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VIRTUAL AND MIXED REALITY SIMULATION SOLUTIONS IN ROMANIAN NAVAL ACADEMY TRAINING PROCESS – CONCEPT STUDY

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Abstract: *A simulator is one of the didactic means used in education, being a device designed to simulate aspects of the real world. Those simulators in which virtual reality (VR), augmented reality (AR) or mixed reality (MR) technologies are integrated are an advanced means used in the training/learning process, being a real and promising way to improve the quality of education. "Mircea cel Bătrân" Naval Academy intends to acquire maritime virtual reality (VR) and mixed reality (MR) simulators as an extension of the existing simulation complex. The paper presents a concept study on these simulators to be used in the training of students and personnel in the Naval Forces.*

Keywords: virtual reality, mixed reality, maritime simulator, naval training, educational technology

1. Introduction

A good way to learn is by doing. To acquire the necessary skills for integration into the labour market, in accordance with the European Union Directives, the principle of student-centred education and the principle "*learn to practice - practice to learn*" are respected. The simulator is one of the means by which these skills can be assimilated, it is a device designed to simulate aspects of the real world. The simulation process has a few benefits, including lower expenses, removal of actual risks or harm, and the ability to consistently recreate simulated scenarios [2].

The simulator in which virtual reality (VR), augmented reality (AR) or mixed reality (MR) technologies are integrated is an advanced mean used in the training/learning process, being a real and promising way to improve the quality of education, inspire the passion for knowledge and prepare students for future challenges.

In recent years, there has been and will continue to be a lot of talk about virtual reality and augmented reality. Although these two technologies are parallel, they are not similar [1]. Virtual reality is a computer-generated environment that enables user interaction within a three-dimensional synthetic space via specialized hardware, including head-mounted displays (HMDs) with integrated screens, sensor-based gloves, and haptic feedback devices. [4]. Depending on the degree of immersion, the user can interact with objects within this simulated world, or just be a simple spectator and experience the environment in a realistic way, visually and audibly. VR gives us access to certain experiences that would be difficult to afford, bringing with it the potential to change our lives [1].

Opposite to VR, augmented reality enhances the real world through overlays with digital content. AR adds information to the physical world by superimposing

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digital content, such as images, widgets, or data, onto the user’s real-world view by spatially anchoring virtual elements to physical environments [4]. When done well, this mixed world seems to be truly real, especially now that the possibility of interacting with digital objects makes them seem real [1].

Mixed Reality (MR) is a convergence of VR and AR, enabling the seamless integration of real and virtual environments to create interactive, hybrid learning spaces. In MR, physical and digital objects coexist and interact in real time, allowing users to engage with both simultaneously. Unlike VR or AR alone, MR spans the continuum between the physical and digital realms, supporting dynamic, context-aware educational experiences. [4].

2. Virtual reality vs. augmented reality

In terms of technology, virtual reality and augmented reality are similar. Both aim to provide the user with an immersive experience.

As mentioned, augmented reality refers to the addition of virtual components to the real world for interactive purposes. By contrast, in virtual reality, the environment is entirely created by the computer and is not necessarily related to reality, if the user does not want it [1].

Another important difference lies in the way this technology is delivered to the user. VR can be experienced with the help of the headset and controllers. Many other accessories are also needed to connect people to virtual reality, to allow them to navigate and control their actions. AR is currently implemented through mobile computing devices, including smartphones, tablets, and laptops, but also with special devices (Google Glass and HoloLens), developed by companies in the field [1].

VR refers to an integrated system of technologies and devices designed to generate immersive simulations within a three-dimensional digital environment. The virtual environment replicates real-world settings using three-dimensional elements, such as depth cues, spatial audio, and interactive interfaces like consoles, to enable user interaction. User movements are typically tracked using head-mounted displays or motion-sensing technologies, allowing for dynamic engagement within the simulated space. [1].

