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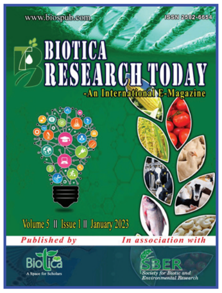

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Innovative and Disruptive Technologies for Aquaculture

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Abstract

The demand for food is growing at a pace with the global population. As the population continues to grow, the pressure on the world's fisheries will continue to increase. The aquaculture industry faces several challenges, including high mortality, disease, feed spill, poor fish welfare, and high water utilization rate. Smart fish farming refers to a new scientific field whose objective is to optimize the efficient use of resources and promote sustainable development in aquaculture through deeply integrating the Internet of Things (IoT), big data, cloud computing, and artificial intelligence. Through Artificial intelligence (AI) fisheries sector can develop rapidly and production can be quadrupled within a short period, making aquaculture a less labor-intensive field. This will help in the tremendous growth of the fisheries sector as the situation of the culture system changes frequently according to the surrounding. Thus, the application of AI seems to be unavoidable in the further development and intensification of fisheries and aquaculture.

Introduction

Global fish production is estimated to have reached about 179 million tonnes in 2018. Aquaculture accounted for 46% of the total production and 52% of fish for human consumption. According to the United Nations, the world population is projected to reach 8.5 billion in 2030, and to increase further to 9.7 billion in 2050 and 11.2 billion by 2100.

Aquaculture has become a field with increasing demand and reduced productivity, where much technological development is still needed to improve farming practices. Artificial Intelligence (AI) devices are available through which we can obtain a better stable environment for the stock. Maintenance of water quality parameters will be much easier as the devices will do the job of both the supervisor and the laborer efficiently. Artificial intelligence-based technology can be a key to achieving higher production with less manpower.

Artificial intelligence is the art of making machines perform activities that otherwise require human intelligence, this is found to have more potential in fisheries and aquaculture. Artificial intelligence began to thrive in the world in the 1950s. Nowadays artificial intelligence is extensively used in aquaculture because most of the time human beings can reach deeper waters and spend long hours researching or analyzing the properties. In aquaculture, using artificial intelligence in the waste management sector is seen to have saved 30% of production costs. 82.1 million tons of aquatic animals were captured and produced in 2020, this great numbers are also due to improved utilization of artificial intelligence. From finding potential fishing zones in mariculture to inspecting feed utilization and growth parameters in cultured fishes, to undergoing research on marking and tagging fishes artificial intelligence has a huge impact and has helped attain great profits. The growing population and in turn the increased demand for nutrition and medicines puts more force on aquaculture day by day, so artificial intelligence can serve as a mastermind behind solving all human issues and creating a healthy and wealthy ecosystem when done with integrity and social concern.

Why AI is Getting Popular?

According to the United Nations, the world population is projected to reach 8.5 billion in 2030, and to increase further to 9.7 billion in 2050 and 11.2 billion by 2100. As the population continues to grow, the pressure on the world's fisheries will continue to increase.

Growing Demand for Healthy Food

In many countries, consumers increasingly demand healthy food from healthy animals. Sustainable production methods, traceability, and animal welfare are becoming competitive factors. The growing demand for healthy food like salmon that provides omega-3 fatty acids requires alternative production methods.

Legal Regulations to Increase Food Safety

- Food safety regulations are putting increasing pressure on producers of animal protein.
- The aquaculture market is projected to grow from USD 30.1 billion in 2018 to USD 42.6 billion by 2023, recording a Compound Annual Growth Rate (CAGR) of 7.2% during the forecast period.
- The precision aquaculture market is estimated to be worth USD 398 million in 2019 and is projected to reach USD 764 million by 2024; it is expected to grow at a CAGR of 14.0% from 2019 to 2024.
- Smart feeding systems are expected to account for a major share of the precision aquaculture farming market by 2024.
- Underwater ROV systems are expected to grow at the highest CAGR during the forecast period.
- The top country in Artificial intelligence adoption is CHINA.

