HoloClass: Enhancing VR Classroom with Live Volumetric Video Streaming

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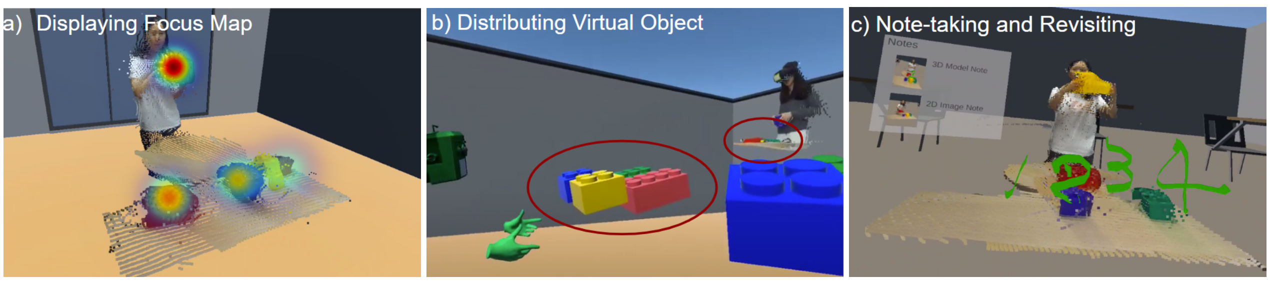

Figure 1: Features of HoloClass: a) displaying 3D focus map over volumetric content to show students' real-time focuses; b) distributing virtual duplicates of physical teaching aids to students; c) taking 3D notes along with volumetric content.

ABSTRACT

Virtual Reality (VR) enhances education by creating immersive and engaging learning environments. Volumetric video (VV) further improves VR classrooms by offering realistic, 3D representations of instructors and materials without high development costs. This study introduces HoloClass, a live VV streaming system for VR classrooms. We conducted interviews with 18 students to identify key design needs, resulting in features of HoloClass that support real-time awareness, classroom scalability, and note-taking. Our contributions include empirical insights into designing educational tools with live VV in VR classrooms and the implementation of features that enhance interaction and learning in a virtual setting.

CCS CONCEPTS

• **Human-centered computing** → **Systems and tools for interaction design**; **Virtual reality**.

KEYWORDS

Virtual Reality, volumetric video, live classroom, education

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1 INTRODUCTION

Virtual Reality (VR) has increasingly gained traction in the field of education, offering immersive, embodied and engaging learning environments that can enhance traditional educational methods [8–10]. Especially for online education, VR provides a shared immersive space where students and instructors can interact in real-time, fostering the sense of presence that is often constrained in conventional online learning platforms [3, 6]. However, many current VR classrooms (e.g., Engage [1]) rely on computer-generated avatars that lack nuanced social cues (e.g., instructors' facial expressions and full-body movements) and fail to incorporate contextual information crucial for enhancing learning experiences, such as teaching environments and materials [10]. Creating and integrating these elements in VR classrooms often involve additional costs, such as advanced avatar modeling and high-quality environmental design, presenting challenges for instructors lacking technical expertise.

Volumetric video (VV) offers new opportunities for VR classrooms to provide learners with realistic and contextualized representations without developing computer-generated avatars or scenarios. It captures people, objects, and surroundings from multiple angles, enabling personalized perspectives and providing spatially detailed information [11]. Compared to other VR video formats like panoramic [10] or light-field videos [14], volumetric video offers a more authentic and flexible immersive 3D experience.

Previous research has primarily focused on using pre-recorded volumetric video for educational purposes in VR, such as supporting embodied learning [11], cultural heritage education [15] and health training [5]. However, these studies have not explored its application in live VR online classrooms, where real-time interaction between instructors and multiple students is essential.

This study targets online classrooms hosted in a live format, which is a widely used teaching scenario. We conducted interviews with 18 students to explore effective strategies for enhancing learning experiences with live-streamed instructors in VR. Based on insights gained from these interviews, we focus on three key aspects of development to address their needs: awareness, scalability, and note-taking/revisiting. This work contributes empirical knowledge on the expectations and design considerations for live VV in VR online classrooms, along with the implementation of features supporting interactive learning experiences.

