DIGITALIZATION AS INNOVATIVE DEVELOPMENT IN AQUACULTURE AND FISHERIES AS FUTURE IMPORTANCE

Abstract

Improving the livelihoods of fishermen, increasing industry sustainability, and economic growth are all possible outcomes of the digitalization of fisheries in India. Yet, it is crucial to ensure that all stakeholders, especially small-scale fishermen and fish farms, have access to and can afford these digital tools. By enhancing productivity, sustainability, and profitability while minimizing environmental effects, artificial intelligence has the potential to revolutionize fisheries and aquaculture. We may anticipate even more cutting-edge applications of artificial intelligence in the fisheries and aquaculture industries as these technologies develop and become more widely available. GIS and GPS have developed into helpful tools for fisheries management, helping to offer important information regarding fish populations, fishing activities, and oceanographic conditions. The creation of efficient management strategies, preservation of fish habitats, and upkeep of sustainable fishing methods all use this data.

Keywords: Digital technology, Artificial Intelligence, Fisheries and Aquaculture

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I. INTRODUCTION

The aquaculture and fish industries have undergone a revolution owing to digital technology, which has made it possible to monitor, manage, and optimize production with new technologies, providing new research and information to farmers. These technologies include a combination of hardware and software tools, including sensors, drones, machine learning techniques, and data analytics platforms. Real-time monitoring and management of manufacturing procedures are among the most important advantages of digital technology in fisheries and aquaculture. The sensors found in drones can also be used to survey fish stocks, monitor the health of fish populations, control feeding, and measure water quality[1] (Morgan *et. al.,* 2020), oxygen levels, temperature, and other environmental factors. In addition, the invention of new aquaculture production techniques has become possible using digital technology. Recirculating aquaculture systems (RAS), for instance, are land-based systems that use digital management systems to maintain ideal water quality for fish growth. Data analytics platforms and machine learning algorithms can be employed to analyze the vast amounts of data gathered from sensors and other sources. This can aid fish producers by increasing productivity, decreasing waste, and increasing profitability. For instance, data analytics can be used to forecast fish growth rates and determine the optimal time to harvest fish, thereby increasing yield and revenue. IoT is used by approximately 50 billion electronic devices today, many of which are AI powered[2,3] (Pauly *et. al.,* 2002; Mohale *et. al.,* 2024). The goal of the computer science field of artificial intelligence (AI) is to develop intelligent machines that can emulate human cognitive abilities, such as perception, reasoning, learning, and problem-solving. AI has been increasingly employed in a variety of industries, including aquaculture and fisheries, which are essential industries that support millions of people worldwide by providing food, jobs, and financial advantages. However, these sectors face several difficulties, including overfishing, environmental damage, disease outbreaks, and climate change. Several of these issues can be solved with AI, which will also increase fishery and aquaculture productivity, sustainability and profitability.

II. DIGITALIZATION OF FISHERIES IN INDIA

The development of digital technology in India is progressing rapidly and is being used in fisheries and aquaculture. The adoption of digital technologies in fisheries has led to significant changes in fish cultivation and catching practices. The primary benefits of digitizing fisheries include improved time efficiency, reduced costs, and increased labor productivity[4] (Pratiwy *et. al.,* 2022). The Indian government launched several initiatives to encourage the use of digital technologies in fisheries and aquaculture. Encouraging sustainable fishing methods and increasing the livelihoods of fishermen will assist in enhancing the production and efficiency of fisheries and aquaculture in India. Some difficulties need to be resolved, such as handling data privacy and security concerns and ensuring that the advantages of digitization are felt by all stakeholders, especially small-scale fishers and the women's industry. Tables 1, 2, and 3 show examples of the digitalization of fisheries and aquaculture. One of the key initiatives is the e-PashuHaat portal[5](Faslu and Kumar 2021), which was established by the Department of Animal Husbandry, Dairy and Fisheries (DAHDF) in collaboration with the National Dairy Development Board (NDDB). Another major initiative is the Matsya setu developed by the NFDB, Fisheries Information System (FIS), which was started by the Government of India[6] (Bhanja *et. al.,* 2023) and many fisheries researchers, to provide information to fish farmers on different aspects of educational fish farming, such as the availability of allows fish farmers to communicate with one another and exchange knowledge and experiences. Fish landings also offer tools for fish farms to manage their inventory, obtain real-time price information, and keep track of sales. The government has also built fish seed banks and fish feed factories that employ digital technology to increase production and distribution efficiency. Shri Parshottam Rupala to Launch the 'Report Fish Disease' App. Developed by ICAR - National Bureau of Fish Genetic Resources (ICAR-NBFGR) under the National Surveillance Programme for Aquatic Animal Disease.

III. DIGITAL TECHNOLOGY IMPLEMENTATION IN THE FISHERIES AND AQUACULTURE

To boost fisheries industry productivity, long-term sustainability, Profitability, digital technology and computorial software and hardware are being used more and more frequently in areas like fish stock assessment, electronic monitoring (EM), precision fishing, supply chain management, GPS and GIS tracking, online marketplaces, aquaculture management, and artificial intelligence, which includes robotics, drone technology, remotely operated vehicles (ROVs), automated identification systems, etc., Table No. 1 shows that Some examples of digital technology.

