

Second Screen Support for Teaching Materials Using Stereoscopic Representation

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ABSTRACT

In recent years, Virtual Reality (VR) technology has been utilized in the field of education, and VR teaching materials using head-mounted displays (HMDs) have been developed. In this research, a VR teaching system using only smartphones is developed so that more people can experience VR teaching materials. The system supports second screen so that the VR experience can be shared simultaneously on multiple devices.

1 INTRODUCTION

Virtual Reality (VR) is a technology that allows users to perceive an artificial environment created by a computer as virtually real by stimulating their sense organs, such as their visual and auditory senses. Technologies that increase, reduce, or change the information presented by a computer to objects in the real world that can be directly perceived by humans are called Augmented Reality (AR) and Mixed Reality (MR). Examples of fields where VR, AR, and MR are used include medicine, health and welfare, education, gaming, aerospace, transportation, tourism, and commerce [1]. Particularly in the medical field, virtual surgery has entered the realm of practical use. Practical applications are also being considered in the field of education, and VR simulation has already been shown to be effective in the field [2]. Specifically, the aim of using VR in education is to enable remote users to simultaneously experience and participate in classes and experiments. In this research, a VR teaching material created using smartphones is made compatible with second screen such that VR experiences can be used in classes. second screen in this study refers to a system that enables multiple terminals to view the VR experience in virtual space [3].

In our research group, a VR educational material has been developed using Unity, an integrated development environment that enables the creation of 3D projects on various platforms, and head-mounted displays (HMDs). A VR educational material as shown in Fig. 1 will be developed. It operates using smartphones, without using controllers or other peripheral devices as electronic equipment. Specifically, the execution platform of the VR teaching material is iOS. The iPhone is used such that the operation feels as similar as possible to an HMD [4]. By allowing each user to use their device, the sharing of devices with others is eliminated and the risk of disease transmission, such as the novel coronavirus infection, is minimized [5]. Furthermore, the VR teaching material has

been improved by introducing a multiplayer platform called Photon, which allows multiple devices to simultaneously share the VR experience [6]. Finally, the developed VR material will be distributed as an application so that users in distant locations can also participate in the VR experience.



Fig. 1 The image of the VR teaching material.

2 THE PROPOSED METHOD

In this chapter, the VR teaching material handled in this study and the method of dealing with second screen are described.

2.1 An Overview of the VR Material

The VR educational material used in this study was developed as an iOS-compatible application using Unity as the integrated development environment and the iPhone as the communication device and display. Figure 2 shows some of the questions implemented in the teaching material. The pentagon represents a boat, and the green and red dots indicate the starting and destination points of the boat, respectively.

There is a boat that travels in still water at 2 m/s. When the river flow is 1 m/s, in what direction should the bow be turned to travel the shortest distance to the opposite shore?

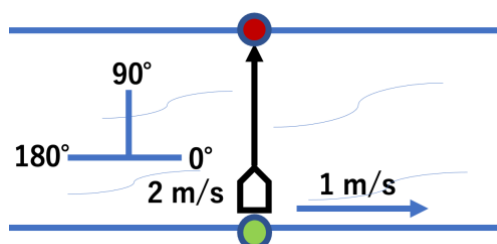


Fig. 2 The questions to be implemented.

Hand tracking [7] is implemented using the Media Pipe [8] system provided by Google Inc.; the hand recognized by the iPhone's rear camera can be handled as a substitute for a controller. As shown in Fig. 3, a virtual hand object is displayed in the VR space, and movements of touching or holding the object can be reflected in the virtual space.



Fig. 3 The virtual hands to be created.

A user interface (UI) is also developed, as shown in Fig. 4, which can be manipulated when virtual hand objects are touched. The UI allows the user to manipulate objects and change values in the VR teaching material using a slider, as shown in Fig. 5. The user selects the problem to be experienced; when the user selects the problem to provide the angle, the slider is used to change the angle of the boat, and the launch button is used to launch the boat.

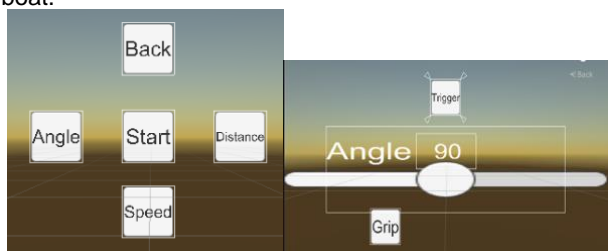


Fig. 4 The UI to be created.



Fig. 5 Numerical adjustment with the slider.

