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Artificial Intelligence in Maritime Industry

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ABSTRACT

Artificial intelligence (AI) is the emulation of human intellect by computer systems, including learning, self-correction, and reasoning. AI systems are being developed in many areas of maritime industry. They are trained with a specific purpose in mind, such as controlling a ship. AI is changing the face of the maritime industry in three particular ways: by providing partial autonomy to the automatized units, evaluating processes and optimizing them, and forecasting future trends. Taking advantage of these three opportunities is a way to outperform the competition and reach sustainability goals. AI is set to seriously shake up the commercial shipping sector in decades to come, with the autonomous ship as one of the major goals to be achieved. This paper explores the role of AI in the maritime industry.

KEYWORDS: *artificial intelligence, machine learning, AI, generative AI, maritime industry*

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INTRODUCTION

The maritime industry, a colossal network of ships, ports, and intricate logistics and supply chain management, stands as the backbone of global trade. Approximately 90% of global trade is carried by sea, underscoring its critical role in international commerce. This complex web encompasses everything from gargantuan container ships traversing vast oceans to nimble tankers navigating intricate inland waterways [1]. Shipping goods is a fundamental aspect of the globalized economy, and growing customers' expectations worldwide enforce constant optimization in this field.

The maritime industry has always been one of the most critical global trade and commerce sectors, playing a crucial role in transporting goods worldwide, and facilitating the movement of goods and raw materials across the world's oceans. It is regarded as one of the most complex sectors around on a global level. As one of the oldest sectors in the world, the maritime industry has traditionally relied heavily on people and their experience.

The sheer complexity of maritime is increasing at a really rapid rate, so people need this order of magnitude efficiency in order to get anything done. Figure 1 shops how massive a ship can be [2]. One thing that artificial intelligence tools will bring to shipping is enabling the onboarding of professionals with less experience than previously required. Artificial intelligence (AI) refers to the simulation of human intelligence processes by machines, enabling them to learn, reason, and make decisions. AI is now starting to make its way into the maritime industry, with the potential for autonomous systems to be introduced, processes to be made more efficient and safety to be boosted. AI is transforming the maritime industry by enhancing efficiency, safety, and sustainability. AI is helping many industries manage operations and implement improvements. In the maritime industry, crew members and vessels can experience many benefits from implementing AI and machine learning into equipment [3]. Figure 2 shows a symbol of AI [4].

WHAT IS ARTIFICIAL INTELLENCE?

The term "artificial intelligence" (AI) is an umbrella term John McCarthy, a computer scientist, coined in 1955 and defined as "the science and engineering of intelligent machines." It refers to the ability of a computer system to perform human tasks (such as

thinking and learning) that usually can only be accomplished using human intelligence [5]. Typically, AI systems demonstrate at least some of the following human behaviors: planning, learning, reasoning, problem solving, knowledge representation, perception, speech recognition, decision-making, language translation, motion, manipulation, intelligence, and creativity.

The 10 U.S. Code § 2358 define artificial intelligence as [6]:

1. "Any artificial system that performs tasks under varying and unpredictable circumstances without significant human oversight, or that can learn from experience and improve performance when exposed to data sets.
2. An artificial system developed in computer software, physical hardware, or other context that solves tasks requiring human-like perception, cognition, planning, learning, communication, or physical action.
3. An artificial system designed to think or act like a human, including cognitive architectures and neural networks.
4. A set of techniques, including machine learning, that is designed to approximate a cognitive task.
5. An artificial system designed to act rationally, including an intelligent software agent or embodied robot that achieves goals using perception, planning, reasoning, learning, communicating, decision making, and acting."

AI provides tools creating intelligent machines which can behave like humans, think like humans, and make decisions like humans. The main goals of artificial intelligence are [7]:

1. Replicate human intelligence
2. Solve knowledge-intensive tasks
3. Make an intelligent connection of perception and action
4. Build a machine which can perform tasks that requires human intelligence
5. Create some system which can exhibit intelligent behavior, learn new things by itself, demonstrate, explain, and can advise to its user.

AI is not a single technology but a range of computational models and algorithms. The concept of AI is an umbrella term that encompasses many different technologies. AI is not a single technology but a collection of techniques that enables computer systems to perform tasks that would otherwise require human intelligence. The major disciplines in AI include [8]:

- Expert systems
- Fuzzy logic
- Neural networks
- Machine learning (ML)
- Deep learning
- Natural Language Processors (NLP)
- Robots

These computer-based tools or technologies have been used to achieve AI's goals. Each AI tool has its own advantages. Using a combination of these models, rather than a single model, is recommended. Figure 3 shows a typical expert system, while Figure 4 illustrates the AI tools. These tools are gaining momentum across every industry. Analytics can be considered a core AI capability.

