

# Development of Maritime VR Training Applications and Their Use in Simulation Networks: Fast Rescue Boat Training in EMSN Connect

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**ABSTRACT:** The theoretical and practical acquisition of skills to carry out the necessary steps consciously and safely in an emergency is essential for training specialized personnel. Due to the lack of trained experts on site, such as firefighters or emergency doctors, learning the skills is a high priority in the maritime sector. Not least through adjustments in the certification of qualifications, through the refreshing of knowledge in specified time frames, the topic has been given greater importance. This paper will further describe the efforts of the FIP-S2@Novia cooperation to develop a virtual reality-based learning application for the maritime sector, in particular an application for learning how to use a Fast Rescue Boat in a person overboard operation. Furthermore, the paper describes the technical approach, the implementation of the VR application in Unity as well as the connection of the application to the European maritime simulation network (EMSN Connect), and its use in a connected simulation exercise.

## 1 INTRODUCTION

The primary purpose of EMSN Connect is to provide a large-scale virtual test environment for maritime safety [1]. The tests are performed in a Virtual world to provide best-case scenario exercises. The EMSN network consists of several different types of Ship Handling Simulators (SHS) spread across different geographical regions. The EMSN Connect is a platform for the exchange of simulation data and the exchange of voice communication data in the field of maritime simulation. The main idea is not to have the data from the simulators but also to provide the information back into the simulator from the VR applications. The common factor between the V2V (Virtual-to-Virtual) worlds is DIS packets. The objective of the paper is not to explain DIS packets in detail but rather how to use them specifically to get or transform the relevant data. Additionally, the idea is not to have the exercise running at a fixed location.

The aim was to build a platform on which a Fast Rescue Boat exercise could be carried out at Fraunhofer CML in Hamburg and at the same time nautical experts from FIP-S2@Novia in Turku could participate in the exercise. At the core, the idea is to build a whole platform that is region independent for the participating entities, and members can perform joint exercises using the simulator in addition to merging VR applications.

## 2 FAST RESCUE BOAT APPLICATION CONCEPT

The Fast Rescue Boat (FRB) application is a maritime virtual reality (VR) training solution, designed to improve the proficiency and preparedness of maritime personnel in rescue operations at sea. The primary aim of this application is to facilitate an immersive and realistic learning environment in

which trainees can perform repeated maneuvers and hone their skills in handling rescue boats during emergency situations, as well as learning the rescue maneuver. By leveraging the power of the Unity game engine [2] and its associated VR technologies, this application ensures that trainees are better equipped to handle real-life scenarios involving overboard rescues.

The technical implementation of the FRB application in Unity involves several key components. A high-fidelity 3D maritime environment is created, which includes elements such as accurate water physics, realistic weather conditions, and dynamic lighting. These factors contribute to the immersion and authenticity of the VR experience, enabling trainees to adapt to varying conditions they may face during real-life rescue operations.

Moreover, the FRB application leverages advanced VR interaction systems, such as hand tracking and haptic feedback, to replicate the tactile sensations of operating a fast rescue boat. Trainees can interact with various boat controls, including the throttle, steering wheel, and other essential equipment, just as they would in a real-world situation. This level of interaction further contributes to the immersive and engaging nature of the VR training experience.

Lastly, the FRB application is designed to integrate seamlessly with the broader EMSN Connect simulation network, promoting interconnectivity and collaboration between various maritime training applications. The FRB application enables trainees to participate in multi-disciplinary exercises and practice coordinating with other maritime professionals during complex rescue operations by linking with other simulation systems.

### 3 EXTENDED REALITY

Extended Reality (XR) is an umbrella term that encompasses all immersive technologies that combine the physical and digital worlds. These technologies exist on a spectrum (Figure 1), ranging from completely real environments to fully immersive virtual experiences. The primary categories within the XR spectrum are Real Environment (RE), Augmented Reality (AR), Augmented Virtuality (AV), and Virtual Reality (VR).

