Mixed Reality Collaboration for Complementary Working Styles

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Figure 1: Collocated VR and touchscreen tablet users sharing a multi-scale interaction with a collaborator who is in mobile VR, through coordinated manipulation of both human-sized and tabletop robots.

ABSTRACT

Our project combines immersive VR, multitouch AR, real-time volumetric capture, motion capture, robotically-actuated tangible interfaces at multiple scales, and live coding, in service of a human-centric way of collaborating. Participants bring their unique talents and preferences to collaboratively tackle complex problems in a shared mixed reality world.

KEYWORDS

Mixed reality, remote collaboration, tangible interface

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1 INTRODUCTION

People work and think differently. Some people may like to work with their hands, while others prefer to think with their whole body, and others do so by coding. As advancing technology allows us to take advantage of multi-scale active haptics and personalized immersive interfaces, our project provides tools that support people's individual needs and preferences when working together, combining the advantages of different working styles.

One of the main objectives of modern collaboration systems is to enable people who are co-located and physically distant to perceive that they are in the same workspace. Asymmetric MR can help achieve this goal in several ways. First, it can provide an immersive experience in either real or virtual environments. Second, collaborators taking on different roles can seamlessly interact with each other by using asymmetric platforms such as VR and multitouch tablets. Third, working in the same virtual workspace helps collaborators to utilize their innate spatial intuition. The majority of collaborative AR and Virtual Reality (VR) systems focused on collaboration between users in either AR or VR [Piumsomboon et al. 2017]. Much previous research has focused on collaborative systems

design and implementation[He et al. 2020, 2017; Radu et al. 2021]. These systems used different aspects of AR/VR to support different collaborative roles, often a remote expert supervising another user who is performing a real-world or virtual task.

Our project supports asymmetric, multimodal collaboration in a shared mixed reality world, combining complementary modalities through multiple technologies and techniques, including immersive VR, multitouch AR, real-time volumetric capture, motion capture, robotically-actuated tangible interfaces at various scales, and desktop-based live coding.

One collaborator might manipulate the shared mixed reality world by moving miniature robots on a table, while viewing them in VR as objects endowed with magical properties. Another might "jump into" that miniature world, seeing and touching those same tangibles as full scale objects. A third might use a motion-tracked tablet to interact through a magic window, peeking into the virtual world from reality. Meanwhile a programmer can immediately change any aspect of the shared world via live coding on a desktop-computer.

Technologies that we bring together include full-body motion capture, untethered immersive VR for multiple participants, parallel active tangibles at full and miniature scale (implemented as swarms of Sony Toios and iRobot Creates), real-time volumetric capture from RealSense cameras that allows people in VR to see the faces of collaborators with proper 3D perspective, WebXR-based live coding, and low latency networking for all components.

All of these technologies are in service of a people-forward, human-centric way of collaborating, allowing all participants to bring their own unique talents and work preferences to tackle complex problems together in a shared mixed reality world.

2 SYSTEM DESIGN

The system employs a server-client architecture. Clients are users with asymmetric setups, including the VR setup, desktop setup, motion capture setup, and touchscreen tablet setup. All users share the same virtual workspace environment. All co-located and remote users virtually gather in the workspace.

2.1 FutureCouncil

The core module, named *FutureCouncil*, is our open-source presentation and visualization system. It supports collaborative interactions and live coding, and runs in desktop and VR modalities as an instance on multiple clients. Changes in the interactive content and code scripting in one instance of this client are reflected across all clients and affect all modules. This enables cross-device participation as users build, iterate, and work together.

2.2 Robot Modules

The feeling of shared immersion is enhanced through active tangibles. The tangible interface utilizes Sony Toios and iRobot Creates to provide physical feedback. The Toios move around on the table as physical proxies to represent the location and velocity of virtual objects when touched and moved by the VR user. The iRobot will match the position with the Toios, providing haptic feedback to the optiTrack user when he/she touches the virtual object. The interface can simulate haptic feedback and mimic the haptic sensations that occur when collocated people manipulate physical objects, such as the feeling of passing an object to another person.

2.3 Touchscreen Tablet Module

The touchscreen tablet user is an observer with the ability to interact with other other users and virtual content such as moving objects. We utilize the iPad's internal camera and LiDAR to track its position and orientation in physical space. That position and orientation drives its view into the virtual environment, and enables the tablet user to explore the environment from different perspectives by looking at the tablet display.

2.4 Connectivity

Our system facilitates asymmetric collaboration between multiple users, who take on different roles in the workspace. A collaboration of this sort requires a low latency network to connect co-located and remote users. Therefore, we chose Corelink (a low-latency, high-bandwidth research network developed by NYU) as the network infrastructure for transmitting data between *FutureCouncil* and the other clients, including Toios, iRobots, iPad, Optitrack and RealSense.

3 USER EXPERIENCE

Attendees will see our team collaborating together on a problem using multiple simultaneous mixed-modalities. Attendees will be able to jump-in and join the team, with the choice of interacting with active tangibles while optionally wearing a VR headset, or alternatively interacting via multitouch while looking into the shared virtual tabletop world through an inside-out tracked iPad. Through the use of real-time volumetric capture, the person holding the iPad will be visible to the people in VR. Attendees will also be able to interact with a miniature tabletop avatar of our mobile team member who is fully immersed in VR. As attendees move miniature robots around on the table, human-sized robotic embodiments of those tangibles will move around the room, where they can physically interact with the mobile team member in VR.

Our project seamlessly bridges the gap between multiple scales at the same time as it bridges the gap between multiple ways of interacting, between tabletop VR, full-body immersive AR and live coding.

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