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Artificial Intelligence (Ai): Viable Solution for Marine Eco-System

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Abstract

Our seas cover 71% of our earth's surface. Seas always play a fundamental role in captivating carbon dioxide from the atmosphere, regulating climate, and providing home for marine living. However, Ocean and it's contained are under threat from pollution, accident, and rising temperatures since recent development of civilization. Artificial Intelligence (AI) is considering as an effective and useful tools to monitoring, managing and decision making to optimize maritime resource extraction, maintain ocean health and industry. AI algorithms and such technology scientists and researchers can monitor and model Ocean environment with extraordinary accuracy, tracking changes over time and space that are important to the health and existence of marine life and even earth. In future, AI will facilitate to analysis of huge datasets obtained from tagging and tracking devices, underwater cameras, or remote sensing technologies, providing new insights into marine species history, seabed exploration, and many more research subjects of related industry. Now, the meticulous surveillance of ocean health is a massive task where AI and Machine Learning (ML) play a crucial role than before. AI-powered sensors, satellite imagery, and projecting models are supreme in furnishing scientists with the tools essential for real-time tracking, observing and early recognition of environmental matters, vessel traffic, surveillance, extending their observational reach and logical capabilities away from traditional methodologies. AI will lead and dictate the future to preserve the ocean and its resources for the mankind. It is an analytical study to evaluate the AI as viable solution marine eco-system.

Keywords
AI, ML, ocean health, ecosystem,

1. Introduction

Our earth has been designed by Almighty for living of life. Seas cover around three-fourth of earth surface, and which absorb unwanted temperature of this planet (Quora 2024; AI World School 2023). Geo-scientist discovered that, the earth formed around 4.5 billion years ago with a red-hot and molten mass. After that, it has cooled and water vapor in the atmosphere has condensed and has fallen as rain. Ultimately, rainwater has covered the low-lying areas of the earth's surface to form seas. On the other hand, plate tectonics play a major role to shaping our planet's surface. The movement of tectonic plates has created basins, which are then filled with water, and eventually leading to formation of seas (Doubtnut 2024). Earth is the home for all living soul. The presence of seas is crucial for life and that is the mystery of creation. Moreover, seas play a fundamental role in regulating the global climate by ensuring habitation for a diverse array of marine life as well as influencing weather patterns. Again, seas support a wide variety of ecosystems, like coral reefs, deep-sea vent, deep sea mountain, terrain, etc. and which are home to countless species of plants, fish and animals. However, these ecosystems contribute to the biodiversity of the earth. Actually, the future of humanity and civilization is extremely reliant on the seas. The seas are always not only important for our planet but also for human populations. The seas drive key global systems that affect us on land (Österblom et al. 2017). Sea exploration and maritime action degrade marine environment and entire eco-system and that mainly caused by human activity like pollution, overfishing, dumping, many economic activities, over exploitation, shipping, other misuse, etc. (Juda et al. 2001; Heilig 2017).

Technology is the application of scientific knowledge to the practical for human life. Technology encompasses machinery, tools, ideas and techniques development. Again, innovation is more than a buzzword or exhortation. 'Innovation is a new thing or a new method of doing something. (Hardy 1982; Thiel 2005). However, technological development is the overall of invention, innovation and diffusion of technology or process (National Geographic 2024; Sinay AI 2024). Smart is something used as a mnemonic device to establish criteria for effective goal-setting and objective development. Anything SMART means it is Specific, Measurable, Assignable, Realistic, and Time-bound. Usual meaning of smart technology is to the incorporation of computing and telecommunication technology into other technologies that did not before have such capabilities.[1] Smart technologies naturally more energy efficient, timelier, easier, accountable in the functions they perform, and more powerful when synchronized or collective. Anything that has to do with inventions or innovations is related to technological advancement. Automation and technological development made the job of industrial operators easier, faster, smarter in terms of physical efforts, but at the same time more complex and challenging, in terms of cognitive and mental efforts. AI is the generic term for intelligence displayed by machines, especially computer systems. (Copeland 2004; McCorduck 2004). AI encompasses a wide range of techniques and methods to enable machines to learn from experience, reason, and make decisions based on data. AI has been applied to fields including computers, electricity, steam or IC engines, and even academia (Dwyer and Hopwood 2010; Collins Dictionary 2023). Today, AI is a versatile technology with a wide range of uses like credit scoring, e-banking, e-healthcare, e-commerce, e-agriculture, e-business, automation, industrial robots, language translation, image recognition, decision-making, and many other fields. AI enables technology such as machines that can observe, comprehend, act, and learn scientific disciplines. Machine Learning (ML)'s as a branch of AI, uses data-driven algorithms to enhance the precision and functionality of AI systems. So, it is a division of AI which focusing on developing algorithms that allows computers to learn patterns from data without being openly programmed. Again, Deep Learning (DL) is a subfield of ML which utilizes artificial neural networks (ANNs) that inspired by the human brain's structure to process and learn from huge amounts of data. ML, DL, DS and DM are the interconnected fields that complement and balanced each other to drive and compel AI's advancements and innovations (Hossain 2023a, 2023b).

