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Thin and Powerful Untethered Haptic Glove for Kinesthetic Feedback

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***Abstract*— We developed an untethered haptic glove that provides kinesthetic feedback to four fingers (excluding the little finger) using electrostatic clutches. Most commercial kinesthetic haptic gloves use motors or brakes, making them bulky, heavy, and power-hungry. To address these limitations, we developed a thin and lightweight electrostatic clutch based on PVC-gel, capable of generating up to 20 N of friction force under low voltages below 100 V. By mounting the clutches on the back of the hand and connecting tendons to the fingertips, we built a compact glove that delivers kinesthetic feedback. A miniaturized, battery-powered circuit was also developed to enable fully untethered operation. A demo was developed to demonstrate object size discrimination and crushing sensations using the proposed glove.**

Keywords—Haptic Glove, Untethered, Kinesthetic, Electrostatic clutch

I. Introduction

Haptic gloves are emerging technologies for training, simulation, and interaction in virtual environments. Most commercial kinesthetic haptic gloves employ electromagnetic motors and clutches, which are bulky, heavy, and consume high power. Electrostatic clutches[1] offer a promising alternative thanks to their thin structure and low power requirements, though they typically operate at high voltages (hundreds to thousands of volts).

In this work, we developed an untethered haptic glove that provides kinesthetic feedback to four fingers using an electrostatic clutch based on PVC-gel. The charge accumulation effect of PVC-gel enables generation of up to 20 N of friction force under 100 V. A miniaturized, battery-powered circuit was also developed, enabling a fully untethered system. We demonstrate the ability to grasp spheres of different sizes and simulate crushing sensations with the proposed glove.

II. Design of Untethered Kinesthetic Haptic Glove

Figure 1. illustrates the structure and working principle of the PVC-gel electrostatic clutch, as well as the developed haptic glove. The electrostatic clutch consists of a dielectric film placed between two electrodes. When a voltage is applied, electrostatic force makes the electrodes adhere, generating a strong friction force. However, conventional dielectric materials require high voltages ranging from hundreds to thousands of volts to achieve sufficient electrostatic force. PVC-gel exhibits a charge accumulation effect, where charges migrate toward the positive electrode under an electric field, reducing the effective distance between electrodes and enabling strong electrostatic forces even at low voltages [2]. Using this property, the PVC-gel electrostatic clutch achieves about 20 N of friction force under 100 V. We implemented a kinesthetic haptic glove using this clutch, with the clutches mounted at the wrist and tendons routed through wire guides along the back of the hand to fingertip thimbles. When no voltage is applied, the fingers move freely; when voltage is applied, increased friction restricts finger movement, providing users with kinesthetic feedback for grasping virtual objects. The low operating voltage also enabled miniaturization of the control circuitry and battery, resulting in a fully untethered haptic glove. We built a demo environment in Unity and used Leap Motion for hand tracking to implement a scenario where users grasp spheres of different sizes and apply force to crush them.

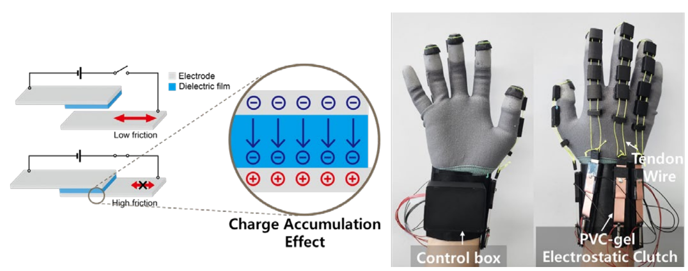

Figure 1. Structure and operating principle of the PVC-gel electrostatic clutch and the implemented untethered haptic glove.

References

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