# Extended Abstract: Development and Evaluation of Interactive Locomotion User Interfaces

Eike Langbehn
*University of Hamburg*
eike.langbehn@uni-hamburg.de

***Abstract - Locomotion in immersive virtual environments (IVEs) is one of the major challenges in virtual reality (VR) research. In particular, natural human walking has shown benefits for spatial perception which are generally not supported by other locomotion techniques. However, until now, there is no satisfying walking user interface that provides a solution to the problem of limited physical space. The approaches to date, like omni-directional treadmills, walking-in-place techniques or redirected walking, are not suitable to receive the same benefits for spatial perception known from natural walking in the real world, or do still need too much physical space which makes them unsuitable for most application domains.***

***My research will contribute to the development and evaluation of novel natural user interfaces for walking in IVEs with a focus on spatial perception, usability, presence and motion sickness.***

***Index Terms – Virtual environments, Locomotion, Perception, Head-mounted displays***

## Introduction

User interfaces for virtual reality (VR) applications are becoming increasingly important since the introduction of novel head-mounted displays (HMDs) in recent years. Many different application domains are interested in using these new technologies, e. g., in the areas of architecture, surgery, engineering, archaeology, tourism, research, entertainment, art and culture. While it is possible to look around freely in an immersive virtual environment (IVE) thanks to modern tracking technology, one major challenge of VR is the locomotion in an IVE.

One of the main applications of VR is to immerse users into a virtual environment (VE) in such a way that perception and action in the VE match the real world. Conventional and unnatural input devices like keyboard or joystick are not suitable for this task. Instead, human walking in IVEs is a basic step to achieve this goal, as it is the most natural and presence-enhancing form of locomotion through IVEs.

State-of-the-art VR technology does not provide a simple solution to the basic problem of the limited physical space within which the user can interact with the virtual world. There are a few approaches for implementing locomotion user interfaces that want to overcome this challenge by exploiting walk-like gestures that give the user the impression of walking, like omni-directional treadmills, motion foot pads or walking-in-place (WIP) techniques. However, these are not suitable to receive the same benefits for spatial perception known from real walking in the real world [16].

An alternative is redirected walking (RDW) [10], which is inspired by findings from the field of perceptive psychology. It guides the user on a different path in the real world than she is traveling in the virtual world. This would solve the problem of limited physical space as well as improve the perception of IVEs in general, as the user is not aware of the manipulation. However, there are still some limitations when using RDW. For example, it is necessary to know where the user wants to go and to have an area of approximately 45m × 45m when using subtle manipulations of the IVE [15].

Natural human walking has the potential to enhance the presence of users in and the perception of IVEs, and it can become a usable locomotion user interface if the limitations are fixed.

## RELATED WORK

Previous research has focused on locomotion technologies like omni-directional treadmills [13], motion foot pads [7] and motion carpets [12]. In the field of WIP several techniques have been developed, including LLCM-WIP [6], GUD-WIP [19], LAS-WIP and K-WIP [20].

Real walking is more presence-enhancing and natural than any of these locomotion user-interfaces [11, 16, 18]. By exploiting perceptual limitations and illusions it is possible to develop subtle RDW user-interfaces, which guide the user through an IVE without beeing aware of the redirection [3].

RDW can be implemented, for example, by reorientation of the user's heading [4], repositioning (manipulation of the relation between virtual and physical space) [1] or change blindness techniques [14], that manipulate the scene geometry. There have been studies about the spatial perception of redirection techniques [17] and about determining thresholds for detecting translational, rotational, and curvature manipulations [15]. When using graphical effects for selfmotion illusions, it becomes even possible to shift or widen these thresholds [5].

