International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 3, May-Jun 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Immersive Technologies in the Maritime Industry

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Immersive technologies have the potential to improve safety, efficiency, and cost-effectiveness in almost every industry. All sectors of the maritime industry, from navigation and cargo planning to management and logistics can benefit from immersive technologies. With its long and eventful past, the maritime industry has always stood tall and fine as the earliest in discovering new axes of training for safety, effectiveness, and skill development. The last few years have dramatically changed the maritime training landscape. VR safety training solutions have grown prominently into one of the leading technologies for workplaces and industrial safety. The growing use of virtual reality (VR) in maritime safety training has the potential for significant expansion. This paper serves as a review on the use of immersive technology in the maritime industry.

KEYWORDS: *virtual reality, VR, augmented reality, AR, mixed reality, MR, extended reality, XR, immersive technologies, maritime industry, maritime education and training*

How to cite this paper: Matthew N. O. Sadiku | Paul A. Adekunte | Janet O. Sadiku "Immersive Technologies in the Maritime Industry" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-3, June 2025, pp.1274-1285, URL: www.ijtsrd.com/papers/ijtsrd97162.pdf

IJTSRD97162

INTRODUCTION

The maritime industry, which encompasses shipping, navigation, and offshore activities, has always been at the forefront of adopting innovative training methods to ensure safety, efficiency, and skill development. In spite of occasional fluctuations, the maritime industry continues to propel the global economy. However, many sectors of the industry rely on dangerous, outdated or inefficient technology for training, planning, design, logistics, and emergency response. Immersive technologies can help to address many of these issues, and immersive training advantages will help bring the maritime industry into the modern world [1].

With the advancement of technology, industries worldwide are exploring the potential of cutting-edge tools like augmented reality (AR) and virtual reality (VR) to enhance training, safety, and operational efficiency. While many people use extended reality (XR), mixed reality (MR), virtual reality (VR), and augmented reality (AR) interchangeably, they are definitely different. VR can be divided into three distinct categories: non-immersive, semi-immersive, and immersive. VR immerses users into an entirely virtual world, while AR overlays virtual content on the real world. In MR, you can either add digital content to the real world, or real-world elements into a virtual world. XR is a catch-all term for AR, VR, MR, and any related future technologies.

WHAT ARE IMMERSIVE TECHNOLOGIES?

The first step in understanding how to use immersive technologies is to learn the differences between various forms. In their simplest form, immersive technologies consist in adding virtual objects to the real world. There are four types of digital realities leading to different types of immersive technologies [2,3]:

- *Augmented reality* (AR)- designed to add digital elements over real-world views with limited interaction.
- *Virtual reality* (VR)- immersive experiences helping to isolate users from the real world, usually via a headset device and headphones designed for such activities.
- *Mixed reality* (MR)- combining AR and VR elements so that digital objects can interact with

the real world means businesses can design elements anchored within a real environment.

- *Extended reality* (XR)- covering all types of technologies that enhance our senses, including the three types previously mentioned.

These devices also enable new user interactions including spatially tracked 3D controllers, voice inputs, gaze tracking, and hand gesture controls.

Extended reality (XR) is the overarching term used to describe employing technology to blend real life and the digital world. It includes all the machine-human interfaces beyond the physical realm (reality) such as augmented reality (AR), mixed reality (MR), assisted reality (aR), and virtual reality (VR), as illustrated in Figure 1 [4]. Figure 2 shows the XR spectrum [5]. Immersive technologies reside along a continuous scale ranging between the completely real and the completely virtual world. At one end, the real environment refers to the actual physical space, objects, and people that exist in the tangible world around us. At the other end, the virtual environment represents a completely computer-generated and immersive digital space, distinct from the physical reality. The space in the middle is called mixed reality, which is a blend of the real and virtual environments, where digital and physical elements coexist and interact in real time. A range of devices makes up XR, and these are used by consumers and in many industries for entertainment, safety, training, or productivity purposes.

1.*VIRTUAL REALITY:* Virtual reality (VR) is XR at its most extreme. It completely immerses the user in a digital world, often using a computer-generated environment with scenes and objects that appear to be real. The term "virtual reality" essentially means "near-reality." Virtual reality is the key technology for experiencing sensations of sight, hearing, and touch of the past, present, and future. VR is a fully immersive technology where users wear a head-mounted display and experience a simulated world of imagery and sounds. VR enables active learning. The terms, "virtual reality" and "cyberspace" are often used interchangeably. A cyberspace may be regarded as a networked virtual reality. A person using virtual reality can look around an artificial world, move around it, and interact with virtual features or items. This effect is commonly created by virtual reality headsets. Head-mounted displays immerse the user in a virtual environment. Virtual reality is a simulated experience that can be similar to or different from the real world. It is a computer-generated, 3D environment that completely immerses the senses of sight, sound, and touch. The complete immersion of the senses overwhelms users engrossing them in the action. Virtual reality technology includes multiple components divided into two main groups: hardware and software components [6].

