Mixed Reality Environments as Ecologies for Cross-Device Interaction

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Abstract
In Mixed Reality (MR) environments, virtual objects can be represented as if they were situated in the viewer's physical environment. While the potentials of MR have been recognized and extensively researched for single user scenarios (e.g., in perceptual studies), MR for collaborative scenarios has not been widely investigated. In this paper we propose MR environments as ecologies for collaborative, cross-device interaction. We provide a scenario that illustrates its potentials and discuss possible research directions. We then present intermediate results of our research.

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Introduction
Mixed Reality (MR) describes the combination of the representation of a physical environment (e.g., a room) and virtual objects (e.g., a virtual plant in a corner of that room) on a single display [6]. Because the virtual objects have a distinct position in the real-world coordinate system, they are perceived as if they were situated in the real world. This allows the user to interact with the real world and the digital world at the same time [1]. When virtual objects are experienced as part of the physical environment, MR environments can leverage our natural abilities that refer to the interaction and navigation in the real world. This includes the perception of spatial relationships of the objects in our environment, but also the social skills we've developed in the physical world (e.g., social protocols). In addition, in MR our physical environment can be considered as an information space in which we can lay out, navigate, and share digital data. This is particularly relevant for collaborative scenarios, as it allows for seamless, computer-supported, collaborative work [2].

Collaborative MR in the early (research lab) days:

Figure 1. "Transvision" [7], a design tool where collaborators look on a real table-top through a palmtop-sized see-through display. 3D data from the display is processed by an external graphics workstation.

Figure 2. "Studierstube" [8], a system capable to visualize three-dimensional, scientific data with see-through glasses. Tracking data is processed on an external tracking server.

To render virtual content correctly, MR devices need to be able to determine their location and orientation within their physical environment. There are several approaches to achieve this spatial awareness. (For an overview see [1]). Precise tracking within larger 3D volumes, however, typically required additional hardware, such as infrared cameras (Figures 1 and 2). Due to technological advances, displays for large-scale MR environments no longer require additional hardware and are now becoming affordable to the public. One of the recent devices is the Project Tango tablet (Figure 3). Spatial awareness is achieved by the principle of area learning: *"Using area learning, a Project Tango device can remember the visual features of the area it is moving through and recognize when it sees those features again. These features can be saved in an Area Description File (ADF) to use again later."*[1]

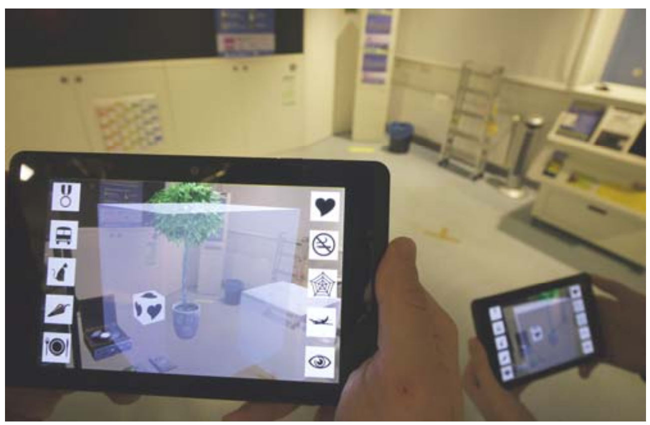

Figure 3. Collaborative MR currently: markerless tracking with Google's Project Tango[1] tablets. In this application, each person can place items on the shared information space and has their own perspective.

[1] https://www.google.com/atap/project-tango/

When an ADF is loaded, the device can localize, i.e., it becomes spatially aware. We consider this a core feature to enable MR-based, cross-device interaction: When collaborators within the same physical environment share the same ADF, their devices become spatially aware in terms of both their physical environment and of the other devices. The physical environment can then be used as a shared information space.

Chances and Challenges

To illustrate the potentials of MR environments as ecologies for collaborative cross device interaction in everyday situations, consider the following scenario:

Bob (an architect) and Alice (a civil engineer) are involved in an architectural project that aims at constructing a new central station. They meet at Alice's office to discuss Bob's latest drafts of the barrier-free main entrance. As Bob enters Alice's office, his tablet notifies him that an ADF is available for the current environment. After the ADF has loaded, he looks on his tablet and sees a virtual construction site laid out in Alice's office. Alice is standing in front of the window where the main entrance is supposed to be placed on the site. Bob opens the local folder on his tablet where he stores his drafts. He walks towards Alice and positions his 3D draft, which is now a part of the MR environment and thus visible to Alice. After a short discussion, Alice picks Bob's newly added model to make some modifications on it later on her computer. Bob in turn asks Alice for some project related text documents. Alice browses her local file system on the tablet and tells Bob that she was going to position them over her little houseplant (she points at the houseplant on her desk). Bob instantly sees the documents on his *display, which appear as a virtual stack of papers, and stores them on his file system.*

In the following we share our first ideas that may help to make such scenarios possible and propose associated research directions.

