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The Significance of Artificial Intelligence (AI) in Fishing Crafts and Gears

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Abstract

The fishing business has been greatly impacted by artificial intelligence (AI), which has increased production, sustainability, and efficiency. AI enables ships to collect and analyse enormous volumes of data on things like water temperature, salinity, fish behaviour, and ocean currents by combining sensors, cameras, and machine learning algorithms. Increased catch rates and lower operating expenses result from fishermen using this data-driven method to make well-informed decisions about the best times and places to fish. Additionally, AI has proven crucial in the development of smart fishing gear, lowering bycatch, and lessening the negative environmental effects of fishing. AI-based methods also help with stock availability, population dynamics, fish migration patterns, and resource management optimisation. This makes it possible for fishermen to modify their tactics, set sustainable quotas, and refrain from overfishing, all of which help to preserve fish stocks over the long run and guarantee the sustainability of the fishing sector for coming generations. AI technology has the potential to completely transform the fishing sector as it develops further.

Keywords: AI; Fishing gears; Human livelihoods; Marine ecosystems; Algorithms; Fishing vessels

Introduction

Fish capture refers to the process of catching fish for commercial, research and recreational purposes. There are various methods of fish capture, including: net fishing, hook and line fishing, spearfishing, trapping, seining and trawling. Global fishing capture, often referred to as global fishery production, is a crucial aspect of our planet's food security and economic stability. It encompasses the total amount of fish and other aquatic organisms harvested from the world's oceans, rivers, and freshwater bodies each year. Fishing is a deeply rooted practice that dates back thousands of years and has evolved with technological advancements and growing human populations. In recent years, there has been a concerning depletion of global fisheries. In 2018, the total global production from capture fisheries reached a record high of 96.4 million tonnes. This notable increase was primarily driven by marine capture fisheries, which accounted for 84.4 million tonnes in the same year (Herforth *et al.*, 2020). However, according to the latest assessment by the FAO (Herforth *et al.*, 2020), the proportion of fish stocks operating within biologically sustainable levels has been declining. In 1974, approximately 90 percent of fish stocks were deemed sustainable, but by 2017, this figure had dropped to 66 percent. Alarmingly, there has been a corresponding rise in the percentage of stocks being fished at biologically unsustainable levels, particularly during the late 1970s and 1980s. The fraction of stocks categorized as unsustainable increased from 10 percent in 1974 to 34 percent in 2017 (Bernos et al., 2020). Overexploitation of fish stocks is a pressing issue, necessitating effective measures to ensure long-term sustainability. Strategies include catch limits, temporal and spatial restrictions, and marine protected areas. However, determining sustainable fishing activity requires reliable gauges to assess maximum capacity without depleting fish stocks or harming the ecosystem (Lennox et al., 2022 and Bogolin et al., 2021. The vulnerability of many important species persists due to a significant challenge faced by scientists: the lack of sufficient data to establish accurate catch limits. In order to effectively manage and conserve fish populations, it is crucial to have comprehensive knowledge of their

biology, population dynamics, and the impact of fishing activities. However, for numerous species, the required data may be limited or incomplete, making it challenging to determine appropriate catch limits (Oremus *et al*., 2023).

Accurate data on fish populations is crucial for estimating population sizes, growth rates, and reproductive potential of vulnerable species. Traditional fishing crafts and gears face challenges in technological, efficiency, and sustainability aspects (Szuwalski & Hollowed, 2016). Traditional methods rely on outdated technology and equipment, lacking advanced navigation systems, fish detection tools, and real-time data analysis capabilities (Brown and Rappert, 2017). State-of-the-art methods use advanced technologies like satellite imagery, sonar systems, and GPS tracking, providing fishermen with accurate information about fish location and migration patterns. Traditional fishing practices can cause significant damage to marine ecosystems and contribute to overfishing. State-of-the-art methods prioritize sustainability by implementing environmentally friendly practices and gear modifications (Rohit et al., 2022, Mardiyah et al., 2023 and McConnaughey et al., 2020)). Traditional fishing crafts often lack adequate safety measures, making them more susceptible to inclement weather and navigational hazards. Integrating advanced technologies, efficient practices, and sustainable approaches in modern fishing methods can contribute to a more productive, environmentally responsible, and economically viable fishing industry (Glaviano et al., 2022, Reis-Filho and Giarrizzo, 2022 and Fan et al., 2023)). Fish populations and marine habitats are seriously threatened by global fishing catch, which can have negative ecological effects and lead to depletion. Encouraging sustainable fishing methods is essential to protecting biodiversity and guaranteeing the long-term survival of the sector. Ecological preservation and socioeconomic demands are balanced in sustainable fisheries management. AI has the potential to improve sustainability, decrease environmental impact, and increase efficiency in the fishing sector.