- *Hardware Components:* The hardware components include a computer workstation, sensory displays, a tracking system, wearable devices, and input devices. Sensory displays are used to display the simulated virtual worlds to the user. The most common type is the head-mounted displays (HMDs), which is used in combination with tracking systems. Head-mounted displays are shown in Figure 3 [7]. Users interact with the simulated environment through some wearable devices. VR depends on special responses such as raising hands, turning the head, or swinging the body. A wearable device is important in making these effects realistic. Special input devices are required to interact with the virtual world. These include the 3D mouse, the wired glove, motion controllers, and optical tracking sensors. These devices are used to stimulate our senses together to create the illusion of reality.

- *Software Components:* Besides the hardware, the underlying software plays an important role. It is responsible for the managing of I/O devices and time-critical applications. The software components are 3D modeling software, 2D graphics software, digital sound editing software, and VR simulation software. VR technology has been designed to ensure visual comfort and ergonomic usage.

2. *AUGMENTED REALITY:* Augmented reality (AR) is a technology that combines real-world environments with computer-generated generated information such as images, text, videos, animations, and sound. It can record and analyze the environment in real-time. In augmented reality, the user typically experiences the real world through a device such as a smartphone, tablet, smart glasses, or head-mounted display. For example, AR allows consumers to visualize a product in more detail before they purchase it. This feature enhances consumer interaction and helps them never to repurchase the wrong item. The key objective of AR is to bring computer-generated objects into the real world and allows the user only to see them. In other words, we use AR to track the position and orientation of the user's head to enhance/augment their perception of the world. Augmented reality falls into two categories: 2D information overlays and 3D presentations, like those used with games. AR blends the virtual and real worlds by overlaying digital objects and information onto the users' view of the physical world.

To obtain a sufficiently accurate representation of reality, AR needs the following five components [8]:

- *Sensors:* AR needs suitable sensors in the environment and possibly on a user, including fine-grained geolocation and image recognition. These are activating elements that trigger the display of virtual information.
- *Image augmentation:* This requires techniques such as image processing and face recognition.
- *Head-mounted Display*: HMDs are used to view the augmented world where the virtual computer-generated information is properly aligned with the real world. Display technologies are of two types: video display and optical see-through display.
- *User Interface:* This includes technologies for input modalities that include gaze tracking, touch, and gesture. AR is a user interface technology in which a camera-recorded view of the real world is augmented with computer-generated content such as graphics, animations, and 2D or 3D models.
- *Information infrastructure:* AR requires significant computing and communications infrastructure undergirding all these technologies. The infrastructure determines what real-world components to augment, with what, and when.

3. *MIXED REALITY:* Mixed reality (MR) is a term used to describe the merging of a real-world environment and a computer-generated one. Physical and virtual objects may co-exist in mixed reality environments and interact in real time. This is an extension of AR that allows real and virtual elements to interact in an environment. MR liberates us from screen-bound experiences by offering instinctual interactions with data in our living spaces and with our friends. Online explorers, in hundreds of millions around the world, have experienced mixed reality through their handheld devices. Mixed reality is a blend of physical and digital worlds, unlocking natural and intuitive 3D human, computer, and environmental interactions, as shown in Figure 4 [9] and Figure 5 [10]. This new reality is based on advancements in computer vision, graphical processing, display technologies, input systems, and cloud computing. Mixed reality has been used in applications across fields including design, education, entertainment, military training, healthcare, product content management, and human-in-the-loop operation of robots [11].

4. *ASSISTED REALITY:* Like mixed reality, assisted reality (aR) is an extension of augmented reality, with a few notable differences to both. One of these differences is that aR is primarily hands-free through the wearing of a headset, whereas AR usually requires the holding of a device such as a mobile phone. While MR is a digital-first, real-world second reality, aR is a real-world first system. It combines software and a head-mounted display. It is best experienced using smart glasses or other wearable technology. The aR market is growing rapidly and promises to be the next great leap to boost workers' productivity. A worker wearing an aR device is shown in Figure 6 [12].

5. *EXTENDED REALITY:* The term "extended reality" (XR) has recently gained favor as an umbrella term that encompasses all of AR, VR, and MR. The primary user inputs for XR devices are described as follows. Voice interfaces are now ubiquitous thanks to mobile devices and standalone smart speakers. Apple's Siri, Amazon's Alexa, Google's Assistant, and Microsoft's Cortana are all voice-driven software interfaces that are continuously gaining new capabilities. Many XR devices enable user control with handheld controllers, which have capabilities beyond button press inputs. Both voice-driven interfaces and human-computer interactions have been developed specifically for XR devices, including gaze and gesture controls [13]. Figure 7 compares conventional computing with extended reality [13].

IMMERSIVE TECHNOLOGY IN MARITINE INDUSTRY

The maritime industry, known for its complex and dynamic environment, is undergoing a significant transformation driven by technological advancements. At the forefront of this evolution is the integration of virtual reality (VR) into crew training, a move that is redefining the way maritime professionals are prepared for the challenges of modern seafaring. Traditional training methods are limited in their ability to replicate certain conditions and scenarios, whereas VR solutions offer immersive, realistic, experiences that can improve learning outcomes, maintain trainee interest, and safely simulate dangerous situations.