GENERATIVE AI

Artificial Intelligence (AI) is increasingly a part of our world and it is rapidly changing our lives. Generative AI (GenAI) is a subset of artificial intelligence that uses generative models to produce text, images, videos, or other forms of data. Generative AI (GenAI) is a term for any type of AI system capable of using generative models to create new forms of humanlike creative content, like text, images, music, audio, video and more. GenAI models include various algorithms able to learn the various patterns and structures of input training data before generating novel outputs with similar characteristics. It is essentially a narrow type and application of the broader artificial intelligence umbrella of technologies. It describes algorithms (such as ChatGPT) that can be used to create new content, including audio, code, images, text, simulations, and videos. It is specifically designed and trained to generate new content. The versatility and potential of GenAI to transform various aspects of business operations make it an attractive investment for companies across industries. GenAI uses neural networks, machine learning, deep learning models, complex algorithms, and large and varied training datasets to produce original content based on user input and how to reason in ways akin to a human brain. The technology is built on AI tools shown in Figure 5 [9]. It uses neural networks to identify the patterns and structures within existing data to generate new and original content.

Generative AI can be thought of as a machine-learning model that is trained to create new data, rather than making a prediction about a specific dataset. Since its inception, the field of machine learning used both discriminative models and generative models, to model and predict data. A generative AI system is constructed by applying unsupervised machine learning or self-supervised

machine learning to a data set. The most common way to train a generative AI model is to use supervised learning. Generative AI can also be trained on the motions of a robotic system to generate new trajectories for motion planning or navigation. Generative AI models are used to power chatbot products such as ChatGPT [10].

Generative AI is transforming nearly all aspects of the pharmaceutical industry, revamping the way companies operate and potentially unlocking billions of dollars in value. The pharmaceutical-operations value chain encompasses sourcing, manufacturing, quality, and the supply chain—and gen AI is expected to improve them all

AI IN MARITIME INDUSTRY

Artificial intelligence is the simulation of human intelligence in machines. The maritime industry is ideal for machine learning algorithms given that huge volumes of data are generated every day in the form of shipping documents, emission information, operating metrics, and other documentation. AI systems can be created to deal with all of these aspects effectively. Chat GPT is one example of an AI-based technology that has the potential to transform the way we think, work, and even interact. Figure 6 shows a seafarer operating a ship with the help of AI [2].

As shown in Figure 7 [11], the maritime industry is increasingly interested in applying advanced AI and ML technologies to address issues related to energy efficiency, predictive maintenance, navigation systems, risk analysis and management, crew resource management, and hazardous material handling. AI systems can process vast amounts of data from various sources, including vessel tracking systems, weather forecasts, maintenance records, and incident reports. By analyzing these data, AI algorithms can identify patterns and correlations that may indicate potential hazards. AI enhances situational awareness by integrating real-time data from multiple sensors and information systems. This comprehensive data analysis allows for the early detection of risks, enabling timely interventions to prevent accidents [11].

APPLICATIONS OF AI IN MARITIME INDUSTRY

Artificial intelligence (AI) is increasingly being integrated into maritime operations to provide real-time decision support to seafarers, enhancing their performance and safety. Key AI applications include risk analysis, crew resource management, hazardous material handling, predictive maintenance, navigation systems, autonomous ships, and environmental monitoring. Below are a few examples of common areas of applications [4,11-13]:

