Artificial intelligence for the optimization of marine aquaculture

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Abstract. In recent years, artificial intelligence has become an inevitable player in the field of development and international competition. Artificial intelligence (AI) has made moves across all industries, and marine aquaculture as one of the pillars of the blue economy of high production growth is no exception. The integration of artificial intelligence into marine aquaculture management and conservation is revolutionizing the intensification and expansion of sustainable aquaculture production systems. AI-powered systems help aquaculturists optimize their operations, production and management of marine aquaculture farms, develop innovative applications for monitoring, control and prediction of marine ecosystems, and to reduce waste and minimize their environmental impact. The adoption of AI technologies in aquaculture will be essential to ensure the long-term sustainability of the industry and the health of our oceans. Overall, AI is proving to be an essential tool for optimizing aquaculture development plans and conservation strategies for marine ecosystems. By providing early warning of environmental changes, identifying and protecting threatened species, and monitoring water quality, AI helps ensure that marine ecosystems remain healthy and vibrant.

Keywords: Blue economy/blue growth; Sustainable development; Sustainable aquaculture; natural resources; Artificial intelligence; Marine aquaculture; development.

1   Introduction

Artificial Intelligence is an inevitable player in the field of development and international competition [1]. Political and economic actors involved in the development of digital technologies promote it with fervor [2]. Artificial intelligence (AI) has made changes across all industries, and aquaculture is one of them. As global demand for seafood continues to grow, so does the need for sustainable aquaculture practices. AI appears to be an essential tool to help the aquaculture industry meet this demand while reducing its environmental impact. From monitoring fish health to optimizing feeding schedules, applications of AI in aquaculture management and conservation are radically transforming the approach to sustainability in marine aquaculture.

One of the major challenges of marine aquaculture is maintaining the health and well-being of populations of aquaculture species. Overcrowding, disease and stress can lead to reduced growth rates and increased mortality, ultimately affecting the productivity and profitability of the industry.

Robot intervention in marine aquaculture is a developing field that aims to improve the effectiveness, efficiency and sustainability of this practice. Robots can be used in several

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ways of aquaculture, such as monitoring water quality, dispensing feed, cleaning pools or cages, and even sorting fish, and detecting contaminants. What role does artificial intelligence play in developing marine aquaculture? The answer to this question involves the contribution of artificial intelligence to the mitigation of pollution of marine ecosystems, then the advantages of monitoring aquatic ecosystems, and finally the use of artificial intelligence to develop sustainable aquaculture practices.

Artificial intelligence is the set of theories and techniques developing complex computer programs capable of imitating certain traits of human intelligence [3-5].

In other words, a logical and automated process mainly involving an algorithm and capable of carrying out well-defined tasks [6-8].

Artificial intelligence (AI) is a process of simulating human intelligence that involves the creation and application of algorithms executed in a dynamic computing environment. Its goal is to enable computers to act and think like human beings [9, 10].

Marine aquaculture brings together animal or plant production activities, in the marine environment or from seawater [11-13]. These productions mainly concern shellfish (shellfish farming), crustaceans (astaciculture), fish (fish farming) and algae (seaweed farming) [14, 15]. In Morocco, marine aquaculture is dominated by shellfish farming and seaweed farming [16, 17]. Marine aquaculture activity is very sensitive to the degradation of the marine environment, whether caused by chronic pollution of an organic, chemical or microbiological nature (from agriculture, industries, boating, urban effluents, etc.), or by accidental pollution (oil spills) [12]. It is subject to imbalances in the functioning of ecosystems, resulting for example from the introduction of invasive species. It is also dependent on factors linked to climate change.

To answer the central problem of our research: marine aquaculture and AI, we start with the scientific literature on investments in the field of automation of aquaculture techniques, then the research methodology, then analyzes and discusses the role of artificial intelligence in ocean protection and digital development in marine aquaculture, and looking to the future of our research for the conclusion.

2 Literature review

2.1 Investments in the field of marine aquaculture

In the growing field of aquaculture technology, the use of artificial intelligence is a game-changer. The systems and technologies used to optimize production, improve profitability, monitor the health and manage diseases of aquatic species. We try to present the best companies providing aquaculture management software and aquaculture industry, taking into account their effectiveness, innovation and impact on the sector.

Aquaculture has seen a remarkable explosion of innovation in a short period of time. Most software applications in the industry were released in the last five years. Of the 82 software applications identified for aquaculture, 70% use machine learning or deep learning algorithms, and 51% deploy computer vision and image recognition algorithms [18, 19].