Sr. No.	Digital Technology	Application
1.	Robotics	Address complicated tasks and laborious work, such as cleaning ponds and repairing damaged nets.
		Monitoring behaviours, removing diseased fish, feeding.
		Injecting vaccines.
		Water inspections of nets, evaluating fish health and escapes.
2.	Drones	Monitor fish farms above and below water.
		Check holes in damaged cages.
		Data collection combining AI and cloud computing to improve aquaculture operations.
3.	Sensors/Remote Sensing	Collecting water parameters in real-time.
		Underwater sensors to monitor hunger levels of fish in ponds and cages.
		Fish metabolism and heart rates.
		Reduced wastage and improved feed rates.
4.	AI	Makes better and faster decisions.
		less labor intensive.
		Improved efficacy of feeders, water quality monitoring and control, harvesting and processing.
5.	Augmented Reality (AR)	Real-time simulation of environmental situations using digital interface (headsets).
		Teaching, training and education.
		Used for high-risk environments (remote) using human computers and multimedia platforms.
6.	3D Printing	Printing hydroponic systems.
		3D verification devices.

		3D printed water sensors for monitoring water parameters.
		Reduced equipment and production costs.
		Connect big data across the aquaculture industry.
		Combined use of social media.
7.	Blockchain	Cybersecurity, safe data sharing.
		Payment processing.
		Industry protection.
		Full traceability across the value chain.
		Reduce food wastage and improve food safety.

Source[7]: Rowan, N.J., 2023

IV. CYBERSECURITY INFORMATION TECHNOLOGY (IT) SECURITY

Protection of sensitive data and important systems against cyberattacks is known as cybersecurity or information technology (IT) security. The cybersecurity code function safeguards gadgets (smartphones, laptops, and tables) and is how both individuals and organizations lower the chance of a cyberattack[7] (Rowan, N.J., 2023)

V. CYBER-PHYSICAL SYSTEMS

Cyber-physical systems are those in which hardware and software are smoothly integrated to perform predetermined functions.

VI. APPLICATION OF GIS, GPS IN FISHERIES AND AQUACULTURE

A precise global radio navigation system, the Global Positioning System (GPS), is currently in use. A satellite-based navigation system called the Global Positioning System (GPS) may pinpoint an object's precise position or placement on the Earth's surface. Aquatic research and limnology have included GPS and satellite remote sensing, which are gradually becoming recognized as significant sources for data collection[8] (Alum - Udensi, *et. al.,* 2016). Global Positioning Systems (GPS) and Geospatial Information Systems (GIS) are crucial tools for managing, researching, and planning fisheries, including mapping fishing grounds, tracing fish movement, observing fishing activities, and conserving and protecting fish populations. Owing to its ability to handle massive spatial datasets quickly and accurately, GIS has several advantages over traditional methods[9,10]. ((Isaak, D.J. and Hubert, W.A., 1997; Verma *et. al.,* 2023).

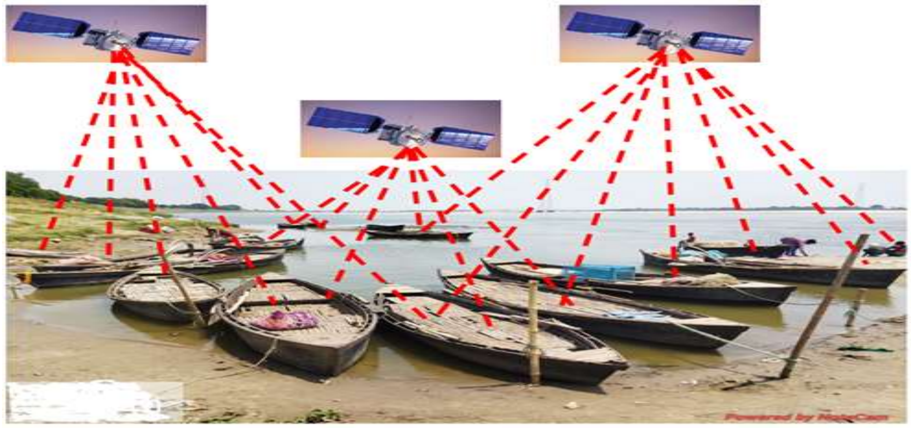

Figure 1: GIS and GPS Satellite

VII. VIRTUAL REALITY

What we refer to as "Fish Tank Virtual Reality" is characterized by a stereo picture of a three-dimensional (3D) scene shown on a monitor, employing a projection connected to the observer's head position[11] (Ware, C. *et. al.,* 1993). When a person uses specialized electronic devices, such as a helmet with a screen inside or gloves connected to sensors, they can interact with a computer-generated model of a 3D image or environment in a way that appears real or tactile.