2 FORMATIVE INTERVIEWS

In order to inform the design of the ideal live VV classroom, we interviewed 18 university students (11 of them have experience as teaching assistants) from eight different departments. Among them, seven were female and 11 were male. Nine participants were considered VR experts, six had basic knowledge, and three had no VR experience. Four had watched volumetric video on a 2D screen before, while others had no prior exposure to it. We ceased recruitment of participants upon reaching data saturation, indicating recurring themes in interviews.

The procedure for the formative interview consisted of a technology probe [7] and several open questions. The technology probe enabled participants to experience live VV in VR, providing them with firsthand technical insights into the possibilities of live VV classrooms. This experience was particularly beneficial for participants who had little to no previous exposure to VR or live VV, empowering them to explore new possibilities as innovators. During this phase (10 mins), two participants were paired to experience a live VV class together, with one researcher serving as a live-streamed instructor following a scripted Lego construction task. Participants utilized a 3D Lego model to complete the task and had the opportunity to collaborate. Following the technology probe, participants were individually interviewed to discuss their experiences with VV or live classrooms on other platforms (e.g., challenges and opportunities) and to brainstorm ideas for live VV classrooms (20 mins).

We conducted thematic analysis for our qualitative data [13]. For our results, many themes, such as incorporating evaluation tools and supporting group discussions, emerged from general VR classrooms, regardless of whether live volumetric instructors were used. As most participants agreed that students do not need to be live-streamed, we target scenarios where instructors are live-streamed while students are represented as virtual avatars. Here, we emphasize three themes closely related to live VV format: 1) enabling visual cues for effective communication with instructors, ensuring **awareness** and clarity for common context for communication; 2) designing flexible access to live-streamed content to maintain viewing and interaction quality, particularly in **larger-scale** class settings; and 3) integrating **note-taking** features to facilitate review and reinforcement of VV content. In the next section, we will delve into the specific needs identified by interviewees and discuss how these features were tailored to enhance live VV classes.

3 SYSTEM

Based on the design needs identified from our formative interview, we propose a 3D live video streaming system called HoloClass. HoloClass is designed for students learning in VR classrooms where the instructor, along with the surrounding physical environment, is live-streamed via volumetric video. We implemented a prototype of HoloClass with Unity 3D and Oculus Quest 3. We used three ZED cameras [2] to capture the live volumetric videos. We implemented a server-client architecture where the server live streams uncompressed volumetric video to clients.

Awareness: Awareness enables students and instructors to understand each other's activities, providing a common context for communication. Since the instructor is live-streamed as a volumetric video (VV) and their status is clearly visible to students, we focus on designing features to help instructors understand students' status and activities. We propose a *focus map* to show where students are focusing by using a heatmap or 3D annotations on the streamed volumetric content. This enhances awareness by giving instructors an overall view of students' attention, ensuring clarity and helping to identify potential issues that students may have, thereby fostering effective communication.

Scalability: Scalability enables instructors to support larger class sizes with a single live-streaming session. In HoloClass, we propose *virtual object distribution* to help instructors scale-up the class. During classes, instructors can distribute digital copies of the physical teaching aids (e.g. experiment equipment, molecular models, etc) being live-streamed. The digital copies are generated with real-time volumetric recognition algorithms. Distributing virtual teaching aids allows instructors to easily scale-up classes as it's easier to duplicate virtual models, in compare to physical copies.

Note-taking: Taking notes and revisiting class content are key steps of learning. Despite the many previous studies on note-taking methods in VR [4, 12], taking notes during a live VV class remains challenging due to the dynamic and spatial information inherent in VV. In HoloClass, students receive a digital copy of the volumetric video to avoid interference, allowing them to create 3D annotations and save as notes, or take 2D snapshots where spatial details are less critical. HoloClass also supports recording live class sessions in 3D, enabling students to revisit and review the material after class.

