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Implementing Immersive Virtual Reality with Haptic Feedback Technology to Enhance Operational Efficiency and Safety in the Oil and Gas Industry

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ABSTRACT

The oil and gas sector deals with complexly hazardous environments, wherein the efficiency and safety with which operations are performed act as preconditions of success and sustainability. This paper focuses on how virtual reality (VR) technology, in particular the most advanced haptic feedback, applied superb and efficiently integrated VR technology to solve challenges and achieve higher performance at the sector level in the building council. By using authentic touch feedback, VR simulations afford a fully–immersive means through which workers can train, strategize and operate in virtual spaces, significantly reducing the risk of injury in the real world. The paper discusses several VR applications, like education, disaster response, and detailed design, emphasizing that haptic feedback is one of the crucial experiences to provide virtual experience. Integration of real-time data enhances operational decision-making, empowering teams to make informed decisions, while simulations improve emergency preparedness and readiness, enabling workers to be capable of managing critical events. Nonetheless, the case examples provide clear evidence that VR and haptics are part of a variety of key tools that can dramatically increase operational efficiencies and safety standards for a safer and more efficient tomorrow for oil and gas operations. It dives into the evolution of new top-of-the-line haptic techs, such as advanced force feedback gloves and full-body suits that provide extremely realistic tactile sensation, further augmenting VR-focused training programs. By harnessing VR and integrating haptic feedback technologies, the oil and gas industry can revolutionize training methods, emergency response planning, and operational decision-making, paving the way for a safer, more efficient, and technologically advanced future for the sector.

Keywords: Virtual reality; haptic feedback; immersive training; operational efficiency; tactile sensations

INTRODUCTION

Ensuring operational effectiveness and safety excellence remain a key goal in this evolving domain (Abich et al. 2021). As the sector develops, it needs to adapt its plan to face arduous challenges and raise performance standards. The article discusses the innovative application of VR technology as a transformative tool in the oil and gas sector. It is a huge shift and embraces virtual reality (VR) as immersive, realistic simulations from which people can train, plan, and conduct operational activities. It gives a real but controlled environment which removes risks associated with real-life events allowing users to practice their skills in a secure environment (Rebelo et al. 2012).

The applications demonstrate the potential of virtual reality technology to enhance workforce capabilities and operational readiness, from immersive training programs for operators and sophisticated simulations for emergency response and facility maintenance. Professionals can visualize workflows to determine hazards and safeguard, adopting this into planning for VR use in project planning and design with the addition of integrating data is pertinent in decision making and application. The safety implications of VR are significant as it also enhances emergency preparedness and incident management, allowing personnel to practice dealing with emergencies in a simulated environment promoting proactive risk management and operational resilience. VR can significantly improve operational efficiency, and safety standards in the oil and gas sector, as illustrated by the case study how this ground-breaking technology has been applied across the industry. Digital transformation in the industrial sector, especially oil and gas plays a crucial role as an aggregator of various applications, which paves the way for a safe, productive, sustainable future for the oil and gas business, making the foundation for resilience in the industrial landscape.

VIRTUAL REALITY IN THE OIL AND GAS INDUSTRY

The application encompasses multiple facets of the industry, particularly in hazardous environments such as offshore platforms and drilling sites. It enables personnel to engage in immersive training scenarios that mirror actual conditions so they can practice emergency procedures, equipment use, and maintenance tasks in a safe environment. The virtual training reduces the risk associated with on-site operations and prepares the team for a possible situation they will encounter in their jobs. Moreover, engineers and project managers are progressively employing virtual reality to visualize oil and gas projects, enabling the evaluation of layouts, workflows, and safety regulations prior to actual execution. By recognizing possible dangers and enhancing procedures in a virtual setting, VR improves substantial cost savings and risk reduction, hence resulting in safer and more efficient operations. The incorporation of VR-enabled drones and remote-controlled cameras is transforming remote monitoring and inspection procedures, enabling inspectors to traverse intricate structures and evaluate equipment integrity without the necessity of personal presence in perilous environments.

The advantages of VR surpass training and project visualization. Through the integration of real-time data streams from diverse sensors and monitoring devices, it delivers extensive visualizations of current operations, enabling prompt anomaly detection and process enhancement. This competence is essential for ensuring safety and efficiency in an environment where conditions may fluctuate swiftly. Furthermore, VR simulations are essential for equipping individuals for emergencies and enhancing their decision-making, communication, and coordination abilities during crises (Smith & Johnson, 2018; Wilson & Davis, 2021; Brown & Wilson, 2022).

EVOLUTION OF VIRTUAL REALITY AND HAPTIC FEEDBACK

VR and haptic feedback technology has come a long way with significant advancements that made these ideas more than just science fiction. What had initially been imagined as a futurist concept has since developed into a sophisticated technology that provides a simulated immersive, 3D experience that closely resembles a real-world environment (Steuer, 1992). Realistic audiovisuals within the VR environmental landscape had to be improved to increase realism in virtual meetings. This led to an explosion of haptic feedback technology for use in virtual reality, where it would simulate touch based on what you were feeling in the virtual world. This revolution was launched by Rosenberg (1995) and laid the framework for integrating haptic input into virtual reality systems.

Used with haptic gloves and controllers, haptic feedback devices allow users to feel virtual objects, textures, and surfaces. These unique devices use various methods to transmit tactile effects to the user's hands or other body parts, enhancing immersion and realism in virtual reality experiences. Haptic feedback technology mimics the feeling of touch, adding another layer of sensory information and allowing users to connect with virtual environments more seamlessly and intuitively. With these technologies, in particular, the evolution of VR and haptic feedback technology, the way we interact with digital environments has changed, bringing forth a new era of immersive engagement in many fields, even in oil and gas (Steuer, 1992; Wanasinghe et al. 2020; Bigliani, 2013; Mansor et al. 2017). As these technologies evolved, quite a lot of advanced and practical VR experiences could be created, which opens up exciting opportunities for the future of VR.

