# Exploring the use of Mobile Devices as a bridge for Cross-Reality Collaboration


Rishi Vanukuru*  Ellen Yi-Luen Do†

ATLAS Institute
University of Colorado Boulder, USA


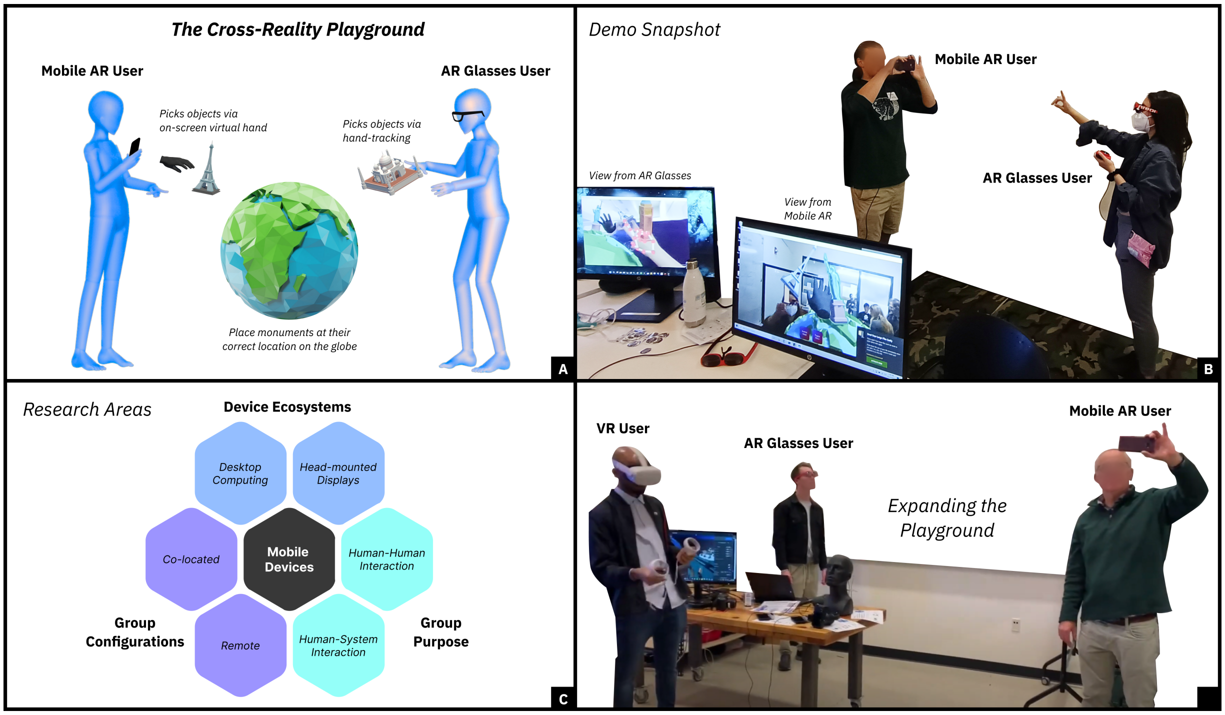


Figure 1: (A) An illustration of the key interactions in the Cross-Reality Playground. (B) An image from the demonstration of the prototype. (C) A diagram representing the overarching research space, with mobile devices as the connecting link between different device ecosystems, group configurations, and group purpose. (D) An image from an expanded version of the prototype, including VR users in co-located and remote spaces.


## Abstract

Augmented and Virtual Reality technologies enable powerful forms of spatial interaction with a wide range of digital information. While AR and VR headsets are more affordable today than they have ever been, their interfaces are relatively unfamiliar, and a large majority of people around the world do not yet have access to such devices. Inspired by contemporary research towards cross-reality systems that support interactions between mobile and head-mounted devices, we have been exploring the potential of mobile devices to bridge the gap between spatial collaboration and wider availability. In this paper, we outline the development of a cross-reality collaborative experience centered around mobile devices. Nearly 50 users interacted with the experience over a series of research demo days in our lab. We use the initial insights gained from these demonstrations to discuss potential research directions for bringing spatial computing and cross-reality collaboration to wider audiences in the near future.



*e-mail: rishi.vanukuru@colorado.edu
†e-mail: ellen.do@colorado.edu



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## 1 Introduction

Collaboration has long been the focus of spatial computing tools based on Augmented and Virtual Reality [8]. Some of the earliest research projects in the field concerned the use of handheld AR displays for 3D object inspection in teams [6], and collaborative scientific visualization using head-mounted displays [9]. Today, AR and VR headsets are growing more available in certain parts of the world, enabling a rich range of collaborative experiences both in-person (such as games on the Tilt Five[1] ) and remotely (through social VR worlds like Rec Room[2] and VRChat[3]). However, access to these devices is not widespread, and the interfaces themselves are unfamiliar to many. In contrast, AR experiences on mobile devices have introduced millions of people around the world to the power of spatial computing through tools, games, and social experiences [1, 4]. Researchers have studied how groups of users can work together with mobile AR [5, 10], but the possibilities for

[1]Tilt Five: tiltfive.com
[2]Rec Room: recroom.com
[3]VRChat: vrchat.com

interaction become much more interesting when asymmetric collaboration is considered—where users can leverage the advantages of diverse spatial computing devices, and share interfaces to work together. Addressing this need, the field of Cross-Reality interaction research has explored ways in which collaboration between users wearing head-mounted displays, and using hand-held devices, can be better supported. The ShareVR project demonstrated how users in VR could collaborate and play games with external users via tracked tablets [3]. Researchers have studied how such asymmetric device configurations affect pair-learning [2], and enable transitional interactions for collaboration [7]. Inspired by these approaches, we have been developing a cross-reality collaborative experience called the *Cross-Reality Playground*, for demonstrations within our research community. While there were pragmatic reasons for this choice—our lab had a limited number of AR glasses, and single-person experiences are insufficient when engaging larger audiences during demo days—we were also interested in observing how people made use of the asymmetric interaction possibilities to inform future research. In the next section, we describe the design of the *Cross-Reality Playground*, followed by a brief discussion on the findings from a series of demonstrations of the prototype.

