Development of a VR Training Simulation with Integrated Hand-Tracking Enhancement for OR Etiquette

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***Abstract*—Virtual reality (VR) technology is rapidly advancing and offers innovative, immersive enhancements for training across various fields, also including the medical sector. This paper presents the development and implementation of a VR training simulation with the assistance of hand-tracking technology to improve operating room (OR) etiquette for individuals unfamiliar with OR protocols. By using the Meta Quest 3 headset and the Unity game development engine for development, the VR simulation provides a realistic, interactive environment for users to learn essential OR protocols.**

A comprehensive review of historical and current VR technologies, focusing on hand-tracking methods, laid out the fundamental bases of the design and development of the VR training application. The system includes highly detailed 3D models to represent OR environments, real-time hand-tracking for user interaction with virtual objects and player movement, and educational mini-games addressing crucial aspects of medical hand hygiene.

The development process involved multiple hospital visits to observe and document the layout and daily workflow of OR staff, ensuring a high level of realism. The outcome of this work is a VR training program that covers essential behavioral guidelines for operating rooms, providing a safe, engaging, and effective learning platform. The program offers several advantages over traditional training methods, such as increased motivation, improved learning outcomes, and automated performance feedback providing a greater addition to traditional training methods.

Future work will focus on enhancing the VR training program's content by incorporating more complex medical procedures and additional interactive scenarios tailored to specific OR personnel groups, thereby broadening the application's target audience.

***Index Terms*—Virtual Reality, Medical Training, Hand-Tracking, Operating Room, Simulation, Unity, Meta Quest 3**

I. Introduction

THE modern area of technology provides humanity with a broad variety of ways to enhance everyday life, make work faster and easier, and much more. But this digital age also represents various challenges for a lot of people. To learn the correct way to operate certain devices requires a lot of commitment and time investment. On the flip side of the coin, modern technologies can also be used to enhance learning methodologies on their own, making learning faster, more effective, and motivating. Virtual Reality (VR) offers the potential for new ways to gain education and to learn. [1][2][3][4]

In the realm of medicine and surgery, education and knowledge are one of the most valuable goods. This is especially true in the context of surgical operations and procedures, where any error can pose significant risks to patients. Violating the stringent behavior protocols in an operating room (OR) can, for instance, lead to contamination of the sterile area, and by that significantly increase the risk of complications for the patient. These complications can reach from wound infections and other post-operative complications, such as prolonged anesthesia to the need for additional surgeries.[1][5][6]

With this risk in sight, it does not come as a surprise, that continuous training and fresh up courses on new procedures methods are required for hospital staff, which puts additional burdens on these people due to the time consumption. [1][7][8]

With the fast development of new ways of implementation and the growing attention towards virtual reality (VR) technology for professional use, VR has emerged as a potential solution to these training challenges. VR training programs offer several advantages over traditional methods like informational brochures and videos, including enhanced motivation and learning efficacy. These benefits arise from VR's immersive and interactive nature, coupled with gamification elements that have proven effective in other fields like rehabilitation. Moreover, VR provides automated feedback on training performance. Several studies have demonstrated the effectiveness of VR training in critical areas such as reanimation training. Yet, to our knowledge, VR has not been applied to OR etiquette training. [1][9][10][11]

A. History of Virtual Reality

The history of VR can be followed back to the mid-20th century. In the 1960s and 1970s the development of VR technology as we know it today had its first fundamental accomplishments in the form of early concepts for immersive experiences. [1][12][13]

In 1962 Morton Heilig invented a 4D cinema with the name Sensorama, which can be considered one of the first examples of an immersive entertainment-based experience. One person at a time could enjoy one of them, in total, five movies that were made for this device, and experience a 4D entrainment through artificially created senses like vibrations, air movement, and even smells. [1] [12][13][14]

The first Head-mounted display (HDM) was developed in 1968 by Ivan Sutherland and his student Bob Sproull. The "Sword of Damocles". This represented one of the biggest milestones in VR history, as this device was able to show

