PhD Proposal

# Collaboration in Hybrid Environments (AR, VR, desktop): multi-Views with Different Physicalities and Dimensions

## Host Institution

IMT Atlantique and Université Grenoble Alpes

This thesis project is a new collaboration between the INUIT research group of the Lab-STICC (IMT Atlantique - Brest) and the IIHM research group of LIG (Université Grenoble Alpes).

## Proposed PhD supervisors

Cédric Fleury 50%, Laurence Nigay 50% cedric.fleury@imt-atlantique.fr, laurence.nigay@univ-grenoble-alpes.fr

## Context

Hybrid environments involving Augmented reality (AR), Virtual Reality (VR) and standard WIMP desktop offer many opportunities for remote collaboration. For instance, a user in AR can share views of their physical environment. These views can be enriched by virtual contents defined by another remote user (using a VR headset or a standard desktop). This is particularly relevant when one or more remote experts want to assist “on-site” collaborators, as they can display virtual aids on the collaborators’ view, enhancing communication and collaboration. Such remote assistance can be useful in many situations, including medical [5] and industrial [7] contexts. However, remote experts may also need to explore other additional views to provide appropriate assistance. They can freely navigate in virtual representations of the collaborators’ environment to get a different point of view. They can also use 2D views to obtain additional information, such as X-rays of the patient in a medical context, or blueprints of the equipment in an industrial context. Synchronizing experts’ viewpoints across multiple views and sharing them with the “on-site” collaborators is a real challenge in such contexts. Multiple views (2D/3D views, virtual/mixed views) define the context of the proposed research on collaboration in hybrid environments.

## Scientific and Technical Objectives

The goal of this project is to support collaboration between several “on-site” collaborators equipped with AR headsets and remote collaborators/experts equipped with heterogeneous devices ranging from standard desktop computers to VR headsets. We target a scenario in which the remote experts have to assist the “on-site” collaborators in tasks they perform in their physical environment. To achieve this, the “on-site” collaborators and the experts need to explore multiple views with different physicalities (virtual or mixed views) and dimensions (2D or 3D views), including augmented views of the physical environment and/or physical objects, views of virtual representations of the physical environment and/or physical objects, and views of other 2D representations such as images, drawings or blueprints. The objective of this project is to investigate, design, implement and evaluate solutions that enable the “on-site” and remote collaborators to share and synchronize their viewpoints on these various views. We therefore propose to explore the key notion of view coordination (strongly coupled views and loosely coupled views) during collaboration between remote users in hybrid environments.

## Positioning and Originality

Many previous systems [4] have used AR to enable remote experts to assist or guide an “on-site” collaborator. However, there is usually only one “on-site” collaborator and the experts are often constrained to follow this collaborator’s viewpoint. Other systems [1, 6] allow the remote experts to freely navigate in a 3D reconstruction of the collaborator’s physical environment. Tait and Billinghurst [11] demonstrated that ensuring view independence can improve collaboration performance. However, remote experts are still limited to one single view in such systems. This does not allow them to combine information from multiple sources and to have their own view of the scene, while still being able to perceive the “on-site” collaborator’s viewpoint.

Previous work has explored how to combine multiple views [2, 12], how to quickly switch between different views [10] and how to seamlessly interact between 2D desktop and 3D AR [9] in mixed reality systems. However, this work focuses only on a single-user context. In a collaborative context, *Duplicated Reality* [13] proposes to duplicate a portion of the physical world into an interactive virtual copy located elsewhere in the AR space, but this work only targets co-located collaboration. Finally, *ARgus* [3] allows remote experts to preview and switch between multiple views on the workspace of an AR user. However, this work does not investigate how the remote experts could share their viewpoint with the AR user and how the users can synchronize their viewpoints.

## Approach

Two complementary axes will be studied:
1 - Transitioning between views: the “on-site” collaborators can have the ability to switch between views to see the viewpoints defined by the remote experts: this is a case of tight-coupling between the views of the “on-site” collaborators and the views of the remote experts. This can involve changing the physicalities of the views, from their current view on the physical augmented environment to views on virtual representations, and vice-versa. Switching to a virtual viewpoint different from the physical one would create a visual inconsistency with the physical environment. To avoid any visual inconsistency between the physical part and the virtual part, physical objects or the physical environment could be hidden. Thanks to this seamless transition from AR to diminished AR or VR mode, only the virtual objects or the virtual environment remain visible until “on-site” collaborators change back to a viewpoint where the mixed environment is coherent. This transition can also involve changing the dimensions of the views between 3D and 2D views. Appropriate transitions between views will be required to preserve users’ spatial awareness and avoid disorientation.
2 - Guiding between views: the “on-site” collaborators can also be guided to physically move in the physical environment and reach the same viewpoints as the remote experts. We plan to use guidance techniques [8] to help them during physical navigation. Once they have reached the correct position, the virtual content of the remote experts can thus be displayed consistently with the physical objects.
We then envision combining the two complementary axes: the “on-site” collaborators can quickly switch between views to take a look at what the remote experts want to show them, and then, be guided to the correct physical location once they need to perform the corresponding tasks. This physical displacement will allow them to restore the spatial relationship between the virtual content and the physical environment.