## 2 Developing the Cross-Reality Playground

We began developing the *Cross-Reality Playground* to broaden participation in demonstrations showcasing hand-tracking interactions on AR Glasses (in this case, the Xreal Light[4]). We created an interactive puzzle experience where users were presented with a 3D globe, and a number of world monuments arranged all around. Their goal was to place the monuments at their correct location on the globe. This was an ideal task for hand-tracking, involving grasping, positioning, and placement, and users could freely walk around the globe. We then designed an equivalent AR experience for mobile devices, but replaced hand-tracking with on-screen touch interactions. Mobile users would see a virtual hand at a fixed distance in front of the screen. They could move their phone and virtual hand close to the monuments, touch the screen to pick up the object, and let go when they wished to place it. To address the issue of view-locking on 2D AR interfaces (where the orientation of picked objects is often fixed at the same value as the phone), we incorporated an interaction technique where once an object was picked by touching the screen, moving the user's finger in the vertical and horizontal axes then twisted the virtual hand similar to the human wrist. This aided mobile users in placing the monuments in their correct orientation, without having to maneuver the phone in odd angles.

Both the AR Glass and Mobile Phone experience were created as a single application using Unity 2022.2[5] and the respective device AR SDKs (ARCore[6] and NRSDK[7]). The application adapts to the device it runs on. We then incorporated the ability for multiple users to operate on the same set of monuments, by networking the movement of players and objects using the Photon SDK[8] for Unity. When multiple users start the application in the same location, the position and orientation of the globe is synchronized using a visual marker, after which the position and orientation of each object is transmitted across all devices, based on the user who is moving it. Users can also hand-off objects between each other, across AR glasses and mobile devices. The AR Glass user can see the virtual hand attached to mobile devices, while the mobile user only sees the monuments moving as if picked up directly by the AR glass user. With this networking framework, up to 6 users, with any combination of mobile phone/AR glass, can work simultaneously on the same set of objects. We also used a PC Client to reset the position of the monuments when a new set of users began the experience. Fig. 1A illustrates of the key functions of the prototype.

## 3 Discussion

We demonstrated the *Cross-Reality Playground* across two major demo days, and numerous in-lab sessions over the course of four months. We estimate about 50 users actively tried the demo[9] (Fig. 1 B), and many more observed their friends and family engage with it from outside AR. The purpose of this demonstration was to provide a glimpse into AR technology and collaboration possibilities, and was not designed to be a formal evaluation of the prototype. These informal engagements helped us include a much wider range of participants, from young children to their grandparents, with different levels of prior experience with AR. We were able to observe users' reactions in a more natural setting, and this encouraged more open discussions about their thoughts and feedback.

For many, the *Cross-Reality Playground* was their first experience with head-worn AR. In past demonstrations with just the AR glasses, we noticed that users were excited by the novel interface, but continued to think of it as something from the distant future. In contrast, being able to perform the same functional task—picking and placing monuments on the globe—using both the AR glasses and mobile devices helped ground their understanding of head-worn AR, and users could envision how the capabilities of phones today might translate to headsets in the future. This experience also seemed to elevate their opinion of mobile AR as being useful and comparable to head-worn alternatives. For those with prior experience in AR/VR, the prototype demonstrated a means for more inclusive engagement with friends, which was previously limited to watching the first-person view of games cast onto screen, or participating in a non-spatial manner using phones or laptops.

The familiarity of mobile devices presented new configurations for social interaction, and helped include users who might otherwise not be able to use AR glasses. The ways in which families interacted with the *Cross-Reality Playground* provided some of the strongest examples for this. Parents who were initially wary about the isolating effect of AR/VR headsets remarked that they would be more comfortable with their children using headsets if they could also participate using mobile devices. Grandparents who could not place the AR glasses over prescription lenses, or who were unable to make the hand gestures required due to limited range of motion, could participate with their grandchildren using mobile devices instead. Younger children, whose hands were too small to be accurately tracked by the AR glasses, could view the globe and monuments via phones, and direct their taller siblings to locations at the bottom of the globe which were easier for them to see. Taken together, the simple inclusion of a mobile device, and the opportunity to experience interactions in a cross-reality setting, can potentially help a wider range of users imagine a future where spatial computing is more integrated into everyday life.

## 4 Future Work

Encouraged by the response to the *Cross-Reality Playground*, we plan to more formally investigate cross-reality interfaces centered around the mobile phone. As evidenced from the demo days, mobile devices can act as a bridge interface, not just between different modalities of AR, but also between users' notions of screen-based computing of today, and immersive computing of the near-future. We have started expanding the prototype to include interactions on laptops and in VR, both in-person and remotely (Fig. 1 C & D). By maximizing the potential for spatial interactions using mobile devices, and building cross-reality ecosystems with stronger connections between mobile devices, PCs, and immersive setups, we can better support meaningful collaboration between people, no matter where they are located, or what devices they have access to.

[4]Xreal Light: xreal.com

[5]Unity: unity.com

[6]Google AR Core developers.google.com/ar

[7]XReal SDK developer.xreal.com

[8]Photon Fusion: photonengine.com

[9]The *Cross-Reality Playground* Demo Video: rishivanukuru.com

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