Virtual Energy Center for Teaching Alternative Energy Technologies

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ABSTRACT

We overview the Virtual Energy Center, a VR environment that models a real energy facility to enable virtual field trips and self-guided exploration. Our goal is to take advantage of emerging low-cost hardware and improved networks to provide students who cannot travel to the real facility with alternatives that provide comparable educational benefit. The virtual facility is augmented by visual guides and educational content to teach students about concentrating solar power technology. A teacher physically near the student can appear in the scene via depth camera imagery, allowing the teacher to walk around in a classroom setting and assist students. Additionally, work-in-progress is streaming the depth images over a network to allow students to virtually meet expert guides from the real facility. We summarize these features, some interaction-related challenges, and ongoing testing.

Keywords: Virtual Reality, Education, Alternative Energy

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

1 INTRODUCTION

The Solar Technology Applied Research and Testing (START) Laboratory, shown in Fig. 1, is a pilot-scale solar thermal power plant that is the first university-owned facility of its type and size in the United States [1]. It supports research on next-generation solar devices and outreach activities to educate K-12 students about solar energy and other forms of renewable energy. Physical tours provide limited opportunities for educational experiences, because it is difficult for many students to travel to START due to geographical or scheduling constraints. For broader delivery of educational experiences, we developed the Virtual Energy Center (VEC), also shown in Fig. 1. Ritter and Chambers [2] described the initial creation of a scale model of the real energy facility for guided virtual tours to groups of students visiting a projection display room.

Emerging low-cost VR devices will enable broad deployment of VR experiences to homes or schools. We expect such technologies are promising for education and training related to alternative energy technologies at START. Increased motivation and engagement can result from immersive and interactive VR experiences and are fundamental to effective instruction [3][4]. We believe the first-person immersive view will also provide students with a better understanding of size and spatial arrangements of energy device components.

We extended the VEC to support consumer VR devices and to include self-guided educational content. We summarize this extended VEC, some related interaction challenges, and our collaboration with local educators for assessing results.

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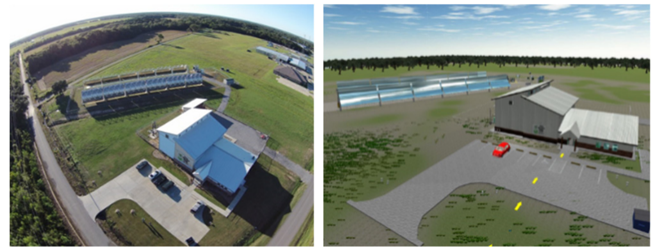

Figure 1: Bird's-eye view of the real (left) and virtual (right) facility.

2 ENVIRONMENT OVERVIEW

The VEC is rendered and scripted in the Unity game engine. It currently uses the Oculus Rift DK2 for immersive visuals and head tracking, Razer Hydra tracked wands for pointing-type interactions and other inputs, and a second-generation Microsoft Kinect as a depth camera to capture a teacher or guide.

2.1 Station Example

Students move through the VEC to visit several interactive stations. The first station provides an overview map and introductory explanations of both the facility and interaction methods. Other stations provide content related to the nearby plant components. For example, students visit a power block including a model of a heat exchanger (Fig. 2). There, they learn how heated fluid arrives from the solar array, how this heats and vaporizes refrigerant by heat exchange, and how the resulting pressure drives a generator through a twin screw expander. Interactive elements include voice recordings indicated and triggered by icons that appear in a constrained order, valves that are manipulated to control the flow of fluids, particle systems to show the associated fluid flows, and an animated exploded view that shows the internal structure of the exchanger (especially a row of metal plates). Small billboards can display additional technical illustrations or photos of the real device. Before a student moves to the next station, the educational module can ask the student to answer quiz questions by pointing to answers or objects.

2.2 Navigation

In a classroom setting, students remain seated for practical and safety reasons, and VR visuals should be comfortable for a wide range of users. We place intentional constraints on virtual player motion, both to provide some control over viewpoint and to reduce mismatches between real and virtual user motion.

At each VEC station, the player's view is that of standing on a small platform with handrails. Platform location and height are set to provide the clearest view of the presented educational content. The viewpoint changes according to tracked head motion, which is naturally constrained for seated classroom users. Larger virtual motion (travel) occurs only when students move to the next station after completing a station's activities.

Finding and moving to the next station may help reinforce students' understanding of overall size and spatial arrangement of the energy devices. One basic travel method is joystick-based control of head-forward translation and left/right rotation. In early pilot tests, this was preferred to automated motion along a fixed path. Audio instructions and arrows guide users to move to the next station platform, with handrails providing virtual constraints to ensure correct target position through collision response.