- *Shipbuilding*: When it comes to shipbuilding, AI is initially set to be predominantly used for designs and process optimization. Engineers will use artificial intelligence to help them design ships in the future. Computers can help make this process more efficient by automatically integrating all kinds of requirements and parameters. Generative design also makes it easier to design structures while saving on costs. Figure 8 shows AI in shipbuilding [2].
- *Autonomous Ships:* Autonomous shipping is another rapidly developing field in the maritime industry. Maritime autonomous surface ships are crewless vessels that transport containers or bulk cargo over navigable waters with little or no human interaction. AI can be used to develop autonomous ships that can navigate, dock, and make decisions on their own, increasing safety and efficiency in the industry. The self-driving autonomous ship control systems reduce the likelihood of human error, the most common cause of safety alerts and accidents. Machine learning algorithms can generate moves of the automated machinery, enabling partial autonomy of the units like ships or ports. That makes them less susceptible to human errors and reduces workforce demand, cutting costs as a result. Automatized cargo processes are also faster, enabling the carriers to save a lot of precious time. The shipping companies can automatize the container vehicles, cranes, and other elements that manage the cargo. Automatized vehicles are a stepping stone for the whole logistics sector, and the maritime industry is not an exception.
- *Predictive Analytics:* AI systems can predict future performance based on historical data, allowing for proactive intervention and support. Predictive analytics enables shipping companies to optimize their vessel scheduling. They use the port calls data like destination, arrival time, trajectory, and trip duration provided by the port community systems to manage their trips most efficiently. Machine learning helps them deal with the unpredicted scenarios caused by emergencies and enforced route changes. Since vessel scheduling predictions depend on many input variables, ML is the best way to handle it, contrary to the traditional, rule-dependent algorithms. Predictive modeling enables production and distribution optimization through better throughput, quality, safety, and yield improvements. AI-driven predictive analytics also

play a crucial role in voyage planning. By forecasting potential risks along specific routes, AI systems can recommend safer and more efficient navigation strategies.

- *Collision Detection and Avoidance*: AI systems are essential for real-time collision detection and avoidance, significantly enhancing navigational safety. These systems integrate data from radar, automatic identification systems (AIS), and other advanced sensors to maintain a comprehensive and up-to-date awareness of the vessel's surroundings. By enabling timely and informed decision-making, AI-driven collision avoidance systems help prevent accidents, ensuring the safety of the vessel, its crew, and its cargo. A combination of cameras, thermal imaging, bridge navigation equipment and other installed sensors actively monitors the ship's surroundings to detect potential hazards. AI-based collision avoidance systems analyze radar and AIS data to predict potential hazards and recommend maneuvers. These systems assist human crews by providing an added layer of safety.
- *Insurance:* Artificial intelligence will bring about major changes within the insurance sector. AI drastically cuts down on the amount of work required, speeds up processes, and allows for much more data to be leveraged when calculating premiums than would be possible without the technology. As a result, ships can be assessed in much greater detail. Insurance companies can use the time they have saved to improve their customer service or allocate it to special cases where AI does not prove to be quite as useful.
- *Risk Management:* AI-based risk management systems can analyze data from various sources to identify and mitigate risks in the shipping industry, such as weather, traffic, and piracy. They can identify and mitigate risks in the shipping industry, such as weather, traffic, and piracy. For instance, AI can analyze real-time data from weather sensors and traffic reports to help ships avoid dangerous weather conditions or high-traffic areas. Risk management in maritime transportation involves the systematic identification, assessment, and mitigation of risks associated with maritime operations. Risk assessment is the process of identifying potential hazards, evaluating the likelihood of their occurrence, and assessing the potential impact on human life, property, and the environment. Risk mitigation includes the implementation of strategies and measures to reduce the likelihood and impact of identified risks. This can involve engineering controls, administrative controls, and the use of advanced technologies such as AI for real-time monitoring and predictive analytics. Regular reviews and updates to risk management plans ensure that they remain relevant and effective in addressing emerging challenges.

BENEFITS

A great deal of effort is going into AI solutions in more or less every branch of the maritime industry. The business benefits of artificial intelligence in the maritime industry are undeniable, fueling business growth and making space for development and new investments. AI solution benefits include safer operation, safeguarding yourself in the unlikely event of an accident, gain visibility and transparency between ship and shore . Some advantages include reduced cost, less risk, improved forecasting, faster deliveries through more optimized routes, and more. AI will help ship operators make better decisions. Other benefits of AI in maritime industry include the following [3,12,13]:

- *Reducing Costs*: AI data tracking and insights can identify inefficient resource use and costly operations. Crews can determine strategies to reduce fuel usage, helping cut organization costs. Other processes like more efficient routes and optimized maintenance also cut fuel use, helping vessels reduce their expenses for each trip.
- *Improving Efficiency*: From streamlining routes and port access to automated navigation, ships leveraging AI and machine learning can help crews maintain and improve efficiency standards. With data collecting in real-time, crew members can react quickly to changing conditions and use historical data to take more proactive approaches to handle problems more efficiently.
- *Automation:* The opportunity to automate processes, and in turn reduce the associated risks for workers and improve the available data, is one of the main motivating factors behind the development of robotic AI applications in particular. AI is tied in closely to robotics, as many AI systems have robotic elements that allow for tasks to be performed autonomously. Robots are set to work alongside vehicles to unpack shipping containers and complete other tasks.
- *Eliminating Human Error:* Human error remains a significant factor in maritime accidents. In any industry, individuals make mistakes, especially in data collection and analytics. Individuals can easily misread numbers, causing them to accidentally omit or incorrectly record information about essential operations. With AI