## RESEARCH GOALS AND METHODS

The main goal of my research is to develop novel perceptually inspired methods that allow the exploration of an unlimited IVE by natural human walking with the same benefits known from walking in the real world. This will be achieved by the following two approaches:

- First of all I will examine, if the perception and user experience of WIP can be improved, so that it offers the same experience as RDW. This will be done by adding leaning as a speed amplifier to a WIP interface. This could have implications on self-motion estimation, which will be evaluated during a laboratory experiment.
- The second approach is to improve RDW by extending the detection thresholds for manipulations of translation, rotation and curvature in order to decrease the necessary physical space.

This could be done by different methods:

- Until now, orientation of the users's head or torso has been used to determine the walking direction. Instead, it would be possible to use the user's gaze, that is detected in real-time by an eye tracking device. This might be more precisely and could be beneficial for RDW.
- Adding visual filters to the user's gaze such as motion blur and depth of field might have an effect on perception and the detection thresholds.
- To my knowledge, fully-articulated tracked 3D body representations (virtual avatar) has not been combined with RDW so far. But it has the potential to enhance presence and immersion in IVEs. Therefore I will develop feet-based RDW techniques that mask visual mismatches between the manipulated virtual camera and the user's body.

All these methods will be evaluated by user studies. Furthermore, I want to make the developed novel RDW techniques available to the public. This will be achieved by adding the algorithms and adaptive controllers to an open source library.

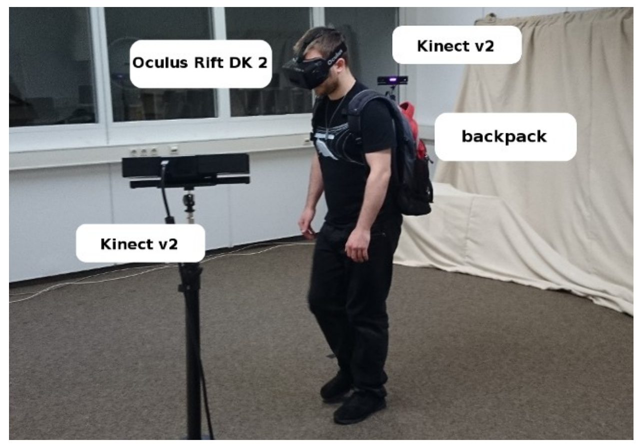


FIGURE 1. USER EXPLORES AN IVE USING LAS-WIP [9].

## CURRENT STATUS

So far, I have been working on the first approach. Me and others developed a novel 360 degrees omnidirectional walking-in-place (WIP) locomotion system, which we designed to work in small laboratory environments and is based entirely on consumer hardware (multiple Kinects and an Oculus Rift HMD, see Figure 1). Using this novel setup we improved on the related work by evaluating leaning as a novel parameter of WIP interfaces. Inspired by observations of changing leaning angles during fast or slow locomotor movements in the real world, we introduced the Leaning-Amplified-Speed Walking-in-Place (LAS-WIP) user interface in a paper [9]. There, we also presented the results of an experiment in which we showed that leaning angle can have a positive effect on subjective estimates of self-motion perception and usability. This is important as it may be a way to improve WIP techniques in general (as stated in the first approach). The next step would be to compare it against RDW techniques regarding spatial perception and usability.

Furthermore, me and others submitted a paper about spatial perception in IVEs to the IEEE 3DUI 2016, which is still under review [8].

[1] B. Bolte, F. Steinicke, and G. Bruder. 2011. The jumper metaphor: an effective navigation technique for immersive display setups. In Proceedings of IEEE Virtual Reality (VR).

[2] G. Bruder, P. Lubos, and F. Steinicke. 2015. Cognitive Resource Demands of Redirected Walking. IEEE Transactions on Visualization and Computer Graphics (TVCG) (2015), 539–544.

[3] G. Bruder, F. Steinicke, B. Bolte, P. Wieland, H. Frenz, and M. Lappe. 2013. Exploiting perceptual limitations and illusions to support walking through virtual environments in confined physical spaces. Elsevier DisPlays (2013), 132–141.

[4] G. Bruder, F. Steinicke, K. Hinrichs, and M. Lappe. 2009. Reorientation during Body Turns. In EGVE/ICAT/EuroVR. 145–152.