Money is now flowing into the sector. According to Crunchbase, the top ten aquaculture technology companies have raised approximately $282 million [20], led by Indonesian eFishery ($100 million), followed by Shang's Aquabyte ($45 million) (represented figure 1). Aquaculture now accounts for 52% of global seafood production and fish prices have increased by more than 60% in real terms, according to the FAO Fish Price Index. Rising seafood prices and falling technology costs mean opportunities for many investors.
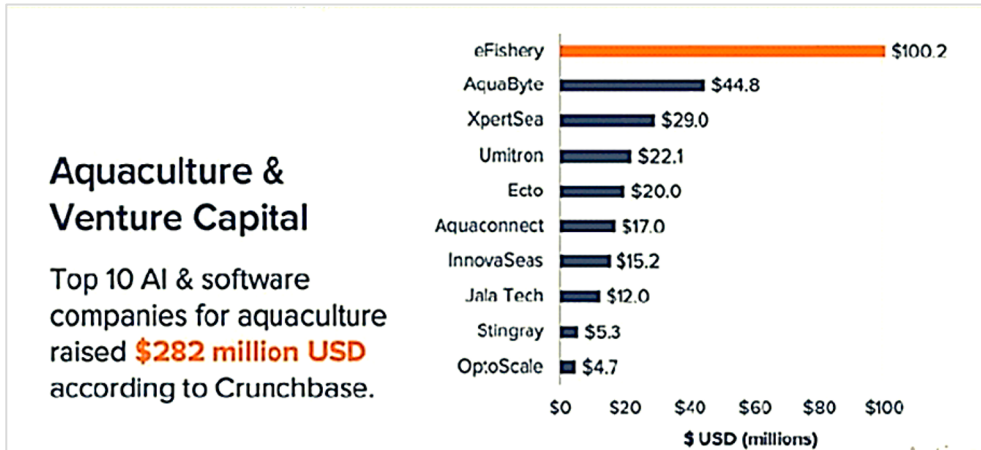
Fig. 1. illustrates the top 10 AI and software companies for aquaculture raised (Source: crunchbase.com)

The convergence of AI and marine aquaculture techniques presents a promising solution to the persistent challenge of predators of farmed species. Investing in AI technologies could not only improve the management of the health of high marine organisms, but also alleviate financial pressure on aquaculturists.

2.2 The attribution of AI in the reduction and identification of pollution of marine ecosystems

In recent years, artificial intelligence (AI) has become an essential tool for reducing and mitigating pollution of aquatic ecosystems [21]. The use cases of technologies and databases in favor of the protection of the underwater environment are increasing: mapping of the seabed for the protection of corals, monitoring of invasive species threatening the balance of biodiversity, or even controlling overfishing. Using artificial intelligence-based sensors, the robots can collect real-time data on environmental parameters such as temperature, salinity and water quality [22, 23]. This allows aquaculturists to monitor and adjust conditions to optimize the growth and health of aquaculture species, while reducing the risk of disease or pollution [24, 25]. Robots can also be programmed to perform routine tasks such as regular feed distribution, freeing up time and resources for livestock farmers [26]. AI-based sensors can be deployed in marine ecosystems to detect pollutants in real time. These sensors can measure the concentration of pollutants, including heavy metals, hydrocarbons and organic compounds[22-25,27]. This data can then be used to create a detailed database of water quality in a given area. This information can be used to develop strategies to reduce pollution and restore ecosystem health.

Finally, AI-driven systems can be used to monitor the health of aquatic species. AI-driven systems can analyze data from sensors and cameras to identify changes in the behavior of aquatic species. This can help researchers and conservationists identify potential threats to aquatic species and take action to protect them.

AI-based aquatic ecosystem monitoring offers a number of advantages over traditional methods [28]. By providing more reliable and up-to-date information about aquatic ecosystems, AI-based systems can help researchers, aquaculturists and conservationists protect the world's oceans [28, 29].

3   Methodology

From a methodological point of view, this article is based on scientific research dealing with AI and marine aquaculture, in light of the work and knowledge accumulated in economics and in related disciplines or currents (for example, human factors, sociology, oceanography, environment, model-based systems engineering) on the incidents of the blue transformation, and the introduction of artificial intelligence technologies in aquaculture activity [28-29]. In other words, it is a question here of proposing an in-depth reflection and taking a step back from current developments in AI and the way in which they are understood to think about the transformations of marine aquaculture.