Other features include incorporating elements of shooting games to help experience the laws of physics, and displaying a results screen to determine whether the calculation results were correct or not.

2.2 Support for second screen

Multiplayer design is implemented by combining Unity and the multiplayer platform Photon so that the experience in the VR material can be shared by multiple terminals to realize second screen as shown in Fig. 6 [9]. Photon has a package called Photon Unity Networking for real-time multiplayer games on Unity, enabling the sharing of virtual space among multiple terminals.

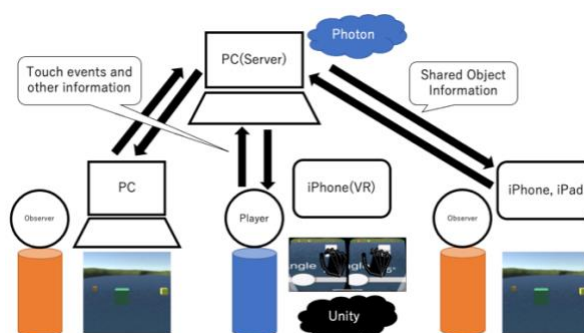


Fig. 6 The schematic diagram of second screen.

The Lobby and Rooms exist in Photon, as shown in Fig. 7, and can be created and accessed by scripts. When different terminals enter the same Room, the behavior of the configured objects is shared and reflected in each terminal.

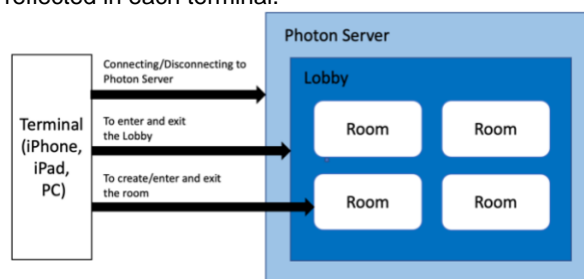


Fig. 7 The structure of communication by Photon.

Photon has three types of services: Photon Realtime, Photon Server, and Photon Chat. In this study, Photon Server was used to allow terminals to communicate with each other on a local network for security reasons. Photon Server can use a Windows-based PC as a server, enabling communication between terminals as shown in Fig. 8. In this study, an iPhone and other terminals used for VR experiences are initially set as the Player, and the macOS PC and other terminals used to observe VR experiences are set as the Observer. A PC with a server needs to be temporarily connected to the Internet, but the other terminals do not need to be connected to the Internet because they only need to be connected to the same network. Although this measure causes restrictions on the range of network communication, not requiring an Internet connection reduces the risk of attacks by third parties and information leaks. Meanwhile, users in distant locations can also communicate via the Internet via an application in the App Store [10].

Since Photon allows users to set objects whose movements they wish to share, the movement of the VR space itself and objects fixed in the space are not shared, but the movements of the boats generated by the Players are shared, which are observed by a camera generated by the Observer. To support multiple platforms, the Player and Observer can be switched on any terminal.

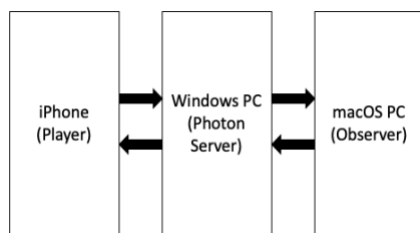


Fig. 8 Server communication.

3 RESULTS AND DISCUSSION

3.1 The Results of VR Material Creation

First, a VR teaching material was created with the configuration shown in Fig. 9, using hand tracking with an iPhone's rear camera to allow users to move objects and change values in the virtual space by touching the UI with virtual hands. As a result, educational materials were created to enable a one-person VR experience using a smartphone.

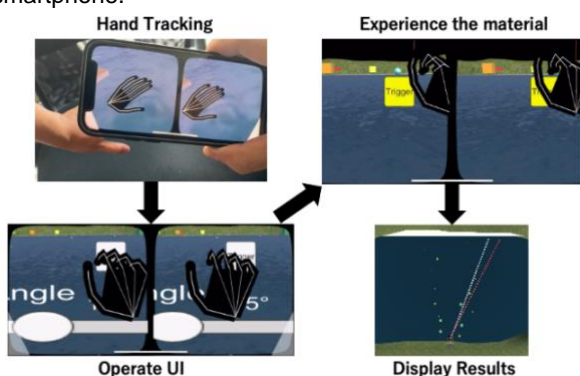


Fig. 9 The created VR teaching material.

