Virtual Rope Slider

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ABSTRACT

This paper proposes "Virtual Rope Slider", which expands a rope sliding experience by stimulating sense of sight, hearing, wind and vestibular sensation. A rope slide in a real world has physical restrictions in terms of scale and location whereas our "Virtual Rope Slider" provides scale and location independent experiences in the virtual environment. The user is able to perceive a different sense of scale in the virtualized scenes by multi-modal stimulation with physical simulation.

Categories and Subject Descriptors

I.3.7 [**Information interfaces and presentation**]: Multimedia Information Systems – *Artificial, augmented, and virtual realities*

General Terms

Human Factors, Entertainment VR

Keywords

Rope Slider, Virtual Reality, Sense of Scale, Multi-modal Stimulation

1. INTRODUCTION

A rope slide is one of the playground equipment for outdoor exercise. Figure 1 shows a snapshot of rope slide. The player holds on its rope and slides downwards along the cable. A rope slide in the real world has physical restrictions in terms of scale and location. For the restriction of the scale, the scale of a human is constrained, so the user can enjoy it in a fixed scale factor. For the restriction of the location, we can only play with it in a specific environment. Our system: "Virtual Rope Slider" expands the experience of rope-sliding in these two points by stimulating sense of sight, hearing, wind and vestibular sensation. Figure 2 shows our "Virtual Rope Slider".

There are many studies on perceived size in static environments. The perceived size of the virtual world can be controlled by interpupillary distance of head mounted display (HMD) [1]. However, our system is in a dynamic environment so the perceived distance of sliding motion was not only affected by interpupillary distance but also by the human-to-virtual-world ratio. We reconstructed and created the virtualized real world environments to measure the perceived distance of sliding. Our system changes the sense of scale by changing the eye position of the user in the virtual world, where other factors (sound, wind and vestibular sensation) are constant.

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Figure 1. Rope Slide

The main contribution of our system is to provide virtual rope sliding experience in 3D reconstructed virtual environments. It is possible to change the sense of scale in our dynamic environment by manipulating factors of the virtual scene graph.

Figure 2. Virtual Rope Slider

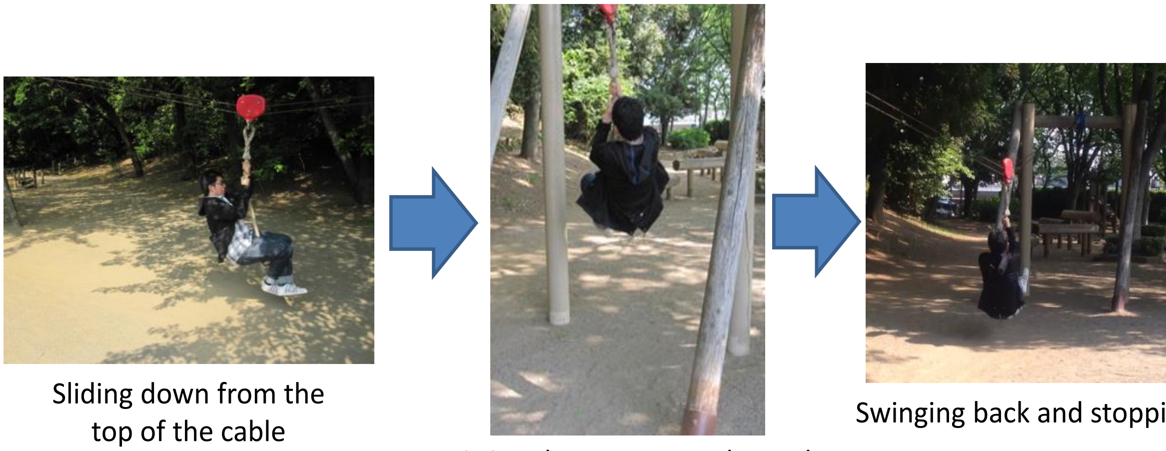


Figure 3. Transition State of Real Rope Slide

2. RELATED WORK

In this section, we refer to the related works of motion platform and perceived size in a virtual environment.

