Operation Analysis

Virtual Reality Modelling in the context of offshore-decommissioning

January 2023

University of Applied Sciences Emden/Leer

Faculty of Maritime Sciences

Project Acronym:	DecomTools
Reference Number:	Interreg North Sea Region
Project Number:	20180305091606
Project Title:	Eco-Innovative concepts for the end of offshore wind energy farms lifecycle
Activities and Deliverables:	Operation Analysis to estimate operation time and risk
Work Package/Deliverable:	WP5D5
Date of Issuance:	January 2023

Research Team

Authors: Marc Hillers (University of Applied Sciences Emden/Leer)

Prof. Dr. Marcus Bentin (University of Applied Sciences Emden/Leer)

Dr. Stephan Kotzur (University of Applied Sciences Emden/Leer)

Prof. Dr. Dirk Schleuter (University of Applied Sciences Emden/Leer)

Jan Schneider (University of Applied Sciences Emden/Leer)

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AR	Augmented Reality
CAD	Computer-Aided Design
COLREGs	International Regulations for Preventing Collisions at Sea
CTV	Crew Transfer Vessel
DoF	Dimensions of Freedom
DWP	Dynamic Water Physics
FoV	Field of View
FPC	First Person Controller
FPV	First Person View
HMD	Head Mounted Display
IMO	International Maritime Organization
IPD	Inter-pupillary distance
OWF	Offshore Wind Farm
OWT	Offshore Wind Turbine
VR	Virtual Reality
VRCC	Virtual Reality Corner Cave
VRTK	Virtual Reality Toolkit

1   Introduction

As part of the DecomTool project, this report addresses the Operational Analysis.

To support people involved in the decommissioning process, modern technologies should be included in the training and demonstration process. For this reason, 3 different virtual reality applications were created.

Modern technologies such as virtual reality (VR) are becoming increasingly important. By linking processes and models with modern information technology, VR can lead to increases in regard to efficiency.

By means of a head-mounted display (HMD), the user is placed in an artificially generated, virtual environment. Work was carried out with the "Meta Quest" (formerly "Oculus Quest").

The models created show different possible applications and potentials of the technology using example scenarios of offshore wind turbine (OWT) decommissioning.

From a technical perspective, one of the computer-aided design (CAD) models was prepared so that a detailed view of individual components is possible in VR. In addition, an exemplary nacelle was designed to be "walkable" and provided with "information" about the dismantling process.

The second model illustrates the transfer from crew transfer vessel (CTV) to OWT under different environmental conditions.

Navigational aspects are addressed in the third model. In the context of gamification, a CTV is controlled from the First Person View (FPV) in an Offshore Wind Farm (OWF).

After a short technical introduction to VR technology, the created models are presented and explained in more detail.

2   Virtual Reality Basics

This section explains the basics of virtual reality for the benefit of a fundamental understanding. It draws a distinction to augmented reality and shows some fields of application of VR.

2.1   Definitions

The term "Virtual Reality" is often used in conjunction with "Augmented Reality" (AR). Augmented reality is the users real environment extended by virtual components. Virtual Reality describes the artificial recreation of virtual environments using computer technology. The user will be completely immersed in the virtuality and experience the generated ambience as a real virtual replicate (Sheldon, 2022).

In the 2000s, Milgram and Kishino defined the "Reality-Virtuality-Continuum." At the respective ends are perfect reality and virtuality. Perfect reality describes the real environment without augmented elements, while virtuality places the user in a holistically modeled environment. Between these extremes is the realm of mixed reality (MR). As reality steadily decreases, virtuality increases. A predominantly virtual environment into which real elements are inserted is referred to as augmented virtuality (AV) (Milgram, Takemura, Utsumi, & Kishino, 1995).

