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The Use of Metaverse in Maritime Sector – A Combination of Social Communication, Hands on Experiencing and Digital Twins

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ABSTRACT

COVID-19 has caused challenges in traveling and sales activities while teleconferencing is at the moment the main communication tool in industry. Various technology giants such as Facebook, Microsoft, and Epic Games have published their visions for remote presence. In February 2021, also Turku University of Applied Sciences started the development of its own metaverse technology. In this paper, we will introduce this technology and its main features to enable social communication, hands on experiencing and digital twin integration. The whole development process has been split in three phases: preliminary study to find the most promising combination of hardware and software tools, prototyping study to create the first version in various test and generate cycles, and finally piloting study to find out how this technology can be utilized in one chosen domain namely in maritime sector. As a result, we have been able to develop a robust technology which can be used as a virtual reality social platform combined with functionalities to enable hands on experiencing and IoT integration.

Keywords: Metaverse, Virtual reality, Virtual reality social platform, Social communication, Hands on training, IoT, Digital twins

INTRODUCTION

Because of the current pandemic various domains have suffered such as aviation industry which has been forced to close flight simulator centers and which has been amongst the most vulnerable verticals during the first months of the pandemic (AviationPros, 2020). In maritime sector, during the most severe restrictions from March to June 2020 for example the global ship mobility was decreasing up to −13.77% for container ships, and up to −42.77% for passenger ships (Millefiori et al., 2021). International Maritime Organization (IMO, 2020) has studied the impact of COVID-19 on maritime education and training and as a conclusion defining distance learning delivered online and/or remotely to be likely a new normal. This trend proposed by IMO is in line with EU which has seen VET (Vocational Education and Training) learners to be at disadvantaged compared to any other learners (EU Monitor, 2020).

Metaverse approach presented later in this paper can be seen as a continuum for Virtual Continuum (VC) presented by Milgram & Kishino (1994). In their visions, an ideal virtual space with reality essential for communication will be needed within the same visual display environment. According to XR4All (20220) eXtended Reality (XR) can be seen as an umbrella term used for Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) – that is to say covering terms used in the VC taxonomy. Virtual reality is defined as a method of interacting with a computer-simulated environment (Das et al., 1994). Augmented reality, in turn, is a technology which allows computer generated virtual imagery to exactly overlay physical objects in real time (Zhou et al., 2008).

In our previous study (Markopoulos et al., 2021), we have focused on virtual reality social platforms (VRSPs) as a precursor to the metaverse allowing its users to host or join multiplayer instances in which users of this platform can socialize and interact with their environment and each other. Actually, the word "metaverse" comes from the prefix "meta", meaning beyond, and "universe". It describes a virtual universe shared amongst its users allowing them to interact with each other within the boundaries of the platform (Nevelsteen, 2017). Second Life launched already in 2003 has been one of the first and the most prominent example of virtual worlds (Kohler et al., 2009). Later VRSP technologies such as MootUp, Breakroom, LearnBrite, Virtway Events, Engage, Microsoft AltSpaceVR, Facebook Horizon, Glue, Mozilla Hub, VR Chat and VirBELA have been among the most commonly used virtual platforms (Jauhiainen, 2020; Österman, 2021).

During year 2021 the metaverse has become more frequently used term. Microsoft's CEO Nadella (2021) has illustrated their visions of an enterprise metaverse as a platform layer bringing together IoT, digital twins, and mixed reality. So, it is evident that boundaries of the platform will be stretched in the near future – Microsoft for example has introduced Mesh for Microsoft Teams to combine traditional teleconferencing and mixed reality features such as shared holographic experiences introduced already in their VRSP called Microsoft AltspaceVR (Microsoft, 2021). Facebook in turn has described their organizations transition from a social media company to a metaverse company called Meta. This transition will require take time around 10-15 years before metaverse products will be fully realized (Bosworth and Clegg, 2021).

