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*Poster*

# Visuo-haptic Redirected Walking Using Handrail

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**Abstract**

*A novel use of virtual reality (VR) was demonstrated. It enables a user to feel walking a straight virtual corridor while touching straight handrails, although the user walks while gripping circular handrails within a limited space. The main contribution of this study is to show that visual-haptic redirect walking is possible using handrails for a haptic presentation. Matsumoto et al. introduced visuo-haptic redirected walking. They used walls as a haptic presentation, and they produced Unlimited Corridor as a VR demonstration using visuo-haptic redirected walking. However, it has not yet been verified whether the same effect can occur by touching other shapes. Therefore, in this study, a VR demonstration using handrails instead of walls was created, and whether visuo-haptic redirected walking is possible even with handrails for haptic presentation was examined. In the demonstration, more than 2000 people participated, and their comments and motion data were gathered. The users' comments implied that visuo-haptic redirected walking was possible using handrails.*

**CCS Concepts**

• ***Human-centered computing*** $\rightarrow$ ***Virtual reality;***

**Figure 1:** *A user is experiencing our work.*

## 1. Introduction

To walk in a large virtual environment (VE) within a small tracking space redirected walking (RDW) was proposed [RSS*02]. RDW can compress a large VE into a smaller real space while maintaining a sense of natural walking, by making good use of vision, which is dominant in spatial perception. One of the fundamental techniques of RDW is a curvature gain, which applies redirection continuously while a user walks through the VE. Under RDW using curvature gains, when a user walks straight in the VE, the camera in the VE, which acts as the user's eyes, rotates little by little to redirect the user to walk along a circular path in real space. Steinicke et al. [SBJ*10] conducted a psychophysical experiment and reported that a circular path with a radius of 22 m or more in real space could be mapped to a straight path in the VE without being noticed by the user. However, it is difficult to prepare a vast real space that can accommodate such a large walking path; therefore, it was necessary to improve the effect of RDW. Matsumoto et al. [MBN*16a] reported that the radius of the walking path in real space can be significantly reduced under RDW using curvature gains by enhancing the effect of RDW using haptic stimuli. They employed the RDW method using haptics "visuo-haptic RDW" and produced a VR demonstration, *Unlimited Corridor*, using this method [MBN*16b]. They reported that the virtual reality (VR) demonstration enabled a user to walk along circular paths with a radius of 3 m in real space and the user could walk straight in a VE. However, because the situation of walking while touching a wall is not common, it would restrict the content of the VEs. However, it is common to walk while gripping a handrail; therefore, the restriction of the contents is considered to be relatively small. However, it has not been confirmed whether visuo-haptic RDW will occur even by touching an object other than a wall, such as a handrail. Furthermore, when a handrail is used as a haptic presentation, the user behaves differently than when touching a wall such that the stimulus received from the user's haptic

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**Figure 2:** *Left: image viewed by the user through the head-mounted display; center: gripping the handrail with a virtual hand in the VE; right: an example of the walking route, green is a route in VR and red is a route in real space*

and proprioceptive sensations would be different. In this study, we made a new Unlimited Corridor was constructed using handrails instead of walls. Participants were allowed to experience it, and whether visuo-haptic RDW is caused by haptic presentation other than walls was studied.

## 2. Visuo-haptic RDW using handrails

For haptic presentation, two semicircular handrails with a radius of 2.5 m were installed with a 1.2 m interval between themselves in real space. Linear virtual handrails were placed in the VE to correspond to the position of the handrails in real space. A user wore an HTC VIVE PRO head-mounted display (HMD) and two VIVE TRACKER 2.0 to track the position of a user's head and hands. The positions and orientations of the HMD and TRACKERs were tracked within a real space of 7 m $\times$ 8.2 m using four SteamVR Base Station 2.0. Because only the position and orientation of the hands in this system were acquired, the curvature of the fingers when gripping the handrail was not reflected in the VE (Fig.**??**).

Through HMD, a user was presented with images walking on straight aisles while gripping straight handrails; however, in real space, the user was walking along a curved path gripping curved handrails, as shown in Fig.2 left and center. These images were obtained at 75 fps by a backpack PC carried by the user. To map real space and the VE, we used the same algorithm used in the Unlimited Corridor was used. This algorithm applied a curvature gain at the outer periphery and a one-to-one correspondence at the central passage between the curved handrails.

To enhance a user's immersive feeling, the VE environment was set as a construction site of a skyscraper. After rising to the construction site of the 200 m above the ground by the virtual elevator, a user walked approximately 40 m on straight virtual aisles including three-way junctions along the way; however, in real space, the user walked around circular paths twice (see Fig.2 right).

## 3. User Study

More than 2000 participants have experienced this work so far, and their comments and motion data have been collected. As comments from the participants, positive impressions such as "I felt like walking straight ahead" and "It seems that I am walking on a high altitude, and my feet trembled" were received. However, negative impressions such as "My hands will not move" and "I feel a sense of incompatibility when the position of the hand deviates" were also given. The positive comments suggest that visual-haptic RDW would occur even with a general haptic stimulus such as gripping a handrail, in addition to touching a wall. The negative comments indicate that, when using walls for haptic presentation, participants did not notice the positional shift of their hands; however, when handrails were used as a haptic presentation, they were noticed when their hand position shifted even a little. Therefore, in the case of using an object to be grasped, such as a handrail, for haptic presentation, measures such as correcting the position of the hand are considered necessary.

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