data tracking, you can ensure your information is accurate, so you can ensure changes in metrics are due to different conditions. In the maritime industry, the collaboration between artificial intelligence and human factors paves the way for continuous improvement, efficiency, and safety.

- *Predictive Maintenance*: Managing, controlling, and executing repair and maintenance work requires proper time management and planning according to the operating conditions of the ship. AI can predict when equipment and ships will need maintenance, helping reduce downtime and save costs. The basic level of monitoring will evolve into predictive maintenance in the future. Predictive maintenance is crucial for the ships themselves due to the nature of the shipping industry. The shipping companies and port management companies use machine learning algorithms for the purposes of predictive maintenance. Regularly scheduled maintenance is not an effective method for such large systems being subject to inspection. Artificial intelligence allows the carriers to react right on time instead of relying on traditional preventive measures and therefore extend machine life. Predictive maintenance powered by AI is revolutionizing the maritime industry by enabling a shift from reactive to proactive maintenance strategies.
- *Validation:* Testing autonomous systems at sea is much more complex than the equivalent process within the automotive industry. There is a lot of work involved in testing AI applications on a ship. It is harder to access systems out at sea. Plus, the costs are higher and there is more chance of a serious incident occurring. Unexpected situations often arise at sea and in port settings.
- *Cargo Optimization:* AI can be used to optimize cargo loading and unloading, by analyzing data on cargo weight and volume, vessel stability, and port infrastructure. For example, AI can analyze real-time data on cargo volumes and vessel stability to optimize cargo distribution, preventing accidents and increasing efficiency.
- *Supply Chain Management:* AI can help the industry optimize shipping processes, from order management to logistics and inventory management. For example, AI can analyze data on shipping routes, cargo volume, and delivery schedules to optimize the supply chain, reducing delays and increasing efficiency.

CHALLENGES

There are pros and cons to everything, and AI is no different. Despite the benefits, the fear surrounding more intelligent solutions can often be a controversial topic. It will be really interesting to coordinate the interaction between AI and man since the decisions made by artificial intelligence are sometimes hard to follow. As AI increases in popularity on ships and vessels, many crew members are concerned they will lose their jobs as computers can perform more and more. Other challenges include the following [12-15]:

- *High Initial Costs:* The financial cost of upgrading maritime infrastructure to support AI integration is a key hurdle. While large shipping companies with extensive fleets may have the resources to invest in cutting-edge technologies, smaller operators may struggle to afford the necessary upgrades. The implementation of AI architecture can be expensive. Developing and deploying AI systems in the maritime industry involves significant capital investment. This includes the cost of hardware, software, sensors, and maintenance, which can be prohibitive for smaller operators.
- *Data Integration:* Integrating new tools that use AI with the company's and ship's existing IT systems can be technically challenging and require significant resources, infrastructure reconfiguration, and the hiring of skilled professionals who understand both the technical aspects of AI and its application in specific maritime contexts. AI needs data and the more the better. Companies looking to develop AI technology need to have enough data at their disposal. In the case of projects that span multiple supply chains and involve several service providers, all parties have to be willing to provide data and interfaces. Data is collected and exchanged in real time on an unprecedented scale. Successful integration of AI-enhanced navigation systems requires not only technological advancements but also a shift in mindset among seafarers and maritime operators.
- *Data Quality*: The importance of data quality and availability cannot be overlooked, as predictive models are only as good as the data on which they are based. When building and implementing artificial intelligence solutions, the importance of data quality cannot be overstated, especially in the context of safety-critical industries like maritime. The industry needs to be prepared for data fragmentation given that the maritime industry is a complex ecosystem with various stakeholders, such as vessel operators, port authorities, and logistics providers, each using different data systems and standards. The data that is fed into an AI system will shape the way it functions, and in

industries where even small errors can have catastrophic consequences, the data being used must be of the highest quality. Data quality checks are essential to ensure that the data is clean, consistent, and free from errors or biases.