Applications of Deep Learning in Smart Fish Farming

1. Live Fish Identification and Species Classification

Machine vision can enable long-term, non-destructive, noncontact observation at a low cost. Light, noise, and water turbidity easily affect the image quality, resulting in relatively low resolution and contrast. Fish swim freely and are uncontrolled targets, their behaviour may cause distortions, deformations, occlusion, overlapping, and other disadvantageous phenomena. Most current image analysis methods are adversely affected by these difficulties.

Fish are diverse, with more than 33,000 species. In aquaculture, species classification is helpful for yield prediction, production management, and ecosystem monitoring. Fish species can usually be distinguished by visual features such as size, shape, and color (dos Santos and Goncalves, 2019).

2. Size or Biomass Estimation

It is difficult to estimate fish biomass without human intervention because fish are sensitive and move freely within an environment where visibility, lighting, and stability are typically uncontrollable. In smart fish farming, the vision combined with DL can enable a more accurate estimation of fish morphological characteristics such as length, width, weight, and area. For example, the Mask R-CNN architecture was used to estimate the size of blue whiting (*Micromesistius poutassou*), redfish (*Sebastes* spp.), tlantic mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harengus*) (Garcia *et al.*, 2019) and European hake. Another method for indirectly estimating fish size is to first detect the head and tail of fish with a DL model and then calculate the length of the fish on that basis. It is suitable for more complex images. The structural characteristics and computational capabilities of DL models can be fully exploited to achieve superior performances compared with other models. The age structure of a fish school is another important input to fishery assessment models. The current method for determining fish school age structure relies on manual assessments of otolith age, which is a labor-intensive and expertise-dependent process. Using a DL approach, target recognition can instead be performed by using a pertained CNN to estimate fish ages from otolith images. The accuracy is equivalent to that achieved by human experts and considerably faster.

3. Feeding Decision-Making

In intensive aquaculture, the feeding level of fish directly determines the production efficiency and breeding cost. In actual production, the feed cost for some varieties of fish accounts for more than 60% of the total cost. Thus, unreasonable feeding will reduce production efficiency, while insufficient feeding will affect fish growth. Excessive feeding also reduces feed conversion efficiency, and the residual bait will pollute the environment.

Therefore, large economic benefits can be gained by optimizing the feeding process. Many factors affect fish feeding, including physiological, nutritional, environmental, and husbandry factors; consequently, it is difficult to detect the real needs of fish. Traditionally, feeding decisions depend primarily on experience and simple timing controls. By using machine vision, an improved feeding strategy can be developed in accordance with fish behavior. Such a system can terminate the feeding process at more appropriate times, thereby reducing unnecessary labor and improving fish welfare. A combination of CNN and machine vison has proved to be an effective way to assess fish feeding intensity characteristics. Many factors affect fish feeding. In the future, additional data, such as environmental measurements and fish physiological data, will need to be incorporated to achieve more reasonable feeding decisions.

4. Water Quality Prediction

It is essential to be able to predict changes in water quality parameters to identify abnormal phenomena, prevent disease, and reduce the corresponding risks to fish. In real-world aquaculture, the water environment is characterized by many parameters that affect each other, causing considerable inconvenience in the prediction. DL-based models such as a CNN or a deep belief network (DBN) can extract the relationships between quantitative water characteristics and water quality variables. Such models have been used to predict water quality parameters for the intensive culturing of fish or shrimp. The results show that the accuracy and stability of such models are sufficient to meet actual production needs.

Will Robots Farm Our Fish?

The future of fish farming could very well lie in giant, autonomous roaming robotic cages, called aquapods, such as the SeaStation by InnovaSea. While these impressive cages might seem costly when compared to other costs of aquaculture, the technology is likely to prove its efficiencies against stationary fish farms, particularly as demand for protein from fish sources increases. Aquapods or robotic cages are free-floating fish farms with the capacity to hold thousands of fish. When compared to other aquaculture costs, cages might seem to be expensive.