METHODOLOGY

As shown in Figure 1, this research technique for development projects consists of three phases including Project Development and Integration, VR Environment, and Collaborative Setup. Each phase is carefully designed to correspond with the overarching aims and objectives. The strategy for the developing phase is outlined as follows:

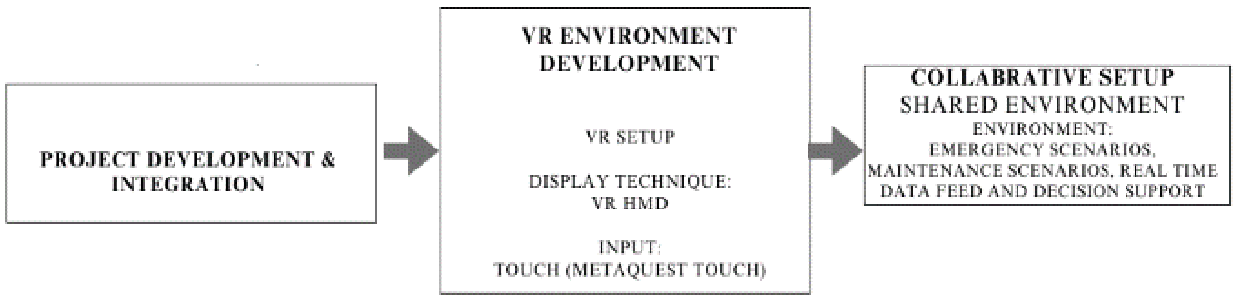

FIGURE 1. Research methodology

PROJECT DEVELOPMENT AND INTEGRATION

Project development is the process of starting to create a cooperative interface for the Virtual Reality (VR) environment. It signifies the initiation of the second objective focused on developing collaborative interfaces. This phase concurrently elucidates the experimental configuration for the VR project. A user has been provided with a Head Mounted Device (HMD) to enhance the display technique. The system employs an urban planning methodology to facilitate collaborative interfaces, coordinating cooperative tasks for users in the VR environment. The VR user is classified as a local user, and their engagement with the VR environment is enabled by the inputs that have been skillfully recorded. It concludes with the design of the User Interface (UI) and the specification of user interactions for both users. This phase also entailed integrating the collaboration interface with the user's VR experience. The integration employs a network plugin to facilitate the connection among several users. The manipulation within the collaborative interface is syncing across the network. It also governs player movement, represented by an avatar as a social presence.

PROPOSED VIRTUAL REALITY ENVIRONMENT IN OIL AND GAS INDUSTRY

Designing a VR environment tailored for the oil and gas industry involves a structured approach encompassing the following steps:

1. Define VR Content: Begin by defining the components of the virtual simulation, focusing on industry-specific situations and tasks. It could also include simulating a drilling campaign, an equipment maintenance procedure, a safety training exercise or reservoir visualization. Knowing what kind of virtual reality content one wants lends itself to ensuring alignment with operational goals and helps to perform targeted action.
2. Develop Virtual Environment: Simulate the realistic oil and gas facilities, landscapes, or operational environment. In an effort to create an engaging experience that supports training, planning, and decision-making, focus must be placed on features such as scale, detail, and realism. For immersive environments, focus on the development of a seamless and visually stunning digital landscape that immerses users in a realistic simulation.
3. Determine Interaction Methods: Describe the interaction techniques that allow users to connect with virtual objects or environments effectively. It involves defining the type and extent of engagement, especially for activities like handling equipment, visualizing data, and exploring scenarios. For example, integrate user-friendly gesture-based controls or custom interfaces designed specifically for the workflows in the oil and gas sector. Interaction methods must enable smooth navigation and manipulation of virtual elements to boost user engagement and productivity.
4. Enable Participant Collaboration: Add interaction between different participants on the virtual scene to enrich collaborative or competition experiences. This may involve the integration of features such as direct messaging, shared workspaces for joint projects, or gamified training programs to enhance collaboration, skill development, or decision-making. Ensuring that collaborative methods are easy to use, safe, and enable effective teamwork processes, particularly in remote team settings as well as complex operational tasks.

The proposed VR content focuses on an oil and gas platform, providing numerous opportunities for enhancement through the incorporation of immersive, interactive, and competitive features.

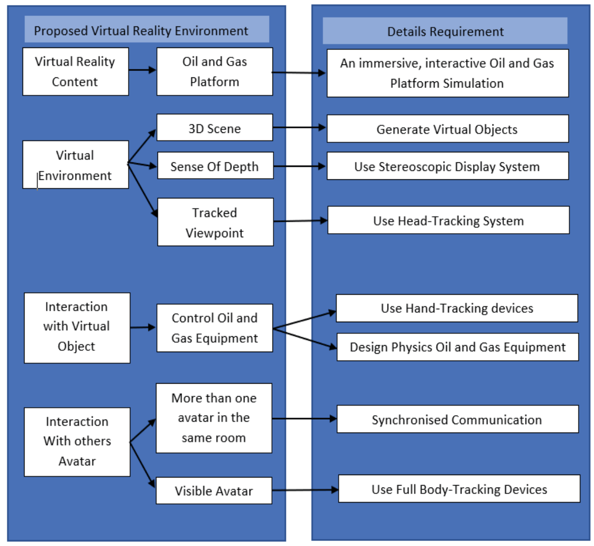

FIGURE 2. Requirement of proposed oil and gas virtual environment

Implementing a system for oil and gas workflows presents challenges related to ensuring effective tracking quality, realistic 3D effects, low response latency, and accurate workflow representations. Developing a virtual environment necessitates meticulous planning of a 3D scene, which includes essential components like the oil and gas platform and avatars representing human operators.