The maritime sector involves several operations which include dangerous situations making safety a primary concern. Virtual Reality is revolutionizing marine training by providing immersive, risk-free environments for mariners to develop essential skills. As a result, maritime safety is reaching new levels of effectiveness and efficiency. VR in marine training offers realistic scenes of different maritime settings, including ship bridges, engine rooms, and cargo holds. The use of simulators in maritime education and training is an essential component for developing seafarer competencies. Emerging immersive technologies, such as virtual reality (VR), augmented reality (AR) and mixed reality (MR) have created new and differing possibilities for maritime simulations and simulators. Emerging technologies and training solutions in the form of VR, AR, MR, and AI should not be looked as a threat or replacement to traditional paradigms of education delivery, but rather a supplementation to the overall system. These are potential solutions to take advantage of and implement when and where they provide benefits [14]. As shown in Figure 8, MR technology allows one to view a whole ship in 3D [14].

APPLICATIONS OF IMMERSIVE TECHNOLOGY IN MARITINE INDUSTRY

VR is becoming more widely used in many areas of the maritime sector. One of these areas is education and training. VR technology creates an immersive learning environment that closely mimics real-world maritime conditions. Trainees can navigate through a virtual ship, experience different sea states, and encounter various scenarios such as engine malfunctions or man-overboard situations. Common areas of applications include the following [15,16]:

- *Maritime Training:* For centuries, maritime training has relied heavily on hands-on experience, with apprenticeships and on-the-job training forming the backbone of seafarer training. Traditional methods, such as classroom instruction, shipboard drills, and simulator-based training, have dominated the landscape. The landscape of maritime training has undergone a significant transformation, influenced by technological advancements and the changing needs of the global shipping sector. This evolution reflects a shift from conventional classroom-based learning to more dynamic and interactive methods, with virtual reality (VR) emerging as a pivotal technology. In the context of professional training, VR stands out for its ability to create realistic, engaging, and controlled environments where trainees can practice and hone their skills without real-world risks or costs. VR provides maritime personnel with safe, realistic training environments. VR enables trainees to explore and interact with a life-like maritime environment, from navigating a vessel to conducting emergency response drills. The risk-free training environment enables trainees to practice their responses to emergency situations, refine their problem-solving skills, and make critical decisions under pressure.
- Simulation is an instructional method that supports experiential learning. In the domain of marine education and training, simulators have been utilized for the purpose of training seafarers in the norms for avoiding collisions or for developing the skill of ship maneuverability. Figure 9 illustrates a variety of immersive and non-immersive simulators for experiential training and learning [17]. An example of VR simulation for navigation training is shown in Figure 10 [18]. The maritime simulator allows learners to train their skills in navigation for every scenario possible and, as a result, enhance maritime safety. Figure 11 shows simulator for fishing [18]. A fishing simulator allows trainees to simulate fishing operations such as longlining, pelagic trawling, jigging, etc.
- *Firefighting Training*: One of the examples of the use of VR technology is a study of a ship firefighting training system. Firefighting and evacuation training are important tasks in maritime education and training, especially for crews working on large passenger ships, to ensure the safety of the vessel, cargo, and passengers. Fire on a ship represents a serious threat to the crew, passengers, cargo, and ship itself. The economic losses can be immense. 3D virtual environment and VR technology simulate fire on board, allowing seafarers to experience real-life accidents. With the evolution of virtual reality (VR) technology and the introduction of wearable hardware, a change in paradigm has happened in firefighting and evacuation training where these new technologies are being introduced. Some studies do not incorporate full immersion of the user into virtual reality but offer a desktop experience of playing a "serious game." The concept of a serious game was used in the development of a prototype multiplayer ship evacuation simulator. An example of VR simulation for firefighting training is shown in Figure 12 [18].
- *Serious Games:* Serious games, a term that transcends the conventional boundaries of gaming, refer to games designed for purposes beyond mere entertainment, often targeting learning, training, or problem-solving objectives. These games are crafted to mirror the complexities and challenges of real-life tasks, offering users a hands-on learning experience that enhances understanding, retention, and practical application of knowledge. The application of VR-based serious games in professional training environments, especially in sectors like maritime, aviation, and healthcare, has revolutionized traditional learning paradigms. VR-based serious games represent a transformative approach in

maritime training, offering an interactive, engaging, and effective learning modality. Maritime trainer harnesses the potential of VR-based serious games to deliver cutting-edge training solutions tailored to the maritime industry.

