Haptic Rendering of Volumetric Shapes in Mid-Air using Omni-directional Electromagnet

Alaa Adel, Mina Maged and Islam S. M. Khalil

Abstract—In this study, we design and develop an Omni-Directional Electromagnet (ODE) for using in mid-air haptic applications to provide controlled magnetic force to the operator through a wearable haptic device. First, we model the electromagnetic force exerted on a single magnetic dipole attached to a wearable haptic device. second, this model is used for the design of ODE. We build a control algorithm for generating the required current to generate a specific force on the magnetic dipole while minimizing the magnetic torque on the magnetic dipole. This enables us to render three-dimensional (3D) virtual objects in a spherical workspace surrounding ODE with a diameter of 160 mm using magnetic force in excess of 500 mN. In order to measure the advantage of using an ODE for haptic rendering, we conduct a comparison study between using a planner electromagnets and using ODE for rendering 3D shapes. Participants experimentally demonstrate an average success rate -% and -% in distinguishing between four shapes for the two cases, our statistical analysis shows that effect of using an ODE on the average success rate is statistically significant for 95% confidence level.

Index Terms—Electromagnets, haptic rendering, omni-directional.

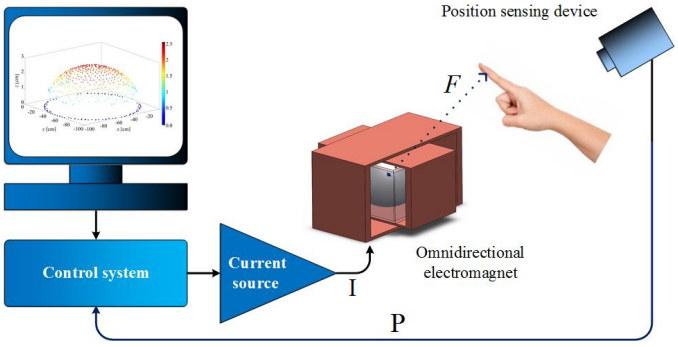

Fig. 1: An omni-directional electromagnet (ODE) based haptic interface enables the operator to interact with virtual objects in spherical space. The system consists of an ODEwhich consist of three orthogonal square section solenoids which surrounding a ferromagnetic sphere and each of this solenoid is powered independently using a current source. A current input is provided to the coils based on the morphology of a 3D virtual object and the position and the orientation of operator wearable finger using a position sensing device. A control algorithm has been built to produce the desired force while minimizing the effect of magnetic torque on the operator wearable device during exploring a virtual object

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