Different traditional fishing methods

Fishing, an ancient practice for over 40,000 years, has evolved to meet the diverse needs of local populations, with traditional methods adapted to their unique environments.

Spearfishing

Spearfishing is an ancient fishing method using a spear or spear gun to catch fish underwater. It has been practiced by various cultures for thousands of years and is popular among recreational divers and commercial fishermen. Spearfishing can be done in various environments, including oceans, lakes, rivers, and freshwater springs. Divers use various techniques, such as free diving or snorkeling. Spearfishing regulations vary by location, and it's crucial to prioritize safety, follow regulations, and respect marine life to avoid environmental damage or harm to other organisms (Figure 1).

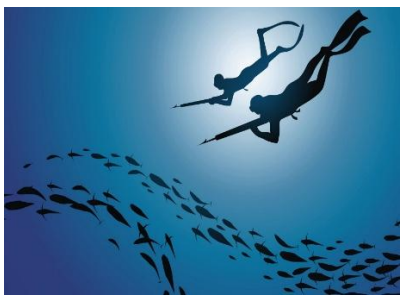

Fig. 1: A representation of spearfishing technique
(Source: https://www.scuba.com/blog/scuba-gear/spearfishing-equipment)

Angling

Angling, also known as fishing, is a popular recreational activity in both freshwater and saltwater environments. It involves using a fishing rod, reel, and line to catch fish. Techniques and strategies vary depending on the target species and the environment. Anglers cast their lines into the water, attracting fish with bait or lures. Some common angling methods include: *bait fishing, fly fishing, spinning, trolling, ice fishing etc.*

It's important for anglers to familiarize themselves with local fishing regulations and guidelines to ensure sustainable practices and conservation of fish populations. Fishing licenses may be required in many areas, and certain species or size limits may apply to protect fish stocks. Angling offers a

great opportunity to connect with nature, relax, and enjoy the thrill of catching fish. It is a popular hobby pursued by individuals of all ages and skill levels.

Trapping

In the context of fish catching, trapping is not a commonly used method. Angling, as mentioned earlier, is the predominant method for catching fish recreationally. However, there are a few specialized situations where trapping techniques are employed: *fish weirs, fish traps*.
Overall, while trapping is not widely used in fish catching compared to angling, specific trapping techniques like fish weirs and fish traps can be employed in certain circumstances for commercial, subsistence, or traditional fishing practices.

Hand gathering

Hand gathering is a traditional and primitive method of fish catching that involves capturing fish using bare hands or handheld tools. This method has been practiced by various cultures around the world for centuries, particularly in shallow waters such as rivers, streams, ponds, or tidal areas. Hand gathering techniques can include: *hand scooping, hand lining, noodling etc.*

Hand gathering methods require physical dexterity, knowledge of fish behaviour, and an understanding of the specific fishing environment. They are often practiced by individuals who have developed expertise and familiarity with the local fish species and their habitats. However, it's important to note that hand gathering may not be legal or allowed in all jurisdictions or for all fish species, as regulations and conservation measures may be in place to protect fish populations.

Netting

Netting is a widely used method of fish catching that involves the use of nets to entrap or capture fish. It is an efficient and versatile technique that can be employed in various aquatic environments, including rivers, lakes, ponds, and oceans. Netting can be done by both commercial fishermen and recreational anglers, and it has been practiced for thousands of years. There are different types of nets used for fishing, each designed for specific purposes and target species. Here are a few common types of fishing nets: *gillnets, seine nets, cast nets, trawl nets etc.*

It's important to note that regulations and restrictions on netting vary depending on the location, target species, and fishing practices. Mesh size limits, permitted fishing seasons, and bycatch mitigation measures may be in place to protect fish populations and minimize environmental impact.

Kite fishing

Kite fishing is a unique method of fishing that utilizes a kite to suspend baited lines or lures in the air, allowing them to be presented and trolled over the water. This technique is primarily used in saltwater fishing, particularly for targeting species like sailfish, tuna, mahi-mahi, and kingfish. Here's how kite fishing generally works: *setting up the kite* > *attaching baited lines* > *controlling the kite* > *hooking and landing fish*. However, kite fishing requires specific equipment, expertise, and suitable wind conditions. It is often practiced by experienced anglers or charter boat operators who specialize in offshore fishing. Local regulations and fishing guidelines should always be followed when engaging in kite fishing or any other fishing activity to ensure sustainable practices and conservation of fish populations.