A motion platform is a mechanism that produces physical movement to provide stimulation of vestibular sensation. Usually, the movements of the platforms are synchronized with a visual display and multi-modal effects in virtual reality applications such as video games, virtual simulation, and so on [2]. A combination of these effects provides a sense of immersion into a virtual environment and enhances the experience of kinematic changes in position, velocity and acceleration.

The researches in size perception have been explored in many years [3] [4] [1] [5] [6] [7]. Here we refer to three types of scale change factors.

Visual effect is the most common way to stimulate the sense of scale. Tilt Sift lens [3] and blur effect [4] are known as the photographic techniques and effects. They create scenes as if the objects look like miniature models. Yanagida *et al.* [1] mention the perceived size is affected by interpupillary distance of HMD with a stereoscopic display.

We can also change the perceived size by displayed human size. S.A. Linkenauger *et al.* [5] propose the system which displays the larger virtual paws and the target object so that the user can measure the size of the object by their body scale. V.D.Hoort *et al.* mention that the scale of a human is a reference scale to measure the size of the world.

Redirected walking system [7] changes the perceived scale by changing the distance of motion in a dynamic environment. Even if the user walks around in a small area in a real environment, it gives an experience as if the user walked around in a large-scale virtual room. In this system, the user can control the scene by their walking, but in our system user's motion is controlled by the motion platform system.

Our system is a motion platform system which provides a variety of sense of scale by changing parameters in a dynamic virtual environment.

3. A SENSE OF SCALE OF MOVEMENT IN DYNAMIC VIRTUAL ENVIRONMENT

The technology of VR allows us to reproduce a sense of reality in our daily life by providing essential stimulations for human perception. By carefully changing the stimulations, it is possible to give different reality beyond the physical restrictions. Our system provides a variety of perceived scale by stimulating sensations.

There are several remarkable studies to stimulate the sense of scale in static environments as already discussed in section 2. According to the related works, the following elements are considered to be effective to the perceived size in our system.

- Interpupillary distance
- Eye position from the ground
- Gravitational acceleration

However, our "Virtual Rope Slider" is based on a dynamic environment. Our motivation is to accomplish the elements which affects to the perceived distance of sliding in a dynamic virtual environment.

4. USER EXPERIENCE

Figure 3 shows a transition state of a real rope-slide. We investigated the experience of a real rope-slide to design our system. There are two important factors; a sliding and swinging sensation of the user's body. To produce these two sensations, our system stimulates sense of sight, hearing, wind and vestibular sensation.

Scenery change is the most important sensation to stimulate. When the user is passing by an object, it looks gradually larger as he or she is approaching and looks smaller as going away from it. It gives a sliding sensation. For body-based scaling, the user measures the scale of the virtual world by comparing the object and their body size.

Auditory stimulation is strongly relevant to rope sliding experience. When a player is sliding down along the cable, he or she can hear the sound of the pulley.

When passing by a sound source, it sounds lager as he or she approaches and smaller as goes away from it. A sound of

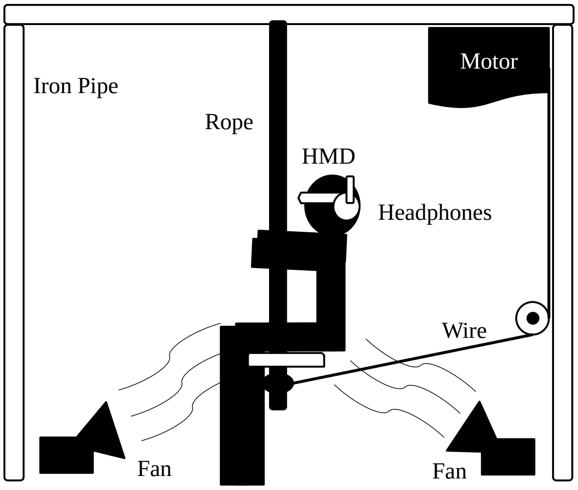


Figure 4. System Configuration

collision at the end of the experience is also one of the effects to make the user notice his/her position in the virtual world.

The wind is an effective sensation to give a hint of the direction of sliding to the user. If the user slides down, he or she feels wind in front of him by air resistance. If the user reaches the end of the inclined cable and sliding back, he or she feels wind from the back.

