Guide Ring: Bidirectional Finger-worn Haptic Actuator for Rich Haptic Feedback

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ABSTRACT

We introduce a novel wearable haptic feedback device that magnifies the visual experience of virtual and augmented environments through bidirectional vibrotactile feedback driven by electromagnetic coils with permanent magnets. This device creates guidance haptic effect through magnetic attraction and repulsion. Our proof-of-concept prototype enables haptic interaction through altering position of wearable structure, vibrating with different intensity, and waveform pattern. Example applications illustrate how the proposed system promotes guided and rich haptic feedback.

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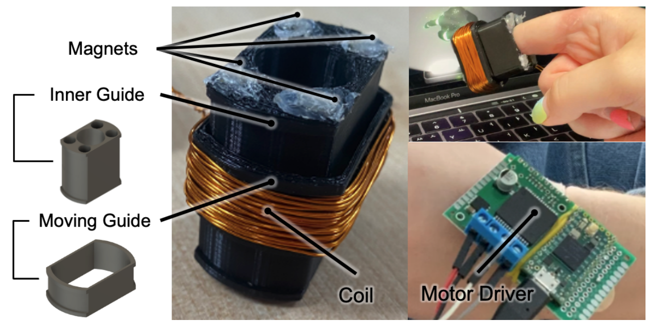

Figure 1: Guide Ring Prototype. The Inner Guide is embedded with magnets on top and bottom. The Moving Guide has a coil wrapped around which freely moves on the Inner Guide.

1 INTRODUCTION

Recent development of AR/VR interfaces has led to enhanced visual experiences that can be magnified with supporting sensing and feedback devices [3]. These interfaces depend mostly on basic haptic feedback methods such as vibrotactile and force feedback. Moreover, researchers employed electromagnets and passive magnets to create effective vibrotactile and force feedback [2, 4, 5, 7]. Here, we aim to develop a novel wearable interface that enables rich interaction by utilizing attractive and repulsive force feedback between a permanent magnets and electromagnetic coils. The proposed wearable interface provides a user with a guided haptic experience without the need for a stationary magnetic system (e.g. tabletop or patches) and controllable force feedback feature.

2 SYSTEM OVERVIEW

Hardware. Our prototype is designed to be fit with an index finger. The device consists of an inner and Moving Guide: the Inner Guide holds the Moving Guide and passive magnets and the Moving Guide slides back and forth with electromagnetic coils to create haptic feedback. Moving Guide slides within the Inner Guide's top and bottom plates. Passive magnets (6mm diameter and 10mm length) are inserted in the Inner Guide as shown in Figure 1. In terms of hardware, we use microcontroller (Teensy 4.0) and motor driver (VNH5019, Pololu) to control the amount of current applied to the electromagnetic coils.

Coil Design. We tested various wire sizes and chose 0.5mm diameter copper wire with PEW coating for our coil. We observed that the diameter of the coil influences the coil's magnetic field strength more than the length of the coil used [6]. However, a coil with a bigger diameter could limit the number of wraps around the ring, but the number of coil wraps did not affect the coil's magnetic field significantly from the user's perspective. We measured the distance from the coil where the vibration was still detectable for different supply voltages. The results showed that increasing the number of wraps from 100 to 300 increases the distance by only 2~3mm. Thus, we employed 100 wraps for the prototype.

Waveform Selection. The different waveform pattern on the driving current can increase the strength of haptic feedback. We tested four different waveform patterns including sine, triangle, sawtooth and square, with 500 milliseconds duration. The sensation felt weaker for sine and triangle waveform and the strongest for sawtooth waveform. Then, we further adjusted the frequency of the waveform pattern to maximize the sensation. According to the threshold for vibration detection [1], the feedback is the most detectable between 40~300 Hz. In our experiment, we found that 75~90 Hz was the most effective frequency range.

Magnet Placement. To confirm the magnetic field strength from given permanent magnets, we carried out a Finite Element Method based simulation. Here, we simulated a planar view of the magnetic field's density (Figure 2). From the simulation, we found that the side of the Moving Guide has the strongest magnetic field. We installed permanent magnets in the side of the Moving Guide to maximize actuator performance.

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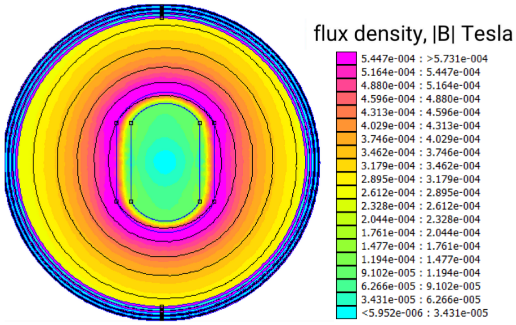

Figure 2: Planar simulation of magnetic field strength density in oval shape.

Table 1: Magnetic strength measurement for different shapes.

Measurement location	Round	Square	Oval	Rectangle
Outer edge	2.38mT	1.54mT	1.67mT	1.29mT
Middle	0.37mT	0.16mT	0.32mT	0.16mT

Shape. We evaluated different shapes of Moving Guide (round, square, oval, and rectangle) to verify the user's wearable experience and magnetic field strength. For each shape, we put 35 turns of 0.5mm PEW wire. We measured the magnetic field strength using Magnetic Field Meter (MG-3002, LUTRON) on two locations: outer edge and middle of the guide. Users reported discomfort in wearing round shape guide since the structure easily contacts neighborhood fingers. We chose oval shape guide even though the oval shape showed the second strongest magnetic field next to the round shape.

3 EXAMPLE APPLICATIONS

VR Controller Haptic Feedback. Figure 3 illustrates depth perception with haptic feedback. When the user's hand moves deeper inside of a virtual object, the vibration gets more intense. For VR gun shooting game experience, the Moving Guide moves back and forth when the shot is made to provide realistic shooting experience.

Mobile Status Feedback. As shown in Figure 4, our prototype can provide information about the interaction status. Here, the user copies and pastes a phone image using hand gestures. When it is in copying phase, the coil moves away from the phone and stays in that position. When the user pastes image, drop feedback is made by releasing the coil from its previous position.

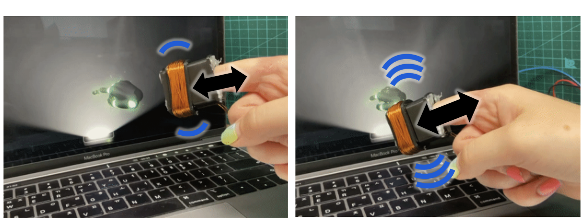

Figure 3: The depth perception could be entitles by increasing intensity as user moves deeper.

Figure 4: Our ring depicts the status of the interaction by altering the position of the moving guide.

4 CONCLUSION

We proposes a novel wearable device driven by electromagnetic coils and permanent magnets. We enable guidance haptic effect through magnetic attraction and repulsion while providing conventional vibrotactile feedback. In the future, we would carry out a user study to evaluate the performance of the suggested haptic feedback in mobile and AR/VR interfaces.

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