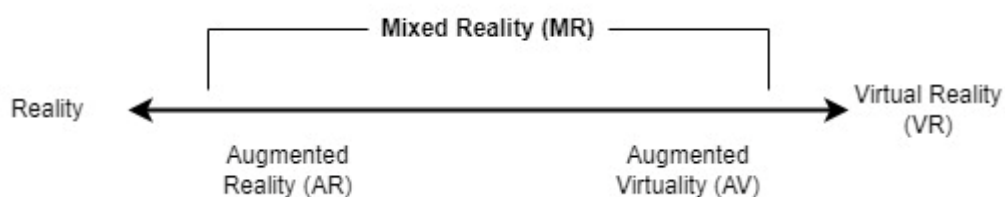The following figure 1 shows a simplified form of the continuum.

Figure 1: Reality-Virtuality-Continuum (Milgram et al. (1995))

2.2   Types of Mixed Reality Applications

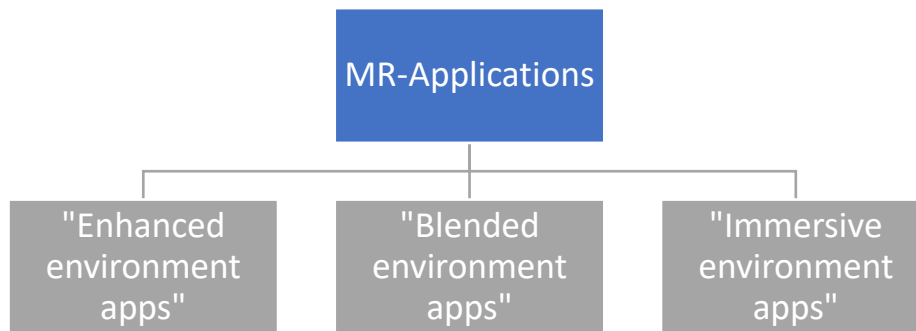MR applications are divided into three different types, which can be seen in Figure 2.

Figure 2: Types of MR-Applications

The type "Enhanced environment apps" describes the extension of the real environment, which remains constantly present to the user. The enhancements usually include digital information and/or elements. The ability to integrate digital components into reality is attributed to "blended environment apps". Here, a virtual, modified and modifiable layer is superimposed on the elements present in the environment. This allows the user to interact with them. "Immersive environment apps" describe a holistic change in the real environment so that the user finds himself in a virtually generated reality (Taylor, 2016).

2.3   Fields of Application and Gamification

VR/AR provides a significant contribution to the development of modern training concepts, processes and engineering. The application possibilities are accordingly diverse. The primary goals pursued with the use of VR/AR are more efficient work design in terms of avoiding errors/mistakes and providing information as well as generating added value for (end-) users.

VR/AR can be used in a variety of ways as early as the plant planning stage. For example, wind turbines can be visualized in advance to check possible workflows and, if necessary, to identify potential savings in terms of increasing efficiency.

Within processes, the technology can be used to visualize work steps to train and/or support employees. The use of VR/AR allows, among other things, the flexible projection of assembly instructions and guidelines for action via various end devices, such as smartphones. The user could therefore be shown precisely which component he should remove where and using which tool. This can result in shorter working times and a reduction in the error rate of improper dismantling.

Gamification plays a special role in this context. Gamification describes the integration of game-typical features and elements into (virtual) environments or contexts. Users can therefore learn playfully. The primary goal is to influence user behavior and motivation (Lippe, 2018).

2.4   Technical Aspects

The following section provides a brief introduction to the hardware components used. These are outlined shortly with regard to their technical specifications and properties.

2.4.1   Head-mounted Display: "Meta Quest" (formerly: Oculus Quest)

The "Meta Quest" is a standalone device that has an android-based operating system. Thus, this HMD does not require an external PC. But the headset itself can be connected and used with a VR-enabled PC via Oculus Link, which is a typical USB cable.

Figure 3: Oculus Quest HMD with Oculus Touch Controllers (Sapizon, 2022)

The table below provides an overview of the Meta Quest's other technical specifications.