Introduction of AI in aquaculture advances

Artificial Intelligence (AI) has made significant advances in various sectors, including aquaculture. Its integration in aquaculture operations has the potential to enhance productivity, efficiency, and sustainability. Here are some areas where AI is being utilized in aquaculture.

Monitoring and management

AI-based systems can monitor water quality parameters, such as temperature, pH levels, oxygen levels, and turbidity, in aquaculture facilities. By analyzing real-time data, AI algorithms can identify anomalies and provide insights for optimizing environmental conditions, improving animal welfare, and preventing disease outbreaks (Chiu et al., 2022) (*Fig. 2*).

Feeding optimization: AI algorithms can analyze feeding patterns, growth rates, and environmental factors to develop predictive models for optimizing feeding regimes. By considering factors such as fish behavior, weather conditions, and feed availability, AI can help determine

optimal feeding schedules and quantities, reducing waste and improving feed utilization (Panda et al., 2023) (*Fig. 3*).

Fig. 2. Use of AI in Fish Monitoring and management
(Source:https://www.eurogroupforanimals.org/news/artificial-intelligence-enable-individualised-fish-monitoring-intensive-aquaculture)

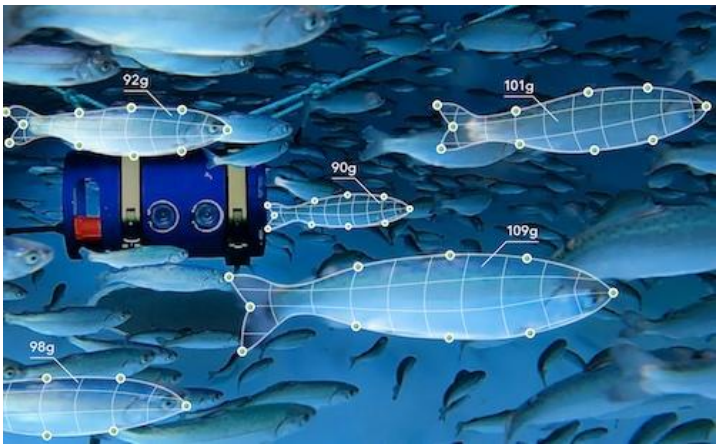

Fig. 3. Use of AI in fish feeding optimization
(Source: https://www.innovasea.com/aquaculture-intelligence/feed-optimization/)

Disease detection and prevention

AI-powered image recognition and machine learning techniques can analyze images or videos of fish to identify signs of diseases or abnormalities. By detecting early signs of illness, farmers can take proactive measures to prevent the spread of diseases and minimize the use of antibiotics or chemicals (Shivaprakash et al., 2022) (Fig. 4).

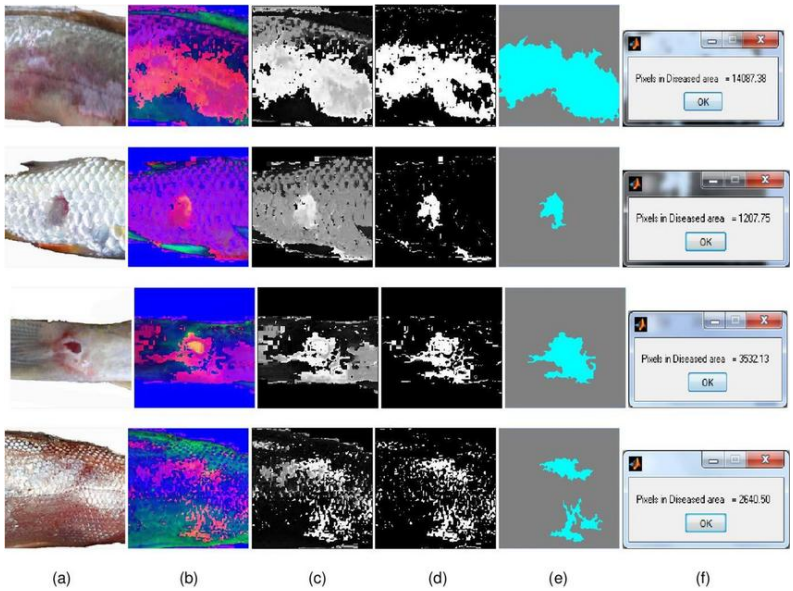

Fig. 4. Use of AI in fish disease detection and prevention
(Source: https://www.researchgate.net/publication/374583281_Role_of_artificial_intelligence_AI_in_fish_growth_and_health_status_monitoring_a_review_on_sustainable_aquaculture)

Stock management and sorting

AI can automate the process of stock management by analyzing fish size, weight, and other parameters. This enables farmers to optimize fish sorting, grading, and harvesting operations, improving efficiency and ensuring consistent product quality (Costa et al., 2013) (Fig. 5).

