Action Reproducer: Virtual Reality Rehabilitation System to Reduce Fear of Walking

Minori Unno
Tokyo Metropolitan University
Hino, Tokyo, Japan
unno@vr.sd.tmu.ac.jp

Yusuke Kikuchi
Tokyo Metropolitan University
Hino, Tokyo, Japan
kikuchi@vr.sd.tmu.ac.jp

Kentaro Yamaoka
Tokyo Metropolitan University
Hino, Tokyo, Japan
yamaoka@vr.sd.tmu.ac.jp

Gaku Sueta
Tokyo Metropolitan University
Hino, Tokyo, Japan
sueta@vr.sd.tmu.ac.jp

Vibol Yem
Tokyo Metropolitan University
Hino, Tokyo, Japan
yem@vr.sd.tmu.ac.jp

Yasushi Ikei
The University of Tokyo
Bunkyo, Tokyo, Japan
ikei@vr.u-tokyo.ac.jp

ABSTRACT

Walking is a daily activity for most people. Lack of opportunities or inability to walk may cause both mental and physical health problems. However, in some circumstances, such as during a global pandemic, fear of heights, or withdrawal from society (*hikikomori*), people tend to walk less. To overcome such issues, we developed a walking rehabilitation system, Action Reproducer, to encourage people to walk in a virtual environment, e.g., around sightseeing spots, or to train walking on a high building. The proposed system comprised a motion seat to present vestibular sensation to the waist, slider-pedal devices to provide motion sensation to the lower limbs, wearable pseudo force devices to pull sensation to the fingers, and an avatar in the virtual environment to hold the user's hand during walking. This system can reduce user burden because the user simply sits on the motion seat and perceives multiple sensations that allow them to enjoy walking activities for long periods of time. During the virtual conference, we will conduct a live demonstration and present the details of our system with some interactive content, such as virtual traveling and walk rehabilitation between high buildings.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Haptic devices**.

KEYWORDS

Walk rehabilitation, virtual walk, holding hand, virtual travel, fear reduction.

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1 INTRODUCTION

The coronavirus pandemic has significantly affected many people's daily lives. For example, it has made many people unable or afraid to walk outside. Consequently, the number of people who have withdrawn from society (*hikikomori*) has increased. However, it is considered that virtual reality (VR) can overcome such issues by allowing people to walk safely inside virtual spaces.

Redirected walking is a well-known phenomenon that allows people to walk in a large virtual environment when, in fact, they are actually walking in narrow space [Steinicke et al. 2010]. Some studies have developed walking rehabilitation systems for lower-limb impaired patients (e.g., [Colombo et al. 2000]). These technologies allow people to walk freely in virtual spaces; however, users cannot sustain the experience for long period of time due to the burden of real walking. Moreover, multiple stimulations are required to encourage someone who is afraid of walking to start the activity.

In this study, we developed a prototype VR rehabilitation system to encourage people to walk outside around sightseeing spots as well as walking through two high buildings to reduce a fear sensation (Fig. 1). A user can experience the stimuli of vestibular at the waist, lower-limb motion sensation at the feet, and a pseudo pulling force at the fingers. In addition, the proposed prototype has an avatar in the virtual space that holds a user's hand to encourage and guide them.

2 SYSTEM

2.1 Vestibular at the waist and lower-limb motion sensation at the feet:

The stimuli in the proposed system generate walking-like sensations. A user sitting on the motion seat can perceive waist motions with four degrees of freedom (e.g., lift, yaw, pitch, and roll) (Fig. 2 (left)). The system has two pedals, each with three degrees of freedom, to move the heels up and down and move the feet forward and backward. In addition, the pedals move around the seat's axis to provide the sensation of turning while walking. These motions not sufficient, but they are basic motions and are important to generate various walking activities.