EXPERIMENTAL SETUP

Establishing the experimental framework requires careful planning and arrangement of critical components for executing a VR experiment. The process covers both physical elements (hardware) and essential technical aspects for data collecting and processing. The hardware and software definition phase highlights the difference between physical equipment such as VR headsets (hardware), and applications, programs, and development tools (software) in VR development. The emphasis in Virtual Reality Sharing Environment Development is on creating a digital area for user interaction and experience sharing. This encompasses the design of the virtual environment, the specification of user interactions, and the facilitation of smooth cooperation among users. The next phase is to develop a Collaborative User Interface (UI), focusing on the design of a graphical interface that enables concurrent interaction among numerous users, enhancing communication, cooperation, and shared experiences. UI focuses on the ways individuals engage with and manipulate the VR environment, encompassing actions, gestures, or input commands via devices for navigation, interaction, and impact within the virtual realm. The concluding phase, Integrate Collaborative Interface for Users in VR Environment, entails incorporating the planned user interface into the virtual area. It guarantees the seamless incorporation of collaboration features, communication tools, and interactive elements, hence boosting the overall user experience in a shared VR environment.

SPECIFICATION OF HARDWARE IN VR APPLICATIONS

The VR configuration required display technology, as the user must don a head-mounted display to visualize the output. The VR user uses the Meta Quest headset. Figure 3 shows the types of HMD devices utilized in this research. The Oculus Touch device has been utilized for VR user interaction with the Meta Quest HMD (Figure 4). Figure 5 shows the Six Degrees of Freedom (6DOF) position provided by the Meta Quest-HMD.

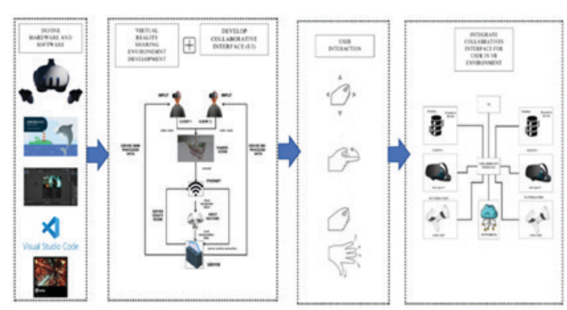

FIGURE 3. Process flow for creating a Virtual Reality (VR) application

FIGURE 4. Meta Quest 3 HMD

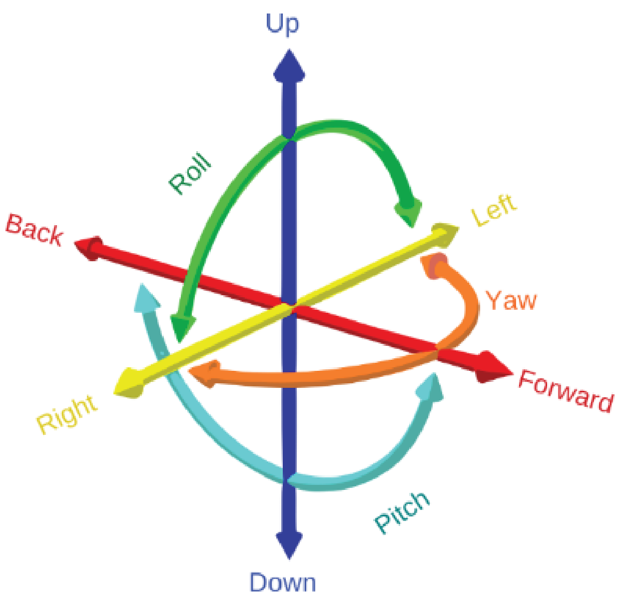

FIGURE 5. Six Degrees of Freedom (6DOF)

Six Degrees of Freedom (6DOF) allows for movement tracking in six dimensions inside a three-dimensional space and is a foundational premise for virtual reality (VR). These include translational movements (left/right, up/down, and forward/backwards) and rotational movements (pitch, yaw, roll). 6DOF ensures precise position tracking, enabling users to walk freely and naturally in a VR world with an accurate representation of their movements in the outside world. The accuracy enhances spatial interactions, helping alleviate motion sickness. Applications include gaming and entertainment as well as professional fields like training simulators. 6DOF shapes real-life and engaging virtual worlds. The Meta Quest HMD requires the installation of the Oculus SDK, configuring the installation parameters and pairing up the controllers/sensors. The setting ensures compatibility, makes a Guardian Boundary for the user's atmosphere, and adjusts the Meta Quest -HMD, growing the entire virtual fact experience.

FIGURE 6. Meta Quest Touch Controller

Figure 6 shows how VR users used the Meta Quest Touch. The Meta Quest controller is essential for the virtual reality (VR) experience, acting as the principal interface between the user and the virtual environment. These controllers function as virtual appendages, enabling users to grasp things, activate buttons, and interact with the VR environment with exceptional accuracy. Furnished with sophisticated sensors, the controllers monitor their location and motion in three-dimensional space, guaranteeing precise and responsive interactions. In addition, haptic feedback augments the immersive experience by replicating the sense of touch, enabling users to perceive vibrations and resistance that emulate real-world feelings. The controllers are equipped with buttons and joysticks for effortless navigation and control, rendering them a crucial element for a smooth and immersive VR experience.