The marine eco-system is undergoing a significant transformation powered by AI, which come as a game-changer. AI revolutionized entire marine activities in general and in maritime sector in particular to resources management, maintenance, decisions making, increase efficiency, safety, security and sustainability (Frost 2022; Marine Technology News 2024; AI Tools Explorer 2024). It encompasses a broad range of applications in marine activities which included ocean monitoring system, ocean surveillance, vessel operation, risk management, ensuring safety, etc. An AI-based satellite monitoring and surveillance tool called Global Plastic Watch is detecting and analyzing plastic waste locations and helping to reduce plastic pollution, mostly in the ocean (Allen Coral Atlas 2024; Lentell 2024). Additionally, it assists in determining who and where improperly disposes of plastic garbage, which ends up in the ocean. AI and ML are also being used to identify environmental problems and disaster early warning indicators. It can also use successfully to detect and analysis of natural pandemics, earthquakes, landslides, heavy rainfall, long-term water supply vulnerability, tipping-points of ecosystem collapse, cyanobacterial bloom outbreaks, droughts and many more (Gounaridis et al. 2016; Duda 2005). Today efficiency, real-time data, effective planning and maintenance, cost reduction, and sustainability in maritime sector are an urgent need. This reviewed paper will evaluate the AI as smart solution for safe marine life, suitable marine activities, useful sea exploration, and ocean health elaborately including the concern issues like ocean observations and surveillance, the application of AI to remote sensing satellites, smart sensors, intelligent underwater robots, vessel tracking, etc. This paper will also encompass the recent development of AI and related useful devices, relevant effective research, and their effective uses (Tsilimigkas et al. 2017; Alexandrakis et al. 2015; Thiel 2005).

2. Literature Review and Methodology

AI is gradually transforming the conventional operational process of the marine activities and maritime industry into self-govern system. Therefore, the amount of research on the application of AI has increased significantly since 2012. This transformation is reshaping and converting the entire marine activities and providing new opportunities to progress productivity, efficiency, user friendly and sustainability along with new challenges.[2] Studies on AI and its application in maritime sector are not usual and that has created a gap in the academic literature due to the importance of AI in maritime exploration, operations, surveillance, preservation, management, safety and security issues. AI-power maritime exploration and surveillance plays a critical role in resource extraction, safeguarding coastal borders, ensuring maritime safety, security and combating all sort of illicit activities at sea. However, traditional exploration and surveillance methods face numerous challenges, including limited coverage, resource constraints and the

complexity of maritime environments. In recent years, the utilization of AI, ML, DS, Big data and other smart technologies has emerged as a promising and very useful approach to enhance maritime exploration and surveillance capabilities. With the time strains and pressures is increasing in the coastal zones due to population growth, increase in coastal economy and continuous expansion of human activities. Again, it becomes more intense by the effects of climate change.[3]

AI offer viable and sustainable solutions to some of these challenges. Future researchers need to consider and include AI and other aspects of smart technology in the maritime domain more widely with contemporary development and examples for better understanding of the specific objective and goal setting. The research and exploration of seas has begun centuries ago, with the aim of business and military function. But now, it's an organized discipline and significant branch of earth sciences.[4] However, from the ancient, human have studied, used and exploited marine resources of seas and maritime research as well as ocean science and engineering has become an inseparable literature in modern age.[5] This paper aims to identify and analyze the use of AI for successful monitoring, management and preservation of ocean and it's contained. The methodology follows[6], a holistic analytical procedure that include the analysis of use of AI in maritime sector, as well as consequences and implementation of AI to assess the interactions between future land and sea uses. Specific effort has been taken to evaluate how AI, ML and other DS driven technology are reshaping and optimizing conventional practices, improving operational and managerial performance in 21st century.[7] Author of this paper has been taken effort to evaluate the use AI to preservation of ocean including its contain and highlighting its potential benefits and future directions and use of AI-power solution of coastal maritime exploration, surveillance, ocean health conservation, safety of maritime industry along with improving threat detection, tracking and protect maritime environments as well as optimize maritime resources extraction. Prospect and challenges due to inclusion of AI will also be high-lighted consequently. This investigative study will help to find out the AI solutions for maritime sector and the way to more committed, intelligent, environment friendly and flexible maritime ecosystem.