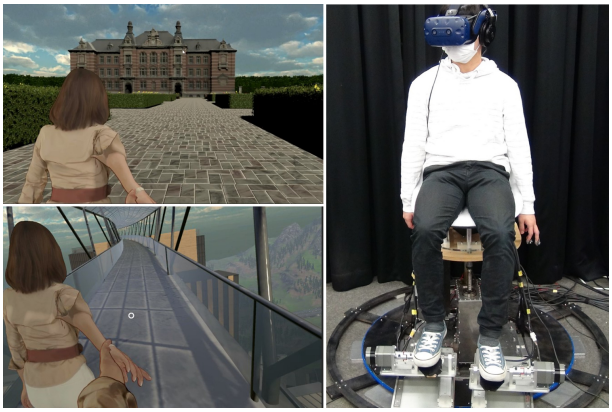

Figure 1: Virtual reality hand-holding walking system

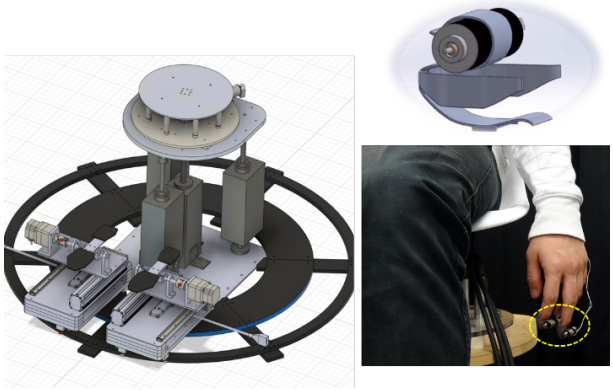

Figure 2: (Left) Design of the motion seat and pedals; (right) pseudo pulling force haptic device

We conducted an experiment that showed that the stimuli required maximum amplitudes of lift, pitch, and roll (i.e., .26 mm, 0.13 degrees, 0.15 degrees, respectively), which are approximately 1/20-time lower than those in real walking due to the high sensitiveness of passive stimuli. The up and down movement of the heels and the forward and backward movement of the feet were also low compare with those in real walking. In the prototype, these movements were 24 mm and 93 mm, respectively. In real walking, these values were approximately seven times higher. These results allowed us to design the system with smaller actuators.

The proposed system is similar to our previous system that was presented at *Siggraph Asia 2018*. During the demonstration of the original system, we receive mostly positive feedback from the audience, and we received the *Best VR/AR award* from the committee [Shimizu et al. 2018]. In the present system, we added more three degrees of freedom of the motion (yaw to the waist and rotation of each foot around seat's axis), which made system suitable for various walking rehabilitation activities.

2.2 Pseudo pulling force at the fingertips and hold-hand walking with a virtual avatar:

Our previous study confirmed that a DC motor can provide a pseudo force sensation to the fingertip when the input signal is saw-tooth waveform voltage [Yem et al. 2016]. We used this phenomenon to include a new external stimulus in the form of wearable device that provided a pulling force sensation to the fingers to represent the force of a virtual partner who is holding the user's hand during walking (Fig. 2 (right)). The ability to use a wearable device made the prototype system more compact.

A virtual avatar representing the user's partner is shown in a HMD to encourage user to walk. The pseudo pulling force sensations on the fingertips are presented simultaneously with the periodic swinging of the avatar's arm.

3 LIVE DEMONSTRATION

During the virtual *Siggraph 2021* conference, we will conduct a live demonstration of the system and describe our research. The live presentation will involve multiple cameras to demonstrate the system from various angles. Three of the authors will be involved in the demonstration. One author will sit on the motion seat, put their feet on the pedals and wear haptic devices on their index and middle fingers. Another author will operate the system. When the system is functioning, the operating author will have access to an emergency stop button in case the system goes wrong. The third author will give a talk to explain our work. The authors who attend participate in the live demonstration will wear face masks and maintain a social distance greater than two m.

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REFERENCES

Gery Colombo, Matthias Jörg, R Schreier, and Volker Dietz. 2000. Treadmill training of paraplegic patients using a robotic orthosis. *Journal of rehabilitation research and development* 37 (11 2000), 693–700.

Koichi Shimizu, Makoto Sato, Koichi Hirota, Michiteru Kitazaki, Gaku Sueta, Kentaro Yamaoka, Kazuki Sawamura, Yujin Suzuki, Keisuke Yoshida, Vibol Yem, Yasushi Ikei, and Tomohiro Amemiya. 2018. FiveStar VR: shareable travel experience through multisensory stimulation to the whole body. *Journal of Rehabilitation Research and Development* 37(6) (12 2018), 1–2. https://doi.org/10.1145/3275495.3275502

Frank Steinicke, Gerd Bruder, Jason Jerald, Harald Frenz, and Markus Lappe. 2010. Estimation of Detection Thresholds for Redirected Walking Techniques. *IEEE transactions on visualization and computer graphics* 16 (01 2010), 17–27. https://doi.org/10.1109/TVCG.2009.62

Vibol Yem, Ryuta Okazaki, and Hiroyuki Kajimoto. 2016. Vibrotactile and pseudo force presentation using motor rotational acceleration. (04 2016), 47–51. https://doi.org/10.1109/HAPTICS.2016.7463154