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Virtual Reality as a Medium for Remote Class Participation

Krzysztof Pietroszek

American University
Washington, DC 20016
pietrosz@american.edu
www.american.edu

Abstract. We discuss the potential of Virtual Reality as a medium for distance learning, with a specific focus on remote access to a class. We also describe a proof of concept of a remote classroom participation system. Our proof of concept mirrors what happens in a classroom into a generative virtual reality, taking into account a potentially low bandwidth data connection. We discuss how ours, or similar VR systems, help to bridge the gap between the efficiency of online and face-to-face education, and how it makes remote classroom participation more accessible.

Keywords: virtual reality · immersive learning · remote classroom

Introduction

Since 1968, when Ivan Sutherland built the first virtual reality head-mounted display (HMD)[1], the new-in-kind immersive medium he created found applications in engineering, big data exploration, entertainment, gaming, medicine, architectural visualizations, and many other domains. A domain that greatly benefits from the proliferation of virtual reality is education. Many immersive educational experiences had already been explored and evaluated.

In this work, we discuss a potential of Virtual Reality as a medium for remote classroom participation. First, we discuss the current issues with remote learning and how these issues can be addressed using virtual reality. We argue that virtual reality medium can effectively bridge the gap between face-to-face and remote learning. Second, we present a novel generative immersive system that allows a remote student to actively participate in a face-to-face class. To the best of our knowledge, no previous work presented real-time virtual classroom environment generation, where face-to-face instruction performed in a physical environment is simultaneously mirrored in virtual reality, so that remote student takes part in it.

Issues with Remote Learning

Over the last thirty years, the rise of the Internet and educational multimedia resources democratized access to education for remote students. However, as

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indicated in various studies [2], remote learning is not always as effective as face-to-face learning.

According to Jonassen et al., the lack of a direct teacher-to-student and student-to-student interaction, “cannot be understated” [3]. Some students can efficiently learn only through interaction with an instructor [4]. It is because, for many students, interpersonal communication is an essential component of effective learning; without it, the learning process is negatively affected [5].

Another negative consequence of the lack of direct communication between the teacher and the student is a difficulty in identifying and supporting students who are at risk of not mastering learning objectives [6]. This issue negatively affects course retention and increases course failure rates.

Online instructors attempt to mitigate the lack of direct instructor-to-learner interaction by recognizing “a unique opportunity for social networking and the development of peer support networks to fill this instructional void” [7]. Another approach to address the solitude of remote learning is to encourage – and support with technology – peer review and peer feedback. However, prior research shows that peer review and peer feedback is not as effective as the review and feedback provided by the instructor [8].

In contrast to remote learning, face-to-face classroom instructor frequently improves both the delivery style and the content of the course based on in-class interactions with students. Real-time classroom response systems, such as NetClick [9], support this approach with the use of mobile devices or classroom technology. In online courses, the instructor may not have timely access to the student feedback. Use of analytical and statistical tools for collecting the student feedback is insufficient in an remote learning context, because it misses on the important *non-verbal* feedback immediately available to the face-to-face instructor. For example, facial expression and body posture of a student may inform the face-to-face instructor about the lack of engagement, but is invisible to the online instructor.

Another criticism of remote learning is that, while distance education promises equitable access to education, many parts of the world still do not have sustained infrastructure to support broadband Internet connection [10]. According to a U.N. report [11], it will take another 125 years to bring land-line broadband Internet to all households in the world. The *digital divide* [12] affects not only developing countries, but also many communities in the US [13]. While in the recent years the digital divide is shrinking due to the fast proliferation of mobile Internet access [11], the coverage and the speed of the mobile data connection [13] is often insufficient for the traditional multimedia-based online education [10].

