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Automation of Maritime Industry in the Era of Digitalization

His Excellency Prof. Dr. Ismail Abdel Ghafar Ismail Farag assumed the presidency of the Arab Academy for Science, Technology and Maritime Transport on 10-25-2011, based on the decision of the General Assembly of the League of Arab States. His Excellency held several positions throughout his career, where he graduated from the Military Technical College in 1978 with a grade of distinction with honors, obtaining a Bachelor's degree in Electrical Engineering, specializing in Computer Engineering, and then obtained a Master's degree in 1982 from Cairo University.

He started his career as a teaching assistant in the Computer Department at the Military Technical College (MTC). Prof. Farag obtained a doctorate degree in electrical engineering from George Washington University in the United States of America in 1989 and became specialized in computer engineering. He then resumed his career within the Military Technical College as a faculty member in the Computer Department in 1989.

In 2001, he was appointed as Head of the Research Planning Department at the College, then Head of the Electrical Engineering Department in 2003. In January 2005, he was chosen to the position of Assistant Director of the College for Graduate Studies and Research, then Assistant Director of the Military Technical College for Education in January 2006. Due to his skills and scientific and professional competence, he was appointed as Vice-Director of the College in January 2007. He remained in this position for two years, then became Director of the Military Technical College in January 2009 until he was chosen to head the Arab Academy for Science, Technology and Maritime Transport in October 2011.

During his tenure of these positions, his scientific expertise varied in the fields of computer networks, security of computer systems, computer algorithms, and computer architecture.

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1. INTRODUCTION

With the rapid technological advancement of the fourth and fifth industrial revolutions in recent decades, the international maritime industry has been challenged to be aligned with the requirements of the new effective and efficient technological development. Key challenges are to sustainably utilize new technologies and applications of artificial intelligence (AI) and unmanned systems efficiently in the maritime industry while maintaining high levels of safe maritime operations.

Technologies such as AI, big data, 3-D printing, virtual augmented and mixed reality, and omniverse are just examples of results of the Fourth Industrial Revolution (4IR). In addition, the world is witnessing the commencement of the transition to the Fifth Industrial Revolution (5IR), which may be defined as a new era of collaboration between humans and machines, with emerging disruptive technologies demanding the maritime community, academia, and industry to act swiftly on many frontiers. The (5IR) can be described as the collaboration between humans and machines in the workplace with various prospects for automation.

Autonomous technology is poised to reshape the maritime sector with crewless vessels; small crafts and unmanned underwater vehicles (UUVs) are already developed and in service with larger vessels under development. Technical feasibility combined with compelling economic advantages, such as improved efficiency, reduced human error, and operating costs, are driving adoption, especially in the maritime industry. It is time for the maritime industry to collaborate and align its efforts within the various sectors to the fact that autonomy is coming and to address current gaps through understanding how autonomy can shape the future of such a rich industry and how to exploit it for the benefit of the blue economy and the shift towards greener vessels. This article aims to shed light on the concept of Maritime Autonomous Surface Ships (MASS), the challenges it presents, and the role of Maritime Education and Training (MET) institutes in preparing for it.

2. DEVELOPMENT OF MARITIME AUTONOMOUS SYSTEMS

The growth in Maritime Autonomous Systems over the past two decades has exceeded the world's expectations. Major initiatives by organizations such as Rolls Royce, Japanese shipbuilders, and the Norwegian-based company "Kongsberg" have revealed plans to develop all-electric and autonomous ships shortly. Other organizations, Universities, and R&D centres throughout the world are developing complementary, even competing concepts and systems to support unmanned operations, coupled with infrastructure initiatives, including autonomous ports and high bandwidth communication channels/equipment.

Chenguang Liu, et al. analyzed the main universities contributing to the MASS research, the top 10 research centres according to the number of publications were selected, and the VOSviewer software is used to cluster the units with more than five publications and more than 20 citations (Van Eck and Waltman, 2010). The results of this analytical study are shown in Figure 1. Fig. 1 demonstrates that the current MASS research is mainly concentrated at the Norwegian University of Science and Technology, Dalian Maritime University, Wuhan University of Technology and Delft University of Technology, etc. (Liu et al. 2022).

