Extended Research Project

VR for soft robotic exoskeletons: Realistic Weight Liquid Feedback System for Virtual Objects

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1. Objective

The topic of this project is VR for soft robotic exoskeletons.The aim of this project is to develop a realistic gravity detection feedback system based on virtual objects.

For objects in virtual reality platforms, the project aims to propose a physical approach to provide realistic gravity feedback for objects that are virtually detected in reality. With the help of virtual reality devices and physical feedback system components, users will be able to approach the actual feeling of gravity feedback.

2. Introduction

The system consists of a virtual reality software component and a physical hardware component. The software component is responsible for the user's grasping data transfer and visual aids, and is implemented by Unity code and controlled and connected by an Arduino development board.

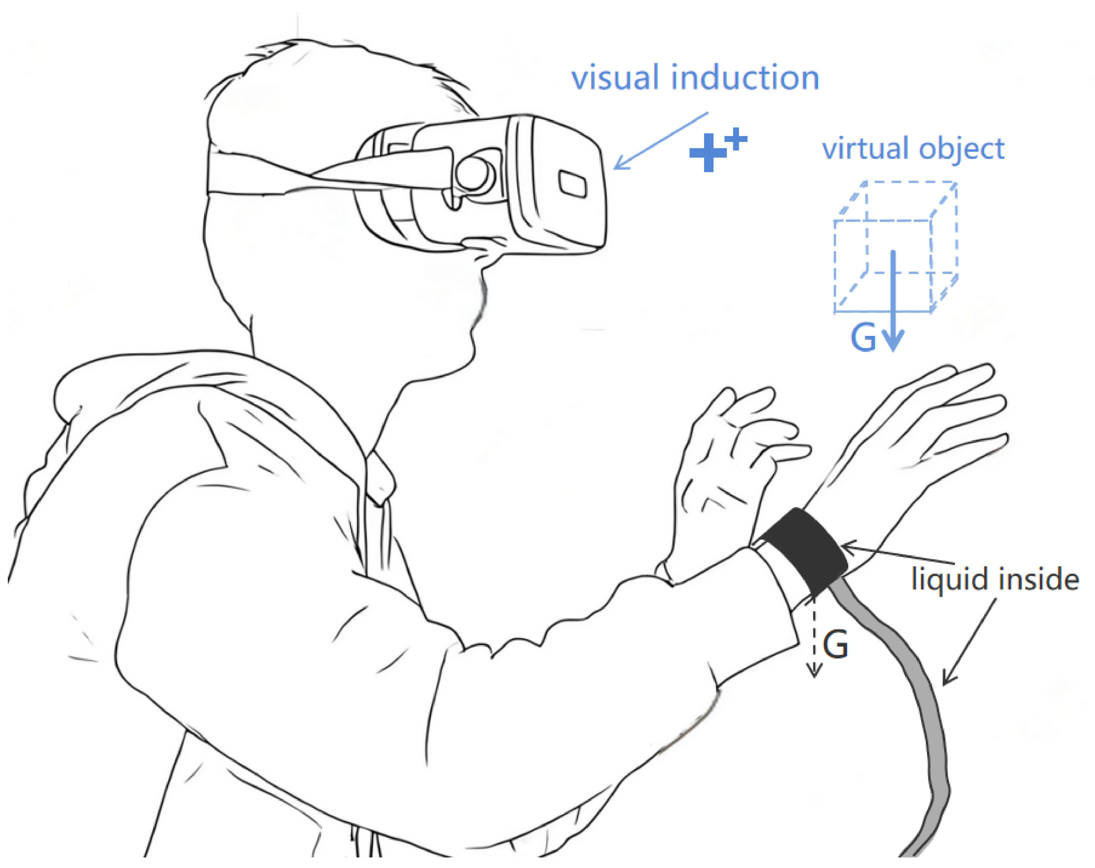

Figure 1: System Schematic

The hardware component is an infusion wristband driven by multiple stepper motors. After the input data is processed, the motors are driven by the development board and the liquid is passed through the motors to realize the mutual transfer and measurement of the container and the wristband. Gravity feedback is achieved by instantly transferring the same weight of liquid to the user's wristband.

3. Methods

In the project, a combination of Visual Induction and Physical Feedback is used to enhance the user's gravity perception and haptic experience in a Virtual Reality (VR) environment.

