A Mixed Reality Platform for Collaborative Technical Assembly Training

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ABSTRACT

We have developed a mixed reality (MR)-based platform for basic mechanical engineering concepts as a learning environment for collaborative assembly tasks. In our platform, multiple co-located users interact with virtual objects simultaneously, and during that time, the platform collects data related to participants' collaboration and team behavior. We implemented four main sections in the platform including setup, introduction, training, and assessment. The platform provides the opportunity for users to interact with virtual objects while also acquiring technical knowledge. Specifically, for the technical component of the platform, users are asked to assemble a hydraulic pump by manipulating and fitting various parts and pieces into a provided pre-assembled blueprint. We conducted a preliminary expert panel review composed of three experts and received positive feedback and suggestions for further development of the platform.

CCS CONCEPTS

• **Human-centered computing → Virtual reality**.

KEYWORDS

mixed reality, training, technical assembly

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1 INTRODUCTION

The popularity of multimedia educational applications and the development of technology boost more and more virtual learning content embedded in STEM education. However, even though some teleconference applications such as Zoom or Google Classroom enable a certain level of verbal and text collaboration, these virtual platforms cannot simply replace classroom learning experience [1] as they lack the capacity to provide hands-on experiences such as exploring real scaled engine parts with multiple views.

Previously, both virtual reality (VR) and augmented reality (AR) have been used for educational purposes and skills training [2]. In VR, users get immersed into the virtual world with minimum interruption from the real world, while in AR, users observe the content placed on top of the real world.

Although we acknowledge the advantages of both VR and AR, we developed a mixed reality (MR) platform in which users can interact with virtual objects to provide an intuitive user experience (see Figure 1). Our platform can be used to provide educational tasks related to object assembly. During the assembly tasks, the platform is also responsible for collecting various data related to user activities and experiences. Such data can later be used to study collaborative team behavior. We plan to use such data to explore how users in STEM fields can collaborate in the MR environment and whether MR has the capability to provide an effective platform for training purposes.

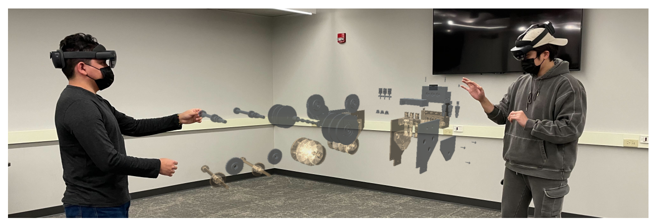

Figure 1: Example scene of our mixed reality platform in which two users collaborate on the assembly of the mechanical device.

2 THE MIXED REALITY TRAINING PLATFORM

2.1 Implementation Details

We implemented our MR training platform in Unity game engine version 2020.3.18f1. We used Microsoft's Mixed Reality Toolkit to provide realistic and intuitive interaction with virtual objects. Through Mixed Reality Toolkit, users can manipulate virtual objects using their hands. Moreover, we used the Photon Unity Networking asset to enable multi-user interaction in the shared MR space. The Photon Unity Networking asset provides private rooms to allow a group of users to share a virtual space with other users. To synchronize the scene across different ends, we used the Azure Spatial Anchors, a managed cloud service and developer platform that enables multi-user, spatially aware mixed reality experiences. Thus, we synchronize the manipulation and position of virtual objects across all ends. Lastly, we note that our MR training platform was developed for the 2nd generation of Microsoft's HoloLens. The chosen MR device houses see-through holographic lenses so that

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users can observe the virtual content placed on top of the real environment. Lastly, we should note that such a device has a number of sensors attached for head and eye tracking as well as houses depth and inertial measurement using sensors and an optical camera.

2.2 Training Application

The purpose of our application is twofold. First, we want our users to receive technical training in mechanical engineering while collaborating with other users. Second, we want to use this platform to understand how users collaborate in an MR space.

