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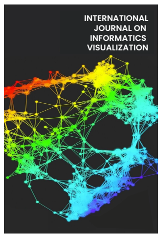

Implementation of Virtual Fiber Optic Module Using Virtual Reality for Vocational Telecommunications Students

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***Abstract*— Virtual Reality (VR) technology is a computer technology capable of replicating a real environment into an immersive world. VR is also capable of simulating the user's physical condition so that they are able to interact. In the world of education as a support for educational activities, especially for vocational high school students who are more dominant in practicum, this study aims to show the results of the early stages of implementing Fiber Optic (FO) learning support modules. The module development process is carried out in several stages: scenario preparation, 3D asset development with low poly optimization, scenario integration with 3D assets, triggering every interaction, multiuser settings, and implementation. To build a good VR Fiber Optic application, measurements using OVR metrics are carried out. This measurement aims to determine the reliability of the application that affects the user experience. In the OVR metric measurement, the highest FPS value is 43, and the lowest FPS value is 27. The value obtained is good enough to run VR applications with low poly asset composition. Measurement of the level of user satisfaction is also carried out by using the PIECES Framework. From the measurement results, the value of each variable is in the range of 3.4 - 4.91, which means that users are satisfied with the VR FO application as a virtual learning support module. This research shows that Virtual Reality technology can provide an overview of practicum that is easy to access and not limited by space and material.**

***Keywords*— Virtual reality; fiber optic; low poly; multiuser.**

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I. INTRODUCTION

Currently, the era of Immersive Technology has developed rapidly, and many researchers and industries are developing AR/VR/MR fields [1]. However, what is still popular that the public can reach is Augmented Reality (AR) and Virtual Reality (VR) technology. Virtual Reality is a computer technology that can replicate real or imaginary environments and can simulate the user's physical condition so that they can interact [2], [3]. Various devices are used to be able to use Virtual Reality technology, ranging from Head Mounted-Display devices, input devices, software, and content to composite devices. Knowledge of Virtual Reality technology can be obtained from the Internet. There is no denying that the use of Virtual Reality (VR) technology can help to simulate a condition so that users can learn from VR simulations that have a big impact on society, including in the field of education [4], [5]. Another benefit of VR technology is efficiency and material savings because using VR is not limited in time and material [6]–[8].

The nature of VR which has unlimited content for use, can of course be used as a consideration for the construction of a virtual learning module due to various limitations. The existence of various limitations on practicum can reduce the skills of students [9]–[11]. These limitations include the limitations of modules, practicum equipment, tools, and materials. In this research, the construction of a virtual Fiber Optic (FO) module based on virtual reality is carried out to help telecommunications students to be able to learn the stages of connecting fiber cables through the media displayed on the VR headset. Also, students can interact with each other through the collaboration feature.

Several research on immersive technology in the field of education such as the application of AR and VR. Research conducted by Sukaridhoto et al. [12] build a virtual lab for chemistry practicum. This study provides steps and practical rules based on a set scenario. There are several interactions added such as, the user can hold a microscope, test tube, Erlenmeyer flask, funnel, titration tool, and dropper pipette. There are 4 types of interaction in applying it: user movements, holding objects, turning knobs, and touching buttons or areas. However, this study still uses single-person interaction and does not provide collaboration between users.

The previous research conducted by Ilham Achmad Al Hafidz et al. explained the impact of COVID-19 in various aspects, especially in the world of education, one of which is medical education to adapt to this unique situation, all learning activities must be done online or video-based, which becomes increasingly popular [13]. This is intended to maintain standards in medical education, maintain clinical learning and minimize impaired judgment. This study designed an immersive medical learning platform to emphasize the importance of virtual education and the potential consequences of integrating immersive experiences of extended reality (XR) into future medical education [14]. This platform can run on PC VR and mobile VR devices by designing and developing medical simulation scenarios to provide experiences to increase the effectiveness of online teaching and learning activities.

The previous research conducted by Haz et al. [15] explained the impact of using VR Simulation in Company Training on the users. Where first real-life practical training will be dangerous and only using basic video instruction or paper instruction is not guaranteed that all participants understand the whole concept. Then, by using VR Simulation to place the first concept of understanding before doing their first real-world practical training, the participant already has an overview of what they will be doing in the field.