Maritime among many other business sectors has struggled during the pandemic and challenges in maritime sector is naturally influencing in the global business growth significantly. According to IMO (2021) some maritime universities have been forced to cancel entire academic years during the pandemic and is now concerned that the pandemic will may have negative consequences for the number of young people choosing a seafaring career. XR seems to have a potential to boost GDP globally by 2030 by up to $1.5 trillion (PwC, 2019). Global XR market size itself in turn is expected to grow from $12.4 billion (2019) to $181.9 billion by 2028 (Fortune Business Insights, 2020a&b). Before the pandemic Goldman Sachs (2017) has estimated global VR and AR markets to grow into a $95 billion market by 2025 in turn. In their forecasts education sector seems to be in margin with just 2.0% market share.

In this paper, three key features of metaverse designed for maritime sector and for technology industry will be introduced namely social communication, hands on experiencing and digital twin integration. In the next chapter, the preliminary study will be reported. The objectives were to find the most promising combination of hardware and software tools. This will be followed by the prototyping study where development of the metaverse technology will be explained in test-generate cycles. Finally, the first pilots will be introduced shortly covering all three key features.

PRELIMINARY STUDY

Turku University of Applied Sciences has started in February 2021 the development of its own metaverse technology. This technology consists of features for social communication, hands on experiencing and digital twin integration. Based on our understanding none of the above mentioned VRSP technologies include all these three features, neither Microsoft nor Facebook have introduced this type of vision. Moreover, existing VRSP technologies typically have challenges such as update management, number of simultaneous users, usability, user experience, license policies, customization but also limited user interaction and user data gathering. In this paper, we will introduce our own metaverse technology. In the preliminary study phase, various existing VRSPs have been tested, a comparison study between Unity and Unreal game engines in the metaverse development has been conducted. Epic Games has plans to publish a metaverse software development tool with $1.0 billion funding round (Epic Games, 2021).

Based on our test results and intention to focus on the technology industry the use of Unreal limits user groups for VR and PC users. The research approach presented in this paper provides metaverse experiences to be used in various ways from VR/AR/XR to PCs and mobile phones. This way, users who have limited resources available are able to participate in metaverse applications where the user experience will vary based the available device. Through the prototyping and piloting studies, we introduce components of IoT integration and multi-user training scenarios which provided requirements for the technical prototyping of TUAS metaverse platform.

PROTOTYPING STUDY

Remote Controlled Robot Application and Testing IoT Integration

First of the IoT prototyping use-cases was Tinkerkit Braccio robot arm (Figure 1), which was remote controlled using VR/XR hand-tracking over Internet public network tunnel. The prototyping provided information and documentation about the required protocol support and data flow requirements for integrating further embedded system solutions (Blanco Bataller, 2021).

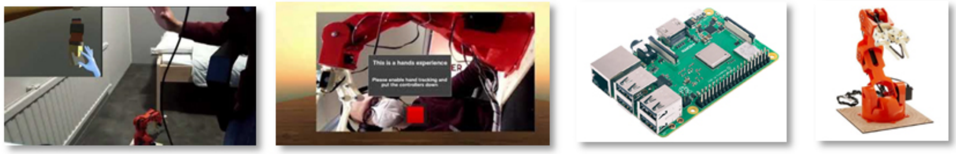

Figure 1: Virtual reality headsets used to control robot arm remotely (Blanco Bataller, 2021).

Once the data flows and interfaces were documented and created, the solution would be scalable to TUAS metaverse usage though environment-triggered connectivity. This framework could be extended to factory environment simulations and digital twins: assembly line of machinery could be remotely operated by multiple users connected into common VR environment.

Multi-User Training of Fire Extinguisher Usage With Real-Time Instructions in VR

Online hands-on-training use cases were tested in a prototype featuring fire extinguisher usage. In this prototype, instructor would be hosting an environment with fire extinguishers and burning barrels. The students would pick up an extinguisher, prime it, target it towards the base of the fire and extinguish it. The scenario calculates the amount of fire extinguisher foam that hits the base of the fire, and fire animation then reacts accordingly.

The instructor can observe the actions of the students from ground view or bird view. They are also able to point a laser-pointer, to instruct students. The scenario also features voice communication between students and the instructor (Figure 2).