The user feels the gravitational acceleration in sliding down by stimulating vestibular sensation [8]. Furthermore, a sense of swinging user's body is also the important vestibular sensation when the user reaches the bottom of inclined cable.

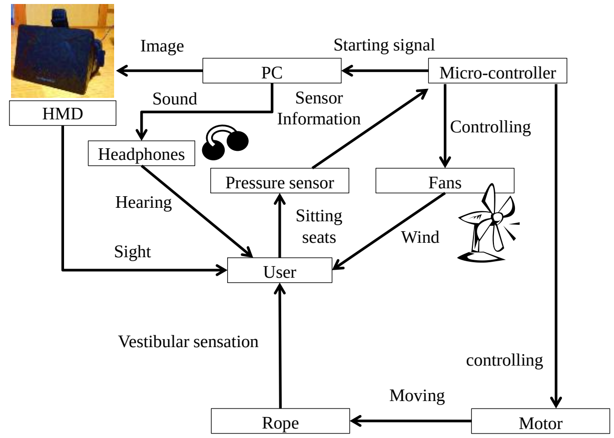


Figure 5. Block Diagram

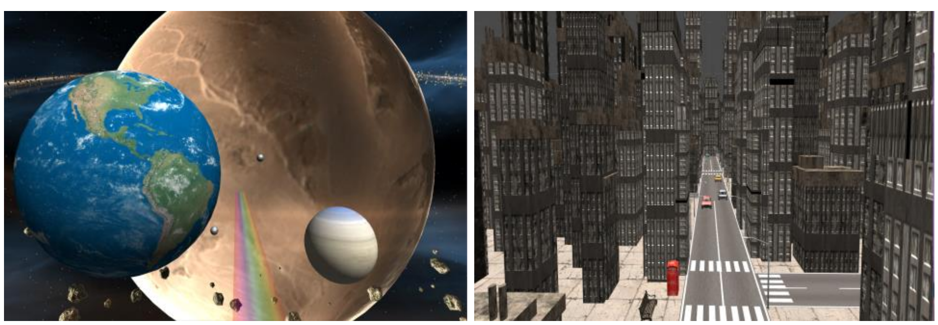
5. SYSTEM

5.1 Configuration

The system configuration is shown in Figure 4.

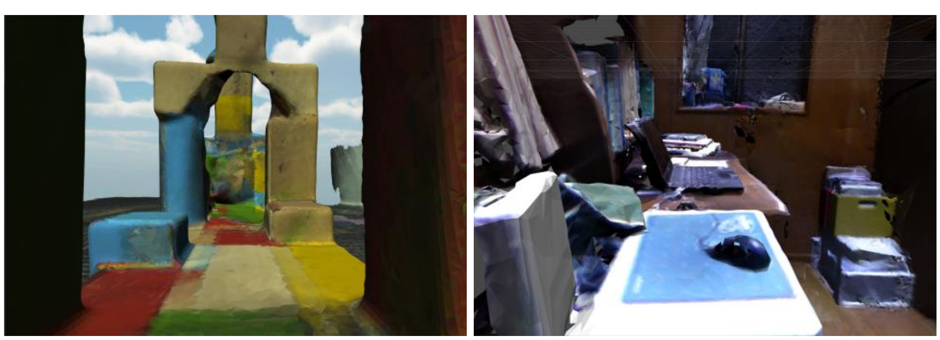
A rope with a seat is hanging from the top of the iron pipe structure. The rope is connected to a motor by a wire. The wire can be wound up and paid out by the motor. Fans are placed on the ground and emit a wind to the user. The user wears HMD (Oculus Rift [9]) and headphones, which both give stereoscopic sensations.

Figure 5 shows a block diagram of our system. The camera position of rendering is determined by the position of the user in a virtual world and the camera pose is determined by the direction



(a) Space (b) City

Figure 6. Computer Graphic Scenes



(c) Toy Bricks (d) Room

Figure 7. 3D Reconstructed Scenes

Figure 8. Sequential Images of Virtual Rope Slider

of the user's head tracked by the acceleration sensor in Oculus Rift.

We use Unity [10] for physical simulation to calculate the speed effect to the motor, fans, volume of the sound and camera position and rotation.

