Designing and Studying Social Interactions in Shared Virtual Spaces using Mobile Augmented Reality

Rishi Vanukuru
rishi.vanukuru@colorado.edu
ATLAS Institute,
University of Colorado Boulder

Amarnath Murugan
amarnath2105@gmail.com
IDC School of Design, IIT Bombay

Jayesh Pillai
jay@iitb.ac.in
IDC School of Design, IIT Bombay

Ellen Yi-Luen Do
ellen.do@colorado.edu
ATLAS Institute,
University of Colorado Boulder

1 INTRODUCTION

Most immersive virtual event platforms enable users to spatially interact with one another using two broad types of modalities: Computer-based Virtual Reality, or Immersive Augmented/Virtual Reality using head-mounted devices. The ubiquity of personal computers means that computer-based VR is much more widely available, however, users miss out on the rich spatial experience that Immersive AR/VR headsets provide—devices that few people have access to today. Large-scale immersive virtual event platforms deal with this trade-off by allowing participants to join using whatever modality the device they have is capable of (such as Mozilla Hubs [7]). Mobile AR is a promising modality that can provide an interactive spatial experience to a larger number of remote participants. While there are virtual event platforms that incorporate Mobile AR to some extent [10], a systematic exploration of the possible interactions in Mobile Social AR would be useful in identifying scenarios where this modality is most suitable. To that end, we have developed a mobile application that enables participants from around the world to socially interact with each other in shared AR spaces (Figure 1A). The activities in the application have been designed to explore different types of group communication, and various spatial interaction techniques. By studying how users navigate these communication-interaction configurations, we hope to understand the contexts in which users feel present and immersed in Mobile Social AR. At the workshop, we seek to gain feedback about our ongoing research on collaborative interactions in Mobile AR social spaces, and begin a conversation about the place mobile devices have in cross-modality virtual event platforms.

2 RELATED WORK

Recent research in the field of Social VR has explored the overarching ideas of self-representation [4] and group dynamics [6, 13], as well as more context-specific implementations [5, 9]. In the case of Social AR using head-mounted devices, researchers have also investigated the effects of avatar representation [14] and interaction techniques [1] on presence and collaboration. Mobile AR has been studied as a tool for co-located social experiences [2, 12], and as a means for spatial referencing between remote pairs of users [8]. However, there has been limited work that explores its use in remote social situations involving larger groups, where issues of Mobile AR interaction techniques, avatar representation, and presence are intertwined.

3 SOCIAL INTERACTION IN MOBILE AR

Our goals for this project are to 1) create a prototype to demonstrate a range of possible interaction scenarios in Mobile Social AR, and 2) to use this prototype to investigate how people interact with each other, and with digital content, in such shared spaces. We aimed to cover a range of group configurations, based on their size and communication dynamics. Using mobile AR for long periods of time is likely to cause fatigue in users, and so we chose short social experiences to implement in our prototype. These were: 1) **Party Mode:** Users can have small parties around a virtual cake (Figure 1B), 2) **Parlor Games:** Simple word games that can be played in large groups, 3) **Pictionary:** Users draw pictures on a shared whiteboard while others guess what is being drawn (Figure 1C), 4) **Chess:** Pairs of users can spatially move the digital pieces on a shared chessboard, 5) **Jenga:** Multiple users can take turns at removing a piece from a stack of blocks in a manner that does not cause it to collapse (Figure 1D), and 6) **Spatial Puzzles:** Users collaboratively solve puzzles where individual pieces need to be arranged to form 3D shapes (Figure 1E). We now discuss these activities in the context of the underlying communication and interaction configurations that they are meant to represent.

3.1 The Communication-Interaction space

(1) **Group Size:** We designed activities specifically meant for pairs of users, as well as activities that could accommodate larger groups of up to ten people (*Parlor Games, Spatial Puzzles*).
(2) **Group Dynamics:**
- **Turn-taking:** We included activities with pairwise turn-taking *(Chess, Jenga)*, many-to-one communication *(Pictionary)*, and one-to-many communication *(Parlor Games)*.
- **Collaborative versus Competitive:** Some activities required all users to work together *(Spatial Puzzles)*, groups of users to form teams and compete *(Pictionary)*, and individuals to compete with each other *(Chess, Jenga)*.
- **Open-ended activities:** While games are good activities to motivate a group of people to interact, we also

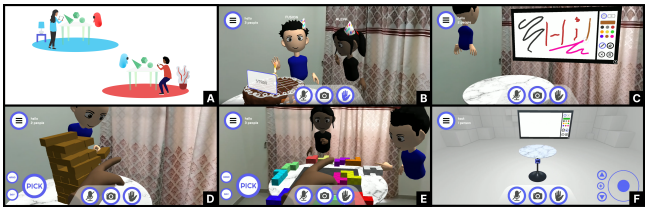

Figure 1: Mobile Social AR: Examples of social activities in the prototype.

included some open-ended scenarios (*Party Mode)* where users could shape the interactions how they wished.

The chosen activities also have specific types of interactions that users need to perform. These can be classified based on the degree to which spatial movement and input is involved.