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the users computer-generated images, which were overlayed in the real world. This made this device the first Augmented Reality (AR) headset. The device held two displays and a half-silvered mirror system. Through sensors, that were mounted on the headset, the device could notice movements of the head, which led to a rendering and display of virtual objects in the displays. Because of its sensors and design, the device was so heavy, that it had to be mounted on the ceiling of the rooms,see image 1, which led to its name originating from Greek mythology. [1][12][13][15]

Fig. 1. First head mounted headset "Sword of Damocles"
[16]

The 1980s marked a transformative period for VR technology. In 1984, Jaron Lanier founded VPL Research, one of the first companies to sell VR goggles and gloves. One of their key technologies of VPL was the Data Glove, which allowed for real-time tracking of hand positions and the movement of each finger. This glove used optical fibers attached to the back of each finger. When the fingers flexed, a change in light transmission through these fibers was detected to determine finger joint angles. As the light fiber approach was only usable to detect the movement of the fingers, a magnetic tracking device was mounted on the back of the hand to track larger movements, such as the position and orientation of the palm. While this device leaked in prediction to replicate complex hand gestures, Lanier's work popularized the terms "Virtual Reality" and "hand-tracking," for further research and development. [1][12][17]

In the 1990s, the growth of VR did not come to a stop, driven by both commercial and academic interests. Entertainment companies like Sega and Nintendo introduced VR to the gaming branch, while the military and aviation sectors adopted VR for training and simulation. Despite the excitement surrounding VR, technological limitations such as high costs and insufficient computational power hindered its development, leading to a temporary decline in its popularity. [1][12][18]

Improvements in computing power were one of the key factors of VR technology advancements in the 21st century. The launch of the Oculus Rift headset, created by Palmer Luckey, marked a significant turning point because high-quality VR experiences were not available at an affordable price. This put the term "VR" back into people's heads. Following the Oculus Rift's example, later on devices like the "HTC Vive" or "PlayStation VR" entered the market, bringing VR and its potential to a broader audience with improved graphics and performance. These systems featured advanced controller tracking technologies, enhancing the immersive experience. The development of hand-tracking and body-tracking technologies, such as Leap Motion and Microsoft's Kinect, further improved the immersive quality of VR by enabling more natural movements and user interactions. [1][19][20]

B. *Evolution of VR Training*

This chapter will briefly outline the history of VR training and its sectors of use. Historically, new and revolutionary technology often finds quick application in military and combat settings, and VR was no exception here. [1][18][21] VR technology found its use in simulation of complex combat scenarios, allowing soldiers to practice their skills in a controlled, risk-free environment. This type of safe training was also adapted for flight simulations, benefiting trainees encountering airborne vehicles for the first time.[1][22][23]

By 2015, VR training had expanded into various sectors, including law enforcement, emergency response, and industrial training. VR simulations enabled police officers to practice critical scenarios, firefighters to navigate dangerous environments, and industrial workers to handle heavy and complex machinery without risk.[1][24]

In the modern era, VR training has become even more sophisticated and interactive. Industries such as automotive, oil and gas, and construction use VR to train employees in hazardous or complex tasks. Companies like Boeing and other airlines have developed highly accurate and costly VR training programs to enhance pilot safety and efficiency. Image 2 showed the AviaSim Flight simulator.

Fig. 2. Setup of the AviaSim Flight simulator
[16]

C. VR Training in the Medical Field

This chapter will outline the use of Virtual Reality training in the broad medical field. VR has been primarily used for knowledge transfer and 3D visualization of anatomical structures. Just like in the other fields, where VR training was used, the complexity and the possibilities of this technology also increased in the 21st century because of the enhanced performance of the devices. This made it possible for surgeons to train through digital simulations and for patient therapy purposes. [1][25]

