A Virtual Reality based Engine Training System
A Prototype Development & Evaluation

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Keywords: Virtual Training, Vocational Training, Engineering Education, Engagement, Immersion.

Abstract: A Virtual Reality based Engine Training System (VRETS) was developed and tested in this study. This training system was developed to use a head mounted display and a motion detector to pursue realistic engine dissembling and assembling training with natural interaction. 26 college students participated in the user test of this training system. The results of the user test show high interest, immersion, satisfaction, and perceived learning effectiveness of VRETS. Participants also reported that they could easily and naturally operate VRETS, and they also had full control of the content.

1 INTRODUCTION

Needs of interactive training system has been increased to enhance students' motivation and training effectiveness. Students tend to deeply participate and join training which offers chances of interaction and direct feedback with various modalities (Clark and Mayer, 2011). Engaging students to the training is one of important issues which is one of key indicators of students' achievements (Ibanez et al., 2014; Freitas, 2006). Learning by doing is particularly emphasized in vocational training due to the importance on transfer of learning. Main purpose of vocational training is to improve trainees' performance as a result of the training. Thus, designing and developing training environment which is close to real-world and high-relevance tasks is critical for the success of vocational training.

Based on this background, new types of vocational training method have been suggested recently. Virtual reality is one of useful technology for training which allows safe training environment, immediate feedback, and repetition without limitation with anytime/anywhere benefits (Bozgeyikli et al., 2016).

2 RELATED WORK

2.1 Virtual Reality Platform

At the early stage of virtual reality technology, big scale virtual reality platforms such as CAVE and multi-channel display were used for training. These platforms were for educating big group of people in a room setting.

Along with the rapid growth of virtual reality technology, small-sized virtual reality devices such as HMD (Head Mounted Display) and Leap Motion are mostly preferred in virtual training. HMD and Leap Motion are useful for individualized, immersive, and interactive training.

HMD has increasingly applied to training systems due to its high immersion, real-time interaction and wide applications (Peden et al., 2016). The size and cost of HMD is becoming more and more reasonable, it is getting popular device for training purpose. Leap Motion is a marker-less motion capture device tracking hand, wrist and forearm position (Smeragliuolo et al., 2016). One benefit of Leap Motion is low cost that makes it possible to use for training purpose as well.

2.2 Virtual Reality based Training

Virtual reality has been applied as an effective training tool in the area of flight simulation, special education, laparoscopic surgery and rehabilitation

Im, T., An, D., Kwon, O-Y. and Kim, S-Y.
A Virtual Reality based Engine Training System - A Prototype Development & Evaluation.
DOI: 10.5220/0006263702620267
In *Proceedings of the 9th International Conference on Computer Supported Education (CSEDU 2017) - Volume 1*, pages 262-267
ISBN: 978-989-758-239-4

training. Ke and Im (2013) developed a virtual reality based social interaction training simulation for high functioning ASD children using SecondLife and found positive effects on performance of responding, initiation, greeting, positive conservation ending and social competence. Bozgeyikli et al. (2016) explored different types of locomotion techniques with ASD individuals and figured out they felt comfortable with joystick and point & teleport techniques. A virtual reality dance training system using motion capture technology was proposed by Chan et al. (2011) and positive effects on improving students' dancing skill as well as increasing motivation was found from the study. A meta-analysis research was conducted with virtual reality training in laparoscopic surgery and it was found that virtual reality simulation is significantly effective than video trainers (Alakeret al., 2016). Researchers concluded that using Proficiency-based virtual reality training with supervision accompanied by prompt instruction and feedback, and haptic feedback would be the most effective way of virtual reality training.

However, there are still limited number of virtual reality based training exits in the area of technical training and most of them are development case study focusing on technical elements with no user test or evaluation. For example, Choi et al. (2015) developed a virtual reality based operation system for steel making process and presented the structure and elements of the system. In this study, a virtual reality based engine training system was suggested along with results of a detailed user test.