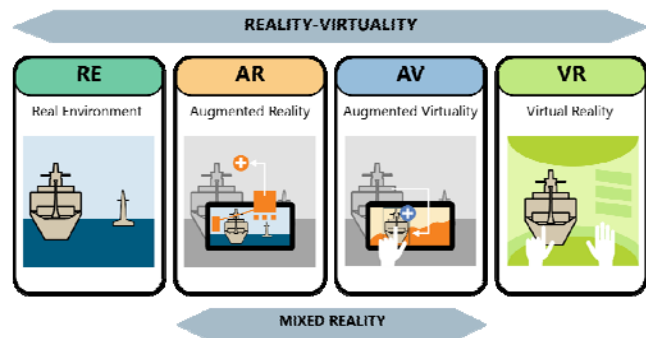


Figure 1 Reality-virtuality continuum [3]

- Real Environment (RE): RE refers to the actual physical world, with no digital elements or

augmentations. In this case, users directly interact with the real surroundings, objects, and people without any computer-generated enhancements.

- Augmented Reality (AR): AR involves overlaying digital information or objects onto the real environment, typically using a smartphone, tablet, or head-mounted display. Users can interact with both the physical world and the digital augmentations simultaneously. AR applications can range from informational overlays and navigation aids to interactive games and collaborative design tools.
- Augmented Virtuality (AV): AV is a subcategory of mixed reality (MR) that refers to the integration of real-world elements or objects into a predominantly virtual environment. In AV, users interact with both virtual and real objects within a computer-generated setting. Examples of AV include virtual teleconferencing systems with live video feeds of participants or physical objects tracked and represented in a virtual space for collaborative design or training purposes.
- Virtual Reality (VR): VR involves the creation of a completely immersive digital environment, in which users are fully detached from the real world. VR experiences typically require the use of headsets, controllers, and sometimes tracking systems to provide users with a sense of presence and enable interaction with the virtual environment. VR is used in various applications, such as gaming, training simulations, and architectural visualization.

#### 3.1 Virtual Reality in maritime training

VR is optimal for training simulations as it provides an immersive, realistic, and safe environment where trainees can practice and hone their skills without the risks and costs associated with real-life scenarios [4]. Its interactive nature enhances engagement and retention, ultimately leading to better-prepared and more proficient professionals.

The Fast Rescue Boat application aims to provide users with a comprehensive and immersive training experience that closely replicates real-life rescue scenarios. By guiding trainees through the entire rescue process, from preparation and boarding the boat to lowering it, rescuing the person overboard, and reattaching the boat, the application ensures that users gain a thorough understanding and familiarity with each step involved.

This comprehensive training not only builds confidence in their abilities but also enhances their preparedness for real-world situations. The application can function as a standalone version for individual learning or be integrated into a broader simulation environment, facilitating collaborative training, and coordinated response exercises.

#### 3.2 Creation of a virtual training environment

Unity [2] is a powerful and versatile game engine and development platform that has become the industry standard for creating immersive virtual reality (VR)

applications. Unity was chosen for this project due to several key reasons.

It provides a comprehensive suite of built-in tools, assets, and resources that streamline the development process, allowing for rapid prototyping and iteration. Unity's extensive support for various VR hardware, including headsets, controllers, and tracking systems, ensures compatibility and ease of integration with the latest technologies. The platform's robust physics engine and scripting capabilities enable the creation of realistic and interactive simulations, which are essential for accurate and effective maritime training. Moreover, Unity's thriving community and extensive documentation provide valuable resources and support throughout the development process. Additionally, Unity's cross-platform capabilities allow for the deployment of the project on multiple platforms and devices, making it accessible to a wide range of users.

In summary, Unity's versatility, robust features, and broad support for VR technologies make it the ideal choice for developing the Fast Rescue Boat application and similar maritime training solutions.

The process of developing a project in the Unity engine typically follows a structured workflow that combines both technical and creative elements. This development process is essential for creating immersive and accurate VR applications. Collaboration with experts in the respective field ensures that the simulation reflects the appropriate procedures, equipment, and environmental factors necessary for effective training.