4 FUTURE WORK

We are working on completing the detailed system design and implementation. We plan to integrate computer vision techniques for volumetric content recognition and division to support real-time object detection and virtual model creation. Future work involves conducting a large-scale user study to assess the usability of HoloClass and its potential to enhance learning outcomes compared to existing online classroom systems. In addition, while this study primarily focused on students' perspectives, further exploration is needed to adapt features from a teacher's viewpoint (e.g., how to manage the integration of real-world teaching scenarios, digital information, and student interactions).

REFERENCES

[1] [n. d.]. Engage VR. Retrieved July 6, 2024, from https://engagevr.io/. Accessed: 2024-07-04.

[2] [n. d.]. Zed Camera SDK. https://www.stereolabs.com/developers/release/.

[3] Miguel Barreda Angeles and Tilo Hartmann. 2023. Easily applicable social virtual reality and social presence in online higher education during the covid-19 pandemic: A qualitative study. *Computers & Education: X Reality* 2 (2023), 1–13.

[4] Adlin Shaflina binti Azizo, Farhan bin Mohamed, Chan Vei Siang, Muhammad Ismail Mat bin Isham, Mohd Khalid bin Mokhtar, and Ira Wirasari. 2021. A Prototype Application of StickAR to Enhance Note-Taking Activity by Using Augmented Reality Technology. In *International Conference on Intelligent Technologies for Interactive Entertainment*. Springer, 353–371.

[5] Matthew Hackett, Basiel Makled, Elliot Mizroch, Simon Venshtain, and Matthias Mccoy-Thompson. 2021. Volumetric video and mixed reality for healthcare training. In *Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC)*.

[6] Elizabeth M Hodge, MHN Tabrizi, Mary A Farwell, and Karl L Wuensch. 2008. Virtual reality classrooms: Strategies for creating a social presence. *International Journal of Social Sciences* 2, 2 (2008), 105–109.

[7] Hilary Hutchinson, Wendy Mackay, Bo Westerlund, Benjamin B Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, et al. 2003. Technology probes: inspiring design for and with families. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 17–24.

[8] Qiao Jin, Yu Liu, Ruixuan Sun, Chen Chen, Puqi Zhou, Bo Han, Feng Qian, and Svetlana Yarosh. 2023. Collaborative online learning with vr video: Roles of collaborative tools and shared video control. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–18.

[9] Qiao Jin, Yu Liu, Svetlana Yarosh, Bo Han, and Feng Qian. 2022. How Will VR Enter University Classrooms? Multi-stakeholders Investigation of VR in Higher Education. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 563, 17 pages. https://doi.org/10.1145/3491102.3517542

[10] Qiao Jin, Yu Liu, Ye Yuan, Bo Han, Feng Qian, and Svetlana Yarosh. 2024. Virtual Reality, Real Pedagogy: A Contextual Inquiry of Instructor Practices with VR Video. In *Proceedings of the CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. Association for Computing Machinery, New York, NY, USA, Article 665, 21 pages. https://doi.org/10.1145/3613904.3642510

[11] Qiao Jin, Yu Liu, Puqi Zhou, Bo Han, Svetlana Yarosh, and Feng Qian. 2023. Volumivive: An authoring system for adding interactivity to volumetric video. In *2023 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*. IEEE, 569–570.

[12] Justin Luo. 2020. VR-Notes: A Perspective-Based, Multimedia Annotation System in Virtual Reality. (2020).

[13] STEPHANIE Riger and RANNVEIG Sigurvinsdottir. 2016. Thematic analysis. *Handbook of methodological approaches to community-based research: Qualitative, quantitative, and mixed methods* (2016), 33–41.

[14] Bennett S Wilburn, Michal Smulski, Hsiao-Heng Kelin Lee, and Mark A Horowitz. 2001. Light field video camera. In *Media Processors 2002*, Vol. 4674. SPIE, 29–36.

[15] Emin Zerman, Néill O'Dwyer, Gareth W Young, and Aljosa Smolic. 2020. A case study on the use of volumetric video in augmented reality for cultural heritage. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. 1–5.