BENEFITS

VR technology in maritime training offers some benefits: an immersive learning experience that closely mirrors real-life conditions, enhanced safety through risk-free simulation of dangerous scenarios, and cost-effectiveness by minimizing the need for extensive physical resources. The cost-effective immersive simulators (AR/VR/MR) are widely used and becoming very popular as effective teaching and learning tools due to their handy software and hardware solutions. Other benefits include [16,19,20]:

- *Cost-Effectiveness:* Maritime training traditionally involves significant costs, including fuel for training vessels, maintenance of equipment, and logistical expenses associated with off-site training locations. Implementing VR in maritime training offers substantial cost benefits. Traditional training often requires expensive resources, including full-scale simulators, operational vessels, and the associated costs of travel, accommodation, and logistical arrangements. VR training, on the other hand, eliminates many of these expenses. Today, we have cost-effective commercially available VR and AR headsets.
- *Enhanced Safety*: One of the most critical aspects of maritime training is safety. Traditional training methods can only go so far in preparing maritime professionals for the unpredictability and potential hazards of the sea. The ability to simulate dangerous or critical situations in a safe and controlled environment is a paramount benefit of VR training. VR allows trainees to practice emergency procedures without any physical risk. Fire drills, evacuation processes, and hazardous material handling can be simulated with high fidelity.
- *Scalability:* The scalability of VR training is another significant advantage. The simulator can be set up for basic desktop training or expanded to add more student stations, where trainees interact directly with simulated scenarios using tools to learn navigation and vessel operation, as well as more scenarios and software as needed. Multiple trainees can participate in a range of scenarios simultaneously, regardless of their physical location. This digital approach is more cost-effective and time-efficient than traditional simulator-based training, as it eliminates the need for physical space and reduces operational costs.
- *Customized Training:* Immersive technologies can be customized to simulate different types of vessels, operating conditions, and specific maritime procedures, making them suitable for a wide range of training needs. This adaptability ensures that the training programs can be tailored to the specific requirements of different shipping companies, vessel types, and regulatory standards. VR allows for the creation of customized training programs tailored to the specific needs of individual trainees or groups. Training modules can be designed to address particular skills, rank requirements, or types of vessels. These bespoke programs ensure that each trainee receives relevant and focused instruction, thereby maximizing training efficiency and effectiveness.
- *Personalized Learning*: Every maritime professional has unique training needs based on their role, experience level, and areas of expertise. VR in marine training can be tailored to individual learning needs. Trainees can repeat simulations as often as they need to master skills and procedures.
- *Improved Knowledge:* Candidates trained using VR simulations show much greater knowledge retention than those who receive traditional training and learning. The immersive nature of VR enhances engagement, allowing trainees to absorb and apply information more effectively in real-world maritime scenarios.
- *Enhanced Skill:* VR simulations permit crew members to continue mastering complex skills repetitively, thus achieving greater competency and faster skill development.
- *Reduced Time:* Immersive marine training provides a significantly faster and more efficient learning experience by immersing mariners in realistic, hands-on simulations. It enables trainees to practice complex maritime operations repeatedly in a controlled virtual environment, helping them grasp concepts more quickly. As a result, VR shortens training time while improving skill retention and operational readiness.
- *Increased Engagement:* VR simulations are interactive and engaging. This boosts trainee motivation and leads to a better learning experience. By allowing hands-on practice in a risk-free environment, VR helps trainees build confidence and improve their decision-making skills more effectively.

- *Sustainability:* The maritime industry is no stranger to the value of simulation training when it comes to enhancing safety, efficiency, and environmental sustainability. The industry is increasingly focused on sustainability and reducing its environmental impact. Crucially, simulation-based training significantly contributes to environmental sustainability. Simulations not only improve the quality of education but also support the Sustainable Development Goals (SDGs) by enhancing the connection between education and sustainability. Simulation-based training is a key driver for sustainable development within the maritime industry, tackling critical issues around education, sustainability, and technology advancement.

Some of these benefits are displayed in Figure 13 [19].

CHALLENGES

While AR/VR has made inroads into various sectors, it still faces challenges in gaining widespread adoption within the maritime industry. Interacting with virtual objects in 3D is a technical challenge. The mouse, keyboard, and touchscreen are not viable in XR environments. Lack of user technical literacy and training slow adoption of any technology; immersive technologies are no different. Until recently, the price and reliability of Internet at sea limited adoption of many technologies on ships, including XR. Other challenges include the following [20,21]:

- *Cost:* One of the primary barriers to the widespread integration of AR/VR in the maritime industry is the cost associated with the technology. The initial setup cost for VR equipment and software can be high, which might be a barrier for some training institutions. Implementing AR/VR solutions necessitates significant initial investment in hardware, software, and infrastructure. High-quality AR/VR devices can be expensive, and the maritime industry's vast scale further adds to the cost burden. Many maritime companies, especially smaller ones, may find it challenging to allocate substantial financial resources for adopting AR/VR solution.
- *Perceived Ease of Use*: Another critical factor affecting the acceptance of AR/VR in the maritime industry is the perceived ease of use (PEU) and overall user experience. The effective integration and utilization of VR in learning and educational environments are contingent upon the users' PEU of this emerging technology. AR/VR requires users to familiarize themselves with the technology and may involve a learning curve. Bulky headsets, motion sickness, and display lag are some challenges that can hinder a smooth user experience, leading to a reluctance to adopt these technologies.
- *Lack of Awareness:* Despite the growing popularity of AR/VR in various industries, there remains a lack of awareness within the maritime sector about the benefits and potential applications of these technologies. Many maritime professionals may not be fully aware of how AR/VR can revolutionize training, improve safety, and optimize operational processes. This lack of awareness can result from limited exposure to AR/VR solutions within the maritime industry or inadequate communication regarding their potential advantages.
- *Legacy Training Methods*: The maritime industry has relied on traditional training methods for generations, and these methods have proven to be effective in many cases. As a result, there is often resistance to adopt newer technologies like AR/VR, with some professionals viewing them as unnecessary disruptions to established training practices.
- *No Regulatory Requirements*: In many industries, the adoption of new technologies is facilitated by government regulations or guidelines that mandate or incentivize their use. However, the maritime industry currently lacks specific regulations or requirements regarding the integration of AR/VR into training and operational practices.
- *Motion Sickness:* Another challenge is VR sickness, characterized by dizziness and nausea during VR experiences. The marine environment itself presents problems for all technology at sea; movement is a particular problem for XR. Motion sickness is a common problem with VR, but not for MR and AR. Because MR/AR users can see the real world, the signals from their eyes and inner ear match, thereby removing the primary cause of motion sickness.
- *Integration with Other Technologies:* The integration of advanced technologies in maritime training is radically changing the way we prepare professionals for the challenges of the future. The future of VR in maritime training is likely to involve integration with other cutting-edge technologies such as AR and AI. AR, for example, can superimpose virtual elements onto physical training scenarios, providing seafarers with a more engaging and realistic learning

experience. AI is also set to play a crucial role in maritime training. The integration of AI with VR and AR could further enrich training programs.

CONCLUSION

The future of VR in maritime training looks promising. With continuous advancements in VR technology, including better graphics, more intuitive user interfaces, and enhanced sensory feedback, the training experience will only become more immersive and effective. By integrating VR into their training portfolios, maritime training institutions can provide more effective, efficient, and engaging training experiences for the next generation of seafarers. Immersive tech allows trainees to engage with complex maritime operations in a safe, controlled environment, thereby significantly improving their technical skills, decision-making capabilities, situational awareness, and teamwork. As adoption of immersive tech grows in related industries, it is inevitable that it will spill over into the maritime industry. More information about immersive technologies in the maritime industry can be found in the books in [22,23] and a related journal: *Journal of Marine Science and Engineering*.

REFERENCES

[1] N. Gardner, "Brief guide to extended reality in the maritime industry," https://thetius.com/brief-guide-to-extended-reality-in-the-maritime-industry/

[2] M. N. O. Sadiku, C. M. M. Kotteti, and S. M. Musa, "Augmented reality: A primer," *International Journal of Trend in Research and Development,* vol. 7, no. 3, 2020.

[3] "What is augmented reality or AR?" https://dynamics.microsoft.com/en-us/mixed-reality/guides/what-is-augmented-reality-ar/

[4] L. van Heerden, "What is extended reality?" August 2021, https://journeyapps.com/blog/what-is-extended-reality/

[5] A. Xperteye, "What is assisted reality? Here is what you need to know," March 2022, https://blog.amaxperteye.com/what-is-assisted-reality-here-is-what-you-need-to-know

[6] M. O. Onyesolu and F. U. Eze, "Understanding virtual reality technology: Advances and applications," *Advances in Computer Science and Engineering*, March 2011, pp. 53-70.

[7] "Exploring the future of immersive technology," July 2023, https://www.talespin.com/reading/exploring-the-future-of-immersive-technology

[8] M. Singh and M. P. Singh, "Augmented reality interfaces," *IEEE Internet Computing*, November/December 2013, pp. 66-70.

[9] "What is mixed reality?" January 2023, https://learn.microsoft.com/en-us/windows/mixed-reality/discover/mixed-reality

[10] C. Rincon and J. Perez, "What are immersive technologies?" March 2025, https://www.adalovelaceinstitute.org/resource/immersive-technologies-explainer/

[11] "Mixed reality," *Wikipedia*, the free encyclopedia, https://en.wikipedia.org/wiki/Mixed_reality

[12] "What is assisted reality? Here is what you need to know," March 2022, https://blog.amaxperteye.com/what-is-assisted-reality-here-is-what-you-need-to-know

[13] C. Andrews et al., "Extended reality in medical practice," *Current Treat Options Cardiovasc Medicine,* vol. 21, no. 4, March 2019.

[14] S. C. Mallam, S. Nazir, and S. K. Renganayagalu, "Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies," *Journal of Marine Science and Engineering,* vol.7, no. 12, November 2019.

[15] G. Vukelic et al., "Application of VR technology for maritime firefighting and evacuation training—A review," *Journal of Maritime Science and Engineering*, vol. 11, no. 9, 2023.

[16] "The role of virtual reality in enhancing maritime training," April 2024, https://maritimetrainer.com/blog/vr-based-maritime-training

[17] M. H. Dewan, "Immersive and non-immersive simulators for the education and training in maritime domain—A review," *Journal of Maritime Science and Engineering*, vol. 11, no. 1, 2023.