1. **Concept Development and Planning:** The development process begins with defining the project's objectives, scope, and desired outcomes. This stage involves creating storyboards, outlining key features and interactions, and identifying the necessary assets and resources. Consultation with maritime experts ensures that the project accurately represents real-life processes, industry standards, and best practices.
2. **Asset Creation and Acquisition:** In this stage, 3D models, textures, and animations are either created from scratch or sourced from existing libraries. It is crucial to ensure that these assets are accurate, optimized for performance, and compatible with the target VR platforms. Collaboration with experts helps to validate the authenticity and functionality of these assets.
3. **Environment Design and Assembly:** Using Unity's built-in tools and features, developers create the virtual environments, incorporating the assets, environmental effects, and any required physics simulations.
4. **Interaction and Mechanics Implementation:** Developers create the necessary scripts and program the logic for user interactions, controls, and game mechanics using Unity's scripting languages (e.g., C#). This stage involves implementing features such as boat navigation, equipment usage, and performance tracking.
5. **Integration of VR Technologies:** The project is tailored to support the chosen VR hardware, including headsets, controllers, and tracking systems. Developers optimize the application for performance, ensuring a smooth and immersive experience across different devices.

6. **Documentation and Step-by-Step Manuals:** Developers create detailed documentation and step-by-step manuals outlining the usage and implementation of the VR application. These resources provide users with the necessary guidance to navigate the virtual environment, learn from the training experience, and correctly perform the simulated tasks.
7. **Testing and Iteration:** The project undergoes rigorous testing and evaluation to identify any bugs, performance issues, or inaccuracies. Feedback from experts and users is collected, and improvements are made iteratively to refine the application and ensure it meets its intended objectives.
8. **Deployment and Distribution:** Finally, the VR application is packaged and distributed across the target platforms, making it accessible to end-users for training purposes.

### 3.3 Modularity

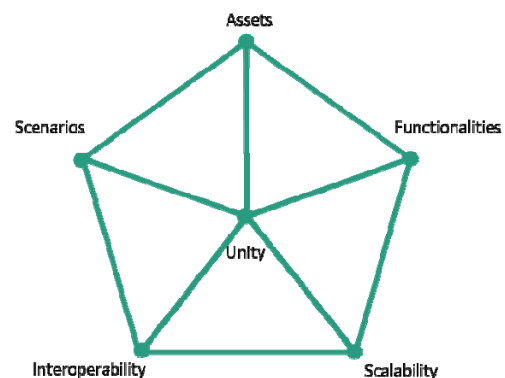


Figure 2. Modularity in Development

A modular approach (Figure 2) in VR refers to the development of virtual reality applications using interchangeable and reusable components, also known as modules. This method allows for increased flexibility, scalability, and adaptability in VR development, making it easier to create customized training scenarios, expand the application's capabilities, or adapt the system to various user needs and requirements [5]. Some key aspects of a modular approach in VR include:

- **Modular Assets:** Designing and organizing 3D models, textures, animations, and sounds as separate, interchangeable modules allow developers to easily swap, combine, or modify these assets to create a variety of environments, objects, and interactions. This results in more efficient development, simplified asset management, and increased creative possibilities.
- **Modular Functionality:** Implementing core functionalities, such as interaction systems, navigation, and physics simulations, as independent, reusable modules enable developers to quickly integrate these elements into different projects or scenes. This approach reduces development time and ensures consistency across various applications and scenarios.
- **Customizable Training Scenarios:** By employing a modular approach, VR applications can easily generate various training scenarios using

combinations of pre-built modules. This flexibility allows for the creation of tailored training experiences to suit specific learning objectives, user preferences, or operational requirements.