2.1 Marine Coastal Ecosystem

Marine coastal ecosystem may be defined as a marine ecosystem and that occurs during the land meets the ocean. It includes different types of marine habitats with their own characteristics and species composition. (Österblom et al. 2017). Those are characterized by high levels of biodiversity and productivity. As we know that around 71% of Earth's surface is made up of marine waters, which also offer 97% of the planet's water and 90% of its livable space. (Hardy 1982; Thiel 2005). Depending on the coastal features and depth of the water, marine habitats can be classified into several zones. Coastal zones play a significant role to the human society and its development. They have great environmental, economic, social, cultural and recreational importance. They are considered among the most productive, exploited, inhabited and threatened areas due to their characteristics. (Juda et al. 2001; Heilig 2017). Moreover, many social, economic and environmental reasons, they led people to the coast where the environmental conditions like climate, natural environment, etc. and those are qualitatively better. Again, tourism growth is a key factor of the rapid expansion of built-up areas along the coasts. (Sutari and Rao 2014, Österblom et al. 2017, Gounaridis et al. 2016). In addition to the socioeconomic benefits, coastal ecosystems also contribute to maintaining global biodiversity.

Coastal landscape and ecosystems are under severe pressure due to their environmental sensitivity, coastal people activity and uses concentration. Increasing populations in the coastal zone, in addition with the expansion of the economic activities, those threaten even more the environmental and the social coherence of coastal zones. Those pressures cause many miscellaneous social, economic and environmental impacts like landscape degradation, land use conflicts, degradation of natural and cultural heritage properties, land waste, coastal erosion, etc. These pressures, enhanced by the effects of climate change and natural hazards, are compromising the viability, sustainability and conservation of coastal resources and increase socioeconomic risks. However, threats to the coastal environment arise from natural hazards and the main triggering factor is the human-made innervations. There are two major types of conflicts arises in the coastal zone namely conflicts among human activities and conflicts between human and environment. The importance of coastal zone has reflected by the use and benefitted by most of the coastal population and their economic activities in all maritime country like Bangladesh, Singapore, Indonesia, India, Britain, Japan or United States (Österblom et al. 2017; Heilig 2017).

2.2 Use of AI for Healthy Ocean

AI united with promising ML or other smart techniques as known from computer science is largely affecting various aspects of many fields like science, technology, industry, agriculture, business and even our day-to-day life. AI gives marine scientists the ability to fully explore a new area of marine research. Scientists are using AI to help them tackle several issues, from plastic waste to climate change. Scientists are using AI to gather vast amounts of ocean data and find fresh insights to produce better solutions. (Hossain 2023b; Khandakar 2023b). The oceans give us several advantages, including the provision of minerals, gas, and oil. AI has the capacity to effectively harvest energy resources, create new medications, stop climate change, preserve fish, and identify endangered species (Doubtnut 2024). At present, autonomous ships is monitoring the ocean, AI-driven satellite data analysis, passive acoustics or remote sensing (Tsilimigkas et al. 2017). and other applications of environmental monitoring are making use of ML. Marine ecosystems and coastal communities can suffer greatly from oceanic events. AI can assist in the forecasting of wind, wave, and cyclone activity. AI systems can forecast natural disasters like storms, cyclone and tsunamis, providing communities with extra time to prepare and perhaps even avert needless loss of marine life.

2.3 AI Use for Explore the Ocean

In the current research it has discover that, around 95% of the oceans remain as unexplored. In order to explore, comprehend, and find those parts of the oceans and maritime industries that are physically inaccessible to humans, scientist and researchers are now adopting AI to explore those effectively (Hossain 2023c; Guan 2021). Now, scientist and researchers use AI algorithms, ML and other smart investigative tools to record data and useful information from underwater marine vehicles, robots and camera systems for exploration, monitor, collection and assessment. Now, AI helps in detection and identification new marine animal, plant, living species and mineral deep under the sea. (Cova et al. 2022; Batra et al. 2021). Today AI and other smart technology are helping to discovering and collecting data about many living species and non-living substances. Those data are very beneficial for food, medical and industrial applications.[8]KAIKO is a top-tier remotely operated vehicle (ROV) with exceptional mobility and a focus on heavy lifting. It was invented and built by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) for exploration of the deep sea. The most recent iteration of this ROV, the 4th generation Mk-IV, has undergone multiple upgrades and is primarily meant for labor-intensive deep sea and marine resource surveys. (Li et al. 2018; Hossain 2023d). At a depth of 10911 meters in the Mariana Trench, the first ROV KAIKO captured benthic animals like Hirondellea gigas and found hydrothermal vent organisms in the Indian Ocean.

