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Comparing hand gestures and a gamepad interface for locomotion in virtual environments

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Highlights

- Motivated by previous work, we designed and implemented three hand gesture interfaces for virtual locomotion.
- We systematically compared these three gesture interfaces and a gamepad interface using two virtual locomotion tasks.
- Results show that the Finger Distance gesture and the Finger Number Gesture are promising for virtual locomotion.

Abstract

Hand gesture is a new and promising interface for locomotion in virtual environments. While several previous studies have proposed different hand gestures for virtual locomotion, little is known about their differences in terms of performance and user preference in virtual locomotion tasks. In the present paper, we presented three different hand gesture interfaces and their algorithms for locomotion, which are called the Finger Distance gesture, the Finger Number gesture and the Finger Tapping gesture. These gestures were inspired by previous studies of gesture-based locomotion interfaces and are typical gestures that people are familiar with in their daily lives. Implementing these hand gesture interfaces in the present study enabled us to systematically compare the differences between these gestures. In addition, to compare the usability of these gestures to locomotion interfaces using gamepads, we also designed and implemented a gamepad interface based on the Xbox One controller. We conducted empirical studies to compare these four interfaces through two virtual locomotion tasks. A desktop setup was used instead of sharing a head-mounted display among participants due to the concern of the Covid-19 situation. Through these tasks, we assessed the performance and user preference of these interfaces on speed control and waypoints navigation. Results showed that user preference and performance of the Finger Distance gesture were close to that of the gamepad interface. The Finger Number gesture also had close performance and user preference to that of the Finger Distance gesture. Our study demonstrates that the Finger Distance gesture and the Finger Number gesture are very promising interfaces for virtual locomotion. We also discuss that the Finger Tapping gesture needs further improvements before it can be used for virtual walking.

Introduction

Locomotion in virtual environments is a hotspot for virtual reality (VR) research. Implementing intuitive and natural locomotion interfaces is an important factor for consideration when designing a new VR environment and system. Low-cost optical tracking devices, such as the Kinect sensor and the Leap Motion sensor, for body and hand skeleton tracking have resulted in many methods for body gesture (Lun and Zhao, 2015) and hand gesture recognition (Bachmann et al., 2018). Ample opportunities have become available for VR researchers to investigate the utility of hand gestures for virtual locomotion.

One major advantage of these low-cost optical sensors is that they do not require attaching markers or other tracking devices on the body parts to be tracked while providing tracking information that is sufficiently accurate for interaction in VR. Compared to locomotion interfaces using gamepads, hand gesture interfaces do not require users to hold devices in their hands, hence more sophisticated gestures can be recognized and are generally more flexible compared to VR systems using controllers in terms of gesture recognition (but implementation of force feedback without holding controllers or wearing exoskeletons remains a challenging problem). On the other hand, if we compare virtual locomotion interfaces using hand gestures to interfaces using body tracking with the Kinect sensor or other full-body optical tracking systems, hand gesture interfaces do not involve large-scale body movements. This provides users with an advantage that hand gesture interfaces can be operated in places that are limited in physical space. Such scenarios typically include personal gaming, virtual classrooms and teleoperation, *etc.*, in which large-scale tracking may not be available due to constrained physical space or other reasons. Combined with hand gesture recognition methods for other types of interaction, different interaction activities will be made possible in a VR system. More recent VR headsets, such as the Oculus Quest 2 and the Microsoft Hololens 2, have integrated hand-tracking modules and algorithms. This makes hand gesture locomotion interfaces and other interactions using hand gestures more accessible as additional hand-tracking hardware is not required when using these headsets.

Some previous studies on locomotion using hand gestures used different geometric features of hands for gesture recognition (Cardoso, 2016, Cisse, Gandhi, Lottridge, Amor, etal., 2020, Zhang, Chu, Pan, Ji, Xi, etal., 2017). In such designs, each hand shape with a set of geometric features corresponds to a specific walking speed. By designing a set of hand gestures with different hand shapes, one can achieve variable walking speed with a set of hand gestures tracked by optical devices (*e.g.* the Leap Motion sensor). Another approach was to use the distance between the index finger and the centre of a tracked hand and map the distance to locomotion speed (Huang etal., 2019). In addition, methods that simulate bipedal walking using two fingers were designed based on multi-touch pads (Kim, Gračanin, Matković, Quek, etal., 2008, Yan, Lindeman, Dey, etal., 2016). Although previous hand gesture interfaces have been assessed on a case-by-case basis, there lacks a comparison among different hand gesture interfaces to reveal their differences in terms of performance and user preference. In addition, it is also uncertain how these hand gesture interfaces can be compared to locomotion interfaces using gamepads.

