A Comparison of Virtual Reality Locomotion Techniques in Indoor Environments

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Abstract. The proposed study explores diverse virtual reality (VR) locomotion techniques, categorized as motion-based, controller-based, and teleportation-based methods. With a focus on confined Virtual Indoor Environments (VIE) that integrate indoor cartography, 3D cartography, and VR, this research employs a within-subject design in static settings. Utilizing Unity-generated environments and HTC Vive Pro Eye headsets, controllers, and trackers, the study examines spatial cognition and user experiences to determine the suitability of the methods in this type of environment.

Keywords. Virtual Reality, Locomotion, Indoor, User Study, Spatial Cognition

1. Introduction

Locomotion in VR is one of the important aspects of building an immersive virtual environment. It is necessary to provide a means to navigate the environment for the user. It can be achieved by using a variety of hardware devices as well as different software methods.

Several criteria can categorize virtual locomotion. Boletsis (2017) propose classifying the locomotion techniques into four distinct groups. Motion-based techniques use the user's physical movement to enable locomotion and interaction in the environment, typically using continuous movement. Room scale-based techniques are similar to motion-based but aim to use the natural walking of the user for navigation in the environment. Because of this, the dimensions of the virtual environment are bounded to the user's physical space. Controller-based techniques use an artificial controller to enable the continuous movement of the user. Finally, teleportation-based techniques also use a controller, but the user's movement is realized in discrete jumps. All these types have their benefits and disadvantages.

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Even though the research on different virtual locomotion methods has gained momentum, not all aspects have been studied, especially regarding their usability in different virtual environments. One of the specific types is an indoor environment. It presents limited space with defined borders (usually represented as walls), preventing free (direct) movement and limiting environmental visibility. Indoor also has specifics regarding verticality including moving between different vertical levels (floors). For this study, virtual environments of this type are called virtual indoor environments (VIEs). VIEs can be perceived as a combination of indoor cartography, 3D cartography, virtual reality, and (in some cases) building information models (BIM). However, the combination of the unique characteristics of the VIEs and the different locomotion methods has yet to be thoroughly studied as there are not many studies combining these characteristics (Pospíšil 2023).

2. General Method

2.1. Procedure

User study will use a within-subject design with the order of locomotion techniques randomized between users. As the primary environment will be static (spatial composition and dimensions will not change), every locomotion technique will use a different path (similar in length) through the environment. This way, the impact of participants learning the spatial characteristics of the environment should be mitigated. Workflow of the experiment is shown in *Figure 1*.

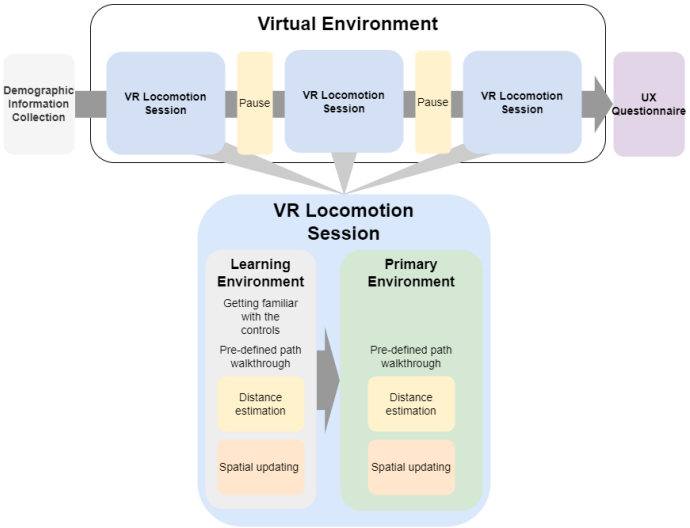

Figure 1. Workflow of the experiment

During each VR locomotion session, the participant will be asked to estimate the distance of a predefined part of the path. After finishing the whole path, participant will be asked to estimate the distance of the whole route and to point in the direction the walkthrough started. The angle between the direction participant points and the starting point will be measured to provide data about spatial updating. During the whole walkthrough, positional data and a view direction of the participant will be recorded.