3 VIRTUAL REALITY BASED ENGINE TRAINING SYSTEM (VRETS)

3.1 System Architecture

We implemented a virtual reality based engine training system (VRETS) which empowers users to see and to manipulate virtual objects. The VRETS was configured to allow two or more users into a single private lesson from any location. The proposed VRETS consists of a natural interaction module, a head mounted display (HMD), and a virtual reality server as shown in Figure 1. In this system, the natural interaction module plays a role of sensing a trajectory of a human hand. When a user moves his/her hands, the natural interaction module captures the motion in real time and conveys the motion to the virtual reality server. There are four major parts in the virtual reality server. A motion recognizing part computes and understands the trajectory of a user's hands. Based on the computed trajectory, a transformation part calculates the position of a user's hands in the absolute coordinate which uses X, Y, and Z axis to establish a point in a common origin. In the absolute coordinate, a collision detection part computes the collision between a user's hand and a target virtual object, and furthermore it calculates new positions of the target object in virtual environment. Finally, all virtual objects are redrawn in the new positions by a graphic rendering part and then are displayed on the head mounted display (HMD).

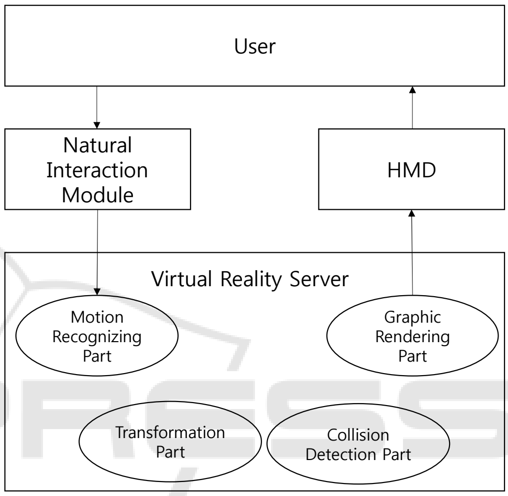

Figure 1: System structure of the proposed training system.

3.2 Interactive Virtual Reality Contents

The most important thing in constructing virtual training systems is to minimize a gap between virtual and real worlds. The minimization of the gap can be achieved by creating realistic virtual world (virtual environment) with high quality images. Virtual environment was constructed using a PC with 3.4 GHz i7 processors. A sleek head mounted display (Oculus Rift) was used for allowing users to see and enjoy computer generated virtual objects. All virtual objects were modelled with 3DMax and the model was subsequently simplified by a triangulated surface mesh simplification method (Algorri and Schmitt, 1996) for achieving real-time rendering on our PC. After that, we prepared two-dimensional image file to be applied to the surface of the model. The prepared image (texture) is mapped onto a target object's surface in 3D space. The model was then shaded using C# with unity 3D as a graphic engine and rendered at about 30 frames/sec (Figure 2).

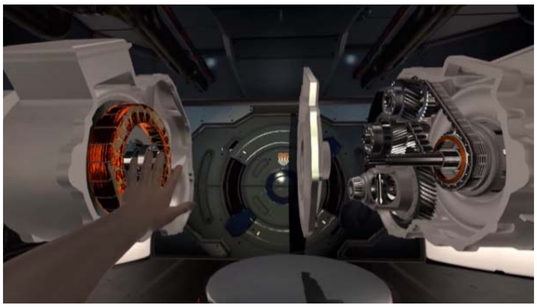

Figure 2: Constructed virtual environment.

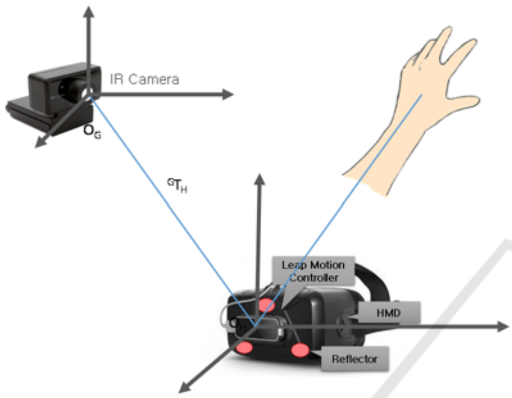

Figure 3: Coordinate frame of the proposed system.