Optics	Optics	Fresnel lenses
	Inter-pupillary distance (IPD) Range	58mm – 72 mm
	Passthrough	Grayscale via tracking cameras
Display	Display Type	2x OLED binocular
	Resolution	1440x1600 (per eye)
	Refresh Rate	72 Hz
Image	Vield of Fiew (FoV)	93° horizontal/vertical
Tracking	Tracking Type	6 DoF Inside-Out via 4 integrated cameras
	Tracking Frequency	60 Hz
	Hand Tracking	Yes
Controllers	Controllers	2x Oculus Touch (6 DoF)
	Input Methods	Capacative face buttons, joystick, touch pad, index trigger, middle finger trigger
	Finger Tracking	Partial finger and thumb tracking
Connectivity	Ports	USB-C
	Wired Video	USB-C (via Oculus Link)
	Wireless Video	WiFi Straming (via AirLink or Virtual Desktop)
	WiFi	WiFi 5
	Bluetooth	Bluetooth 5.0 LE
System	Operating System	Android 10
	CPU	Qualcomm Snapdragon 835
	GPU	Qualcomm Adreno 540
Storage	Memory	4GB
	Storage	64 GB/128 GB

Table 1. Meta Quest/Oculus Quest Specifications (Brown)

2.4.2   VR-Corner Cave (VRCC)

The VR-Corner Cave of the University of Applied Sciences Emden/Leer installed at the Department of Maritime Sciences is a 2-sided Corner Cave with floor projection.

Figure 4: VR Corner Cave at the faculty of maritime sciences of the University of Applied Sciences Emden/Leer

This Corner Cave has a total of 3 projection screens with movable frames. The respective image size is 3.60m x 2.00m. The projections are generated by 3 "Optoma 3D beamers" with a resolution of 1920x1080p in 16:9 aspect ratio.

The VRCC is controlled via the "moreViz Virtual Reality Bridge" software from the company "more3D". The installed optical marker-based tracking system (ART DTrack) comprises three infrared cameras. In addition to 3D shutter glasses, this also tracks a flystick3, which is used for input control.

3   VR-Demonstrators

The following is a detailed presentation of the three VR demonstrators, which were created during the project. All models cover different aspects of virtual reality so that users can be shown a range of possibilities offered by this technology.

3.1   Computer-aided Design in Virtual Reality

The time-consuming creation of 3D CAD models is usually/in most cases done without a general understanding of installation. The iterative creation process is characterized by adjustments and updates. By means of VR technology, the people involved can move into the environment/object or view it virtually to eliminate possible design conflicts/issues.

Immersion is therefore a concept that can be used not only to increase performance or create "safety awareness", but also to close experiential gaps.

3.1.1   "Walkable Nacelle"

In this model, an existing, exemplary CAD model of a nacelle was configured to be "walkable". The user is located directly in it and can move freely in it by means of the hand controllers. A "beam" for target selection was added to this. By pressing the trigger button the teleport to the selected location is executed.

Furthermore, the model was equipped with additional information in the form of panels.

Figure 5: Exemplary Panel in the 3D-Model

It should be noted here that the information shown is only to be regarded as exemplary and in a figurative sense.

The stored information can thus be provided with QR codes on the specific components as an example. The QR codes can contain any information. For example, used materials, hazardous substances and/or instructions for component-specific disassembly, which can thus be made available to its users without any issues.

In this context, it should be noted that the area of VR is being left behind and AR is being used. Virtual information is projected into the user's field of vision/onto the end device.

3.1.2 Presentation 2.0

With the use of a 2D screen to display a 3D model, the realism of the rendering is limited. Thus, no "real picture" of the created object can be made. By means of VR/AR technology, the models can be brought into the "real world" and the user into the virtual world.

With the advancing digitalization, traditional presentation and learning methods are extended and possibly replaced in the future.

