Maritime Safety Education with VR Technology (MarSEVR)

Evangelos Markopoulos[1], Jenny Lauronen[2] , Mika Luimula[3], Pihla Lehto[1], and Sami Laukkanen[3]
[1]Hult International Business School, London UK
[2]Novia University of Applied Sciences, Turku Finland
[3]Turku University of Applied Sciences, Turku Finland
evangelos.markopoulos@faculty.hult.edu; jenny.lauronen@novia.fi; mika.luimula@turkuamk.fi; pihla.lehto@novia.fi; sami.laukkanen@turkuamk.fi

Abstract— This paper presents the development of a virtual training technology that can be used in maritime safety training. This system is under testing phase and has being developed with a multidisciplinary team consisting of maritime specialists, computer scientists, business developers and VR experts. The technology is a cost effective, portable maritime training system that can be used on board, in training centers or even at home environments. Boosting situation awareness in navigation with VR- training applications is an easy and efficient method to practice whenever an officer has time for training. This can be done in an effective and fun way, giving measurable training progress indexes. The paper emphasizes on the need of VR Training in the shipping industry, the industry challenges and the description of the proof-of-the-concept through the MarSEVR (Maritime Safety Education with VR) technology. The main objective in this paper is to present a prototype of the technology which can be utilized to train trainees and professionals in immersive training scenarios.

Keywords: Virtual training, Virtual reality, Maritime safety training, Shipping.

I. INTRODUCTION

The virtual reality market in Europe grows with an impressive rate. In 2018, the virtual reality market was expected to reach a value of 12.1 billion U.S. dollars, with Goldman Sachs, estimating AR and VR to grow into a $95 billion market by 2025. The continuous demand for AR and VR technology derives primarily from the creative industries [1], but it is now effectively in many business sectors such as the engineering, education and training, medicine, logistics and transport and others. Particularly in education, the future of Virtual reality (VR) seems very promising. Due to the interactive content accessible by anyone, anytime and anywhere, VR transforms the industry effectively and impressively.

Two organizations that perform extensive research on applied VR are the Aboa Mare Maritime Academy and the Game Lab of the Turku University of Applied Sciences.

Aboa Mare, a Maritime Academy at Novia University of Applied Sciences is currently involved in several smart and autonomous maritime research programs and networks, such as One Sea S4V, STM Validation Program, AIF and RAAS. The academy developed solutions for autonomous city ferries and now is in the development of remote operation simulators and training technologies. As a training provider, Novia and Aboa Mare continuously develop education tools and content such as the ASTP (Arctic Simulator Training Program) project, an improved simulation tool for ice breaking and winter navigation with integrated pedagogical tools for instructors and students. The newest simulator project is the MasterSIM, a remote operation simulator for training and research purposes, developed together with the maritime industry. Autonomous ship operations, procedures and technology are studied and trained with the simulator. The latest study on navigation tools and their effects on maritime safety was conducted in the Sea Traffic Management Project. Furthermore, the new ECDIS (Electronic Chart Display System) tool was tested in large scale simulator runs together with several European Maritime Simulator Centers. The test campaign had two scenarios, without and with the new tools, compared in the view of safety of navigation and workload of the operators.

II. THE GROWING NEED FOR VR SIMULATORS

According to Goldman Sachs [2] knowledge transfer is the biggest business area for augmented and virtual reality technologies. Virtual reality (VR) has been defined as an immersive, interactive system based on computable information [3]. VR as an interactive technology offers for training centers ways to educate students in immersive learning environments.

Simulators and virtual reality are used in training for the situations that should not happen, but also in dangerous situations by considering the skills of the trainee. Simulation is a hands-on method that is measurable and repeatable in debriefing, which the most powerful part of learning. According to M. Rall et al. [4] debriefing is the most important part of realistic simulator training for the successful learning process, providing standards for virtual learning feedback system. If feedback is performed wrongly, it impacts negatively the training session, the trainee's knowledge.

However, and despite the projected and expected effectiveness of VR and AR in the global markets, education holds today the smallest market share, indicating the potential growth the sector can have (Figure 1).

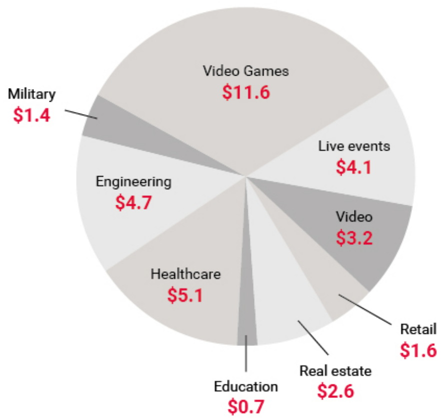

Figure 1. Global 2025 VR/AR Market share, by use case in billions (USD) [5].