Technological Challenges

First, in order to enable participation in cross device activities, devices need to be able to communicate with each other. Thus, cross-platform technologies (e.g., HTML 5) should be used. Secondly, besides the spatial capabilities of devices described in this paper (e.g., through ADFs), there are other features and sensors that enable other forms of cross-device interaction. Therefore, profiles or a classification of device capabilities are needed. These profiles should summarize the features that are relevant for cross-device interaction. Following the example scenario, imagine a third person – Carol – is joining the meeting. Unlike Alice's and Bob's devices, Carol's device cannot handle area description files but has some other sensors (e.g., a proximity sensor) that can be used to establish cross device interaction in a different way. If such profiles are provided, a server could suggest to Carol an alternative way to establish a connection to the other devices. A third aspect refers to the type of task. Certain cross-device interaction techniques may be more appropriate for specific tasks than others. Once a server has registered the profiles of the present devices and the anticipated task, it could make suggestions considering the way interaction between the devices should be established.

Research Directions

On a conceptual level, spatial relations between the entities in an MR environment (persons and other physical and virtual objects) can be taken into account to facilitate interaction and collaboration. In particular for MR-based, cross-device interaction, proxemics dimension [4] and F-formations [5] could be used to trigger situation-dependent actions, e.g., render specific content at specific positions depending on the spatial and personal constellation of present collaborators. Furthermore, for tasks that require negotiation, visual cues play an important role [3] and help coordinating users' actions. Users who interact within the same MR environment can thereby make use of the same spatial cues. This raises the question what features and representation need to be available in MR environment in order to leverage "seamless, computer supported collaborative work" [2].

Ongoing Research

In our ongoing research, we are interested in the representation of MR environments, in particular in how virtual cues (Figure 4) shape communication and coordination in search and reconstruction tasks. We conducted a controlled lab experiment with 16 dyads. The experiment was designed as a counterbalanced, within-subjects design with the presence of virtual cues (cues provided vs. no cues provided) being the independent variable. For MR devices we provided each participant a Project Tango tablet which allowed a shared view on the MR environment.

Figure 4. Top: Dyads during the search task. All boxes are covered in this state. Lower left: no virtual cues provided, lower right: virtual cues provided (e.g., virtual chair, plant, and snack machine). Collaborators made extensive use of virtual cues to communicate spatial information (e.g., "I remember that symbol 'x' is located in front of the snack machine").

Search task: Dyads had to collaboratively solve a three-dimensional memory game. 10 symbol pairs from the Wingdings font were randomly distributed in a 3D volume with a dimension of 4m x 4m x 2m. Each symbol was represented as a texture on a box. In their initial state, boxes where white (Figure 3) and could be "uncovered" by touching them so that the symbol became visible. Collaborators had to find matches by uncovering two boxes per move. In order to induce the communication of spatial information, each collaborator had to uncover one box during each turn. Once a match was found, the boxes were removed. If the two uncovered boxes were not matches, they had be covered again in order to continue with the next move.

Reconstruction Task: In the reconstruction task, collaborators had to reconstruct the virtual scene by placing the symbol boxes at the correct position (Figure 3). The task was performed in the same condition (virtual cues provided or virtual cues not provided) as in the prior search task.

Intermediate results and implications: Our intermediate results show that all groups made extensive use of virtual cues to communicate object locations and to coordinate their actions. In the concluding interview, participants reported to have fully accepted the virtual objects as part of the environment. In addition, all groups gave the condition with the virtual cues a better rating. We therefore propose to provide virtual cues to support collaboration in MR environments.

Conclusion

In this paper we proposed MR environments as one possible approach to establish collaborative, cross-device interaction. We presented recent technological advances and discussed potentials and challenges for ad hoc, MR environments in everyday situations. Finally, we reported intermediate results from our ongoing research in which we suggest the use of virtual cues in MR environments to facilitate collaboration.

References

1. Mark Billinghurst, Adrian Clark, and Gun Lee. 2015. A Survey of Augmented Reality. *Foundations and Trends® in Human–Computer Interaction* 8, 2: 73–272.
2. Mark Billinghurst and Hirokazu Kato. 1999. Collaborative Mixed Reality. *Proc. of ISMR '99*, Springer, 261–284.
3. Alphonse Chapanis. 1975. Interactive Human Communication. *Scientific American* 232 (3): 36–42.
4. Saul Greenberg, Nicolai Marquardt, Rob Diaz-marino, and Miaosen Wang. 2011. Proxemic Interactions : The New Ubicomp ? *interactions* XVIII, february: 42–50.
5. Nicolai Marquardt, Hinckley, and S Greenberg. 2012. Cross-Device Interaction via Micro-mobility and F-formations. *Proc. of UIST 2012*, 13–22.
6. Paul Milgram and Fumio Kishino. 1994. Taxonomy of mixed reality visual displays. *IEICE Transactions on Information and Systems*, 1321–1329.
7. Jun Rekimoto. 1996. Transvision: A hand-held augmented reality system for collaborative design. *Proc. of VSM '96*, 85–90.
8. Dieter Schmalstieg, Anton Fuhrmann, Zsolt Szalavari, and Michael Gervautz. 1996. "Studierstube" - An Environment for Collaboration in Augmented Reality". *Proc. of CVE (Extended abstract)*, 19–20.