In this context, an exemplary OWT was graphically prepared to be used in the VRCC or in HMDs for demonstration purposes.
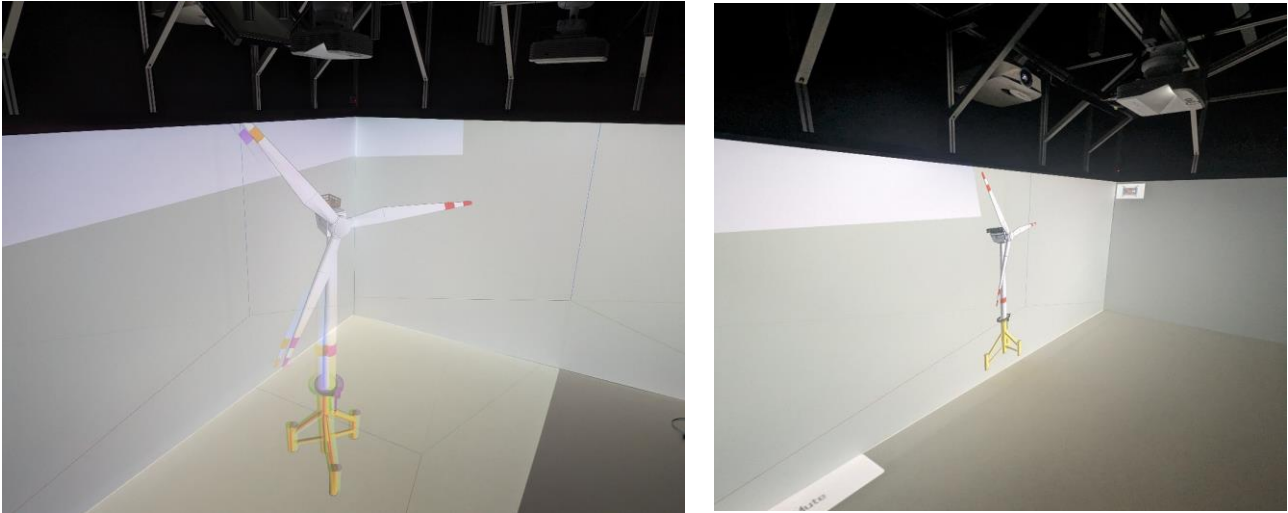

Figure 6: Offshore Wind Turbine Model in the VRCC

In addition to the presentation of models, object analyses can be carried out using VRCC. Involved persons only need one of the shutter glasses to view the projected model. This leads to a better understanding of the model and helps to avoid potential problems later on.

Another positive aspect of this visualization technique is the emerging interest for the model or object. The demonstration - even of simple facts - strengthens the learning effect compared to reading or simple presentation. Interactivity also plays an important role here. Furthermore, the discussion is stimulated, in which the experiences in dealing with the object can be debated.

Another fundamental aspect in this context is swarm intelligence. Users from different departments acquire a common understanding and work hand in hand.

In regard to use cases, there is virtually no limit. The possible applications range from simple model presentations to the implementation in workshops or the illustration of processes, such as the disassembly of components in wind turbines.

However, it should be noted here that the corresponding hardware and software must be available so that a certain haptic can be created.

3.2   Transfer from CTV to OWT

The aim should be to ensure that people do not fall into the sea, or become trapped between the CTV and any part of the OWT during transfers. Besides other aspects such as foundation design, vessel selection, operating procedures etc. this should be mainly achieved via training and competence.

At this point, the model covers personnel transfer from the deck of a CTV to the platform on the Transition Piece (TP). It was assumed that the transfer involves stepping from the vessel onto a stationary vertical boat landing ladder.