- *Privacy:* AI implementation entails not only technical but also ethical considerations. Many AI systems rely on input from cameras and real-time footage, raising concerns about crew privacy. Owners must have a clear and transparent strategy regarding predicted benefits, especially for the crew. Additionally, robust procedures must be in place for handling AI data to ensure privacy and compliance with relevant legislation.
- *Fairness:* Fairness in AI operations is another ethical challenge. AI systems must be designed and trained to operate without introducing biases that could lead to unfair or discriminatory outcomes. Implementing robust bias detection and mitigation strategies is essential to ensure that AI systems operate fairly and equitably.
- *Fear of Job Replacement:* When we hear of "artificial intelligence," images of workforces being replaced by machines come to mind, even more so if robots and autonomous vehicles are involved. This underlying fear can cause employees to feel anxious and concerned. In the worst case scenario, they may sabotage AI projects or be reluctant to even start working with this technology. The ability to address these worries through open communication and training is key if AI projects are to prove successful. There are concerns that computers and technology will have an impact on the type of jobs being created or replaced. The kind of work is likely to shift when AI is fully adopted. Workers will need to spend time understanding and learning new technology in their workplace. We still are going to need great engineers and great surveyors. Figure 9 depicts a surveyor attending to a ship with the help of AI [2].
- *Sustainability*: AI is playing an increasingly important role in promoting sustainability in the maritime industry by enhancing the efficiency, safety, and sustainability of the sector. The world is not very likely to step away from globalized trade. Thus, it is essential to make the shipping industry greener. Its significant impact on the environment due to CO2 emissions and pollution can be reduced with machine learning algorithms that suggest the most sustainable usage of resources, the least fuel-consuming routes, and automated container configuration that brings space management to the next level.
- *Operational Complexity*: There is complexity in the integration with existing systems. Many legacy systems on vessels are not built to support AI-driven applications, making it challenging to integrate modern technology into older fleets. This incompatibility can lead to high costs in upgrading or retrofitting existing equipment for AI compatibility.
- *Skill Gaps*: The lack of skilled personnel can derail projects and plans. The maritime industry faces a shortage of workers skilled in AI, data science, and cybersecurity. Effective implementation and maintenance of AI systems require specialized knowledge, and the industry is still building its talent pool to support these advanced technologies.
- *Safety:* Safety in maritime transportation refers to the measures and practices implemented to prevent accidents and incidents that could endanger human life, damage property, or harm the marine environment. Ensuring safety in maritime transportation is crucial. The International Maritime Organization (IMO) has established various regulations and standards aimed at enhancing maritime safety, reflecting the industry's commitment to minimizing risks and promoting a safety culture. Maintaining safety is vital for economic stability, as accidents and disruptions can result in significant financial losses and impede global trade. There is a growing interest in leveraging advanced technologies, particularly artificial intelligence (AI), to enhance maritime safety and risk management. Shell, a leading global energy company, has implemented AI technologies to enhance navigational safety for its fleet.
- *Cybersecurity*: Given that AI systems are increasingly connected, they are also susceptible to cybersecurity threats. Vulnerabilities in the system could allow unauthorized access or tampering, leading to the manipulation of cargo segregation settings. Cybersecurity is one of the major digital challenges being faced in modern society. With more reliance on networking and digitalization comes a greater risk of cyber attacks. And so it is vital that cybersecurity is always given due care and attention as part of AI projects. Cyber attacks can put individual ships and processes out of action and they can affect entire ports and soon bring the entire logistics chain to a standstill. AI-based security systems can monitor the digital flow of data and respond quickly if they pick up on any anomalies.

CONCLUSION

AI has revolutionized the maritime industry, introducing unprecedented possibilities and transforming traditional practices. AI is already being applied in the marine sector for several purposes, including fleet management, predictive maintenance, cargo optimization, risk management, and supply chain management. AI systems are increasingly being integrated into maritime operations to provide real-time decision support to crew members. Work is underway to introduce AI technology across the board, but we are still a long way away from widespread application. To stay competitive and sustainable, the maritime sector will need to adjust to this new technology. Individuals interested in working in the maritime industry advance their careers by learning more about the AI technology used on ships.

