Implementation of Interactive E-learning System Based on Virtual Reality

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***Abstract*—VR (Virtual Reality)-based e-learning applications have become an important part of the educational program in kindergarten as well as in the National Children's Library (NLCY), in Republic of Korea. As kindergarten pupils and their teachers use the VR-based e-learning system, they can be more visually aware of ongoing course materials and more intuitively aware of getting quick response from event handling on screens. However, the existing VR-based e-learning system consists of complex equipment such as a large screen and beam projector to show the actual scene in 3D, more than two PCs, a forward camera to detect the pupils' movement, and a rear camera to capture the pupils' image. In this paper, we introduce a VR-based interactive e-learning system, which is implemented to enable kindergarten pupils to quickly experience a better sense of reality and immersion in a virtual reality environment without regard to the floor space. Applying technologies such as RTSP (Real Time Streaming Protocol) to the VR-based interactive e-learning system allows users to display the same view on different remote display devices, allowing separate users to share interactive events for collaboration.**

Keywords-e-learning; virtual reality; user interaction.

I. INTRODUCTION

The popularity of VR (Virtual Reality) application systems as e-learning resources has increased significantly. Many e-learning applications have focused on developing online course materials, but VR-based e-learning applications [1][2] mainly have focused on making course materials interactively. VR-based e-learning applications are becoming a key part of the educational program in NLCY (National Library for Children and Young Adults) [3], Republic of Korea. The people who support the library are trying to expand its use of VR-based e-learning system nationwide. In particular, the e-learning system using VR technologies can enhance attention and engagement of kindergarten pupils who have short attention spans [4]. As kindergarten pupils and their teachers use the VR-based e-learning system, they can be more visually aware of ongoing course materials and more intuitively aware of getting quick response from event handling on screens. However, the existing VR-based e-learning system [1][3] consists of complex equipment such as a large screen and beam projector to show the actual scene in 3D, more than two PCs, a forward camera to detect the pupils' movement, and a rear camera to capture the pupils' image. As a result, the process of installing the system becomes complicated, and once the system is installed in a specific place, it becomes impossible to move it to another place. It also requires an isolated and large room to install and operate the system. It is necessary to develop a system to increase the learning efficiency by giving the kindergarten pupils a feeling of immersion in a certain virtual space or situation and providing a vivid virtual experience. Also, it is necessary to develop technologies that enable virtual experiential learning classes held in one kindergarten to be shared with other kindergartens in remote locations in real time, to enable collaborative learning. In terms of the kindergarten administration, the introduction of an interactive virtual experiential learning system, which features a low cost and simple system installation process, is preferable to the existing system.

The rest of this paper is organized as follows. Section II describes the functional components of the proposed system and Section III explains the process of evaluation in terms of the system performance. Finally, in Section IV, we present the conclusions and our future work.

II. SYSTEM DESCRIPTION

The environment of the VR-based e-learning system installed in the NLCY [3] for the purpose of running interactive storytelling programs for kindergarten pupils is shown in Figure 1. This system projects pupils into the background of various fairy tales in VR through large screens and it promotes reading by stimulating the interest in books. The VR-based interactive e-learning system developed in this study is shown in Figure 2.

Figure 1. Interactive storytelling program in NLCY

As an output of the previous project [5], the VR-based e-learning system installed at the NLCY had a very positive effect on kindergarten pupils in that they improved attention, comprehension and retention. By deploying the one-wall full-scale VR-based e-learning system, we can take this to the next level by offering immersive and realistic hands-on

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virtual learning experiences in which several pupils can participate at the same time.

