GravityPack: Exploring a Wearable Gravity Display for Immersive Interaction Using Liquid-based System

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Introduction

We present GravityPack, a wearable gravity display to simulate the weight of grabbing, holding, and releasing the virtual object in the virtual world using the liquid-based system consisting of pumps, pipes, valves, a water tank, and water packs. This system can provide a wide weight range from 110g to 1.8 kg in 40 seconds. Additionally, we design and investigate the visual feedback of weight transition for the delay time of liquid transfer to understand the feasibility of visualization by a user study. With the revealing of design consideration and implementation, the paper also shows the potential use of the liquid-based system and its possibility of the visualization technique to simulate the weight sensations.

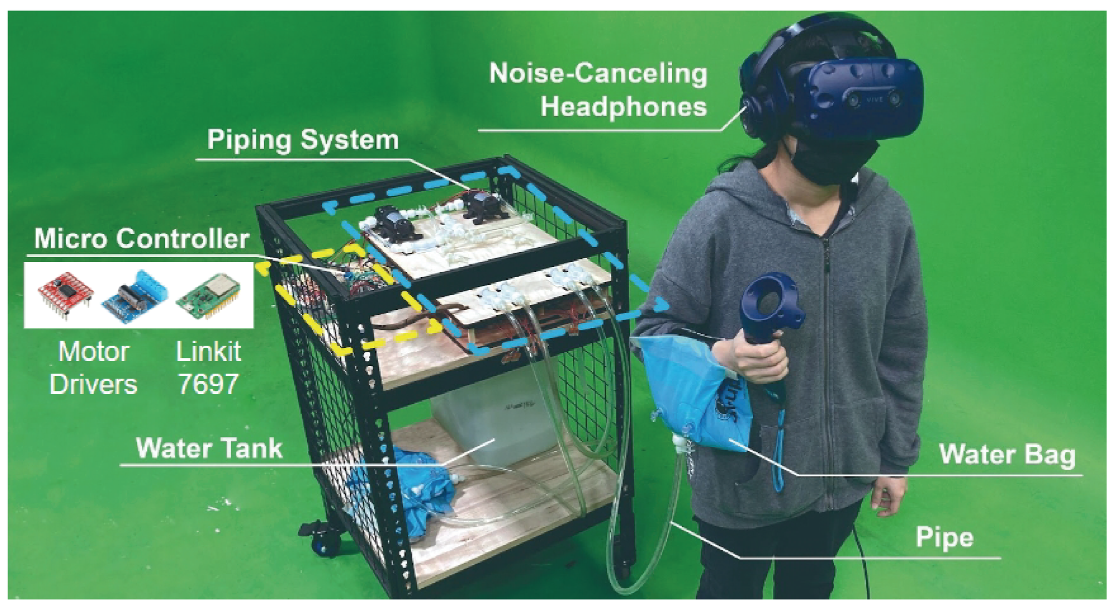

Figure 1: System Overview

Related Work

To communicate the perception of an object's weight, previous works have utilized (1) **Leverage** or (2) **Additional Force** techniques to simulate weight feedback in virtual reality. Few studies utilize **Liquid** to provide tactile sensations. Due to the fluidity and deformability of the liquid, it can be delivered to multiple parts of the body, giving users a wide range of weight sensations.

Figure 2 : Works utilized (1) Leverage (2) Additional Force or (3) Liquid to simulate weight feedback.

Reference

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Design and Implementation

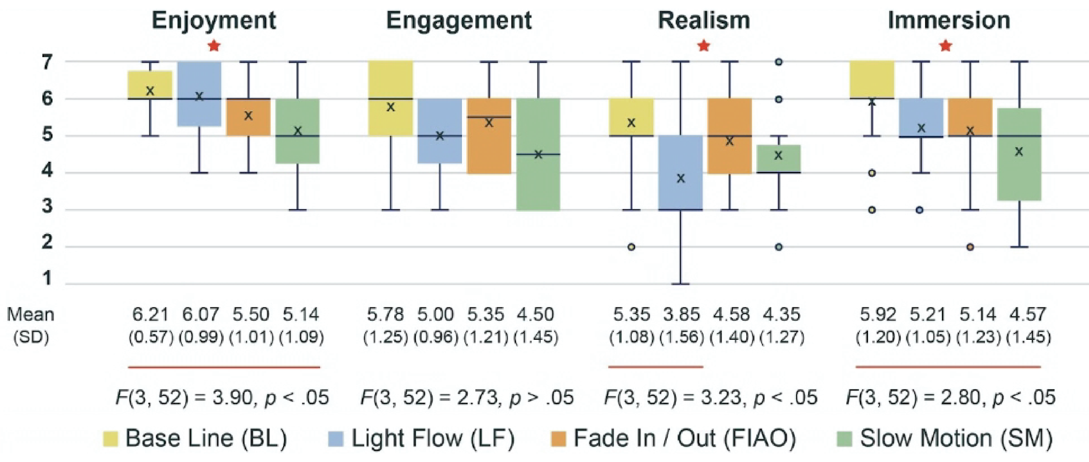
Based on the characteristic of liquids, we have designed 4 fixable water bags that can be worn on the limbs, connected to the piping system with a 120cm long 80g hose. The micro controller will send on/off signals to 2 17A motor drivers and 5 TB6612FNG motor drivers via Bluetooth. By turning on or turning off the pump and water valve, we can dynamically adjust the amount of water between the water tank and water bags to achieve the purpose of weight change.

Interaction Design

The VE was designed as a ***feeding rabbit scenario***. Users need to pick up a water bottle to fill the water and then water the carrot. When the carrot grow, users need to put down the water bottle, pull up the carrot, and finally feed the rabbit.

14 participants (6 males) were recruited, whose ages ranged from 20-25 years old (mean=22.7, SD=1.54); 12 participants had worn VR headset before. We asked them to wear a water bag on their arm and a VIVE HMD with the noise-canceling headphone. In the VE, they were asked to ***pick up and drop off an object with a controller trigger to experience weight feedback with visual feedback.*** We design 4 user interfaces ***(1) BaseLine(BL)***: no visual effect when the weight transfers. ***(2) Light Flow(LF):*** when the weight transfers, a beam of light flow will flow from the weight source to the object receiving it, and the light flow will disappear after reaching the specified weight. ***(3) Fade In/Out(FIAO)***: objects gradually appear or disappear as the weight transitions. ***(4) Slow Motion(SM)***: the physical hand with the object will move slowly in the direction of the virtual hand when the weight transfer. Until the water bag reaches a specified weight, the physical hand will return to normal speed, and the virtual hand will disappear. Users can experience each interface until they are satisfied. Finally, participants took off the HMD and ***filled in a custom questionnaire, which used a 7-point scale (7 = totally agree, 1 = totally disagree). In the end, we interviewed the participants.***

Discussion and Future Work



Overall, we found that when the weight change situation is in a real scene, ***users will be appealed to the changes in the interfaces*** (LF, FIAO, and SM) but will pay less attention to the weight change.

However, ***the interface can give users an idea of what will happen next***. Because BL has no visual effect, it can make people pay more attention to the weight change, and its realism is also the closest to the situation. Therefore, the BL with haptic feedback has a high score. Besides, if we combined BL with haptic and the visual effect, ***the effect gives users a stronger feeling than the haptic, so the overall score decreases.*** Consequently, the effect may not be suitable for real-world simulation. In the future, we will make different scenarios, such as weightlessness in the universe and the situation of weight change in the magic world. We will use the visual connection effect between objects and the weight conversion to ***explore how the effect of weight change in non-realistic situations can increase the immersive experience.***