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Demonstration of RedirectedDoors: Manipulating User's Orientation while Opening Doors in Virtual Reality

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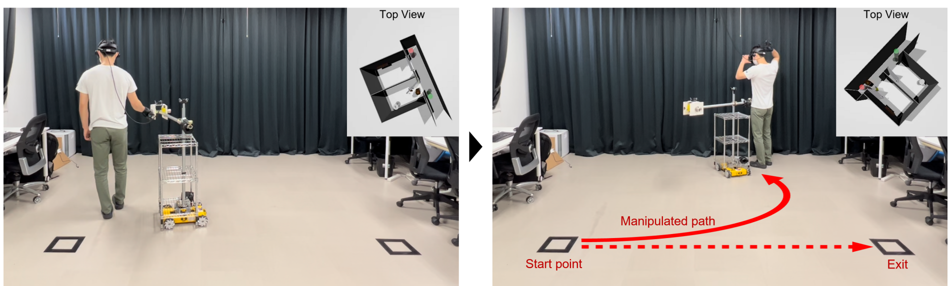

Figure 1: Overview of demonstration.

ABSTRACT

We present an installation demonstrating the applicability of RedirectedDoors, a redirection technique that occasionally manipulates the user's orientation during door-opening motions. In this demo, the player explores an indoor virtual environment containing doors while wearing a head-mounted display (HMD), and their orientation in reality is manipulated as a function of the door's opening angle. In addition, when the player opens the door by pushing or pulling the doorknob in virtual reality, the corresponding passive haptic feedback is provided by the self-actuated doorknob-type prop. When reaching the goal, they can see the manipulation results by comparing their virtual position with a real landmark position. Consequently, this demo both makes the player's experience more realistic and presents the virtual environment in a comparatively small physical space.

KEYWORDS

Redirection, Door, Haptics, Virtual reality

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1 INTRODUCTION

Room-scale virtual reality (VR) is a highly immersive experience where users can freely move around the virtual environment (VE) by actually walking. However, exploring large virtual environments is limited by physical play area. To address such constraints, redirection techniques that imperceptibly manipulate the viewpoint of the user in VR have been studied. While some techniques (e.g., Redirected Walking [Razzaque et al. 2001]) manipulate the user's translational distance or direction in VR by *constantly* applying a gain while the user is walking, Hoshikawa et al. proposed RedirectedDoors [Hoshikawa et al. 2022], a redirection technique that *occasionally* manipulates the user's orientation while the user is opening doors. Their experimental results showed higher space efficiency through redirection. However, this study only clarified the user's perception of redirection in a laboratory experiment, and no application of this technique has yet been implemented or demonstrated.

In this work, we present an installation like a room escape game where players explore rooms through opening doors in VR, thereby demonstrating the applicability of RedirectedDoors. In this demo, the player explores an indoor VE with two neighboring rooms connected through a corridor to collect items and reach the goal. Through several door-opening motions, the player's orientation in reality is manipulated by approximately 150 degrees. In addition, a doorknob-type prop driven by an autonomous wheeled robot

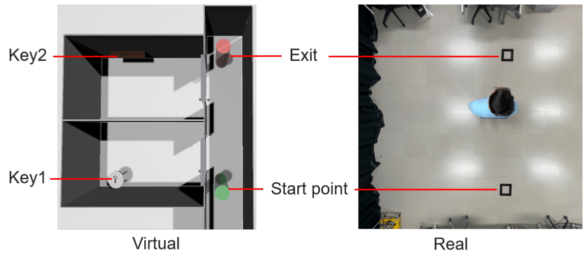

Figure 2: Virtual and real environment used for the demo.

provides passive haptic feedback in the appropriate position when the player opens the doors. Consequently, this demo offers both increased realism of the player's exploration experience and high compression of the physical play area.