An underwater crab with six legs, created to scan and check submerged facilities like offshore oil and gas rigs off the Korean Peninsula, was unveiled by the Korean Institute of Ocean Science and Technology. Their creation, Crabster, is a robot with AI that works underwater to repair undersea structures, like gas or oil pipelines or rig. The Crabster CR200 seabed exploration technology provides a substitute for propeller-based explorers for researchers and industry conducting underwater activities. It presents an opportunity to increase the efficiency of oil rig inspections and reduce the chance of mishaps or infrastructure damage for the offshore sector. The Crabster's primary reasoning is that, like its real-world counterparts, it will be well-equipped to withstand inclement weather. The Crabster can move with enormous force, unlike ROVs and AUVs, which become unstable in strong tidal situations.

2.4 AI Use for Collect Large Computational Data on Marine Species

Big data and AI work together to enable advanced analytics and intelligent decision-making. Today AI algorithms handle large datasets efficiently through various strategies for example utilizing parallel processing enables algorithms to divide tasks among multiple processors speeding up computation. Sampling methods like mini-batch gradient descent, process subsets of data, are reducing memory requirements. AI technologies are being used by modern marine researchers to collect vast amounts of data on the ocean environment, including temperature, a variety of marine life, earthquakes, tsunamis, data about unknown minerals, and many other things.[9] Those important data that cover the entire oceans can prove to be very useful for insights into pH changes, identify marine species and patterns,[10] fish stocks information, sea plants, mineral, etc. The next stage involves integrating the AI into a robotic system to enhance our comprehension of the world's waters. Scientists and researchers, including one from India, have created an AI tool that can automatically identify minute marine organisms at the species level. The study, which was published in the journal Marine Micropaleontology, reveals that the AI software is specifically capable of detecting six species of foraminifera, or forams creatures that have been common in Earth's oceans for over 100 million years. An AI program created by North Carolina State University researchers is capable of identifying tiny or marine creatures. Implementing AI and Big Data in commercial, research and business operations can significantly enhance

efficiency, providing insights derived from complex data analysis that human capabilities alone cannot match(Cova et al. 2022; Batra et al. 2021).

2.5 AI Help to Reduce Plastic Pollution

Oceans and marine life are being severely harmed by plastic pollution. Scientists and researchers, estimate that each year, the annual death toll from plastic waste is approximately one million seabirds and 100,000 marine species. Ecosystems and human health are seriously threatened by plastic pollution, which has become a major worldwide environmental catastrophe. However, technological developments in AI present novel opportunities to address plastic waste and encourage environmentally friendly building methods. (National Geographic 2024; Sinay AI 2024). Scientists and researchers could gather more data and analytics to gain deeper insights with the help of ML models. (Allen Coral Atlas 2024). AI is being used to develop better-informed methods to lessen ocean plastic pollution. AI can offer significant insights into the sustainability of diverse material possibilities through the analysis of multiple parameters, including resource consumption, emissions, and waste generation. Using recycled plastic in building can be done sustainably with the help of AI-controlled 3D printing technologies. Now, the 3D printers can streamline the printing process and guarantee the correct usage of recycled plastic resources by integrating AI and ML algorithms.
Waste management in the construction sector is being revolutionized using AI sensors and data analytics. Construction organizations can reduce the environmental impact of plastic waste by implementing specific measures and keeping a close eye on it. In the context of reducing plastic waste, AI technology has the capacity to evaluate and interpret enormous volumes of construction data, enabling data-driven decision making. To combat plastic waste and advance sustainable practices, the construction industry has a lot of potential when it comes to integrating AI and other smart technologies. Microsoft and Sustainable Coastline, a Non-Profit-Org (NPO) with headquarters in New Zealand, are collaborating to repair coastal habitats. AI is being used to identify the origins, reasons, and remedies for coastal pollution and it will continue further (Frost 2022).