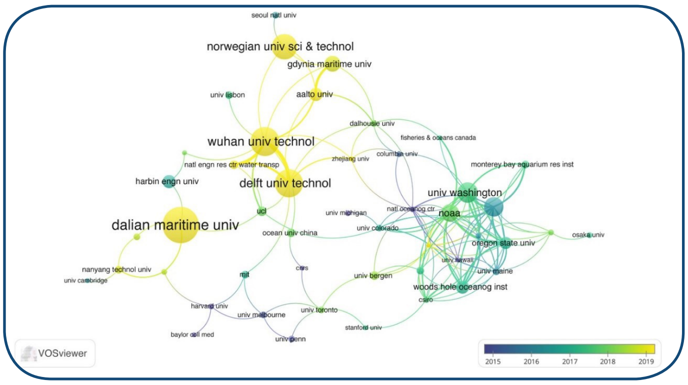

Fig. 1: A summary of research centres and universities contributing to MASS development (the darker colour means the earlier research is carried out, the thicker connecting line means the more mutual cooperation, and the larger circle means the larger number of publications) (Source: Liu et al. 2022).

Many companies and institutions launched their autonomous systems just after the concept of MASS was formally proposed at the MSC 98th session in the IMO in 2017. Later that year, "ABB" Group launched a navigation situation awareness solution designed to make ship operations safer and more efficient under the name of "ABB Ability Marine Pilot Vision", which realized real-time visualization and autonomous perception of the ship environment.

In 2017, Wuhan University of Technology (WUT) developed a ship-borne safe navigating intelligent assistance system, which enabled the monitoring of all ships in different navigation areas in three-dimensional real-time.

In 2018, "Maersk Group" and "Sea Machines" used AI technology to improve the ability of maritime target recognition, tracking and situation awareness. In the same year, "Rolls-Royce" launched its ship navigation situation awareness system, which integrated ship 3D Map and Light Detection and Ranging (LiDAR) to create a 3D environment by linking GPS data and providing the navigation situation information to ship navigators in the form of virtual reality (VR) and augmented reality (AR). The system has been utilized for sailing Merchant Marine Mitsui in Japan. The test was conducted on the 165-meter Sunflower passenger ferry between Kobe and Oita.

In 2019, "Kongsberg" developed a situational awareness solution combining multiple sensors with AI, machine learning, and traditional sensor fusion. This solution introduced real-time detection, tracking, and classification of objects and situations to replace human visual identification. Table I shows a sample of research projects that contributes to MASS development.

Table I: A Sample of Research Projects that Contributes to MASS Development
(Source: Liu et al., 2022)

Year	Project/Name	Introduction	Source
2017	NOVIMAR	• "The NOVIMAR project aims to expand the entire waterborne transport chain up".	NOVIMAR (2017)
2020	IntelliTug	• "Smart navigation assists the Tug Master with passage planning to prevent potential collisions".	Wärtsilä (2020)
2017	Great Intelligence	• A 38,800-ton smart bulk carrier "Great Intelligence" was built, which is the world's first "i-Ship" and "iDolphin" smart ship certified by China Classification Society and Lloyd's Register of Shipping.	CSSC (2017)
2017	Roboat	• "Roboat investigates the potential of self-driving technology to change the waterways with autonomous floating vessels"	Roboat (2017)
2018	Falco	• Demonstrated the world's first unmanned ferry Falco, and completed unmanned and remotely piloted navigation.	FinFerries (2018)
2019	Samsung	• Samsung Heavy Industries have conducted several tests of remote control and autonomous navigation for the model ship and the tug based on 5G and other technologies.	Samsung Heavy Industries (2019)
2020	KASS	• "aimed to successfully develop core technology for MASS in order to promote Korean interest in creating a synergy effect among shipping, shipbuilding and relevant industries".	KASS (2020)
2019	NYK	• NYK has conducted the world's first MASS trial performed in accordance with the IMO's Interim Guidelines for MASS trials.	NYK (2019)
2020	Seafar	• Seafar NV conducted a remote piloting test on a 135-metre-long barge Zonga.	Seafar (2020)

With the development of artificial intelligence, unmanned driving, and advanced communication technology, autonomous ships have attracted many researchers to develop ship capabilities in recent years. Europe, China, South Korea, Japan and other developed countries in the shipbuilding industry have performed intensive research, including numerical simulations and experimental tests in this field, as shown in Table I (for further information see: Liu et al. 2022).