VR is applied across diverse domains, including gaming, engineering, education, psychological therapy, e-commerce, and marketing. In the contexts of engineering and education, VR enhances mechanical modelling by integrating with Computer-Aided Design (CAD) software. This enables engineers and students to create, visualize, and manipulate three-dimensional models in an immersive environment, closely mimicking the interaction dynamics of real-world physical objects. [1].

AR enables users to perceive computer-generated virtual elements seamlessly integrated into their physical environment. The "real world" refers to the sensory environment that an individual experiences directly through visual, tactile, auditory, olfactory, and gustatory inputs. The "virtual world" is defined as an environment generated, stored and calculated with the help of a computer. An AR monitoring system captures and tracks virtual elements within the physical environment, facilitating the integration of digital and real-world data to provide users with contextualized information [1].

Video AR systems consist of "*Video See-Through*" and "*Optical See-Through*" technologies. "*Video See-Through*" utilize cameras to capture real-world scenes, which are then digitally combined with virtual images to generate the augmented display. In contrast, "*Optical See-Through*" projects virtual images directly onto a transparent display, enabling users to simultaneously view the superimposed virtual content and the real-world environment through the same optical interface. Because it allows people to easily and correctly associate virtual information with a real-world

problem, task, or situation, augmented reality brings great benefits to a society flooded with information [1].
An AR system can be used to simulate real-world activities such as piloting a flying machine or manoeuvring a ship/boat, or even more, for training, education, and research [1].

3. Virtual reality and augmented reality in university education

There are many more uses of virtual reality than was realized at the beginning, uses that cover various fields, from engineering, design to business, arts and entertainment. Regardless of the use, it is important that virtual reality produces a set of data that is later used in the development of new models, training, communication and interaction methods. The possibilities are, in many ways, limitless [1].
VR has been increasingly integrated into educational settings to enhance teaching and learning experiences. A key advantage of VR is its capacity to enable multiple users to simultaneously interact within a shared three-dimensional environment. This immersive approach allows for the presentation of complex data in an intuitive and engaging manner, thereby facilitating easier comprehension and fostering enjoyable learning experiences. Furthermore, users can actively manipulate virtual objects to explore and acquire deeper knowledge [1].
AR also plays a significant role in education by aiding students in the acquisition, processing, and retention of information. AR enhances learner engagement by making educational content more interactive and appealing. Its versatility allows it to be effectively implemented across diverse age groups and educational levels, ranging from early childhood education through higher education and professional training [1].
AR applications can enrich traditional curricula by overlaying graphics, videos, text, or audio onto students' study materials in real-time, thus providing dynamic and contextually relevant learning support.
In higher education, several applications help students understand the concepts of physics, mathematics, geometry, chemistry, or mechanics. These are active learning processes in which students learn using technology [1].
Virtual reality has also been adopted as a method by the military field, in all its three branches, the Army, Navy and Aviation, where it is used for training. It is especially useful in training servicemen for combat situations, avoiding the risk of injury or even death. They can repeat certain scenarios, without exposing themselves to the real risks of war, safely and at lower costs than through traditional training methods [1].
Also, there is a lot of investment in the use of augmented reality in the military field, this being the sector where the results are most promising. AR services and military products are not limited to the battlefield but go all the way to training procedures [1].
Traditional information systems, which are not wearable, require military personnel to consult maps or mobile devices to access tactical data. This often results in a "head-down" posture, diverting their attention from the immediate operational environment. In contrast, wearable AR systems enable soldiers to receive critical tactical information in real-time while maintaining a "head-up" position, thereby enhancing situational awareness and operational responsiveness [1].
While these technologies can still be technically and financially challenging, their benefits and positive impact go far beyond the efforts made. Thus, VR and AR can be implemented in university education by:

- *virtual labs*: realistic lab environments are recreated, where students can experiment, interact, and test hypotheses in a safe and controlled way. This provides practical and applied learning opportunities without requiring expensive equipment or health risks.