Medical training has historically faced challenges such as the limited availability of cadavers, ethical concerns, and the complexity of human anatomy [1][26]. VR offered a solution by providing realistic and interactive simulations that medical students and professionals could use to practice procedures and enhance their skills. In the late 1990s and early 2000s, early adopters in medical education began using VR to simulate surgical procedures. Simulators like the MIST VR (Minimally Invasive Surgical Trainer) allowed surgeons to practice laparoscopic techniques virtually, improving their skills without involving real patients. [1][27]

In the 21st century, developers for VR training in the medical field have focused on creating more specialized medical simulations to provide expertise to professionals. To meet the increasing quality requirements for surgical and medical staff, new VR platforms were developed to simulate various medical scenarios, including daily patient treatment, emergency room procedures, and complex surgeries. These simulations offered detailed anatomical models and real-time feedback, allowing users to repeat scenarios until they achieve proficiency. [1][27][28] The use of hand-tracking technologies has provided additional methods for interacting with virtual tools and tissues, showing similar learning outcomes to VR controllers and expanding the implementation options for VR in education. [1][29][30]

This paper has two main objectives. The first and primary objective is to present the conceptualization and development of the VR training simulation with integrated hand-tracking. The secondary objective of this paper is to present the results of this development and to discuss possible further improvements.

II. Methods

This section is meant to describe the conceptualization and development of the VR training simulation and the overall design of each VR environment. First of all, the red thread for sequence will be outlined, followed by a description of the hardware and software components used. Then the hand-tracking input system as well as the interaction with digital objects will be explained. This will be followed by a walkthrough of the simulation sequence. For this, each designed room will be individually addressed.

A. Concepted sequence

To better understand the environmental setup of an OR wing and the preliminary steps required for someone entering the OR tract, multiple hospitals were visited. These visits also provided valuable insights into the daily workflow of surgeons and the entire OR staff, which could potentially be incorporated as side events into the VR training simulation to enhance its realism and immersion. [1]

For a realistic simulation of a surgical area, several key aspects were of major focus during the visits:

- **Important rooms before entering the OR - area** Identifying which rooms are essential to include in the simulation before the person enters the OR.
- **Changing - Room** Understanding the setup and furniture layout of the changing room. Noting any special hygiene and cleanliness restrictions that need to be followed.
- **Washing - Room** Analyzing the general setup of the OR, including the placement of surgical equipment, safety features, lighting setup, room illumination, and the layout of the sterile area. Understanding the positions of the surgeon and OR staff within the room.
- **Events** Identifying general events that can be implemented in the simulation to make it more intuitive and immersive for the user.

The first visit was at the HNO Surgery at Innsbruck Klinik Tirol. Under the guidance and supervision of Assoc. Prof. Priv. Doz. Dr. Joachim Schmutzhard, a cochlea implantation surgery was observed and thoroughly documented. In addition to witnessing the surgery, Dr. Schmutzhard provided a comprehensive tour of the entire OR wing, covering all essential steps required to enter the OR, behavior and cleanliness rules, as well as the proper way to exit the OR. [1]

The second visit was at the Bezirkskrankenhaus St. Johann in Tirol. Led by Mr. Simon Brandtner, head of the nursing department in the surgery wing, a partial knee surgery and a laparoscopic procedure were observed. This visit included a complete tour of the OR tract, highlighting all important steps and mandatory rules in every surgical area. Given the smaller size of Bezirkskrankenhaus St. Johann compared to Innsbruck Klinik Tirol, a variety of different operations and procedures are conducted in the central surgery of St. Johann, providing additional insights into room layout, safety measures, and OR staff behavior. [1]

As a result of the information gathered in these visits, the following red thread of sequence was set for the VR simulation:

1) **Main Menu** The start of the virtual simulation. This place to set options or to go to a tutorial area to train the hand tracking input system of the application.
2) **Additional options** Settings for the player to further customize the application to personal needs.
3) **Changing Room** A scene in the simulation where the hand hygiene protocols of hospitals can be trained.
4) **Washing Room** The user is required to perform hand sterilization here.
5) **OR** The surgical area with multiple different events implemented, inspired from the experiences made during the hospital visits.