Another research was also conducted by Fajrianti et al. [16] explained that Augmented Intelligence technology can facilitate human work, especially in the field of education. Because the all-virtual learning process raises new challenges, especially in clinical practice, which requires open modules as practical guidelines by maintaining the impression of interactive learning, for the application of Augmented Reality technology to build human anatomy modules using smartphones that can be run inside and outside the room without any space and time. The platform can run on Android and iOS which is built on the AR Foundation framework to work across platforms. In this module, you have to follow the rules of the anatomical atlas, which have labels on each part of the human anatomical body and also obtain a license from an anatomy teaching doctor. This study also validates the satisfaction and importance of the platform through the measurement of the PIECES framework for each user who uses it [17].

The development of this system is divided into four parts: physical engine development, interaction, multiuser, and integration. Physical engine development and interaction depend on the scenario being built. The scenarios that are built include fiber optic preparation and fiber optic splicing. In collaborative interaction, the Photon server is used as a service provider for student collaboration when running Fiber Optic virtual practices.

II. Materials and Methods

A. *System Design of Virtual Reality in Fiber Optic*

This research develops VR-based virtual modules for telecommunications students to provide fiber optic learning modules. At this stage, the research system design is designed and carried out in several stages of work to achieve good results at each stage of the work. Referring to the problems that have been described previously, this section describes the research system, which is divided into 4 processes, as shown in Fig.1.

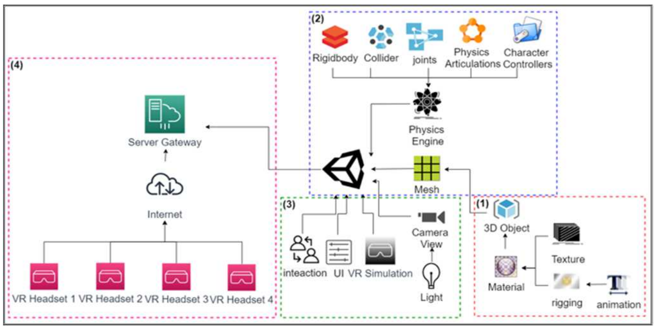
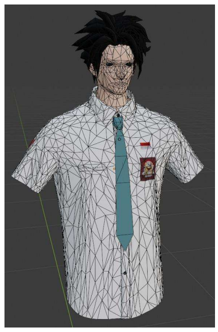
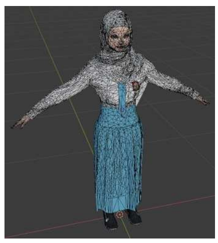


Fig. 1 Fiber Optic Virtual Module System Design

Part 1 is the construction of 3D Fiber Optic assets. Optimization needs to be done in asset development before assets are integrated into the scenario. The assets built consist of avatars, main assets, and supporting assets. Table 1. is an example of some of the assets used. Every 3D asset has been optimized from High poly to Low poly to run the system properly and avoid bugs when running the FO virtual module application [18].

TABLE I
3D Asset with Optimized Poly Count Values

Fiber Optic Equipment 3D asset	**Poly Count**	**3D Topology**
Man Torso	47.587	
Woman Torso	186.194	

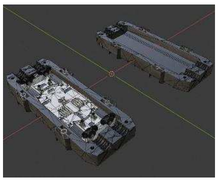
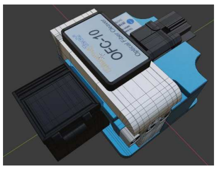
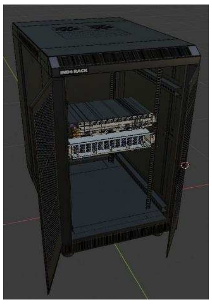
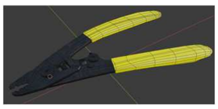
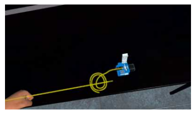
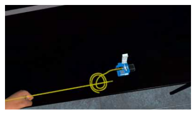
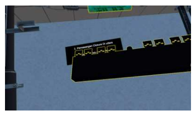
OTDR	75.578	
Closure	54.616	
Cleaver	74.900	
INDORACK	258.498	
Splicer	53.076	
Stripper	73.702	

Table 1 shows the 3D assets used with poly values that are still acceptable for distribution to Quest 1 devices. Every asset that is entered into the FO module development scene has gone through the poly reduction stage. After asset development and optimization have been carried out, building a physics engine for each 3D asset and FO virtual laboratory environment is necessary.

