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

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Description of the PhD proposal

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 with 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 [8] contexts. However, remote experts may need to explore 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 in a medical context, or blueprints 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.

Problem and Scientific 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

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 one expert, who is constrained to follow this collaborator’s viewpoint. Other systems [1, 7] allow the remote expert to freely navigate in a 3D reconstruction of the collaborator’s physical environment. Tait and Billinghurst [12] demonstrated that ensuring view independence can improve collaboration performance. However, the remote expert is 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.

Other previous work has explored how to combine multiple views [2, 13], how to quickly switch between different views [11] and how to seamlessly interact between 2D desktop and 3D AR [10] in mixed reality systems. However, this work focuses only on a single-user context. *Duplicated Reality* [14] proposes to duplicate a portion of the physical world into an interactive virtual copy located elsewhere in the AR space, but this work 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 users can synchronize their viewpoints.

Research Questions

We plan to investigate the following research questions:

1. How can the “on-site” collaborators and the remote experts share and synchronize their viewpoints when using multiple views with different physicalities and dimensions?
2. What are the impacts of transitions between different views on users’ cognitive load and spatial awareness?

Approach

Two complementary axes will be studied:

1. *Transitioning between views:* “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 such visual inconsistency, 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:* “on-site” collaborators can be guided to physically move and reach the same viewpoints as the remote experts. We plan to use guidance techniques [9] 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.

Evaluation of the contributions

To assess our contributions and the impacts of transitions between different views on users and their collaborative activities, we will conduct controlled experiments in which we will collect quantitative data on performance, as well as qualitative data on cognitive load and co-presence. In addition, we will probably ask participants to perform additional tasks at certain times to assess their spatial awareness. Finally, we could also rely on the methods and systems [6] that our candidate used during this master’s internship to evaluate the collaboration in real-time during collaborative activities in VR.

Theoretical foundations

The proposed research will be based on collaborative work and the management of multiple views.

1. *Collaborative work:* Collaborative work usually involves both shared and individual activities: “tightly coupled” and “loosely coupled” collaboration. The research will be based on collaborative coupling styles: for instance the descriptive framework proposed by Neumayr et al. for coupling styles in partially distributed team:
   T. Neumayr, H-C Jetter, Mi. Augstein, J. Friedl, and T. Luger. 2018. “Domino: A Descriptive Framework for Hybrid Collaboration and Coupling Styles in Partially Distributed Teams”, in Proceedings of ACM Hum.-Comput. Interact. 2, CSCW, Article 128 (November 2018), 24 pages. https://doi.org/10.1145/3274397
   Based on the taxonomies and descriptive frameworks for coupling styles, we will focus on the coupling of views, and particularly the coordination of viewpoints between the views.
2. *Multiple view systems:* A key notion of multiple-view systems is the coordination of the views. This notion of coordination reflects how the changes on a given view affect the others. Strongly-coupled views imply that any change in one view is applied to the other views. On the contrary, with loosely-coupled views, changes in one view do not affect the other views. Several studies in the Visualization domain have focused on this concept of coordination between multiple views.
   M. Scherr 2008. “Multiple and coordinated views in information visualization”. Trends in Information Visualization 38, 1-33 (2008)

In the context of coupling styles in collaboration, we will consider only the coordination of viewpoints between collaborators' views. Combining views of different dimensions and physicalities (i.e. a mixed view and a virtual view) raises unique challenges for collaboration.

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Nature of digital collaboration

This PhD project will target group activities that involve **sharing** views and annotations on both digital and physical content, **coordinating** viewpoints on this content and **communicating** information about the contents and the tasks at hand. In this PhD, we will focus on **synchronous** collaboration, involving instantaneous communication with a time scale below the **second**. As a first step, we will be targeting a **remote collaboration** between an “on-site” user and a remote expert, but we will then extend the collaboration to multiple “on-site” users and multiple remote users, which implies **hybrid collaboration**. However, we will not be targeting collaboration with large groups of more than **five or six users**.

Contribution to digital collaboration: Expected results and Impact

The expected contributions of this PhD project are threefold:

- **Empirical:** the user studies performed during the PhD will enable us to determine the most appropriate solutions for allowing users to share and synchronize their viewpoints across different physicalities and dimensions. We will also be able to observe the impact of these solutions on collaborative activities.
- **Theoretical:** this PhD work will enable us to gain new insights:
    a. on the need for and use of tightly-coupled views in collaborative activities along with a visual notation to describe and analyze collaboration in terms of loosely/tightly-coupled views;
    b. on how users can transition between views, especially between AR and VR views, and on how this affects the users’ cognitive load and spatial awareness during a collaborative task.
- **Technical:** we will design collaborative systems that allow remote users to share digital data and video streams. These systems will also provide interaction techniques to synchronize viewpoints, to transition between views and to guide remote collaborators in a physical environment.

Positioning in the eNSEMBLE program

This project is in line with the research of the PC1 targeted project “Collaboration Spaces (CATS)” of PEPR eNSEMBLE. The project directly addresses the CATS axis 1 on heterogeneous collaboration spaces and the CATS axis 4 on transitions between collaboration spaces. Its originality lies in taking into account the different physicalities and dimensions of the views that populate collaboration spaces, and focusing on the transitions between these different types of views.