STREAMSPACE: A Framework for Window Streaming in Collaborative Mixed Reality Environments

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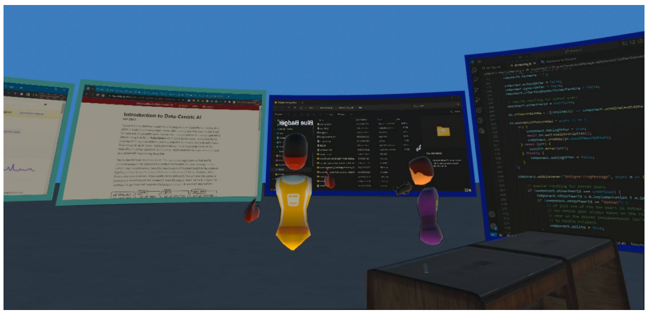

Figure 1: Multi-screen streaming in a collaborative environment.

ABSTRACT

We introduce STREAMSPACE as a framework for exploring screen-based collaborative MR experiences, focusing on the streaming, integration, and layout of screen content in MR environments. Utilizing Unity and Ubiq, this framework allows users to engage with, reposition, and resize uniquely identified screens within a user-centric virtual space. Building on Ubiq's WebRTC capabilities, our framework enables real-time streaming and transformations through peer-to-peer communication. Key features of STREAMSPACE include distributed streaming, automated screen layout, and flexible privacy settings for virtual screens. Introducing STREAMSPACE, we aim to provide a foundational basis for research on screen-based collaborative MR applications.

Keywords: virtual screen, virtual reality, collaborative interaction

Index Terms: Human-centered computing—Visualization—Visualization design and evaluation methods

1 INTRODUCTION

The development of multi-screen mixed reality (MR) applications is a notable advancement in computing, altering how we interact within digital environments. Integrating such elements in an immersive environment addresses the growing demand for effective collaborative tools in remote working context [10, 3]. By bringing traditional 2D content, such as web pages and office documents, into 3D virtual spaces, these technologies can be used effectively at home, in transit, or combined with traditional screens, offering versatile and adaptive solutions for diverse work settings [4, 1]. The trend towards incorporating 2D content into MR environments reflects an ongoing effort to harmonize the familiar functionality of standard desktop applications with the immersive experience of VR or MR [9, 8]. This allows users to create personalized, virtual workspaces where traditional 2D windows are placed and manipulated within a 3D context, typically loaded in the scene. Extensive research and commercial efforts have investigated advanced applications and spatial arrangements of 2D virtual screens in MR [7, 2]. To support the ongoing research in this field, we introduce STREAMSPACE, an open-source framework that implements key features for virtual content streaming, layout, and manipulation. This framework is intended to form a foundation for research aimed at addressing the limitations and enhancing the capabilities of traditional desktop computing through the potential of collaborative multi-screen MR interfaces. STREAMSPACE facilitates applications permitting users to access and interact with multiple virtual streams concurrently, thereby streamlining workflows, particularly in professions where integrating varied information is essential. It incorporates a color-based streaming source identification system, an automatic screen layout mechanism, and options to alter collaborator screen visibility. STREAMSPACE is characterized by its user-friendly interface and ease of setup. Users can integrate 2D window streaming from any machine into their MR headsets using a browser, allowing for the creation of collaborative virtual workspaces.

2 DESIGN AND IMPLEMENTATION

STREAMSPACE is built on Ubiq [6, 5], utilizing its decentralized, peer-to-peer (P2P) system and WebRTC capabilities for direct client communication, moving away from the traditional use of centralized servers for media transmission. This P2P model is key to achieving low-latency interactions, which are crucial for the real-time aspect of VR, and it also helps in reducing the bandwidth costs often seen with centralized streaming. WebRTC's API plays an essential role in setting up media streams and data channels between VR devices, which helps maintain privacy and lessens reliance on external server infrastructure. The system is built using the Unity 3D engine, known for its wide range of features suitable for VR development, like rendering, physics simulations, and user input handling. Unlike centralized systems, the structure of STREAMSPACE avoids common issues like single points of failure and performance bottlenecks, contributing to its scalability and reliability. This decentralized approach allows many users to engage in the same environment without compromising performance, even with multiple streams running simultaneously. By integrating Unity for VR development and Ubiq for WebRTC for P2P streaming and managing networked interactions, STREAMSPACE provides a stable and scalable platform for exploring screen-based MR interactions and applications.