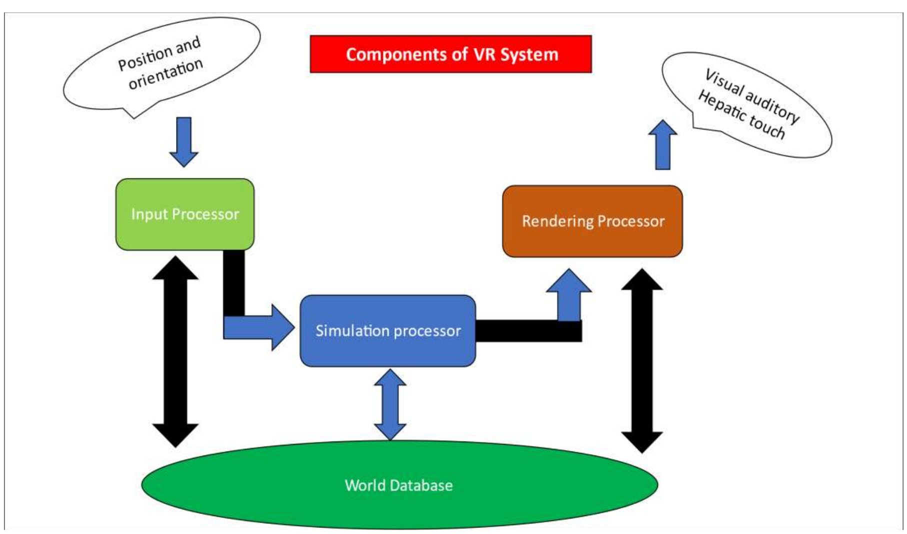

Figure 2: Component of VR system

VIII. SMARTPHONE APPLICATIONS IN AQUACULTURE AND FISHING

Mobile applications can be beneficial in fisheries and aquaculture. These are examples of how mobile apps might be helpful, such as monitoring weather, managing feed, tracking diseases, managing harvests, and monitoring water quality[12] (Calderwood, J. 2022). Many types of phone apps used in fisheries and aquaculture

1. Application of Mobile apps in fish angling such as Fishing Lures, Fishing Spots - Angling Map, iFishIllinois, IGFA mobile, NPS - Fishing App, Pro angler, Fishing Knots Lite, Knot Wars, Knots 3D, My Fishing Advisor, Fishing & Hunting Solunar Time, Fishing My-Cast, Trimble GPS Fish Free, NZ Fishing Rules, Fish Anglers, Fish Washington, Fish Legal, Fish Smart app,
2. Application of Mobile App in Aquaculture such as Aqua app, Aquabrahma, Aqua deals, Aquaimate, Aqua Plant, Aqua Reef, Aquatic Log, Fish Advice, m Fish, m-KRISHI Aqua Service, Pescare, Pondcalc, Source Trace ESE™ Aqua solution, Texas Farm Pond Management Calenda, Vanamei shrimpapp, Aquall App, Fish Disease advisory, Fish Names, Ind Aqua, Aquatic Disease Field Guide app,
3. Application of mobile app for aquarium management such as Ammonia Calc, Apex Fusion, aquaPlanner, Aqua Planner Pro, Aquaria Pro, Aquarimate, Coral Tank Pro, Reef Tank, The Fish Room, Aquarium Note.
4. Application of mobile app in marine fisheries such as Blue Chart Mobile, Boating US, Deeper, Drop hook, eObS, First Mate, Fish Brain, Fish finder, Fish Hunter, Fish rules, Fish track, Fish Alerts, Fisher Friend Mobile Application (FFMA), Fishidy, Fishing Calendar, Fishing Deluxe, Fishing Knots Lite, Fishing Log, Fishing Points GPS Navigation, Fishing Times, Fishing Times Pro, Fishing Weather, Fishing & Hunting Solunar Time, Go free hooked, IFISH, iNavX, Isolunar, Knot guide, Marines Tide Planner, Minute cast, mKrishi@Fisheries, mkrishi@aqua, My Fishing Advisor, Net fish, On Board, Pacific islands fisheries forum agency, Plan2Nav, Potential Fishing Zone Advisory (PFZA), Precision Trolling, Regional Information Management Facility (RIMF), Sagar Vani, SONA. r Ball, Su FishIn T, Tail, WISE, Chile es Mar, SOpHIE (The Surface Ocean pH Interactive Explorer), Fish Landing App, Fishency, Time Zero, GRI Bview, ISD App, Infish, INCOIS, SARAT (Search and Rescue Aid Tool), Sagara, Pac Fish ID, Odaku, Fish Locator, Navisea, Sea Status Marine Weather etc

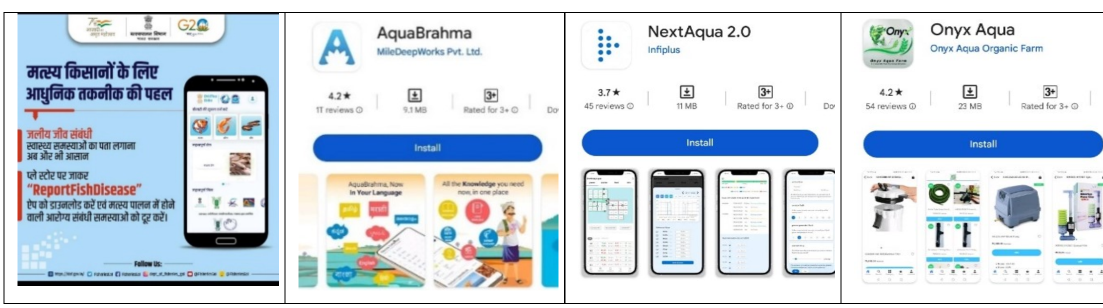

Figure 3: Mobile Application use in aquaculture

IX. QUALITY OF EXPERIENCE (QoE)

Quality of Experience (QoE) is the level of enjoyment or irritation experienced when using a product or service.

X. USE OF ARTIFICIAL INTELLIGENCE (AI) IN FISHERIES AND AQUACULTURE

Artificial intelligence (AI) has the potential to revolutionize the inland water fisheries sector in numerous ways. Artificial intelligence (AI) is used in Fish Population Management, Fish stock assessment, fishing gear optimization, water quality management, fish identification, aquatic ecosystem monitoring, fish detection and classification, feed optimization, disease detection and diagnosis, aquatic weed detection and control, and intelligent solutions for aquaculture and fisheries. We anticipate that more ground-breaking ideas will emerge to assist these industries in becoming more efficient and sustainable as technology develops[13] (Jothiswaran, V. 2022). Examples of AI are listed in Table 2.