- Scalability: A modular VR system can easily be expanded by integrating new modules or upgrading existing ones. This adaptability ensures that the application remains up to date with evolving technologies, industry standards, and user requirements.
- Interoperability: Modular VR applications can be designed to work seamlessly with other systems and platforms, enabling integration with existing infrastructure, data sources, or third-party applications. This interoperability enhances the overall utility and effectiveness of the VR system, ensuring compatibility with a wide range of tools and technologies.
- Cost-effectiveness: By reusing existing modules and components across multiple applications or scenarios, development costs and time can be reduced. Additionally, a modular approach makes it easier to update, maintain, and support the VR system over its lifetime, resulting in lower long-term costs.

A modular approach in VR offers numerous benefits, including flexibility, scalability, adaptability, cost-effectiveness, and interoperability [5]. By embracing this approach, developers can create highly customized and versatile VR applications that cater to a diverse range of training requirements and user needs, while also ensuring the longevity and compatibility of the system.

### 3.4 Details and Usability

To ensure a comfortable and accessible user experience within the Fast Rescue Boat application, several measures have been implemented to mitigate motion sickness and enhance usability [6]. For instance, the flowing motion of the ship on the waves and dynamic controls have been simplified, reducing the risk of disorientation and discomfort commonly associated with complex motion in VR environments. To further prevent motion sickness, the application adopts teleportation methods for navigation, allowing users to move instantly between locations rather than moving continuously through the virtual environment.

In addition to these motion-related adjustments, other usability enhancements have been incorporated to ensure a seamless and intuitive training experience. For example, invisible walls have been strategically placed to prevent participants from accidentally throwing essential tools overboard or teleporting out of bounds. These safeguards not only help maintain the focus on the core training objectives but also minimize user frustration and potential disruptions to the learning process.

The Fast Rescue Boat training simulation encourages trainees to learn from mistakes in a safe and controlled environment, enhancing their understanding of the importance of following proper procedures. For instance, participants must remember to turn on a cog to cool the motor; failure to do so will cause the motor to break down after approximately

half a minute, requiring a scenario restart. To support the learning process, multiple information sources are available, such as a whiteboard on the ship's deck and an information panel on the boat (Figure 3), outlining the necessary steps. Additionally, hovering textboxes are strategically placed to guide users and offer helpful tips. These features ensure trainees have access to comprehensive resources, promoting effective learning and preparation for real-life rescue situations.

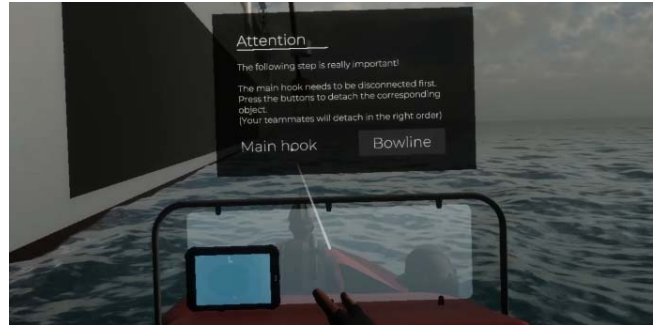


Figure 3. Information display

By implementing these thoughtful design elements and functionality adjustments, the Fast Rescue Boat application creates a user-friendly VR experience that minimizes motion sickness and maximizes engagement. The result is an accessible and effective maritime training solution that accommodates a wide range of users while providing a safe, immersive, and interactive learning environment.

## 4 EMSN CONNECT - THE SYSTEM ARCHITECTURE

EMSN Connect is used to distribute the simulation data as well as VoIP (Voice over IP) data in a separate shielded environment only accessible to the participating entities (EMSN Partners or Participants). As the EMSN partners are located diversely over the graphical region. The network has been established with the help of IP (sub) networks and VPN (Virtual Private Networks) tunnels.