The number of successful case studies and examples will continue to grow as we look toward the future, for the integration of AI in the shipping industry. As we sail into the future, the waves of innovation driven by artificial intelligence (AI) and machine learning (ML) are set to change the marine industry in ways we can only begin to imagine. The future of AI in maritime operations is poised to bring transformative advancements that will further enhance safety, efficiency, and sustainability. The maritime industry has a bright future, and AI will help get it there. More information on artificial intelligence in the maritime industry is available from the books in [16-19] and the following related journals:

- The AI Journal
- AI Magazine
- Energy and AI
- Journal of Intelligence

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Figure 1 How massive a ship can be [2].

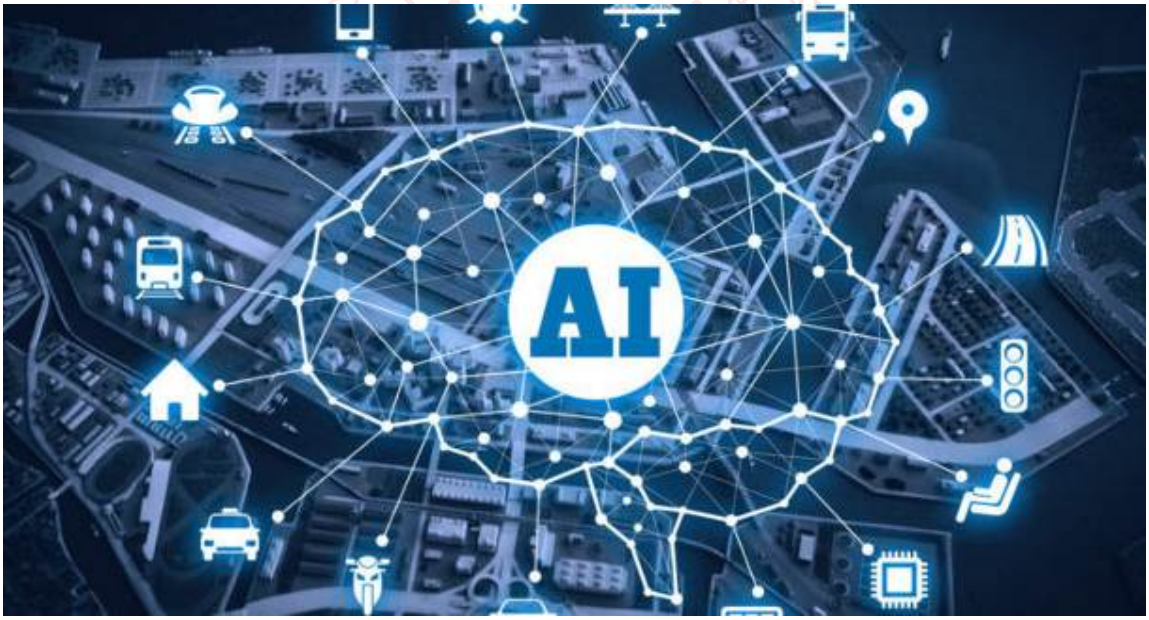

Figure 2 A symbol of AI [4].

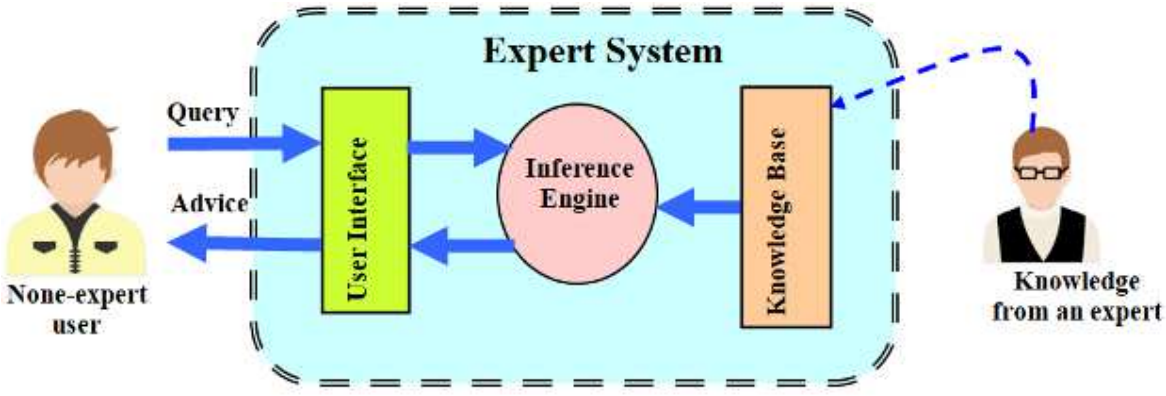

Figure 3 A typical expert system.