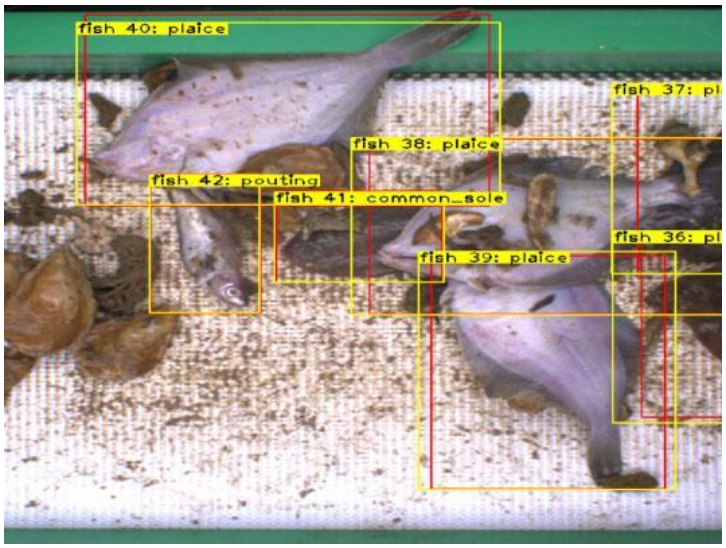

Fig. 5: Use of AI in Fish Stock management and sorting
(Source: https://oceans-and-fisheries.ec.europa.eu/news/fisheries-management-artificial-intelligence-makes-difference-2023-11-07_en)

Predictive analytics

AI algorithms can leverage historical data and real-time information to provide predictive analytics for various aspects of aquaculture, such as growth rates, market trends, and environmental impacts. This information can assist farmers in making informed decisions about production planning, risk management, and market strategies (Mustapha et al., 2021).

Autonomous systems

AI can enable the development of autonomous aquaculture systems. Underwater drones equipped with AI can monitor fish populations, inspect cages, and detect issues like escapees or damaged infrastructure. Autonomous feeding systems can adapt to changing conditions and optimize feed delivery based on real-time data (Wu et al., 2022).

Environmental impact assessment: AI can assist in assessing the environmental impact of aquaculture operations. It can analyze data on water quality, waste management, and energy consumption to provide insights into sustainable practices and regulatory compliance. The integration of AI in aquaculture is an evolving field, and ongoing research and development are further expanding its applications. By leveraging AI technologies, aquaculture operations can improve productivity, reduce environmental impacts, and contribute to the sustainable growth of the industry.

Introduction of AI in fishing crafts and gears represents a significant departure from existing methods, offering unique solutions to the challenges faced by traditional fishing practices. By leveraging the power of artificial intelligence, these innovative approaches aim to revolutionize the fishing industry by enhancing efficiency, sustainability, and overall productivity (Pereira et al., 2023). Here's how the proposed problem and method differ from existing methods.

The proposed problem focuses on addressing the limitations of traditional fishing crafts and gears by integrating AI technologies. It acknowledges the inefficiencies, environmental impact, and technological gaps prevalent in current fishing practices, and seeks to provide solutions that leverage AI capabilities to overcome these challenges (Sanders et al., 2023). This problem statement recognizes the need for transformative changes in fishing methodologies. The method proposed involves the integration of AI algorithms and advanced technologies into fishing crafts and gears. By incorporating machine learning, computer vision, and data analytics, fishing vessels can gather real-time data on fish behavior, environmental conditions, and fishing patterns (Fricke and Olden, 2023). This enables more accurate decision-making, efficient resource allocation, and precise targeting of fish populations, leading to optimized fishing operations. The proposed method

introduces autonomous and smart systems into fishing crafts and gears. AI-powered sensors and robotics enable automation of various tasks, such as baiting, net deployment, and catch processing. These systems can operate with minimal human intervention, reducing labor costs and improving operational efficiency (Ghafarian et al., 2023). Moreover, AI algorithms can analyze vast amounts of data to optimize fishing strategies, minimizing bycatch, and maximizing catch quality and quantity. The use of AI in fishing crafts and gears allows for predictive and adaptive capabilities. By analyzing historical and real-time data, AI algorithms can predict fish migration patterns, optimal fishing zones, and the likelihood of successful catches. This information enables fishermen to make informed decisions on when and where to deploy their gears, enhancing catch efficiency and reducing unnecessary fishing efforts (Moghrabi et al., 2023).