ROLE OF SOFTWARE IN VR APPLICATIONS

Numerous software tools are utilized in VR App Development to create immersive experiences and complex worlds. Unity is one of the most popular game engines and development platforms in the world used by VR developers. It offers a vast range of advanced features, an excellent user interface, and sufficient documentation. Visual Studio Code (VS Code): It is a lightweight but powerful code editor that is often used by VR developers, particularly those using Unity, providing flexibility, support for various programming languages, and features such as IntelliSense for code completion and debugging support. Android Studio serves as the primary integrated development environment (IDE) for developers working on VR applications for Android devices, offering a comprehensive set of tools tailored for developing VR experiences on Android platforms.

Blender has numerous applications within VR content development, making it an excellent all-in-one 3D modelling and animation software, boasting extensive modelling and animation features including but not limited to modelling, texturing, rigging, animation and rendering, only further solidifying its popularity among VR developers for 3D asset and environment creation. By providing the building blocks for immersive and interactive experiences, these software tools empower VR developers to push the boundaries of VR technology and create compelling VR applications on a wide range of platforms and devices, bringing captivating experiences to users within the virtual world.

DEFINING USER INTERFACE (UI)

Creating a virtual world involves combining different geometric models, which serve as the building blocks of a digital environment. These models are crucial for the creation of the visual and spatial experience, thus enhancing the user's immersive and interactive experience within the virtual environment. By layering these abstract shapes effectively, designers can create a continuous world for users to travel through and inhabit. These models come in many shapes and add depth to the experience, allowing for a more engaging interaction with the virtual world. All of the models perform an important function within the overall design of the virtual world, ensuring that visitors have variety and stimulation as they explore the space.

A Cartesian coordinate system is crucial in 3D modelling, consisting of three orthogonal axes (x, y, and z). Their intersection, the global origin, acts as a critical point of reference for space measurement, where negative and positive distances from the global origin are represented through the x, y, and z values (Figure 7). The technology allows putting objects in 3d space and letting them rotate around pitch, yaw and roll. It enables developers to accurately orient objects in 3D space, achieving greater realism and interactivity.

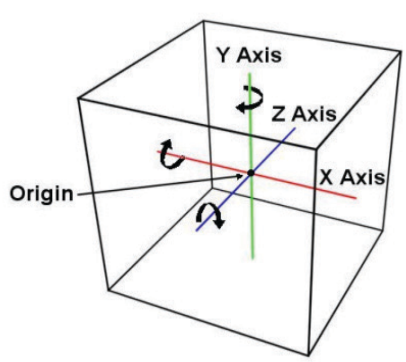

FIGURE 7. Cartesian coordinate system

In the world of 3D modelling, essential components like points, lines, and faces—also known as vertices, splines, and polygons—act as the basic units for crafting complex 3D objects. Knowing their definitions and characteristics is crucial for accurately constructing virtual worlds.

1. Points (Vertices): These are individual coordinates represented by XYZ values, indicating positions along the x, y, and z axes in 3D space. Each point serves as a fundamental building block for constructing more intricate shapes.
2. Lines (Splines): Defined by the XYZ values of their two endpoints, lines connect points in space and form the framework for creating edges and contours within 3D objects.
3. Faces (Polygons): Made up of multiple points outlining its shape, a face is a flat surface defined by XYZ values. All points on a face must lie on the same plane and faces give 3D objects their form and structure.

Each face owns a normal face, which is a vector indicating the orientation of the face. These norms are essential for determining the visible side of a face. They are employed to rectify surface inaccuracies resulting from modelling processes or the importation of meshes from other software. The precision and integrity of the 3D model can be guaranteed by manually adjusting, flipping, or unifying them. Figure 8 presents an example of a face in 3D space, highlighting its geometric characteristics and spatial orientation. Comprehending these fundamental 3D components establishes the foundation for constructing intricate and realistic virtual environments.

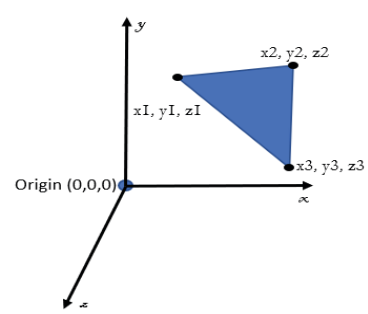

FIGURE 8. Example of a 3D triangulated face

As part of this VR project, a very detailed 3D model of an offshore oil rig and drilling rig was created, as shown in Figure 9, by employing a Cartesian coordinate system. The 3D model was then used as the anchor of our interactive VR experience, allowing users to explore and interact with this oil rig in a vibrant and informative way.

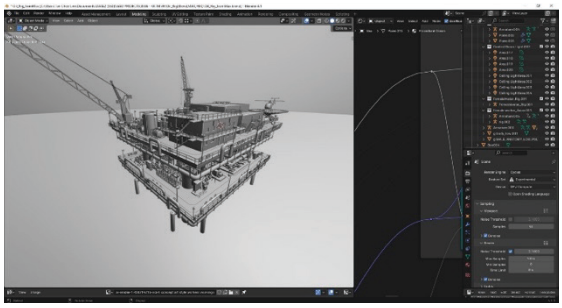

FIGURE 9. 3D modelling for oil rig

Figures 9, 10, and 11 depict the 3D models of the oil rig and drilling rig, which were constructed using blender software to provide an accurate representation of an offshore oil rig systematically. These models have classic features such as tall drilling derricks, helipads, and drilling platforms, all playing against a realistic ocean head. It shows the various parts of the rig, including the drilling deck, control room, and living quarters, providing a good view of the building. These 3D models are only used for the purpose of providing an immersive educational and training environment for offshore oil and gas professionals. By mimicking real-world scenarios, users can practice safety measures, learn about the intricacies of the work taking place on an oil rig, and better prepare themselves for work in the field.

