Multi-View AR Streams for Interactive 3D Remote Teaching

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Figure 1: (a) An instructor with a mobile augmented reality teaching setup demonstrating a 3D printer, (b) scalable streaming of multi-camera annotations to students for interactive review via a web interface.

ABSTRACT

In this work, we present a system that adds augmented reality interaction and 3D-space utilization to educational videoconferencing for a more engaging distance learning experience. We developed infrastructure and user interfaces that enable the use of an instructor's physical 3D space as a teaching stage, promote student interaction, and take advantage of the flexibility of adding virtual content to the physical world. The system is implemented using hand-held mobile augmented reality to maximize device availability, scalability, and ready deployment, elevating traditional video lectures to immersive mixed reality experiences. We use multiple devices on the teacher's end to provide different simultaneous views of a teaching space towards a better understanding of the 3D space.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**; *Collab. interaction*; • **Applied computing** → *Distance learning*.

KEYWORDS

AR, remote teaching, video conferencing, multi-view, telepresence

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1 INTRODUCTION

The online education market with its hitherto unfulfilled promise to democratize education through accessibility at scale[6] is expected to grow by hundreds of billions of dollars during 2020-2024 [24]. Over the past year, the COVID-19 pandemic and resulting social distancing restrictions have kept students and educators from learning and teaching in a traditional classroom setting. Video meetings and pre-recorded lectures have served as the prevalent substitutes but are not equivalent replacements for classroom learning which has therefore led to exploration of other modes of remote instruction [20, 23, 26, 28].

Augmented reality (AR) provides an opportunity to increase the sense of presence in a remote classroom, as it enables mixing physical and virtual elements to create an interactive environment [8, 18, 22]. AR classrooms allow instructors to share their (potentially mobile) physical teaching spaces with their students [5, 7, 12, 14, 15] to create an educationally enhanced immersive 3D environment [1–3], which is something that plain video conferencing does not easily provide. We focus on allowing video stream viewers to gain context of and interact directly [9–11, 16, 17] with the remote physical teaching space using AR.

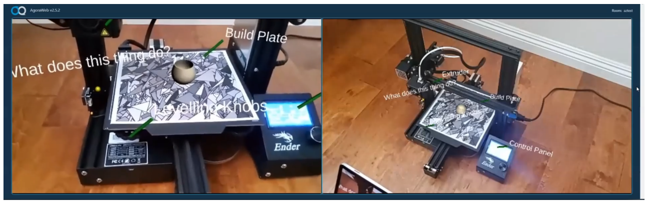

Figure 2: The student view of the 3D printer lesson. The instructor labels parts of the printer and simulates a print. The right view provides context for the entire scene while the mobile view on the left focuses on the specific component being demonstrated by the instructor.

We present a system that leverages AR for remote virtual learning and works with familiar videoconferencing technology. Instructors can create and stream AR lectures from their 3D "teaching stage" to their students, who can attend the lectures live via a web browser. In our exploration of system capabilities and example content for different lesson plans, we specifically saw value in the utilization of multiple simultaneous AR views [13, 16, 21, 27] onto the same 3D teaching stage. To illustrate a few potential objects, behaviors and interaction techniques, we examine an example lesson on 3D printing [4] to demonstrate the system capabilities, and in particular the advantage of multiple simultaneous views for the audience to better comprehend AR space [25].

Explaining Physical Equipment via Multiple Views: We re-create part of a lecture from a computational fabrication class [4] focusing on how to use a 3D printer. The instructor's setup includes two mobile devices, an Android tablet and phone, providing two different views of the same teaching space. The tablet sits directly in front of the instructor at a lower level and can be picked up and moved around to focus on specific parts of the printer. The phone is mounted above the printer to give an overhead view of the scene. Figure 2 shows a frame from the student view of the instructor's space and the 3D printer in the web application used during the lesson.

An image target is placed on the printer, and a phantom virtual printer model is attached to the image target and superimposed on the physical printer. With this, both instructor and students can interact with the printer virtually by triggering behaviors through any augmented view. The audience can see the entire printer and what the instructor focuses on *simultaneously* (see Fig. 2). Without an overhead view, it may be difficult to understand the context of what the instructor is presenting if the entire printer is not in frame. However, with only an overhead view, it may not be clear what the specific item the instructor is focusing on.

Student-instructor Interaction. In the 3D printer lesson, the instructor moves the tablet to focus on specific parts of the printer, like the *extruder*, *build plate*, and *control panel*. The instructor annotates them with AR labels by tapping on the tablet screen. Some labels will be out of the tablet's view, while the overhead phone provides an unbroken view of the entire printer with all the labels.

A student may ask about one of the printer's *limit switches* by clicking on it through their video stream. The student can precisely point out the object in the scene instead of describing it through text or voice call. The ability to directly interact with the mixed-reality space can give them a greater sense of presence in the lecture and mimic, to an extent, the experience of being in a physical classroom.

The instructor can explain the 3D printing process by playing an animation of an object being printed. Physically printing an object would not be practical given the time requirements. This showcases the flexibility of virtual mixed-reality content, as the lesson is not confined to physical constraints while maintaining a sense of immersion.

2 SYSTEM DESIGN AND IMPLEMENTATION

Our system allows instructors to turn their physical space into an engaging and interactive virtual classroom using AR. It consists of the instructor's AR mobile application, the students' web application, and a database for networking and synchronization purposes.

The AR application allows the instructor to use their mobile devices as video see-through displays to view and add virtual content to their physical space. The application is built using Unity for ARCore capable Android devices using Unity's AR Foundation with ARCore Image Targets. Using more than one device in the same space (including, e.g., a top-down overview, an instructor-facing webcam, and an instructor-held phone- or tablet-based AR magic lens) can provide a better understanding of the 3D space for the students viewing it on their 2D screens. This setup can be used for effectively teaching specific types of content that can benefit from the added spatial component.

Students view and interact with the instructor's augmented video stream live using the web application, built with Agora's Video Call SDK. A student can interact with the virtual content in the video stream by clicking on anything they have a question about; providing a way to ask questions about a specific part of an object, provide feedback, or other use cases. This triggers behaviors within the mixed-reality space. Managing remote interaction from students and networking between multiple instructor applications is implemented using Google's Firebase Realtime Database.

3 CONCLUSION

We implemented a system that leverages AR to extend standard video-based communication by adding 3D physical space to it for educational purposes. Our system introduces new ways for instructors and students to interact and engage with virtual lectures. Providing multiple simultaneous views of the teaching space provides remote users an understanding of the streamed 3D teaching space. Unlike other, more hardware-reliant technology, our mobile setup can scale readily to massive open online courses. Future work includes in-situ lesson planning and authoring tools, the additional modes of interaction, and evaluation studies that compare student learning outcomes against traditional videoconferencing, and perhaps immersive VR.

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