This prototype was created using Photon Bolt using Photon Cloud network connectivity which requires Internet connection also for local network multi-user setup. The maximum feasible number of concurrent users with the scenario's complexity and physics was found to be between 6 and 8 users. More users would cause noticeable stuttering and break the immersion as well as cause difficulties from the training's perspective. The stutter, latency and bandwidth issues were caused by the Photon Cloud connections, where each concurrent user would increase the data transfers exponentially, since every concurrent user is connected to every other user through the cloud.

PILOTING STUDY

Porting Harbor Environment

This paper introduces the TUAS metaverse technology, the first experiences of developing it and how the first prototype version of this technology has been used in various maritime sector projects. To demonstrate the technology a harbor area has been selected as a test environment. In the first test, AltspaceVR technology was used to develop the environment itself with features needed in virtual exhibition called Match XR (XR Center, 2021). This

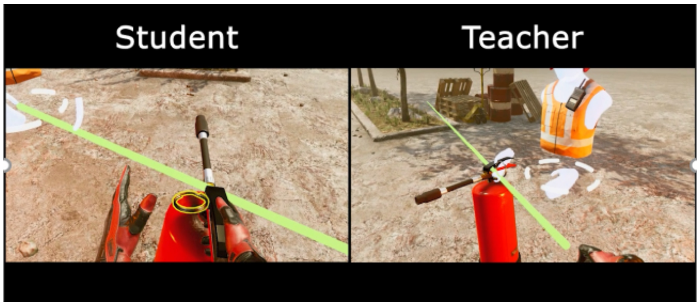

Figure 2: Multi-user training of fire extinguisher usage enabling the teacher student communication.

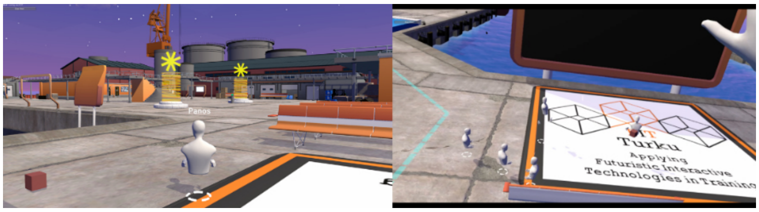

Figure 3: The 3rd person gameplay on desktop (left) and the 1st person gameplay on VR (right).

was followed by an experiment where the harbor environment with same functionalities was moved to the TUAS metaverse technology (Figure 3).

During the event week, a system update was initiated to the AltspaceVR technology backend, which rendered ready-made scenario dysfunctional. This downtime of the backend and system update with breaking changes would have caused significant disturbance of the event in case it would have happened during the environment event. AltspaceVR technology restrictions regarding scripting and dynamic activities was found to limit both the environment design and the activities that could be presented to the visitors. The environment supports static images, videos and text content, which dynamic updates of the content would require a new release of the environment.

Environment isolation is one of the core features in TUAS Metaverse technology. The architecture could be maintained in its launch state indefinitely, without need of regular downtime from updates. The feature set is locked into the environment and future development can be integrated to an environment on-demand. The TUAS metaverse technology is built and structured to be modular from functionality and graphical representation of the environment perspective. Any graphical assets and functionalities created into the base platform feature set are available as core features for all environments, which provides significant improvement to development and prototyping cycles.

Unity environment conversion from AltspaceVR technology into TUAS metaverse technology is directly supported with minimal development effort requirements. Digital twins with specific functionalities can be integrated into the platform. With fully customizable API support of the platform, the digital twins and their sensors could be coupled to real world machinery and equipment, providing access to executing remote operations. With data collection, this functionality could be further developed to user-assisted autonomous systems and to gather training data for neural network operated autonomous systems. Multi-user environment and activities provide high variance in the behavioral data, reinforcing the neural network training data set.