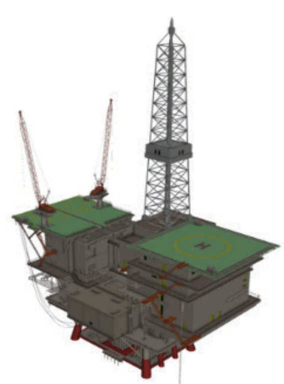

FIGURE 10. 3D modelling for drilling rig

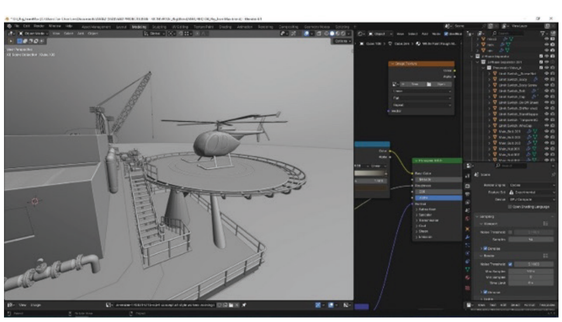

FIGURE 11. 3D modelling for helipad

Additionally, this detailed 3D render serves more than just a visual purpose. A protected and controlled training environment where personnel can get accustomed to the rig's layout and operations procedures. In addition, it permits the simulation of emergency scenarios and users to practice and patch their safety protocols effectively.

Figure 12 presents the wireframe technique in 3D modelling. The rendering happens in a wireframe model, which is a visual representation showing the overall shape and structure of the object by using lines to facilitate easy manipulation and viewing of the 3D model. It offers advantages such as flexibility in angle adjustments, quick rendering of changes, and ease of creating photorealistic effects. Furthermore, wireframe modelling increases photorealism and the chance of human error in visual effects placement. Wireframe modelling enables the acquisition of accurate photorealism. It provides a clear view of the structure of the object helping the artist or designer to check correct dimensions and relationships between the different elements of the model. This accuracy reduces the chances of human error when applying visual effects or textures, producing final outputs that closely resemble reality.

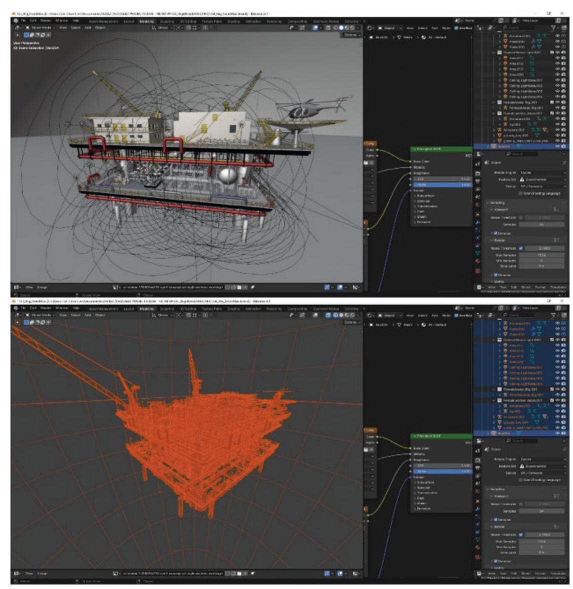

FIGURE 12. Wireframe 3D modelling for oilrig and drilling rig

Another advantage of wireframe models is their simplicity, which makes them an ideal tool for analyzing and refining form and design from different angles. Ease of manipulation and visualization is beneficial in many fields, such as animation, video games, and architectural visualization, where design iteration speed and improvements are critical.

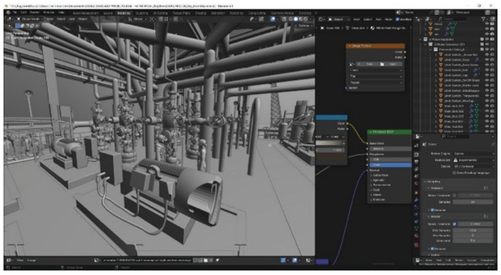

FIGURE 13. 3D modelling for equipment in oil rig

The 3D oil rig model has interactive components, like control panels, machinery, and safety devices, which users may manipulate and participate in. Realistic lighting, environmental effects, and sound simulations augment the overall immersion, as illustrated in Figures 13, 14, and 15. The model is flawlessly incorporated into the VR experience, enabling users to wear VR headsets and navigate the oil rig in a virtual setting. Users can engage with equipment, rehearse emergency protocols, and traverse various sections of the rig, thereby augmenting their knowledge and competencies.