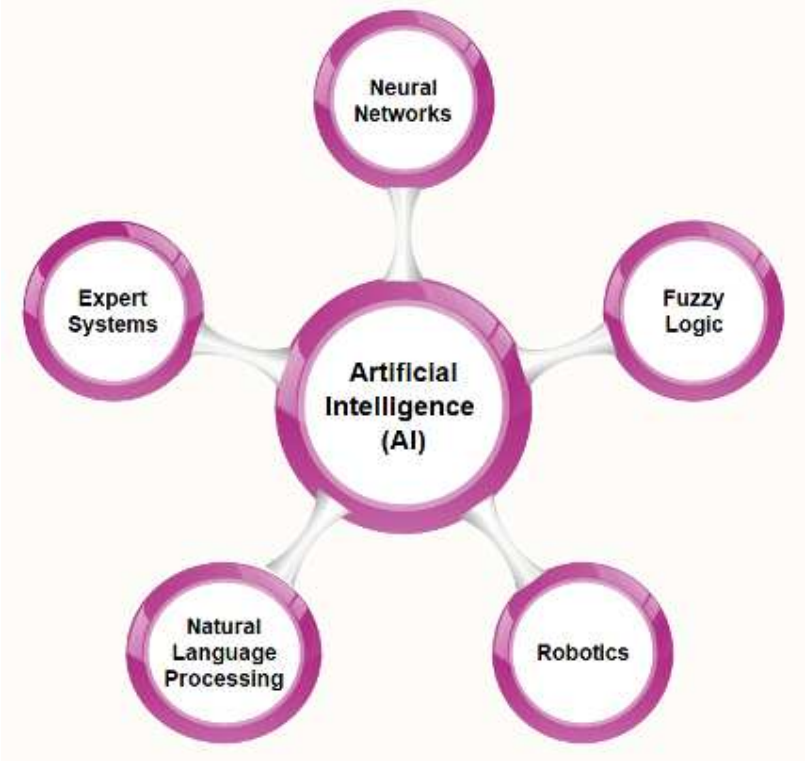

Figure 4 AI tools.

