GroundFlow: Multiple Flows Feedback for Enhancing Immersive Experience on the Floor in the Wet Scenes

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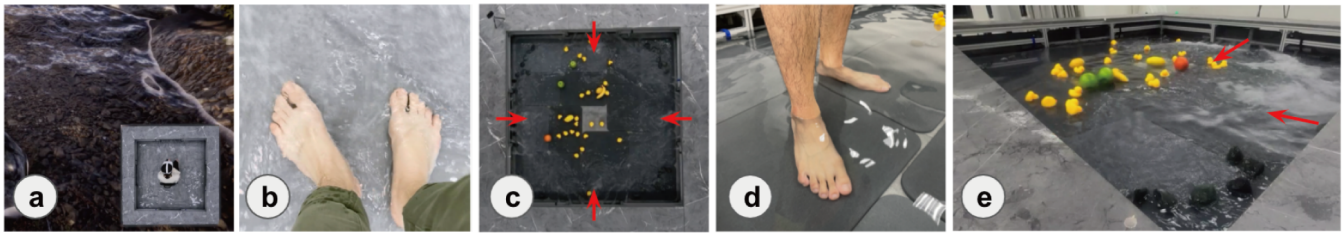

Figure 1: We introduce GroundFlow, a water recirculation system that provides multiple flows feedback, the users can also experience several kinds of fluid that have a corresponding scene in the immersive virtual reality. (a)We implement 5 virtual scenes which are possible in the real world to simulate the fluids. (e.g. the river scene with unidirectional flow.) (b)Users can experience the fluid simulation with no shoes. (c)Water will come from different directions. (d) The water can be over the ankle. (e)Simulate the places where there is no source direction of water flow.(e.g. the interpolated flow.)

ABSTRACT

With haptic technology, the uses can experience an enhanced immersion in virtual reality. Most haptic techniques focus on the upper body, such as the head, chest, and hands, to provide strength feedback when interacting in the virtual world. Thus, researchers have been exploring different techniques to simulate haptic feedback for walking around in virtual space, such as texture, height, vibration, shape, and resistance. However, those techniques can not provide a real wet sensation in the virtual scene. Therefore, we present GroundFlow, a water recirculation system that provides multiple flows feedback on the floor in immersive virtual reality. Our demonstration also implemented a virtual excursion that allows users to experience different water flows and their corresponding wet scenes.

CCS CONCEPTS

• **Human-centered computing** → **Interaction paradigms**; Virtual Realty.

KEYWORDS

Multisensory Feedback, Fluid Simulation, Liquid-based Haptic, Virtual Reality

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1 INTRODUCTION

The first foot interaction has been a proposal by [Pearson and Weiser 1988], researchers explore diversification techniques to simulate the haptic feedback from the soles of our feet. One of the methods is wearable devices. Capsoles [Matthies et al. 2017] contribute to utilizes capacitive sensing and machine learning technique to design an insole, which users can recognize texture and wet floor feedback. Level-Ups [Schmidt et al. 2015] present mechanical shoes which can simulate different heights of scenes. SnowWalking [Yokota et al. 2015] presents a boot that can simulate walking in the snow. RealWalk [Yang et al. 2020] utilizes magnetorheological fluid of shoes to simulate the wet desert. Although wearable device researches enable users to recognize different textures, wet and dry floors, they do not perceive the wet sensation from their feet. Besides, to have a good wearable experience, several sizes of shoes need to be provided. Instead of wearable devices, floor systems

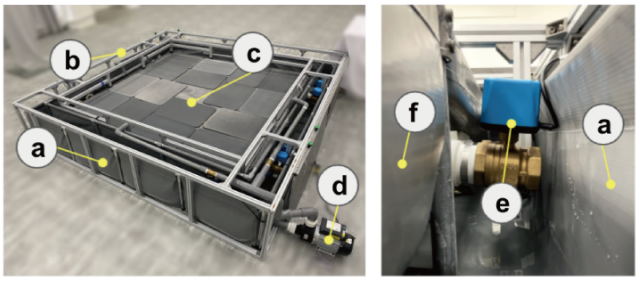

Figure 2: Hardware Design: (a)lower canvas ponds, (b)aluminum extrusions, (c)diatomaceous earth, (d)centrifugal pumps, (e)electric valve, and (f)upper canvas ponds.

