
Cooperative Mixed Reality: An Analysis Tool

Lisa M. Rühmann

Clausthal University of Technology
Clausthal-Zellerfeld, Germany
Lisa.Ruehmann@tu-clausthal.de

Michael Prilla

Clausthal University of Technology
Clausthal-Zellerfeld, Germany
Michael.Prilla@tu-clausthal.de

Gordon Brown

Clausthal University of Technology
Clausthal-Zellerfeld, Germany
Gordon.Brown@tu-clausthal.de

Abstract

While mixed reality scenarios are highly relevant for cooperation support, most work done in this context is on individuals. When working on cooperation support scenarios in MR, we arrived at situations in which we needed insights into the way how people used the technology to work together. To support the investigation of this question, we created a 3D analysis tool for interactive and cooperative task support in MR.

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.

GROUP '18, January 7–10, 2018, Sanibel Island, FL, USA

© 2018 Copyright is held by the owner/author(s).

ACM ISBN 978-1-4503-5562-9/18/01.

<https://doi.org/10.1145/3148330.3154510>

The tool and exemplary results from applying to a visual search experiment conducted in a cooperative mixed reality setting with Microsoft HoloLens devices are presented here. We show how it can uncover interaction otherwise not or hard to discover.

Author Keywords

Augmented reality, mixed reality, cooperative tasks, visual search, HoloLens, AR analysis tool.

ACM Classification Keywords

H.5.1 Multimedia Information Systems: Artificial, augmented, and virtual realities; H.5.3 Group and Organization Interfaces: Computer-supported cooperative work.

Introduction

Augmented reality (AR) with its multiple application areas is a technology that is currently gaining more importance. Using Azuma's words, AR "allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. (...) AR supplements reality, rather than completely replacing it." [1:356]. By using AR technology, users enter a mixed reality (MR) setting, in which digital and physical objects and information are tightly integrated and can be used together.

While there is potential for AR in cooperation support

(e.g., [2,3]), observing interaction and cooperation in MR is difficult, as it needs an integrated view on the virtual and real (physical, spatial) aspects of MR. This paper presents a novel tool for this analysis. The tool uses log and sensor data of devices, connects them to the spatial environment, and visualizes individual and cooperative activities.

Augmented Reality Analysis Tool

Common means for analysis of cooperation such as videotaping the cooperators and analyzing their work cannot capture the virtual aspects of the mixed reality setting (i.e., the virtual objects), and using the first-person view as seen by actors through head-mounted AR devices makes it hard to analyze the cooperation between the actors, i.e. to see how one actor influences another (cf. Figure 2). To our knowledge, no specific tools for the analysis of cooperative AR exist that help to overcome these issues. Due to the lack of such tools, we created a new tool for cooperative AR interaction analysis that uses log data created by our applications (see Figure 1). It represents the spatial environment in which actors are working together and makes their interaction with the



Figure 2: As a contrast to Figure 1, these two pictures here show the same situation as to be observed from outside the MR space (leaving out the virtual contents, top) and from the point of view of one participant (losing the spatial context, bottom).

