Magnetic Haptic Display for Stable Remote Force Presentation

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Abstract. Haptic displays that remotely present force using magnetism have been developed, but existing devices have limitations in the freedom of movement of the user's hand. In this study, we propose a device that uses a Maxwell coil with large opening to drive a magnet grasped by the user. Preliminary experiments show that the force that can be presented by this device is comparable to that of devices based on illusory force induced by asymmetric vibration.

Keywords: haptic display, force presentation, magnetic force

1 Introduction

Haptic displays are divided into grounded and ungrounded types, and as an intermediate form between the two, there are displays that remotely actuate the grasped part using magnetic force. For example, Berkelman et al. [1] proposed a device that uses magnetic levitation to present force of six degrees of freedom within a range of motion of several centimeters. In addition, Lu et al. [2] proposed a device for presenting force of one degree of freedom in a cylindrical electromagnet array with a diameter of 210 mm and a length of 234 mm. However, the former has a smaller workspace than existing grounded devices, and in the latter device, the user's hand movement is limited to insertion of hand into a cylinder.

In this study, we propose a haptic display that can present force of one degree of freedom and allows the user to move more freely, using a pair of widely spaced coils and a rotating permanent magnet. This device can present stable force sensation, because it presents physical force without rather than illusory one.

2 Proposed Method

The electromagnets that generate force consist of a pair of square air-core coils of approximately 200 mm, facing each other at intervals of approximately 170 mm (**Fig. 1**, left). The two coils have currents of the same intensity and opposite directions. This configuration is called a Maxwell coil [3, 4], and a magnetic field of linearly varying intensity can be generated between the coils. The user grasps a spherical neodymium magnet with a diameter of 20 mm, which is placed in a case and around which coils are wound in three orthogonal axes (**Fig. 1**, right). The orientation of the spherical magnet can be changed by varying the current flowing through each coil.

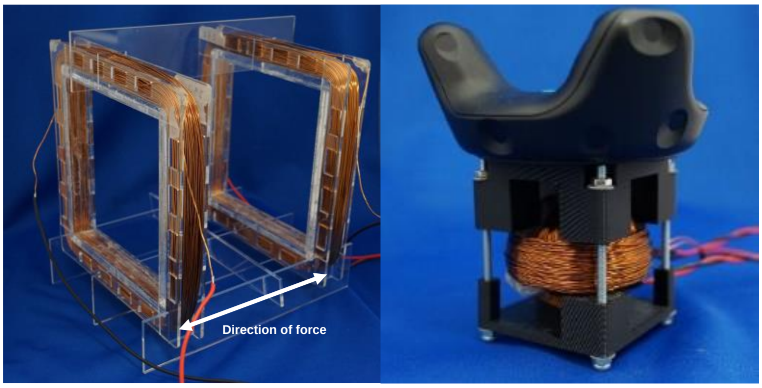

Fig. 1. The proposed device (left: the Maxwell coil, right: the grasped part)

3 Preliminary Experiment

When a voltage of 23.3 V was applied to each coil of the Maxwell coil while the orientation of the neodymium magnet was controlled so that it was aligned with the axis of the Maxwell coil (i.e., the maximum force is generated), a force of 0.298 N was generated. This force is equivalent to 30.4 g, which is comparable to the illusory force perceived by Traxion [5], an ungrounded haptic display based on asymmetric vibration. The total current consumed by the Maxwell coil was 10.2 A (238 W in power).

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