2.6 AI Help to Save Marine Life

We must be conscious of the various dangers that our oceans confront. The undersea realm needs adequate protection from plastic waste and coral bleaching. Marine life is negatively impacted by climate change in addition to terrestrial animal and plant species. Numerous aquatic species are at danger of going extinct. These days, AI has potential fixes. AI methods are being used by scientists to monitor and safeguard mammals and marine life. AI has the potential to reduce illicit poaching. Today, the tedious process of figuring out how proteins fold themselves into origami like forms inside cells has been completely transformed by the AI tool AlphaFold of UK. (Hossain 2023a; Khandakar 2023c) . Previously, it used to be possible to take months or even years to determine the structure of a single protein. AlphaFold has released 200 million protein structures expected for a calendar year. In the last 60 years, the scientists and researchers has been using advanced experimental methods to determine the structures of over 180,000 proteins in atomic detail. This work has already improved our understanding of many fundamental processes in health and disease (Copeland 2004; Batra et al. 2021). Through the provision of shared data portal and automatic species identification, Flukebook.org is an online research platform in Europe, powered by AI that assists conservationists in their study and protection of whales and dolphins. A joint effort between Queens College and Columbia University, OOICloud offers an AI-powered platform that allows scientists, oceanographers, and conservationists to access vast amounts of data for ocean research and management.

AI and ML are promising development in the field of marine conservation as technology advances further. We may strive toward a future in which our oceans serve as a thriving, healthy ecosystem for all life on Earth rather than only serving as a source of inspiration for scuba divers by utilizing artificial intelligence. It can be labor-intensive and ineffective to manually monitor large oceanic areas.[11]Researchers and conservationists can examine underwater photos with AI's assistance. Innumerable underwater images and videos can be successfully scanned by sophisticated algorithms to identify and measure marine animals, assess the health of the coral, and spot any irregularities. Researchers can get real-time data collection with AI's assistance. AUVs and sensors with AI capabilities can keep an eye on contaminants, pH levels, and water temperature in addition to providing information about the general health of the marine ecosystem. Artificial Intelligence can help detect and monitor plastic. Large areas of floating plastic garbage can be found and tracked using satellites and AI. AI can help with automated cleanup as well. AI-driven robots can be created to gather plastic debris from the ocean on their own, providing a cleaner home for marine life. (McCorduck 2004).

2.7 AI Help to Save Coral Reefs

Over 25% of marine species finds a home in coral reefs, which are a rich environment that also offers numerous advantages to people. The condition of coral reefs is continuously declining because of pollution and other human activities. Scientists are using AI to monitor and restore coral reefs. AI has demonstrated potential in numerous initiatives, including the mapping of sea-grass meadows from space and the discovery of undiscovered reefs that may contain heat-resistant coral. AI has proven to be helpful in recent times to researchers in locating previously undiscovered reefs that feature corals poised to survive despite warmer waters. Nearly all the heat trapped in the atmosphere by the trillion tons of greenhouse gases that humans have released is absorbed by the oceans. They discovered AI is helpful in identifying environmental conditions that reefs will tolerate as the oceans warm. AI-based image identification algorithms are being used in coral reef mapping to examine hundreds of underwater photos. These algorithms enable the construction of precise maps of the composition and health of reefs by differentiating between live coral, dead coral, and non-coral substrates. One prominent example is the Allen Coral Atlas, which combines satellite data and field observations with ML techniques to map and monitor the world's coral reefs at a never-before-seen scale. (Hardy 1982). Project CORai is an AI-powered solution to monitor sea life around coral reefs in the Philippines. Using a live video feed, Google and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) have collaborated on another research that uses computer vision detection models to identify harmful COTS outbreaks. (Lentell 2024).

2.8 AI Use for Sustainable Fishing

The illicit seafood trade is expanding quickly, but global fish populations are rapidly declining. Researchers are using AI to help tackle this issue and guarantee effective fisheries and aquaculture management. The marine species are seriously threatened by both illegal fishing and human influence. Via the analysis of satellite imagery, AI and ML can assist in the monitoring of fishing activity. AI has the capability to instantly identify illicit fishing activity, enabling prompt action from the authorities. AI can be used to track and identify marine creatures (Gounaridis et al. 2016). AI can help scientists identify and monitor targeted marine species, enabling them to learn more about the species' breeding patterns, migration patterns, and other possible dangers. Presently, scientists employ artificial intelligence's remarkable capability of pattern recognition to comb through satellite imagery and map the masses of plastic debris endangering our oceans in real time. (Hossain 2023b). AI can save the oceans by offering vital insights. Organizations from many sectors are collaborating closely to use AI technology to collect pertinent data and turn it into goals that can be implemented.

There is a threat of extinction for many types of aquatic life. AI can forecast the degree of overfishing threat in addition to monitoring poaching actions. In addition to reducing ocean damage and maximizing fishing efforts, AI techniques can assist fishermen in locating and predicting the best fishing zones. Oceanographers, scientists, and conservationists can access big data for ocean research and conservation through the Columbia University and Queens College partnership project OOICloud, which is an AI-enabled platform. The analysis and provision of critical information from maritime data is the primary role of AI in most of the use cases previously stated.[12]With the insights provided by AI techniques, data conservationists may monitor species populations, determine the effects of human activities, and contribute to the preservation of endangered species. Astute researchers can use computational sustainability to examine vast amounts of data acquired from these instruments to forecast, comprehend aquatic life abnormalities, and arrive at well-informed conclusions. Additionally, by reducing illicit fishing and poaching, this data can support the preservation of the seas' delicate natural balance.