[18] N. Makarevych and A. Bitkina, "Maritime VR simulator development: Benefits & types," March 2024, https://onix-systems.com/blog/developing-marine-vr-simulator

[19] R. Gupta, "VR marine training: Enhancing safety in the maritime industry," February 2025, https://www.kompanions.com/blog/vr-

marine-training-enhancing-safety-in-maritime-industry/

[20] A. Marc, "How virtual reality is transforming maritime training," https://www.linkedin.com/pulse/how-virtual-reality-transforming-maritime-training-marc-asselin-n0bpe/

[21] "5 Reasons why AR/VR is not commonly used in the maritime industry," August 2023, https://www.marineinsight.com/future-shipping/ar-vr-is-not-commonly-used-in-the-maritime-industry/

[22] S. Aurelia, *Immersive Technologies: Navigating the Impacts, Challenges, and Opportunities.* Boca Raton, FL: CRC Press, 2024.

[23] J. Dalton, *Reality Check: How Immersive Technologies Can Transform Your Business.* Kogan Page, 2021.

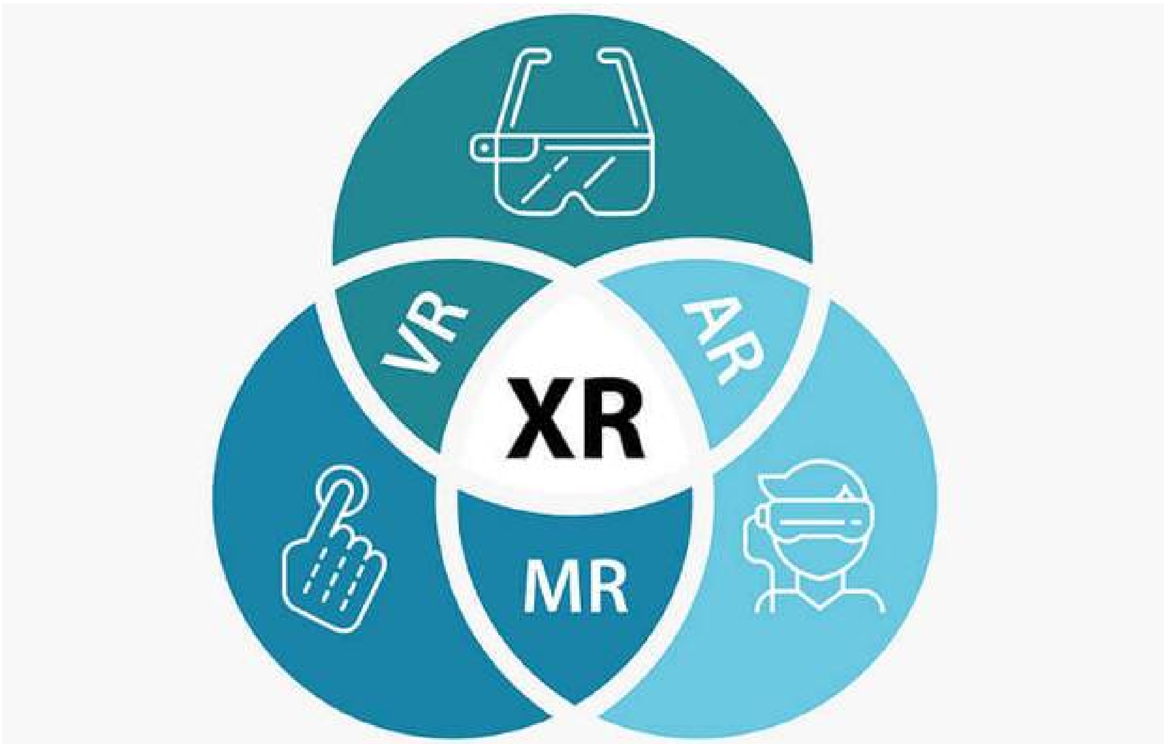

Figure 1 Extended reality (XR) includes AR, MR, and VR [4].