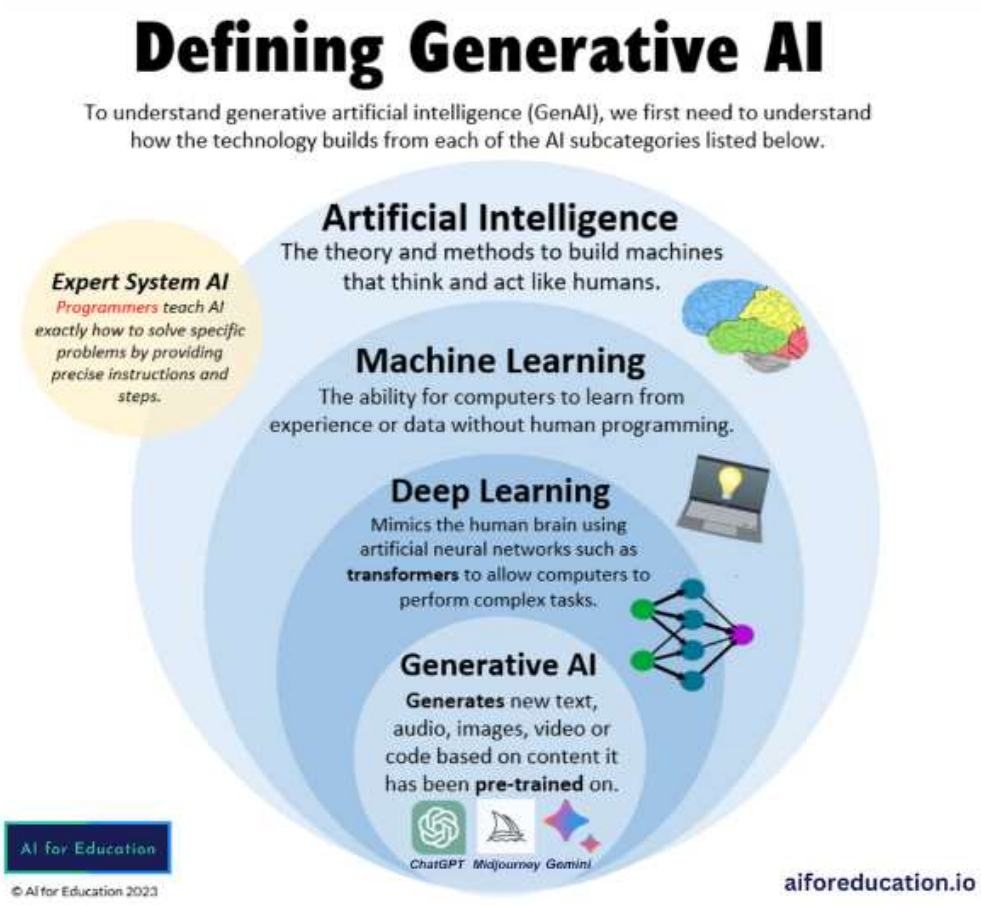

Figure 5 GenAI built on AI tools listed above [9].

Figure 6 A seafarer operating a ship with the help of AI [2].

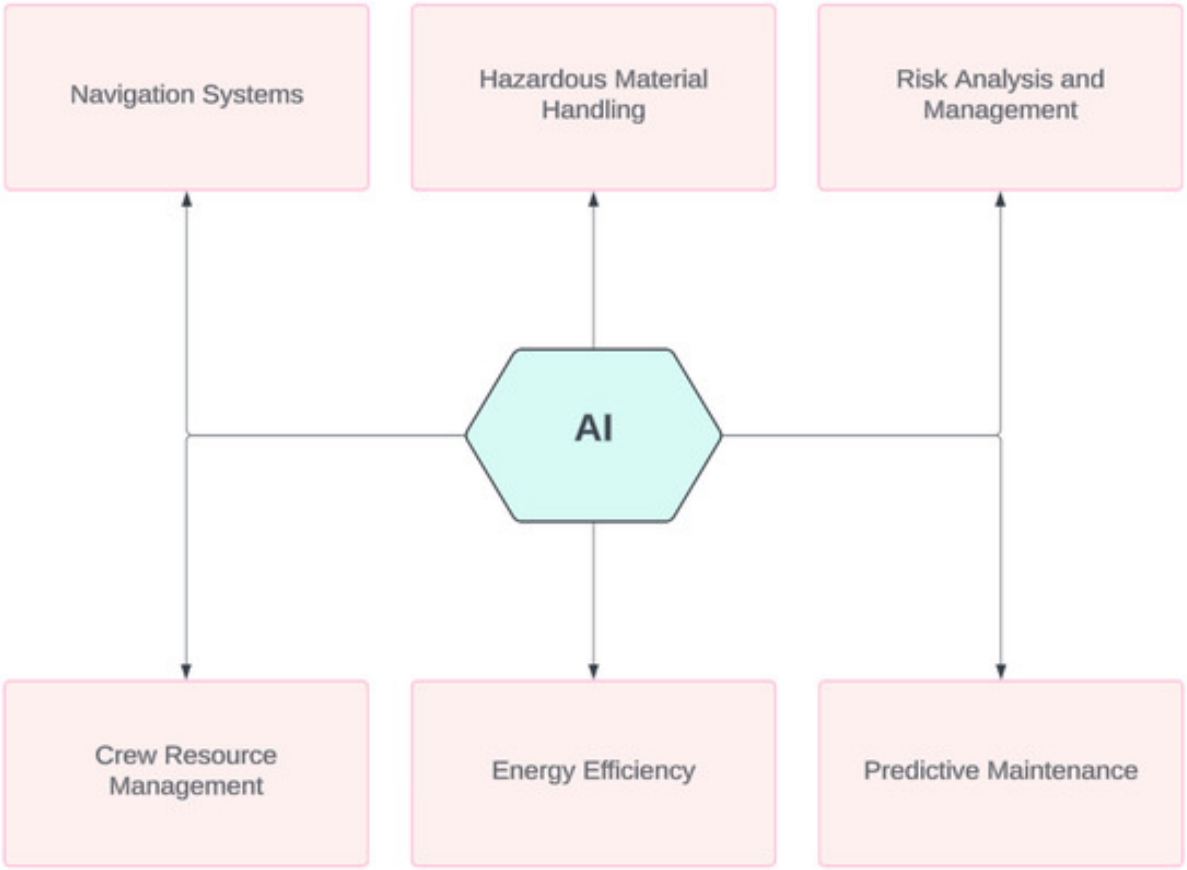

Figure 7 Potential AI implementations in maritime transport systems [11].

Figure 8 AI in shipbuilding [2].

Figure 9 A surveyor attending to a ship with the help of AI [2].