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# Group WiM: A Group Navigation Technique for Collaborative Virtual Reality Environments

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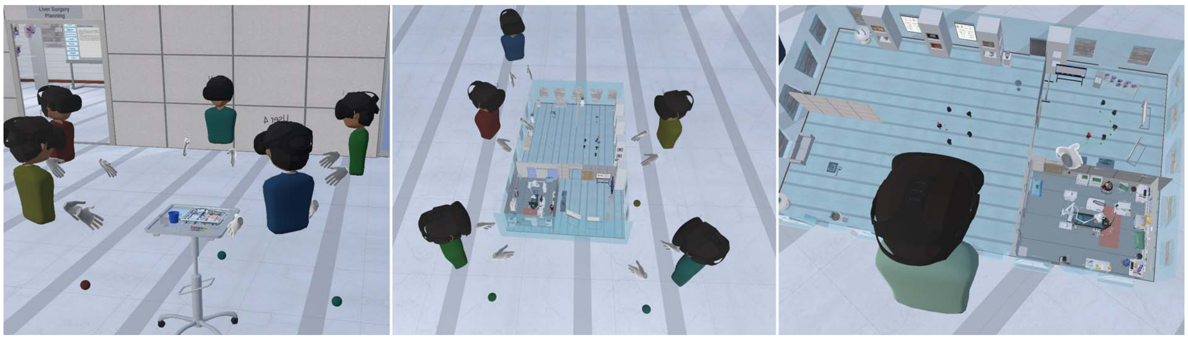

Figure 1: Overview of the group WiM navigation. *Left:* Five users discuss with each other. *Center:* The group explores the environment and is ready for navigation. *Right:* The group navigates using the group WiM navigation technique.

## Abstract

In this work, we present a group *World-in-Miniature* (WiM) navigation technique that allows a guide to navigate a team in collaborative virtual reality (VR) environments. We evaluated the usability, discomfort, and user performance of the proposed technique compared to state-of-the-art group teleportation in a user study ($n = 21$). The results show that the proposed technique induces less discomfort for the guide and has slight usability advantages. Additionally, the group WiM technique seems superior in regards to task completion time for obstructed target destination. However, it performs similarly to the group teleportation technique in direct line of sight cases. The group WiM technique provides potential benefits for effective group navigation in complex virtual environments and harder-to-reach target locations.

**Index Terms:** Computing methodologies—Computer graphics—Graphics systems and interfaces—Virtual reality; Human-centered computing—Collaborative and social computing—Collaborative and social computing theory, concepts and paradigms—Social navigation; Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Collaborative interaction;

## 1 Introduction

Group navigation in immersive virtual reality (VR) allows users to create an arrangement and navigate together at the same time. The most common approach for navigation in collaborative VR environments is to allow each user to navigate individually using single-user techniques [1]. However, the group navigation technique is advantageous compared to the single-user technique, which supports group formation and team collaboration [2–4].

In this work, we propose a group navigation technique based on a *World-in-Miniature* (WiM) for collaborative VR environments. We evaluated the proposed technique compared to a state-of-the-art group teleportation technique in a user study. The study results reveal the technique's usability and provide insights based on user performance. These insights help identify the perceived advantages, disadvantages, and potential research directions for group navigation.

## 2 A Group WiM Navigation Technique

Collaborative VR allows users to join either remotely or physically co-located to form a group and collaborate within a shared virtual environment. These users often have common interests. While individual navigation in the collaborative VR could lead to some difficulties, e.g., a risk of losing each other. The aim of group navigation is to allow all group members to stay and navigate together at the same time [5]. In addition, rather than allowing users to navigate individually with a single-user navigation technique, we believe that group navigation is advantageous in forming a group and assigning the user roles for effective collaboration in the VR environment.

The WiM represents a miniature replica of the entire environment that serves as a proxy to the original environment [6]. WiM-based navigation provides better spatial understanding and reduces motion sickness during virtual travel [7]. It allows the users to explore the target locations and quickly navigate without concerning the line of sight and availability of physical space.

As shown in Fig. 1, the group gathers together in the virtual environment. Each user is represented by an avatar with a name tag, a randomized color for the virtual body, and virtual hands. A small sphere with the same color as the virtual body is projected onto the floor to represent the current position of the user. A leader has a guide's role and other users are assigned as group members. The guide can enable the WiM and get an an overview of the entire environment with other members.