In the current version of our application, we are using a hydraulic pump as an application example. The hydraulic pump is composed of several functional parts (60 parts in total), and each functional part is made up of basic parts. Note that the 3D model of the machine has the same size as the actual machine. In total, we implemented four sections in which users follow a specific order. Furthermore, we implemented the setup, introduction, training, and assessment sections to enhance learning. Finally, in each section, a virtual agent gives instructions to the users on what exactly they need to do to accomplish the tasks at hand.

In the setup section part of our application, the system synchronizes the spatial information between users. To share the same spatial information, one user creates spatial anchors and shares these anchors with the rest of the group members. After all other users get these anchors, they can access the 3D objects in the same MR space.

In the second section (introduction section), the users learn how to interact with the virtual objects. Our platform provides tutorials about object transformation in the MR space, button pressing, and sliders. In each tutorial, users can access their virtual objects and train themselves. After the training is over, users are asked to self-evaluate whether they are fully trained and decide whether they as a group should move on to the following tutorial. After completing all tutorials (five in total), users move into the third section.

In the third section (training), our platform shows all the basic parts of the hydraulic pump. Users can use their hands to select a part of the hydraulic pump by touching it to receive information (e.g., the name of that selected part). After they become familiar with these basic parts, they can move to the final section.

The final section (assessment) is divided into two parts. The first one asks users to combine single parts to form functional parts. The second one asks users to use the functional parts to assembly the hydraulic pump. We used a translucent pre-assembled mechanical device (blueprint) to guide users during the assembly process. Thus, users can pick a part and place it in the appropriate position through visual indicators. Users can collaborate to assemble the entire hydraulic pump through these subsections and learn the assembly sequence. When users experience this last section, our system collects data that we can use to understand their task performance and collaborative behavior in the MR space.

2.3 Data Collection

We collect data to analyze how users collaborate with others in the MR space when using our platform. Our platform collects logs, including the position and orientation of the user in the MR space and how many times the user interacts with the virtual objects. Our platform also collects data related to the distance between users, the distance of each user with the 3D object, errors users might make in placing an object in the wrong position, and the time users need to complete the assembly process.

3 PRELIMINARY STUDY AND FEEDBACK

Preliminary Study. We asked experts (an extended reality [XR] developer, an organizational scientist, and a mechanical engineer) for the preliminary review to use the platform and provide feedback. They were briefed about the platform prior to engaging in the simulation. During the preliminary review, the experts explored the MR environment freely and provided immediate feedback for improvement. Such interdisciplinary feedback further helped us improve the platform.

Feedback. In addition to the formative feedback we received from the experts during the panel review, they provided us with summative feedback during an open discussion process. Furthermore, we initially intended to help users by providing an independent experience; however, one of the experts suggested that it would be better to share virtual objects in the introduction section when users learn how to interact with virtual objects. Isolating the interactions during the introduction section created an unrealistic experience. Additionally, the experts suggested that it was hard for them to find the appropriate position for each part; therefore, providing some additional visual indication would enhance the MR experience. Finally, one of the experts shared with us that the MR assembly was very different from what he had experienced in the real world; however, all experts acknowledged that they could efficiently access the actual size of the hydraulic pump in the MR setup and that the developed MR platform application was interesting to use.

4 CONCLUSION AND FUTURE WORKS

We developed an MR platform for collaborative technical assembly training. Our platform provides realistic and intuitive ways to learn and collaborate with others. We found that our platform could help people learn how to assemble a mechanical device and receive feedback from experts through a preliminary study. Based on the feedback we received from the experts, we plan to revise our platform and then conduct a research study to explore the potential impact of MR environments on technical training. Specifically, we are interested in exploring how such a platform can be utilized to teach mechanical engineering concepts (i.e., object assembly) in general and STEM concepts in particular. Finally, understanding how learners collaborate in MR space is vital to better understand the potentials of this technology in team settings.

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