B. Software and Hardware used for development

Unity is a versatile graphics engine and development environment for creating games and graphical applications across various platforms. It supports tasks ranging from simple operations, like rotating a cube, to developing complex, high-performance games for computers, mobile devices, and consoles. Developers can assign properties and behavioral dependencies to game items and other objects, known as GameObjects, using C# scripts. Applications made with Unity are downloaded up to five billion times each month, and it is used to develop up to 50 percent of all games for mobile devices, PCs, and consoles. Additionally, more than 60 percent of popular VR applications are developed with the Unity game development engine. [1][31]

Beyond video game development, Unity is employed in animation, film, art design, data analysis and visualization, architecture, engineering, and more. [1][32]

While Unity is a popular choice for VR development, other game engines also offer robust features. This section briefly compares Unity and Unreal Engine, the two main game development engines considered for this project.

- **Graphics and Visuals**: Unreal Engine, developed by Epic Games, is known for its high-end graphics capabilities, real-time rendering, and photorealistic visuals, making it a preferred choice for AAA games and high-fidelity VR experiences. While Unity offers impressive graphics, Unreal Engine's visual quality is often considered superior. However, the high-end graphics of Unreal Engine were deemed unnecessary for the VR training simulation, making this advantage trivial.
- **Ease of Use**: Unity is generally considered more user-friendly, especially for beginners, due to its intuitive interface and extensive documentation. Unreal Engine has a steeper learning curve because of its complexity and advanced features.
- **Scripting**: Unity uses C#, which is widely regarded as a more approachable language for beginners. Unreal Engine uses C++ for scripting, which is more powerful but can be more challenging for those new to programming.
- **Asset Store**: Unity's Asset Store is extensive and well-integrated into the development workflow. While Unreal Engine's Marketplace also offers a wide range of assets, Unity's store is often seen as more user-friendly and diverse.

These factors made Unity the preferred development platform for the VR training simulation.

The used hardware for the simulation was the Meta Quest 3 headset, developed by Meta (formerly Facebook). This standalone VR headset is designed to provide an immersive experience without requiring a PC or external sensors.

- **Display and Optics**: The Meta Quest 3 features high-resolution displays with advanced optics to ensure a clear and immersive visual experience. It uses a dual-panel LCD system with a combined resolution of 3664 x 1920 pixels, delivering sharp and vibrant images. The headset's refresh rate reaches up to 120 Hz, which smooths motion and reduces motion sickness. [1][33]
- **Processing Power**: Powered by the Qualcomm Snapdragon XR2 platform, a chipset specifically designed for extended reality (XR) applications, the Meta Quest 3 is equipped with 6GB of RAM. This powerful processor enables the headset to run complex applications and games with high graphical fidelity and low latency. The XR2 platform also supports AI and machine learning capabilities, further enhancing the overall performance and user experience. [1][33]

C. Hand tracking and the interaction with virtual objects

To implement the possibility to manipulate and interact with digital objects within the virtual environment, the XR Interaction Toolkit was used. This package, provided by Unity holds the key components to set up a VR / XR experience within this development engine and supports cross-platforming to the Pico headsets, OpenXR, Windows, and Mixed Reality applications.

These 3D hand models simulate the tracked hand movements performed by the user. The integrated hand-tracking system of the XR Interaction Toolkit was implemented in each scene, using pre-modeled 3D meshes of each hand, rigged to provide natural hand movements. The hand-tracking systems start with pose estimation, identifying and tracking key points on the hand (such as fingertips, knuckles, and wrists) using machine learning models like convolutional neural networks (CNNs) and sensor data. [1]

These key points are projected onto the kinematic models of the corresponding hand, which contain a skeletal structure of bones and joints. Each joint has a specific degree of freedom (DoF) to prevent overbending or unnatural movements. The vertices of the hand mesh are "skinned" to the bones and joints, ensuring smooth deformation of the hand model to mimic the real hand's skin and flesh, see image 3. [1]