can avoid wearing and taking off shoes, which is easy to adapt to different users. TilePoP [Teng et al. 2019] utilizes a pneumatically-actuated interface to operate 30 airbags, which can be inflated into an object in a virtual environment. Elevate [Je et al. 2021] utilizes a haptic floor base on a pin-array display, which can dynamically adjust the ups and downs of the terrain. Nevertheless, the users still can not perceive wet sensation or interact with water. Additionally, previous research has utilized the characteristics of liquids to deliver liquids into wearable devices through water pipes to achieve a variety of haptic feedback, such as temperature, gravity, or pressure feedback but not wet sensation. To interact with water, AquaTop [Koike et al. 2013] presents vision-based HCI of water surface display, in which the users can use their fingers to touch the projection on the stagnant water while taking a bath.

This paper presents a water recirculation system that provides multiple flows feedback on the floor in immersive virtual reality. Our floor system can provide walking space for the users, or multi-users can sit at the edge. Users can take off shoes to experience multiple waters flows corresponding to the wet scenes in virtual reality.

2 DESIGN AND IMPLEMENTATION

GroundFlow is a water recirculation system that provides haptic feedback to the feet in virtual reality. By combining the haptic feedback system with virtual reality, our work allows the user to feel the fluid simulation corresponding to the virtual environment. GroundFlow hardware design is shown in figure 2. The total length and width of the installation is 260cm, and the height is 51cm, using 200cm*200cm*28cm raised floor(29.5cm height) and aluminum extrusions as support. We use centrifugal pumps (AQUA WAY JA150, flow rate: 350 L/min) to avoid users getting the electric shock to pump water from the lower canvas ponds to the upper one. We can store water in the lower large canvas ponds (260cm*260cm*30cm), and users can stand in the other canvas ponds for experience (220cm*220cm*46cm), thus achieving maximum space utilization. Besides, to make the wet floor dry when the canvas pond is without water, we use sixteen pieces of diatomaceous earth (40cm*55cm*1cm)on the floor.

The maximum water level of the system is 95mm, the rising water level speed is 100 mm/min with turn on two pumps, lowering water level speed is 74 mm/min with turn on eight electric valves. Our device utilizes the Linkit 7697 Bluetooth via the handmade wiring and Unity to operate the system with software. We have eight electric valves to discharge the water from the upper canvas ponds back to the lower one to complete the water circulation. Thus, we can control the number of electric valves to increase or decrease the water discharge rate.

We use two centrifugal pumps and set them at opposite corners. The pump is paired with two normally closed electric valves installed on the left and right sides of the pump. When the pump is pumping water, we can control the electric valves to open one or two so that the water will come out in one direction or two directions. Thus, we implement the multiple fluid simulation. Our system can create (a)dry, (b)the unidirectional flow, (c)static, (d)2-way flow, (e)waving, (f)interpolated flow, (g)T-flow, and (h)4-way flow. For more detail, please refer to our video.

3 APPLICATION: VIRTUAL EXCURSION

To show that our device's possibility can be present, we implement a virtual excursion experience. Users can stand or sit in our device to relax in nature environments, even meditate. In this experience, we choose the general water flow and make the corresponding scene. Users can experience the waving pair to sea, unidirectional flow pair to the river, 2-way flow pair to forest SPA, 4-way flow pair to underground house, and static pair to temple. For more detail, please refer to the video.

4 SUMMARY AND FUTURE WORK

A water recirculation system provides multiple flows feedback on the floor in immersive virtual reality in this project, which can create diversified fluid simulations. We also implement a virtual excursion in which the users can experience multiple fluid simulations. In the future, we will further explore the human foot's perception of liquid interfaces and the utility of enhancing the immersion of virtual reality.

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