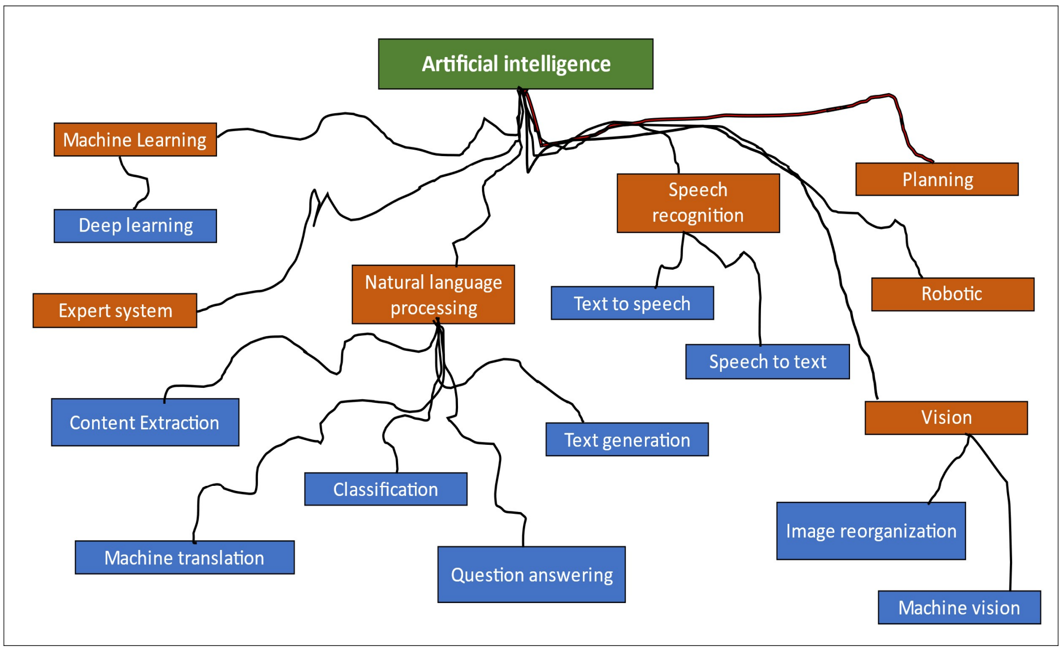

Figure 4: Application of Artificial Intelligence

Table 2: Examples of Commercially Available Intelligent Solutions for Aquaculture and fish processing.

Sr. No.	Application	Developer/Products	Country	Weblink
1	Monitoring and control of feeding rate	Observe Technologies	United Kingdom	https://observe.tech
		eFishery- Feeder	Indonesia	https://efishery.com
		Umitron-CELL, FAI &EAGLE	Japan, Singapore	https://umitron.com
		AQ1feedingsystems	Australia	http://www.aq1systems.com
		Eruvaka-Pond Mother	India	https://eruvaka.com
2.	Monitoring	Real Tech-LiquidAi	Canada	https://realtechwater.com

	and control of water quality	Aqua Manager	Greece	https://www.aqua-manager.com/
		Osmo Systems-Osmobot	USA	-
		Siemens - SIMATIC S7–1500 and Totally Integrated Automation Portal	Germany	https://new.siemens.com
		Smart Water Planet-Medusa and Cloud	Spain	https://smartwaterplanet.com
		ShanghaiYuXi Automation Technology	China	http://www.yuxiel.com/
		Eruvaka- Pond Guard	India	https://eruvaka.com
3.	Monitoring of fish biomass and growth rate (including counting and sorting)	XpertSea- Xpercount	Canada	https://www.xpertsea.com/
		VAKI-Bioscanner, Smart Flow and Cloud	Iceland	https://vakiiceland.is
		Innova Sea- Sea Station	USA	https://www.innovasea.com/
		Aquabyte	Norway	https://www.aquabyte.ai/
		Aqua Scan	Norway	https://www.aquascan.com/
		SkalaMaskon-AGM fish egg sorter	Norway	www.skalamaskon.no
4.	Monitoring and forecasting disease outbreak	AquaCloud	Norway	https://aquacloud.ai
		BioSort - iFarm	Norway	https://www.biosort.no/
		IPI-IREF system	Singapore	https://www.ipi-singapore.org/
		Aquaconnect-FarmMOJO	India	https://aquaconnect.blue
		4-Deep-Holographicmicroscopes	Canada	http://4-deep.com/
5.	Monitoring and forecasting disease outbreak	CageEye	Norway	https://www.cageeye.com/
		View Point Behavior Technology	France	http://www.viewpoint.fr/
		ZebraZoom	France	https://zebrazoom.org
		idTracker	Spain	http://www.idtracker.es/
6.	Farm activity tracking and production planning	AKVA group-AKVA connect & Fishtalk	Norway	https://www.akvagroup.com/
		Scale Aquaculture AS-Mercatus	Norway	https://scaleaq.com
		Poseidon AI	Singapore	https://www.poseidon-ai.com/
		Kamahu-SaaS	France	https://www.kamahu.com/

		solution		
7.	Automation of fish processing systems	Marel - FleXicut, FleXisort and RoboBatcher	Iceland	https://marel.com
		Skaginn3x	Iceland	https://www.skaginn3x.com
Source[14] : Gladju, *et. al.,* 2022				

XI. BIG DATA

Big data represents an ongoing growth in data and technologies that require collection, storage, management, and analysis. Complex and multifunctional procedures and technologies. Volume (number of datasets), velocity (rate at which data is processed), variety (data sources/types), and reliability (analyzed data quality)[7] (Rowan, N.J., 2023).