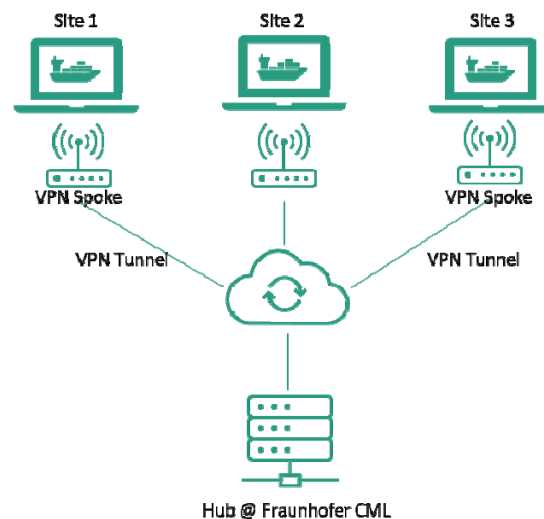


Figure 4. Simulation sites are Connected through a VPN tunnel to Hub



The VPN tunnels are established between the EMSN participants (centers), providing confidential and authenticated links with integrity over the public internet. The hub-and-spoke topology [7] of the VPN is used in EMSN. Also, In EMSN only a Spoke-to-hub connection through a VPN tunnel is possible as shown in Figure 4. The tunnel creates secure connections between remote users and a private EMSN network.

The simulation management systems (inside the Ship Handling Simulator (SHS)) are manufacturer specific. Therefore, the Distributed Interactive Simulation (DIS) protocol is used to provide the distribution of simulation data over proprietary simulation protocols [8]. An additional DIS gateway is used if an SHS does not support the DIS protocol and vice versa.

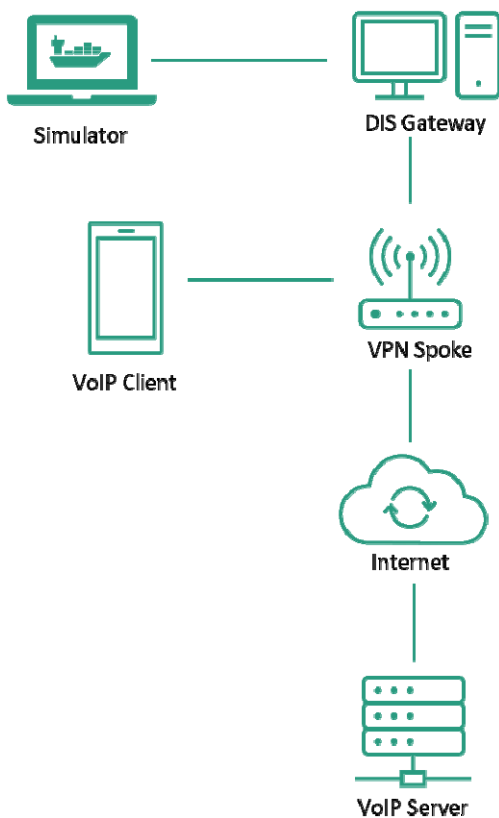


Figure 5. VoIP Server Client Architecture

The DIS PDUs (Protocol Data Units) in EMSN are distributed by User Datagram Protocol (UDP) through multicast over VPN (Virtual Private Networks) [8]. Moreover, Generic Routing Encapsulation (GRE) is used to encapsulate the data [9] for more security. Thereafter, the data is secured by IPsec (Internet Protocol Security) in a VPN. The security appliance (SA) functions as a bidirectional tunnel endpoint. The security appliance uses the ISAKMP (Internet Security Association and Key Management Protocol), and IPsec tunnelling standards to build and manage tunnels. ISAKMP and IPsec accomplish various functionalities like establishing tunnels, managing security keys, encrypting, and decrypting data, and managing data transfer across the tunnel. It can receive plain packets from the private network, encapsulate them, create a tunnel, and send them to the other end of the tunnel

where they are unencapsulated and forwarded to their destination. This functional chain comprising the SHS and the DIS gateway is present at all sites. The communication between different sites happens through the hub and spokes configurations (physical devices – routers). The configurations of the hub and spoke routers define further internal IP addresses and routing to cover the other needed functionality within a site for internal and external communications, e.g., multicast groups, tunnel interfaces, etc.