## Organization of the project (Duration)

- State of the art and handling of the subject: 3 months
- Transitioning between views: design space and experimental exploration: 18 months
- Guiding between views: design space and experimental exploration: 11 months
- Thesis writing: 4 months

## Bibliography


1. H. Bai, P. Sasikumar, J. Yang, and M. 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 (CHI '20)*, pp. 1–13. https://doi.org/10.1145/3313831.3376550
2. C. Bailly. 2020. “Interagir en réalité mixte avec un casque : application à la chirurgie augmentée”, PhD Thesis, Univ. Grenoble Alpes, Chpt 5. https://theses.hal.science/tel-03185064
3. A. Fages, **C. Fleury**, and T. Tsandilas. 2022. “Understanding Multi-View Collaboration between Augmented Reality and Remote Desktop User”, *in Proceedings of the ACM on Human-Computer Interaction*, Vol. 6, Issue CSCW2, no. 549, pp. 1–27. https://doi.org/10.1145/3555607
4. C. G. Fidalgo, Y. Yan, H. Cho, M. Sousa, D. Lindlbauer, and J. Jorge, 2023. “A Survey on Remote Assistance and Training in Mixed Reality Environments”, *in IEEE Transactions on Visualization and Computer Graphics (TVCG)*, vol. 29, no. 5, pp. 2291-2303. https://doi.org/10.1109/TVCG.2023.3247081
5. D. Gasques, J. G. Johnson, T. Sharkey, Y. Feng, R. Wang, Z. Robin Xu, E. Zavala, Y. Zhang, W. Xie, X. Zhang, K. Davis, M. Yip, and N. Weibel. 2021. “ARTEMIS: A Collaborative Mixed-Reality System for Immersive Surgical Telementoring,” *in Proceedings of the ACM CHI Conference on Human Factors in Computing Systems (CHI '21)*, Article 662, pp. 1–14. https://doi.org/10.1145/3411764.3445576
6. P. Mohr, S. Mori, T. Langlotz, B. H. Thomas, D. Schmalstieg, and D. Kalkofen. 2020. “Mixed Reality Light Fields for Interactive Remote Assistance”, *in Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20)*, pp. 1–12. https://doi.org/10.1145/3313831.3376289
7. O. Oda, C. Elvezio, M. Sukan, S. Feiner, and B. Tversky. 2015. “Virtual Replicas for Remote Assistance in Virtual and Augmented Reality”, *in Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST '15)*, pp. 405–415. https://doi.org/10.1145/2807442.2807497
8. P. Perea, D. Morand, and **L. Nigay**. 2019. “Spotlight on Off-Screen Points of Interest in Handheld Augmented Reality: Halo-based techniques”, *in Proceedings of the 2019 ACM International Conference on Interactive Surfaces and Spaces (ISS '19)*, pp. 43–54. https://doi.org/10.1145/3343055.3359719
9. C. Plasson, R. Blanch, **L. Nigay**. 2022. “Selection Techniques for 3D Extended Desktop Workstation with AR HMD”, *in Proceedings of IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp.460-469. https://doi.org/10.1109/ISMAR55827.2022.00062
10. M. Sukan, S. Feiner, B. Tversky and S. Energin. 2012. “Quick viewpoint switching for manipulating virtual objects in hand-held augmented reality using stored snapshots”, *in Proceedings of IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, pp. 217-226. https://doi.org/10.1109/ISMAR.2012.6402560
11. M. Tait, and M. Billinghurst. 2015. “The Effect of View Independence in a Collaborative AR System”. in Computer Supported Cooperative Work 24, pp. 563–589, Springer. https://doi.org/10.1007/s10606-015-9231-8
12. M. Tatzgern, R. Grasset, E. Veas, D. Kalkofen, H. Seichter, and D. Schmalstieg. 2015. “Exploring real world points of interest: Design and evaluation of object-centric exploration techniques for augmented reality”, in Pervasive and Mobile Computing, Vol. 18, pp. 55-70. https://doi.org/10.1016/j.pmcj.2014.08.010.
13. K. Yu, U. Eck, F. Pankratz, M. Lazarovici, D. Wilhelm, and N. Navab. 2022. “Duplicated Reality for Co-located Augmented Reality Collaboration”, *in IEEE Transactions on Visualization and Computer Graphics (TVCG)*, vol. 28, no. 5, pp. 2190-2200. https://doi.org/10.1109/TVCG.2022.3150520