To fill these research gaps, we presented three hand gesture interfaces and their algorithms, called the Finger Distance gesture, the Finger Number gesture and the Finger Tapping gesture, which were inspired by previous studies (Cardoso, 2016, Huang, Harris-adamson, Odell, Rempel, etal., 2019, Kim, Gračanin, Matković, Quek, etal., 2008, Zhao, Allison, 2018). These are typical gestures that people are familiar with in their daily lives or people can naturally come up with when they intend to make hand gestures. For comparison, we also designed and implemented a gamepad interface based on the Xbox One controller. We compared these four interfaces using two virtual locomotion tasks, which are called the target pursuit task and the waypoints navigation task. The first task evaluated the performance of the gestures in terms of their usability in speed control while the second task focused on waypoints navigation as a more general locomotion task with direction control introduced. We also respectively assessed user preference in these tasks through a subjective user interface questionnaire. Due to the current Covid-19 situation, we opted to use a desktop setup to conduct our experiments as sharing headsets among participants is a health concern (Steed etal., 2020) and the procedure for sanitizing VR headsets has not been established at the moment.

The goal of the present study was to compare the differences of these four interfaces in terms of their performance and user preference in virtual locomotion tasks. The main contributions of the study are two-fold:

(1) We present three hand gesture interfaces and their algorithms for virtual locomotion.

(2) We systematically evaluate these three hand gesture interfaces and a gamepad interface using two virtual locomotion tasks and demonstrate their performance and user preference.

The rest of the paper is organized as follows: Section2 discusses related work; Section3 presents hand gesture interfaces, a user interface questionnaire and VR hardware and software for experiments; Section4 presents the design and results of two VR experiments that evaluated four interfaces; Section5 provides discussion and Section6 concludes the study.

Section snippets

Related work

In this section, we review previous work on virtual locomotion interfaces using hand gestures. Methods using hand gestures for virtual locomotion can be generally divided into two categories: gestures based on touch pads and mid-air methods based on hand-tracking sensors.

For example, Kim etal. (2008) proposed a hand gesture locomotion technique called Finger Walking in Place (FWIP) using a multi-touch pad, which belongs to the first category. The gesture required users to use two fingers: the …

Finger distance gesture

The Finger Distance gesture is a method that controls locomotion speed via the Euclidean distance between the fingertips of a users thumb and index. This was inspired by previous work by Huang etal. (2019) who used the distance between a users fingertip of the index and the hand centre to control walking speed. We decided to use the Euclidean distance between the tips of thumb and index fingers to calculate walking speed. Compared to the previous work, our method does not need to capture an …

Participants

Sixteen undergraduate students (age: 18–25, eleven males and five females) were invited as volunteers for this experiment. All had normal or corrected-to-normal vision. An informed consent was signed before the experiment. Participants were naïve to the purpose of the experiment. …

Design

We adapted the experiment from Zhao and Allison (2018) to assess the performance of speed …

Discussion

In our study, we found that the Finger Distance gesture had close performance and user preference to the gamepad interface. Our explanation was that the Finger Distance gesture allowed more precise control of walking speed through fine control of the distance between the fingertips of the thumb and the index of a tracked hand compared to two other hand gesture interfaces. The Finger Number gesture was slightly worse on the waypoint navigation task compared to the Finger Distance gesture but it …

Conclusion

In this paper, we presented three hand gestures and their algorithms for virtual locomotion and implemented a gamepad locomotion interface for comparison using the Xbox One controller. Through two virtual locomotion tasks, we systematically compared the performance and user preference of these interfaces using a desktop setup. We showed that the performance and user preference of the Finger Distance gesture were close to that of the gamepad interface. The performance and user preference of the …

CRediT authorship contribution statement

Jingbo Zhao: Conceptualization, Methodology, Software, Writing – original draft, Writing – review & editing. **Ruize An:** Methodology, Software, Investigation, Visualization. **Ruolin Xu:** Investigation, Visualization. **Banghao Lin:** Investigation, Visualization. …

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

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