Application of Augmented Reality (AR) / Virtual Reality (VR) Technology for Remote Maintenance of Autonomous Ships

Sanjeev S. Vakil, B.E.(Mech)., C. Eng., FIE, F.I.Mar.E., FNI.
Research Scholar, Indian Maritime University, India and
CEO, Hindustan Institute of Maritime Training (HIMT), Chennai, 600 010, India;
E mail :ssv@himtmarine.com

Abstract

Autonomous ships are going to be the ships of the future. The operation and maintenance of Autonomous ships will be vastly different, requiring proper knowledge and understanding of many interrelated human and machine components. Today's skills would become obsolete for running Autonomous and remotely operated ships. Modern technology tools will need to be incorporated, so that the seafarers could be trained to use such tools and enhance their knowledge to help them operate ships from remote locations, and also improve the safety of the vessel as also the safety of lives of those few human beings who would be required to work onboard such vessels. Thus, the entire training will need to be revamped and various skills including Augmented Reality (AR) / Virtual Reality (VR) technology will need to be included in the curriculum and syllabus of Maritime Education and Training programs. Since there will be limited crew on board, it will be necessary to carry out trouble shooting and diagnosis of failure of machinery from remote locations and also plan the survey and repair of the machinery using AR technology. The future education experience can also be enhanced by using Augmented Reality (AR) / Virtual reality (VR) and such technologies like the HoloLens technology, which will make learning more effective through annotations and interaction by simulating various conditions that could be experienced on board a vessel. It would also help to simulate conditions which might not be safe and practically possible to be carried out on board a vessel. Such training could be carried out in shore- based establishments where various types of vessels operating under different environmental conditions could be replicated through simulation, thus, making training as effective, if not more effective, in comparison with the current training methods. In this paper an attempt is made to outline appropriate trouble-shooting procedures, machinery survey procedure from remote locations as also suitable training methods for training crew for autonomous ships of the future.

Key Words

Augmented Technology, Virtual Reality Technology, HoloLens Technology, Training, Curriculum.

1. Introduction

Technology is advancing at a tremendous pace and to keep in step with it the way of operating and maintaining ships is also changing rapidly. In the past, during the era of ships with sails, the number of sailors required for working onboard to rig the sails and operate and maintain the ships was large. The dawn of the industrial revolution and the consequent induction of the steam engines onboard for propelling the ships resulted not only in the reduction of crew onboard, but also in the changes in the method of training and certification of mariners to safely operate and maintain the ships.

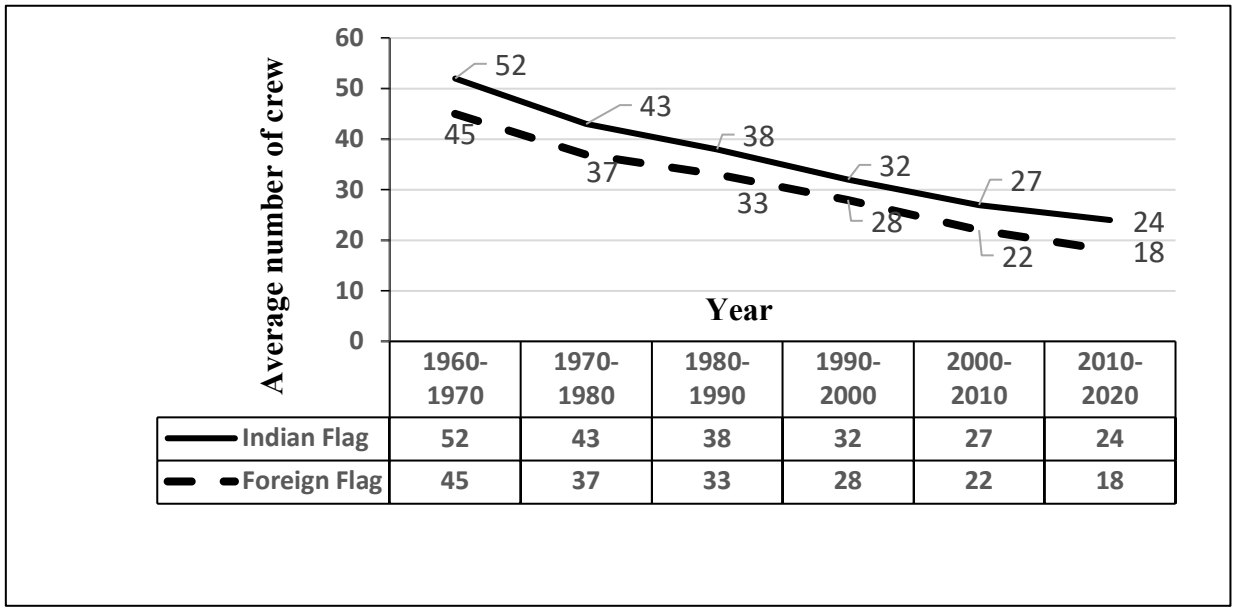
The introduction of diesel engines and other auxiliary machinery to replace the steam engines for propulsion of ships as also for power generation brought in further changes in the form of reduction in the number of mariners onboard, the methods of training and certification of mariners and their deployment onboard to safely operate and maintain the ships.