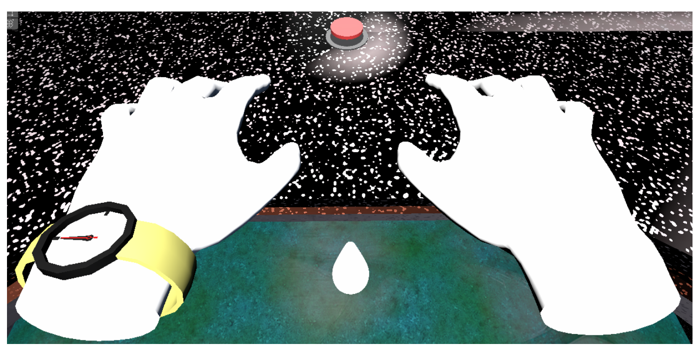

Fig. 3. Virtual 3D hand models for VR/XR applications

To enable interactions between the 3D hand models and virtual objects (called GameObjects in Unity), each GameObject requiring interactivity had to be individually configured based on its intended use.

- **Colliders**: Each GameObject was assigned a 'Collider' component to define physical boundaries and detect collisions with virtual hands. Depending on the shape and requirements of the GameObject, different types of colliders (box, sphere, or mesh) were used. [1]
- **Rigidbody**: GameObjects needing to respond to physics-based interactions were given a 'Rigidbody' component, allowing them to be manipulated through grabbing, pushing, or other physical interactions. Rigidbody settings were carefully adjusted for appropriate mass, drag, and gravity properties to ensure realistic behavior. [1]
- **XR Grab Interactable**: Each interactive GameObject was assigned an 'XR Grab Interactable' component, enabling it to be grabbed and manipulated by the virtual hands. Interaction parameters such as attach transforms and movement types were configured to achieve the desired interaction behavior. [1]

GameObjects not intended for transformation (like buttons) were assigned the XR Poke Filter script and the XR Poke Follow Affordance script from the XR Interaction Toolkit. These scripts managed the behavior of poked objects, such as poke distance and response speed, and were essential for hand-tracking interactable UI elements to prevent virtual hands from accidentally passing through UI elements. [1]

Hand tracking enhances interaction between virtual hands and digital objects, but without VR controllers, a new mobility method was necessary. A teleportation system was implemented, working with the hand-tracking input system. An interaction ray was integrated into the user's right hand. When pointed at the floor, a moving circle appeared, showing the user the destination area, see image 4. Teleportation was executed by pinching the index finger with the thumb of the right hand. [1]

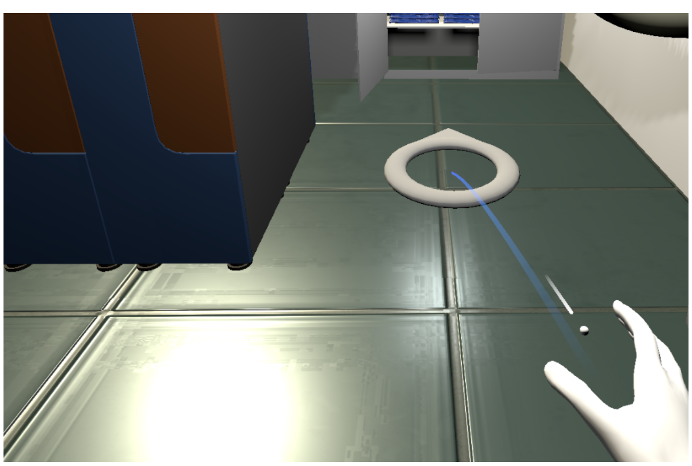

Fig. 4. Teleportation ray with marked target of teleport

D. The scenes within the VR simulation

The final part of this section covers the description of each scene in the simulation as well as the individual key features.