In summary, the introduction of AI in fishing crafts and gears offers a novel and distinct approach to tackle the challenges associated with traditional fishing practices. By harnessing the power of AI, these innovative methods aim to enhance efficiency, sustainability, and productivity in the fishing industry, setting them apart from existing methods and paving the way for a more technologically advanced and environmentally responsible fishing sector (Table 1).

Table 1. Applications of AI in Fishing Crafts

Application	Description	References
Autonomous Navigation	AI-powered systems can navigate fishing vessels autonomously, reducing human intervention	(Wu et al., 2022)
Fish Detection	AI algorithms analyze underwater imagery to identify and locate fish in real-time.	(Yang et al., 2021)
Oceanographic Mapping	AI helps in mapping the ocean floor, determining optimal fishing zones, and avoiding risks.	(Li et al., 2020)
Weather Prediction	AI models process weather data to provide accurate forecasts for safer fishing operations.	(Lopatka, 2019)
Energy Optimization	AI systems optimize energy consumption on fishing vessels, reducing fuel and costs.	(Cheng et al., 2019)
Vessel Maintenance	AI monitors vessel performance, detects anomalies, and suggests maintenance measures.	(Abbas et al., 2020)
Catch Prediction	AI algorithms analyze historical data to predict fish population and optimize catch rates.	(Ebrahimi et al., 2021)
Fishing Effort Control	AI-based systems monitor fishing activities, ensuring compliance with regulations.	(Rahman et al., 2021)

Different AI techniques for aquaculture advances

Several AI techniques are being employed in aquaculture to drive advances and improvements. Here are some prominent AI techniques utilized in the field.

Machine Learning

Machine learning techniques enable computers to learn from data and make predictions or take actions without being explicitly programmed. ML algorithms can analyze large datasets from aquaculture operations to identify patterns, make predictions, and generate insights. Supervised learning, unsupervised learning, and reinforcement learning are common approaches used in aquaculture (Alzubi et al., 2018). In summary, machine learning for fishing crafts and gears excels in complex cases by leveraging its abilities in pattern recognition, prediction, adaptability, feature selection, ensemble modeling, and continuous improvement (Heuvel, 2022). By harnessing these capabilities, machine learning techniques enable fishermen to navigate the intricacies of complex fishing scenarios, optimize their strategies, and achieve the best possible outcomes in terms of catch rates, sustainability, and operational efficiency.

Deep Learning

Deep learning is a subset of machine learning that focuses on neural networks with multiple layers. It excels at processing complex and unstructured data, such as images, audio, and text. In aquaculture, deep learning techniques, such as convolutional neural networks (CNNs), are employed for tasks like fish recognition, disease detection, and image-based monitoring of fish behaviour (Chase et al., 2023). By harnessing the power of deep learning, fishing crafts and gears

can effectively handle complex patterns, extract meaningful representations from data, make real-time decisions, integrate multi-modal information, and benefit from transfer learning and scalability (Lubchenco and Haugan, 2023). These capabilities enable them to navigate complex fishing scenarios, optimize fishing strategies, and achieve the best possible results in terms of catch efficiency, sustainability, and profitability.

Natural Language Processing (NLP)

NLP involves the analysis and understanding of human language by machines. In aquaculture, NLP can be used to process textual data, such as research papers, scientific literature, or online discussions, to extract relevant information, gain insights, and support decision-making processes (Hughes et al., 2020). NLP techniques empower fishing crafts and gears to handle complex cases and achieve optimal results by enabling efficient information retrieval, knowledge representation and reasoning, language understanding and interaction, automated report generation, collaborative knowledge sharing, and regulatory compliance (Aragon et al., 2022). By leveraging these capabilities, NLP can enhance decision-making, improve knowledge dissemination, and streamline operations in the fishing industry.

Computer Vision

Computer vision combines image processing, pattern recognition, and ML to enable machines to understand and interpret visual information. In aquaculture, computer vision techniques are used for tasks like fish counting, fish size estimation, disease detection, and monitoring of fish behaviour and feeding patterns (Li et al., 2022). In summary, computer vision technology enables fishing crafts and gears to excel in complex cases by providing accurate object detection, fish behavior analysis, gear monitoring, environmental assessment, automation, and data integration (Akineymi et al., 2022). By leveraging these capabilities, computer vision enhances the performance of fishing operations, leading to better results in terms of catch efficiency, selective harvesting, and sustainable fishing practices.