With the rapid development of electronics and automation and their successful deployment in various shore- based industries prompted the introduction of instrumentation and automation onboard ships as well. This move further brought down the crew requirement onboard ships.
We are today on the threshold of another major change in the shipping industry in the form of autonomous ships which could drastically alter the size of the crew onboard, possibly reducing it either to zero in the case of fully autonomous ships or to a very small number in the case of remotely controlled autonomous ships. The arrival of autonomous ships is also expected to bring about major changes in the method of training and certification of mariners.

2. Changing Work Culture Onboard

The reduction of crew onboard ships over a period of time as depicted in Figure 1, due to induction of newer and more advanced technology onboard, in order to bring down the operating costs of ships, has had an impact on the work culture onboard. Right up to the late 1970s / early 1980s the crew complement onboard average sized ships ranged between 40 and 60 members. During this period, due to the presence of sizeable number of hands available onboard, all the activities pertaining to the maintenance of the vessel were carried out by the ship's crew. Also, at that time due to relatively long port stay for cargo loading and discharging work, the ship's crew could undertake time consuming tasks such as opening up of main engine units for overall and maintenance work. But due to the progressive reduction in the strength of

ship's crew, ranging from 28 members to 10 members, as a result of increasing automation onboard coupled with the reduction in the port stay from a number of days to a few hours due to shorter turn-around time, maintenance work requiring many days to complete were not undertaken by the ship's crew. Such time- consuming tasks depending upon their nature were either outsourced to shore based marine workshops or to the experts from Original Equipment Manufacturers(OEM) as the per the requirement or were taken up at the next dry-docking opportunity. All these developments over a period of time have contributed to the present day changed work culture onboard ships. It is evident from these historic changes that maritime operations would further be simplified by integrating VR/ AR technologies for maintenance.



	1960-1970	1970-1980	1980-1990	1990-2000	2000-2010	2010-2020
Indian Flag	52	43	38	32	27	24
Foreign Flag	45	37	33	28	22	18

Courtesy: *Archives of Shipping companies(South India Shipping, India Cements Ltd, Good Earth Maritime)*

Figure 1: Average number of crew from 1960 to 2020

3. Autonomous Ships

The past three years have seen a flurry of activities on the autonomous ships front by the shipping industry, as described below:

-The era of autonomous shipping dawned on the 3rd of December 2018 with the world's first autonomous car ferry FALCO making its maiden voyage from Parainen to Nauvo in Finland. The return voyage of this ship was remote controlled from a control centre located 30 kms away in Turku.

-The first autonomous cargo vessel made an international maiden voyage crossing the high seas from Mersea island in the UK to Ostend in Belgium on 6th May 2019.

-IRIS LEADER a 70,826 DWT autonomous car carrier made its maiden voyage on 14th September 2019 from Xinsha in China to Nagoya in Japan and later from Nagoya to Yokoyama on the 19th of September 2019. However, the vessel had onboard the full crew complement for carrying out other normal tasks.

In addition to the above, the world's first transatlantic voyage by a fully autonomous research ship MAYFLOWER 400 fitted with special equipment for carrying out scientific survey is expected to sail out in early June 2021, from Plymouth in the UK to Plymouth in Massachusetts in the USA.

The above -mentioned events seem to prove to the world that autonomous ships are a reality and that this type of vessels are the ships of the future (Chary,2018). There is, however an urgent need for a regulatory framework to be put in place for governing the safe operations of autonomous ships on high seas. It is reliably understood that the following organizations, among others, are working overtime to achieve this objective:

1. The International Maritime Organization (IMO).
2. The Maritime Autonomous Systems Regulatory Working Group, UK.
3. Safety and Regulations for European Unmanned Maritime Systems (SARUMS).
4. Advanced Autonomous Waterborne Applications (AAWA), Finland.

