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Design of Collaborative WebXR for Medical Learning Platform

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The Corona-Virus Disease 2019 (COVID-19) pandemic has affected all levels of society and has had a disruptive effect on all aspects of life, including education. Additionally, it puts a strain on the ability of medical educationists to adapt to this unique situation. Clinical mentors and students from all health-related fields are considered potential carriers when considering hospital-based education. On the other hand, the current economic crisis is reviving the need for online learning opportunities and virtual education programs. Most medical schools respond to lockdown by shifting to live online or video-based learning, which is becoming increasingly popular. In the face of a pandemic, maintaining standards in medical education, keeping clinical learning on track, and minimizing assessment disruption are all difficult tasks to accomplish. This new environment requires adaptation in order to better prepare future clinicians for their roles. In this research paper, the authors design an immersive medical learning platform to emphasizes the importance of virtual education and the potential consequences of integrating the immersive experience of extended reality (XR) into medical education for the future of clinical competency learning and assessment in the healthcare education field. This platform can run on PCVR and mobile VR devices. We have designed and developed a medical simulation scenario using the considerations of medical educators or doctors to ensure that the platform we designed can provide an immersive experience to increase the effectiveness of online teaching and learning activities.

***Keywords*—COVID-19, virtual education, clinical competency learning, immersive learning, extended reality,**

I. Introduction

The Corona-Virus Disease 2019 (COVID-19) outbreak has affected all levels of society and has had a disruptive effect on all aspects of life in education. Currently, the ongoing pandemic is having a tremendous effect on medical education or other relevant medical fields [1].

This is a new challenge for educational institutions, especially health education, to adapt to all these situations because teaching and learning activities cannot be carried out attractively but must be carried out boldly. So that the implementation of knowledge transfer does not run effectively, considering that the implementation of practical activities in health education mostly requires direct practice using physical tools or teaching aids. Indeed this has a significant impact on health students to practice their medical skills. So that health workers can adapt to the current situation where there is no online practical medical learning module yet.

Therefore, a solution is needed to increase the efficiency of the teaching and learning process boldly in medicine and other relevant medical fields or other educational fields, namely by applying immersive collaborative technology using Extended reality (XR). XR is a combination of Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) technology which is a technology that can change the world in various fields such as tourism, education, retail, games, and health care to manufacturing by bridging the physical world into the digital world so that there is no limit to connecting the far to the near. Today XR is getting more and more famous because of its wide application in various fields. This technology provides better opportunities for 3D visualization in teaching and learning activities, especially in the medical field. Students and doctors can now interact virtually with the human body [2]. They can get immersive experiences with holographic images using VR headsets. XR technology is growing in popularity with the advancement of hardware and software. It helps the surgeon to operate without harm. In certain cases, this technology can train doctors or nurses to take quick action during an emergency that puts the patient's life at risk. Combining Web and XR technologies and using WebXR, which is a combination of 3D webspace and virtual representation of the user that includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) [3] [4].

This paper focuses on the initial design of a collaborative WebXR platform in the medical field that supports doctors, lecturers, or medical students to collaborate in the virtual world to perform medical simulations in real time. This paper has the following structure. Section 2 will explain the related work of this research. Section 3 will discuss conceptual design, which explains the design of the system platform used in this research. In section 4 will describe the implementation and experimental platform in this research. Section 5 will explain the conclusion and future work of this research.

II. Related Works

Based on the research motivation discussed in section 1, this paper aims to develop an XR-based medical learning platform that can connect doctors, nurses, medical lecturers, and medical students in the same virtual room to perform medical simulations. Therefore, we have conducted a literature study on several related studies.

Blaire MacIntyre and Trevor F. Smith [3] explain how the WebXR Toolkit API can be used to solve issues with immersive web development. The underlying AR and VR platforms are exposed by XRDA, which provides a uniform abstraction layer for real-time rendering and access to device interactions on these platforms. Web developers are given a simple interface to various interaction controllers and can use WebGL to create 3D graphics using device poses and timing data provided by WebXR.

Muhammad Fajrul Falah et al. [5] divided the open-source digital twin platform architecture and virtual engineering into three parts: 3D object management, virtual engineering module, and interactive visualization. 3D object management is the management of 3D object data imported from input CAD files or asset stores or reconstructed using RGBD camera-based 3D scanning. The VE module, which is at the heart of this platform, is made up of six parts: a cloud gateway, data storage, streaming data processing, machine learning services, decision-making services, and the VE interface. Simultaneously, interactive visualization manages user interaction with the platform in a virtual space. Virtual engineering can be divided into four system parts [6]. In the first section, the user creates 3D assets that will be used for user interaction in web VR and saves them to the database. In the second part, users must create a database for 3D asset storage, Web Asset Management, which will manage the assets that users upload from the 3D scanner, and a virtual environment to interact with on WebXR. If all platforms and databases are complete, users can access Web XR via Web Browser with any device and browser connected to the internet in the third part. The final step is to connect WebXR to hardware in the real world. Hardware will be connected to Web XR via MQTT Protocol and will be connected to the internet.