- *virtual field trips*: Students can virtually travel to remarkable places and events around the world and in history. These virtual field trips allow students to visit inaccessible places or experience important historical events, thus increasing their understanding and interest in various topics.
- *real-life simulations*: creating realistic scenarios for various fields. Students can be involved in a wide range of experiences, from solving complex problems to dealing with crisis situations, which provides them with opportunities for applied learning and the development of decision-making skills.
- *interactive training*: Students can participate in interactive experiences such as communication simulations, practical skills, or art demonstrations. Thus, they can learn by doing and receive real-time feedback to improve their skills.
- *collaborative learning*: VR facilitates collaboration between students and teachers, regardless of geographical location. Students can work together on projects, develop joint presentations, and interact in real-time in virtual spaces, which enhances team communication and learning.
- *visualization of complex data and models*: In fields such as science, engineering, and architecture, VR allows students to visualize and interact with three-dimensional models and complex data. It facilitates a deeper understanding of abstract concepts and phenomena.
- *personalized learning experiences*: Teachers can tailor learning experiences to students' individual needs. Thus, each student can progress at their own pace, having access to personalized resources and challenges appropriate to their level of knowledge.
- *health and safety training*: VR is useful in health and safety training, where students can practice medical procedures, improve their emergency management skills, or train for certain high-risk professions and activities.

By applying these technologies in education, universities can bring new dimensions to the learning process, increase student engagement, and improve the quality of education offered. However, it is important to consider technological requirements, costs, and accessibility aspects to ensure that benefits are available to as many students as possible [6].

4. VR and MR simulation solutions for bridge and engine compartment in "Mircea cel Bătrân" Naval Academy

The Intersessional Simulator Working Group (ISWG), established under the International Maritime Organization (IMO), is tasked with structuring and coordinating simulation-related matters. The ISWG defines simulation as a realistic, real-time replication of ship operations, including ship handling, radar and navigation, propulsion, cargo/ballast management, or other ship systems, featuring an interface designed for interactive use by learners, either within or external to the operational environment. Moreover, such simulations must comply with the performance standards outlined in the relevant sections of the STCW Code.

Maritime simulators integrate modern equipment that manages to provide virtual training in terms of obtaining the standard on-board routine for seafarers and improve safety in the operation of commercial or military vessels [2].

Since 2009, "Mircea cel Bătrân" Naval Academy has been equipped with an integrated simulator for ship management, last updated in 2024. This simulator meets the certification standard for marine simulators, being a full-mission Class A (NAV) simulator.

However, "Mircea cel Bătrân" Naval Academy intends to acquire maritime virtual reality (VR) and mixed reality (MR) simulators as an extension of the existing simulation complex.

The main goal is to improve the training program and the way maritime educational content is delivered to students, military and civilian, from the navigation and naval electromechanics specializations. The use of maritime virtual reality and mixed reality simulators enhances student learning and engagement and provides them with the skills and knowledge to carry out safe, efficient and environmentally friendly transport on waters around the world.

The mission of the Naval Academy is to train graduates at university level who will meet the need for professionals of the Romanian Naval Forces and of the economic environment in the naval and port, maritime and river fields. Thus, virtual reality and mixed reality simulators for ship handling and engine compartment can achieve professional training at a higher level of students and master's students, in accordance with international standards, as well as military ship crews.

VR and MR simulators for ship handling and engine compartment are an immersive mixed reality solution for ship and tug handling training, using state-of-the-art VR equipment, providing an unlimited field of vision. They can be offered as standalone training tools, running on a single PC, integrated with an instructor station, or as an add-on to an existing simulator.

Virtual reality and mixed reality simulators for ship handling and engine compartment in the Naval Academy will be divided into four types, as follows:

- *Virtual reality (VR) simulator for conventional ship handling* – provides realistic environments for navigator training, where learners can practice manoeuvring and navigating ships in different weather conditions and scenarios (Figure 4).
- *Virtual Reality (VR) simulator for tug manoeuvring* – provides realistic environments for training tug masters and marine ship pilots who steer ships in and out of ports (Figure 7).
- *Mixed reality (MR) simulator for fast boats* – involves a mini navigation simulator on a mobile platform intended for two people with maritime seats, where learners practice navigation and vessel manoeuvring with the help of mixed reality that superimposes virtual information on top of the physical deck configuration. Learners can interact with both real-world and virtual commands simultaneously, creating a more immersive and real-world training experience (Figure 10).
- *Virtual reality (VR) simulator for the engine compartment* – represents a virtual space in the engine control room, with the possibility of simulating the operation and interaction with aggregates, as well as with the high voltage circuit breaker (HVB), in the VR environment (Figure 11).

