

Application of Virtual Reality to Instructions of Manual Lifting Analysis

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ABSTRACT

Virtual reality (VR) allows the user to experience a 3D immersive digital environment through a sense of presence. Thanks to advancement of hardware and software development the costs associated with providing virtual environment have been affordable for educational institutes so that the application of virtual reality to active learning has been widely applied in higher education. In engineering education, the instruction is usually predominantly descriptive and difficult for students to follow. From the perspective learning style, it is quite passive. Meanwhile, a new generation of engineering students who are entering higher education has significant experience of VR through digital video games and tend to expect being educated through active involvement in problem solving. This study aims to design teaching instructions for manual lifting analysis by applying a 3D interactive virtual reality visualization program to compare effectiveness of instructions between passive learning and active learning.

Keywords: Virtual reality, Higher education, Manual lifting

INTRODUCTION

Learning outcomes in engineering education have relied on effectiveness of teaching instructions for discipline. However, since styles of instructions vary from one instructor to another instructor even for the same subject, student's learning outcome may be dependent upon instruction approach (Michael 2006). Since engineering education has been predominantly descriptive traditionally, opportunities for students to learn materials based on their own learning styles have been low. Teaching styles in higher education, however, has been consistently challenged and been changed to student-oriented instructions of which students are encouraged to actively engage with the learning material by analyzing the concepts taught by the instructor and understanding the discipline rather than passively accepting the instructed material without comprehending (Christie and de Graaff, 2017; Hernandez-de-Menendez et al. 2019). It is called an active learning teaching style that many studies (Michael, 2006; Koh et al. 2008; Sisk, 2011; Freeman et al. 2014; Betihavas et al. 2016) has shown a significant impact on student learning.

Virtual Reality (VR) has been emerged as an active learning teaching style for students to learn materials with driven engagement and motivation to learn through high levels of interactivity with VR programs (Brewer et al. 2012; Stepan et al. 2017; Harrington et al. 2018). A number of studies (Teranishi and Yamagishi, 2018; Makransky et al. 2019; Maresky et al. 2019) have evaluated interactive VR programs as learning tools in terms of long-term retention and revision of concepts as well as engagement with teaching materials and enjoyment of learning activity. The studies have concluded that a simple introduction of VR program to a class material can't create the active learning teaching style as being expected. Rather, the VR program can turn back to a passive learning style if the user is constrained to interact with control activities. Although the levels of control and immersion capabilities of the program are still important, student learning can be improved by a motivation to learn while enjoying and engaging with a learning tool (Jang, 2008; Kahu et al. 2017). Several studies (Brewer et al. 2012; Chessa et al. 2016; Stepan et al. 2017; Harrington et al. 2018) have reported that VR programs with immersion capabilities can make a learner keep the levels of engagement and enjoyment high during the use of programs. When implementing VR tools into curricula, interactivity with the tools should be also considered to improve visual-spatial conception of the topic.

Continuous improvements in affordability and accessibility of VR technologies have allowed teaching in higher education to utilize the potential practicability of VR as an education tool. A variety of tools using VR technology have been developed in the fields of studies such as biology (Borrel and Fourches, 2017; Goddard et al. 2018; O'Connor et al. 2018; Maresky et al. 2019), medical training (Cha et al. 2016; Parkhomenko et al. 2018; Pulijala et al. 2018), computer engineering (Teranish and Yamagishi, 2018), engineering education (Abulrub et al. 2011), geology (Reynolds et al. 2005; Woods et al. 2016). Although the degree of effect of VR as an education tool on student learning outcomes will be different from one curriculum to the other, it may be also significantly relied on the design and delivery methods of VR program. When VR program is interceded with conventional teaching materials, student can get help to not only revision of discipline previously studied but also long-term retention of knowledge learned from a course (Marsh et al. 2008). Therefore, learning experience for students may be improved by VR program along with other teaching materials.