XII. APPLICATION OF DRONE TECHNOLOGY IN FISHERIES AND AQUACULTURE

Unmanned aerial vehicles/systems, known as drones, deliver near-real-time data on the people, processes, and landscapes they examine using radio frequencies and pre-programmed GPS-guided flight scripts[15] (Toonen, & Bush, 2020). Fisheries and aquaculture applications of drone technology include stock assessment, illegal fishing monitoring, search and rescue, fish population monitoring, environmental data collection, fish behavior monitoring, surveillance, mapping and surveying, and product delivery[16] (Andronova *et. al.,* 2019).

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Figure 5: Drone Carma

1. **Blockchain:** Blockchain is a decentralized, unchangeable database that makes it easier to track assets in a corporate network and to record asset transitions using cryptographic techniques. Blockchain protocols collect, verify, and transmit transactions over a blockchain network. The transactions were recorded sequentially using blockchain technology. Value exchange or activation of a smart contract can be included in a transaction[17] (Zhang, Hanwen, and Fukun Gui. 2023).

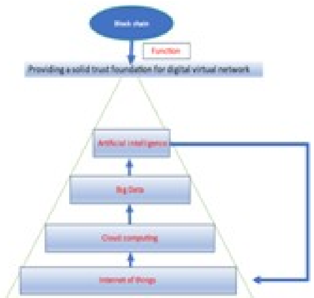

Figure 6: Application of blockchain

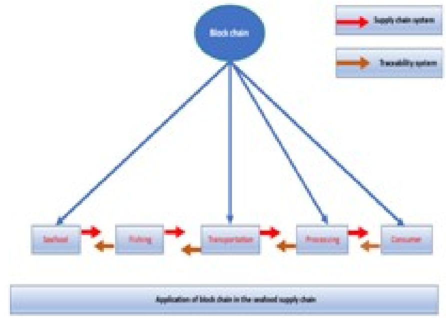

Figure 7: Application of blockchain in the seafood supply chain

Source[17]: Zhang and Fukun 2023

XIII. APPLICATION OF REMOTE SENSING IN FISHERIES

Remote sensing plays a crucial role in fisheries by providing valuable information regarding the ocean environment, fish stocks, and fishing activities. Remote sensing plays a significant role in fisheries by providing timely and spatially extensive data on the oceanographic conditions, fish stocks, fishing activities, and habitat characteristics. These applications help improve efficiency, sustainability, environmental indicators of fish distribution[18] (Klemas V., 2013), fishing ground properties, measuring ocean temperature, measuring turbidity, oil pollution detection, acoustic sensing of fish schools, and management of fisheries resources.

XIV. USE OF ROBOTIC TECHNOLOGY IN FISHERIES

Robotic technology has the potential to completely transform the aquaculture and fishing sectors, enhancing their productivity, sustainability, and profitability. Some examples of current robotic applications in fisheries and aquaculture include automated fish feeders, fish processing and packaging, aquatic weed removal, environmental monitoring, autonomous underwater vehicles (AUVs), fish tracking and monitoring systems, fish transportation, and fish harvesting. Therefore, Robofish and other biomimetic robots are beneficial for studying public receptiveness in guppies and possibly other small fish species[19] (Bierbach, D., *et. al.,* 2018).

XV. DIGITAL TWIN

Electronic and digital twins, a virtual model created to faithfully represent a real object, are called digital twins. To track fish eating behaviour, illness, and growth, the system combines artificial intelligence (AI)-based Internet of Things (IoT) technology, cloud-based digital twins, machine learning, and computer vision capabilities[20] (Lan H. *et. al.,* 2003.

Figure 8: Digital twine

Machine Learning (ML): Machine learning (ML), a subset of artificial intelligence, is the application and development of systems of computers that adapt and learn without following specific instructions by analysing data patterns and making conclusions from them applying algorithms and statistical models, by using sensors and machine learning, assess fish quality[21] (Saeed, R. *et. al.,* 2022).

XVI. USE REMOTELY OPERATED VEHICLES (ROVs) IN FISHERIES AND AQUACULTURE

Fish stock evaluation, habitat mapping, aquaculture operations and management, fish behavior studies, and underwater inspection are only a few of the uses of remotely operated vehicles (ROVs) in fisheries and aquaculture. The purpose of an ROV is to promote the safety of people working in underwater environments that are challenging to reach to collect samples for laboratory analysis or to take measurements using a probe. The evaluated characteristics included water pH, dissolved oxygen (DO), nitrates, and dissolved ammonia (nitrate)[22] (Rahim A., 2022).

XVII. CLOUD COMPUTING

The use of software and tools based on a network of servers connected via the Internet, including storage for data, servers, databases, and software, is known as cloud computing. Users can now rent resources for their computers on demand to access all data through the Internet and store files and apps on virtualized servers. Using cloud computing, the water quality in a fishpond can be remotely monitored[23] (Sivakumar, S. and Ramya, V., 2021).

XVIII. EDGE CLOUD

As a supplement to cloud computing, edge computing consists of storage and computation resources that are situated at the edge and connected via portable application-aware networks that can sense and respond safely and instantly to changing needs.