III. THE CHALLENGING MARITIME SECTOR

Despite the need for strategic changes in the global economy, the shipping industry remains a driving force. Container shipping remains a world leading industry that connects businesses, markets, and people. Most of the products in the global market are transported between producers and distributors via ocean freight. [6]

S&P Global Ratings announced 2018, as the first year, after several, that the demand in the three main segments of the global shipping industry (dry bulk, tankers, and containers) will outstrip supply [7].

However, the development of the shipping industry faces significant challenges most of them related with the integration of the advanced technologies such as Modern control systems and autonomous shipping modules, Blockchain technology, Cyber-attacks and data theft, Safety culture, Blue Economy and Decarbonization.

On the safety culture challenge, research indicates that 49% of the organizations with effective cultures are less likely to have accidents and 60% make less errors in the workplace.

The continuous and unexcepted incidents at sea create a need for a different point of view on safety, outside the traditional thinking, ways and pracseatices. Today safety within a safety culture and safety climate is a priority for the shipping companies [8]. An effective contribution on building a safety culture in the shipping sector is through the use of simulators. The sector today is well suited to simulation and especially simulated based training.

However not all simulators operate effectively. The investment cost on developing reliable and effective simulations is significant, making them rare not available everywhere and at all times as they get overbooked.

Aboa Mare maritime academy delivers today approximately 900 days simulation training days, aiming in the next ten years (by 2030) to reach 225.000. These estimations derive from the extensive demand for simulation training.

According to the International Chamber of Shipping, the worldwide population of seafarers serving on internationally trading merchant ships is estimated at 1,647,500 seafarers, of which 774,000 are officers and 873,500 are ratings. Simulator training is expensive, out of reach for most of the officers.

Due to the scarcity of simulators, there are many advantages VR training offers to maritime education, contributing significantly to the resolution of key maritime changes [9]. With VR training, the training becomes visual: the learning process real life experiences by visualizing the tasks. It is also a safe place to practice complex situations. The cost of education becomes cheaper based on the learning groups the education frequency and the education place. Lastly, on-site training is available anytime and anywhere.

IV. THE MARITIME EDUCATION

The adaptation of simulation training is mostly an industry and not a company challenge. Over the years, computer simulation in the airline industry has been accepted as a practice that offers risk-free environment to test the capabilities of the trainees and to support classroom learning. However, this does not seem to be the case in shipping, where most training practices are actually based on the physical time served on a training session in which the trainees learn from senior personnel, not necessarily educators, situations that may occur on board. Shipping keeps on insisting on a ‘manual’ training compared to the ‘automated/digital’ one innovatively adopted by the airlines. This however is not quite effective as on a modern vessel, where everything works well, the trainee experiences few practical challenges. This many make the training complete, but the trainee is not capable to handle unexpected scenarios. The increased use of simulators is considered a pro-active training approach expected and demanded from quality operators and managers. It is therefore important to admit and recognize the value of advanced simulation training and use it effectively by taking advantage the lessons learned from the aviation industry. [10]. To do this it will require the wider shipping industry to recognize the benefits of simulation training in order to justify such investments and standardize such practices. Afterall shipping industry continuously seeks practices to improve its safety, operations and management standards and this change has begun.

Maritime education with simulators has been become one of the most advanced education fields globally. Today, maritime simulators training start with theoretical education to build up the required knowledge of the trainee needed to obtain knowledge on how to handle the expected training scenarios by following specific steps to test and set to practice the theoretical knowledge in a simulation exercise. This provides to the trainee the needed practical experience and hopefully delivers better understanding on the required decision-making process and on how different actions will affect a situation.

Simulations can be used by all. Even the experienced professionals are regularly trained on how to prioritize in challenging traffic and emergency operations and situations.

V. MARITIME SAFETY TRAINING

Maritime safety training is a critical sector as it aims to improve safety at sea. This is achieved by various training programs for the professional and amateur seafarers [10].
The European Maritime Safety Agency (EMSA) offers a wide range of training programs on Maritime Legislation, Maritime Safety, Maritime Security, Accident investigation, Maritime Environment, and others.
Due to the importance and expectations for continuous training in the maritime sector, there have been hundreds of training academies offering all types of training courses with all teaching methods and techniques. From the traditional classroom teaching, to off-line digital teaching, to on-line interactive e-learning platforms, up to modern Virtual Reality environments, maritime training is a fast and unstoppable market. There are numerous examples of impressive investments and in maritime training made by leading organizations.