2.9 AI Helps to Underwater Exploration

The ocean bed is not only home for plants and species but also home for battery metals or minerals like lithium, cobalt, copper, manganese, etc. which are critical for the planet’s clean energy transition. Autonomous, AI-driven submersibles can minimize the risks to human lives from deep-sea exploration and would allow faster mapping of ocean floors. Autonomous Unmanned Underwater Vehicle (AUV) has made a real revolution in the field of ocean research and deep-sea exploration by the introduction of AI and smart technology (National Geographic 2024). The trends in the development of AUV to explore deep water beneath the sea has evolved and changed since its inception successfully. During the last two decades AUV were transformed seriously, costly and exclusively equipment for ocean academic research into a tool or devices for solving a wide range of issues in many fields including commercial and military fields. AI has emerged as a revolutionary force that is altering the game in recent times. Now, future of AI for underwater exploration, examination is very hopeful, and AI has significant influence on perception observation, evaluation and interactions within the underwater environment. (Tsilimigkas et al. 2017). AI is enlightening the depths of ocean. Scientists, marine biologists, and explorers have long been captivated by the ocean,

with its mysterious species and hidden treasures. The depth, endurance, and effectiveness of traditional exploration techniques, which include remotely operated vehicles (ROVs) and human divers, are all limited. AI can help in this situation. In the field of oceanography, AI driven AUVs are revolutionary. These self-navigating robots can explore the depths on their own thanks to their sophisticated sensors and ML algorithms. Without human assistance, they gather priceless information on submerged shipwrecks, geological structures, and underwater ecosystems. However, small submersibles, often without-crewed and driven by AI might be the future. AUV has made a real revolution in the field of ocean research and deep-sea exploration by the introduction of AI and smart technology. However, AI-driven unmanned or smart underwater vehicle will be recharged automatically and will be sent deep under water and will be operated for months to years continuously.

2.10 Use of AI to Fight against Climate Change

Climate change is an important driver of many maritime related issues, like coral bleaching, sea accident, natural calamity and rising sea levels. (Heilig 2017). It does no longer astonish that climate change is a global crisis that is challenging to all from farmers to fishermen to industry experts to scientists to engineers to doctors. To process massive volumes of climate data and to progress our capacity to predict and respond to severe weather occurrences, a new discipline called AI for climate prediction uses sophisticated algorithms and ML techniques. AI can assist coastal communities in adapting sustainably to the effects of climate change, including storm surges, flooding, and other tragedies, by offering more accurate forecasts. AI has the potential to transform disaster management by enhancing prevention and response efforts. (Batra et al. 2021). To forecast and track natural catastrophes, ML models can evaluate data from sensors, satellites, and other sources. This enables more effective resource allocation and prompt disaster response. Earth is vital for the future of the planet. Seas are vital to the survival of the earth in the face of increasing climate change. The vast seas bodies produce over half of the oxygen we breathe and absorb 90% of the heat produced by different sources of emissions. But overfishing, more frequent oil spills, and rising plastic waste are gradually starving the marine ecosystem. (Frost 2022; Hossain 2023c). One technology that can aid in saving the oceans is AI. In the 95% of the world's seas that have not yet been explored, AI can be useful. These days, astute academics are analyzing data from camera systems or marine exploring vehicles using AI algorithms. The technique facilitates the identification of novel species of marine animals and plants in the deep sea, as well as the understanding of behavioral anomalies and the causes of those anomalies. For sea exploration, the Japan Agency for Marine Earth Science and Technology has created an underwater remotely operated vehicle called Kaico. (Li et al. 2018; Hossain 2023d). Numerous biological species that potentially have uses in industry and medicine have been found by this AI-powered vehicle. A NPO Water Cleanup employs AI techniques to detect plastic trash and clean up the water. [13] The objective of NPO was to implement AI algorithms is very effective to identify the sources and causes of coastal pollution and build up solutions to take corrective measures.

