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Visualizing indoor layout for spatial learning using Mixed Reality-based X-ray vision

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Abstract:

Humans rely on the spatial knowledge about their living environments to perform daily spatial tasks, such as localization, orientation and navigation. When navigating in the real world, especially in indoor environments, the integration of local spatial memory at landmarks and decision points is significant for spatial learning (Stankiewicz & Kalia, 2007). However, it is more difficult for humans to correctly anchor in memory places that can only be seen from different viewpoints than places that can be directly seen from the same viewpoint(Ishikawa & Montello, 2006). In such cases, some fragments of spatial memory are omitted or misplaced, which causes spatial distortions in mind and may lead to poor performance on spatial tasks, especially in areas with complex sturctures (Dickmann et al., 2013; Stevens & Coupe, 1978; Tversky, 1992). Such error-prone spatial knowledge may also lead to safety issues in emergency situations, such as during a fire or natural disaster, where people need to rely on their personal spatial knowledge and memory to navigate. Therefore, we need to seek suitable spatial visualizations that can provide aids and cues to reduce the aforementioned spatial distortions.

Previous studies have proved that mixed reality (MR) can influence human in perceiving and learning the space with the help of situated visualization (Keil et al., 2020; Liu et al., 2021, 2022) One of the most useful MR-based visualization solutions is the X-ray vision (Eren & Balcisoy, 2018; Muthalif et al., 2022). The X-ray vision enables users to see occluded objects and structures, and thus the users have a continuous view of the spatial layout. Similar with map learning, the comprehension of global layout is essential for users to build spatial knowledge under a common allocentric reference (Meilinger et al., 2015). By extending users' navigation visibility, such MR-based visualization may be beneficial in integrating spatial knowledge acquired from different places and perspectives, and thus improve the accuracy of cognitive maps. However, X-ray vision can also be detrimental, e.g., potentially overlapping objects and structures from the same direction but at different distances can cause excessive visual complexity. How to properly visualize the spatial layout in-situ by X-ray vision remains to be investigated.

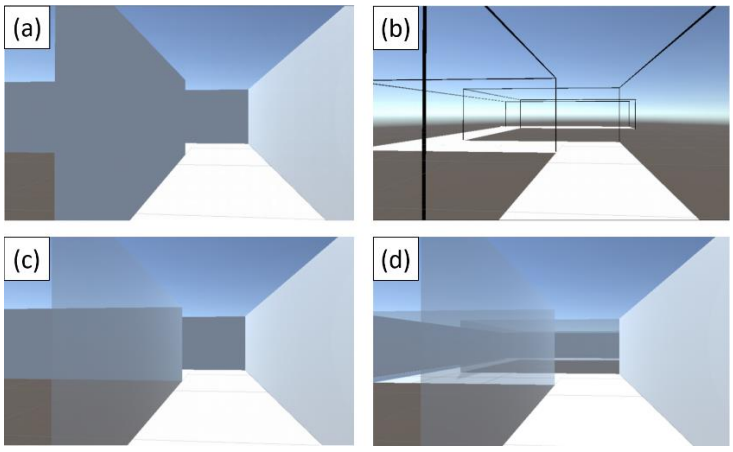

Figure 1. An example scene of x-ray vision for indoor layout visualization. (a) original scene; (b) scene with line-structure-only x-ray vision; (c) scene with first-layer-only x-ray vision; (d) scene with multi-layers x-ray vision.

This ongoing work explores alternative visualization methods based on X-ray vision to represent indoor spatial layout without the occlusion of walls as demonstrated in Figure 1. It addresses two research questions:

1) how do different methods perform in reducing visual complexity caused by overlapped holograms and improving the usability of spatial layout visualization?

2) how does an X-ray vision-based approach to spatial layout visualization influence human spatial learning strategies and behavior?

By reporting our experimental results, we aim to enrich research findings about meaningful combination of Mixed-Reality with X-ray vision to improve spatial learning and navigation efficiency. The proposed MR-based visualization has the potential to provide new insights into the development of user-friendly navigation interfaces and spatial training tools for various environments, including complex environments and emergency situations where personal spatial knowledge is crucial.

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