- **Main Menu**: The main menu is the user's first encounter after launching the VR application on the headset, setting the overall theme for the rest of the game. After arriving, the users find themselves in front of a desk, which allows them to familiarize themselves with the hand-tracking-based user experience. Since the game is controllable with hand-tracking only, a traditional VR user interface was not an option, but pokable buttons are used for the first user interaction. When pressed by the virtual hand, these buttons trigger events or UI actions. When the main button is pressed, the complete menu with all available options appears in front of the user. The options include starting the game, adjusting settings, selecting scenarios, accessing the tutorial, and exiting the game. Selecting "Start Game" begins the training simulation, starting in the first room leading to the entry of the OR tract. In the "Options" menu, users can choose whether to play music throughout the game and decide if additional information should be displayed in individual game scenes. This additional information provides further details about tools or events, which are otherwise hidden from the player. The "Scenario Selection" menu allows users to choose between being an unsterile or sterile visitor. If the sterile visitor option is selected, an additional scene is added to the game sequence, covering the essential steps of sterilization before entering the OR area. The "Tutorial" option directs users to a scene where they can practice hand-tracking input actions. This was implemented because user tests showed a wide variety of VR experiences, from intuitive interaction with virtual objects to no movement due to insecurity. This tutorial scene allows users to calmly train the user-input actions required for the subsequent scenes in the game. Selecting "Exit" quits the game and returns the user to the general Meta Quest 3 Menu interface. To avoid visual and cognitive overload, each UI element becomes visible only when the user hovers their virtual hand over the corresponding button. If UI elements that provide further options are selected, such as in the options or scenario sections, a smaller version of each UI element appears in front of the user to enable easier input. In image 5 the full UI of the menu is displayed. The dark setup of the scene and the overall simple structure of the UI elements were very beneficial for the headset's performance. The frame rate for this scene and subsequent scenes was measured using the Performance Analyzer in Oculus Developer Hub. The minimum frames per second were 76 FPS, with an average of 80-86 FPS and a maximum of 89 FPS. [1]

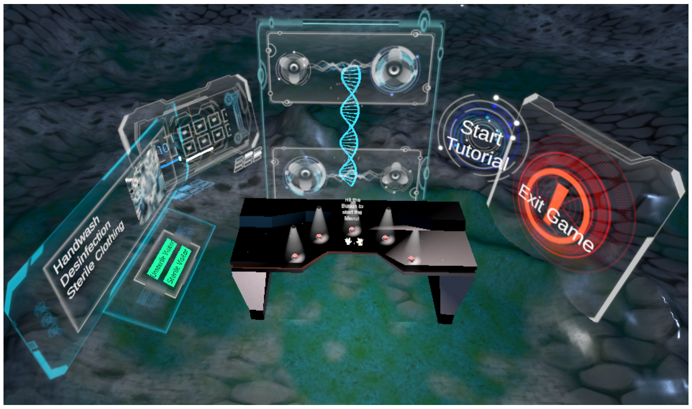

Fig. 5. Complete UI of the main menu

- **ChangingRoom**: Despite variations in overall design and layout among real-life examples, the changing rooms consistently contained the same essential elements:
  - **Lockers for storing belongings**
  - **Wardrobes with clean OR clothing available in multiple sizes**
  - **Seating for changing**
  - **Sink for washing and disinfecting hands**