Harbour environment from AltspaceVR, specifically graphical assets, can be directly imported to TUAS metaverse technology. The required changes were:

- Defining the possible teleportable areas, which determine where the users can teleport,
- Defining the spawn points for the users,
- Defining which objects in the environment would be synchronized over the network,
- Defining the scaling of the environment to match the scaling of generic avatar

The bandwidth consumption of the TUAS metaverse server scales with the number of concurrent users and the type of devices that users use to join the hosted environment. This includes desktop users (namely non-VR users) and VR users. Each type of user has different interaction input to the virtual world but visually represented the same in a 3D graphical model, namely avatar.

- *For desktop users*, only the position and orientation of the avatar are synchronized over the network. This combination represents 1 transform package.
- *For VR user*s, in addition to the avatar transform, the position and orientation of the head, left hand and right hand are also synchronized over the network, as well as finger animations. Each of these individual components represents one extra transform package. Additionally, high-end VR headsets can produce eye-tracking data and this data could be optionally sent over the network.

Most of the interactions in TUAS metaverse are physics-based interactions. This makes interaction in the virtual world more intuitive and immersive because this mimics real world interaction. For the interaction synchronization part, there are 2 most commonly used network models to consider: server-side authority and client-side authority.

- *Server-side authority*: clients send inputs to server, the server processes and simulates the world based on that input then broadcasts the world states back to all clients. This introduces a lag between the user's input action and its local visual representation of the world since the client has to wait for the world state to arrive and then update its local world based on it. However, VR interaction requires instant input response to deliver the most immersive experience possible. Client-side prediction technique is usually applied to solve this problem where the clients apply the input immediately and then send it to the server. However, client-side prediction requires state reconciliation technique to resolve conflicts between the server state and the client-predicted state, this, in turn requires a deterministic physics engine to produce an acceptable result. Unfortunately, Unity's physics engine is not deterministic, and even if it is, this approach would not scale well with substantial number of concurrent users due to high amount of physics state rollbacks performed per frame.

- *Client-side authority*: clients process input locally and send its world state to the server which in turn broadcasts that state to all other clients. This approach makes each client a contributor to a collective world state. Each client claims its authority over the object it interacts with and does not allow other clients to interact with it to avoid state conflict between clients. This approach provides instant input response to match the visual of the local world regardless of the internet delay and also scales well with numerous amounts of concurrent users because each client simulates its own world regardless of other clients.

The TUAS metaverse mainly adopts the client-side authority due to its lower complexity compared to server-side authority approach and its capability to scale with high number of concurrent users. Under highly delay simulated connection condition of 500ms, the synchronization as well as input response were still well performed.

CONCLUSION

For massive number of concurrent users, peer-to-peer connections were found to be exponentially demanding, growing in relation to the number of users. Therefore, dedicated server solution was selected as the architecture for TUAS metaverse platform development. The dedicated server architecture moves the bandwidth and resource demand towards the server that hosts the environment. Especially calculations needed for server-side authority would require server hardware and performance. Unlike in peer-to-peer architecture, the hosting server does not need to run any graphics. The server itself would be hosted either locally in internal network, or in a datacenter connected to public Internet, depending on the intended clients. Both solutions may also exist in parallel: the same server could host environment for both development (only internal connectivity) and production (publicly reachable or tunneled).

Future development efforts will be targeted towards hands-on-trainings, which require realistic simulations of physics and machinery operations. Especially physics synchronization over network to massive amount of users in a stutter-free environment remains a key development path. Maritime simulations require realistic physics and synchronization of ocean as well as forces between all participants.

In the near future, we will continue piloting research through command bridge training environment, where operations can be exercised by several users, maneuvering a ship together in various typical maritime scenarios. The environment would support data collection through eye-tracking and hand-tracking, providing logged information on user's order of operations, focus and logical reasoning. We will also investigate how multilingual versions could be developed for example enabling real-time translations between the trainer and the trainee.

Multi-user trainings with IoT integration and data collection offer attractive possibilities for collaboration and co-operation trainings in observed and repeatable scenarios, as well as in digital twin remote control operations. Data collection of multi-user environment actors provides options for autonomous systems research as well as automatic evaluation of the training activities.

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