4.1. Configuration of VR simulator for conventional ship handling

The bridge is composed of a physical console with ship control hardware for conventional and azipod types. The rest of the bridge and visual environment is projected inside a virtual reality headset. The movements of the learners' hands are synchronized with those of the virtual hands, and all the buttons of the equipment are inside the virtual environment.

The virtual environment also includes deck information indicators, a map presentation for navigational situational awareness, and exterior viewing (Figure 1). The user can move in the navigation control, look out the window, observe the side of the ship at the time of docking and change the control positions between the two wings of the bridge and the central position.

The manoeuvring consoles are designed to require minimal space and have a flexible solution for switching between conventional and azipod propulsion (Figure 2).

Figure 1: Example of a virtual environment on a navigation bridge

Figure 2: Example of conventional manoeuvring consoles, virtual (left)and physical (right)

The navigation console contains interchangeable ship control equipment for conventional and azipod propulsion and virtual reality equipment (Figure 3).
Virtual reality equipment includes:

- virtual reality headset with built-in motion sensor
- virtual reality processing PC for the student
- virtual reality processing PC for instructor
- virtual reality trackers
- base stations for positional tracking of the headset.

Figure 3: Example of Virtual Reality equipment

Figure 4: Virtual reality (VR) simulator for conventional ship handling – MBNA project

4.2. Configuration of VR simulator for tug manoeuvring

The bridge is composed of two physical consoles with equipment for the control of the tugboat. The rest of the bridge and visual environment is projected inside a virtual reality headset (Figure 5). The movements of the learners' hands are synchronized with those of the virtual hands, and all the buttons of the equipment are inside the virtual environment.

Figure 5: Example of a virtual environment of a tugboat navigation deck

The navigation bridge is composed of two consoles with clutch out azimuth controllers for the propulsion of the ASD (Azimuth Stern Drive) tug and virtual reality equipment (Figure 6).

Figure 6. Example of a hardware console with ASD commands

Figure 7: Virtual reality (VR) simulator for tug manoeuvring – MBNA project

4.3. Configuration of MR simulator for fast boats

The Mixed Reality bridge for fast boats combines elements of both virtual and augmented reality to create immersive experiences where virtual and real-world objects coexist and interact in real time. Realistic scenarios can be simulated for advanced manoeuvres on restricted waterways, including ship assistance or emergency procedures. In the context of maritime simulation training, mixed reality offers unique advantages by merging virtual elements with the physical environment of a ship's bridge.

The MR simulator for fast boats comprises the following main elements:

- the fast boat bridge mixed reality platform for two operators (navigator and helmsman), with marine seats on a mobile platform having movements synchronized with the simulated vessel model (Figure 9)

- real hardware controls for the fast boat
- screens for conning, ECDIS and radar/ARPA interfaces displayed on touch displays
- virtual reality equipment for two people.

The rest of the virtual bridge and the environment are projected inside the headset, where the panels with a green background are present (Figure 8). This means that everything on the learners' deck that is not coloured green (physical controls, navigation equipment, etc.) will be visible through the MR headset cameras, just like in real life, and the learner can manoeuvre the equipment or interact with other team members on the deck, just as they would on a standard simulator deck. Thus, the virtual environment of the simulated scenario will be projected on the green panels, creating an immersive, 360° viewing area, without interruptions.