Prior studies advocate designing online courses in a way that ensures content accessibility. Online education should not only provide participants with the opportunity to take part but also consider the role that unreliable infrastructure might play in undermining the availability of online resources [3]. It is argued that to improve the availability of online courses in underdeveloped areas, the course should be designed to use as little bandwidth as possible. Yet, it is difficult

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to do so in practice. For example, some excellent learning content comes only in a form of audiovisual recordings. Providing the same content in textual form is not an adequate solution, because some students learn more efficiently when using audiovisual learning materials rather than relying solely on text-based materials [14].

Use of Virtual Reality in Education

Virtual Reality has been used in education and training since it was invented. At first, virtual reality has been used for educational purposes in the context of military training, followed by surgery training [15]. Virtual campus tours and experiences were implemented for CAVE systems and head-mounted displays as a means for encouraging pursuing a college degree. Experiments in persuasive virtual reality (where persuasiveness can be considered an educational goal) were also performed, showing that VR is a strongly persuasive medium. VR games, virtual reality tourism, VR documentaries, VR arts exhibits, and galleries, or VR performances, while not having educational objective per se, do constitute a learning or self-development experiences.

Immersive environments were also developed for language learning, science, and engineering, distance learning, or for virtual campuses as meeting spaces for students and faculty [16]. Sometimes, classes were held in 3d virtual environments. These systems did not usually use head-mounted displays, due to their high cost of the hardware at the time. More recently, a number of virtual field trips were designed for K12 education in biology, natural sciences, music, or arts.

Immersive technologies increase accessibility of computer systems across one dimension while limiting its accessibility across another dimension. On one hand, the spatial input often used in virtual reality requires full body mobility (for navigation and exploration) or hands mobility (for selection and manipulation, for example, using the virtual hand metaphor). On the other hand, virtual reality allows learners to transcend the limitations of physicality, e.g. location, individual physical abilities, or safety concerns. Consequently, in VR-aided learning co-located and the remote learners utilize face-to-face and remote learning modes not as a consequence of their physical location, but in a result of their, and the instructor's, choice. The choice of learning mode can be therefore informed by what serves best to achieve learning outcomes, rather than what is possible. This paradigm shift: applying learning mode that is most efficient for a given learning outcome, is what makes VR-aided learning a *disruptive* technology for education.

VR-aided learning also has a potential to positively impact the society, by responding to the need for life-long learning, attenuating learning barriers, and reducing costs of attaining educational goals. VR-aided learning directly supports equitable access and diversity by enabling disadvantaged groups to take full advantage of learning opportunities that may be otherwise inaccessible to them.

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Bridging face-to-face and remote learning

We believe that while immersive technologies will play an increasing role in both online and face-to-face learning, they also have the potential to address many of the issues with remote learning. To support that claim, we design and implement a prototype of a system that brings the online instructor and the remote student back together. The system also addresses the issue of low-bandwidth Internet connection. We call our prototype system Uni*VR*esity.

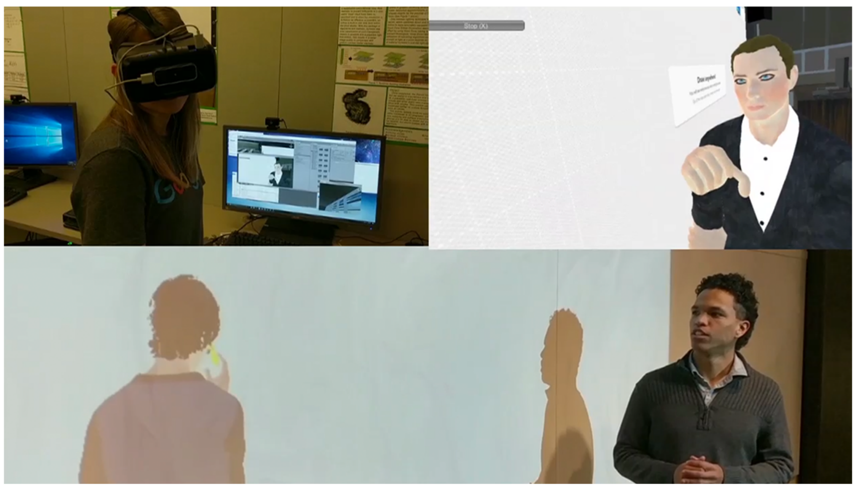

Fig. 1. A remote-student looking at the avatar of a teacher in VR, and the teacher looking at the avatar of the remote student projected onto the whiteboard.