XIX. INTERNET OF THINKS (IoT)

The " Internet of Things (IoT) is a system of connected, intelligent objects and services that can perceive or hear commands and respond by employing actuators. The IoT enables sensor networks to connect remotely to, administer, and watch systems and products. Fisheries Water Quality Monitoring System Using the Internet of Things[24] (Ya'acob, N., *et. al.,* 2021). Sensors have evolved from simple sensing devices to more modern, adaptable, portable, nanoplasmonic, versatile, fatigue-resistant, and outstanding performance-effective sensors in high-volume applications such as the Internet of Things and monitoring systems. and temperature-tolerant sensor devices, respectively. Monitoring fish quality is one of the very few industries in which high-grade innovative sensors are used[21] (Saeed, R., *et. al.,* 2022).

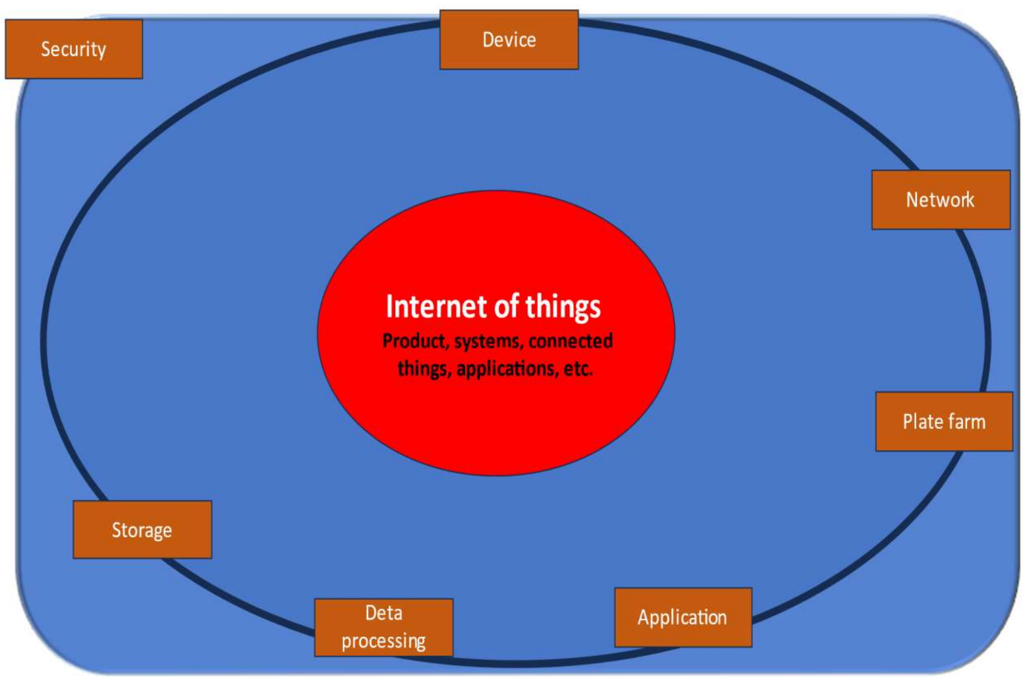

Figure 9: Internet of thinks

XX. USE OF COMPUTATIONAL (DATA MINING AND MACHINE LEARNING) METHODS IN FISHERIES AND AQUACULTURE

Data mining and machine learning techniques can be used to improve productivity, control disease, and promote sustainability in fisheries and aquaculture operations. These methods can reduce the environmental effects of these activities, while increasing their productivity and profitability. Some of the software names are listed in Table 3.

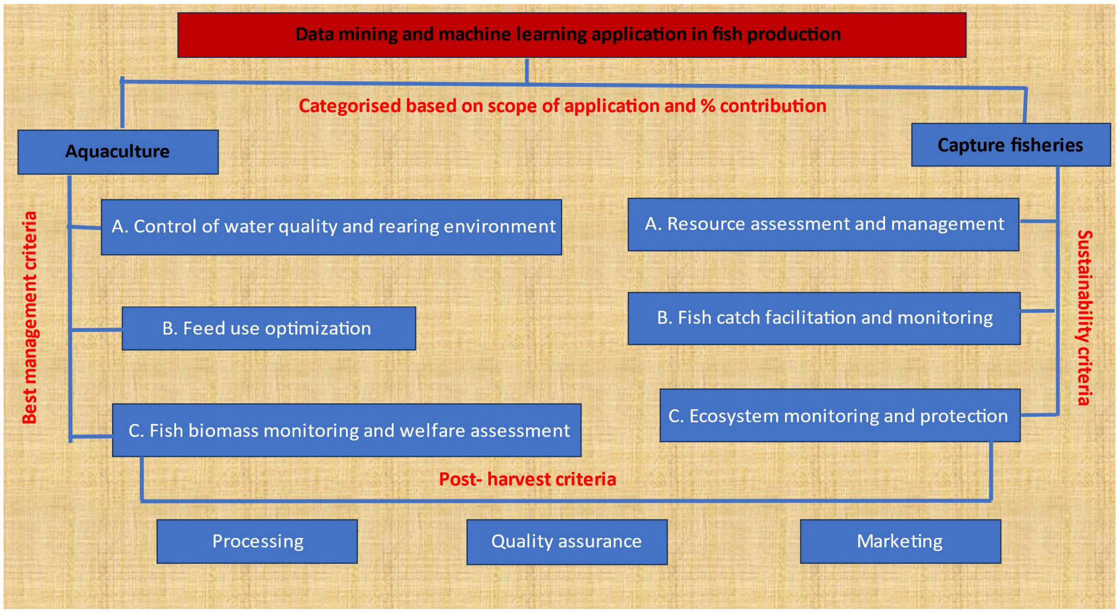

Figure 10: Data mining and machine learning application in fish production
Figure Source[7]

Table 3: Different computational methods (data mining and machine learning) and their applications in aquaculture operations.