- Lloyd's Register's, in order to raise awareness in the critical area of safety and risk in the oil and gas industry, showcased during the last SPE Offshore Europe, its Virtual Reality Safety Simulator and gaming technology.
- Korean Register intends to develop a VR training simulator using a realistic ship environment, to provide surveyor training on the classification rules and inspection procedures.
- Mitsui O.S.K. Lines, Ltd. develops a mariner safety education tool goggle, that uses VR technology created by Tsumiki Seisaku Co. Ltd.
- Immerse, a London startup with leading role in the VR learning movement, developed a platform to create bespoke live learning experiences. The technology can be used in any industry and training center, to teach any subject.
- Kongsberg Digital provides Virtual Reality (VR) solutions for enhanced training experiences. The company innovates by integrating mixed reality (MR), virtual reality (VR), augmented reality (AR) and augmented virtual reality.
- Propel developed SAYFR, a 3D-simulation model, to allow people interact in different scenarios onboard and ashore.
- K Line LNG Shipping (UK) Ltd, uses the Propel 3D simulation tool, to train crew onboard.
- Carnival opened CSMART in Almere, Netherlands, a Simulator and Maritime Training, to provide maritime training through technology solutions from Transas.

The list of the examples and cases where technology and VR, in particular, impacted significant investments, decisions, and organizations structures of maritime training is not limited on the above. In fact, it can be considered quite rich, impressive and diverse.

VI. THE MARSEVR TECHNOLOGY.

Maritime safety training is general can be a very wide topic. While developing Virtual Reality environments one of the research areas is to study how the communication of the information can be as natural as possible for the users (cf. 11]). To be more effective each simulation or training technology needs to be concentrated on specific operations. Decision making on the ship bridges is a challenging professional skill. Conditions can change dramatically in a few minutes and understanding of decision-making procedures must be clear in real life situations.
A bridge simulator gives great value for training when situations can be custom made to create challenging training conditions which provide the opportunity to test scenarios that would not be possible in real life due to the high risk involved or could be dangerous to try.
MarSEVR is a prototype of a maritime VR training technology which can be utilized to train both trainees and professionals. Compared to traditional command bridge simulators, the MarSEVR developers had no limitations while designing the learning content. The technology adopts the same design principles as in the game industry to implement, immersive training scenarios that assure the engagement of the user to understand the right decision-making factors in a gamified environment (Fig 2).

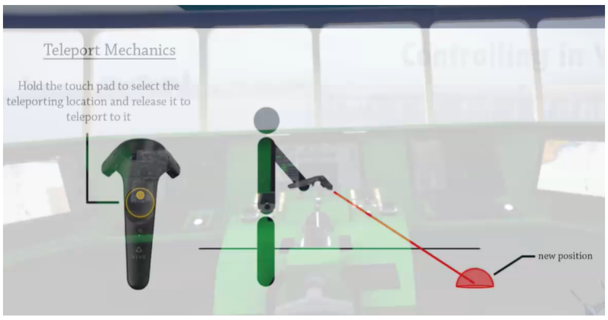

Figure 2. Gamified teleport mechanics in MarSEVR

In addition, these learning environments can be fully configurable with a full range of customized features and difficulty levels. After an exercise has been completed a debriefing is provided by the instructor and a playback of the whole exercise is shown.
Furthermore, as a portable solution VR can be used on board which will increase further education opportunities especially among professionals.

VII. THE MARSEVR OPERATIONS.

The goal of the training scenario is to practice situation awareness and decision making by replicating a ship bridge environment and then by creating different training scenarios with different difficulty levels (Fig 3).

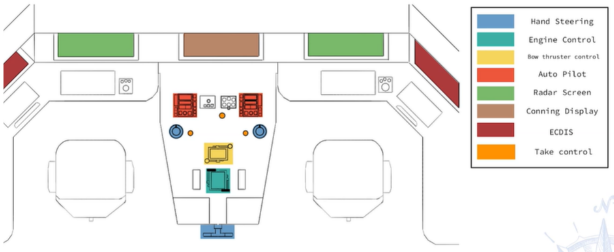

Figure 3. Ship bridge replication

The first training scenario includes watch change and collision avoidance situation. This scenario has learning goals to get the trainee to practice its attention to equipment status and settings and take actions when required as collision avoidance.

When an off duties navigational officer is relieving another officer from the bridge watch there a handover must be performed. This procedure has many recommendations given by different maritime organizations on how it should be executed, even that a watch change may seem a regular routine event on the ship. With this reason, the habits may become too familiar and the level of information change may get reduced. After a time, routines to carry out hand over and take over procedures may be at very low level and dangerous situations can occur.