The audio communication between the centers is distributed by Voice over IP (VoIP). The VoIP in VPN is a standard protocol [10]. As shown in Figure 5, a Server-Client architecture with TeamSpeak software [11] is used for voice communication between the participating sites.

#### 4.1 Data exchange architecture

The Fraunhofer CML development, Data Tracker, can handle the PDU packets and use them in communication. The participating sites can track the data by sending and receiving PDUs using their own tool-generated Application ID. There are different types of PDUs, that are used in communication between the tracking applications of each site. An explanation of the different types of PDU packets is out of the scope of this paper. But, for the transmission of simulation parameters from each site to the tracking application the Data PDU is used. Thereby, each simulation site sends a Data PDU for each object entity (objects created inside the SHS) to the Data Tracker at regular time intervals that contains all relevant parameters for tracking. The Data Tracker can capture these PDUs and transfer the data into a database. Vice versa, the Data Query PDU will be used to enable an information transfer from the Data Tracker to all sites.

To comply with the applicable global GDPR regulations, in addition to mutual consent, a further necessary confirmation has been provided in the data tracker, i.e., if a certain site does not want to send its data to a certain other participating site, the data tracker blocks the transmission. This is done on a two-way handshaking process. Furthermore, the data will not be available in the database from the non-willing site.

The tracker tool can be used in planning the exercise and emulating the data received from the real ship (outside the virtual world). Below are further details on the features of the Data Tracker:

- Monitor: A healthy status indicator allowing each simulator site to individually track its own and the participating centers, DIS-states, and connectivity. Also, view all the ships in the simulator network on an integrated map.
- Data tracking: Transfer of information between all the sites. Takes care of the data encryption and decryption part. Also, has a feature like synchronous stop and start exercises in the whole simulation network
- Data Storage: The tracking tool can capture the DIS PDUs, decrypt them, and store them in the database. These altered datasets are planned by the experts and can then be used for multiple navigational exercises and test purposes.

- DIS Emulator: This tool can also mimic the function of the large simulator. This tool can create its own ship and random traffic ships for a particular simulation site and send this message in the form of DIS PDU packets in the simulator network. The feature also supports predefined or real-time AIS tracks which can be used in testing. The DIS emulator is also equipped with the functionality of a plain SHS, used to mimic the ship's movement as in real-life scenarios.
- Simulation Plotter: The data stored during the exercise in the database (which can be accessed in the form of a simulation id) can be reflected in the integrated map of the tool. The graphs for the performance parameters can be generated based on the simulation run. The data can further be investigated or analyzed with a visual presentation.

#### 4.2 Virtual Reality Integration with EMSN Connect

For the seamless integration of the VR application FRB App into the EMSN Connect infrastructure, the distribution of important information is implemented via DIS Messages. The Data Tracker application sends via a dedicated UDP port (data port) decoded DIS messages, which are interpreted in the Virtual Reality application. The instructor can create ships through the Virtual Reality environment and control them.

The communication for the control commands is through a dedicated UDP port (command port). The Rudder and EOT commands from the VR will be communicated through this UDP port. The data tracker application (DIS emulator) will then mimic the movement of the ship like a large simulator according to the control commands from the VR (explained in Figure 6).

The DIS Emulator creates the scenario (generates DIS packets) based on the control commands in the simulation network or on the corresponding simulator. The ship created inside the virtual reality application will also be reflected on the SHS as a ship object entity. Which are used in command motion translation. The ship information is reflected on the SHS or on the integrated map of the tracker tool, but the VR application-level features are reflected on the VR glasses. The Simulator, Data Tracker application, and VR environment work hand in hand inside the simulation network to provide an immersive experience for the participants.