In this article, we try to present the investments allocated to AI in the field of marine aquaculture, with an emphasis on the large companies involved in this area. Then we look at the attribution of AI in the reduction and identification of pollution of marine ecosystems and the development of marine aquaculture in general and in Morocco.

4   Analysis and discussion

Aquaculture is one of the rapidly growing branches of the blue economy; global aquaculture production will increase from 49% in 2020 to 53% in 2030 [29]. This growth must be sustainable if it is to succeed in the long term.

Artificial intelligence technologies have improved spatial planning and selection of areas for aquaculture operations. For example, the availability of satellite images and the possibility of accessing oceanographic, hydrological and meteorological data (water temperature, precipitation pattern, salinity levels, storm frequency) thanks to long-term remote sensing, combined with the use of digital drone imagery, have enabled not only more efficient and faster planning, but also a more complete application of the ecosystem approach to aquaculture (EAA). [29, 30]

To this end, artificial intelligence (AI) is used to improve sustainable aquaculture practices. AI can be used to optimize the growth of fish and shellfish, as well as monitor and protect the environment. Traditional feeding methods often lead to overfeeding, leading to food waste and increased water pollution. AI-powered systems can analyze data on fish behavior, growth rates and environmental conditions to determine the optimal feeding schedule for each species. This not only reduces waste but also ensures that fish receive the proper nutrition to support healthy growth [31].

Technological advances are expected to make a remarkable contribution to the creation of international policies that aim to encourage the sustainability of aquaculture and ensure their growth [32].

AI-based marine aquaculture systems can be used to monitor water quality, identify and track fish, and detect diseases and parasites. This data can then be used to optimize the growth of fish and shellfish, as well as to ensure they are kept in a healthy environment. AI can also be used to monitor the environment for potential pollutants and to alert aquaculturists when action needs to be taken.

AI can also be used to optimize food supply and distribution systems. By monitoring water

quality and fish health, AI can be used to determine the most appropriate feeding and feeding schedules. For example, machine learning algorithms can analyze video footage from underwater cameras to detect signs of stress or illness in fish, allowing aquaculturists to take corrective action before problems worsen. This can help reduce waste and improve the overall efficiency of the aquaculture system. Finally, AI can be used to help aquaculturists manage their aquaculture operations more efficiently. AI-based systems can be used to monitor and analyze aquaculture system data, allowing aquaculturists to make more informed decisions regarding their operations.

By using AI to support sustainable aquaculture practices, aquaculturists can ensure their operations are both economically profitable and environmentally friendly. AI-based systems can help fish farmers optimize their operations, reduce waste and protect the environment. This is essential for the long-term success of the aquaculture industry.

In summary, the use of robots in intensive aquaculture or integrated multi-trophic aquaculture (AMI) [33] presents several potential advantages, notably the production of fish meal, the improvement of productivity, the reduction of costs and environmental impacts. However, it should be noted that this technology is still in development and there may be challenges in terms of cost, usability and reliability before it becomes widely adopted.

In Morocco, Moroccan aquaculture farms use smart sensors to collect real-time data on parameters such as temperature, salinity, water quality, oxygen level, AI can analyze this data and create predictive models to predict ideal conditions for each species or to detect potential risks such as infections or variations in water quality [34-36].

Additionally, AI can be used to optimize fish feeding systems by analyzing data on their feeding behavior, nutritional needs, and variations in their responses to different foods and diets. This allows the development of more efficient and economical feeding strategies, thereby reducing food waste and environmental impact.

Finally, AI can also be used for disease monitoring and early detection of health problems in fish. By analyzing images and data collected from underwater cameras, AI can identify early signs of disease or infection, enabling rapid and targeted intervention to minimize losses.

These applications of artificial intelligence in Moroccan marine aquaculture can contribute to more sustainable production, more efficient use of resources and reduced risks, while maximizing yields and ensuring fish health.

5 Conclusion

By way of concluding, that artificial intelligence is a crucial element in the global vision known as the common ocean [37, 38]. The integration of artificial intelligence into the management and conservation of marine aquaculture is revolutionizing the approach to sustainable fishing. AI-powered systems help aquaculturists optimize their operations, reduce waste and minimize their environmental impact. At the same time, AI plays a crucial role in conserving global fish stocks by monitoring fishing activities and identifying patterns that may indicate illegal or unsustainable practices. As demand for seafood continues to grow, the adoption of AI technology in aquaculture will be critical to ensuring the long-term sustainability of the industry and the health of our oceans [39, 40]. The sustainable aquaculture technology wave is here, and it's powered by artificial intelligence.