After all the locomotion sessions are concluded, participants will take a questionnaire aimed to assess the user experience for all the virtual locomotion methods. For this VR Locomotion Experience Questionnaire developed by Boletsis (2020) will be used.

To have a variety in the types of locomotion methods, especially regarding the artificial vs. natural movement and continuous vs. non-continuous types, these methods will be used: **teleportation** (artificial, non-continuous), **controller** (artificial, continuous), and **walking-in-place** (natural, continuous). The study will not use a real-walking method (representing room scale-based methods) as it is technically and financially challenging when using a building/floor-scaled environment.

2.2. Materials

The user study will use an environment created by de Cock (2022), representing one floor of a semi-fictive building (*Figure 2*) as the primary environment. A less complex fictional (training) environment is used to familiarize users with the locomotion technique. Both virtual environments are developed in the Unity engine.

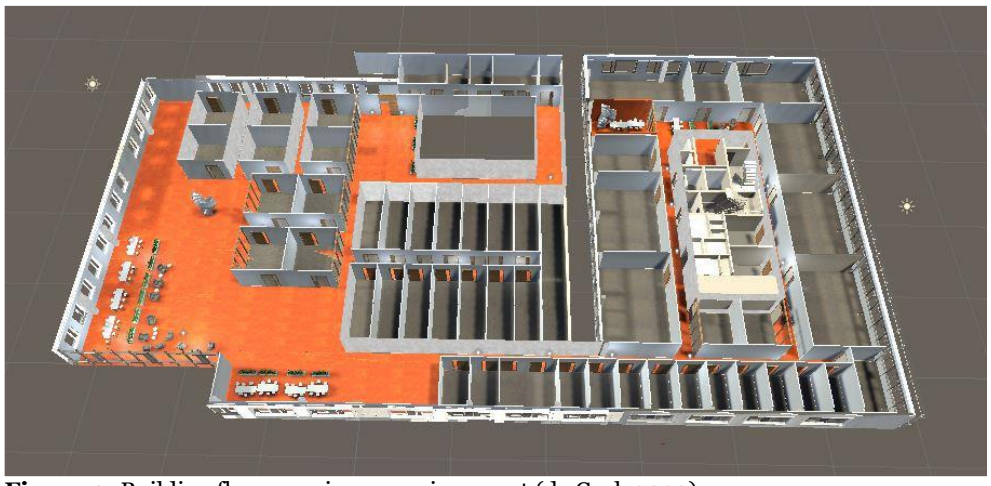

Figure 2. Building floor as primary environment (de Cock 2022).

HTC Vive Pro Eye will be used as a VR device with default HTC controllers to be used for the movement control (in controller and teleportation methods). To obtain information about movement of participant legs, Vive trackers v2.0 are attached at an ankle level and monitored by two Vive Lighthouse base stations. To translate the movement to the virtual environment, custom scripts are created in the Unity engine.

3. Conclusion

The proposed experiment aims to gather data for evaluating users' spatial cognition across various locomotion methods. This endeavour seeks to clarify the impact of locomotion on user perception and potentially determine the most apt methods for future Virtual Indoor Environment (VIE) studies. Additionally, the study assesses user experience subjectively, offering insights into the immersivity of different techniques.

References

Boletsis, C. (2017). The New Era of Virtual Reality Locomotion: A Systematic Literature Review of Techniques and a Proposed Typology. Multimodal Technologies and Interaction, 1(4), 24. https://doi.org/10.3390/mti1040024

Boletsis, C. (2020). A User Experience Questionnaire for VR Locomotion: Formulation and Preliminary Evaluation. In L. T. de Paolis & P. Bourdot (Eds.), Augmented Reality, Virtual Reality, and Computer Graphics (Vol. 12242, pp. 157–167). Springer. https://doi.org/10.1007/978-3-030-58465-8_11<

de Cock, L. (2022). Unity project for VR user study on adaptive mobile indoor route guidance (Unity v2019). https://doi.org/10.1080/13658816.2022.2032080

Pospíšil, P. (2023). Moving indoors: a systematic literature review of locomotion in virtual indoor environments. International Journal of Cartography, 9(2), 173–195. https://doi.org/10.1080/23729333.2023.2183553