Sensors for Smarter, More Sustainable Aquaculture

Sensors play an essential role in the development of intelligent aquaculture (Su *et al.*, 2020). It is believed that with the development and application of new sensors in all aspects of intelligent aquaculture, field monitoring, remote debugging, remote fault diagnosis, remote data collection, and real-time operation can be realized through IoT, enabling unmanned intelligent aquaculture production. Many of the drones and robots mentioned above use sensors to navigate underwater and collect data such as water pH, salinity, oxygen levels, turbidity, and pollutants. Shrimp farms in India are using Sensorex to monitor dissolved oxygen levels and balance pH to create an ideal atmosphere for improved shrimp efficiencies and yields.

The current way of measuring fish growth involves sampling an adequate number of fish frequently, and this is not only a labor-intensive operation for farmers, but can also cause stress to the fish, sometimes resulting in injuries or even death. The lens utilizes small stereo cameras and artificial intelligence (AI) to automatically measure the fish size in the cages and connects to the Internet to store data in the cloud (Figure 1). In this way, the process of checking fish growth is made much easier for farmers.

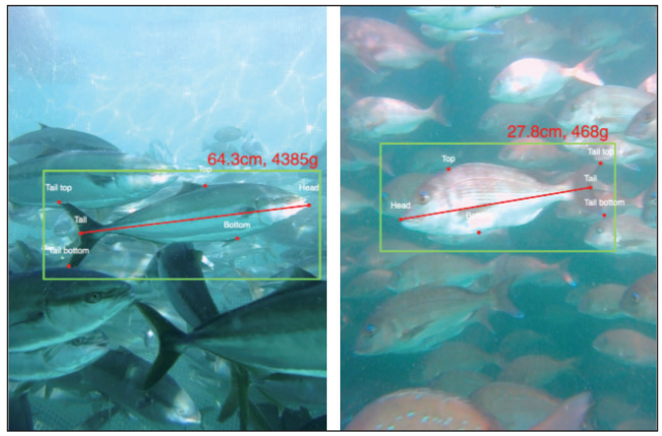

Figure 1: Smart Fish Body Measurement System Called "UMITRON LENS"

AI Feeding Devices

Feeding less can decrease muscle conversion and in extreme cases (in shrimps) it can lead to cannibalism and mutual attack. Excess feeding, on the other hand, will result in feed wastage and depletes the water quality. Feeding represents the biggest cost to fish farmers, so optimization in this area always means better profitability. Pellet dispersal is based on observation or, very often, intuition. Measurement of appetite can help in feeding the right amount of feed at the right time. AI plays a great role in reading fish through vibration-based sensors and acoustic signals. This will help in differentiating a hungry fish from a full one. In an aquaculture system, feed costs nearly 60% of the total cost invested.

The e-Fishery is a fish and shrimp farming integrated feeding solution. This machine can feed the fish automatically, sense the fish's appetite, and regulate the amount of feed supplied according to the fish's appetite (Figure 2). It allows you to control the feeding performance of the fish and shrimp from your smartphone or laptop at any time and from anywhere. It can save up to 21% on feeding costs, increase profits, and make it easier to manage the business remotely as shown in Table 1.

AI in Open Sea Fisheries

Due to increasing population and demand, overfishing and poaching have increased within a short time. Illegal, unregulated, unreported (IUU) fishing has

Figure 2: eFishery sensors device to detect the hunger level of the fish

Table 1: Global competitors in AI feed dispenser technology

Company	Country	Technology	Benefits
eFishery	Indonesia	AI feed dispenser	Reduce the cost of feed by about 21%.
Observe technologies	Indonesia	Feed dispenser	Tracks the feeding pattern of stocks guidance on the quantity of feed that is in need to be fed by the farmers.
Umitron cell	Singapore and Japan	The smart fish feeder can be controlled by a remote	Reducing feeding costs and maintaining water quality.
Eruvaka	India	Appetite-based intelligent feeder	Reduce the cost of feed.

increased to a great extent. Traditionally to stop this, some organizations have hired observers at high cost in order to monitor fishing activities on ships. But in locations like the arctic, the climate and area made it difficult for observers to track IUU vessels. AI plays a great role in these areas. Through satellite and AI programs, fishing vessels can be monitored by image recognition and automatic review of video footage (Figure 3). An independent organization called **'Global fishing watch platform'** collaborated with Google, Oceana, and Sky truth (a digital mapping non-profit organization) to combine AI and satellite data for understanding fishing activity all over the world. This collaboration made it possible to track IUU vessels, poaching, overfishing, and at-sea transshipments (moving goods from one ship to the other) in a more precise way.