The MarSEVR VR training tool focuses on watch change between two navigation officers on a cargo ships bridge and on events happening after the watch change. The object is to train the user's readiness to plan and execute navigational obligations, collision avoidance, be observant of equipment status and settings and to take actions and catching errors early before they get out of control.

Compared to the traditional simulator the MarSEVR objectives are to bring the training method to the ship and offer the pedagogical supports and learning analytics in form of instant feedback. This gives opportunity to practice anytime and anywhere.

The learning goals of training are the understanding the instructions, the use and checkup of the main technologies, and a solid base of visual route and traffic information for the safe navigation. The training experience must be realistic, especially on touch-feel side. The virtual training replicates the real-life situation authentically.

VIII. SCENARIO ON A CONTAINERSHIP

Vessel type: Feeder containership 1 (1610 TEU). Displacement: 24080.0 t. Max speed : 20.5 knt. Length : 196.0m, Breath: 27.2m, Bow draft: 8.5m, Stern draft 9.5m, Height of eye: 31m. Type of engine : Slow Speed Diesel (1x12640kw). Type of Propeller: CPP, Thruster bow : Yes. Thruster stern: Yes.

Scenario: It's 4 am in the night. After receiving and acknowledging the hand over for the user, the relieving watch leaves the bridge (Fig 4).

Figure 4. The watch change at 400hrs in the virtual training tool.

The user has now a moment to get familiar with the situation and adjust the equipment (i.e. radar, autopilot) according to user's wish. There is a small fishing boat trawling and making slow speed positioned right after the waypoint (WP) near the route. There is also shallow water (depth <10m) on the west side of the fishing boat. (Fig. 5). The user receives sound alarm from ECDIS: Approaching WP. The user has a possibility to start the turn already and in fact, manage the situation easily. If the user won't turn, the next alarm will come soon, indicating the ship will aground after 6min, if the user doesn't change the course. Soon comes the next alarm: Reached WP. Turn to new course 168°. The ship was not following her route exactly in the beginning. Furthermore, the small fishing boat complicates the situation

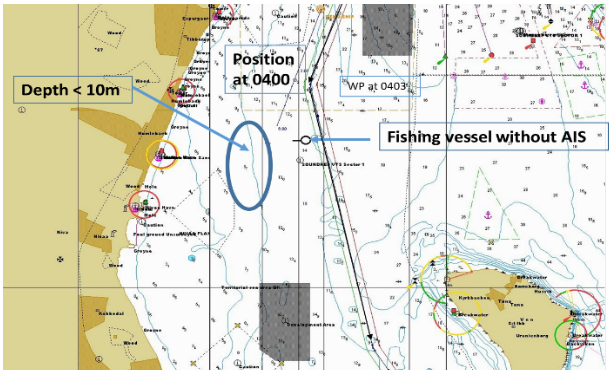

Figure 5. Position & route nr. 2

The user can choose the difficulty level in the beginning. Degrees of difficulty can be created in a few ways. Weather can also be adjusted from clear visibility to dense fog. The pre-adjustments of radar may hide the small fishing boat invisible in the beginning and the amount of traffic can be increased (Fig 6).

Figure 6. The traffic situation

Furthermore, various equipment failures can be created. The program gives tips along the training. If, for example, the adjustments of the radar are not tuned at an early stage or before the first ECDIS alarm, the user receives a reminder (Fig. 7). Pedagogical and gamified aids are used when testing real users.

Figure 7. Pre-adjustments of radar hiding other vessels.

A training solution has been developed for HTC Vive virtual reality glasses. These glasses are today an industry standard and widely used in gaming but also in other sectors and applications. This immersive training solution is fully portable and can be brought onboard. Artificial intelligence technology has been integrated to track and trace user's behavior in hazardous situations. During a training session the user receives instant feedback (warnings, instructions, etc) on the actions takes, but also immediate performance feedback at the end of every training session (Fig. 8).

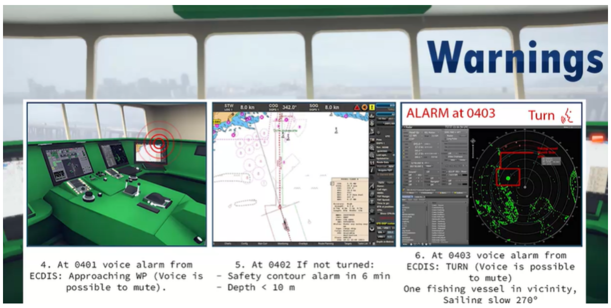

Figure 8. Instant warnings and action feedback.