Such travel techniques cause a mismatch between real and virtual user motion that may induce motion sickness, especially with a wide field of view [5]. This is a substantial concern based on our own VEC experiences and comments during pilot tests. An alternative approach is direct teleportation to a target pose, allowing fast travel without the undesirable motion. However, we seek a compromise that preserves some aspects of motion for possible benefits in terms of naturalness or educational goals. Our next step is to assess techniques that limit the field of view during travel, reducing visual-vestibular conflict depending on the extent of the effect. One approach is to automatically narrow the field of view during motion, e.g., by blacking out peripheral imagery or displaying a scaled-down view. Various metaphors may help integrate this more meaningfully into the user experience, e.g.: using a vehicle with a narrow window, looking through a scope to find and select travel targets, or viewing the moving scene inset in a virtual panel instead of immersively. Yet another approach is to teleport through a few discrete waypoints, rather than directly to the target. Future work will assess some of these alternatives.

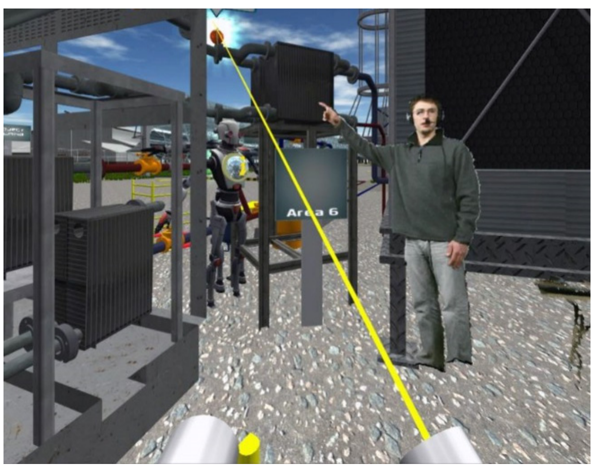

Figure 2: Student view near a power block with yellow ray selecting an interactive icon and a live teacher giving help.

2.3 Depth Camera Based Teacher and Networking

A teacher or guide can appear in the environment using a dynamic mesh with geometry and texture based on depth camera (Kinect) data. One goal is to help a live guide better interact with students, for example, by pointing to objects to support verbal descriptions. The depth camera coordinate system is posed in a standard way per VEC station to support this pointing, and with the mesh facing the student when the guide faces the depth camera.

In a classroom arrangement, a monitor on each student's desk lets a teacher see the student's view of the VEC. Thus, the teacher can walk between students and interact with them individually through a depth camera image. However, a limitation of this approach is that the teacher must have some sense of the 3D space that is not provided by conventional monitors. For example, pointing at an object behind the teacher mesh requires the teacher to point "backwards" or rotate to point to the right depth. While an expert guide can manage this effectively, it is unclear how much experience will be needed for others. Alternatives include immersing the teacher in a networked game version, using additional 3D displays to aid teachers, or developing visual cues to better communicate pointing direction based on analysis of depth camera data (or of a Kinect-tracked skeleton).

Work in progress is extending depth camera aspects in two ways: one is to use prerecorded depth camera video for educational content, showing experts explaining energy device components. The other is to stream depth camera data to students in a networked version of the game that allows a teacher or remote expert to guide students. Students can request expert assistance through a help button, and the expert can manage visits to students through a control panel. A main focus of our current and future work is to develop and assess these networking aspects of the VEC. In 2015, the network-streamed teacher was shown at a 22nd GENI Engineering Conference demo session that showcased potentially-transformative internet applications.

3 Assessment and Deployment

We are collaborating with local educators including the David Thibodeaux STEM Magnet Academy (DTSMA) in Lafayette, Louisiana. We first presented a projection-based VEC along with an Oculus HMD tech demo to teachers from DTSMA. They expressed excitement about the technology and identified how the VEC would fit into lab activities for an environmental science class. Five VR stations will be placed in a room where students rotate between lab projects. We incorporated substantial feedback about suitable levels of instruction (e.g., suitable language).

In early 2015, we demonstrated an HMD-based VEC to an engineering teacher's class and the head administrator at DTSMA. Feedback emphasized "problem-based learning" with motivating storylines. VEC students will be asked to start up the plant in order to meet power needs of their town after an outage. This requires students to learn about plant components and concepts.

Subsequently, 30 subjects tested an extended VEC in a research lab to check basic usability and as a pilot test of proposed questionnaires. Comments were largely positive in terms of the overall approach and motivation level. These subjects, as well as earlier teacher feedback, repeatedly indicate a desire for a high level of direct interactivity and associated active content.

Non-immersive VEC deployment began in December 2015 with eight students. Full VR deployment is planned for 2016. Students explore the VEC with minimal prior instruction. Pre- and post-tests and questionnaires assess learning and experience. Students also have group discussions and write summaries. 75% of students gave high ratings on questions about motivation, animated content, etc. Some reported difficulty with interaction, due in part to using VR-like interactions non-immersively.

Future educational extensions can include other START-supported alternative energy processes (torrefaction, gasification).

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