Mohd Javaid and Abid Haleem [2] discussed the use of VR in various health fields such as pain management treatment, orthopedics, cancer patient treatment, surgery simulation, and so on. VR can provide accurate information in the same way that it does in the real world. The purpose of this paper is to determine the capabilities of VR in the medical world, such as identifying the VR process in the medical world and providing significant benefits from VR technology for studying medical and surgical procedures. The use of virtual reality technology in the medical field can train new doctors and nurses to learn anatomy, practice surgery, and provide infection control training. Adopting VR in the medical field can be accomplished by determining the specific treatment goals and gathering background information. Various hardware and software are used to generate 3D virtual data, which results in the creation of a 3D virtual environment. The necessary medical data for virtual reality is created and identified using the best possible procedures [14]. This procedure is used to plan treatment and, ultimately, to perform surgery. VR technology can be used in psychological therapy, rehabilitation, medical research, and education to allow students to perform safe and controlled operations virtually without risk. 3D VR is critical in assisting with precise calculations on the patient's body condition, changes in vital signs, reporting various symptoms, and so on. Finally, VR can be a health facility that creates a 3D virtual environment to provide real experiences for patient treatment.

Shima Tabatabai [1] explained about the virtual education transformation that determines the priority of the medical education curriculum during the pandemic by keeping students safe, supporting each other, helping to keep education programs moving forward, with quality being a priority of the medical education system. Virtual Reality Simulation has a unique ability to make students believe that they are in a different environment. This virtual reality simulation allows medical students to learn from virtual simulations of clinical experiences just as they would in a hospital simulation.

III. Conceptual Design

In this section, we will describe our initial design of a WebXR-based medical learning platform.

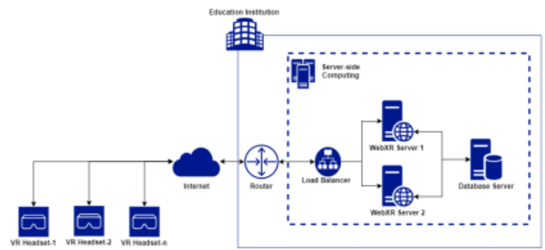

Fig. 1. Infrastructre Architecture

A. WebXR

In this research infrastructure design, users can access WebXR via the Internet. The application of the high availability concept will affect the performance of the WebXR system. The load balancer in the infrastructure design serves as a vital component of the infrastructure used to increase the performance and reliability of WebXR by distributing workloads to other servers. The use of a load balancer and two web servers can minimize failure if the system takes a long time to access or does not connect due to many users trying to access the server simultaneously and cannot handle the traffic load. So that when one web server dies, the traffic will be diverted to another web server. The database server in this research infrastructure functions to store 3D assets, user credentials, the position of the last 3D object, and scenarios.

B. Microservices and Load Balancing

Based on the problems described previously, we designed a system based on a microservice approach. A server environment is divided into several separate services connected, as shown in Fig 1. We use this approach because it has several advantages according to the system's characteristics in this research. These advantages include:

1) Microservice applications are scalable, secure, and reliable. Each service can run simultaneously without disturbing other services [7].
2) The maintenance process is easier to do considering that each service is independent.
3) Can adapt to new technological developments.

We use two servers using containers to host medical learning platform applications. Containers are packages or applications that rely on virtual isolation to run applications that can run multiple operating system kernels simultaneously without the need for virtual machines (VMs). Containers provide overall flexibility compared to using physical servers and virtual machines [8]. Containers can run directly on the Operating System (OS) without using a hypervisor. We use containers as opposed to VMs because the resource allocations for containers and VMs are different. The Virtual Machine fetches resources based on the settings specified during installation. This allocation is isolated. For example, VM 1 has a 2GB RAM setting and a 120GB HDD capacity. When VM 1 is running. VM 1 can only use a maximum of 2 GB of RAM. When VM 1 uses very little RAM usage (say only 512 MB). The remaining resources from such usage remain the property of VM 1 and cannot be used with other VMs. VMs Resource allocations are different from containers. Containers have resource allocations that can be shared directly by the Host Server itself. The container will take the resource allocation that is on the hardware according to what the container needs. This research uses Node JS as a backend system for simulating a medical learning platform. We use node.js as a server because Node.js is a JavaScript platform for general-purpose programming that allows users to build network applications quickly [9]. By leveraging JavaScript on the front-end and back-end, development can be more consistent and designed within the same system. We will use the REST API and Publish-Subscribe Gateway for data connection between clients and XR scenarios that have been created on the medical learning platform.

