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See-through techniques for referential awareness in collaborative virtual reality

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Abstract

Multi-user virtual reality systems enable natural collaboration in shared virtual worlds. Users can talk to each other, gesture and point into the virtual scenery as if it were real. As in reality, referring to objects by pointing results often in a situation whereon objects are occluded from the other users' viewpoints. While in reality this problem can only be solved by adapting the viewing position, specialized individual views of the shared virtual scene enable various other solutions. As one such solution we propose show-through techniques to make sure that the objects one is pointing to can always be seen by others. We first study the impact of such augmented viewing techniques on the spatial understanding of the scene, the rapidity of mutual information exchange as well as the proxemic behavior of users. To this end we conducted a user study in a co-located stereoscopic multi-user setup. Our study revealed advantages for show-through techniques in terms of comfort, user acceptance and compliance to social protocols while spatial understanding and mutual information exchange is retained. Motivated by these results we further analyze whether show-through techniques may also be beneficial in distributed virtual environments. We investigated a distributed setup for two users, each participant having its own display screen and a minimalist avatar representation for each participant. In such a configuration there is a lack of mutual awareness, which hinders the understanding of each other's pointing gestures and decreases the relevance of social protocols in terms of proxemic behavior. Nevertheless, we found that show-through techniques can improve collaborative interaction tasks even in such situations.

Keywords: Evaluation/methodology; Interaction techniques; 3D pointing; Collaborative virtual reality

1. Introduction

Multi-user virtual reality enables the joint experience of a shared 3D space in a similar way as in real life. Consequently, natural forms of gestural communication, such as pointing, can immediately be used for the collaborative inspection of computer-generated 3D models. Such real-world correspondence also results in real-world problems. One might want to show a virtual object to colleagues, but the object might be occluded from their respective viewpoints. To solve this problem in reality, people have to walk around the occluding objects to obtain a suitable viewing position. A common behavior is to move close to the person who is pointing to in order to see the specified object (e.g. by looking over his shoulder), which can result in physical proximity of users that does not comply with social protocols of formal presentations.

Co-located multi-user systems offer the possibility to provide each user with an individual view of the shared 3D scene (Agrawala et al., 1997). Our central idea is to equip users with augmented viewing capabilities for allowing them to look through objects if another person points at an occluded target. In particular, X-ray vision techniques are promising candidates, considering that they can be used to reveal hidden objects while maintaining most of the 3D local context information. We refer to these novel type of collaborative interaction techniques as "show-through" techniques, since the

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objects being pointed at are showing through occluding objects. We hypothesized that users would greatly appreciate show-through techniques and also that they would maintain larger distances to each other in order to feel more comfortable. On the other hand, we were concerned about the understanding of spatial relations in the presented 3D scene, as users can see referred objects without being actively involved in their visual discovery. Although objects can be identified more rapidly if occluding objects vanish automatically, it is likely to be more difficult to understand and memorize their exact 3D location in a complex environment. In addition, most humans are not experienced with such "magical" viewing capabilities.

Our study on show-through usability in a co-located multi-user VR system revealed that users become rapidly proficient with augmented vision and appreciate the techniques for facilitating collaboration at convenient interpersonal distances. Furthermore, we found no evidence of any negative impact of show-through techniques on the spatial understanding of the 3D model. In such a co-located situation, the actions of collaborators are very noticeable and thereby afford excellent understanding of spatial references. In a remote collaboration scenario, collaborators are replaced by virtual avatars. In particular for single screen displays, avatars are often hardly visible if the collaborators are working side by side and thus the level of co-presence and mutual awareness is much lower. The potential lack of accurate knowledge about the position of others in the shared virtual space may hamper the understanding of spatial references and relations (Fig. 1).

Show-through techniques can reduce the chance of ambiguous references in such situations. Selected objects are not only highlighted; they become fully visible by showing through occluding geometry. This visualization aid ensures that others can always see what a remote collaborator is referring to, but not necessarily where the respective items are exactly located. In fact, the ease of discovery may even discourage users from actively examining the scenery around selected objects. Our study on show-through techniques in a distributed setup demonstrates advantages of our augmented vision approach for the rapid identification of objects being pointed at by a remote collaborator. However, in some cases, we also observed that such support for object discovery can indeed affect the users' ability to retrieve these objects later on.

2. Related work

2.1. Co-located multi-user virtual reality

Multi-user virtual reality can enhance collaborative work in scenarios such as presentations and joint reviews of architectural and mechanical design. Ideally, the interface must not be an obstacle to the direct communication between multiple users in such systems. Unfortunately, most virtual reality display systems do not support multiple tracked, co-located users appropriately. Head-mounted displays strongly compromise the user's visual perception of collaborators and the operational environment. Projection-based systems, on the other hand, are commonly limited to displaying only one stereoscopic view shared by all users. Thus, just one user can see the virtual world in a perspectively correct manner, while surrounding users perceive distorted views. It is impossible in such settings to communicate locations of interest through natural pointing.

Nevertheless, projection-based VR systems are often used by groups of people rather than a single person since their spatial layout affords collaboration (Bayon et al., 2006; Simon, 2007). To meet the requirements of group interaction in single-view VR setups Simon (2007) proposed to render the scene for a fixed viewing position, unaffected by the users' head movement. He argues that basic manipulation techniques can still be well supported in such a setting if the virtual interaction tools (such as pointing ray, menus, etc.) are rendered in a perspectively correct for the operating user. This work around tries to cope with the limitations of single-view projection systems, but it implies that all users perceive a distorted view of the actual scene. The approach also inhibits natural viewpoint maneuvering in terms of head movement. We argue that co-located collaboration in virtual environments requires to render perspectively correct views of the scene for each involved user.

Head-mounted displays (HMDs) do provide individual views for each user but most of them also impede the

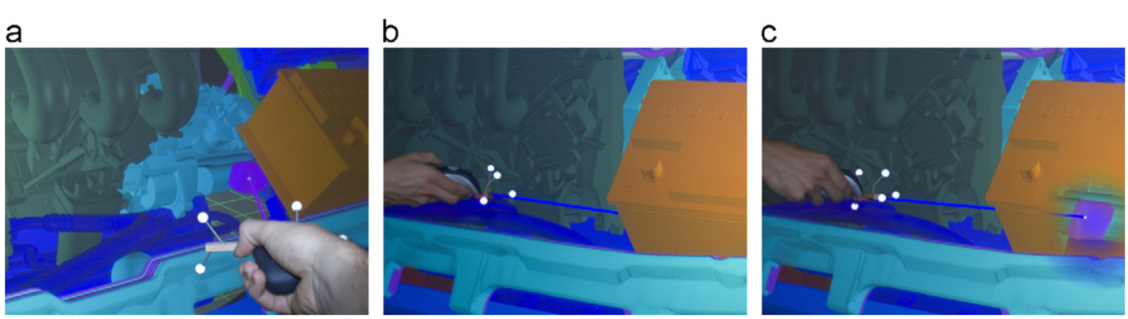

Fig. 1. The first two images (a, b) illustrate the issue of interpersonal occlusion between two tracked users in a multi-user VR system: an object that is fully visible to one user (a) cannot or only partially be seen from other viewpoints (b). Show-through techniques can improve target discovery in such situations by showing the indicated object through the occluding environment (c).