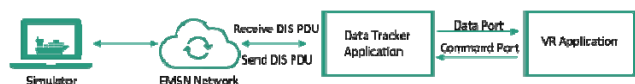


Figure 6. Physical Integration of EMSN with VR Application

## 5 THE VR APP IN A SIMULATION RUN

Each exercise is termed a Simulation Run. The data in the databases are stored based on these simulation runs. In the simulator environment, the Fast Rescue Boat VR application seamlessly integrates with the EMSN network through the exchange of DIS

packages. This integration allows users to choose from the simulation which ships to follow based on incoming DIS packages. The selected ship's movements within the VR scene accurately mirror those of its real-time counterpart in the simulation. Furthermore, other ships present in the EMSN network are also displayed within the Unity scene, providing users with a comprehensive and realistic view of the surrounding maritime environment. By maintaining a 1:1 scale for the distances between ships, the application ensures spatial accuracy and fosters a greater sense of immersion. The Fast Rescue Boat VR application also sends back DIS packages into the EMSN-network, so that every other participant can display the FRB in its own simulation.



Figure 7. Ship Models in the VR Environment through DIS-packages

### 5.1 Exercise planning

Planning and execution of simulations are currently managed by the instructors via the user interface of their simulator. In EMSN Connect, a wide range of vessels and objects are available with DIS entities, which are transmitted via the network. The FRB App does not require any planning at this stage, only a vessel from which the Fast Rescue Boat is to be launched or on which the "person overboard" sub-scenario is to be carried out. The planned exercise will thematically force a man overboard situation at a time  $x$ , which is to be handled by the crew. The communication between the bridge crew and the boat crew is to be carried out as required by the applicable regulations. A voice recording or listening by the instructors is possible at any time through the server-client architecture via TeamSpeak. As soon as the Fast Rescue boat is detached from the vessel, it is assigned its own DIS entity so that it is clearly visible to other traffic participants on the radar. When the boat is later recovered, this is switched to inactive again.

Exercises of this specific type can be carried out on-site or at several separate locations.

### 5.2 Communication

Within the simulation environment, the Fast-Rescue-Boat application facilitates seamless and realistic communication between the participant in the VR training and the simulation bridge through VoIP. This is achieved by integrating the VR headset's voice activation feature with a TeamSpeak server, where the simulation bridge is also connected. When the participant holds the virtual radio device in the VR environment, their voice is transmitted to the server,

allowing for direct communication with the simulation bridge. By mimicking real-life communication methods, this feature enhances the authenticity of the training experience and ensures that participants develop effective communication skills essential for coordinating and executing rescue operations in real-world scenarios.

## 6 CONCLUSIONS

The development and implementation of the Fast Rescue Boat application fit seamlessly into the philosophy of the EMSN Connect network. The technical findings outlined here will soon be presented to a wider range of test persons for further evaluation of the benefits of such technologies. However, at this early stage, it is already evident from smaller test campaigns that VR applications in the maritime sector are an asset as a consolidation of theoretical knowledge and preparation for practical experience. In combination with the joint exercise, the processes are internalized, and, in this context, the necessary communication structures are created.

Not only the experience of the application in VR through the immersive training an important point, but the bridge crew, who must now wait for realistic times until certain actions have been realized, who must actively provide support in the form of orders but also for the provision of a safe position of the ship to launch and recover the fast rescue boat.

A solution purely in VR as a standalone training would of course be interesting especially for on-board operations to ensure a constant refreshing of knowledge and especially of the procedures for the preparation for an emergency. Combinations with real ship data would also be conceivable so that the ship would react in reality, and the respective participant would see this data as a basis in his environment during his exercise in virtual reality.

In its final form, the implementation, in combination with EMSN Connect or on its own, keeps various approaches open for further developments and far more complex scenarios. The complex training currently carried out in nautical schools could be largely implemented in VR and, in combination with the bridge crew, bring the training much closer to reality. This would add value to the training of the participants in terms of time and in terms of the process itself, but also for the evaluation of their performance.

## ACKNOWLEDGEMENTS

This work received funding from the FIP-S2@Novia research platform.

Further, the author would like to thank all participating institutions of the EMSN-Connect initiative for their trust and contribution to this network.

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