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A Novel Haptic Feedback Device Using Stick-Slip Actuators for Multimodal Interaction

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I. Introduction

Stick-slip actuators (SSAs) are commonly used in high-precision positioning systems. However, their potential for haptic feedback applications remains largely unexplored. We propose a compact haptic device using an SSA to simulate sensations such as grasping, texture, and slippage in VR.

Numerous studies have explored the development of interfaces that deliver richer haptic experiences. Previous studies have proposed a range of devices to address these aspects [1], [2]. However, many existing methods require complex structures and multiple actuators to simultaneously provide force feedback and friction or slippage sensations, remaining miniaturization and simplification problems.

To address these issues, we present a novel haptic feedback device employing a SSA. An SSA consists of a piezoelectric element, a drive rod, and a slider (Fig. 1). By applying periodic electrical signals to the piezoelectric element attached to the drive rod, microscopic vibrations and displacements are generated. The resulting frictional and inertial forces between the drive rod and the slider produce linear motion [3].

Furthermore, by synchronizing the device with visual content, we aim to establish multimodal interaction systems where, for example, a CG character's biting motion is synchronized with the device, conveying sensations such as the feeling of chewing and the reactive force from an object to the user's fingers.

II. System Configuration

Figure 2 illustrates the prototype of the haptic feedback device based on the SSA and implemented scenario. The device consists of the SSA, hand grips, and a distance sensor installed on one of the grips to measure the distance between the two grips. Based on this distance information, the system dynamically controls the SSA's movement direction and operation mode, enabling various tactile sensations in response to finger motions. Simultaneously, a CG model displayed on a PC (Unity) changes in coordination with the measured distance.

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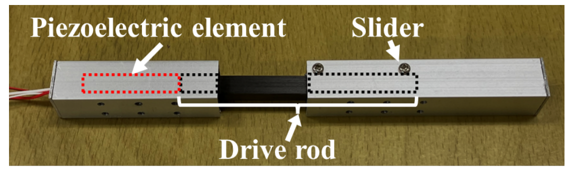

Fig. 1. **Structure of the stick-slip actuator.** The left end of the drive rod is fixed, with the piezoelectric element attached. A friction material is mounted inside the slider. When a periodic electrical signal is applied to the element, it induces microscopic vibrations in the drive rod. By varying the signal pattern, the slider moves left or right.

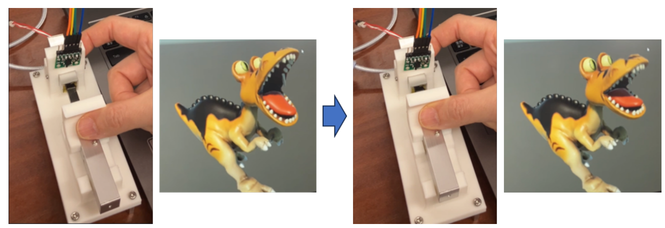

Fig. 2. **Example implementation of synchronized visual and haptic feedback.** The user operates the device by pinching and releasing it, which controls the mouth movement of a CG character. During the biting motion, the user feels varying tactile sensations, firmness, vibration, and softness, simulating the experience of biting through a hard object like a can.

As an example implementation, we developed a content scenario where the opening and closing of the device corresponds to the mouth movement of a CG dinosaur character (Figure 2), aiming to present sensations such as the feeling of chewing and the reactive force from an object to the user's fingers by driving the SSA accordingly. While a virtual object (e.g., a can) being bitten by the character has not yet been implemented, the haptic feedback component is functional. In this scenario, the user can feel tactile sensations such as initial firmness, followed by vibration and then a softer sensation, simulating the crushing of a hard object like a can.

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