At the beginning of the scene, the user is on the deck of the CTV. The vessel is in close range to the OWT in a stable position ready for the transfer.
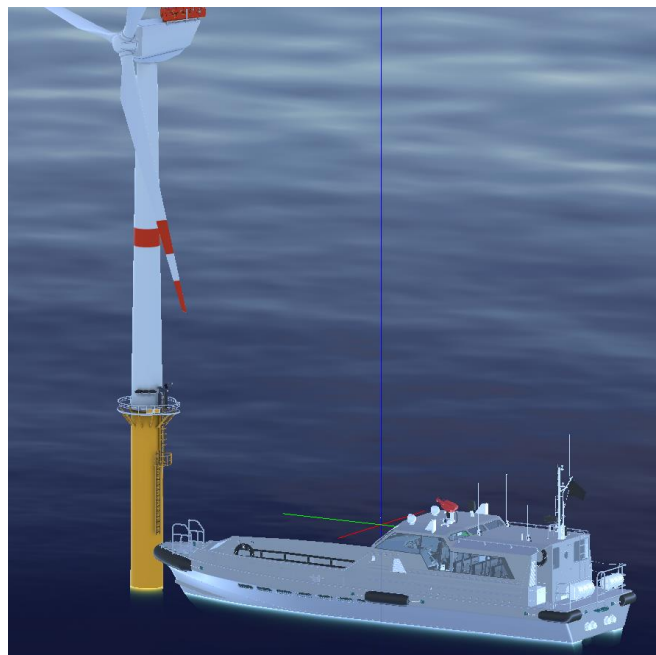

Figure 7: Sideview of the Basescenario

The HMD and controllers allow the user to move freely on the deck. Horizontal movements are controlled by the thumbstick of the right controller. Similar to the WASD-keys of a computer keyboard, the user thus moves in his line of sight.

Once the user has moved to the bow of the vessel, he must wait for the right moment to climb onto the OWT. Once the right moment is found, the user can grab the rungs of the ladder and climb it.The climbing process is realized via both controllers. These must be located on the graspable object (here: landing ladder). Gripping is simulated by pressing the trigger button on the back of the controller. In case of a successful grab, the respective controller temporarily "disappears" until the respective trigger button is released again. This allows the user to climb the ladder rung by rung. Once on the platform, it is also possible to move freely.

As a test, in addition to the basic scenario with "calm sea", another model with " heavier sea" was developed.
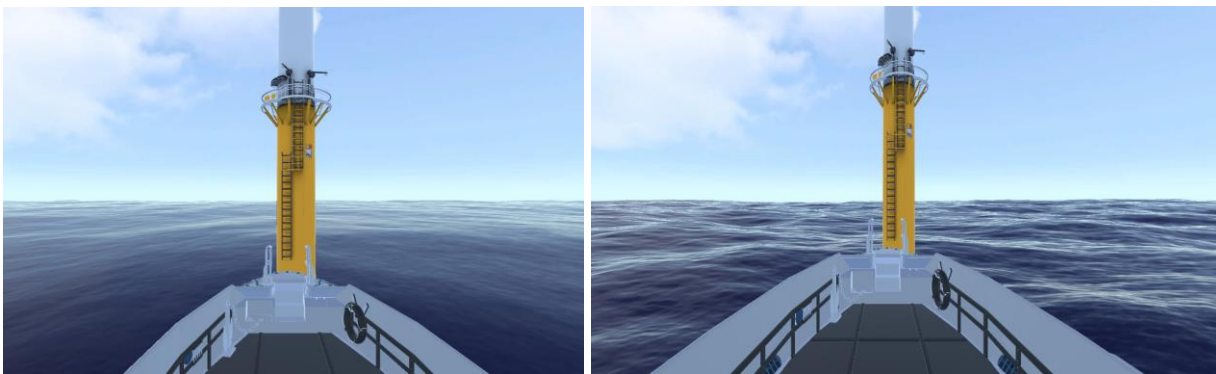

Figure 8: Comparison of the seastate in both models (Left: "Calm Sea"; Right: "Moderate Sea")

The conditions associated with this increase the difference-level of the transfer much more. It should be noted, however, that if the weather conditions are too bad, no real transfer would take place. So, it serves only demonstrative purposes.

3.3   OWF-Navigation

For centuries, ships have navigated waterways around the globe. The installation of OWTs for offshore green energy generation has been accompanied by restrictions on existing ship routes, increased collision risk, and more limited access to previously navigable areas.