We use a load balancer to distribute network traffic to two WebXR Servers. The load balancer ensures that one of the servers does not take on too many requests. The load balancer software we use is Nginx Load Balancer. Many Sysadmins or DevOps Engineers have also used the advantages of Nginx as an HTTP Load Balancer to overcome web application overload [10]. In this case, Nginx acts as a load sharer. When used as an HTTP Load Balancer, Nginx will manage the load based on the specified criteria. Not only HTTP, but Nginx can also do forwarding for TCP Load Balancer and UDP Load Balancer. We use the least connection method to manage the traffic load on the WebXR medical learning platform application. The Least Connection Algorithm is a method that evaluates the shortcomings of Round Robin in reading the load of each server. The Least Connection method maintains an even distribution of traffic across all available servers [11]. If a server has a large connection load, the data requests will be distributed to the more spare servers. When a request occurs, Least Connection tries to distribute it to the server with the least number of connections. This is done to avoid overloading the server due to a large amount of traffic it receives.

C. Data Storage

All data related to scenarios and users will enter the database server. We use SQL database data storage for users and NoSQL database as data storage for XR scenarios. SQL and NoSQL have backward compatibility on the previously described system. This will make it easier for us to develop this medical learning platform. SQL is designed for relational database management systems, so it is suitable as data storage that stores user data. The main applications of SQL include writing integrated scripts, setting up and running query analysis, and adding, updating, and deleting rows and columns of data in a database [12]. As for NoSQL, we can store large volumes of unstructured XR scenario data. This process results in much better throughput, read/write speeds, and scaling out of the server horizontally [13]. The infrastructure we design supports remote networks using the internet. So that users can access the content of the medical learning platform from anywhere and anytime, this fits perfectly with our goal of creating a flexible online learning alternative.

D. Multi-cross VR Platform

Based on the infrastructure described above, we design an initial stage development design for the WebXR platform, which will be integrated with VR devices, namely Oculus Quest 1, Oculus Quest 2 and Oculus Rift S. Development is carried out on the WebXR scene, which will display WebXR visualizations. In the WebXR scene, a WebGL engine functions to render a set of 3D objects on the web. The WebGL engine will develop several services, namely physics engine, mesh, camera view, lighting, GUI, and WebXR API. At this stage, the user will be able to interact directly with the virtual model freely and perform simulations according to the simulation scenario that has been built on the medical scenario stored in the database. Users can access this service through a Web Browser that supports WebXR technology on their respective devices. Then to support collaborative and multiuser features, a gateway server will be used, which can synchronize 3D in the virtual environment that has been created. The gateway server will always publish and subscribe to all connected users for every 3D transfer in real-time [15]. With the WebXR API feature on the WebGL engine, this service can be integrated with VR / MR devices, such as Oculus, Magic Leap, and others.

IV. Platform Implementation and Discussion

The initial platform implementation of this research is to create some simple XR simulation scenarios. We developed the medical scenarios based on the medical learning modules and regularly consulted with the medical educator to ensure the simulation runs according to the medical learning modules. We also pre-configured the infrastructure of this platform by creating a container web server that was integrated with a simple XR simulation.

A. Platform Environment

The server devices we use has the specifications described in table I.

TABLE I
SERVER SPECIFICATION

Hardware	Specification
CPU	Intel(R) Xeon(R) Gold 5218 CP
GPU	NVIDIA Quadro RTX 6000
RAM	128 GB (4 x 32) DDR4-2933
Disk	5 x 500 GB SSD
Virtualization Platform	VMWare VSphere 7
Interconnection	WAN: 150Mbps LAN: 2Gbps

B. Collaborative Anatomy Scenario

The anatomical scenario has several features. Users can grab the human organs and collaborate in the same virtual environment. When user A grabs and moves an object, then the object's movement is synchronized to all users who are connected to the same environment, as shown in Fig 2. So that other users can see the movement of the object. Users can also talk to each other using the mic on their VR headset in real-time.

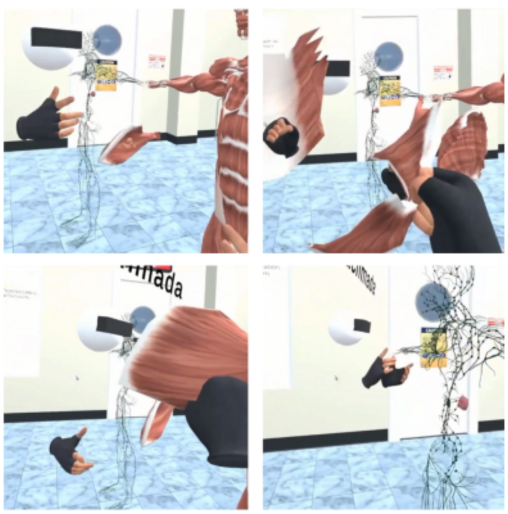

Fig. 2. Collaborative Anatomy Simulation

C. Child Birth Surgery Scenario

We created a task manager script to manage tasks in a simulated child birth scenario. As seen in Fig 3, the instructions for each task will always be visible in front of the user and always follow the user's position or rotation, and it will help the user carry out each task in the scenario. The user can also follow the hint by looking at the highlighted object, making it easier for the user to learn medical treatment in a virtual environment.