The successful completion of voyages by the autonomous ships enumerated above indicate that not only the business of shipping itself is set for a major change but also the way of operating and maintaining the autonomous ships. Advanced technologies like Augmented Reality / Virtual Reality, HoloLens technology and the like are expected to play major part in the efficient management of autonomous ships.

4. **Advanced Technologies and Their Application in Shipping**

Virtual Reality (VR), is a simulation of the real world around us. It is not physical but a clone of the reality that can be seen, felt and heard thus giving one an impression that it actually exists. In other words it is a digitally created environment that makes one believe that he or she is physically present in this environment. A person can interact within this artificially created environment using certain special electronic devices.

Augmented Reality (AR), on the other hand is a blend of real life and Virtual Reality (VR). AR lets the user to interact with virtual entities in the real world through the use of certain

devices called Optical Head Mounted Displays (OHMD) which enable AR and VR live audio and visual functionalities.

Both Augmented Reality and Virtual Reality have the same goal of making the user delve deep into a virtual world. With AR, users continue to be in contact with the real world while interacting with the virtual objects around them, whereas with VR the user is far away from the real world while being completely immersed into the virtual world.

HoloLens (see Figure 2**)**, a short name for holographic lens is an example of OHMD. It is a creation of Microsoft for the realization of Augmented Reality. It uses multiple electronic sensors, advanced optics and holographic processing software that enables a seamless merger with its environment which could, for example, be the engine room or the wheel house of a ship.

The components of the HoloLens are:

1)The Visor which contains number of HoloLens sensors, displays, brightness control buttons, volume control buttons, power on/off switch and USB port.

2)The head band to wear the HoloLens.

There are a variety of HoloLens sensors such as:

a)The head tracking sensor consisting of four visible light cameras.

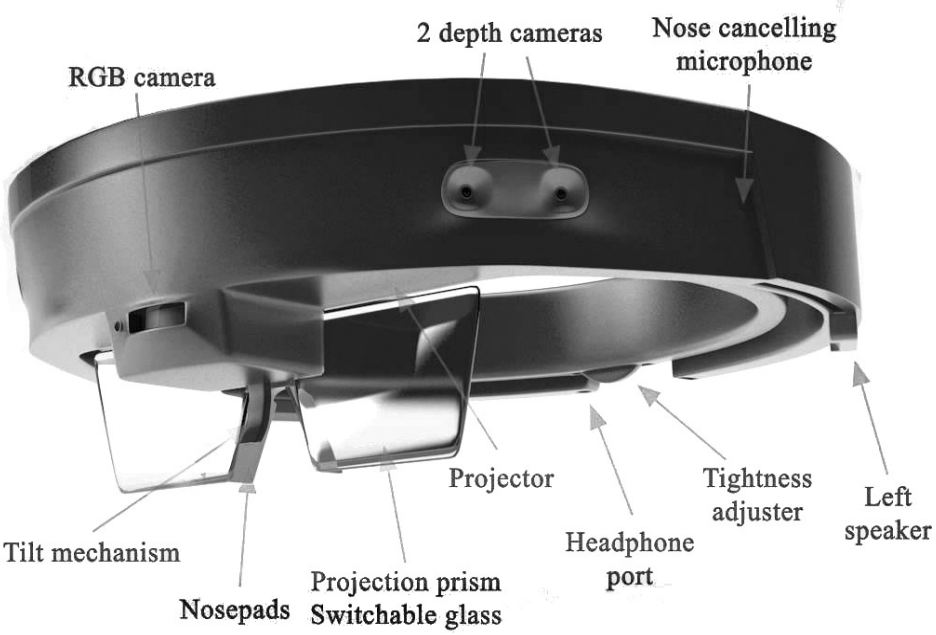
b) The Eye tracking sensor consisting of two infrared cameras.

c) The depth sensor

d) The Inertial Measurement Unit consisting of accelerometer, gyroscope and magnetometer

e) An array of Microphones

f) A set of multiple speakers



Source: *https://mspoweruser.com/instead-of-5-cameras-hololens-2-0-may-just-have-one/*

Figure 2: HoloLens (OHMD)

Augmented Reality and Virtual Reality allow experiences that are evolving more rapidly than anticipated and are finding scope for application in various fields such as entertainment, education, science, medicine, simulation, robotics, military applications, etc. Augmented Reality is ahead of Virtual Reality, as there are several products already in the market. Virtual Reality has its limitations. In spite of providing whole immersive experience VR blocks the user's interaction with the surroundings. Augmented Reality devices, on the other hand are more commercially successful as they do not completely disconnect people from the real world. AR headsets do not require users to stand at one place; they can move around and remain productive while attending to other tasks as well. This is also an important reason why AR despite being behind VR on application development, is expected to have a bigger impact on the enterprise market.