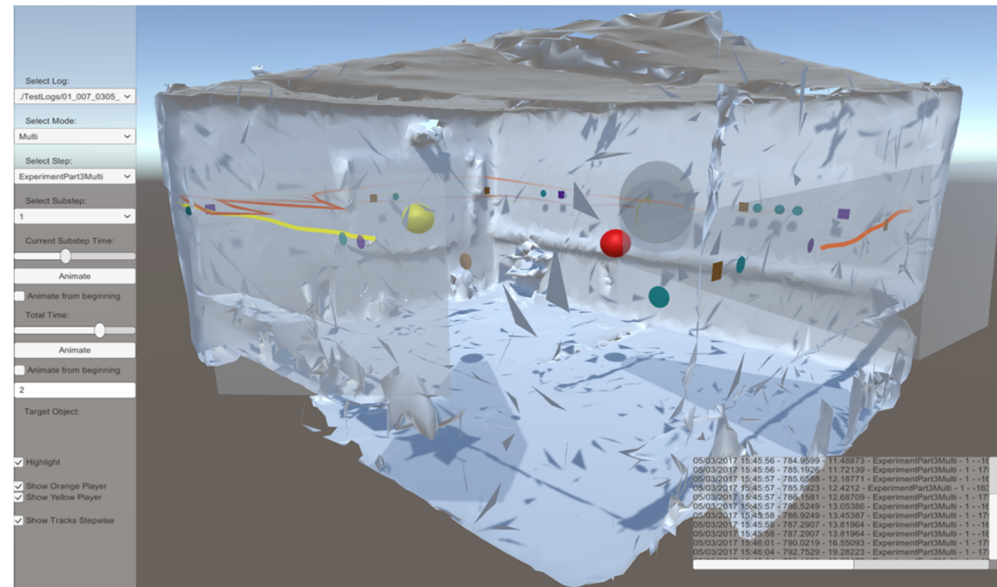


Figure 1: The AR Analysis Tool during the analysis of visual search, including the 3D model of the room, the 2D objects to be searched, the participants' field of view (shadows and cylindrical projection), the participants' positions (yellow/A, left; red/B, right), and gaze cues on the wall.

MR setting available. It uses different log data created by a tool we create for Microsoft HoloLens devices:

Model of the room: In order to place virtual objects accurately, the HoloLens creates a 3D model of rooms it works in (see Figure 1).

Head movements for gaze cues: The head tracker built into the devices was used to keep track of gaze cues ([5], cf. Figure 1). This was used for detecting search behavior, and the current gaze is available in real time to cooperators.

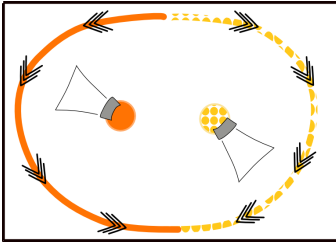


Figure 3: Depiction of Spinner Movement – the circles in the center represent the participants in their corresponding color (orange/solid (B) left, yellow/dashed (A) right) with a representation of their field of view. The lines on the outside show the gaze cues of the participants and the center shows a representation of their field of view. The arrows indicate in which direction the gaze developed over time.

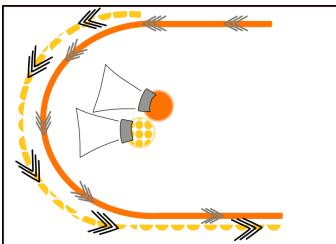


Figure 4: Depiction of a Following pattern. In this example, B is the one following and A is the leader during the search. This is shown through making the B's gaze line thinner and applying grey arrows that indicate the direction.

Body movements: We track movements by logging the position measured by the device. This is a very accurate way of determining the position.

Intersections with and looking at virtual objects: Movements and gaze are related to virtual objects in the room, which allows to identify where an object is in relation to a person and whether the person has looked at it, including the duration of looking at the object.

User interaction: The use of gestures for selecting and moving objects is logged for the analysis.

Application of the tool

Figure 1 shows a sample view of the tool during the analysis of a 2D search task performed by two people. Their task was to find a specific (virtual) object, which was randomly displayed amongst similar objects in a room via HoloLens devices and select it together. Figure 1 shows the heads of the two participants as balls, their gaze as cues on the wall and the virtual objects placed on the walls.

The tool offers different features for the analysis of cooperative MR (Figure 1). To support different levels of granularity for the analysis, it enables the selection of steps within an interaction such as the search task described above (i.e., repeated 2D searches). The timeframe can be manually controlled through a slider, and it features a time lapse for looking at interactions in more detail as well as selective hide and show mechanisms for virtual objects, users and gaze cues. The resulting tool provides a flexible and powerful means to analyze interaction of actors in MR. The features included in the tool currently are a subset of what may be needed, and we will discuss additions for the analysis of search patterns later on. The tool has

not been evaluated through a user study. This is a limitation we are aware of and will explore further in the future.

Exemplifying MR Analysis: Visual Search Patterns

To exemplify the usage of the tool and the benefit it creates for the analysis of interaction in MR, we describe search patterns we found by applying the tool. To identify the search patterns, we replayed the interaction during the search experiment described above and looked at gaze cues as coherent movements during search. Such cues were found to be a key to guiding co-located cooperation such as understanding other people's activities [5] and performing visual searches together [4,6]. Figure 1 shows gaze cues of two experiment participants. We also looked-for ways in which the participants of the experiment consciously worked together to carry out the search tasks. After the participants had received information on the object to look for and started to move within the search space, the identifying of the pattern began. The identification of patterns started once participants had the task presented to them and they started to move. In 2D search we identified two patterns with different specifications, with the "Spinner" pattern being the most common strategy used among the pairs:

Spinner: The "Spinner" (cf. Figure 3) describes a circular movement throughout the complete space from the starting point to the object searched, where one of the participants turned at least around halfway.