Despite the spacing of the OWTs, vessels operating in the field will need to take further safety precautions to reduce the risk of collision with the fixed structures.

The "Convention on the International Regulations for Preventing Collisions at Sea,1972 (COLREGs)" constitutes an international maritime law and provides collision prevention rules. These include, for example:

- Regulation 5 states, "All vessels shall at all times maintain an adequate lookout by sight and hearing reasonably available to the circumstances and conditions to form a complete appraisal of the situation and of the risk of collision (IMO, 2002)

- Regulation 6 specifies, that "every vessel shall at all times proceed at a safe speed so as to be able to take appropriate and effective action to avoid collision and to be stopped at a distance appropriate to prevailing circumstances and conditions." In determining a safe speed, proximity to other vessels and structures, as well as other (environmental) factors, must be considered. (IMO, 2002) Therefore, vessels within and in the vicinity of the wind farm must be operating at a speed that allows the vessel to stop or avoid collision with another vessel or OWT.

- Rule 7a states "every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist." (IMO, 2002) Vessels are therefore obliged to constantly assess the possibility of a collision with another vessel or OWT while being on site.

- "Actions to avoid collision" are listed in Rule 8 of the COLREGs: "Any action to avoid collision shall be taken in accordance if the circumstance of the sea admit, be positive, made in ample time and with due regard to the observance of good seamanship". (IMO, 2002) In detail, rule 8e requires that if more time is necessary to assess a situation or avoid a collision, the vessel shall slow down or stop in accordance with rule 7 while navigating in the offshore windfarm.

- Rule 19 addresses vessel conduct in restricted visibility conditions. According to it, every vessel shall proceed at a safe speed adapted to the prevailing circumstances and conditions. The presence of the OWTs is to be considered as a temporary restriction of visibility.

Overall, the rules clarify on the vessel captains responsibility to properly assess the potential risk of collision, operate with safe speed and take necessary actions to avoid a collision. Seafarers have to be aware of the site and adjust operations accordingly to comply with the COLREGs.

To get an overview of these responsibilities and to develop a feeling for such situations, a VR demonstrator was developed. In this modeling, the user is in the captain's position of a CTV. Via keyboard inputs he is given the possibility to control this ship in the context of gamification. The W key moves the ship forward and the S key moves it backward. The A and D keys allow maneuvering in port and starboard direction.
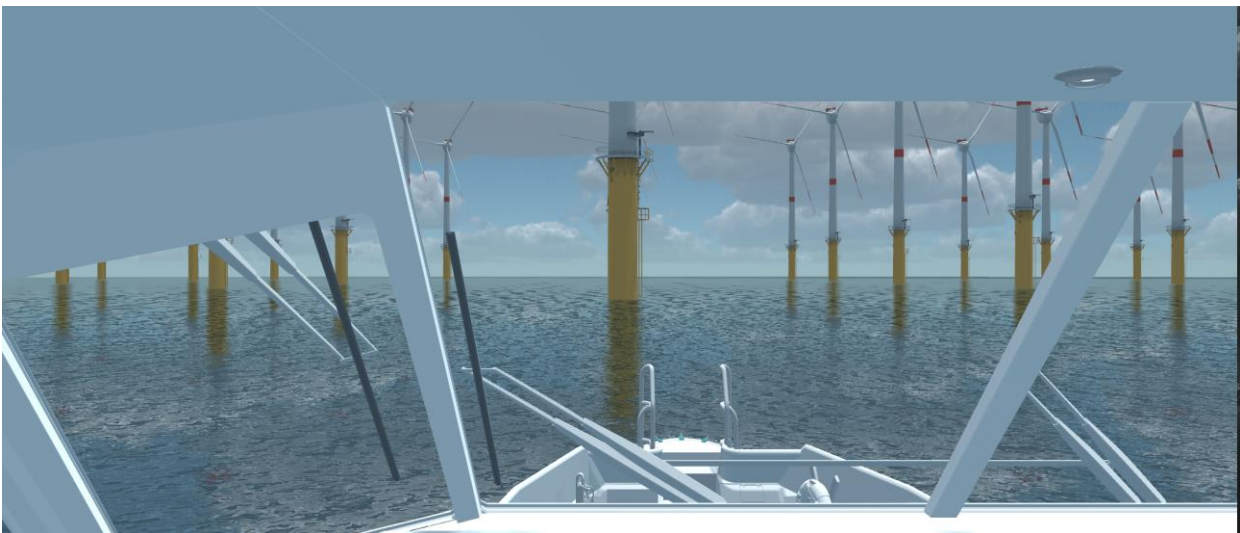