Although high quality images are essential to provide a better sense of reality to users, it is not easy to increase the degree of the users' immersion to the level users truly want. A promising way of improving upon this problem is to construct a natural interaction module which allows a user to intuitively manipulate virtual objects with his/her gesture or motion. We constructed a natural interaction module that captures a user's motion as shown in Figure 3. The natural interaction module is made with an infrared (IR) camera, a commercial motion detector (Leap motion controller), and three IR reflectors. We applied a coordinate frame on the IR camera. This coordinate frame is used as the reference frame. The IR camera captures three IR detectors which are attached to the HMD to measure a user's head motion. The commercial motion detector was attached to the HMD to track a user's hand in real time. Therefore, a user can watch and enjoy every parts of virtual world by turning his/her head and can manipulate the parts with his/her hands as if he/she interacts with objects in real world. VRETS provides feedback with sound based on the results of success or failure of each mission.

4 EVALUATION & RESULTS

4.1 Participants

26 college students were recruited for the user test. Average age of participants was 23 years old ranging from 20~27. There were 15 male students and 11 female participants (Table 1).

Table 1: Gender.

Male	15
Female	11
Total	26

Majority of participants have majors in engineering department. 5 students have prior experience of Virtual Reality Applications and 21 students have never tried VR related application before (Figure 4).

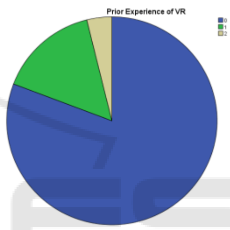

Figure 4: Participants' Prior experience of VR.

4.2 User Test

The purpose of user test for this study was to explore how people think, feel, react toward VRETS. For this user test, participants came to a virtual reality lab at KOREATECH one by one. Two of researchers led user test and observed participants' interaction with the content. Before starting user test, one of researcher clearly explained the purpose and the procedure of test to each participant. A brief guide about how to manipulate the virtual engine training system was provided. Once a brief introduction of the test was over, participants put on Oculus Rift with Leap Motion and tried the VRETS (Figure 5). Participants should disassemble an engine within the virtual training system and reassemble it by themselves. They could ask help to researchers if they need.

The aspects of user experience that were explored in this study are listed as below.

- Arousing Interest
- Immersion
- Interaction
- Ease of Operation

- Locus of Control
- Perceived Learning Effectiveness
- Satisfaction

Figure 5: Scenes from User Test.

4.3 Materials

A questionnaire was modified for this study based on prior research studies regarding user experience, game evaluation and motion sickness with a 5-point Likert scale. Participants filled out the questionnaire once completing their mission with VRETS.

4.4 Results

4.4.1 Interest

The mean score of participants' interest to VRETS is 4.69 and the standard deviation is .471 (Figure 6). 70% of participants answered that VRETS was very interesting to them.

Many participants responded that they were interested in VRETS due to the high reality of the system. This is from participants' comment related to interest.

"It was very interesting to me because VRETS looks very real to me. It looks almost like a real engine."

Some participants found similarity between VRETS and games.

"Even though this was first time to see engine system, I enjoyed VRETS and thought it very interesting since I could work on this content like playing a game."

4.4.2 Immersion

The mean score of participants' immersion to VRETS is 4.19 and the standard deviation is .801 (Figure 7). 85% of participants felt immersion to VRETS when they were using the system. Participants seem to experience immersion to VRETS from the feeling of they were actually working on a real engine by

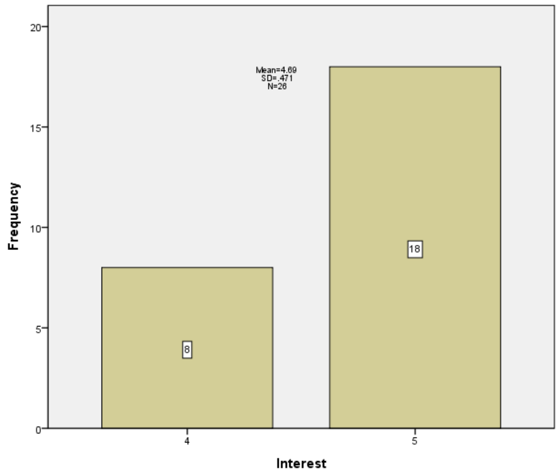

Figure 6: Mean and SD of Interest scores.

themselves. They reported they did not feel much gap between VRETS and real engine.