Figure 2. Proposed VR-based e-learning system: (a) environment, (b) virtual experience to *Santa village* (deployment screen shot)

The disadvantages of the existing system were that the system installation was complicated, a lot of equipment was needed, and space was limited. Also, there was a color image resolution (640x480) issue. In order to overcome these problems, we have developed the VR-based interactive e-learning system that enables kindergarten pupils to experience a better sense of reality and immersiveness in a virtual reality environment, and can be quickly and easily installed by kindergarten teachers or administrators. The system consists of a keyboard, an RGB-D camera (Kinect V2, Full HD), a 64-bit windows desktop PC, and single TV monitor. Through a wireless mobile network, we have expanded to enabling parents or pupils in remote locations to use their mobile screen devices to access the same VR hands-on contents outside of kindergarten. This will enable pupils to conduct virtual learning experience outside of kindergarten before coming to class where teachers can tutor the pupils in VR. The proposed VR-based interactive e-learning system consists of three functional components in terms of design, as shown in Figure 3.

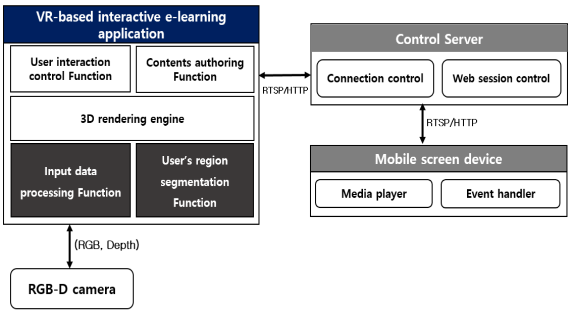

Figure 3. Functional configuration of proposed system

One is a *VR-based interactive e-learning application* including RGB-D camera, another is a *control server*, and the other is a *mobile screen device*. The *control server* processes messages/events such as a session, an access URL, and a contents streaming URL for connection management between the screen device and the e-learning application. The mobile screen device is responsible for functions such as audio/video and user screen transmission of experiential contents, and handles media player and event handler functions for RTSP (Real Time Streaming Protocol)-based content streaming. The *VR-based interactive e-learning application* includes *input data processing function* that receives RGB data and depth data from a RGB-D camera and a *user's region segmentation function* that extracts only a user region through image processing techniques. There is a *user interaction control function* for controlling interaction and event processing between the extracted actual user region data and virtual objects, *and a contents authoring function* for authoring and modifying the experiential contents.

A. User's region segmentation function

The *user's region segmentation function* extracts user pixel candidates based on color and depth frame images obtained from the Kinect V2 device. It extracts image objects corresponding to the user's foreground region from the depth frame image, and applies temporal filtering and vectorization processes to minimize outline noise and to correct blinking outline of user's foreground regions. After eliminating the background image objects that are not the user's foreground regions, the resulting images are synthesized into three-dimensional virtual contents. The workflow of the *user's region segmentation function* applied in the proposed system is illustrated in Figure 4.

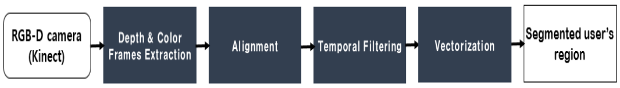

Figure 4. Workflow of user's region segmentation

B. User interaction control function

This function consists of two kinds of interaction control processing. One is the interaction control through user speech recognition, and the other is through user gesture recognition. The recognition rate of user speech is different according to the surroundings environment where Kinect is installed and the state of speech signal. In order to process interaction events based on user speech recognition between virtual image objects and real image objects, the Kinect Sensor performs an audio search and locates the sound. After finding the direction of the sound, it recognizes the speech the user has spoken.

According to the recognition result, the interaction event between the user and the virtual object is performed and the result screen is rendered. In general, there are two approaches to user gesture recognition. One is a heuristic approach and the other is a machine learning approach. For this function, we use machine learning based user gesture recognition. The more iterations of the action recording and tagging process for many people, the higher the accuracy of gesture recognition can be. Finally, the gesture recognized and the corresponding event are mapped and the set interaction is performed.

C. Input data processing function

The function receives the color image, depth image, audio stream, and skeleton information from the Kinect sensor, and converts it into the required data format. Then, the converted data is input to the user's region segmentation function and user interaction control function.