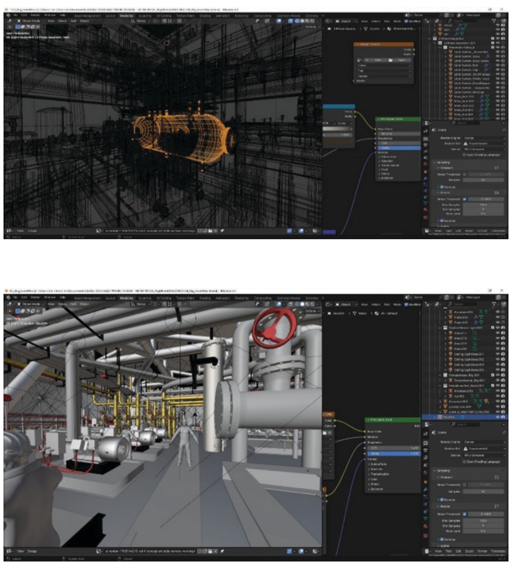

FIGURE 14. 3D modelling for avatar in oil rig environment

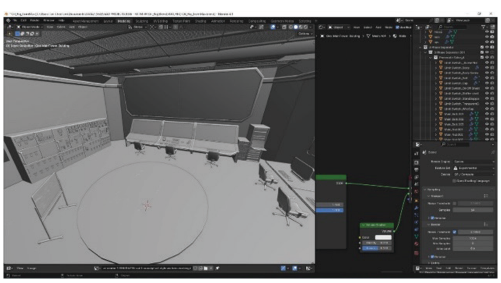

FIGURE 15. 3D modelling for avatar in oil rig environment

COLLABORATIVE USER INTERFACE FOR USER

The project has established a platform for users to collaborate on tasks within a virtual environment. The emphasis is on urban planning, characterized by numerous interactions occurring within this communal area. It employs a 3D object for urban planning activities, facilitating collaboration among two or more users. Users are classified into local (Client 1) and distant (Client 2) types. The local user creates a room, after which the remote user joins it. Both users can then collaborate in the same environment on urban planning projects. The communal room is linked via ethernet to provide synchronization between both users. When users manipulate items in the shared environment, their actions are transmitted to the server. The server processes this information and transmits it back to the users, refreshing their views. The bidirectional data flow guarantees that all participants engage in the cooperation instantaneously.

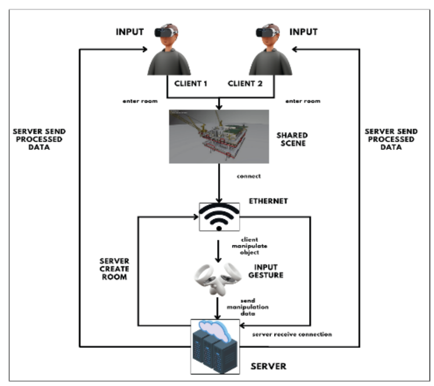

FIGURE 16. Process of collaborative interfaces in the shared environment

The collaborative interface features designated buttons for logging in and signing out, facilitating user connectivity (Figure 16). The procedure commences with the activation of the Photon service, directing the user to a designated waiting area. The local user initiates the shared space by hitting the start button, so establishing a collaborative room. The biggest challenge was the remote user could not click on the start button if the local user had not created a room. Collaboration only starts after both users enter the room. In this mode, the server acts as both a transmitter and a receiver, which is responsible for synchronizing player's positions and object attributes such as rotation and creation across the users. When the exit button is pressed, the application removes all instantiated objects in the network. The user is notified after closing the application. Figure 17 gives a glimpse of the user interface progress across the application.

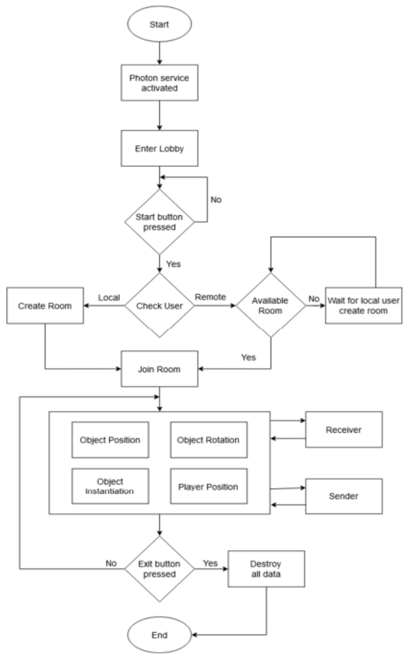

FIGURE 17. A T flowchart for collaboratives user interface

USER INTERACTION AND HAPTIC FEEDBACK

A key feature of this project is the use of a Virtual Reality (VR) Head-Mounted Display (HMD) equipped with gesture input and haptic feedback for interaction. The interaction methods include drag, tap, pinch, and release gestures, enhanced with haptic feedback to provide a more immersive and tactile experience (Sinclair et al., 2019; O'Malley & Gupta, 2008). The tap gesture is discrete, detecting one or more fingers touching a 3D button without significant movement from the initial touchpoints. In this project, the tap gesture is used to interact with a 3D button to initiate a spawn action. Haptic feedback provides a tactile sensation that confirms the button press, enhancing the realism of the interaction.

The pinch gesture is an ongoing process that measures the distance between the first two fingers inserted into a 3D object. It is used only for grabbing virtual objects in the VR world. By generating haptic feedback, a feeling as if the object is being held, the interaction becomes more sensorial. Specifically, the drag gesture transfers an object from one location to the destination location (Moosavi et al., 2023). In this project, the drag gestures are combined with the pinch gestures to let users drag the devices and move the background of visual markers in the shared interface. Differentiated textured haptic feedback resists and feels dragged.

The release gesture uses extended fingers, preceded by a pinch gesture, which is used to free virtual objects from the user's hand. The haptic feedback provides a sense of releasing, which increases the feeling of reality (Moosavi et al. 2023; Aziz & Mousavi, 2009). Figure 18 illustrates the hand techniques employed for drag, tap, pinch, and release actions, demonstrating how these gestures, combined with haptic feedback, are utilized in the VR environment to create a more immersive and interactive experience.