Computation method	Application	Domain	
1.	Recirculating intensive aquaculture experts' system (RIAX)	To increase the productivity of tilapia culture, feeding, temperature, water quality, flow, oxygen and water level must be monitored and controlled.	Farm management (RAS)
2.	Fuzzy logic-based expert system	Nitrate removal) rates and preventing the discharge of toxic byproducts in an automated denitrifying bioreactor in recirculating aquaculture systems.	Farm management (RAS)
3.	Fog computing for data acquisition and processing	Water quality and biomass management are monitored and controlled in real-time in recirculating aquaculture systems.	Farm management (RAS)
4.	Artificial neural networks	System for remote online water quality monitoring, forecasting, and management in intensive fish culture.	Farm management (RAS)

5.	Fuzzy logic controller	Using geothermal energy and a plate-type heat exchanger, the recirculating aquaculture system's water temperature is monitored and managed.	Farm management (RAS)
6.	Bond graph technique and air control algorithm	Using wave height and activity to automatically manage the submerging and surfacing of a submerged fish cage system.	Farm management (Cage system)
7.	Fog computing for data acquisition and processing	Detection and remote control of water flow and level in the grow bed of Aquaponics systems.	Farm management (Aquaponics)
8.	Kalman filter algorithm and optimization scheme	Based on water level sensing and prediction, fish farm water pumping is optimized and controlled for effective energy use.	Farm management
9.	Computational fluid dynamics software ANSYSFLUENT and modified DO ecological model	To maintain sufficient oxygen levels in fish ponds and to increase energy savings, diffused aeration control system development and monitoring of dissolved oxygen profiles are necessary.	Farm management (Pond system)
10.	Microcomputer-processor and BASIC program	Automatic for the purpose of maintaining adequate oxygen levels in fish ponds and maximizing energy savings, diffused aeration control systems are being developed and dissolved oxygen profiles are being monitored.	Feed management
11.	Visual sign all processing system and support vector machine based classifier	Monitoring fish feeding operations continuously and automatically in aquaculture tanks.	Feed management
12.	*k*-Nearest neighbor and principal component analysis	classification of fish behavior or condition for better feed usage using an automated feeder and image processing.	Feed management
13.	Adaptive neural-based fuzzy inference system	Using variations in water quality metrics to assess and make feeding decisions.	Feed management

14.	Spectral data processing and computing	Real-time bioreactor monitoring and control of the algal production system's efficiency in terms of nutrient delivery, biomass harvesting timing, light, and temperature.	Live feed production
15.	TDoA algorithm with acoustic telemetry and SLIM-LPWAN	Using telemetry data, real-time monitoring of fish behavior and decision-making in marine fish farms.	Fish behavior and welfare
16.	Adaptive neural-based fuzzy in refence system	fish behavior and decision-making in marine fish farms being tracked in real-time using telemetry data.	Fish behavior and welfare
17.	Kullback- Leibler divergence method	Using inter-individual time series data, we investigate the cause-and-effect dynamics of social learning and foraging behavior in fish.	Fish behavior and welfare
18.	AEFishBITtri-axial accelerometer and Cosinor analysis	For accurate phenotyping of farmed fish and the selection of more productive farmed fish, monitoring and connecting locomotor activity and respiratory frequency with body weight is necessary.	Fish behavior and welfare
19.	Multi-layer perceptron neural network and support vector machine models	Using visual machine technology, an intelligent system can distinguish between live and dead rainbow trout eggs.	Hatchery operation
20.	Support vector machine with radial based kernel	Using nutritional effects to categorize farmed rainbow trout non-intrusively.	Fish nutrition/product quality
Source[14] Gladju, *et. al.,*2022			

XXI. INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

The advantages of ICT for groups such as farmers, rural communities, urban communities, students, teachers, and businessmen have been the subject of a plethora of prior studies, but there has been very little research on how ICT can help the aquaculture, fishing sector, and fishermen[25] (Omar, 2011). Collection, retention, retrieval, processing, presentation, display, representation, management, organization, security, transfer, and exchange of information and data.

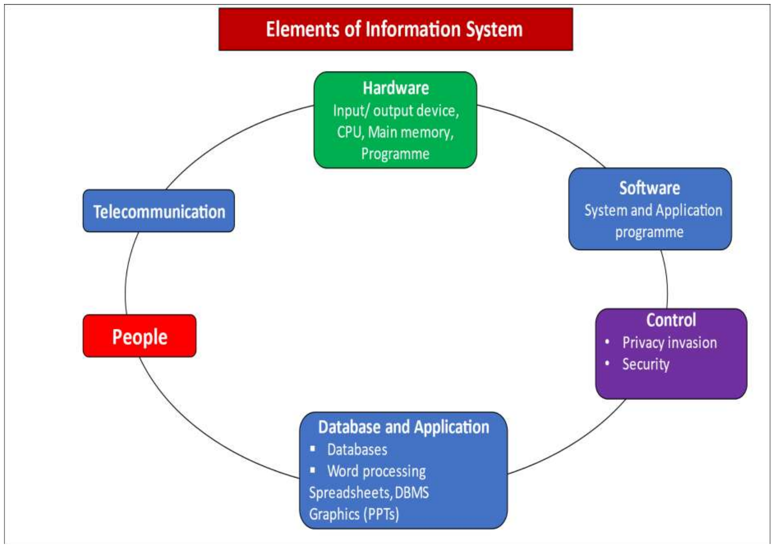

Figure 11: Element of Information System

XXII. AUGMENTED REALITY

A computer-generated image is covered by an operator's revelation of the actual global image using augmented reality technology, creating a composite view.