In summary, the research of MASS is in the ascendant, and its application experiments have proved the feasibility of related technologies.

3. MASS AND INTERNATIONAL REQUIREMENTS

MASS in concept presents several challenges within the areas of application, operation, management, and administration, which must be addressed before the concept may be fully integrated within the international shipping regime.

The IMO Maritime Safety Committee (MSC), at its 103rd session in May 2021, has concluded a regulatory scoping exercise, which aimed to determine how the safe, secure, and environmentally sound operation of MASS can be introduced into the IMO instruments. Consequently, the MSC (104) agreed to develop a goal-based instrument for MASS, a possible MASS-Code, with a target completion year of 2025. This goal-based instrument aims to identify functional and operational requirements and corresponding regulations suitable for all four degrees of autonomy, as classified by the IMO, and address the various gaps and themes identified by the regulatory scoping exercise.

Other key issues that emerged are to include the functional and operational requirements of the remote-control station and MASS reception facilities, the possible designation of a remote operator as a seafarer, the role and responsibilities of the shipmaster, in addition to the challenges related to safety and security, including issues like environmental protection, piracy, and cyber security. And consequently, the type of education and training required to ensure the safe and secure operation of MASS both onboard and ashore.

4. HUMAN ROLE IN MASS OPERATION AND DEVELOPMENT

Ship navigation situational awareness is complex and requires the ship operator to understand technical limitations, surrounding severe environment, encountering scenarios, and conducting risk assessment based on perceiving the navigation environment with integrated sensors and systems. To develop a dependable situation awareness system, three levels must be efficiently functioning:

- The first level is to perceive the current environment state accurately.
- The second layer is to allow the machine to understand the current situation.
- The final layer is to reflect and respond with a timely decision.

Seafarers, at the current stage, cannot be entirely replaced by machines. Although the machine has several pros in conducting massive calculations and analyzing big data with high levels of certainty, machines lack reasoning within a rapidly changing fuzzy environment. On the other hand, humans have the upper hand in understanding such complex situations and have the ability to respond timely. On the downside, humans have higher error probabilities. Therefore, the maritime industry and researchers have put in massive efforts over the past two decades to take human-machine cooperation to the next level of autonomy for safer and more efficient ship navigation; a step forward toward a fully intelligent ship.

With the further development of AI, communication, and brain-like computing technologies, machines will undertake more tasks than humans during the ship's intelligent navigation, resulting in an intelligent, and more importantly safer maritime industry.

5. MASS AND CHALLENGES IN MARITIME EDUCATION AND TRAINING (MET)

The application of autonomous and remote technologies to shipping unquestionably requires a different caliber of maritime professionals possessing a new set of talents and skills. MASS, therefore, presents two main challenges to MET institutes: each challenge involving several sub-challenges.

Firstly, the application of new technologies on MASS requires higher standard maritime talents. With the wide application of automatic control and decision support systems in MASS, a new set of knowledge, skills, and attitudes needs to be introduced in the existing education and training process.

The IMO has, for now, classified MASS into four degrees of autonomy. Ships of the first degree depend on the shipboard crew to manage limited automated processes onboard. The following two degrees of autonomy are ships that are remotely controlled with degree-three ships having no crew on board. A ship of the fourth degree is intended to have complete autonomy over its processes with no onboard crew.

This brings one to the second challenge; MET needs to adapt to and accommodate the various degrees of MASS. As the concept of MASS develops, seafarers and remote operators will require increasing levels of knowledge and skills. To the extent that some seafaring tasks onboard will be completely replaced by either remote operation or complete process autonomy. MET institutions owe it to the seafarers of the future to prepare them to be competent operators whatever the degree of autonomy is. More importantly, Seafarers need to be prepared for a possible shift to shore occupations.

6. AASTMT COPING WITH MARITIME AUTONOMY

The strategy in AASTMT is aligned with the advancement in the maritime industry to meet the market needs. For example, in 2017, AASTMT established the first Artificial intelligence (AI) College in the Middle East and North Africa region (MENA). The AI College is located in the New Alamein City, on the North Coast of Egypt, where students practice a series of closely entwined technologies that the author believes will transform maritime operations and underpin autonomous systems. During their studies, AI students learn about sensors and situational awareness technologies that are fundamental to the process of autonomous systems and their safe operation.