"Disassembling and assembling a real engine is not that easy due the difficulty of access as a student. However, VRETS allowed me working with engine and I felt I was practicing with a real engine by myself. I fully concentrated on VRETS and enjoyed it."

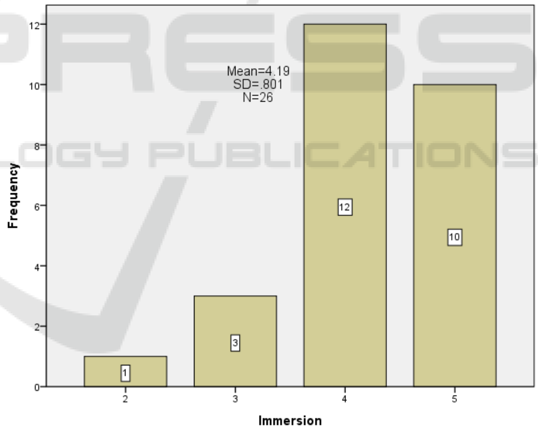

Figure 7: Mean and SD of Immersion scores.

4.4.3 Interaction

The mean score of participants' responses about interaction in VRETS is 4.04 and the standard deviation is .774 (Figure 8). The question was about how participants feel when they interact in VRETS using Oculus Rift and Leap Motion. 88% of participants answered interaction in VRETS was natural and smooth. Many participants commented that movement of hand and motion detect was natural as real in VRETS.

"The hand in VRETS looked like my real hand. The

position of virtual hand and real hand was adequate. Quality of engine visualization was very high.”

It seems like natural interaction in VRETS have positive impact on participants’ interest, immersion, and satisfaction.

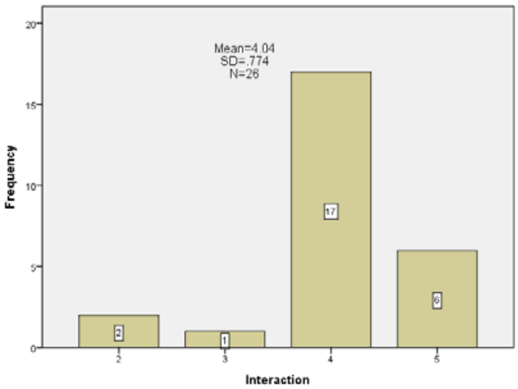

Figure 8: Mean and SD of Interaction scores.

4.4.4 Ease of Operation

The mean score of ease of operation is 4.62 and the standard deviation is .51 (Figure 9). 96% of participants reported that operating VRETS was very easy for them.

“This was my first time to experience VR contents. I was little worried about what if I made mistakes during VRETS operation. However, it was very easy to use this content and so much fun.”

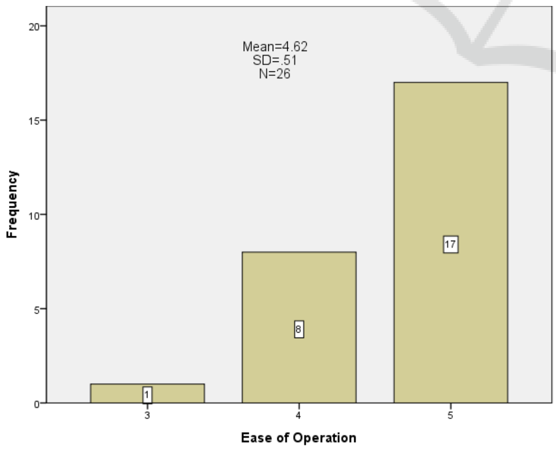

Figure 9: Mean and SD of Easy of Operation scores.

4.4.5 Locus of Control

The mean score of participants’ thought to locus of control is 4.08 and the standard deviation is .845 (Figure 10). 80% of participants felt they had full control of VRETS during their operation. Locus of control is an important factor for motivation and satisfaction.