In traditional instructions of manual lifting analysis, workplace or task conditions for manual lifting are usually given by statements, sometimes with pictorial descriptions. From the perspective of learners who need to investigate and analyze lifting tasks, it would be necessary to convert two-dimensional descriptions of task conditions into three-dimensional spaces for better understanding of tasks. However, the conversion would be limited with individual's capability of imaginary perception. Providing virtual task environment for lifting task conditions to learners would be very helpful to understand underlying conditions for lifting task. The objective of this study was to design a teaching aid to improve instructions in virtual reality environments and to compare effectiveness of instructions between traditional

instructions and virtual reality instructions. One exemplary lifting task published by Centers for Disease Control and Prevention was designed by using the Unity software (Unity). This example may be used by other educators to develop their own virtual instructions for different task analyses.

METHODS

Lifting Equation

National Institute for Occupational Safety & Health (NIOSH) has provided methods and guidelines to reduce low back pain and injuries, which is one of the leading occupational health and safety issues caused by a lifting task. The lifting task is defined as an activity that requires the operator to grasp an object manually with two hands and to move the object vertically or horizontally without any mechanical assistance. As a guideline for assessing the risk of low back disorders associated with manual lifting task, a lifting equation has been developed and revised to calculate a recommended weight limit (RWL) by considering lifting conditions for task. The lifting equation (Walters et al. 2021) is based on several factors of the lifting condition. The factors are initial location of the object for lifting, target location of the object to be placed, moving distance of the object, rotation of body, frequency of lifting, and coupling condition of the object. The lifting equation is summarized as follows:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

Where, LC: load constraint; HM: horizontal multiplier; VM: vertical multiplier; DM: distance multiplier; AM: Asymmetric multiplier; FM: frequency multiplier; CM: coupling multiplier.

Selection of Lifting Task

One of the lifting task examples from Applications Manual for the Revised NIOSH Lifting Equation (Walters et al. 2021) was selected to build a virtual program. That example was called a package inspection task that requires a worker to inspect compact containers for damage on a lower shelf and lift them using two hands to an upper shelf in front of the worker. The task was needed to be repeated at 3 times per minute and lasts 45 minutes. The worker was supposed to perform the task under three assumptions about working conditions. The first assumption was that the worker was not able to step forward when placing the container on the upper shelf due to the lower shelf configuration. Secondly, the worker was needed to control movement, so-called significant control, when placing the object at the destination on the upper shelf. Thirdly, the container did not have a coupling. Figure 1 shows the detail information of lifting conditions.

Virtual Reality Program

The selected package inspection task will be transformed from the 2D description into a 3D virtual environment using the Unity software. Unity is a virtual reality development platform with a lot of applications for games,

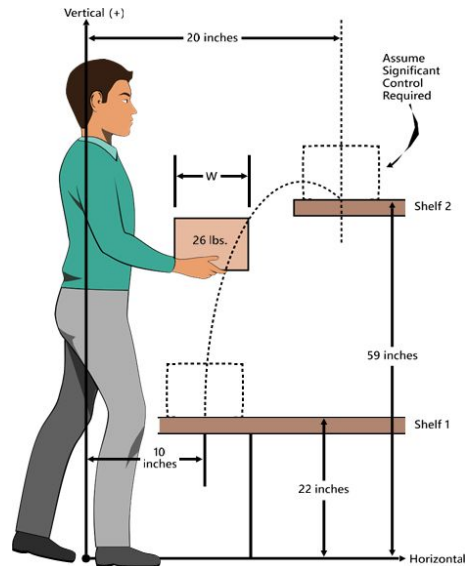


Figure 1: Lifting conditions for package inspection task (Adapted from Walters et al. 2021).

