Title: Remote Collaboration Strategies for Everyday Public Spaces

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Context

Recent advances in Virtual and Augmented Reality (VR and AR) technology are enabling people to experience VR and AR in a plethora of everyday spaces, such as at home, the office, and even more restrictive environments such as in airplanes or even public transport. Differently from conventional devices such as laptops and mobile phones, VR and AR (which constitutes Extended Reality, or XR) users can use their whole body or 3D devices as input, which may be suited for more specialised tasks such as architecture or more complex games that require 3D input [1]. However, physical affordances of such everyday spaces may pose a problem, as obstacles and other people may be present, which may hinder the ability for users to move freely within the virtual environment (VE) and limit the socially acceptable experience for both immersed users and bystanders.

Previous work has shown that in more restrictive everyday spaces, such as the airplane, users may prefer to compromise physical comfort to avoid social collisions caused by physically colliding or staring at people in close proximity [2]. Further work [3] expanded on this concept by showing that users tend to use physical affordance to anchor virtual content, and orientation and proximity to other people influence how they prefer to visualize content within a virtual environment to ensure a more socially comfortable experience. The social impact of interaction techniques also may need to be considered, as gestures may enable more close-to-real experiences and increase the sense of "being there" in the environment but may make the user feel more awkward when in a public setting [4].

Thus far, research in public everyday spaces has been confined to single-user use, leaving unexplored one of the key applications of XR, which is remote collaboration. XR allows people to share the same virtual space as they were physically present, facilitating remote collaboration using verbal and non-verbal cues, such as gaze, pointing, and deictic gestures [5,6]. The use of XR for remote collaboration in public spaces presents a unique challenge, as both users may be in different physical spaces with varying sizes, physical affordances, and the presence of people. Including an additional user to interact with necessitates that remote collaboration in everyday spaces considers the physical affordances of all remote collaborators and the potential impact collaborators may have on enabling a socially acceptable experience for all participants. The primary objective of this research is to delve into the possibilities of enabling remote collaboration in everyday spaces by examining how to position remote participants in a shared space and what are the most socially acceptable interaction techniques to use in such a public context. Ultimately, we aim to tackle these challenges by proposing guidelines that can be used to dynamically adapt virtual content and interaction in public spaces.

Motivation and Thesis Objectives

The main goal of this thesis is to explore how to enable remote collaboration in public, everyday spaces in collaborative sessions with two or more people, where all of them are in a public environment. We want to categorize the types of social spaces that may be used for collaboration, and research effective ways to position all users in a way that makes remote collaboration possible without a high compromise in social acceptability for public use.

Most importantly, in this research we want to gather understanding in how to position users in such a way to enable effective interaction and collaboration, while maintaining a meaningful level of social

acceptability. Additionally, we want to explore combination of interaction techniques that minimise the use of voice and expressive gestures to enable more acceptable forms to interact in a remote session. Finally, we plan to use the guidelines proposed to enable to dynamically adapt both the content and the interaction technique to the space people are in. The results of the research conducted will be submitted in major venues in the HCI and VR domain in conferences such as ACM CHI, IEEE Virtual Reality and ISMAR (Core A*) and top journals in the field such as IEEE Transactions on Visualizations and Computer Graphics and is part of the priority themes of PC1 of PEPR Ensemble.

Year 1 – Definition of Public spaces, tasks, and interaction scenario

In this phase the student will categorize the different public spaces that can be used for XR interaction. This will be followed by an evaluation building of a prototype to test different forms of remote user placement in each of the defined scenarios.

Year 2 – Exploration of Interaction Techniques

Another major aspect of remote collaboration is what type of interaction techniques are used. Single-user previous research has identified that more discreet gestures are better for interaction in public spaces [4]. However, they lack the precision needed for interaction in complex VR scenes. Also, this work is limited to a video survey in a single-user scenario, which may affect the general results. This phase will consist on lab studies to define a combination of interaction techniques for use in everyday public spaces, to determine how to find the best compromise between efficient collaboration, interaction and social acceptability.

Year 3 - Adaptive User placement based

Based on the previous milestones, we will propose methods to enable to adapt user, interaction and content placement according to the environment the user is in.

Bibliography

[1] de Klerk, R., Duarte, A.M., Medeiros, D.P., Duarte, J.P., Jorge, J. and Lopes, D.S., 2019. Usability studies on building early stage architectural models in virtual reality. *Automation in Construction*, *103*, pp.104-116.

[2] Ng, A., Medeiros, D., McGill, M., Williamson, J., & Brewster, S. (2021, October). The passenger experience of mixed reality virtual display layouts in airplane environments. In *2021 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)* (pp. 265-274). IEEE.

[3]Medeiros, D., McGill, M., Ng, A., McDermid, R., Pantidi, N., Williamson, J., & Brewster, S. (2022). From shielding to avoidance: Passenger augmented reality and the layout of virtual displays for productivity in shared transit. *IEEE Transactions on Visualization and Computer Graphics*, *28*(11), 3640-3650.

[4] Medeiros, D., Dubus, R., Williamson, J., Wilson, G., Pöhlmann, K., & Mcgill, M. (2023). Surveying the Social Comfort of Body, Device, and Environment-Based Augmented Reality Interactions in Confined Passenger Spaces Using Mixed Reality Composite Videos. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, *7*(3), 1-25.

[5] Medeiros, D., Dos Anjos, R., Pantidi, N., Huang, K., Sousa, M., Anslow, C., & Jorge, J. (2021, March). Promoting reality awareness in virtual reality through proxemics. In *2021 IEEE Virtual Reality and 3D User Interfaces (VR)* (pp. 21-30). IEEE.

[6] Sousa, M., dos Anjos, R.K., Mendes, D., Billinghurst, M. and Jorge, J., 2019, May. Warping deixis: distorting gestures to enhance collaboration. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-12).