III. System Performance

In order to build the proposed system, the user's whole body image is extracted in real time and synthesized into three-dimensional virtual contents, and the gesture according to the user's motion and the speech of the user are recognized to process the interaction events between the virtual object and the user. To evaluate the performance of the proposed system, we test the accuracy of *user's region segmentation function* and *user interaction control function* applied inside the system. For the *user's region segmentation function*, we extract the user's body region at 16 FPS (frames per second) in the image frames obtained from Kinect and test the performance of the *user's region segmentation function* as follows. First, we digitize the Full HD color image obtained from Kinect and directly extract the user's whole body region. Through this, a ground truth image (1920x1080 resolution) is prepared, which is divided into a user's body region and a background region, and the accuracy is compared with the result image (1920x1080 resolution) generated by the *user's region segmentation function* of the VR-based interactive e-learning system. In the same dataset range, the ground truth image is paired with the result image of user's region segmentation function. Then, TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative) values are calculated for each image frame, and Recall, Precision, and F-measure values are obtained using TP, TN, FP, and FN values. Finally, the *user's region segmentation function* applied to the VR-based interactive e-learning system shows an average of 91.1% F-measure for a total of 20,000 frames of input image. In order to evaluate the performance of the user speech and gesture recognition, we examine the result of recognition event processing by inputting English and Korean data strings. Looking at the front of the Kinect attached to the large screen, a single user shouts tomatoes. The user confirms the virtual tomato object displayed on the screen. The user touches a virtual object (tomato) with one hand, and then performs an action of throwing it in the forward direction, as shown in Figure 5. At this time, when the virtual object is thrown forward, it is judged that speech and gesture recognition is successful. Throughout a total of 50 field tests, the recognition rate of English and Korean data strings for the same object was about 90%. Researchers, not pupils, directly participated in testing the accuracy of the *user's region segmentation function* and *user interaction control function*.

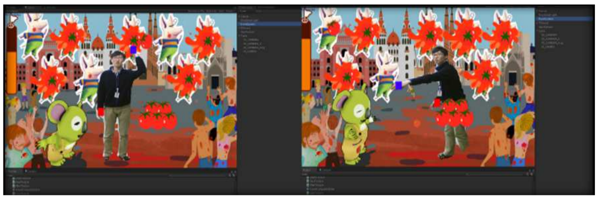

Figure 5. Test for user interaction control (throwing virtual objects) in the proposed system

The proposed system in this study has been developed based on Unity 5.6 64bit. For performance tests, we have used *Nuri curriculum* contents. The *Nuri curriculum* is an educational welfare project targeting the holistic development of children aged 3 to 5 in Republic of Korea. The user interface of the display configuration to experience the content is simple, and the entire system for running the contents can be installed within a few minutes, without the need for large facilities or costly physical equipment. As shown in Figure 6, applying technologies such as RTSP to the VR-based interactive e-learning system allows users to display the same view on different remote display devices, allowing separate users to share interactive events for collaboration.

Figure 6. Real-time synchronization of experiencing *Nuri curriculum* content (life safety) across multiple screens

The users can share speech and gesture interaction results for the co-registered virtual objects with other users on a single shared display.

IV. Conclusion and Future Work

In this paper, we propose a VR-based interactive e-learning system, which is implemented to enable kindergarten pupils to quickly experience a better sense of reality and immersion in a virtual reality environment without regard to the floor space. The proposed system is easy to install, easy to use, and easy to configure. A performance evaluation of the proposed system shows that it is effective for speech and gesture interaction to the co-registered virtual objects between users on a single shared display.

In the future, we will install the proposed system in a kindergarten and perform the tests in which the kindergarten pupils participate. Also, we plan to find a method to enhance the high-speed synchronization on display views across multiple smart devices so that virtual learning held in one kindergarten can be shared with other kindergartens in remote locations in real-time.

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