2 DESIGN

This demo provides a minimal virtual exploration that allows a player to experience the benefits of RedirectedDoors; the player explores an indoor VE containing two doors and a corridor to reach a goal (Figure 2). The orientation of the player is manipulated through multiple door-opening motions required to accomplish the task, and when the player reaches the goal, the player's position in reality is considerably distant from that in the VE. The player can see the distance by taking off the HMD at the end of the experience to recognize how much their actual movement is manipulated by RedirectedDoors.

The following is an overview of the experience scenario. First, the player is instructed on the goal and operations of the experience. The goal is to escape from the building by reaching the exit after collecting two items (i.e., keys) from each room. The exit (red cylinder in Figure 2) is located at the straight end of the corridor as seen from the start (green cylinder in Figure 2), and these two points are indicated by landmarks in reality on the same scale. The player wears an HMD and explores the VE with two rooms and a corridor connected to them (see Figure 2). Because each door automatically closes after opening it, the player needs to open the doors four times in total to obtain all items. When the player opens the door by pushing or pulling the doorknob, corresponding passive haptic feedback is provided by controlling the self-actuated prop. When the player reaches the goal, they take off the HMD and can see how their position in reality is considerably manipulated by the system by observing the difference of the exit position in VR versus reality.

3 IMPLEMENTATION

In our implementation, we use Valve Index HMD and employ the HTC VIVE system to get positional data of the player. The player wears the HMD and a glove with a VIVE tracker on their right hand. To provide haptic feedback, we employ our custom-maid self-actuated haptic prop driven by a wheeled robot (Figure 3).

Referring to the RedirectedDoors algorithm [Hoshikawa et al. 2022], the system manipulates the player's orientation by rotating the entire VE at a certain angular ratio (i.e., gain) of the door being opened. The gain g_d indicates the ratio of the mapped door-opening angle (rotated around the axis of the hinge) in VR to that in reality, represented by the following equation:

$$g_d = \frac{\theta_{virtual}}{\theta_{real}} = \frac{\theta_{real} + \theta_{redirect}}{\theta_{real}} \tag{1}$$

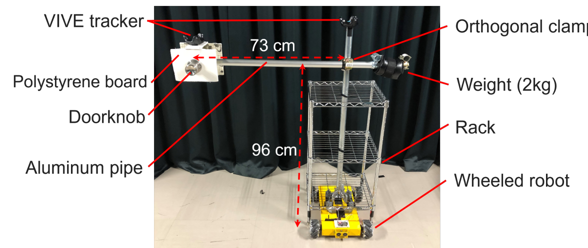

Figure 3: Implemented self-actuated doorknob-type device.

Here, θ_{real} is the door-opening angle in reality. $\theta_{virtual}$ is the door-opening angle in VR, also represented by the sum of θ_{real} and $\theta_{redirect}$. $\theta_{redirect}$ refers to the VE rotation angle by the manipulation. In this demo, we used a gain of 1.73 based on the detection thresholds obtained by the previous study [Hoshikawa et al. 2022], in which users did not notice the manipulation by RedirectedDoors when pushing the door with haptic prop.

The original RedirectedDoors had a limitation that the implementation used a fixed doorknob-type prop for providing haptic feedback, which decreases the technique's applicability. Thus we implemented a self-actuated doorknob-type device using an autonomous wheeled robot. Figure 3 shows the self-actuated doorknob-type device. For the actuation, we use the 4WD 100mm Mecanum Wheel Robot (10011, Maker: Nexus robot, Model: 4562179395876), and attached a steel rack as a support for stability when moving and opening the door. In order to obtain the position, orientation, and door rotation of the device, we attached two VIVE trackers to the hinge and the top of the doorknob, respectively. The device is initially placed at the door position of the front room, but when the player finishes exploring the room, it automatically moves to the door position of the back room. For a safer path planning of the wheeled robot, we use the RVO algorithm used in prior work [Yixian et al. 2020] so that the whole device avoids collision with the user based on the velocity of the player through a series of predictions. After determining the path, we use PID control method for the controlling algorithm, which computes the parameter according to the path from the current position to the target position. Consequently, this device maintains a distance of at least 0.5m from the player while moving. If the device makes an exceptional move, the presenter can stop it at any time.

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