Two-Finger Grasping Virtual Environment with Realistic Stick-Slip Vibration

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Abstract. We propose a two-finger grasping virtual environment that generates realistic vibrations and frictions when the virtual fingers make contact with and slide over virtual objects. By incorporating a precise friction model into the haptic rendering, we reproduced stick-slip vibration more realistically than conventional methods. We will demonstrate how users can experience the grasping operation of virtual objects using the proposed and conventional methods. We use a 6-DOF SPIDAR with a force sensor attached to its rigid gripper as a haptic interface.

Keywords: Virtual Grasping · Friction · Haptic Rendering.

1 Introduction

By attaching a force sensor to the rigid gripper of the haptic interface and reflecting the measured grasping force in the virtual world, grasping operation on virtual objects can be realized[2]. Some of the dexterous grasping operations in the real world can also be realized in the virtual world: the shifting and sliding of the fingers depending on the grasping force and moving an object with a part of it touching the floor to adjust its position. However, the problem is that the fingers hold the gripper too tightly, and after operating it for a while, they become tired. We hypothesized that this is because although the friction force is presented, it is difficult to sense the moment when the slip occurs, and it takes time for the user to notice that the object has slipped.

In real-world object manipulation tasks, stick-slip phenomena may occur at the fingertips when an object begins to slide, and humans are sensitive to this phenomenon[6]. In the performance of virtual object manipulation tasks, fingertip vibration information also plays an important role[7]. Therefore, we think the operability of virtual grasping can be improved by reproducing the stick-slip phenomenon more realistically.

Conventional friction calculations in haptic rendering generally employ *Coulomb* friction, which consists of static and dynamic friction. However, in addition to *Coulomb* friction, real-world friction includes various frictional phenomena: viscous friction, the *Stribeck* effect[8], which occurs at the contact surface of two fluid-lubricated objects, pre-sliding displacement[1], a partial slip that occurs prior to a large sliding displacement, and time dependence of static friction[5], the phenomenon that the static friction coefficient increases with sticking time. These frictional phenomena affect the behavior of the stick-slip phenomenon.

In order to reproduce the stick-slip phenomenon more realistically than conventional haptic rendering methods, we devised a friction model with friction properties such as the pre-sliding displacement and the time dependence of static friction and incorporated this into haptic rendering.

2 Proposal

The LuGre model[3] is one of the friction models in which *Coulomb* and viscous friction, the *Stribeck* effects, and the pre-sliding displacement are considered. We proposed a new model that incorporates the time dependence of static friction[5] into the LuGre model so that the dependence is treated in a unified manner with the *Stribeck* effect. Furthermore, at the moment of a slip, a damped vibration corresponding to the characteristic vibration of a real object is presented. We incorporated this method into the haptic rendering. As a haptic interface, we used a 6-DOF SPIDAR with a force sensor attached to its rigid gripper. We used virtual coupling[4] to connect the haptic interface to the virtual fingers.

3 Demo

We will demonstrate how users can experience the grasping operation of virtual objects using the proposed and conventional methods. Virtual fingers and several virtual objects are displayed on the screen. By looking at the screen and manipulating the SPIDAR, users can lift the virtual objects or slide the virtual fingers on the surface of the objects.

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