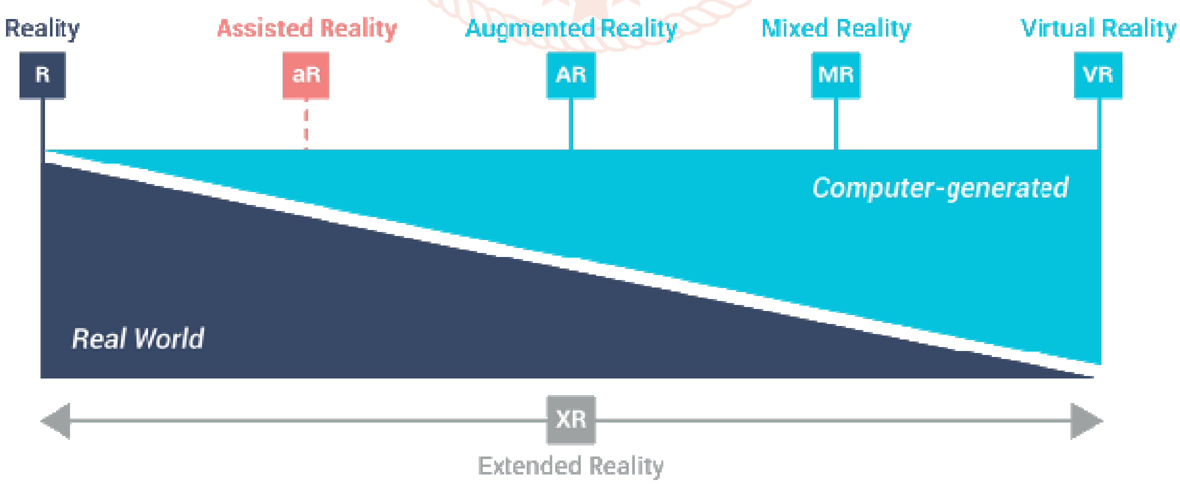

Figure 2 The XR spectrum [5].

Figure 3 Head-mounted displays [7].

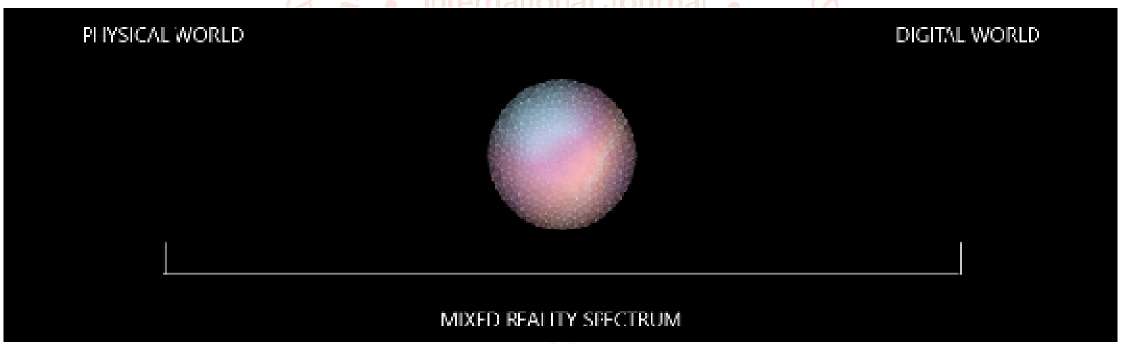

Figure 4 Mixed reality is a blend of physical and digital worlds [9].

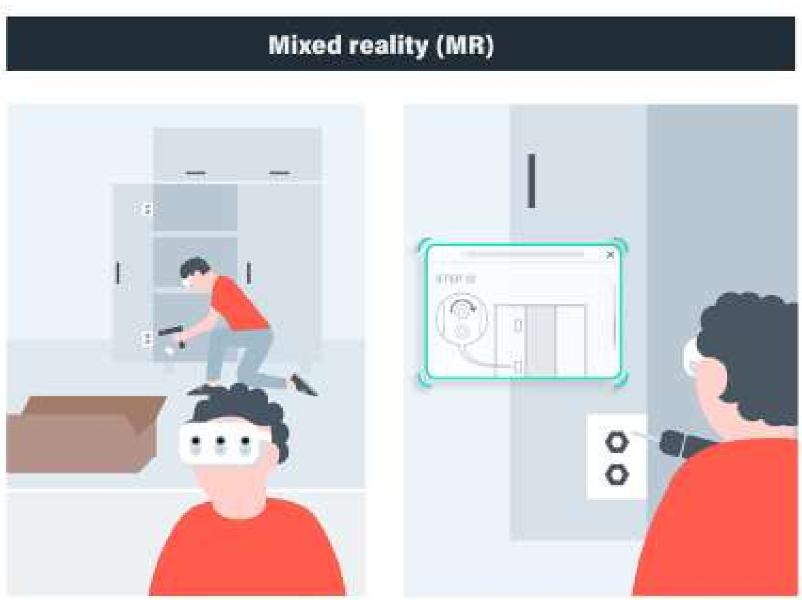

Figure 5 Mixed reality [10].

Figure 6 A worker wearing an assisted reality device [12].

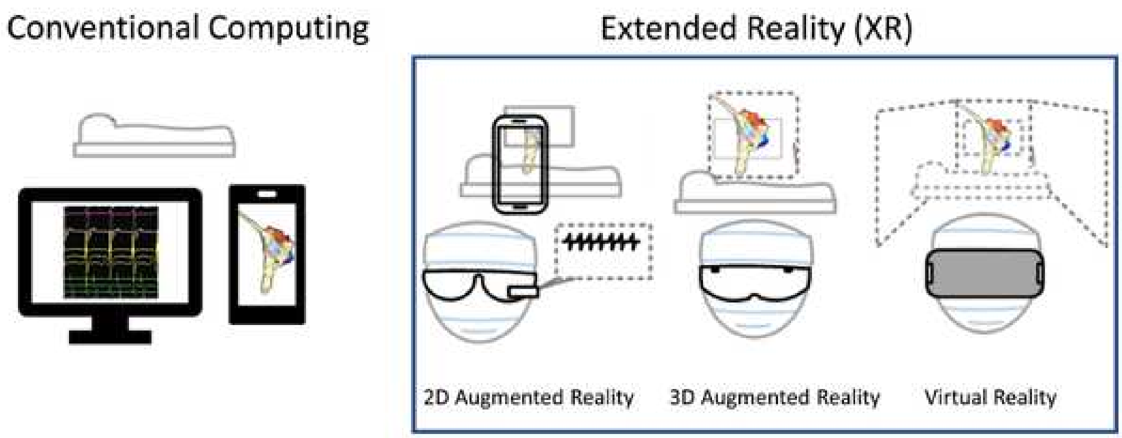

Figure 7 Comparing conventional computing with extended reality [13].