Following: The "Following" pattern (Figure 4) refers to one participant following the other while searching. This

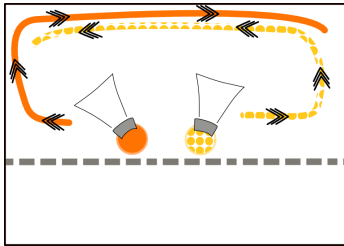


Figure 5: Depiction of the „Sep. Space (front half)“. The participants only searched in the space in front of them and did not turn around wherefore the part behind their backs was not searched.

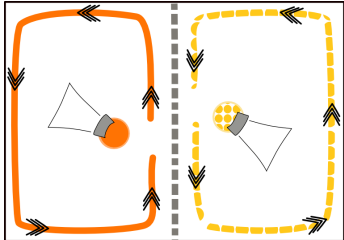


Figure 6: Depiction of „Sep. Space“ with the „My Half“ facet. The participants only explored the „half“ of the room they were standing in.

pattern was used to categorize the search if one participant began their motion shortly after the other participant moved and followed the other participant and the gaze cues were largely identical and did not differ from another except for the timing.

In the 3D search condition, we found three patterns:

Spinner: The “3D Spinner” pattern is similar to the Spinner described for 2D search.

Random: The “Random” search pattern refers to a search strategy in which the participants seemingly randomly and quickly looked around the search space.

Sep. Space: The “Sep. Space” (separation of space, cf. Figure 5 and Figure 6) refers to situations in which the participants only searched a specific part of the search space and neglected the other search space. In addition to the different patterns, differences within the groups concerning the ‘evolution’ of the search also became apparent. The analysis of these findings is beyond the scope of this paper and will be described elsewhere.

Discussion: Analyzing MR

While the tool presented here helped us to detect patterns we may have missed otherwise, our work also points to improvements and features for the tool, which we are exploring. One area could be automatic detection of patterns. As we know the characteristics of the patterns, this can be done in real time and displayed to the researcher, who then may analyze the searches deeper. We may also add pattern learning algorithms to the tool in order to detect new patterns or expand the existing catalogue of cooperation in MR.

Another area we are looking into is the integration of audio and video into the analysis tool. Audio would be helpful to understand how participants discussed and decided on search strategies and how they coordinated their search. The integration of video would do the same for deictic communication and analyzing outer actions of the actors. We used both sources for additional analyses in this paper, and integrating them into the analysis tool would be beneficial.

Conclusion

In this paper, we presented a novel tool for the analysis of cooperative MR settings, in which people work together supported by head-mounted AR devices. With respect to the tool for analysis we presented here, we show how it enables researchers to analyze situations in which users cooperate supported by AR devices, and how it goes beyond existing means for this analysis. We also identified needs for further development of this tool. In addition, the conduction of a user study is also needed. Our future work will further investigate the aspects discussed in this paper, and we invite other researchers to help develop methods for the analysis of this setting.

Acknowledgements

We would like to thank the developers of the analysis tool and the experiment application. We would also like to thank the participants of the search experiment.

References

1. Ronald T. Azuma. 1997. A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments* 6, 4: 355–385.
2. Mark Billinghurst and Hirokazu Kato. 2002. Collaborative Augmented Reality. *Commun. ACM* 45, 7: 64–70.
3. Dragoș Datcu, Stephan G. Lukosch, and Heide K. Lukosch. 2016. Handheld Augmented Reality for Distributed Collaborative Crime Scene Investigation. *Proceedings of the 19th International Conference on Supporting Group Work*, ACM, 267–276.
4. Marc Pomplun, Tyler W Garaas, and Marisa Carrasco. 2013. The effects of task difficulty on visual search strategy in virtual 3D displays. *Journal of vision* 13, 3: 24–24.
5. Randy Stein and Susan E. Brennan. 2004. Another Person’s Eye Gaze As a Cue in Solving Programming Problems. *Proceedings of the 6th International Conference on Multimodal Interfaces*, ACM, 9–15.
6. Yanxia Zhang, Ken Pfeuffer, Ming Ki Chong, Jason Alexander, Andreas Bulling, and Hans Gellersen. 2017. Look together: using gaze for assisting co-located collaborative search. *Personal and Ubiquitous Computing* 21, 1: 173–186.