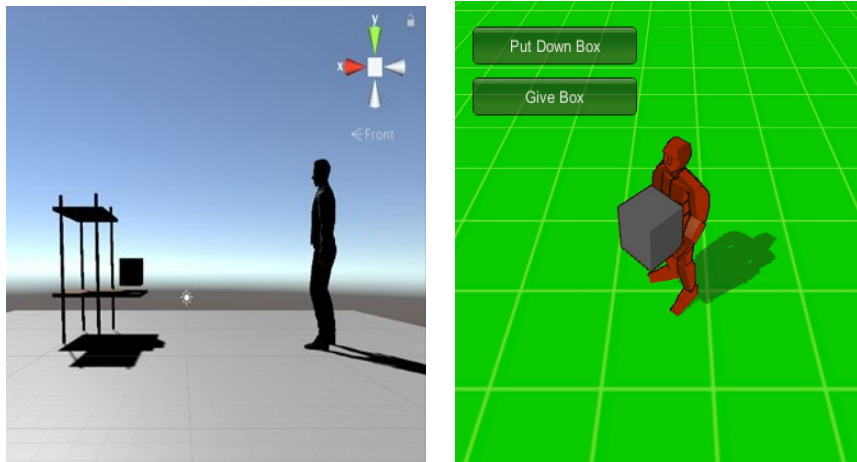


Figure 2: 3D virtual development.

which uses a hierarchy to connect multiple models within a scene. Within Unity, assets are coded properties that can be assigned to selected models in the hierarchy to simulate complex physical properties to make a model more realistic. An asset, for instance a color, can be simply assigned to a box to make it look with different colors depending on its status. There is also an asset for a movement of model such as a C# coding asset that can be assigned to a humanoid model to pick up a box from its initial location. There are also assets that can be assigned to keep the models from falling through the ground or floor of the scene and make them move through space. Figure 2 shows the early stages of the 3D virtual development. On the right of Figure 2, a humanoid model has a coding asset to pick up and put down a box from the

same level by pressing 'pick up or put down' button as a toggle key, as well as to give the box by pressing 'give box' button to trigger a giving action. In particular, the humanoid model holds coding properties assigned to its arms and legs to simulate various detailed human joint movement. In the code, the box is labeled as an item below the humanoid model based on the hierarchy so that the box would move based on the activation of the humanoid model. On the left, is a scene designed to have the lifting conditions shown in Figure 1. That humanoid model can simulate picking up the box, but the box would not move the humanoid model according to the hierarchy. The completed VR program will be used to instruct students how to assess the lifting equation. The effect of instruction using the VR will be evaluated by comparing student's learning outcomes to traditional instructions with 2D description.

Statistical Analysis

Two different assessments of learning outcomes (subjective and objective measure) will be collected from three different instructions such as traditional instruction with 2D description of lifting task, instruction with 3D virtual program, and a combined instruction with 3D virtual program and conventional PowerPoint presentation. The subjective measure will be a survey using Likert's 5 scale questionnaires about student's conception of the given lifting task requirements, amount of effort for analyzing lifting equation, and effectiveness of teaching instruction. The objective measure will be assessed by grading student's answer for lifting equation. A simple descriptive statistic comparison between teaching instruction methods will be applied to the subjective measure. For the objective measure, analysis of variance will be used to find an effect of difference between the instruction methods.

DISCUSSION

It is expected for students to improve the learning outcome by utilizing a VR program with 3D interactive control for examining lifting task environment. However, it will be difficult for general educators to develop a 3D VR program because of complexity of Unity application. In addition, it is not easy to find an exemplary VR program for uniquely customized activities. If educators intend to develop a VR program but are non-professional programmers with limited experience of computer programming C# scripting, they may face a hardship for creating VR programs. The example in this study is solely based on animations with minimum C# scripting. This study may help interested educators get some thoughts on VR program instruction development for manual lifting tasks.

CONCLUSION

In this study, the teaching outcome based on interactive VR instruction was hypothesized to be improved by student's active involvement into conception of a given problem. A development of VR program for manual lifting task assessment using the Unity platform was elaborated in this study. Although a

considerable number of VR examples and videos can be found in the internet, few VR examples for manual lifting tasks are available to evaluate potential low back injury risks at particular working environment. This study can be an example for other educators in engineering educations who will want to develop VR instruction methods to enhance traditional teaching approach. When the development of the VR program is completed in the near future, the effect of the VR program compared to a traditional teaching method will be analyzed to validate the hypothesis.

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