B. Virtual Reality in Fiber Optic Scenarios

In the development of the VR FO application, it is not only necessary to optimize the required 3D assets, but also to adjust the built scenario. The practicum scenario applied starts from the preparation of tools to virtual fiber cable installation. Table 2. is an example of a scenario that is applied considering interactions that resemble a real environment.

TABLE II
FIBER OPTIC SCENARIOS AND EXAMPLES OF THE INTERACTION

Scenarios	**Interactions**	**VR Environment**
Preparation of cables and covers.	The user takes the bolts and plastic pipes and places them on the highlight of the bottom cover.	
Installation cable and strain relief.	User-readable strain relief installation instructions on the HUD display.	
Installation of insulation at the end of the cable.	The user grabs the insulation and brings it closer to the highlight end of the cable	
Grounding installation	The user brings the grounding closer to the highlight in the closure	
Fiber optic splicing.	The user grabs the optical fiber to clean it using a tissue	
Cutting wires with a cleaver, then the user brings the cable closer to the cleaver to cut.	the user brings the cable closer to the cleaver to cut	
Fiber optic splicing with a splicer.	The user opens the splicer by approaching the highlight, then the animation of opening the splicer will be active.	
Closure Installation in the Air	The user puts the closure in the air in the highlight box	

In the steps for splicing optical fiber, validation has been carried out on the practicum books used by vocational students. The shape and size of the assets built have followed the reference standard of the original object.

C. Physics Engine on VR FO Implementation

The second step is the development of the Physical Engine. A physic Engine is designed to display/simulate various types of phenomena of physical objects in nature [6], [19]. There are some main Physic Engine concepts used in this research [20], namely:

1) Colliders are used to configure collisions between GameObjects in game development software, there are 4 types of colliders, namely Box colliders, Sphere colliders, Capsule colliders, and Mesh colliders. The determination of the collider is adjusted to the object. In the development of the FO module, it is not recommended to use a Mesh Collider because the primitive mesh shape is close to the original shape which causes objects in the FPS to get low values.

2) Rigidbody: used to apply gravity to the object, it is necessary to add a rigid body component, by activating "Is Kinematic" as a trigger.

3) Joints: in physics engines, the constraint between two objects are featured. In this study, the Hinge Joint is used for the PAZ ODC door and the INDORACK door with the condition that there is a collider. When there is a collision, the force generated is like a door hinge in general.

4) Physics articulations: used to provide realistic physics behavior for non-gaming industrial applications involving joints. Physics articulations used are fixed joints on the Hand Collision object by adding a connected body to the rigid body (CenterEyeAnchor) and placing a box on the body of the Hand Collision.

5) Character Controllers: so that the body does not fall to the floor or penetrate the wall the object used is the PlayerController. in the character controller section set the lope limit, step offset, center, radius, and height as needed.

D. Interaction Section

In the Virtual Reality Fiber Optic simulation, there is an interaction section. the user can interact with the object so that its activities such as installation, installation, and connection to the FO occur. Fig. 2. is an example of user interaction with the installation of a plastic pipe that is placed on the bottom cover. Can be found in highlights that are used as instructions for placing the object to be placed.

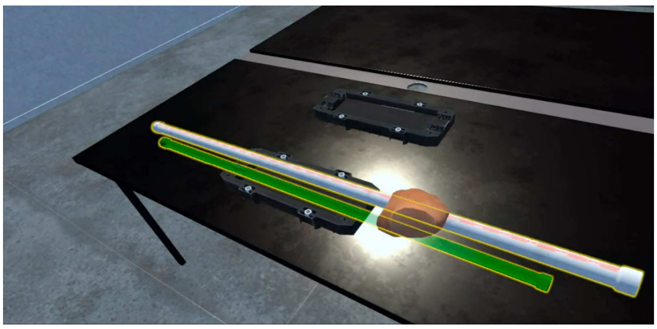


Fig. 2 User Interaction Using Grabbable Trigger

To make an object have a trigger so that it can be held by the user, it is necessary to add three kinds of triggers that are tailored to the needs. Network Grabable is used to make it easier for users to pick up or move objects [21]. The Trigger Task can trigger the object to be called.