3.2 The Results for second screen Support

Next, second screen support was implemented, using a Windows PC with Photon Server as the server and enabling local network communication by specifying the local IP address of the server from Unity. When a public IP address is specified, Internet communication is also possible. When the application is launched, a script creates a new Lobby and Room in the server, enabling the user to experience VR in the Room. If other terminals start the application at the same time, they will automatically enter the already existing Room. This means that the same VR experience can be shared by multiple terminals. The Player and Observer can enter the same VR space from the viewpoints shown in Fig. 10 and Fig. 11, respectively, and can watch the synchronized boat movements.



Fig. 10 The Player's viewpoint.

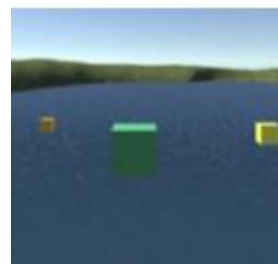


Fig. 11 The Observer's viewpoint.

3.3 The Result of Multiple Terminal Connections

Furthermore, a menu screen was created so that the Player and Observer can be switched depending on the terminal. This menu screen is displayed when the educational material is launched. To enable the selection of the Player and Observer regardless of the type of terminal used, it is not feasible to distinguish between the operations by identifying the type of terminal. Therefore, when a special camera for the boat and VR experience must exist in the VR space in advance, as in this research, the viewpoints of the Player and Observer are the same. We can solve this problem by generating a new camera independently on the Observer side, without using Photon. As shown in Fig. 12, the terminal that selects the Player is redirected to a screen where the user can experience VR with a virtual hand, and the terminal that selects the Observer is redirected to a screen where the user can view the boat's movement from a bird's eye view. The Observer screen is displayed 5 seconds after the Player enters the VR space. Although the Observer does not allow the use of virtual hands, the camera viewpoint can be moved with the arrow keys on the keyboard on a PC and with a flick of the finger on an iPhone.

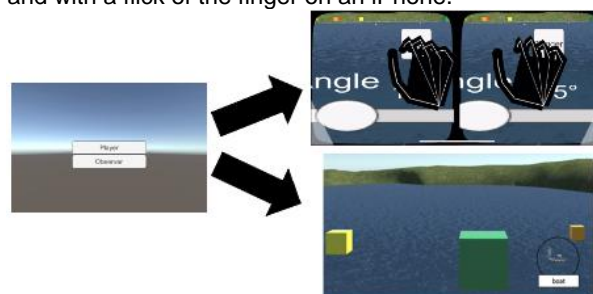


Fig. 12 Menu screen and transitions.

Since it is no longer necessary to consider the type of terminal used, various terminals can now play the role of the Player and Observer. For example, an iPhone can be used as a Player and a PC as an Observer, or an iPad as a Player and an iPhone as an Observer. As shown in Fig. 13, a total of three terminals can be connected and operated simultaneously with an iPhone as a Player, a PC, and an iPad as an Observer.



Fig. 13 Simultaneous connections on an iPhone, a PC, and an iPad.

3.4 Discussion

VR educational material was developed as a smartphone application, and was made compatible with second screen. The development of this study was conducted with oral informed consent and with input from the people in the laboratory. Currently, the VR educational material created is being tested for a limited release on the App Store such that online experience sessions can be held instead of face-to-face sessions. In this study, the experiment was repeated using high-speed and stable local network communication. However, it was discovered that there is a possibility that problems, such as operation delays and sharing failures, may occur when more users are connected at the same time or when users in distant locations communicate with each other via the Internet. Although the concerns about various problems can be resolved to some extent by reducing the number of objects and the data that share operations, it is necessary to conduct the experiment to the largest extent possible since the goal is to use the system in school classes and experiments. In addition, it is necessary to teach the users how to operate VR materials, such as mounting the terminal in a state that enables VR experience, projecting their hands on the camera, and touching objects with their virtual hands, but currently, this can only be explained orally or in writing. In addition, the difference between the Player and Observer and the order of communication should also be communicated, thus it is necessary to consider how to provide users with easy-to-understand explanations through experiments. One possible solution is to provide a tutorial with diagrams in the teaching materials or an easy-to-understand display that allows users to operate the system more intuitively.

4 CONCLUSION AND FUTURE WORK

In this study, a system of VR teaching materials developed to be operated using a smartphone was adapted to second screen to enable more people to easily access VR teaching materials. As a result, applications were created using hand tracking and Photon.

Prospects include enabling not only the Player but also the Observer to experience VR, having multiple users try out the application, and conducting a questionnaire survey to determine which functions should be added or removed and how comfortable the application is to use.

Ultimately, we would like to continue the development of practical educational materials that can be introduced into school classes and experiments.

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