(1) **1 Dimensional:** This category includes interactions that only require users to press buttons on the device's screen *(Parlor Games).*
(2) **2 Dimensional:** Drawing objects on the shared whiteboard by moving a finger on a touchscreen is an example of this interaction.
(3) **3 Dimensional:** These interactions involve the manipulation of digital 3D objects in the shared space *(Jenga, Spatial Puzzles).* In order to assess the impact of object size and fatigue due to physical movement, we implemented two variations of this type of interaction:
   - **Direct Manipulation:** Here, users have to physically move closer and farther away from objects to pick and move them around. The user sees a virtual hand on the screen as a visual aid for this process.
   - **Distant Interactions:** In this mode, we allow users to manipulate objects that fell in the path of a ray cast from the center of their device.

3.2 Social AR Prototype

We designed and developed an Android application to demonstrate these possible interactions[1]. The application was developed in Unity and utilizes the AR Foundation framework [11] to create a room-scale AR environment that users can move around in. We use Photon [3] to implement multiplayer communication, where we transmit speech audio, user movement, and interactions in the shared space. Users are represented by personalized avatars, and can move around a shared AR table.

3.3 Towards Cross-modality Collaboration

To further increase access to at least some form of spatial interaction, we developed the application so that it can be used on any mobile device with a gyroscope (many phones still do not support device tracking with 6 degrees of freedom). In such cases, the experience becomes one with 3 degrees of freedom, and users have the ability to look around a virtual scene in all directions by rotating their device. User movement is controlled by a joystick on the screen (Figure 1F). Users with devices capable of room-scale AR can switch back and forth between the two modes (6DOF and 3DOF). We are interested to see how people in the same shared virtual space, but using different modalities, are able to interact and work with each other.

[1]https://imxd.in/socialxrparty

4 CONCLUSION

This position paper presents ongoing research into the use of Mobile AR as a modality for remote social experiences. We have outlined the activities in our prototype, and discussed the rationale behind their selection and design. We plan to conduct user studies over the coming months, and hope to present some of our findings at the workshop. Moving forward, we are interested in studying cross-modality platforms involving Mobile AR alongside Computer-based VR and Immersive AR/VR. Mobile AR is bound to have its limitations, but we think that it has the potential to strike a balance between the spatial interactions that make virtual events so compelling, and the wider availability that would allow more people to be included in the future of immersive virtual collaboration.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant IIS-2040489.

REFERENCES

[1] Huidong Bai, Prasanth Sasikumar, Jing Yang, and Mark Billinghurst. 2020. A user study on mixed reality remote collaboration with eye gaze and hand gesture sharing. In *Proceedings of the 2020 CHI conference on human factors in computing systems*. 1–13.
[2] Po Bhattacharyya, Radha Nath, Yein Jo, Ketki Jadhav, and Jessica Hammer. 2019. Brick: Toward a model for designing synchronous colocated augmented reality games. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–9.
[3] Photon Engine. 2022. *Multiplayer Game Development made Easy.* Retrieved February 28, 2022 from https://www.photonengine.com/
[4] Guo Freeman and Divine Maloney. 2021. Body, avatar, and me: The presentation and perception of self in social virtual reality. *Proceedings of the ACM on Human-Computer Interaction* 4, CSCW3 (2021), 1–27.
[5] Divine Maloney, Guo Freeman, and Andrew Robb. 2020. A Virtual Space for All: Exploring Children's Experience in Social Virtual Reality. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. 472–483.
[6] Fares Moustafa and Anthony Steed. 2018. A longitudinal study of small group interaction in social virtual reality. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*. 1–10.
[7] Mozilla. 2022. *Mozilla Hubs: Meet, share and collaborate together in private 3D virtual spaces.* Retrieved February 28, 2022 from https://hubs.mozilla.com/
[8] Jens Müller, Roman Rädle, and Harald Reiterer. 2017. Remote collaboration with mixed reality displays: How shared virtual landmarks facilitate spatial referencing. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 6481–6486.
[9] Anthony Scavarelli, Ali Arya, and Robert J Teather. 2019. Towards a framework on accessible and social VR in education. In *2019 IEEE conference on virtual reality and 3D user interfaces (VR)*. IEEE, 1148–1149.
[10] Spatial. 2022. *Spatial - Seamlessly Connect From Any Platform.* Retrieved February 28, 2022 from https://spatial.io/
[11] Unity. 2022. *AR Foundation Cross Platform Development Framework.* Retrieved February 28, 2022 from https://unity.com/unity/features/arfoundation
[12] Thomas Wells and Steven Houben. 2020. CollabAR–Investigating the Mediating Role of Mobile AR Interfaces on Co-Located Group Collaboration. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.
[13] Julie Williamson, Jie Li, Vinoba Vinayagamoorthy, David A Shamma, and Pablo Cesar. 2021. Proxemics and social interactions in an instrumented virtual reality workshop. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–13.
[14] Boram Yoon, Hyung-il Kim, Gun A Lee, Mark Billinghurst, and Woontack Woo. 2019. The effect of avatar appearance on social presence in an augmented reality remote collaboration. In *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*. IEEE, 547–556.