Figure 9: FPV on "captains chair"

It should be noted here that this is a pure demonstrator, in which the real environments were not taken into account 100% accurately. Furthermore, the users should get a "feeling" about the maneuverability of ships and possible situations in wind farms. This includes, for example, the curve or heeling behavior or the increased turning circles.

4 Conclusion

VR is a valuable resource that, when used correctly, has the potential to support the offshore industry in aspects such as design, safety training, and the like to generate sustainable efficiencies.

VR enables modeling and simulation of a wide variety of environments along the entire value chain in the maritime offshore sector.

Using HMDs or other interactive output media, training or education can be provided. Users and/or potential employees can thus familiarize themselves in advance with the details of the environment before entering this terrain for the first time. This leads to the further acquisition of competencies and an increase in awareness of problem situations that may arise, including the general increase in safety-related aspects.

The cost and time dimensions for training/safety courses in the offshore sector are usually quite high. Since training in the real environments involves significant hazards, employees spend a lot of time in training centers or at computers with regard to training. The use of VR allows users to train in the simulated models repeatingly, as often as they want, without being exposed to the risks of an unfamiliar offshore environment. By giving users the opportunity to make mistakes without real-world consequences, they are better prepared for the real world and have more confidence in putting what they learn virtually into practice.

Some HMD's allow users to learn anywhere, at any time, and at their own pace. This mobility allows "lessons" to take place regardless of location and be customized to the user's skill level. Further, VR training enables the collection of data, such as duration, sequence, error quantity - and frequency. These are logical data points that can/should be used to iterate the learning process and possibly discover and implement potential improvements for reality.

In summary, it is obvious that even the best training in the world cannot cover all risks and situations that may occur. Nevertheless, virtual or augmented reality will probably be a closer partner in the education/training of offshore personnel in the future.

References

Brown, R. (kein Datum). Oculus Quest Data Sheet. Abgerufen am 22. 08 2022 von https://vr-
compare.com/headset/oculusquest

IMO. (2002). *Convention on the international regulations for preventing collisions at sea: 1972*
(Consolidated ed. 2002, 3. ed Ausg.). London. Abgerufen am 09 2022

Lippe, L. (27. 11 2018). Was ist eigentlich Gamification? Abgerufen am 16. 08 2022 von
https://t3n.de/news/was-ist-eigentlich-gamification-1128037/

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented Reality: A class of displays
on the reality-virtuality continuum. In *Photonics for Industrial Applications* (S. 282-292).
Kyoto: ATR Communication Systems Research Laboratories. doi: 10.1117/12.197321

Sapizon. (2022). Von https://sapizon.com/blog/new-quest-vr-hmd-under-development-by-oculus/
abgerufen

Sheldon, R. (08 2022). Virtual Reality. Abgerufen am 11. 08 2022 von
https://www.techtarget.com/whatis/definition/virtual-reality

Taylor, A. G. (2016). Developing with Unity and Visual Studio. In *Develop Microsoft HoloLens Apps
Now* (S. 75-90). Oregon City: Apress Media LLC. doi:10.1007/978-1-4842-2202-7_9

Appendix

Es wurden keine Einträge für das Inhaltsverzeichnis gefunden.