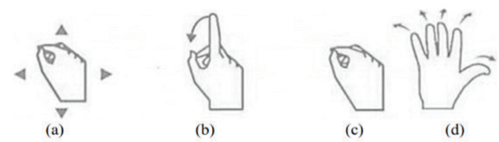

FIGURE 18. Hand techniques employed for (a) drag, (b) tap, (c) pinch, and (d) release actions

FIGURE 19. Haptic feedback system on Meta Quest Touch Controller

The haptic feedback system in the Meta Quest is a crucial element that markedly improves the user experience by delivering tactile sensations that align with interactions in the virtual environment. This technology enables users to perceive tactile feedback, enhancing realism and immersion in virtual encounters. The haptic feedback technology enhances interactions by mimicking the sensation of touch and texture in virtual objects, making them more intuitive and engaging. For example, users can perceive the sensation of pressing a button, pulling a lever, or holding an object, which not only validates their actions but also enhances their overall experience. The integration of haptic feedback establishes a sensory-rich environment, enabling users to sense a greater connection to the virtual realm. This element is essential for accessibility, providing extra sensory signals for users with visual impairments or other limitations, hence enhancing the usefulness of the Meta Quest for a varied audience.

Haptic feedback is built upon advanced technology with high-quality parts such as Linear Resonant Actuators (LRA) and Voice Coil Motors (VCM) capable of replicating more nuanced and localized sensations. When LRA technology is involved in the index trigger, upon triggering the index, accurate feedback is provided in response to interaction, allowing for a more immersive interaction between the virtual and real world. The thumb rest, likewise—the LRA adds comfort and stability while giving tactile feedback that corresponds to what you are doing in VR. The use of VCM technology in the Meta Quest pushes the limits of the sensations you can experience while playing on the device, from the lightest vibrations to heavy haptic feedback. This comprehensive approach to haptic feedback enhances immersion and realism, delivering a more captivating and dynamic virtual environment to users solidifying the Meta Quest as an adaptable tool in the field.

RESULTS AND DISCUSSION

3D MODELING OF OILRIG AND DRILLING RIG INTEGRATED WITH VIRTUAL REALITY TECHNOLOGY

A prototype 3D model of offshore oil and drilling rig integrated into VR technology is presented in Figure 20. It also shows how avatars are incorporated as human substitutes in the virtual reality atmosphere. The novel methodology aims to enhance the training and simulation aspects of the oil and gas industry.

As depicted in the figure, the VR environments feature a good 3D model which connects the offshore oil rig and drilling rig organically. The photos portray the architecture of the oil rig, such as the drilling rig, control room, equipment, as well as surroundings in a contextualized VR-like immersion. In this illustration, the 3D model has been integrated with VR technology. The integration allows us to explore oil rigs and drilling rigs realistically and interactively. The user will be able to walk around the rig in a virtual space, interact with the equipment, and practice emergency procedures, all inside VR. The 3D modelling in VR serves two different purposes. At one level, it is a serious training tool for oil and gas field workers, providing an opportunity to play out realistic situations in a safe setting. On the other hand, it shows how VR technology can evolve the industry and be used to improve the efficiency and safety of operations through training and simulation.