The group navigation procedure starts with the target and group arrangement specification, spatial extent adjustment, and group travel. There are four pre-defined group formations, i.e., circle, half-circle, grid, and line (queue) formations. Hence, the guide can choose one of them to specify the group arrangement. In addition to the mimicked avatars in the WiM, there are also preview avatars and

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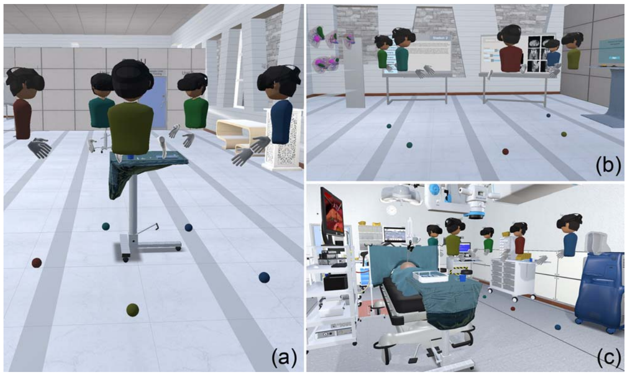


Figure 2: Five collaborative users form as a group and discuss with each other in the lobby (a); the group travels to the liver surgery planning room (b); the group explores and discusses in the virtual operating room (c).

a convex-hull line representation that support the group navigation procedure when the guide chooses a formation.

After specifying the group formation, the guide can further adjust the spatial extent and rotation of the group arrangement. Thus, the preview avatars and the convex-hull line in the WiM are scaled up and down based on this adjustment. To change the rotation, the guide uses the controller and rotates it in the roll angle's direction. The view directions of preview avatars are modified as such that the group members are looking into the centroid. It will also change the users' view directions after arriving at the destination. It could be essential for group discussion so the users do not need to rotate and find each other.

Besides the shared WiM, group members can inspect the target locations with an additional mini-map equipped individually on their virtual tablets. We also developed a simple approach to avoid virtual obstacles by detecting the collision between the preview formation line and the mesh geometries. For group travel, if they are satisfied with the current arrangement, the guide can execute the group travel and the group members are notified by the controller's vibration.

## 3 Evaluation

We conducted a user study to evaluate and compare the proposed technique with a reference group teleportation technique. The aim was to investigate the guide's tasks. Therefore, we added additional simulated users to provide a more realistic group size. An advanced collaborative VR environment on the example of medical planning and training was used to evaluate the proposed technique (see Fig. 2). The user study was planned as a within-subject design with a two-factor test. The factors were defined by two independent variables: *group navigation technique* and *difficulty*. The *group navigation technique* consists of two techniques: group WiM and group teleportation. The *difficulty* refers to the difficulty level of the navigational path for reaching the target location. Additionally, we recorded quantitative data which were defined as dependent variables: *task completion time* and *placement accuracy*. In addition to the measured data for statistical analysis, we recorded *number of jumps* that we analyzed descriptively. Two additional dependent variables were measured from the standardized questionnaires for *usability* and *discomfort scores*.

## 4 Results

21 participants (12 male, 7 female, and 2 non-binary) participated in the user study. The total average time of the study was 50.29 min ($SD$ = 6.84), while the technique training of the first technique lasted 12.87 min ($SD$ = 4.65) and 6.32 min ($SD$ = 2.38) for the second technique. We found significant effects with respect to the task completion time for variables *group navigation technique*, *difficulty*, and their interaction effect. However, no significant differences were found for *placement accuracy*. The *number of jumps* for the hard level was required more than the easy level for group teleportation. However, accuracy for group placement was better at the easy level. For usability, the results of average scores for group WiM are higher than the reference technique. In addition, the results of discomfort scores indicate that all the increased discomfort symptoms of the proposed technique were lower than the group teleportation.

Furthermore, qualitative feedback from all participants was collected to identify the potential benefits and limitations of both group navigation techniques. All participants agreed that the preview avatars and the convex-hull line representation were helpful to support the navigation procedure. The group teleportation provides a good understanding of the spatial environment and navigational path during the travel. The group WiM technique could provide full control and an overview for exploring the target destination and navigation in complex virtual environments. Some participants stated that combining both techniques could show additional potential for effective group navigation.

## 5 Conclusion

We have presented a group WiM navigation technique to support group navigation in collaborative VR environments. We evaluated the proposed technique in a user study to investigate the comprehensibility and usability, and compared it with state-of-the-art group teleportation. The group WiM technique seems superior in terms of task completion time and usability. No significant differences were found in the placement accuracy. The results of discomfort scores indicate that the group WiM induces less discomfort than the reference technique. In conclusion, the group WiM is an effective navigation tool for group navigation in collaborative VR, especially for complex virtual environments.

While the study results are promising, the study was conducted only with the guide's role. More studies are necessary to investigate the technique's usability with the passenger's role. Furthermore, the target configuration of the technique, constraints for long-distance, and the influence on passengers should be investigated for future work.

## Acknowledgments

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