Cyberith Virtualizer ELITE 2 –
Second Generation VR Locomotion Device based on a 2 DoF Motion Platform

Holger Hager, Tuncay Cakmak, Johara Jägers
Cyberith GmbH

Abstract

Locomotion devices for virtual reality allow users to walk through infinitely sized virtual environments, while requiring limited space in the real world. Alongside the development of Head Mounted Displays and other VR technologies, multiple concepts of such devices have been proposed. This paper introduces a VR locomotion device using a novel approach for walking in VR: A motion platform implemented in the baseplate the user walks upon, supporting the user in walking in VR. The Virtualizer ELITE 2 uses an electrically powered motion platform with 2 degrees of freedom of motion (2 DoF) in order to actively support the user's walking movements by adjusting the baseplate's state accordingly. The second generation Virtualizer is based on the first generation Virtualizer, that represents a passive VR locomotion device. The first version of the Virtualizer was described by Cakmak and Hager in 2014.[1]

1 Introduction

Locomotion in virtual reality has been a well known challenge for multiple decades of virtual reality research. In the past years multiple concepts, prototypes and products have been presented by research institutions as well as by private companies.[2],[3],[4]
All of these devices can be segmented into two mayor categories: Passive and actively powered devices.
Passive devices, that track the users movements, but don't actively support the user in walking in place and actively powered devices, that use motorized systems in order to simplify the users walk-in-place motion.

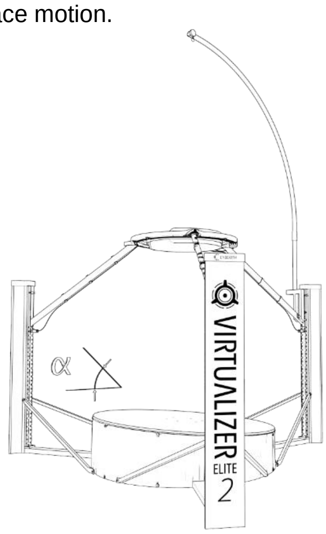

Figure 1: The Virtualizer ELITE 2

Passive devices typically require the user to push their hips forwards, against a static or movable holding construction, resulting in a walking movement, that is not fully intuitive and resulting in an increased effort of walking.[1]
In contrast, actively powered devices use motorized systems to hold the user in place and thus to reduce the effort of walking compared to passive devices.

2 State of technology of actively powered VR locomotion devices

Multiple concepts of actively powered VR locomotion devices use bi-directionally movable conveyor belts to reposition the user in the center of the platform. [2],[4] These devices typically track the position of the user located on the bi-directionally movable conveyor belt system and reposition the moving user in order to keep the user close to the center of the conveyor belt system, using a control loop. As such devices require the user to walk out of the center of the conveyor belt system before being able to reposition the user accordingly, the belts react to movement of the user with an unavoidable delay. To reduce the delay of repositioning the user, the belts need to be accelerated and slowed down swiftly, which in turn applies abrupt forces to the user's feet. These forces require the user to be very careful while moving on the device, due to the risk of falling, while not being able to see the physical surrounding due to a commonly worn Head Mounted Display.
Alternative concepts have been presented as well, which use rollers or similar components replacing the conveyor belt system.[5] By concept, the limitations of these systems are very similar to those of conveyor belt systems.

3 The second generation Virtualizer with implemented Motion Platform

The Virtualizer ELITE 2 uses a different, yet unseen, approach: It uses an electrically driven 2 DoF motion platform to compensate for the required force of pushing the user's hips forwards, instead of moving conveyor belts or rollers underneath the feet of the user. Thus, the device avoids applying abrupt horizontal forces to the user's feet.
The system measures the orientation of the person standing on the device and elevates the baseplate in front of that person in order to allow the user to walk in place without requiring to push the hips forwards. The motion platform reacts to a rotation of

the user by moving the baseplate in a way, that the elevation continues to be in front of the user. It does so without rotating the platform, but by lowering and increasing the height at different points. Thus, the inclination of the platform can rotate, without requiring the platform to rotate by itself. This means, that no torque is applied to the user's feet. Therefore, a user can not get rotated by the platform, which significantly differentiates the system from systems with a turning floor.

The platform can react to the user's movement speed and to individual characteristics and preferences of the user by increasing or lowering the angle of inclination of the platform.
For walking backwards, the platform inverts the inclination of the platform.

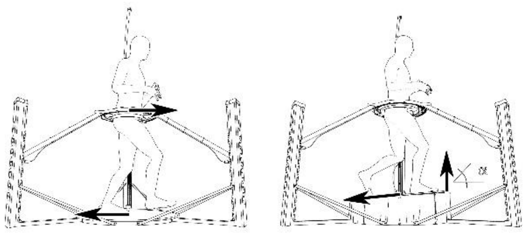

Figure 2: Comparison of first generation and second generation Virtualizer:
In the left picture, the user pushes his hips against the ring, in order to initiate his feet to slide.
In the right picture, the electrically driven motion platform is inclined, in order to eliminate the requirement of pushing the hip forwards.

