1 Introduction

Nowadays, we can interact with humans or objects even if they are located in remote places or in virtual environments. In these interactions, we can watch, listen, touch, and move objects. However, the properties of an object are not present in conventional systems. When we communicate or perform a task, a lack of haptic sensation reduces the realism and interactivity. Therefore, there is increasing requirement for haptic technology presently.

“Haptic Telexistence” aims at achieving highly realistic haptic interaction among humans and objects located in remote places. In order to realize this, a slave hand with sufficient mobility and a master hand that can operate the slave hand easily are required. In addition, haptic sensors and displays are needed to perceive the haptic information correctly. We developed innovative devices and constructed a robot hand master-slave system (Figure 1). We can perceive both the stiffness and the exact shape of an object by using our system. Further, more natural and dexterous manipulations of an object become possible.

Figure 1: Master-slave system for “Haptic Telexistence.”

2 Devices for “Haptic Telexistence”

Our system consists of four innovative devices, namely, a dexterous slave hand, finger-shaped haptic sensor for the slave hand, exoskeleton encounter-type master hand, and electrotactile display. Each of these devices have more advantages than the corresponding conventional ones.

Our multi-fingered slave hand has a total of 15 degrees of freedom (DOF). Each fingertip has independent DOF and the index finger and the thumb can be countered. Therefore, a pinching operation by a fingertip is possible. In addition, we developed a finger-shaped haptic sensor using GelForce technology. GelForce is a haptic sensor that measures the distribution of both the magnitude and direction of force. The structure of this sensor is so simple that we were able to minimize the size and realize a high resolution.

To operate the slave hand and to present force feedback, we constructed a multi-fingered master hand. This hand has two features. One is a compact exoskeleton mechanism called “circuitous joint,” which covers a wide workspace of an operator’s finger. Another is the encounter-type force feedback. This avoids unnecessary contact sensation and enables unconstrained motion of the operator’s fingers. Subsequently, we mounted an electrotactile display on the master hand to present the tactile sensation. The electrotactile display directly activates nerve fibers within the skin surface by an electrical current from the surface electrodes. It can selectively stimulate each type of receptor and produce vibratory and pressure sensations with an arbitrary frequency.

3 Haptic Transmission

The master-slave manipulation is realized by bilateral impedance control of the dexterous slave hand and the encounter-type master hand. This control is done from position of the master and slave fingers and force applied to them. The position is calculated from the angles of each finger joints. The force is measured by the finger-shaped GelForce on the slave hand and the force sensor on the master hand. When the slave hand touches an object, the finger-shaped GelForce mounted on the slave hand acquires haptic information. Then, this information is transmitted to the master system. The electrotactile display presents us tactile sensation based on this information. As a result, we can feel a field, edge, peak, and movement of an object. By integrating these kinesthetic and tactile sensations, we can perceive the exact shape and stiffness of an object (Figure 2). This enables highly realistic interactions with objects in remote places.

Figure 2: Sensing and presentation of haptic information.