The perspectives of our article on the importance of financial support for companies working on the development of AI technologies in the marine aquaculture sector and thus the encouragement of the transfer of AI technology to Morocco [41].

Currently, the integration of AI techniques in marine aquaculture becomes a necessity of aquaculture management, in order to automatically record the provenance, growth, water quality, harvests, feed use, and mainly measuring the carbon footprint of aquaculture using the sensors and life cycle analysis (LCA) methods of each aquaculture product. The AI involved the monitoring of performance indicators of aquaculture farms, in terms of production, fish health and water quality. Combining Artificial Intelligence with underwater holographic imaging technology to transform the way predators of farmed species are detected faster than traditional methods. Otherwise, AI tries to solve other problems related to aquaculture such as feeding, mortality and maintaining water quality, in general the health of the oceans.

References

1. PAPON Pierre, «Science and Technology: actors of development and international competition. A Prospective Analysis », Innovations, 2022/2 (n° 68), p. 199-219. DOI : 10.3917/inno.pr2.0125. URL : https://www.cairn.info/revue-innovations-2022-2-page-199.htm

2. VAYRE Jean-Sébastien, «Artificial intelligence: between science and market. Some Sociohistorical Elements for a Better Understanding of a Strange Scientific Experiment (1956-1990)», Annales des Mines - Managing and Understanding, 2021/3 (N° 145), p. 55-69. DOI : 10.3917/geco1.145.0055. URL : https://www.cairn.info/revue-gerer-et-comprendre-2021-3-page-55.htm

3. Shukla Shubhendu, S., and Jaiswal Vijay. "Applicability of artificial intelligence in different fields of life." International Journal of Scientific Engineering and Research 1.1 (2013): 28-35.

4. Simon, Herbert A. "Artificial intelligence: an empirical science." Artificial intelligence 77.1 (1995): 95-127.

5. Kumar, Koushal, and Gour Sundar Mitra Thakur. "Advanced applications of neural networks and artificial intelligence: A review." International journal of information technology and computer science 4.6 (2012): 57.

6. Kant, Elaine. "Understanding and automating algorithm design." IEEE Transactions on Software Engineering 11 (1985): 1361-1374.

7. Marrella, Andrea. "Automated planning for business process management." Journal on data semantics 8.2 (2019): 79-98.

8. Rosé, Carolyn, et al. "Analyzing collaborative learning processes automatically: Exploiting the advances of computational linguistics in computer-supported collaborative learning." International journal of computer-supported collaborative learning 3 (2008): 237-271.

9. Pannu, Avneet. "Artificial intelligence and its application in different areas." Artificial Intelligence 4.10 (2015): 79-84.

10. Hassani, Hossein, et al. "Artificial intelligence (AI) or intelligence augmentation (IA): what is the future?." Ai 1.2 (2020): 8.

11. Edwards, Peter. "Aquaculture environment interactions: past, present and likely future trends." Aquaculture 447 (2015): 2-14.

12. Grigorakis, K., and G. Rigos. "Aquaculture effects on environmental and public welfare–the case of Mediterranean mariculture." Chemosphere 85.6 (2011): 899-919.

13. Iwama, George K. "Interactions between aquaculture and the environment." Critical Reviews in Environmental Science and Technology 21.2 (1991): 177-216.

14. Mañanós, Evaristo L., Jerónimo Chirivella, and Francisco J. Espinós. "Diversification of the production cycle." (2011).

15. Director, ICAR-CIBA. "English-Hindi Glossary Fisheries Science and Aquaculture." (2015).

16. Boudouresque, Charles-François, et al. "Impacts of marine and lagoon aquaculture on macrophytes in Mediterranean benthic ecosystems." Frontiers in Marine Science 7 (2020): 218.

17. Ortega, Aurelio, et al. "Aquaculture in the Alboran Sea." Alboran Sea-Ecosystems and Marine Resources. Cham: Springer International Publishing, 2021. 659-706.

18. Vo, Thi Thu Em, et al. "Overview of smart aquaculture system: Focusing on applications of machine learning and computer vision." Electronics 10.22 (2021): 2882.