Detailed view of the forces at the user's gliding foot:

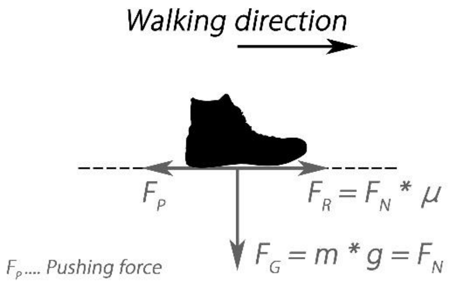

Figure 3: In order to move the foot backwards on a flat surface, a "pushing force" F_p must be applied to the foot. The user needs to push his hips against a holding construction in order to walk.

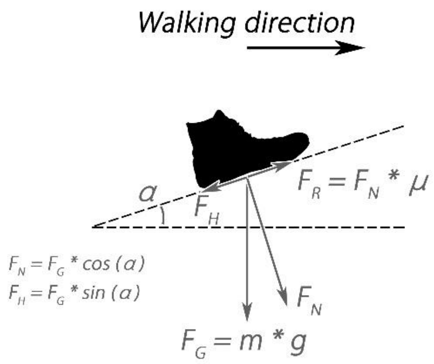

Figure 4: The inclination removes the requirement of a "pushing force" F_p. As a first approximation, we estimate the angle as follows:

$$F_H = F_R$$
$$F_G * \sin(\alpha) = F_G * \cos(\alpha) * \mu$$
$$\alpha = \arctan(\mu)$$

The calculation of Fig. 4 suggests, that for a μ of approx. ~0.1, an angle in the magnitude of single digit degrees should be sufficient for an effortless gliding.
This approximation has been confirmed by practical testing. Nevertheless, it should be pointed out, that this calculation relies on significant simplifications, such as the assumption of μ = const.

4 Sensor System

The user's movements are detected by optical sensors, that are located in the baseplate, on which the user walks on, the ring construction and one of the three pillars. Six optical sensors integrated in the baseplate represent the devices main sensory system, measuring the velocity and direction of the user's feet movement at a framerate of 1.000 Hz.
The sensor implemented in the ring tracks the user's body orientation, while the sensor in one of the pillars tracks the user's hip height.
The sensor data is processed by an integrated microcontroller. It is used for both controlling the movement of the implemented 2 DoF motion platform and for providing the required locomotion data to the application. In order to keep latency minimal, the motion platform is addressed internally and directly, without the detour of sending the required data to an external computer. Thus, the motion platform works independently of a connected PC or a software application running on the PC.

5 Software Interface

The device comes with a Software Development Kit (SDK), available in C++, C# & Python. In addition to the native SDK, Plugins are provided for the commonly used engines Unity & Unreal Engine.

The main functions provided by the Virtualizer define locomotion in the following way:

- Body Orientation (Measured at the hip/pelvis)
- Movement Speed (of the feet)
- Movement Orientation (of the feet)
- Height (of the hips/pelvis)

In addition to the main functions of locomotion input, the SDK allows to control gain, volume & frequency of an implemented haptic unit, which can be used optionally.
For support of a wide range of pre-existing content, the device was integrated into SteamVR via an according Driver. SteamVR allows for basic locomotion controls, but a native integration into the desired applications via the SDK remains to be preferred.

6 Conclusion

The functionality of the concept is verified by dozens of products, that are in daily operation by customers. The product has been first presented at the Laval Virtual international Exhibition and Conference on VR/AR & Immersive Techniques[6] in 2019 and received positive reviews.[7],[8]
All internal and external testing procedures have shown a significant improvement compared to all commercially available passive locomotion devices with regards to ease of use, intuitive walking and pleasant physical effort.
Due to the significantly higher price of the only other commercially available actively powered VR Treadmill[5] and the lack of commercial availability of further actively powered VR locomotion devices, it was not possible to directly compare the product to other actively powered VR locomotion devices so far.

Acknowledgements

To the Austrian Research Promotion Agency for supporting the development, to Dipl.-Ing. Thomas Krainer for the valuable hints and to all employees of Cyberith GmbH, without whom it wouldn't have been possible to bring this product to live.

References

[1] Cakmak T., Hager H. 2014. Cyberith Virtualizer – A locomotion device for Virtual Reality. *ACM SIGGRAPH 2014 Emerging Technologies Article No.6*
[2] Lee H., Pyo S., Park S., Yoon S. 2016. Design of omni directional treadmill based on an Omni-pulley mechanism. *13th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI)*
[3] Jan Goetgeluk. 2013. Omnidirectional locomotion platform. *Patent USD766239S1*
[4] George Burger. 2010. Single Belt Omni Directional Treadmill. *Patent US20140336010A1*
[5] Micael Schmitz, Daniel Johannson. 2011. A device for allowing a user to walk or run on the spot in an arbitrary direction and control method therefor. *Patent EP2522403B1*
[6] *https://www.laval-virtual.com/nominated-awards/* retrieved on 03.10.2019
[7] Cédric Ruiz, Laurent Chretien. 25.04.2019. Cyber It > Marcher dans l Univers Virtuel. *Radio France Bleu* (*https://www.francebleu.fr/emissions/la-minute-connectee/mayenne/cybert-it-marcher-dans-l-univers-virtuel* retrieved on 03.10.2019)
[8] Amélie Charnay. 22.03.2019 Vous allez pouvoir vraiment courir dans un univers virtuel. *01net.com* (*https://www.01net.com/actualites/vous-allez-pouvoir-vraiment-courir-dans-un-univers-virtuel-1657707.html* retrieved on 03.10.2019)