We have seven computer graphic scenes (Figure 6) and two 3D-reconstructed real environments (Figure 7). Both should be created in the off-line phase so that the rendering works on real time.

5.2 Physical Simulation

As mentioned in section 5.1, speed is related to the control of the motor, fans, volume of the sound and camera position and rotation. In this section, we refer to physical simulation of the sliding rope. Figure 8 shows sequential images of the user experience.

Figure 9 shows the rope model in our virtual environment. A camera for rendering is attached to the middle of the rope. As sliding down along the cable, air resistance affects the vertical angle of the rope. Air resistance is high in high speed. When the resistance gets high, the power of the fan gets high and the vertical angle gets steep. Since the camera is attached to the rope, a direction of the camera is facing down and the seat of the slide gets steep.

When the rope reached to the end of the cable and collides with it, it swings forward due to the moment of inertia as shown in Figure 9. The camera is facing to the ceiling and the angle of the seat changes.

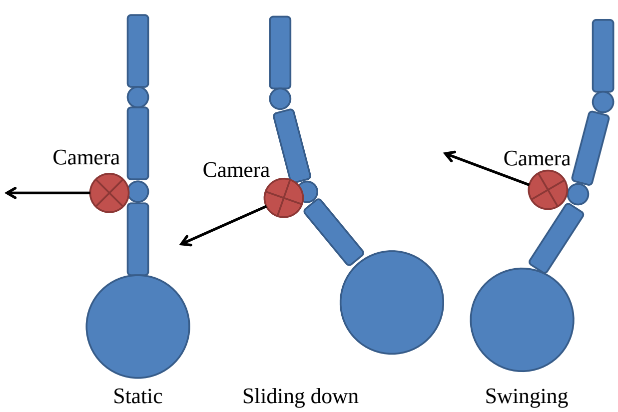


Figure 9. Physical Simulation of the Rope and Camera Angle

6. CONCLUSIONS

This paper introduces our virtual rope sliding system in 3D reconstructed real world and the system configuration to provide the virtual sliding experience in our virtualized environment. We stimulate sense of sight, hearing, wind and vestibular sensation and manipulate the sense of scale through the rope-sliding experiences in virtualized real environment. This system allows us change physical restrictions of scale and location. It provides a new rope sliding experience in various scenes.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] Yasuyuki Yanagida and Susumu Tachi. Dynamic Effects of Inconsistent Field of View in HMD-based Telexistence Systems. *Trans. of the Virtual Reality Society of Japan*, 7, 1 (Mar. 2002), 69-78.

[2] Scanlon, Charles H. Effect of Motion Cues During Complex Curved Approach and Landing Tasks. *NASA TP-2773* (1987)

[3] Park, Sung W, Linsen, Lars, Kreylos, Oliver, Owens, John D, and Hamann, Bernd. Discrete sibson interpolation. *Visualization and Computer Graphics, IEEE Transactions on*, 12, 2 (2006), 243-253.

[4] Held, Robert T, Cooper, Emily A, O'brien, James F, and Banks, Martin S. Using blur to affect perceived distance and size. *ACM transactions on graphics*, 29, 2 (2010).

[5] Linkenauger, Sally A, Leyrer, Markus, Bülthoff, Heinrich H, and Mohler, Betty J. Welcome to Wonderland: the influence of the size and shape of a virtual hand on the perceived size and shape of virtual objects. *PloS one*, 8, 7 (2013), e68594.

[6] Bjorn van der Hoort, Arvid Guterstam, H. Henrik Ehrsson. Being Barbie: the size of one's own body determines the perceived size of the world. *PLoS One*, 6, 5 (2011), e20195.

[7] Steinicke, Frank, Bruder, Gerd, Jerald, Jason, Frenz, Harald, and Lappe, Markus. Analyses of human sensitivity to redirected walking. In *ACM* (2008), 149-156.

[8] Virre, E. Virtual reality and the vestibular apparatus. *Engineering in Medicine and Biology Magazine, IEEE*, 15, 2 (1996), 41-43.

[9] OculusVR. *Oculus Rift - Virtual Reality Headset for 3D Gaming | Oculus VR*. http://www.oculusvr.com/

[10] Unity. *Unity – Game Engine*. http://japan.unity3d.com/