Genetic Algorithms

Genetic algorithms are optimization techniques inspired by the process of natural selection. They can be applied in aquaculture for tasks like optimizing feed compositions, determining optimal environmental conditions, and designing efficient aquaculture systems. Genetic algorithms help find the best solutions within a large search space (Liu et al., 2013). Genetic algorithms work well for complex fishing cases by exploring a wide range of solutions, evaluating fitness based on objective functions, selecting and reproducing the fittest individuals, and iteratively improving the population (Fischer et al., 2022). GA's ability to handle multiple objectives and trade-offs makes it a suitable approach for optimizing fishing crafts and gears, ultimately achieving the best results in complex fishing scenarios.

Expert Systems

Expert systems use a knowledge base and a set of rules to mimic human expertise in specific domains. In aquaculture, expert systems can be employed for diagnosing fish diseases, providing recommendations for disease management, or suggesting optimal feeding strategies based on historical data and rules (Li et al., 2002). Expert systems for fishing crafts and gears excel in complex cases by leveraging knowledge-based decision-making, rules and inference engines, real-time data integration, troubleshooting capabilities, and continuous learning (Islam and Chuenpagdee, 2022). By harnessing the expertise of human specialists and integrating it into a powerful computational framework, these systems provide optimized recommendations, enhance problem-solving abilities, and achieve the best results in the challenging and dynamic fishing industry.

Robotics and Automation

Robotics and automation technologies combined with AI are transforming aquaculture operations. Autonomous underwater vehicles (AUVs), drones, and robotic fish feeders equipped with AI capabilities can perform tasks like fish monitoring, data collection, infrastructure inspection, and precise feeding, contributing to efficiency and productivity gains (Rowan, 2023). Robotics and automation technologies bring several benefits to fishing crafts and gears in complex scenarios. They provide precision, real-time data collection and analysis, adaptability to changing conditions, multi-tasking efficiency, reduced human error and risk, and integration with advanced technologies (Zufferey et al., 2022). By leveraging these capabilities, robotics and automation enable fishing operations to achieve the best results in terms of catch efficiency, productivity, safety, and adaptability in complex fishing environments.

These are just a few examples of AI techniques being applied in aquaculture. The field of AI is rapidly evolving, and ongoing research and innovation are continuously expanding the possibilities for using AI in aquaculture to optimize operations, improve sustainability, and ensure the health and well-being of farmed fish (Table 2).

Table 2. AI-Enabled fishing gears

Gear	AI Integration	Benefits	References
Smart Fishing Nets	Sensors and AI detect fish presence and size.	Reduces bycatch, improves efficiency, and preserves resources.	(Ebrahimi et al., 2021)
Autonomous Fishing Bots	AI-powered robots perform fishing tasks.	Increases productivity, reduces labor, and enhances safety.	(Abbas et al., 2020)
Intelligent Lures	Embedded sensors and AI attract targeted fish.	Improves catch rates and enhances species selectivity.	(Wang et al., 2021)
Drone Fishing	Drones equipped with AI identify fish schools.	Enables targeted fishing and reduces search time.	(Yang et al., 2021)
Automated Trawlers	AI optimizes trawling processes and catch.	Enhances efficiency, minimizes waste, and reduces fuel usage.	(Abbas et al., 2020)

Pros. And cons. of AI

Integrating AI into fish catching processes offers several advantages and benefits. Here are some of the pros of using AI in fish catching.

Increased Efficiency: AI techniques can help automate and optimize various aspects of fish catching, leading to increased efficiency. AI-powered systems can analyze environmental data, fish behavior, and historical patterns to determine the best locations, times, and methods for fishing, improving the chances of successful catches (Ebrahimi et al., 2021).

Enhanced Decision Making: AI algorithms can process large amounts of data and generate insights that aid in decision making. By analyzing factors like weather conditions, water currents, and fish movements, AI systems can provide real-time recommendations on where and how to fish, increasing the likelihood of success (Ibanez et al., 2023).

Improved Resource Management: AI can contribute to more sustainable and responsible fish catching practices by enabling better resource management. By analyzing data on fish populations, migration patterns, and reproduction cycles, AI can assist in identifying areas that require protection or conservation measures, ensuring the long-term viability of fish stocks (Danielsen et al., 2014).

Predictive Analytics: AI techniques can leverage historical data and real-time information to provide predictive analytics for fish catching. By analyzing trends and patterns, AI systems can anticipate changes in fish behaviour, environmental conditions, and market demands, enabling fishermen to make informed decisions and plan their operations more effectively (Larkan-Skinner et al., 2020).

