Waving Blanket: Dynamic Liquid Distribution for Multiple Tactile Feedback using Rewirable Piping System

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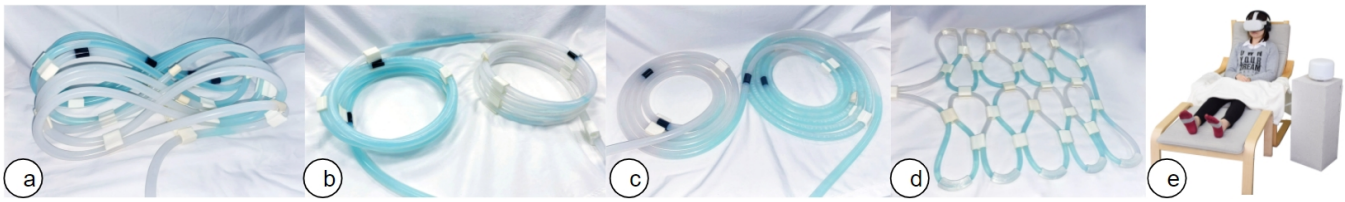

Figure 1: Wire forms of water pipe: (a) 8-shape, (b) dual cylinder, (c) dual spiral,(d) web-shape, and (e) Scenario of VR Relaxation.

ABSTRACT

Perceiving multiple tactile sensations in virtual reality(VR) is one of the keys to enabling a compelling, immersive experience. The haptic experience consists of different receptors on the human body. Although several haptic technologies can produce different tactile stimulation to achieve the experience, the hybrid haptic system needs to combine each technique, requiring a complex configuration. Therefore, our goal is to provide several stimulations in one technique to reduce the effort to integrate haptic devices. This paper presents Waving Blanket, a dynamic liquid distribution system for multiple tactile feedback, utilizing a water pump and air valve to transmit and allocate the liquid in the pipe. We designed a virtual natural scene and developed a relaxation application called "Water Forest" with our haptic system to show the possibility by combining visual-auditory feedback. Additionally, a rewirable piping system is adopted to explore the mechanism of simulating vibration, pressure, weight, and weight-shifting feedback.

CCS CONCEPTS

• **Human-centered computing** → **Haptic devices**; • **Hardware** → **Emerging interfaces**.

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KEYWORDS

Multiple Tactile Sensations, Liquid-based Haptic, Piping System, Liquid Distribution, Virtual Reality

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1 INTRODUCTION

To enhance the immersive experience, many research groups have dedicated different techniques to provide multiple tactile sensations in virtual reality (VR). Besides, human skin can perceive several kinds of stimulation such as vibration, pressure, weight, etc., so one of the strategies is to combine techniques to bring a new hybrid-haptic system for the application. However, it is hard for the contact feedback system to provide stimulation at the same spot on human skin. In addition, a non-contact feedback system requires a complex configuration for the physical environment. Therefore, it would be a new approach to reduce the complexity with fewer techniques but the same number of multiple tactile sensations.

One of the possible answers is utilizing liquid material to produce tactile stimulation. INVISIBLE [Nakano et al. 2006] utilizes a water recycling system to provide vibration and weight at the tube's end to enhance a projection-based mini-game on the floor. Niiyama et al.[Niiyama et al. 2014] using liquid metal to provide weight feedback in a sphere-shaped interface. GravityCup[Cheng et al. 2018] gathers the whole liquid system on the users to show the

concept of a wearable liquid system to provide weight sensation in VR. LiquidMask[Liao et al. 2019] has shown the possibility of simultaneously generating vibration and pressure on the face with a VR head-mounted display (HMD). Pumping Life[Huang et al. 2019] utilize an expandable water container to present a shape-changing interface with liquid. Therminator[Günther et al. 2020] utilizes heat conduction from the water to provide thermal feedback for the users. Additionally, FlowGlove[Liu et al. 2020] presents a wearable glove to provide pressure, vibration, and temperature on the user's hand. Although previous works have shown the potential of the liquid interface to provide tactile feedback, this work is trying to integrate the benefit to explore the multiple tactile sensations in virtual reality with not only hands but other body parts. Therefore, this paper designs and implements a haptic device utilizing the piping system to dynamically control the liquid distribution with air column, allowing users to perceive multiple tactile sensations. In addition, a VR application for relaxation has been developed to show the utility of our haptic device.