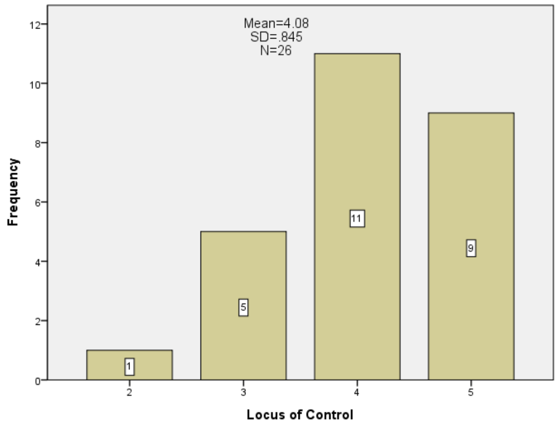

Figure 10: Mean and SD of Locus of Control scores.

4.4.6 Perceived Learning Effectiveness

The mean score of participants’ perceived learning effectiveness of VRETS is 3.85 and the standard deviation is 1.0 (Figure 11). 70% of participants perceived that VRETS would be effective for engine training.

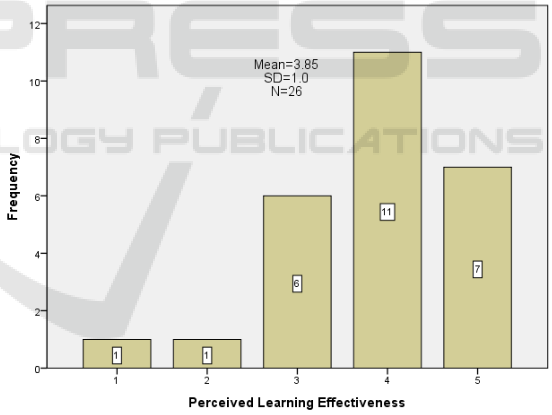

Figure 11: Mean and SD of Perceived Learning Effectiveness scores.

4.4.7 Satisfaction

The mean score of satisfaction to VRETS is 4.46 and the standard deviation is .506 (Figure 12). We could find many reasons for high satisfaction to VRETS from participants’ comments. First, having an opportunity to manipulate virtual engine that is very close to real engine made participants satisfied. Second, many participants enjoyed natural interactions through the virtual hand and motion detect technology in VRETS. Third, participants showed positive attitude on VRETS since it gives ownership to them and allows try and errors repeatedly. Fourth, participants mentioned they felt safe to work on VRETS comparing to real engine situation.

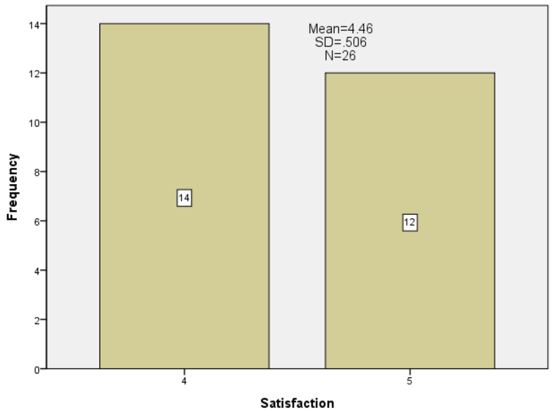

Figure 12: Mean and SD of Satisfaction scores.

5 CONCLUSIONS

In this study, a virtual reality based engine training system (VRETS) is proposed. We used Oculus Rift and Leap Motion to provide natural interaction during engine disassembling and assembling simulation. Through these VR devices, VRETS use can see their hand on the content, which is a result of real time tracking. In addition, VRETS user can experience 360 degree of virtual world by turning his/her head with Oculus Rift and can manipulate the parts with his/her hands as if he/she interacts with objects in real world. Immediate feedback with sound was provided in the content.

The results of user test show high interest, immersion, satisfaction, and perceived learning effectiveness to VRETS. Participants also reported that VRETS was easy to operate, interaction was natural, and they had full control of the content. We suggest that realistic virtual environment is important for users' immersion, interest and satisfaction from the results of this study. Designing natural interaction would be also critical to enhance user experience with virtual reality training system. We suggest that true value of virtual reality based training as creating real world like demonstration and experiment for users in a safe virtual environment.

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