Figure 8 MR technology allows one to view a whole ship in 3D [14].

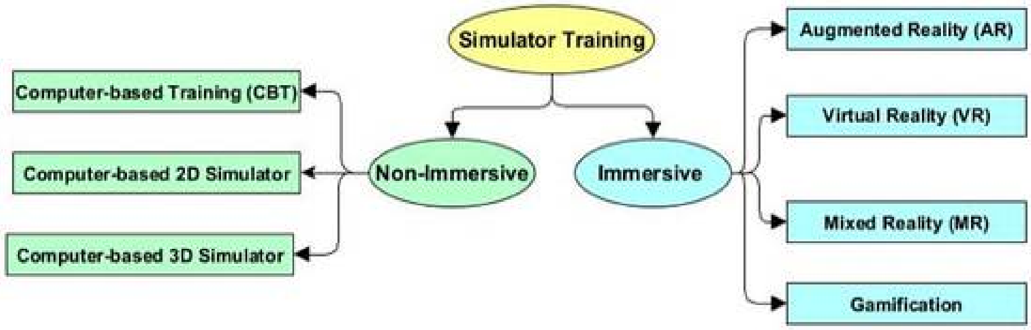

Figure 9 A variety of immersive and non-immersive simulators for experiential training and learning [17].

Figure 10 An example of VR simulation for navigation training [18].

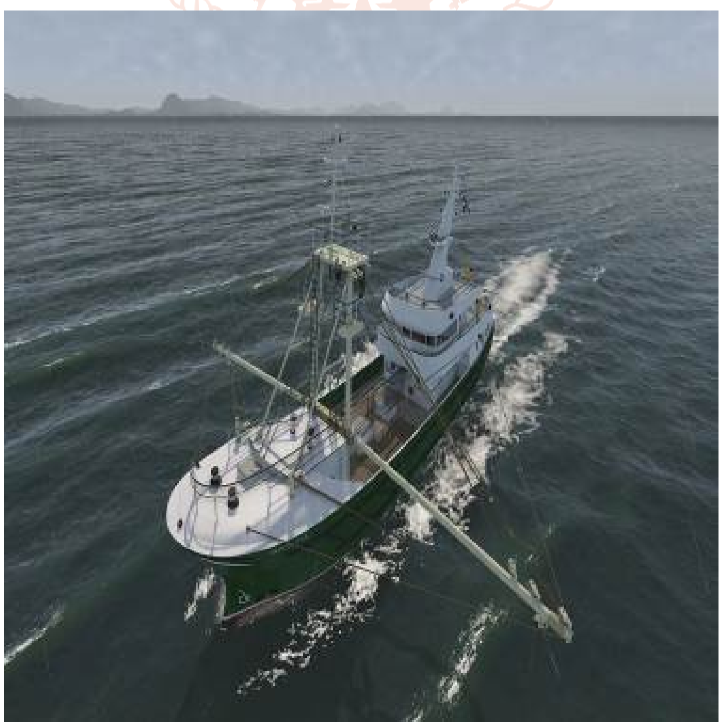

Figure 11 Simulator for fishing [18].

Figure 12 VR simulation for firefighting training [18].

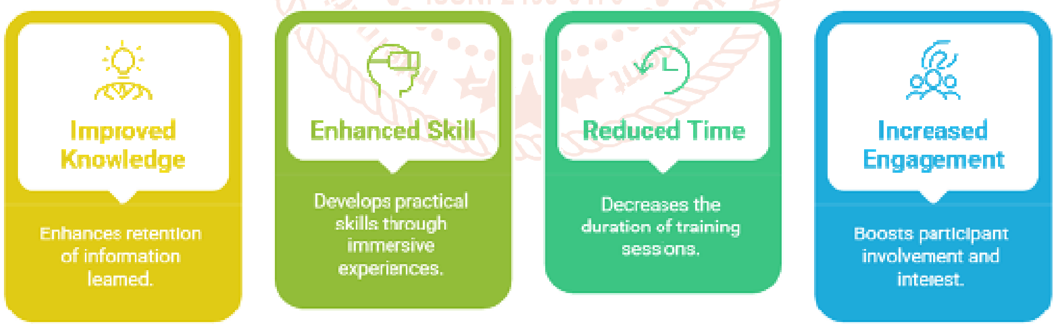

Figure 13 Some benefits of immersive maritime training [19].