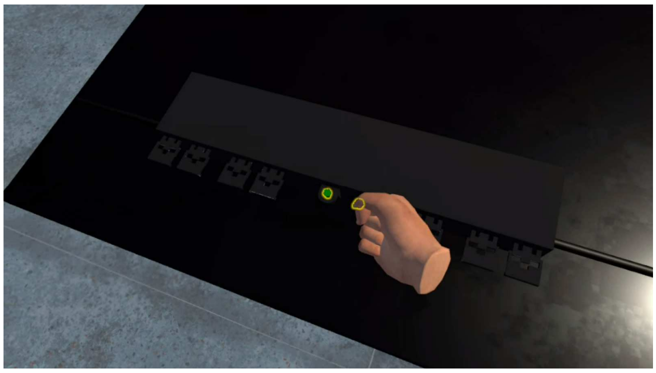


Fig. 3 User Interaction Using Box Collider Trigger

Fig. 3 shows the application of the Box Collider trigger. The application of these triggers is used to provide action functions both from the user and from other objects in the scene. In the figure above are the bolts on the closure set installed in the air. The step taken is to close the lid and then take it and put it on the available highlights.

E. Multiuser Interaction

Section 4 is a system design that focuses on multiple users. This research uses an open-source platform that can be accessed online, namely Photon Unity Networking (PUN) as a gateway server [22], [23]. The function of this platform is to provide a server to allow users to collaborate in a virtual environment in real time. The gateway server used in this research is using publish-subscribe technology [24]. The use of servers in multiuser is used to store messages and send messages in real time with high availability and consistent performance at a large scale. PUN has two main concepts, namely lobby, and room. Connecting to the lobby is a process for connecting a device to a photon server. While the process for connecting to available rooms and interacting with other users can be called connecting to rooms. Fig. 4. is the stage of connecting one user to another through the Photon Unity Network.

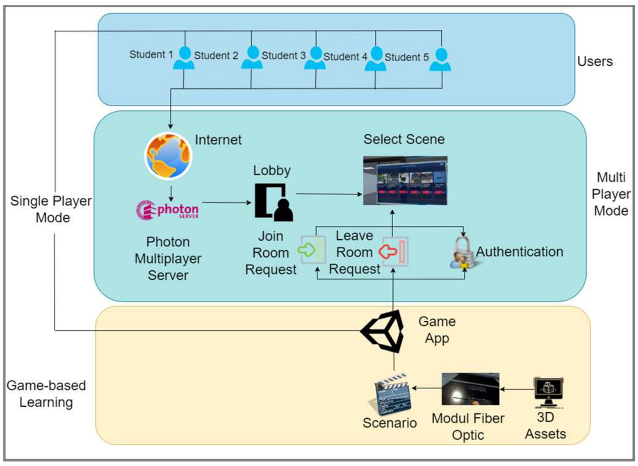


Fig. 4 Multiplayer Fiber Optic System Design

With this multiuser feature, it is easier for users to interact with each other via voice chat conference. This feature provides collaboration with a maximum number of 20 users in 1 room.

III. Results and Discussion

In this research to determine the performance of a scenario and the assets that have been built can be measured through several measurements, namely device performance and user experience based on satisfaction and interests.

A. Device Performance Monitor

To run the VR FO scenario well and smoothly with a total amount of poly counts <1,000,000, this study uses the Oculus Quest 2 device as a tool to run virtual reality FO applications [22]. Before the application is distributed to users, it is necessary to optimize and check scenarios by considering the workload of the device. Table 3. is a specification of the device used.

TABLE III
DEVICE SPECIFICATION

No	Description	Specification
1	Processor	Qualcomm Snapdragon XR2
2	RAM	6 GB
3	ROM	64 GB
4	Sensor	6 degrees of freedom head and hand tracking
5	Display resolution	1832 x 1600 @eacheye
6	FPS	72 Hz

To analyze the workload of the VR FO scenario, the OVR Toolkit is used to measure the metric values on Quests that have installed VR scenarios [25], [26]. The experimental parameters used in this Fiber Optic VR module application are using the VR OVR Toolkit tools which in real-time read metric values such as FPS (Frame Per Second), CPU level (processor), GPU level (integrated graphics chip), Display Refresh Rate (refresh rate/frequency), Foveation level (FOV=FFR in application), Eye Buffer Width (texture resolution across the width), Eye Buffer Height (texture resolution at height). Table 4. is the result of the OVR Metric measurement.