Virtual Reality has already manifested itself in the shipping industry more than a decade ago in the form of bridge simulator, engine room simulator, full mission simulator and cargo handling simulator that are used for the purpose of training shipboard personnel. Augmented Reality though apparently lagging behind Virtual Reality in the race, has the potential to play a very important role of a different kind , particularly onboard remotely controlled autonomous ships, using for the purpose OHMD device like the HoloLens.

5.1. Remote Trouble Shooting Technique

5.1.1 Consider the case of three remote controlled autonomous ships sailing with highly reduced shipboard staff, in different geographical locations and needing the guidance of a shore based expert for trouble shooting purposes onboard. It is quite obvious that a shore based expert can not be present in different locations at the same time. AR combined with HoloLens can enable the shore based expert to interact with the ship staff onboard all the three ships on a real time basis, view the problems along with them and guide them in resolving the issue.

5.1.2 Marine engineers maintain the operational status of all the systems in the engine room so as to diagnose and rectify problems that arise, and to understand what kind of maintenance will be required in order to maintain the vessel in an operational and safe condition. Through training and experience, the engineering crew can read and interpret the various parameters displayed by the engine room instrumentation and employ their intuitive feel for normal operation in-situ. In order to examine the possibilities of maintenance of crewless autonomous vessels from remote locations, developments have taken place for the creation of virtual reality simulated engine room based on a real vessel. Even though the end product is effectively a virtual simulation, the original audio from the engine room is recorded and used, thus providing a more accurate and immersive experience to the users. Research is already on for the application of a remote server to feed audio and other data into the simulated virtual engine and to create hypothetical scenarios of failures for the purposes of testing and training. The results suggest that the upcoming paradigm of the Internet of Audio Things can become a vital element in the operation of Autonomous Ships in the future.

5.2.Remote Inspection/Survey Technique

In the shipping industry a trend is developing to enable Classification Society surveyors to carry out remote inspection of ship's tanks using for the purpose custom built drones fitted with suitable sensors like Normal Visual Light Range camera, Infra-red/Thermal camera, Stereoscopic (3D) camera, LIDAR, etc. (Doshi et al., 2021). On similar lines, Augmented Reality using OHMD devices like HoloLens can be used for the live presentation of engine room as well as deck machinery and equipment for inspection and certification by the surveyors who are based at remote locations.

6. Maritime Education And Training

It is a well known fact that the evolution of maritime education and training closely followed like a shadow the induction of technology onboard ships. For example, soon after the industrial revolution when the steam engines were introduced to replace the sails for the propulsion of ships, the concerned maritime authorities introduced the concept of training and certification for the seafarers. Those seafarers who chose to operate and maintain the steam engines were given appropriate training and were awarded a certificate which was later called MOT 1st Class (Steam) certificate of competency(CoC). Subsequently, when diesel engines were introduced to replace steam engines for propulsion and also for electricity generation onboard ships the seafarers who successfully completed their training on the operation and maintenance of diesel engines were awarded the certificate of competency of MOT 1st Class(Diesel). At about this time those seafarers who could prove their competence in operation and maintenance of both steam and diesel engines were awarded the MOT 1st Class(Combined) certificate of competency.

A similar trend can be noticed on the nautical department side of the ship as well . Until the late 1980's the use of the sextant together with the ability to read and interpret the outputs presented by the devices like Decca, Omega and Loran C hyperbolic radio navigation systems were considered a treasured skill for position fixing onboard. With the advent of Global Navigation Satellite Systems, the GPS / GLONASS have been introduced onboard ships as the preferred primary electronic position fixing system along with the Electronic Charts and Display Information System (ECDIS). It can thus be observed that the Navigation Bridge or the Wheelhouse of a modern seagoing vessel is equipped with microprocessor based electronic systems and devices that are crucial for monitoring the vessel's position as also for safe navigation of the vessel. These developments necessitated a sea change in the curriculum and the content of the syllabus for the nautical officers and cadets across the world.

As and when newer technologies such as instrumentation and alarm systems, automation systems, navigation and communication systems, etc., were introduced onboard, the Standards of Training , Certification and Watchkeeping (STCW)convention requirements for the ship's crew got updated and revised. As a result, the revised STCW convention made it mandatory for the seafarers to update their knowledge through appropriate training and revalidate their CoCs in order to become eligible to work onboard ships. These developments support the

conjecture that the training requirements of seafarers closely followed the induction of new technologies onboard.