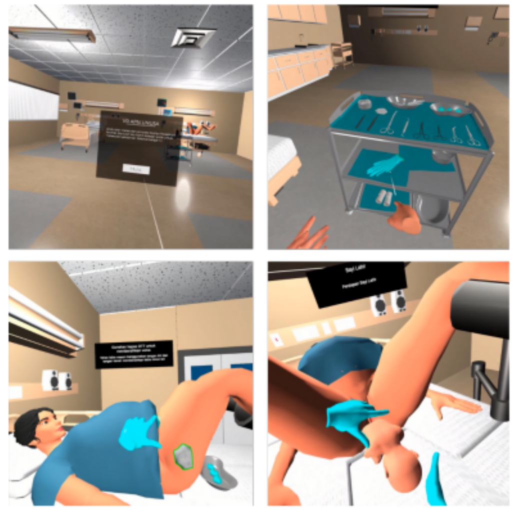

Fig. 3. Child Birth Simulation Simulation

D. Personal Protective Equipment (PPE) Scenario

We also developed a simple scenario about personal protective equipment (PPE), which consists of 4 levels: level A, level B, level C, and level D. The user will be directed to choose the correct equipment based on the level, as shown in Fig 4. In this PPE scenario, the task manager also has a big influence on the simulation flow. The task manager manages a set of equipment contained in a virtual environment. When the user selects equipment, the task manager will immediately match it with the correct equipment. If the equipment is correct, then the user's score will increase, and if the equipment is incorrect, the user's score will decrease. This PPE scenario is very useful for students to have basic medical treatment skills.

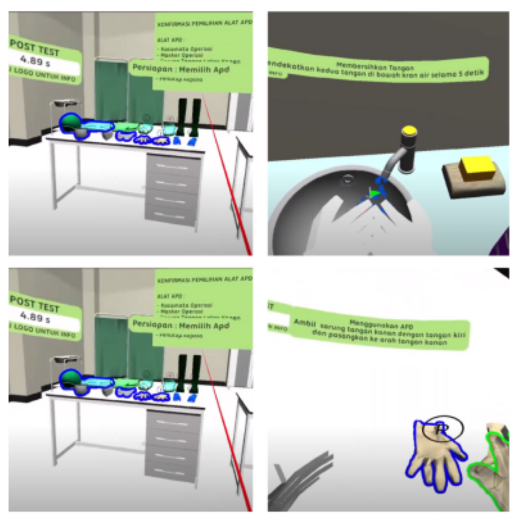

Fig. 4. PPE Simulation

E. Initial User Experimental

We also involve doctors and medical students in implementing this initial stage to try out simple simulations that have been made, as shown in Fig 5 and Fig 6. The use of XR content developed is an alternative medium for distance learning during the current pandemic. It does not rule out the possibility that it will continue to be used in the future when the pandemic is over. Because of the enormous potential that XR has.

Fig. 5. User Testing (1)

Fig. 6. User Testing (2)

From several experimental platforms that have been carried out, we see that the platform has been successfully implemented on several VR devices, namely the Oculus Quest 2 and Oculus Rift S. Users have also succeeded in conducting virtual simulations remotely online, thus proving that this platform has potential as alternative online learning. Based on this experiment result, the stakeholders can learn medical simulations without worrying about certain risks. However, there are still some problems to be solved. The simulation loading time for some users is still very slow, so 3D and network optimization are needed to overcome this. The animation in the simulation is still rough, so it still does not provide a more immersive experience. Therefore, this platform still needs much development to provide an immersive experience, and users can practice medical treatment like in the real world.

V. Conclusion

This research aims to design and implement a medical learning platform based on immersive technology, namely extended reality (XR). With this developed platform, the transfer of knowledge between medical educators and medical students will be more effective because the knowledge gained is directly applied to solve medical problems. This research has succeeded in creating an immersive platform that brings together doctors, lecturers, and students in the same virtual environment to collaborate in a virtual world and perform medical simulations in real-time. In our future work, we will measure the effectiveness of our immersive medical platform and conduct user testing using a questionnaire and the PIESCES framework. We will measure the level of understanding of medical students before and after using the platform and compare the measurement results with the test results using the traditional method. We will also plan to develop the design of this platform further with some optimizations in terms of performance and an immersive approach and create several complete scenarios to support online learning in medical education during the pandemic or in the future.

VI. Acknowledgement

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