time monitoring using high-quality HD video feeds to enable deep image processing would create new prospects for livestock surveys. Additionally, it will be possible to scan the microenvironment, such as the weather or local activity, to stop poaching.

6. Conclusions and future perspectives

We now can create cutting-edge solutions that make life easier thanks to the Internet of Things (IoT), which has evolved into a highly adaptable solution for several use cases, from smart cities to the smart aqua farming business. IoT and cloud technology development has opened up new avenues for developing innovative farming techniques. To improve sustainability, this study focuses on disease control and water quality monitoring to examine the possible effects of IoT in aquaculture. It covers a variety of IoT applications in aquaculture, such as fish tracking and monitoring systems, feed automation systems, environmental control systems, and water quality monitoring.

Integrating AI and machine learning, developing sensors, and expanding IoT infrastructure are the future directions for wise decision-making, predictive analytics, and sustainable aquaculture production.

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