  After entering the changing room, users appear just inside the entrance door, looking towards the room. Here, they have to follow a strict hygiene protocol before entering the OR environment and to change into hospital-issued clothing. The protocol starts at the sink, where a poster provides instructions for proper handwashing. The hand-washing process begins with a minigame, initiated by pressing the soap dispenser with a virtual hand. This triggers a green particle system simulating dispensed soap. When the virtual hand is placed under the dispenser, soap particles collide with it, and a green tick appears on the instruction poster, indicating completion of this step. Next, users must wet their hands using the sink. They can push the sink levers with the backs of their virtual hands to activate the water particle system. Collision between the water particles and the virtual hands results in another green tick on the instruction board. A progress bar above the sink indicates the remaining time for each step, ensuring that each task is performed for the required duration. Image 6 shows the VR environment for the hand washing minigame. After rinsing the soap from their hands, users must dry them by grabbing a paper towel from the dispenser and disposing of it in the bin. This final step completes the hand hygiene sequence. With hand hygiene completed, users can grab a set of clean hospital clothing from the wardrobe using their virtual hands. The clothing parts disappear from the closet upon selection. If the user attempts to grab more clothing, a UI message informs them that the necessary clothing has already been collected. Next, users are instructed to place their personal belongings in a designated locker, labeled with a UI text component for easy identification. This action automatically changes the user's attire to that suitable for the OR environment, confirmed by an additional UI message. After completing these tasks, users can proceed to the next scene by exiting through the door at the back of the room. The water particle system posed the most significant performance issue in this scene, reducing the FPS by 15 when activated due to the collision system of each particle. To address this, the number of particles allowed in the scene was reduced from 5000 to 2000. The minimum frames per second were 42 FPS, with an average of 69-74 FPS and a maximum of 76 FPS. [1]

Fig. 6. Setup of the hand-washing minigame

- **WashingRoom**: This scene is accessible to the player only if the "sterile visitor" option is selected in the Main Menu. This area, based on real-life observations, is typically compact and serves as a transition space to the actual operating room of the simulation. A small room was created in Unity to replicate this layout. Although the room contains sinks with a working water system similar to those in the changing room, its primary purpose is to cover the steps of proper hand disinfection. An instruction poster is placed on the right-hand side of the entrance door, where the player spawns. By pressing one of the dispensers, a particle system is triggered, starting the hand disinfection minigame. Continuous movement of the virtual hands after receiving the disinfection lotion triggers a progress bar, indicating the time needed to complete each step. Once all steps on the instruction poster are marked with a green tick, a UI message confirms that hand disinfection is completed. The player can then proceed to the exit door, entering the OR. This scene contains a small room with fewer demanding GameObjects, resulting in one of the best FPS counts in the game. Unlike the changing room, the washing room does not require water particle systems, which significantly enhances performance. The minimum frames per second were 68 FPS, with an average of 75-80 FPS and a maximum of 86 FPS. [1]
- **Operation Room**: The operation room is the largest and most detailed scene in the game. Its design was inspired by real OR visits and information from Dräger, which provided insights into room layout, equipment, and safety features. Image 7 shows the complete VR setup of the

OR. The main key areas are:

- **Patient Area**: Contains the operation table with the patient under anesthesia.
- **Sterile Area**: High cleanliness and sterility; marked with green paper towels.
- **Old OR Tools**: Stores containers for used operating tools.
- **New OR Tools**: Stores containers with fresh, sterile tools prepared for the next surgery.
- **Equipment Room**: Space for storing expensive OR equipment like anesthesia machines or CT scanners after surgery.
- **Office**: Small area for surgeons or OR staff to do initial office work post-surgery.

In the operation room, only the surgeon and sterile OR staff are permitted within the patient and sterile areas. Non-sterile personnel must maintain a distance of at least one meter to prevent contamination. Sterile items are clearly marked with green paper towels to differentiate them from non-sterile items. Surgical tools are meticulously prepared and sorted on operation tables to ensure they are ready for use. Ceiling-mounted surgery lights provide essential illumination to the sterile area. These lights have three arms: two dedicated to lighting and one equipped with a screen that displays vital patient information. To enhance the realism, a particle system is used to simulate the visible light beams emanating from the light sources, providing a more immersive visual experience. The unsterile area encompasses everything outside the one-meter radius of the sterile area. Users can move freely in this space but must be careful to avoid contaminating the sterile zone. Tasks in this area include assisting the surgeon, preparing supplies, and monitoring the patient's vital signs. Two large flat screens are mounted on the walls to provide the surgeon with crucial information, such as camera images of the surgery, the patient's vital signs, and the current time. The power outlets in the room are color-coded for clarity: green outlets are connected to the hospital's emergency power generator and are reserved for life-sustaining devices, while orange outlets are for regular power and do not connect to the emergency generator. Additionally, there is a small office corner where the surgeon can document procedures and make post-surgical notes. This setup ensures that all necessary tasks and documentation can be efficiently handled within the operation room. To increase the realism and the overall immersion of the OR area, the following events were implemented. [1]