Now with the high possibility of ships becoming autonomous in not too distant a future along with the possibility of new technologies like Artificial Intelligence(AI) (Stuart J. Russell & Peter Norvig, 2016) , AR,VR and the related technologies getting introduced in the field of shipping, it is reasonable to expect changes in the STCW requirements in due course of time and the consequent changes in MET both in its content and methods. Hence it is felt that there is an urgent need to introduce Augmented Reality (AR) and Virtual Reality (VR) in the curriculum of Maritime Education and Training.

7. Conclusion

- The era of autonomous shipping has arrived thus necessitating a different approach for the operation and maintenance of ships as also for training the seafarers who will be running them.
- Extensive use of latest concepts and technologies like, Augmented Reality, Virtual Reality and HoloLens technology will be made for the purposes of remote operation, trouble-shooting and maintenance of autonomous ships in a cost-effective manner.
- The methods of training and certification of shipboard as well as shore-based personnel who will be required to run the autonomous ships will need to change.
- New and relevant courses as mentioned above will need to be introduced in the curriculum for Maritime Education & Training programs in order to enhance the competencies of shipboard as well as shore-based personnel who will be involved in the running of autonomous ships.

Acknowledgments

I would like to place on record my sincere thanks to Dr. Malini V. Shankar, IAS(Retd.), Vice Chancellor, Indian Maritime University for the encouragement to participate in the forthcoming international conference being organised by the IAMU.

I would like to thank my guide Dr. K. Sivasami, Dr. J. Siva Durga Prasad, Co-Guide and Prof. K. M. Sivakholundu, from IMU, for their whole hearted support in my endeavour.

Last, though not the least, I would like to express my profound sense of gratitude to Dr. L R Chary, Maritime Consultant & Academician and Doctoral Committee member of IMU, for not only helping me to select a contemporary and appropriate topic for the paper but also

for ungrudgingly sparing his valuable time to guide me during the preparation of the manuscript.

Reference List

[1] Chary L R, Autonomous Ships of the Future, 2018,Marine Engineers Review(India)-Volume 12,Issue 7.

[2] Doshi K, Apurb Rajan Kar & Girish N, Remote Surveys: The past, the present and the future,2021, Marine Engineers Review(India)-Volume 15, Issue 6

[3] Stuart J. Russell, Peter Norvig, Artificial Intelligence, 3rd Edition, 2016,Pearson India Publication.

[4] Average number of crew from 1960 to 2020, archives of Shipping companies, compiled by the author.

[5] HoloLens (OHMD), https://mspoweruser.com/instead-of-5-cameras-hololens-2-0-may-just-have-one/

BIOGRAPHY

Sanjeev S. Vakil graduated in Mechanical Engineering from University of Madras in 1990. He was selected and sponsored for one year Graduate Marine Engineering program to Garden Reach Ship Builders and Engineers Ltd. Starting his Merchant Navy Career in 1991 as 5th engineer swiftly rose up to the rank of Chief Engineer, and sailing with various Indian and Foreign shipping companies. He has been upgrading his Certificate of Competency of MEO Class 1 every five years, and holds the same been revalidated till 2025.

Mr.Vakil started a Maritime Training Institution named Hindustan Institute of Maritime Training (HIMT) in September, 1998. In 3 years' time, HIMT grew from an institute conducting three courses to India's Largest Maritime Institute in terms of number of courses approved by Directorate General of Shipping.

He is an active member of various professional bodies including Fellow of Institute of Marine Engineers (India), Fellow of Institute of Engineers, Founder member of Maritime Trainers Guild, Association of Maritime Training Institutes of India, Association of Maritime International Commercial Interests & Expertise, etc. He has made presentations at various National and International level conferences on various topics related to training.

He is the 1st Marine engineer in the World to be conferred with fellowship by the prestigious Nautical Institute, UK. He is currently the Secretary, of Institute of Marine Engineers (India), Chennai and actively involved in organizing various International & National level Marine Symposiums including World Shipping Forum. He is also the Vice Chair of National Maritime Day Celebration Committee (NMDC), Chennai. He was an active member of various committees of DGS in revising STCW 2010 and involved in framing guidelines for various courses.

He is currently pursuing his Ph.D. at Indian Maritime University, researching on Maritime Education and Training for Autonomous Ships of the future.