In addition, the College of Computing and Information Technology develops the graduate's capabilities with the required skills in connectivity, communications, and information exchange, which will provide a catalyst for the future by enabling the digitization of the marine environment. On the other hand, it allows AASTMT graduates to consider risks for systems protection in 'cyberspace'.

It is worth mentioning that AASTMT researchers in the College of Engineering and Technology are putting effort into developing energy management and sustainability, which is seen as a limiting factor in the widespread deployment of autonomous systems. The author wants to ensure that AASTMT is well prepared and ready for the upcoming challenges. AASTMT strategy considers that the more the maritime industry depends on advanced technologies, the more the staff need to push their educational borders towards producing highly skilled, well-trained, and qualified people to lead the futuristic, intelligent and robust maritime industry shortly, under the umbrella of the IMO.

7. GMP-BOK ADDRESSING MARITIME AUTONOMY

The International Association of Maritime Universities (IAMU) launched its Global Maritime Professional (GMP) initiative in 2017. AASTMT, then Head of the Academic Affairs Committee of the IAMU, was part of a three-member-university Task Force entrusted by the IAMU to develop the Global Maritime Professional Body of Knowledge (GMP-BoK), which is intended to meet the envisaged needs of industry and a rapidly evolving educational and career context. The GMP-BoK was introduced to the maritime community in July 2019 at the headquarters of the IMO.

The GMP-BoK is applying the modern concepts of maritime higher education and an outcome-based approach. Of the 28 focus areas identified in the GMP-BoK, many of them are of relevance to preparing graduates of maritime institutes for MASS.

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AASTMT is currently using its vast resources and expertise to implement the GMP-BoK to its MET system. In doing so, AASTMT hopes to provide its graduates with the necessary set of knowledge, skills, and attitudes they need to successfully cope with the future, a future where MASS is no longer a concept, but a reality.

8. CONCLUSION

The challenge in the Maritime Industry development is always how to manage and safely control the new technologies introduced to the maritime field, keeping them suitable and efficient in the era of digitalization.

Technologies such as artificial intelligence (AI), big data, 3-D printing, and virtual and augmented reality were brought forth by the Fourth Industrial Revolution (4IR), while (5IR) combined humans and machines in the workplace with various prospects for automation such as (MASS). The maritime industry and researchers have put in massive efforts over the past two decades to take human-machine cooperation to the next level of autonomy for safer and more efficient ship navigation, which is considered a step forward toward a fully intelligent ship. the author trusts that within the coming few years, with the further development of AI, communication, and brain-like computing technologies, machines would undertake more tasks than humans during the ship's intelligent navigation, resulting in an intelligent, and more importantly, a safer maritime industry.

Autonomous technology is poised to reshape the Maritime Industry with crewless vessels, which means it is time to understand how autonomy will shape the future industry and how best to exploit it. There are growing numbers of small-scale autonomous vessels being operated across various applications.

Regulatory schemes are being revised and the IMO has concluded a regulatory scoping exercise, which aimed to define the safe, secure, and environmentally sound operation of MASS and its compatibility with the current maritime regulatory regime.

Despite the comprehensive brought forth of such technologies, the shortage of skilled seafarers worldwide and the relatively high operational costs of running such ships are key factors and cornerstones. Capacity building is one of the principal challenges in developing and operating MASS. Thus, MET institutes are eager to continue developing and delivering world-standard educational programs to their graduates. They will need to adapt to and accommodate the various degrees of MASS as the concept of MASS develops.

AASTMT strategy considers that the more the maritime industry depends on advanced technologies, the more its staff need to push their educational borders toward producing highly skilled, well-trained, and qualified people to lead the futuristic, intelligent and robust maritime industry.

As one looks to the future, it appears that Maritime Autonomous Surface Ships are just around the corner; autonomous vessels are already being developed and tested, regulatory schemes are being revised, roles and responsibilities are being reconsidered, and MET regimes are being renewed. In short, MASS is no longer a prospect of the future; it is a reality in the making.