[FM23201]

The Development of Haptic Feedback Data Glove for Enhancing Immersion in VR Experiences

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1 Introduction

Virtual reality (VR) provides immersive experiences through multisensory feedback, enhancing user interaction with digital environments. One key aspect of immersion is texture rendering, which is commonly achieved through visual and auditory cues. However, incorporating haptic feedback for realistic texture perception remains a challenge. While haptic feedback has become a mainstream approach, most existing methods rely on hand-held devices, often limiting natural hand movements. This research explores the development and performance of a haptic glove equipped with flex sensors, an Motion Processing Unit (MPU), and a coin motor, enabling texture perception at three vibration granularities.

2 Previous Methods

Deep-Texture [1] is a foldable device that renders shape and texture in VR using a linear resonant actuator and a 1-bar mechanism, with a one-finger haptic feedback system for localized sensations. A follow-up study [2] explored how vibrotactile parameters (granularity, amplitude, timbre) influence texture perception by synchronizing vibrations with user movement. Building on this, our research develops a data glove with five-finger haptic feedback, utilizing Pulse Width Modulation (PWM) to create varying granularity for texture rendering.

3 Proposed Method

Our proposed device is a sensor-equipped glove designed to enable finger tracking while delivering realistic haptic feedback. The glove integrates multiple key components to enhance interaction and immersion. Flex sensors are attached to each finger, allowing the system to detect bending and movement, accurately measuring the degree of flexion to interpret finger gestures in real time. An MPU, is embedded to track hand orientation, acceleration, and rotation, enabling motion capture and seamless interaction within virtual environments. Micro-vibration motors are placed within the glove to enhance tactile realism and provide haptic feedback, generating subtle vibrations that simulate textures during virtual interactions.

4 Experimental Setup

We involved six male participants in their 20s, who conducted two experiments to evaluate haptic feedback perception. The haptic feedback in this experiment were generated using PWM method at three different cycle rates: 20 cycles, 50 cycles, and 100 cycles, each representing a distinct texture sensation. The experimental setup involves the following steps:

In the first experiment, participants conducted a blind test to distinguish between three different haptic feedback. Before starting, they were introduced to all three granularities. A white 3D plane then appeared in the virtual environment, randomly generating one of the granularities upon contact with the virtual hand. Participants identified the perceived granularity, repeating the process 15 times to assess their ability to differentiate between them.

The second experiment explored the relationship between haptic feedback granularities and texture perception. Participants interacted with a textured 3D plane (brick, grass, or marble), each generating three different haptic feedback granularities. After experiencing all three granularities for a given texture, they selected the one they felt best matched the material before proceeding to the next texture.

After completing an evaluation questionnaire after the experiments.

5 Results

The results indicate that in the blind test involving three haptic feedback granularities, participants were able to distinguish between the lowest granularity (20 cycles) and the highest granularity (100 cycles), as shown in Fig. 1. However, the scores for the middle granularity (50 cycles) were similar to those of the lowest granularity. Some participants noted that 'the glove is too big for my hand, making it difficult to identify the granularities accurately.' This may be due to the use of a standard glove with an attached component, which cannot be adjusted to fit every hand.

the result of second experiment as shown in fig.2. For Marble which represent the smoothest material is compatible with 100 cycle while the grass is likely to 50 duty cycle and for the last one that represent the least smoothness is 20 and 50 duty cycle is equal

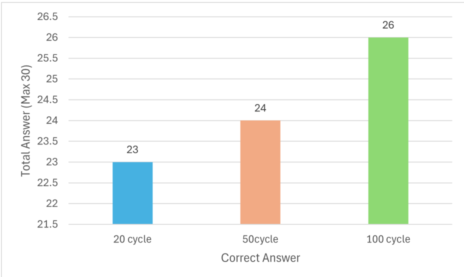

Figure 1 Result of First Experiment

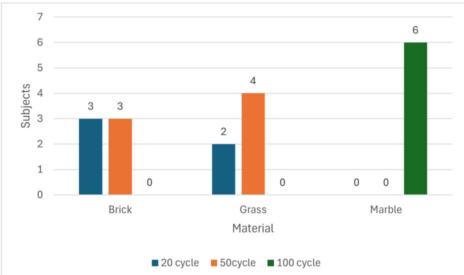

Figure 2 Result of Second Experiment

6 Conclusion

The results show that participants could distinguish between the lowest (20 cycles) and highest (100 cycles) haptic granularities, but not the middle (50 cycles), possibly due to glove fit issues. Additionally, material smoothness influenced duty cycle compatibility, with marble aligning with 100 cycles, grass with 50 cycles, and the roughest material showing no clear preference between 20 cycles and 50 cycles. These findings highlight the role of both granularity and material in haptic feedback effectiveness.

References

[1] Y. Sung, D. Kwak, T. Kim, W. Woo and S. H. Yoon, "Deep-Texture: A Lightweight Wearable Ring for Shape and Texture Rendering in Virtual Reality," 2024 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), Orlando, FL, USA, 2024, pp. 911-912

[2] Paul Strohmeier and Kasper Hornbæk. 2017. Generating Haptic Textures with a Vibrotactile Actuator. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17). Association for Computing Machinery, New York, NY, USA, 4994–5005.

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