- **Entering of Hospital Staff**: Staff enter to pick up supplies and chat with the surgeon.
- **Adjust Monitoring**: The surgeon asks the unsterile nurse to adjust the screens due to reflections.
- **New Gloves for Surgeon**: The surgeon requests fresh gloves from the sterile nurse.
- **Adjust OR Lighting**: The surgeon asks the user to adjust the surgical lights.
- **New Surgery Tools**: Freshly sterilized tools are brought in for the next surgery.
- **Order of Next Patient**: The surgeon asks the unsterile nurse to prepare the next patient.
- **Packup Used Tools**: OR staff pack used tools into sterilization containers after surgery.
- **Office Work**: The surgeon performs post-surgical documentation in the office corner
- **Put Away Surgery Equipment**: Equipment is stored near the walls to simplify cleaning and preparation for the next surgery.

The user must pay attention to avoid obstructing the OR staff, even if they are not directly interacting with the events.

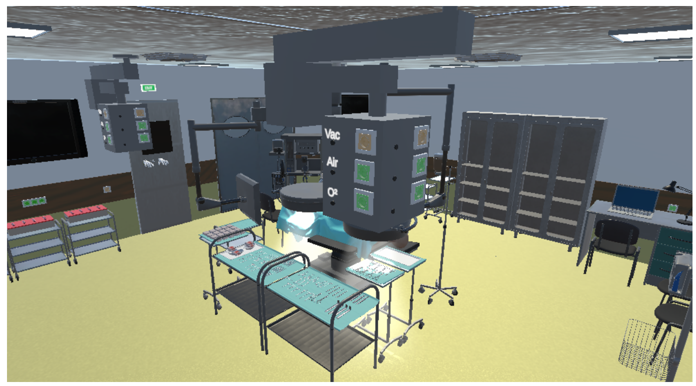

Fig. 7. Overall design and setup of the OR

III. Discussion and Conclusion

The high density of virtual assets and realistic 3D models of furniture, surgical equipment, and OR staff embedded in each scene of the simulator contributed to a deeper immersion into the game. This enabled the incorporation of events influenced by real-life scenarios observed during OR visits to various hospitals During the testing of the prototype course project, it became apparent that not all users handled the VR simulation with the same level of confidence. While some users interacted seamlessly with the VR headset and controllers, others exhibited significant insecurity and were overwhelmed by the virtual environment. This insecurity often resulted in minimal controller movement and limited interaction with the virtual environment. Given that this educational method introduces trainees to a type of technology they may not be familiar with, it is essential to have a responsible person guide users through their first VR experience. The use of hand-tracking input systems, while more intuitive, could potentially cause even greater confusion for some participants compared to VR game controllers. Therefore, a tutorial area, as implemented in this thesis, is crucial for helping users understand the game's mechanics. However, it also requires parallel assistance from a supervisor to address any questions that may arise. The Unity game development platform provided a user-friendly environment for developing the VR application. The implementation of new assets allowed for nearly limitless creativity in game and environmental design. The Unity Asset Store offered a range of free and paid assets, which further enhanced the quality of each room design within the VR game. Future development could further enhance the game's performance on standalone devices. Step-by-step, new and detailed features and events could be integrated into the simulator, covering advanced aspects of the OR environment. Players could choose between education for sterile or unsterile visitors or hospital staff, broadening the target audience. For hospitals and surgeons, a level system could be implemented to cover more complex procedures as players progress. This thesis, while challenging for a single developer, could be significantly improved with an experienced development team for virtual applications. There is substantial potential in implementing hand gesture recognition to enhance control possibilities and facilitate faster interactions between virtual objects and the user. Additionally, the content of the game could be enriched with various surgical rooms and tasks, further diversifying the educational experience. [1]

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