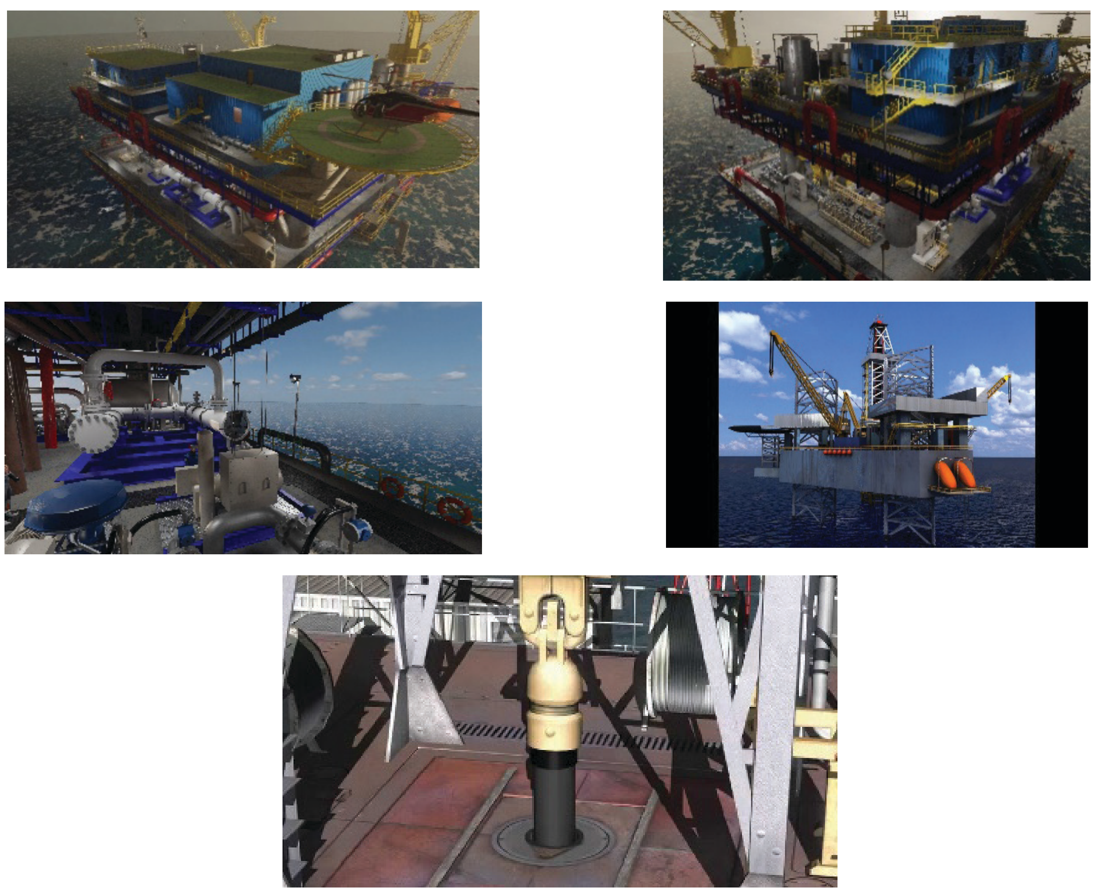

FIGURE 20. 3D modelling for oil rig and drilling rig integrated with VR

Human substitute within the virtual reality room, multiplayer avatars serve as human replacements, allowing multiple users to reside and interact simultaneously within the virtual realm (Figure 21). These avatars serve as virtual duplicates of real people, enabling users to engage in collaborative activities, training scenarios, or virtual meetups. Through the use of avatars, users can interact, cooperate and perform activities in the virtual realm, giving a feeling of presence and immersion. For the oil and gas industry, multiplayer avatars have many benefits. They enable teams of staff members to participate in online training scenarios or simulations, regardless of their location. Technicians found across all offshore rigs can gather in the virtual reality room for emergency response drills or equipment maintenance training. Avatars might even copy real-life behaviours or interactions, creating a credible simulation for practising a procedure or solving a problem.

FIGURE 21. Avatar as a human substitute in a Virtual Reality environment

Since skilled workers can train or supervise novices in the virtual environment using a multiplayer avatar, this helps facilitate knowledge transfer and skill acquisition. But the mentoring can happen in real-time, where more senior employees will direct less-experienced people on specific jobs or procedures, while providing feedback and guidance. In the oil and gas industry, using multiplayer avatars as human surrogates in VR environments boosts collaboration, training, and simulation efficiency. It encourages easy cooperation between statewide groups, encourages the advancement of skills, and improves safety and operational efficiency.

CONCLUSION

In conclusion, the introduction of VR technology has given the oil and gas industry a considerable leap ahead, greatly enhancing training, project safety, operational efficiency and collaboration. It could be a game changer for this critical industry, and this project has explored those possibilities in detail, as well as concrete steps to translate that potential into tangible action. What makes virtual reality technology stand head and shoulders above any others is its unique ability to aid in oil and gas industry safety protocols and training programs. It creates highly realistic and immersive simulations, allowing workers to rehearse complex equipment and procedures in a safe, controlled environment. The benefits of this method of training, whereby employees learn more rapidly in an immersive scenario and are better equipped to deal with real-world situations, are immense. Conducting safety procedures and emergency response drills in a virtual environment minimizes the risk of accidents and operational errors, paving the way for a safer workplace.

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DECLARATION OF COMPETING INTEREST

None.

REFERENCES

Abich, J., Parker, J., Murphy, J.S., & Eudy, M. 2021. A review of the evidence for training effectiveness with virtual reality technology. *Virtual Reality* 25(4): 919-933.

Aziz, F.A. & Mousavi, M. 2009. A review of haptic feedback in virtual reality for manufacturing industry. *Journal of Mechanical Engineering* 40(1): 68-71.

Bigliani, R. 2013. Reducing risk in oil and gas operations. *IDC Energy Insights* 1-15.

Brown, C. & Wilson, E. 2022 Collaborative design and engineering using virtual reality in the oil and gas industry. *Journal of Oil and Gas Engineering* 10(3): 78–92.

Mansor, N.N., Jamaluddin, M.H., & Shukor, A.Z. 2017. Concept And Application of Virtual Reality Haptic Technology: A Review. *Journal of Theoretical & Applied Information Technology* 95(14).

Moosavi, M.S., Raimbaud, P., Guillet, C., Plouzeau, J. & Merienne, F. 2023. Weight perception analysis using pseudo-haptic feedback based on physical work evaluation. *Frontiers in Virtual Reality* 4: 973083.

O'malley, M.K. & Gupta, A. 2008. Haptic interfaces. *HCI beyond the GUI: Design for Haptic, Speech, Olfactory, and other nontraditional Interfaces* 25-64.

Pereira, D., Oliveira, V., Vilaça, J.L., Carvalho, V. and Duque, D. 2023. Measuring the Precision of the Oculus Quest 2's Handheld Controllers. *Actuators* 12(6): 257.

Rebelo, F., Noriega, P., Duarte, E., & Soares, M. 2012. Using virtual reality to assess user experience. *Human factors* 54(6): 964-982.

Roberts, J. & Thompson, L. 2022. Virtual reality training for emergency response in the oil and gas industry. *Journal of Occupational Safety and Health* 14(3): 112-125.

Rosenberg, L.B. 1995. Virtual haptic overlays enhance performance in telepresence tasks. *Photonics For Industrial Applications* 2351: 99-108.

Sinclair, M., Ofek, E., Gonzalez-Franco, M. & Holz, C. 2019. Capstancrunch: A haptic vr controller with user-supplied force feedback. *Proceedings of The 32nd Annual ACM Symposium on User Interface Software and Technology* 815-829.

Smith, A. & Johnson, B. 2021. Enhancing safety training through virtual reality simulations. *Journal of Petroleum Technology* 73(2): 45-54.

Smith, J. & Johnson, A. 2018. Virtual reality training for offshore oil and gas operations: A systematic literature review. *Journal of Petroleum Science and Engineering* 169: 322-334.

Steuer, J. 1992. Defining Virtual Reality: Dimensions Determining Telepresence. *Journal of Communication* 42(4): 73-93.

Wanasinghe, T.R., Wroblewski, L., Petersen, B.K., Gosine, R.G., James, L.A., De Silva, O., Mann, G.K. & Warrian, P.J. 2020. Digital twin for the oil and gas industry: Overview, research trends, opportunities, and challenges. *IEEE Access* 8: 104175-104197.

Wilson, K. & Davis, R. 2021. Enhancing safety practices in the oil and gas industry through virtual reality technology. *Occupational Health and Safety Review* 29(2): 76-89.