2 DESIGN AND IMPLEMENTATION

We present Waving Blanket, a dynamic liquid distribution system for enhancing the haptic experience in VR with multiple tactile feedback. Our system consists of two subsystems: (a)water-air cycle system and (b) rewirable piping system. The water-air cycle system is designed for dynamic controlling the distribution of water and air, and to reuse the water stored in the water tank(1000ml), which utilizes an arduino with motor driver and bluetooth to send the command to a water pump (70˜76ml/s) and an air valve. To reduce the noise generated by the water pump, we utilize sound-absorbing cotton to cover the inner wall of the device and an anti-vibration pad below the pump. Additionally, we design a rewirable piping system to explore the possibility of wire forms and liquid distribution for multiple tactile feedback. To secure the water pipe with different forms, we 3D printed the following widgets made by TPE or EVA to retain some flexibility: double clamp, triple clamp, 3-ways straight clamp, 3-ways triangle clamp, 4-ways straight clamp, 4-ways square clamp, 8-ways straight clamp, bending holder. With the above widgets, we propose four wire forms: (a) 8-shape (850cm) , (b) dual cylinder (790cm), (c) dual spiral (750cm), and (d) web-shape (717cm) to simulate vibration, pressure, weight, or weight-shifting feedback adequately by the distribution of water and air.

3 APPLICATION: WATER FOREST

In order to demonstrate our concept, we design a virtual environment (VE) with multisensory feedback and develop a relaxation program called Water Forest, which utilizes Unity to integrate the VR application with our haptic device. The users can lie on a recliner with the VR-HMD and the noise-canceling earphone, their legs are straight and covered by our Waving Blanket. In the VE, the web-shape provides vibration to simulate a group of fishes is swinging by. The dual spiral can simulate the water rising and falling to submerge the legs. The dual cylinder provides weight on each cylinder to simulate the duck is stepping on the user's upper legs. The 8-shape provides pressure to simulate the landing of the frog jumping. Finally, the virtual environment gets dark, the sound disappears, and the tactile feedback smoothly stops.

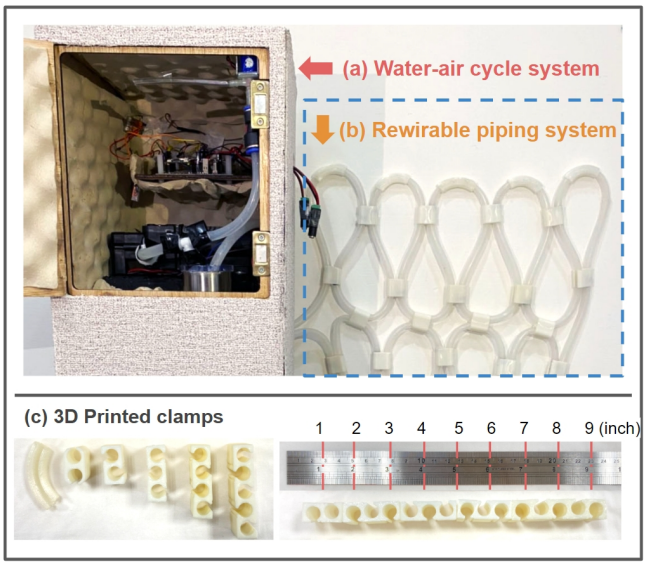

Figure 2: System Overview of Waving Blanket

4 DISCUSSION AND FUTURE WORK

This work presents a dynamic liquid distribution system to enhance the immersive experience with multiple tactile sensations, including vibration, pressure, weight, and weight-shifting feedback. By wearing the HMD, the users can sit on a recliner to perceive different haptic experiences on the user's legs in our relaxation VR application. In the future, we will conduct user studies to understand the feedback on different body parts and their connection and the scratch produced by the liquid transmission.

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