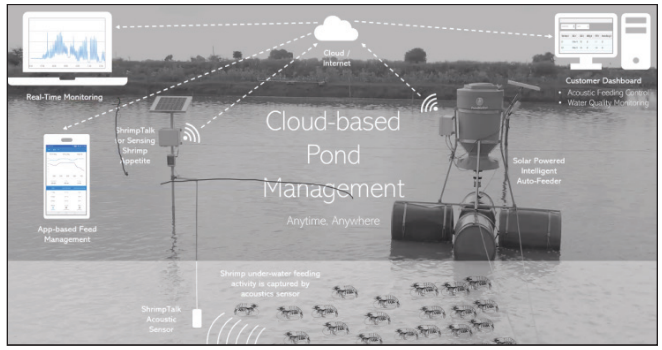

Figure 3: IoT for shrimp farming -Eruvaka Technologies

Connecting all of the disruptive technologies is the internet of things (IoT). It is this technological revolution of computing and communications that makes the robot capable of performing tasks as assigned by a remote user or that transfers information obtained through sensors to producers for analysis on smartphones, tablets, or computers.

AI Smartphone Applications

'Aquaconnect', an Indian aquaculture technology start-up created a mobile application called 'FarmMOJO' (Figure 4) which helps shrimp farmers to analyze water quality and predict diseases. Periodically, pictures of shrimp diseases, parasites, etc are uploaded into the app by the farmers and the developers. Using these pictures, the program can learn about the diseases and preserves them for future use.

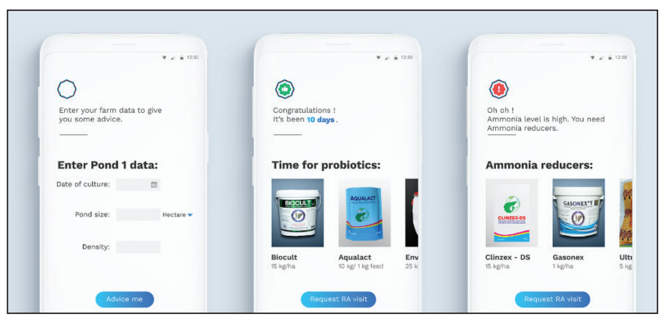

Figure 4: 'FarmMOJO': Mobile application created by Indian aquaculture technology

Advantages of AI in Fisheries

- It helps to manage aquaculture in a much more efficient way and maintains high accuracy in the prediction of disasters (disease outbreaks or depletion of water quality).
- Intelligent aquaculture can greatly improve the output, quality, and safety level of aquatic products and can comprehensively reduce the production and operation costs of aquatic products.

• Intelligent aquaculture improves resource utilization. That is, it can reduce feed use and provide better control of waste and water quality through big data analyses and instant adjustments.

Limitations of AI in Fisheries

• A failure of a sensor or other components can lead to catastrophic error and crop loss, so models that are more robust need to be developed to achieve a fully unmanned operation system.

• Maintenance of AI systems has a high cost too. And another great disadvantage of AI is that it creates unemployment for labourers.

Conclusion

Intelligent aquaculture can reduce labor costs, improve productivity, and increase the quality of aquatic products. However, other factors, such as high capital cost and energy costs should be addressed to improve intelligent aquaculture. Due to the high-risk nature of aquaculture practices, a total lack of human management is difficult to imagine in the foreseeable future. The Production of aquaculture goods can increase rapidly if AI is used in a proper way. The application of AI seems to be unavoidable in the further development and intensification of fisheries and aquaculture.

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