A VR Training System for Learning and Skills Development for Construction Workers

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Abstract

The purpose of the project is to build a virtual reality learning program that helps to mitigate human error in construction work. The application will act as a virtual trainer teaching a user how to build a basic wooden wall structure. The product will be an application that immerses users in a 3D interactive video, a step-by-step walkthrough where the user builds it themselves and a final evaluation of whether or not the user can do it by themselves all through a Unity3D program and an Oculus Quest headset. For our performance metrics, we want a working prototype that has been user-tested by people with and without construction experience. We also want to have a guideline for future virtual reality training software development based on our process.

Keywords: Virtual Reality, Construction, Unity3D, Training

1. Definition of Problem

Training for jobs can often be faulty when done by a human being. New workers are often subject to bias by their trainer and can be taught incorrect shortcuts or simply miss things due to differences between the trainer and the trainee. Furthermore, human error is the primary cause of quality and production loss for most industries. Bad training methods only make this more likely. Unfortunately, for a job like that of a construction worker, much of the job is muscle memory. This means that all of your training cannot be done with an online system that you see in most workplaces. But, even if they are trained well, they may need to be proficient until that muscle memory begins to form. A virtual reality (VR) training system like the one we are developing could help that and be the perfect mix between building muscle memory and lessening human error.

The purpose of the project is to design, implement, and evaluate a virtual reality digital simulated learning program for the installation and construction process of wooden light frame structures (or WLF). The system will allow the user to using multiple kinds of virtual tools such as timber studs, panels, and carpenter tools in the area of a VR simulated experimental construction site to learning the process of assembly and disassemble a WLF structure with predefined connections. During the simulation, the user might cycle between each discrete stages or phases of the construction from the start to the end of the process, which could be useful for both the teaching or training purposes.

2. Proposed Solution

The solution to our problem will be to build a system using a well-developed physical engine such as Unity3D with a properly designed system structure that will fulfill the requirement of the training process and target. Since Unity3D, the engine we are using, was already designed to work with existing VR headsets such as the HTC Vive or the Oculus Quest, then the task of the project can be focused on the system design part. This is significantly easier to implement then creating a new physical system of the project that support the VR systems.

Our virtual reality application will be capable of three functions for efficient training of construction workers. First, it will have a viewing option of 3D animations for various stages of the construction sequences. The user will be able to pause, play and explore the space from all angles as if it was a virtual reality movie. It will also include captions and the ability to physically interact with the animated objects.

Second, the user will be able to do a step-by-step walk through of wall construction in virtual reality. In this section of the application, the user will be given the virtual materials needed to create a WLF structure and will be walked through the process step by step.

The first of these steps is recognizing material. We will show the user the various materials they will be working with including studs, top plates and bottom plates. The second step is wall layout where the user will learn how to properly mark studs for the specified wall layout. The third step will be framing. This will teach the user how to avoid wavy sheathing. Next, the fourth step shows users how to maximize wall shear strength as well as how to properly use a circular saw to cut sheathings. Then the fifth and final step will teach the user wall standing procedure

Finally, the third and final ability of our VR application will be to present the user with the same scenario. Build a wall. This time however, there will be no instructions or walk through. It is simply the user left to their own knowledge and they tools they are given.

From these abilities within our application, we will have created a solution to mitigate user error in construction work, but also set the foundation for possible virtual training systems in other industries.

3. Performance Metrics

Part of the purpose of our project is to see how virtual reality training stacks up against normal training. To determine a comparison, we need to create parameters to quantify the performance of users. Recent research in the VR assembly training advocate for time and error count as measurements that assess the user performance: For example, [1] in the industrial mining field and in [2] for the assembly of medical devices.

For the sake of our project, we are going to define an error as an incorrectly performed step in the sequence of building a WLF structure. We will then use completion time and number of errors to determine a final grade as to whether or not the user has become competent at building a simple wooden wall. Errors will be determined by factors like the accuracy of the position and inclination of nails during nailing, the placement of specific structures for the wall, and the user's finished wall vs the ideal wall.

Our goal for this project is to have a working virtual reality application capable of the processes listed out in the proposed solution. To confirm that this goal is hit, we plan to do usability tests. Numbers are yet to be decided, but we will have a set number of people with no construction experience test our program to see how well they learn construction. If they are able to build a wall on their own and pass with few enough errors, it will be considered a success. Despite these terms, we will not rate the application on these successes and failures. Rather, we will look at how the user is interacting with the environment and the tools they are given. Users are not expected to be perfect after their first time through and the reason users can skip through the 3D animations is to help with specified gaps in knowledge.

We also plan to have a written guideline for the future development of interactive virtual training system design as one of our performance metrics. Not only will this help us keep track of our process, but it will also help streamline the process for any other teams wanting to make similar projects for their respective fields.

References

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