2.11 AI Effectively Useful for Oceanography Development

An important advancement has been made in oceanographic research with the use of AI. Conventional approaches to investigating the ocean's diverse elements frequently have drawbacks, such as the impossibility or safety of human presence in the deep sea and the sometimes-overwhelming amount of data that needs to be processed. AI is essential in this situation because it can process massive datasets, identify patterns that are invisible to the human eye, and carry out operations that would be hazardous or time-consuming for people. Oceanographers can use AI to sort through data from biological sampling, satellite imaging, and acoustic surveys to learn more about the intricate relationships that exist within these ecosystems. This method informs conservation measures to protect these delicate settings in addition to helping to understand the fundamental dynamics of marine biodiversity. Today, AI is bringing about a revolution in the analysis of intricate undersea ecosystems, ocean health monitoring, and marine species behavior research. These days, AI is processing data from sonar, satellites, and underwater drones. It is also revolutionizing oceanographic research. This investigation will highlight the present situation as well as the enormous potential for future developments in this fascinating interdisciplinary topic. Oceanographers and marine biologists have historically faced many difficulties when exploring undersea environments (Cova et al. 2022; Tsilimigkas et al. 2017). The most challenging of these has been the harsh surroundings. Because the deep seas are inhospitable, devoid of light, and under tremendous pressure, direct human exploration is hazardous and resource intensive. Furthermore, because of the oceans' immense size and the diversity of their ecosystems, data gathering is frequently sporadic and inadequate, and the analysis that follows calls for a comprehensive understanding of intricate biological, chemical, and physical interactions.

2.12 AI and Effective Vessel Traffic System

Safe and effective vessel traffic system (VTS) is paramount and now acts as heart of modern maritime operations. As example, NeuralBoost is an AI based VTS invented by MakarenaLabs (Hossain 2023b; Khandakar 2023b) which enhances vessel traffic services by offering real-time analysis of maritime data, significantly improving safety measures. Such modern and advanced technology swiftly pinpoints potential collision risks, navigational hazards, and anomalies, enabling proactive steps to avert accidents and guarantee the uninterrupted flow of vessel traffic. Integrating NeuralBoost advanced tools into any vessel traffic services is necessary and useful to oversee and manage the complexities of modern maritime traffic. NeuralBoost's technology transforms the way maritime data analyzed and turning vast amounts of information into actionable insights and that ensures vessel traffic services work effectively and can anticipate or mitigate risks before they escalate. It also ensures fostering a safer maritime environment. It ensures a safer, more efficient pathway through the busiest waters, protecting vessels, cargoes, and crews against the dynamic challenges at sea. It is providing the clarity, but more foresight needed to navigate the future of maritime operations confidently.

2.12 AI and Surveillance

Today, the amount of data in the maritime domain is rapidly increasing due to the increase in devices that can collect marine information, like weather, port, sensors, buoys, ships, satellites, etc. Maritime surveillance encompasses the monitoring, detection, and tracking of vessels, activities, and threats within maritime domains. Effective surveillance is essential for various purposes, including national security, law enforcement, environmental protection, and maritime commerce. However, traditional surveillance methods, such as radar, AIS, and visual observation, have limitations in terms of coverage, accuracy, and efficiency. (Frost 2022; AI Tools Explorer 2024) . The dynamic nature of maritime environments, characterized by vast expanses of open sea, diverse vessel types, and complex operating conditions, further complicates surveillance efforts.AI and other advance technologies like ML, DL and big data analytics offer new opportunities and viable solution to enhance maritime surveillance capabilities. By analyzing large volumes of diverse data from various sources, AI algorithms can identify patterns, anomalies, and potential threats in real-time. AI powered systems can augment traditional surveillance methods by providing advanced data processing, decision support, and predictive analytics capabilities. Moreover, AI enables autonomous and adaptive surveillance systems that can continuously learn and improve over time.AI applications in maritime security cover a wide range of tasks, including followings.

2.13 AI and Maritime Security

Maritime security is a wide and vital as well as unformulated concept. It has become a large task linking many entities from global, local, public and private sectors. The object and goal of maritime security are to preserving the freedom of the seas, and to facilitating and protecting trade/commerce, as well as to maintaining good governance at sea or ocean. The utilization of AI in maritime surveillance offers several many potential benefits. AI algorithms can analyze data from multiple sources and identify subtle patterns or anomalies that may be missed by human operators or traditional surveillance systems. (Hossain 2023a; Batra et al. 2021). AI driven surveillance systems provide real-time insights and alerts, enabling maritime authorities to make informed decisions and respond promptly to security incidents (Gounaridis et al. 2016; Heilig 2017). Automation and optimization of surveillance tasks through AI technologies help streamline operations, reduce false alarms, and allocate resources more effectively.AI systems can adapt to changing maritime environments and evolving threats, continuously learning from new data and improving performance over time. There are several examples, successful and case study from around the world that demonstrate the effectiveness of AI in enhancing maritime security.