19. Gladju, J., Biju Sam Kamalam, and A. Kanagaraj. "Applications of data mining and machine learning framework in aquaculture and fisheries: A review." Smart Agricultural Technology 2 (2022): 100061.

20. Liu, Peiyuan, Yuxiong Huang, and Slav W. Hermanowicz. "Shifting entrepreneurial landscape and development performance of water startups in emerging water markets." Plos one 16.2 (2021): e0246282.

21. Hoang, Tuan-Dung, et al. "Artificial intelligence in pollution control and management: status and future prospects." Artificial Intelligence and Environmental Sustainability: Challenges and Solutions in the Era of Industry 4.0 (2022): 23-43.

22. Manjakkal, Libu, et al. "Connected sensors, innovative sensor deployment, and intelligent data analysis for online water quality monitoring." IEEE Internet of Things Journal 8.18 (2021): 13805-13824.

23. Paepae, Thulane, Pitshou N. Bokoro, and Kyandoghere Kyamakya. "From fully physical to virtual sensing for water quality assessment: A comprehensive review of the relevant state-of-the-art." Sensors 21.21 (2021): 6971.

24. Mustapha, Umar Farouk, et al. "Sustainable aquaculture development: a review on the roles of cloud computing, internet of things and artificial intelligence (CIA)." Reviews in Aquaculture 13.4 (2021): 2076-2091.

25. Mandal, Arghya, and Apurba Ratan Ghosh. "Role of artificial intelligence (AI) in fish growth and health status monitoring: a review on sustainable aquaculture." Aquaculture International (2023): 1-30.

26. Pavkin, Dmitriy Yu, et al. "Development Results of a Cross-Platform Positioning System for a Robotics Feed System at a Dairy Cattle Complex." Agriculture 13.7 (2023): 1422.

27. Tournay, Virginie. Artificial intelligence. The political stakes of improving human capacities. Editions Ellipses, 2020.

28. Muraccioli, Pascal. Location of an aquaculture farm in Corsica. Use of decision support methods. Diss. Corte, 1998.

29. Food and Agriculture Organization of the United Nations (FAO). The global situation of fisheries and aquaculture. Towards a blue transformation ; FAO : Rome, Italy, 2022, pp.117-123.

30. Sylla, Diogone. Fusion of data from different satellite sensors for monitoring water quality in coastal areas. Application to the coast of the PACA region. Diss. University of Toulon, 2014.

31. Food and Agriculture Organization of the United Nations (FAO). The global situation of fisheries and aquaculture. Towards a blue transformation; FAO: Rome, Italy, 2022, p.132.

32. ZOUINAR, Moustafa. Evolution of Artificial Intelligence: what are the challenges for human activity and the human-machine relationship at work? Activities, 2020, no 17-1.

33. Aubin, Joël, et al. "Integrated Multi Trophic Aquaculture: the IMTA Effect project."

(2019).

34. SARTI OTMANE. Environmental approach of the interaction of a fish farming activity with its local ecosystem: case of the bay of M'diq Moroccan Mediterranean." Master's thesis. 2016; p.10.

35. Thebaud, Olivier. "Blue economy, common goods and sustainable development." Maritime Journal 519 (2021): 22-28.

36. Arid H, Moudni H, Orbi A, Talbaoui M, Idrissi J I, Massik Z, et al. Remote sensing and GIS for integrated management of aquaculture potential. GEO OBSERVER. Royal Centre for Remote Sensing in Space, (2005) ; (14), 63-79.

37. ANTOINE-SANTONI, Thierry. From wireless sensor networks to ambient intelligence in environmental monitoring. Synthesis of work. 2019. PhD thesis. University of Corsica Pasquale Paoli.

38. European Commission "Communication From The Commission to the European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions." Brussels, 2021, Com(2021). P.14-15.

39. Chow, Jean-Yves, et Matthieu Brun. «Singapore: the Asian dragon's dreams of food self-sufficiency», Sébastien Abis éd. , Le Déméter 2022. Food : new frontiers. IRIS editions, 2022, pp. 269-286.

40. DALLAIRE-NICHOLAS, P. N. The impact of artificial intelligence in environmental law. Essay submitted to the University of Sherbrooke, Quebec, 2021, p. 67.

41. Slimani, K., Khoulji, S., Mortreau, A., & Kerkeb, M. L. (2024). From tradition to innovation: The telecommunications metamorphosis with AI and advanced technologies. Journal of Autonomous Intelligence, 7(1).