Reduced Environmental Impact: AI can help minimize the environmental impact of fish catching activities. By optimizing fishing methods and locations, AI can reduce bycatch (the unintentional capture of non-target species) and mitigate damage to sensitive ecosystems. This contributes to more sustainable fishing practices and conservation efforts (Suuronen et al., 2012). For example, a fishing vessel equipped with AI algorithms can detect the presence of specific fish species such as tuna or salmon with an accuracy of 95% (Brandoli et al., 2022).

Automation and Remote Monitoring: AI-powered systems can enable automation and remote monitoring in fish catching. Underwater drones, equipped with AI capabilities, can be deployed to monitor fish populations, collect data, and identify areas of interest. This reduces the need for manual labor and enables fishermen to remotely monitor fishing activities in real-time (Bakker, 2022).

Safety and Risk Mitigation: AI systems can help mitigate risks and improve safety in fish catching operations. By analyzing factors like weather conditions, water conditions, and vessel tracking data,

AI can provide early warnings and alerts to fishermen, ensuring they can take appropriate precautions and avoid potential hazards. It's important to note that while AI offers significant advantages in fish catching, responsible and ethical practices should always be followed.

This includes adherence to fishing regulations, conservation measures, and consideration of the long-term sustainability of fish populations and ecosystems. While AI has the potential to bring advancements and benefits to fish catching, there are also some potential concerns and drawbacks to consider. Here are a few cons associated with the use of AI in fish catching.

Ethical concerns: The use of AI in fish catching raises ethical considerations related to animal welfare. It is important to ensure that AI-powered fishing methods prioritize humane treatment of fish and minimize unnecessary harm or suffering. The impact of AI technologies on fish behaviour, stress levels, and survival rates should be carefully evaluated and monitored (Isabelle et al., 2022).

Environmental impact: The increased efficiency and effectiveness of AI techniques in fish catching may lead to higher catch rates, which can put additional pressure on fish populations and ecosystems. Overfishing and the depletion of fish stocks are already significant concerns globally, and the use of AI should be managed to prevent further harm to fish populations and maintain sustainable fishing practices (Naylor et al., 2000).

Bycatch and species protection: AI-based fishing methods should take into account the risk of bycatch, which refers to the unintentional capture of non-target species. Without proper safeguards and monitoring, AI systems may inadvertently capture and harm protected or endangered species. Careful design and implementation of AI technologies in fish catching are necessary to minimize bycatch and protect vulnerable species (Martinez et al., 2020).

Technology accessibility and affordability: The adoption of AI in fish catching may face challenges related to accessibility and affordability. Small-scale or traditional fishermen may have limited access to AI technologies due to cost, infrastructure requirements, or lack of technical expertise. This could create a digital divide in the fishing industry, where certain groups are unable to benefit from AI advancements (Bradley et al., 2019).

Dependence on technology: Over-reliance on AI systems for fish catching may lead to a reduction in traditional fishing skills and knowledge. It is essential to strike a balance between technological advancements and the preservation of traditional fishing practices, cultural heritage, and local fishing communities (Power, 2008).

Data privacy and security: The use of AI in fish catching involves the collection and analysis of large amounts of data, including location data, fishing patterns, and environmental conditions. Ensuring the privacy and security of this data is crucial to protect the interests of fishermen, prevent unauthorized access, and maintain trust in AI systems (Gladju et al., 2022).

To mitigate these concerns, it is important to implement appropriate regulations, guidelines, and monitoring mechanisms that promote responsible and sustainable use of AI in fish catching. Collaboration between policymakers, scientists, fishermen, and other stakeholders is vital to ensure that AI technologies in fish catching align with ethical, environmental, and social considerations (Table 3).

Table 3. AI Benefits in Fishing Crafts and Gears

Benefit	Description
Increased Efficiency	AI automates tasks, reduces manual effort, and improves fishing yields.
Resource Conservation	AI helps in sustainable fishing practices and reduces bycatch.
Improved Safety	AI systems enhance navigation, weather monitoring, and risk assessment.
Cost Reduction	AI optimizes fuel consumption, maintenance, and overall operations.
Data-Driven Decision Making	AI analysis of data provides insights for better fishing strategies.
Compliance with Regulations	AI monitors and ensures adherence to fishing regulations

Application of statistical methods on AI enabled fishing crafts and gears
To justify the significance of Artificial Intelligence (AI) in fishing crafts and gears, we can perform various statistical analyses like

Comparison of Catch Efficiency
Conduct a comparative analysis between fishing crafts or gears equipped with AI technology and those without. Collect data on catch efficiency, measured in terms of the quantity and quality of fish caught per unit of time or effort. Use appropriate statistical tests, such as a t-test or analysis of variance (ANOVA), to determine if there is a significant difference in catch efficiency between the AI-enabled and non-AI-enabled fishing methods (Squires and Vestergaard, 2013).