2.14 AI and Cybersecurity

Today, AI is changing basically the way of IT solutions which are implemented and operated across both application and geospatial domain (Khandakar 2023c; Hossain 2023c). This contribution outlines AI-driven techniques for 3D point clouds and geospatial digital twins as generic parts of geospatial AI. Now, AI technology can be used to simplify and accelerate workflows for geo-data processing and geo-information systems. Geospatial AI leverages high-resolution satellite imagery to monitor maritime activities. Algorithms detect vessels, track their movements, and identify anomalies like illegal fishing, smuggling, drug trafficking, etc. Real-time analysis enhances situational awareness. AI models learn from historical data to recognize patterns. (United Nations Convention on the Law of the Sea). As maritime systems become increasingly digitized, AI can play a crucial role in identifying and mitigating cybersecurity threats, like hacking attempts on port infrastructure or maritime communication networks. The rolling threat of cyber-attacks got a shacked from the recent advancements in AI. AI-driven cybersecurity solutions can detect

anomalous network behavior, prevent cyber-attacks, and safeguard critical maritime assets along with ensure vanguard maritime assets in complex maritime conflict scenario. (Hossain, 2023b). AI-driven solution is going to become a game changing system in maritime industry.

3. Conclusion

The maritime sector as well as industry has travelled a long way up till now. But there is still enough room and opportunity to go ahead further. AI is already being used onto land in many ways that are not so far available in the maritime sector. AI is becoming a staple in healthcare, from medical chatbots to cancer diagnosis or education or industrial field. But despite these, it's still unused in maritime medical care. But with the financial and regulatory pressure, it will just become a matter of time before telemedicine supported by AI will also come to use out at deep sea. Now, AI can do things that were impossible a decade ago. Maritime sector has already adopted AI to achieve sustainability, efficiency, and cost-effectiveness in some extent. But we need to solve regulatory compliance issues carefully. The maritime industry already has come a long way since the days of oars and sail, although we need to go further. All technology and development have replaced its predecessor as new one was more efficient, effective, offered benefits, user friendly, better, cheaper, cost-effective and safer. AI optimization follows same trend in modern era. It's already helping to optimize fuel, maintenance, operations, tracking, monitoring, paperwork, port calls, logistics, voyage planning, managing, decision-making, etc. So, with regulatory and commercial pressure towards optimization, these uses will only expand further in future. Again, the marine activity by its nature is the most dangerous work environments among other industries on the planet. Seafarers at sea and other marine workers at ashore has involved in high-risk tasks, like sea exploration, oil-spill cleanup and search-and-rescue (SAR) operations, firefighting, fishing, tank inspections and solve various maintenance, accident and incident problems.

At present world of advanced technology, AI is important to research to harvest its potential and advantage, whereas avoiding possible drawback. Today, many economists, researchers and scientists agree that there is precious research to be done on how to optimize the economic benefits of AI by avoiding or extenuating undesirable effects, like inequality, unjust and unemployment in the society. Great scientist Stephen Hawking, Microsoft founder and great hi-tech industrialist Bill Gates, and SpaceX founder and great future-tech thinker Elon Musk have articulated anxiety about the possibility where AI could develop to the point that humans could not control it, and uncertainty may arise as singularity may occur. AI is already used in innumerable ways in ashore, whereas there are not yet much available in the maritime industry. Although we know that, maritime industry is in international nature, that's why it faces exclusive barriers to adopt AI. So, as the technology has full-grown up, it will include every aspect of the different segments within the industry, by improving safety, usability, sustainability, accountability and efficiency. As an example, when Steve Jobs unveiled and make public the iPhone or smart phone in 2007, no-one foresaw and forecast the innumerable uses as it become today. In near future, we are going to see that, AI become as familiar as smart phones. Again, at sea, port and harbour, the major obstacle and challenge to adopt AI are not technical or legal; main barrier is human and our attitude. So, unless we address the maritime industry's struggle to change, those traditions and practices will become an anchor holding us back. So, let's change our attitude and accept AI and other smart technology spontaneously in maritime sector to make this century remarkable. However, AI may present various risks and challenges, such as job displacement, privacy concerns, complex technical problem and potential misuse of technology. Addressing these risks requires a multidisciplinary approach, involving collaboration, cooperation between researchers, industry professionals, policymakers, businesspeople, government and whole community and society. AI technologies are helping and will continue to assist us to save and preserve ocean and it's contained. We need to train our workforce and future generation with the knowledge and skill of AI to prepare them to utilize and deploy its power to flourish the maritime industry by preserving our earth.

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