XXIII. ADVANTAGE OF DEGITALIZATION IN FISHERIES AND AQUACULTURE TO FISH FARMERS

Digitization in fisheries and aquaculture offers fish farmers numerous advantages. The following are some of the key benefits.

1. **Data-Driven Decision-Making:** Digital tools enable fish farmers to collect and analyze data related to water quality, feeding patterns, growth rates, and disease prevalence. These data can be used to make informed decisions, optimize feeding strategies, and adjust farming practices in real-time to improve productivity and profitability.

2. **Precision Farming:** Digital technologies allow for precision in various aspects of aquaculture, such as feeding, water circulation, and temperature control. This precision leads to efficient resource utilization, reduced waste, and improved growth rates.

3. **Remote Monitoring:** Farmers can remotely monitor their aquaculture systems using sensors, cameras, and Internet of Things (IoT) devices. This feature is particularly beneficial for farmers with large or multiple farms, enabling them to keep an eye on their operations, even from a distance.

4. **Early Disease Detection:** Digital tools can assist in the early detection of diseases through continuous monitoring of fish behavior, health parameters, and water conditions. This enables prompt intervention, reduces the risk of disease outbreaks, and minimizes losses.

5. **Environmental Sustainability:** Digitalization helps farmers monitor and manage the environmental impact of their activities more effectively. This includes tracking the water quality, waste management, and energy consumption, thereby supporting more sustainable practices.

6. **Market Access and Marketing:** Online platforms and digital marketplaces connect farmers directly with buyers, potentially expanding market reach and reducing the need for intermediaries. Farmers can also use digital channels to market their products and share farming practices with consumers, thus enhancing transparency and trust.

7. **Data Sharing and Collaboration:** Digital platforms facilitate information-sharing and collaboration among farmers, researchers, and experts. This collective knowledge exchange can lead to innovation and adoption of best practices.

8. **Financial Management:** Digital tools can help farmers manage their finances, track expenses, and estimate returns more accurately. This supports improved financial planning and risk management.

9. **Capacity Building:** Digital training resources, webinars, and online courses can provide farmers with access to valuable knowledge and skills, even in remote areas. This will contribute to continuous learning and professional development.

10. **Traceability and Quality Assurance:** Digital systems can enable the traceability of products from farm to fork, ensuring the safety and quality of seafood products. This is increasingly important for meeting consumer demand and complying with regulations.

11. **Climate Resilience:** Climate-related data such as temperature and weather patterns can be integrated into digital systems. This information helps farmers anticipate and respond to climate-related challenges, thereby minimizing losses due to extreme weather events.

XXIV. DISADVANTAGE OF DIGITALIZATION IN FISHERIES AND AQUACULTURE TO FISH FARMERS

While digitalization can offer several benefits to the fisheries and aquaculture industries, it also brings some disadvantages and challenges to fish farmers. However, there are several potential disadvantages.

1. **Cost of Implementation:** The initial cost of implementing digital technologies may be high. This includes expenses related to purchasing hardware (sensors, monitoring equipment, etc.), software development or subscriptions, and training farm personnel. Small-scale fish farmers, in particular, may find it financially challenging to adopt these technologies.

2. **Technical Skills and Training:** Operating and maintaining digital systems requires a certain level of technical expertise. Fish farmers who are unfamiliar with these technologies may face a learning curve, and training programs may be necessary. This could be an additional cost and time investment for the farmers.

3. **Data Privacy and Security:** Digitalization involves the collection and storage of data, which can include sensitive information about the farm's operations. Ensuring data privacy and protecting against cyber threats are crucial. Without proper cybersecurity measures, farmers may be at risk of data breaches or unauthorized access.

4. **Reliability and Maintenance:** Digital technologies can be prone to technical glitches, software bugs, or hardware malfunctions. If the digital systems used to monitor fish farms break down, farmers can face disruptions in their operations. Regular maintenance and technical support are essential, but can also be resource-intensive.

5. **Dependency on technology:** Overreliance on digital systems can make farmers vulnerable if those systems fail. Traditional farming skills and knowledge can diminish as farmers rely on automated systems. If these technologies fail, farmers may struggle to revert to the traditional methods.

6. **Accessibility and Infrastructure:** Digitalization requires a reliable internet connection and other supporting infrastructure. In rural or remote areas with poor connectivity, fish farmers may not be able to fully benefit from these technologies, creating a digital divide in the industry.

7. **Market Disruption:** As digitalization enhances supply chain efficiency, it may lead to changes in market dynamics. Fish farmers who are unable to adopt these technologies may find it difficult to compete with those who can potentially affect their market access and prices.

8. **Data Overload:** While digital systems can provide a wealth of data, managing and analyzing these data effectively can be overwhelming. Fish farmers may struggle to extract actionable insights from the data, making it challenging to make informed decisions.

XXV. CONCLUSION

Fishing communities, customers, and the environment in India stand to gain significantly from the digitalization of the industry. But there is still a way to go, and more work needs to be done to guarantee that technology is used effectively and fairly to advance equitable and sustainable development. The efficiency and sustainability of fisheries and aquaculture can be increased with the help of artificial intelligence, ensuring a consistent supply of fish for food and other uses. Cobots, or collaborative robots, are intended for direct human–robot interactions in a shared space or where humans and robots are nearby.

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