Uni*VR*esity allows a remote student to connect to a virtual, procedurally generated classroom. The classroom is a real-time representation of what is happening in an ongoing, face-to-face classroom. When the face-to-face instructor speaks in a real classroom, his voice is transmitted over the network to the virtual classroom. At the same time, the avatar representation of the instructor is being animated, enriching the voice communication transmitted from the real classroom with animations of synthesised movement, facial expressions, and gestures. The animation synthesis is instructor's voice-driven.

To enable remote student access, the teacher opens an app on her laptop or mobile device. There is no need for any specialized equipment in the classroom. The role of the app is to broadcast the teacher's voice to all connected remote students.

The remote student joins the class by starting VR application and using a class-unique code provided by the teacher. Once connected, the student participates in the class.

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The communication between the remote student and the instructor is two-way. A remote student can ask questions, which will be heard by the class and the instructor. The instructor or classmates answers are heard, and visualized, in the virtual world the remote student is connected to.

In our prototype implementation, animations of the teacher's avatar are not pre-recorded but are generated in real-time from the voice of the teacher. The quality of the voice-driven animations is far from sufficient in the presented prototype. However, we actively research animation synthesis techniques that have a potential to improve the quality of the body and the facial animations in future implementations of the Uni*VR*esity system. In the future, we plan to use Uni*VR*esity system as a platform for development and testing of new models of relations between human voice and motion, drawing upon theories of human communication.

Interactive Whiteboard as a Shared Interaction Surface

The interaction between an instructor and a remote student can be facilitated beyond voice if the classroom is equipped with an interactive whiteboard or an interactive projector. In this case, the app enables using the interactive surface as a proxy connecting the virtual and the real world. Anything that the instructor writes on the interactive whiteboard is reflected, in real-time, on the virtual whiteboard the remote student sees in the virtual world. Moreover, the remote student can be called to the whiteboard, in which case he is represented in the physical classroom as an avatar visible on the interactive whiteboard (Figure 2). Movements of a remote student are animated based on the student's voice and spatial input. For example, when the student draws on the virtual whiteboard, her avatar draws on the interactive whiteboard in the physical classroom. The student's avatar can also face the instructor and the classroom, for example, to ask her peers a question.

We experimented with four low-cost spatial input devices for remote students: Leap Motion, Oculus Touch, a smartwatch, and a custom-designed bend sensor. Based on experience from previous projects, we know that Leap Motion with Orion SDK can provide freehand interaction and high-quality animation of the student's hands. However, positional precision errors that the device is prone to may make it difficult to precisely draw on the virtual whiteboard. Thus, we may decide to trade freehand interaction for precision and switch to Oculus Touch controller. Based on our previous experience with the device, the controller provides seamless, precise tracking at the cost of less accurate mapping of hand animations. To support mobile-based virtual reality interaction for a remote student, we also plan to use an off-the-shelf smartwatch as a spatial input device for smartphone-based HMDs. We will use smartphone-based 3D pointing and navigation techniques published previously [17, 18].

Supporting mobile-based access to our platform is important for the equitable access considerations; mobile-based VR is forecast to proliferate much faster than the desktop-based VR [19].