2.1 Layout Manager and Dynamic Mesh Generation

The `Layout Manager` in STREAMSPACE orchestrates the spatial configuration of streamed content within a customizable cylindrical VR space. It supports the creation of both curved and flat display meshes, allowing for flexible presentation styles that accommodate

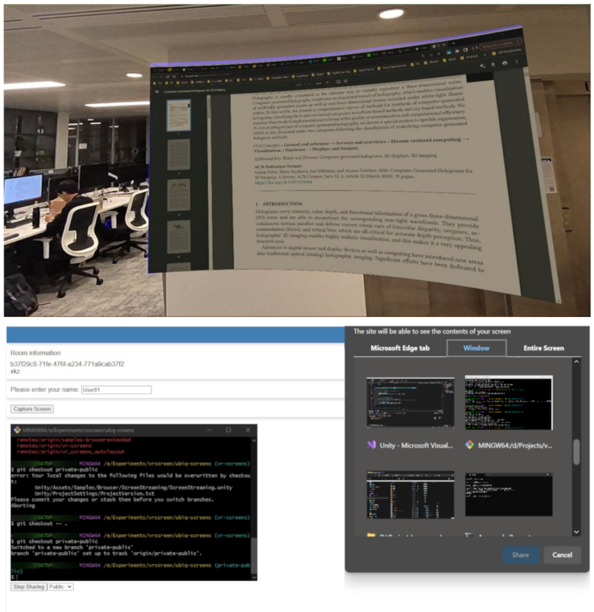

Figure 2: Top: Window streamed to StreamSpace workspace. Bottom: StreamSpace browser interface including a prompt for capturing a window/screen and a dropdown for private screen.

user preference and the specific requirements of the virtual environment. The system's layout algorithm strategically places multiple views into a coherent positions, arranging screens based on their dimensions. It determines the most effective distribution by calculating a score that reflects the arrangement's spatial economy and visual harmony. Rows are included in the layout if their total width remains within an acceptable range – no more than 50% above the average row width. This approach maintains order and clarity within the VR space as users add or alter streams. The `Layout Manager`'s ability to adjust to changes ensures a consistent and organized presentation of the VR content, facilitating user interaction within MR.

2.2 Public and Private screens

In the StreamSpace environment, the distinction between public and private screens is effectively managed to support various types of user interactions. Public screens act as shared elements, visible to all users in the VR environment. As such, they are well-suited for group activities such as collaborative projects, presentations, or collective media viewing, enhancing community engagement. Conversely, private screens provide users with a personal area for individual tasks or handling sensitive information, crucial for preserving confidentiality in the VR space. This function is essential when dealing with private content or when a user needs an undisturbed area for concentration. For users who do not have access to the private screens, the screen is visualized as a blurred screen. The system allows users to toggle screens between public and private modes from the browser-based interface (Figure 2). This functionality is beneficial in settings like education and business, where users frequently alternate between solo and collaborative work. The `Layout Manager` in StreamSpace adapts the distribution of screen space to respect these privacy choices, ensuring that private screens remain concealed from others while keeping the overall layout of the workspace organized and unified.

3 Future Works and Conclusion

In the next phase of StreamSpace, we plan to refine streaming efficiency with an attention-based compression algorithm. This feature will dynamically adjust the compression of various screens based on the user's focal point in the VR environment to optimize resource utilization. By enhancing visual quality for screens in direct view and compressing peripheral content, we aim to achieve substantial bandwidth and computational savings. Inspired by foveated rendering, this targeted streaming approach aims to deliver high-quality visuals where most impactful. Another planned feature is direct user interaction with windows, allowing users to engage with screen content actively. This is intended to bridge the gap between passive viewing and interactive engagement and to significantly enhance the utility of MR environments. Hand-tracking, gesture recognition, and MR controllers will facilitate intuitive, user-friendly interactions. Furthermore, we aim to implement security protocols, including advanced user authentication and secure data transmission, to ensure a secure and reliable experience. We propose StreamSpace to explore screen-based interactions and layouts within MR environments. We seek to offer a foundation for methodical research and development in the emerging field of screen-based MR applications. Source code is available at `https://github.com/UCL-VR/streamspace`.

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