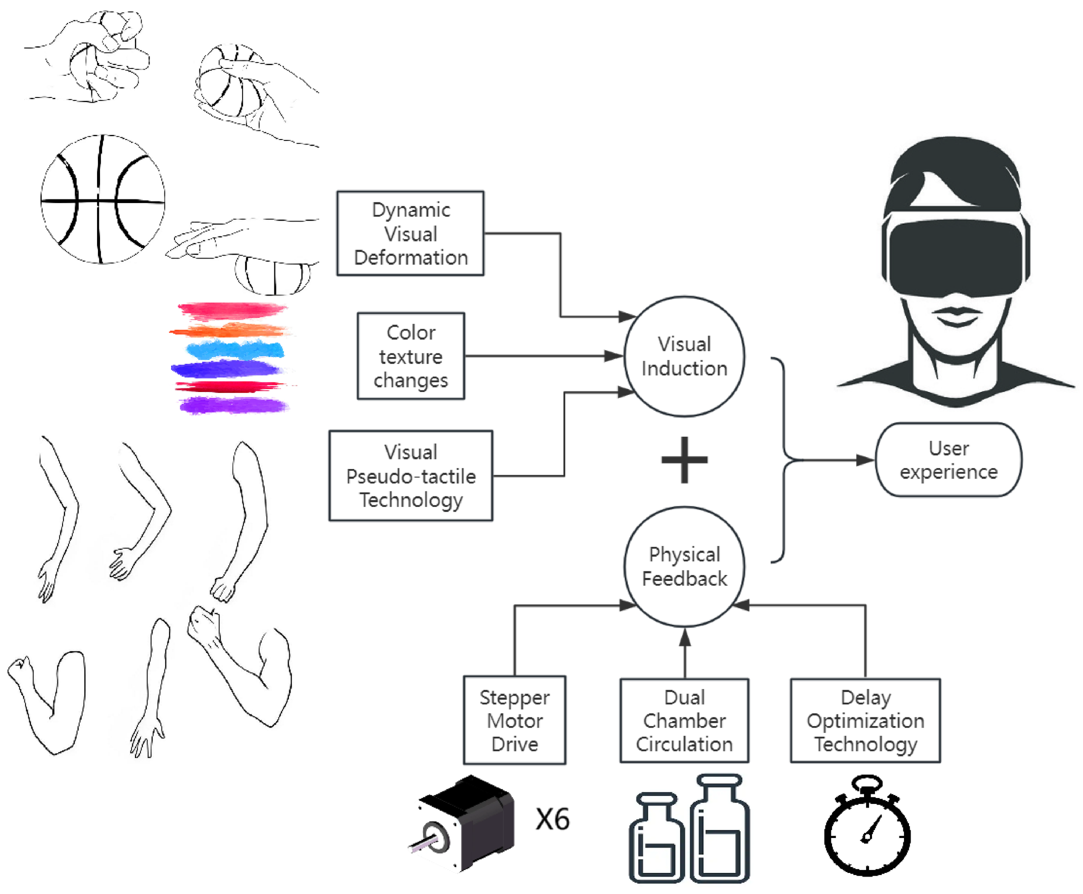

Figure 2: System components and functions of each component

3.1 Visual Induction

Dynamic Visual Deformation: Simulates the weight and force feedback of physical contact through small changes in the shape of objects.[1]

Color & Texture Changes: Adjust the color and texture of visual elements based on weight and pressure to enhance immersion.[2]

Visual Pseudo-tactile Technology: Utilizing visual means such as motion illusion and environmental response to enhance the user's tactile perception.[3]

3.2 Physical Feedback

Stepper Motor Drive: 6 sets of stepper motors control the external physical feedback device to realize the fluid flow changes to provide real gravity feedback.

Dual Chamber Circulation: Dynamically adjusts gravity perception using dual chambers and a wristband fluid circulation system to match the virtual experience to the real physical experience.

Delay Optimization Technology: Optimizes the delay between sensors, rendering, and physical feedback to ensure a smooth and real-time user experience.

4. Results

The experimental results show that the combination of visual induction and physical feedback in this project can effectively enhance the perception of gravity in VR environments. User experience data shows that the user's perception of the weight of a virtual object is reduced by about XX% compared to a system that relies only on visual or single physical feedback, and more than XX% of users report that the system provides a more realistic haptic experience.

Feature	Visual Only	Basic Haptic	Proposed System
Gravity Perception Accuracy (%)	XX.X%	XX.X%	XX.X%
Immersion Score (1-10)	X.X	X.X	X.X
Latency (ms)	XXX	XXX	XXX
User Satisfaction (%)	XX.X%	XX.X%	XX.X%

Figure 3: Comparison chart of user experience data

5. Conclusions

This project successfully developed a VR gravity perception enhancement system based on visual sensing + physical feedback. Through dynamic visual deformation, liquid feedback control, stepping motor drive and other technologies, users can obtain a more realistic gravity perception and force feedback experience during VR interaction.

The system can be widely used in VR training and simulation, virtual reality games and entertainment, remote tactile interaction and other fields.

6. References

[1] 'A study of the effect of stereo image acquisition distortion on visually induced motion sickness | Advances in Lasers and Optoelectronics - Chinese Optical Journal'. Accessed: Feb. 25, 2025. [Online].

[2] 'Effects of optical aberrations on visually induced motion sickness in near-eye displays | Liquid Crystal and Display – Chinese Journal of Optics'. Accessed: Feb. 25, 2025. [Online].

[3] 'SP.J.1089.2024.2024-00278.pdf'. Accessed: Feb. 25, 2025. [Online].