In the first demonstration version of MarSEVR, all behavioral data are stored locally and are anonymous. At a later stage a backend system will be build including learning analytics and dashboard services for administrators in order to detect possible challenges in safety issues. MarSEVR intends to integrate data analytics and machine learning technologies that will evolve the existing it into a gamified Artificial Intelligence VR training technology on maritime safety.

IX. CONTIRBUTION TO THE MARITIME SECTOR

It is well known that about 60-80% of the accidents are attributed to human error (directly or indirectly). Generally, each operator or seafarer must undergo training before starting professional work. In the recent decades, emphasis on operator training has increased – resulting in advance training simulators with several features like immersivity, stereoscopic sounds, hydraulics, and even use of different odors. However, the design of training methodologies can have a significant impact on the skill acquisition of trainees. The growth of integration of technology in existing systems as well as newer systems is much higher than that of improvement in training methods. The increase of complexity in process and maritime industries was higher than that of improvement/ up-gradation of the training methods. This resulted in to an evident gap between training needs and demands of operators, some of which are lack of :

- realism in training (e.g., immersive environments, virtual reality;
- simulated abnormalities and accidents;
- team training;
- objective performance assessment;
- integration of technological tools to aid training/learning phenomena;
- non-technical staff training;
- generation of data from training simulators;
- scenarios imitating abnormalities and malfunctions;
- integration of results and research from other domains where safety and training are relatively more developed (for instance, process, nuclear and aviation industries) [2], [12]

MarSEVR has been designed to contribute on resolving the above challenges with an onboard education service to all seafarers, maintaining their safety education requirements fulfilled in an affordable and effective way.

X. AREAS OF FURTHER RESEARCH

MarSEVR is a technology at its very early stages. Significant advances have been designed and expected to be implemented on both hardware and software level, aligned with the virtual reality technologies progression but also with the maritime sector maturity to adopt VR education especially on safety issues.

Hardware wise, MarSEVR intends to integrate one of the most promising new VR technologies which is the Varjo's VR-1 glasses with human-eye resolution. This type of glasses can offer, especially in maritime, opportunities to focus on solutions where detailed textual or other visual information is a crucial part of learning aspects in maritime education.

Software wise MarSEVR will expand its safety training simulations beyond the watch change to cover at least 30 more critical safety cases related with different processes inside a ship where continuous training onboard and ashore is expected to be repeated to all seafarers.

The continuous changes on the crew and the fast operations cycle does not allow time for effective safety training prior boarding. MarSEVR will primarily operate as an onboard safety training virtual classroom assuring optimal training to all, anytime and anywhere. MarSEVR.V2 will operate as a training jukebox with each scenario to be executed upon schedule or upon demand (Fig. 9).

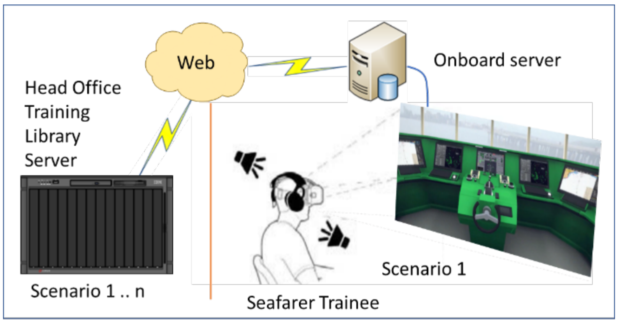

Figure 9. MarSEVR VR Safety training library.

MarSEVR allows VR training in diverse areas to train amateur but also qualified and certified personnel. The trainee practices with virtually digital equipment that incorporate the same features of the real operations environments, machines and tools. MarSEVR is fully parametrical allowing the users to change functional (technical, operational, etc) and nonfunctional (temperatures, weather, etc) conditions and requirements. on regular or emergency situations.

XI. CONCLUSIONS

The paper presented the first prototype version of the MarSEVR virtual training technology for maritime safety training. Emphasis was given on the concept of a portable training system which is cost effective and able to be used in on-board, training centers or even office environments. The technology is now at the testing phase and several research activities are planned such as usability tests, user and game experience evaluations, and finally effectiveness studies. It must be noted that just one learning content of the technology has been described. This system can consist of various learning chapters either as individual training scenarios or as continuous episodes part of a training curriculum / program. The future of maritime training with help of virtual reality training moves on board, far from the physical training centers that require time and expensive training periods. MarSEVR, and the upcoming version of MarSEVR attempt to address the critical maritime training challenges and contribute to the effective training standardization of the maritime industry.

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