Figure 8: Example of a virtual environment on navigation bridge for fast boats

Figure 9: Mobile platform for the mixed reality (MR) bridge

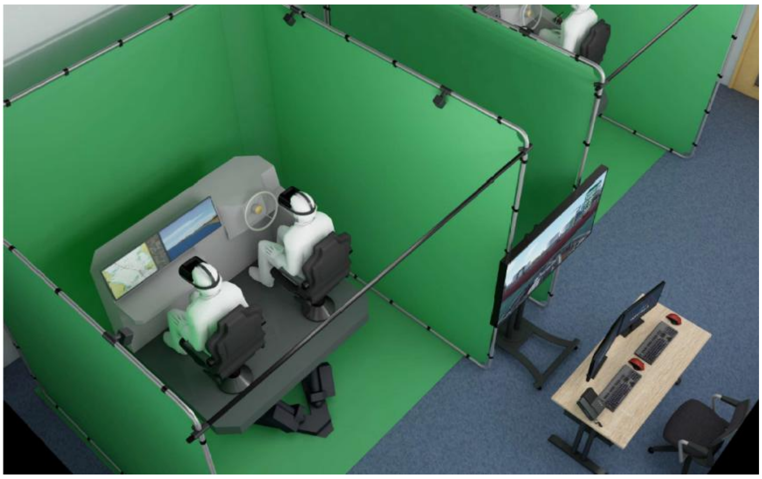

Figure 10: Mixed reality (MR) simulator for fast boats – MBNA project

4.4. Configuration of VR simulator for the engine compartment

The virtual reality stations in the engine compartment are made as an extension of the current simulator (Engine Room Simulator). The virtual space is an animated and operable replica of the engine control room, with the possibility of moving the user, but also the aerial view.

The virtual environment in the engine room is played and demonstrated through VR headsets and, with the help of controllers, the user can move through the entire environment, reproducing the movements of a real person. In addition, the user can interact with other users (in the form of avatars), which will add a new perspective of reality to the exercise.

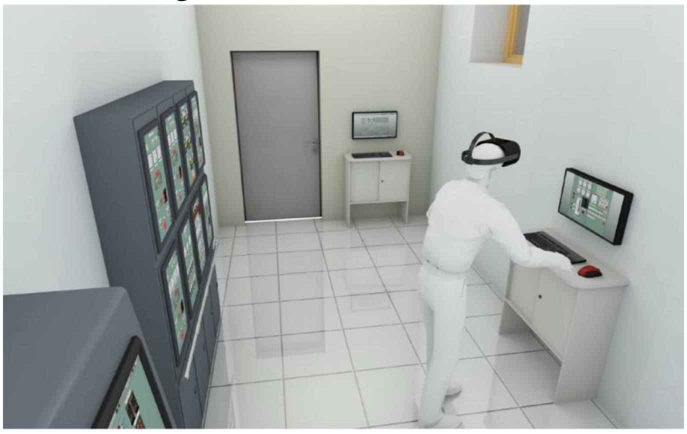

Figure 11: Virtual reality (VR) station in the engine control room – MBNA project

5. Conclusions

Virtual Reality and Augmented Reality are emerging as transformative and continuously evolving technologies, increasingly adopted across a wide range of sectors. These immersive tools are reshaping real-world experiences by introducing new modes of interaction and communication. By enhancing user engagement and enabling novel forms of social and spatial interaction, VR and AR are redefining the way individuals' interface with digital environments.

While augmented reality can be accessed very easily from a smartphone or tablet, having digital content superimposed on the environment, in contrast, virtual reality makes the user completely block the real world, immersing him in the virtual experience, which means that he cannot be on the move and needs more complex equipment.

Although "Mircea cel Bătrân" Naval Academy is equipped with an Integrated Simulator for the ship handling used in the training of students, it intends to acquire VR and MR maritime simulators as an extension of the existing simulation complex; to improve the training program and the way educational content is delivered to students.

These simulators for ship handling and engine room compartment in the Naval Academy are:

- VR simulator for conventional ship handling (two bridges)
- VR simulator for tug manoeuvring (two bridges
- MR simulator for fast boats (two bridges)
- VR simulator for the engine compartment (one station).

In this way, "Mircea cel Bătrân" Naval Academy fulfils its fundamental mission of training graduates at university level to meet the need for professionals of the Romanian Naval Forces and of the economic environment in the naval and port field.

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