[5] G. Bruder, F. Steinicke, P. Wieland, and M. Lappe. 2012. Tuning Self-Motion Perception in Virtual Reality with Visual Illusions. IEEE Transactions on Visualization and Computer Graphics (TVCG) (2012), 1068–1078.

[6] J. Feasel, M.C. Whitton, and J.D. Wendt. 2008. LLCM-WIP: Low-Latency, Continuous-Motion Walking-in-Place. In Proceedings of IEEE Symposium on 3D User Interfaces (3DUI). 97–104.

[7] H. Iwata, Y. Hiroaki, and H. Tomioka. 2006. Powered Shoes. ACM SIGGRAPH Emerging Technologies (2006).

[8] E. Langbehn, and others. 2016. (hidden title because still under blind review). In Proceedings of IEEE Symposium on 3D User Interfaces (3DUI).

[9] E. Langbehn, T. Eichler, S. Ghose, K. von Luck, G. Bruder, and F. Steinicke. 2015. Evaluation of an Omnidirectional Walking-in-Place User Interface with Virtual Locomotion Speed Scaled by Forward Leaning Angle. In Proceedings of the GI Workshop on Virtual and Augmented Reality (GI VR/AR). 149–160.

[10] S. Razzaque. 2005. Redirected Walking. Ph.D. Dissertation. University of North Carolina, Chapel Hill.

[11] R.A. Ruddle and S. Lessels. 2009. The Benefits of Using a Walking Interface to Navigate Virtual Environments. ACM Transactions on Computer-Human Interaction (TOCHI) (2009), 5:1–5:18.

[12] M. Schwaiger, T. Thümmel, and H. Ulbrich. 2007. Cyberwalk: Implementation of a Ball Bearing Platform for Humans. In Proceedings of HCI. 926–935.

[13] J.L. Souman, P. Robuffo Giordano, M. Schwaiger, I. Frissen, T. Thümmel, H. Ulbrich, A. De Luca, H.H. Bülthoff, and M. Ernst. 2011. CyberWalk: Enabling unconstrained omnidirectional walking through virtual environments. ACM Transactions on Applied Perception (TAP) (2011), 1–22.

[14] F. Steinicke, G. Bruder, K. Hinrichs, and P. Willemsen. 2010a. Change Blindness Phenomena for Stereoscopic Projection Systems. In IEEE Proceedings of the Virtual Reality (VR). IEEE, 187–194.

[15] F. Steinicke, G. Bruder, J. Jerald, H. Fenz, and M. Lappe. 2010b. Estimation of Detection Thresholds for Redirected Walking Techniques. IEEE Transactions on Visualization and Computer Graphics (TVCG) (2010), 17–27.

[16] F. Steinicke, Y. Visell, J. Campos, and A. Lecuyer. 2013. Human Walking in Virtual Environments: Perception, Technology, and Applications. Springer Verlag.

[17] E. Suma, D. M Krum, S. Finkelstein, M. Bolas, and others. 2011. Effects of redirection on spatial orientation in real and virtual environments. In Proceedings of IEEE Symposium on 3D User Interfaces (3DUI). 35–38.

[18] M. Usoh, K. Arthur, M.C. Whitton, R. Bastos, A. Steed, M. Slater, and F.P. Brooks, Jr. 1999. Walking > Walking-in-Place > Flying, in Virtual Environments. In Proceedings of ACM SIGGRAPH. 359–364.

[19] J. D Wendt, M. C Whitton, and F. P Brooks Jr. 2010. Gud wip: Gait-understanding-driven walking-in-place. In Proceedings of IEEE Virtual Reality (VR). 51–58.

[20] Y. Zheng, M. McCaleb, C. Strachan, and B. Williams. 2012. Exploring a virtual environment by walking in place using the Microsoft Kinect. In Proceedings of the ACM symposium on applied perception. 131–131.