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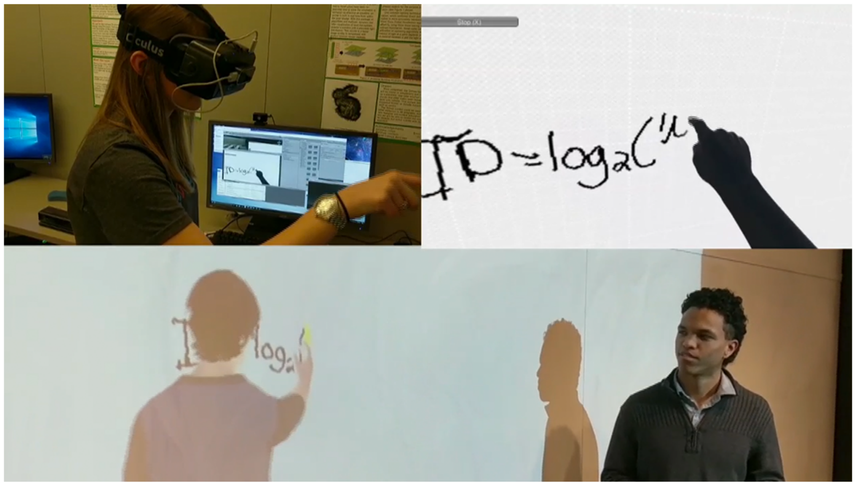

Fig. 2. A remote student writing on the virtual whiteboard, while her avatar is simultaneously writing on the interactive whiteboard in the class.

Addressing Low-Bandwidth Constraint

By generating, rather than transmitting, virtual reality environment that can run on the remote student VR device, we remove the requirement for a broadband Internet connection. The data transmitted between the classroom and the remote students consists of voice only. In the version of our prototype, where the interactive whiteboard is used, the transmission additionally includes the position of the teacher's and the remote student's cursor. No other information needs to be transmitted over the network.

User Feedback

To date, the system under development was evaluated in informal tests within our research group. The user responses to the system were overly positive. Users pointed out that the interaction with an avatar of a teacher is more interesting than a voice or videoconference connection. Also, younger users expressed a request to be able to modify their avatar, if presented to the class. One common criticism of the system was the quality of gesture and face animation - an area of improvement that we are aware of and actively work on. To make any claims about systems efficacy as a remote learning tool, a formal evaluation of the system is required and is planned in a near future. Currently, we are developing an online platform that will serve as a sandbox for pedagogical studies in efficiency and accessibility of virtual-reality-based class participation. Using the platform, we plan to perform two types of long-term evaluations in the future.

In the first type of study, we are interested in understanding how virtual-reality-based class participation compares to traditional remote learning and

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face-to-face participation in class. Our goal is to identify a set of requirements and design principles that VR-based class participation must conform to, to match the learning outcomes of face-to-face pedagogy.

We will perform the study by dividing online students into two groups: one using traditional online resources and the other participating in face-to-face instruction using our remote access system. This setup will allow us to compare learning outcomes of three groups of students: online students who use traditional distance learning means, online students who participate in face-to-face class using our system, and traditional face-to-face students.

We will repeat the pedagogical efficiency study over the period of a semester – a timeframe corresponding to an iterative improvement in the development of the platform – as well as platform integration of the animation synthesis models and algorithms.

The third type of study we are planning to perform is a quantitative plausibility experiment. We understand Plausibility as a component of presence. We adopt the deconstruction of presence postulated in [20] into the concepts of Place Illusion as *being there*, and Plausibility, which is the illusion that events in the virtual environment are really happening.

Summary

In this position paper, we argue that Virtual Reality is a medium that has a potential to be used as a medium of choice for remote classroom access. We also presented a proof of concept of a system which does not require specialized equipment in class, yet delivers virtual reality representation of that class to a remote student. We believe that in near future students will be able to choose on a daily basis whether they want to participate in face-to-face learning in person or as an avatar, and that choice will not negatively influence their learning outcomes. We also believe that immersive systems have a potential to have a transformative impact on remote learning. Virtual Reality can be used to bridge the gap between the virtual and the real – or between the online and the face-to-face learning.

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