

Virtual Field Trips with Networked Depth-Camera-Based Teacher Heterogeneous Displays, and Example Energy Center Application

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ABSTRACT

This demo presents an approach to networked educational virtual reality for virtual field trips and guided exploration. It shows an asymmetric collaborative interface in which a remote teacher stands in front of a large display and depth camera (Kinect) while students are immersed with HMDs. The teacher's front-facing mesh is streamed into the environment to assist students and deliver instruction. Our project uses commodity virtual reality hardware and high-performance networks to allow students who are unable to visit a real facility with an alternative that provides similar educational benefits. Virtual facilities can further be augmented with educational content through interactables or small games. We discuss motivation, features, interface challenges, and ongoing testing.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

Field trips are a valuable educational tool for giving students physical context for information and for long-lasting information recall [4]. However, field trip availability is limited by economic, geographic, and scheduling constraints. Schools may benefit from virtual guided field trips using consumer VR hardware. We present a framework for such experiences, including networking to allow students to meet a real expert guide and an example application in which students explore a virtual energy center (Fig. 1). Preliminary tests to guide interface development have been performed at three high schools and at many demonstrations [6] [1].

The framework supports an asymmetric collaborative approach. While students are immersed with HMDs, the teacher stands in front of a large monitor with a “virtual mirror” view (Fig. 2). The interface was developed for practicality and long-term comfort of a teacher guiding multiple VR sessions, and it additionally preserves the teacher's classroom (real world) oversight. We summarize problems and justifications related to this view.

The live 3D image of the unencumbered teacher is captured by a depth camera (Kinect) and streamed into the environment. The addition of a live, realistic teacher may increase student immersion and allow for more personalized explanations with immediate response to student questions. For extended replayability and to minimize scheduling conflicts, the teacher can also create 3D teacher recordings for the students to play back.

2 ASYMMETRIC COLLABORATIVE INTERFACE

Teacher and student interfaces have different device setups, interaction methods, and challenges. Because the application is networked, the teacher can be geographically distant from students.

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Figure 1: A student's view at a station in the virtual environment.



Figure 2: Teacher's virtual mirror using a large TV display.

2.1 Student Interface

The student interface uses a consumer-grade HMD and its controllers. Students use standard ray-based interaction to activate certain interactables in the environment that the teacher points out. Ray-based interaction is also used to pick locations (viewing platforms) to teleport to. Teleportation is handled by stepping through a few discrete waypoints, rather than moving directly to the target or applying smooth motion. Anecdotally, this maintains spatial awareness of motion while reducing chances of simulator sickness.

2.2 Teacher Interface

A teacher interface was created through several iterations of informal testing at demonstrations. An early version had the teacher immersed in an HMD, with a simple avatar. However, it was deemed that a live image of the teacher's face could enhance student experience, and that omitting the HMD would help long-term teacher

comfort. Thus, another version had the teacher stand in front of a monitor and Kinect with a first-person perspective. This view did not support the teacher pointing at objects behind the teacher, common in large facility field trips. This was addressed by a mirror-type view with a wide viewing angle, reminiscent of 2D mirror worlds [5], and arranged to approximate a default student view.

This virtual mirror view presents two major problems. First, pointing errors arise due to the indirectness of pointing in a mirror and a low sense of depth. During testing, an experienced teacher's behavior tended to follow 2D "weatherman" style pointing without consideration for depth, confusing immersed students. Second, the teacher is prevented from establishing natural eye gaze toward a student. Pointing and gaze are integral for teacher-student communication. For example, the teacher will frequently need to point out specific objects in the environment for explanation.

We evaluated several visual cues to improve pointing [7]. Notably, stereo, without added visuals, was less accurate than other visual indicators. We therefore use monoscopic viewing, which also avoids occluding the teacher's face. A selection of cues will be available at the demo.

To support teacher-to-student eye gaze, we overlay gaze targets representing students onto the teacher's view, drawn according to perspective projection considering the teacher's head tracking and display geometry [3]. This provides an indicator that the teacher can look at to establish proper gaze.

Future work includes a handheld touch controller for the teacher to select individual students and more directly control UI elements.

3 NETWORKING AND TEACHER MESH

Custom networking and Kinect mesh components handle aspects not supported directly by the development tool (Unity). Networking includes Kinect mesh streaming, state management, and voice chat.

Students' interactions can change local environment states, and these changes are written, per student, to a server. The teacher can synchronize state with any individual student to give more personal attention to a student's actions and questions.

Voice chat is handled through Teamspeak, hosted on the server. To compensate for inherent latency in the visual mesh, audio delay is added to the teacher's microphone input to improve sync. The teacher can switch between group and individual voice chat. This switch is implemented with channel management scripts.

For building the teacher mesh, the Kinect's color and depth images are streamed from the teacher station to the server via our custom plugin ffmpeg, a Unity interface for ffmpeg. The server relays data to student stations.

A base mesh, created in Unity, has vertices displaced into the shape of the teacher by a shader. The Kinect usually provides functions to generate 3d position and texture coordinates using depth data; however, student computers cannot access these functions, so we recreate them using look-up tables (textures) sampled in the shader. The shader uses the streamed Kinect data to construct the teacher as follows: a vertex shader calculates position and texture coordinates, a geometry shader culls background based on invalid or masked values, and a fragment shader textures the final mesh. The mesh is also processed to improve appearance. Raw positions extracted from the depth frame are smoothed, and edge vertices are adjusted by a contour smoothing algorithm.

Details of mesh handling and networking are provided in [3].

4 VIRTUAL ENVIRONMENT OVERVIEW

Our framework is applied to the Networked Virtual Energy Center, modeled after the Solar Technology Applied Research and Testing (START) Laboratory [2], a real solar thermal power plant that supports research and educational outreach activities.

Students explore the virtual center by visiting various educational stations. The first station presents an overview of the facility

and allows the teacher to introduce interaction mechanics and the facility in general. Other stations provide content related to the nearby facility components (e.g., Fig. 1). Interactive elements include animated components with educational voiceovers [1].

5 DEMO DESCRIPTION AND AUDIENCE INTERACTION

Demo visitors can see laptop-run versions of both the teacher and student interfaces (Fig. 3). A visitor in the student role can be immersed with an HMD while a live or pre-recorded demonstrator guides them around as the teacher. This allows visitors to experience the student view, interaction, and navigation. The HMD view will also be duplicated on a laptop monitor for other visitors to see. A visitor may also test the teacher interface, although its size will be reduced to a laptop monitor rather than a large TV.

An earlier demo, with intercity networking, is summarized at: https://youtu.be/dYt01_3xo4g



Figure 3: Demo setup using two laptops, a Kinect, and an HTC Vive.

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