TABLE IV
PERFORMANCE TESTING USING OVR METRIC

Work Steps	Parameter						
	FOV	GPUL	CPUL	FPS	DDR	EB W	EB H
Cable and closure preparation	0	4	5	34	72	1216	1344
Cable laying and strain relief	0	4	5	32	72	1216	1344
Fiber Optic Preparation	0	4	5	43	72	1216	1344
Fiber optic splicing	0	4	5	47	72	1216	1344
Closure	0	4	5	34	72	1216	1344
Closure Installation	0	4	5	27	72	1216	1344

From the table above, it can be observed that the FPS value that is read is from the appearance of the environment seen by the user, while the environment that the user reverses will not be read. This is to reduce the workload and increase user comfort. FPS displays different results in each scenario where the highest value is 43 FPS and the lowest has 27 FPS. The higher the FPS in the observed environment, the smoother it is. In oculus quest the maximum FPS value is 72 FPS, this depends on the object used.

B. User Experience Based on Satisfaction

To determine the level of user satisfaction with the VR FO application, it is necessary to measure using the PIECES framework which includes Performance, Information and Data, Economics, Control and Security, Efficiency, and Service [27], [28]. Measurement of the level of satisfaction is carried out through a questionnaire given to users, namely 30 students of the vocational school after using the VR FO application. Fig. 5. is an example of when students use VR to do a practical fiber cable connection.

Fig. 5 Students Implement Fiber Optic Connection Practices Using VR Headset

The number of questions on the questionnaire is adjusted to the demographics of the users. Table 5. is the number of questions/statements in each variable.

TABLE V
PIECES FRAMEWORK VARIABLE

No	Variable	Number of Questions
1	Performance	10
2	Information and Data	10
3	Control and Security	6
4	Economics	8
5	Efficiency	6
6	Service	8

Determining the satisfaction scale using the model provided by Kaplan and Norton [29]such that the range value is achieved as shown in Table 6.

TABLE VI
LEVEL OF USER SATISFACTION

Satisfaction Level	Abbreviation	Scores	Value Range
Very Dissatisfied	VD	1	1 - 1.79
Not Satisfied	NS	2	1.8 - 2.59
Doubt	D	3	2.6 - 3.39
Satisfied	S	4	3.4 – 4.91
Very Satisfied	VS	5	4.92 - 5

The variables in the PIECES Framework are provided in Table 5, and TABLE 6 reveals the number of questions used to measure the respective satisfaction scales. The equation shows the Likert approach formula used to determine the level of satisfaction from Equation (1) in the VR FO application [30].

$$Ave = \frac{TSQ}{NQ} \quad (1)$$

Where:
Ave : Average Satisfaction/ Importance
TSQ: Total score of the Questionnaire
NQ : Number of Questionnaires

TABLE VII
RESULT OF PIECES FRAMEWORK SATISFACTION PREDICATE

Variable	Satisfaction Predicate Value
Performance	4.22
Information	4.12
Economy	4.28
Control and Security	4.18
Efficiency	4.25
Service	4.19

Based on the results of calculations on each variable Performance, Information, Economy, Control, Efficiency, and Service, the overall satisfaction level is in the range of values of 3.4 - 4.91, it is concluded that the level of user satisfaction with the VR application FO module gets a positive response, namely, the user is satisfied with the existence of the FO module. Virtual Reality-based Fiber Optic learning module.

IV. Conclusion

This study presents an implementation of virtual reality technology in the construction of a fiber optic installation practice module for vocational school students. With this module, students can learn how to install fiber optic cables from the preparation stage, cable cutting, and fiber splicing, until the installation process has been presented in virtual reality applications. Students can do a practical lesson in a virtual world and collaborate with friends and teachers through voice chat conferences. To be able to build this module in real-world conditions, scenario surgery needs to be done, 3D asset development with low poly provisions, scenario integration with assets, triggering each object and environment, and preparing the server for multiuser. The entire development of this practicum module has been adapted to the telecommunications book that has gone through the validation stage by the teacher.

The practicum module that has been built is measuring device performance, this aims to determine the level of device reliability in running applications before being distributed to students. Measurement of device performance using OVR metric with a value of maximum FPS value is 43, while the minimum FPS value is 27. The calculated value is sufficient for running VR apps with low poly asset composition. The PIECES Framework is also used to measure the degree of customer satisfaction. According to the measurement findings, the range of values for each variable is between 3.4 and 4.91, indicating that users are satisfied with the VR FO as a virtual learning assistance module. This study demonstrates that virtual reality technology may give an overview of practice that is easily accessible and unrestricted by physical constraints.

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