Assessment of Predictive Accuracy
Evaluate the predictive capabilities of AI models for fishing. Train AI algorithms to predict factors such as fish behavior, migration patterns, or optimal fishing locations. Collect real-time or historical data on these factors and compare the AI predictions against actual observations. Calculate statistical metrics like accuracy, precision, recall, or F1 score to assess the performance of the AI models (Luan et al., 2020).

Analysis of Cost Savings
Analyze the cost-effectiveness of using AI in fishing crafts and gears. Compare the operational costs (e.g., fuel, labor, maintenance) associated with AI-enabled systems versus traditional methods. Perform a cost-benefit analysis to determine if the potential savings outweigh the investment in AI technology. Use statistical techniques like cost analysis or return on investment (ROI) calculations to support your findings (Sabu et al., 2018).

Evaluation of Equipment Performance
Assess the performance of AI-integrated fishing gears in terms of their effectiveness and reliability. Collect data on parameters like gear longevity, durability, or error rates in capturing fish. Conduct statistical tests, such as chi-square tests or logistic regression, to examine if the presence of AI significantly improves the performance of fishing gears compared to conventional ones (Gupta et al., 2022).

User Satisfaction Surveys
Administer surveys to fishermen, boat operators, or fishing industry stakeholders to gauge their satisfaction levels with AI-based fishing crafts and gears. Utilize Likert scale questions to measure satisfaction and apply statistical analysis techniques like descriptive statistics, correlation analysis, or regression analysis to identify any significant relationships between AI adoption and user satisfaction (Agossou, 2021). Have to remember to ensure that the sample sizes are adequate, data collection methods are appropriate, and statistical tests are chosen based on the nature of the data and research questions. The specific statistical analyses will depend on the available data and the specific aspects of AI integration in fishing crafts and gears that you wish to evaluate.

Introduction of Intelligent algorithms in fishing crafts and gears
Intelligent algorithms can be applied mathematically in fishing crafts and gears in various ways to optimize fishing efficiency, sustainability, and resource management.

Fish Finding Algorithms: Intelligent algorithms can be used to analyze sonar data, satellite imagery, or other sensor inputs to detect and locate fish. These algorithms can identify patterns and characteristics indicative of fish presence, helping fishermen determine optimal fishing spots (Gladju et al., 2022).

Gear Optimization: Algorithms can assist in optimizing fishing gear design, such as nets and trawls, by considering factors like mesh size, shape, and material strength. By leveraging mathematical models and simulation techniques, algorithms can help improve the efficiency of gear, reduce bycatch (unwanted species caught), and minimize damage to the marine ecosystem (Lubchenco et al., 2023).

Catch Prediction Models: Machine learning algorithms can be employed to develop catch prediction models. These models analyze historical fishing data, environmental conditions, and other relevant factors to predict fish abundance and behavior. This information enables fishermen

to make informed decisions on when and where to fish, reducing unnecessary fishing effort and improving catch rates (Goethel et al., 2023).

Route Optimization: Algorithms can optimize the fishing vessel's route based on factors such as ocean currents, weather conditions, and fish distribution. By considering these variables, the algorithm can suggest the most efficient and cost-effective path, saving fuel and time while maximizing the catch potential (Cetinbas et al., 2021).

Stock Assessment and Management: Intelligent algorithms can play a crucial role in stock assessment and fisheries management. These algorithms utilize statistical techniques and mathematical models to estimate fish populations, assess their health, and determine sustainable fishing quotas. This information helps regulatory bodies and fishermen make informed decisions to ensure long-term sustainability (Mosallanezhad et al., 2023). It's important to note that the implementation of intelligent algorithms in fishing practices should consider ethical and environmental concerns, with an emphasis on sustainability and responsible fishing practices. Additionally, local regulations and guidelines should be followed to ensure the appropriate and legal use of such algorithms.

Conclusion

Artificial Intelligence (AI) has the potential to revolutionize the fishing industry by improving efficiency, sustainability, and productivity. Techniques like machine learning, computer vision, and robotics can provide real-time data analysis, enabling informed decisions about fishing strategies and resource allocation. AI can also enhance fishing gear design and functionality, enabling precise targeting and reduced bycatch. However, ethical, environmental, and social implications must be considered. Collaboration between fishermen, researchers, policymakers, and technology developers is crucial for promoting responsible AI use. The evolving role of AI in fishing is essential for navigating challenges, preserving fish stocks, and supporting fishermen's livelihoods.

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