PhD proposal

Acronym and title: PercARSpace - Perception of Shared Spaces in Collaborative Augmented Reality

Host institution and direction: The PhD student will be hosted at IMT Atlantique (Brest campus) within the INUIT team of Lab-STICC. The proposed thesis director is Cédric Fleury.

Context:
Remote collaboration in Augmented Reality (AR) involves that all users bring a part of their own physical environment into the shared environment [3, 8]. There are various ways to share these spaces [2], including: (i) equitable modes where all users bring an equal part of their physical space [4]; (ii) host-guest situations where the host imposes the shape of the augmented environment to the guests [6, 7, 10]; or (iii) mixed environments specifically designed for a collaborative task [5, 9]. Regardless of the configuration, the question of how users perceive this shared environment arises.
While spatial perception has been widely studied in Virtual Reality, it remains an open question in AR. Co-localization and integration of the real environment are crucial factors that significantly impact spatial perception. These factors are even more important in remote collaboration situations, as the presence of several collaborators with their own physical environment contributes to perceptual biases.

Scientific objectives:
The main objective of this project is to study the spatial perception in remote collaborative situations in AR and propose rendering and interaction guidelines for improving collaboration and maximizing users' immersion. We will explore several collaborative situations, as those mentioned previously. However, we also want to investigate situations with more than two users. Especially, we want to target hybrid situations, such as a collaboration between a group of co-located people and a remote user. Creating a true common space is crucial in such a situation to prevent the remote user from feeling excluded from the collaboration.

Approach and challenges:
Most of the previous work mainly focuses on the technical aspects allowing to reconstruct and blend users' physical spaces. The novelty of our approach is to tackle the problem in the opposite direction: we first want to study how users perceive the space of remote collaborators in AR and identify the cues that need to be shared to establish a common ground [1]. We will then create new representations that mix symbolic and realistic elements to build a common space shared between users. This common space will improve users' mutual understanding and allow a fluid interaction between them.
This approach contains two main challenges. First, we need to understand how users perceive space in such a context and which level of information at mandatory to build a mental representation of the shared space.
Second, the proposed space representations must enable users to consider the AR environment as a unique common space and not as a superposition of environments belonging to each collaborator. They should also not overload users and hinder the achievement of the collaborative task.

Organization of the PhD project:
The PhD work will be organized according to the following steps:
- First 6 months: the PhD student will develop an augmented reality environment to connect remote spaces, in parallel with the state-of-the-art analysis.

- Next 12 months: the student will study spatial perception in several collaborative situations ranging from sharing a few virtual or real objects to a complete 3D reconstruction of remote collaborator spaces.
- Next 12 months: the student will design and evaluate new space representations and propose some guidelines to combine remote physical spaces in a same AR space. He or she will test the proposed representations in more advanced scenario including collaborative situations with more than two users.
- Last 6 months: the student will focus on writing the thesis manuscript and finalizing papers.

Partners:

- Cédric Fleury, MCF in computer science/HCI at IMT Atlantique / Lab-STICC, INUIT team
- Etienne Peillard, MCF in computer science/HCI at IMT Atlantique / Lab-STICC, INUIT team
- Nathalie Le Bigot, MCF in Psychology at Univ. de Bretagne Occidentale, Lab-STICC – COMMEDIA team

References:

[1] H. H. Clark, and S. E. Brennan. "Grounding in communication". In: L. B. Resnick, J. M. Levine, & S. D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 127–149). American Psychological Association. 1991.

[2] B. T. Kumaravel, F. Anderson, G. Fitzmaurice, B. Hartmann, and Tovi Grossman. "Loki: Facilitating Remote Instruction of Physical Tasks Using Bi-Directional Mixed-Reality Telepresence". *Proceedings of the ACM Symposium on User Interface Software and Technology* (UIST '19), 2019.

[3] P. Ladwig and C. Geiger. "A Literature Review on Collaboration in Mixed Reality". *International Conference on Remote Engineering and Virtual Instrumentation* (REV). 2018.

[4] N. H. Lehment, D. Merget and G. Rigoll. "Creating automatically aligned consensus realities for AR videoconferencing". *IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, 2014.

[5] T. Mahmood, W. Fulmer, N. Mungoli, J. Huang and A. Lu. "Improving Information Sharing and Collaborative Analysis for Remote GeoSpatial Visualization Using Mixed Reality". *IEEE International Symposium on Mixed and Augmented Reality* (ISMAR), 2019.

[6] O. Oda, C. Elvezio, M. Sukan, S. Feiner, and B. Tversky. "Virtual Replicas for Remote Assistance in Virtual and Augmented Reality". *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology* (UIST '15), 2015.

[7] S. Orts-Escolano, C. Rhemann, S. Fanello, W. Chang, A. Kowdle, Y. Degtyarev, and al. "Holoportation: Virtual 3D Teleportation in Real-time". *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (UIST '16). 2016.

[8] M. Sereno, X. Wang, L. Besancon, M. J. Mcguffin and T. Isenberg, "Collaborative Work in Augmented Reality: A Survey". *IEEE Transactions on Visualization and Computer Graphics. 2020.*

[9] Chiu-Hsuan Wang, Chia-En Tsai, Seraphina Yong, and Liwei Chan. "Slice of Light: Transparent and Integrative Transition Among Realities in a Multi-HMD-User Environment". *Proceedings of the 33rd Annual ACM Symposium on User Interface Software and Technology* (UIST '20). 2020.

[10] J. -E. Shin, B. Yoon, D. Kim, H. -I. Kim and W. Woo, "The Effects of Device and Spatial Layout on Social Presence During a Dynamic Remote Collaboration Task in Mixed Reality," *Proceedings of the IEEE International Symposium on Mixed and Augmented Reality* (ISMAR), 2022.