Haptic Transmission System to Recognize Differences in Surface Textures of Objects for Telexistence

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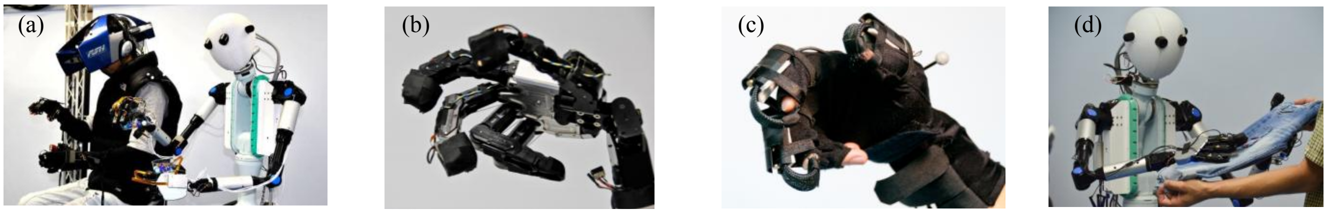

Figure 1: (a)TELESAR V. (b) Haptic scanner on TELESAR V slave hand. (c) Haptic display on operator glove. (d) Checking for denim touching sensation by TELESAR V.

ABSTRACT

In this paper, we propose a haptic transmission system for telexistence to improve the ability to sense the presence of remote objects. This system can transmit information about the existence and surface textures of objects in remote locations. The system consists of a conjugated haptic sensor and display. The sensor on the robot's finger detects the pressure, vibration, and temperature of a remote object, and the display provides above information on the operator's finger. Based on this information, the operator can understand what he/she is touching and whether its surface is hard or soft, cold or hot, and smooth or rough. With the use of our system, the operator can recognize the difference between objects such as silk and denim.

Keywords: Haptic devices, telecommunications, scanners.

Index Terms: B.2.11 [communication hardware, interfaces, and storage]: tactile and hand-based interfaces — haptic devices; J.1.3 [human-centered computing]: human computer interaction (HCI)—interaction devices

1 INTRODUCTION

Telexistence is a concept referring to technology that enables a human to experience the real-time sensation of being at a place other than where he/she actually exists, and to interact with remote environment [1]. In telexistence, it is necessary to provide an operator with not only visual and auditory information but also haptic information about the remote environment and objects in order to realistically represent those remote objects and environment. We have developed a haptic transmission system that is installed in TELESAR V telexistence system [2].

Human haptic sensations are composed of two types of sensations: kinesthetic and cutaneous sensations. Cutaneous sensations include sensations of pressure, flutter, vibration, cold, warm, and pain. The sensations of pressure, flutter, vibration, cold, and warm are acquired by Merkel cell neurite complexes, Meissner's corpuscles, Pacinian corpuscles, cold receptors, and warm receptors respectively [3]. There have been numerous studies on the transmission of haptic information, but most of these have only been able to transmit a limited amount of information [4-7]. On the other hand, some haptic scanners [8] and haptic displays [9] have been developed that can detect or provide relatively rich haptic information.

In this paper, we propose a multiple haptic information transmission system that consists of a haptic scanner, haptic display, and processing block as a package that can transmit pressure, vibration, and thermal sensations. The system is designed based on physiological haptic perception, as well as a one-to-one correspondence between the scanning and displaying components to reproduce a sensation for each receptor.

2 SYSTEM DESIGN AND IMPLEMENTATION

As shown in Figure 2, the haptic transmission system consists of three parts: a haptic scanner, haptic display, and processing block.

When the haptic scanner touches an object, it obtains haptic information such as contact pressure, vibration, and temperature. The haptic display provides haptic stimuli on the user's finger to reproduce the haptic information obtained by the haptic scanner. The processing block connects the haptic scanner with the haptic display, and converts the obtained physical data into data that include the physiological haptic perception for reproduction by the haptic display. The details of the mechanisms for scanning and displaying are described below.

First, a force sensor inside the haptic scanner measures the pressure magnitude when the haptic scanner touches an object. Then, a motor-belt mechanism [10] in the haptic display reproduces the pressure on the operator's fingertips. The processing block controls the electrical current of the motor to provide the target torque based on the measured pressure. As a result, the mechanism reproduces the pressure sensation when the haptic scanner touches the object.

Second, a microphone in the haptic scanner records the sound generated at its surface when the haptic scanner is in contact with an object. Then, a force reactor in the haptic display plays the recorded sound as a vibration [11]. This vibration provides a high frequency haptic sensation. Therefore, the information should be transmitted without delay. For this purpose, the processing block transfers the sound signals using circuits with no transformation.

Third, a thermistor sensor in the haptic scanner measures the surface temperature of the object. The measured temperature is reproduced by a Peltier actuator placed on the operator's

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fingertips. The processing block generates a control signal for the Peltier actuator. The signal is generated based on a PID control loop with a feedback from a thermistor located on the Peltier actuator. The P and D parameters in the PID control loop are set to large values for a high response rate.

As shown on the left side of Figure 3, the haptic scanner consists of ten parts, including three sensors: the Base Part, Top, Force Sensor, Resilient Material, Movable Part, Microphone, Microphone Base, Soft Material, Temperature Sensor, and Skin Part. The Base Part and Top serve as human nails. The Movable Part, Resilient Material, and Soft Material serve as an elastic body like a dermis and subcutis. The Skin Part serves as the epidermis.

As shown on the right side of Figure 3, the haptic display consists of the Body Part, Motor, Belt, Peltier, and Force Reactor. The Body Part and Motor are arranged on the nail side. The Belt, Force Reactor, and Peltier are arranged on the fingertip side in order to attach both the Force Reactor and the Peltier firmly to the fingertip. Moreover, the haptic display was designed to be compact so as not to restrict bending and stretching movements of the finger.

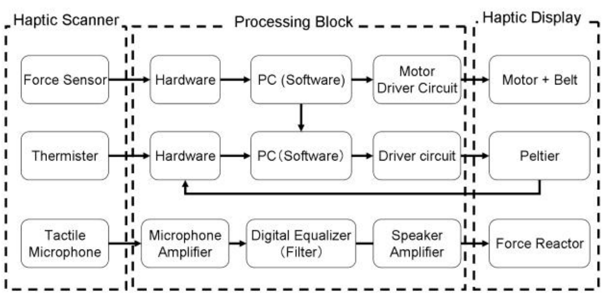

Figure 2: Data flow chart of the haptic transmission system.

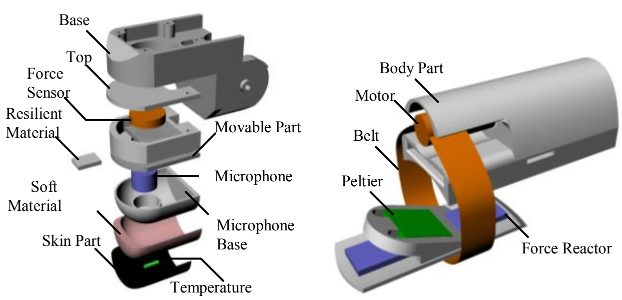

Figure 3: (Left) Construction of haptic scanner.
(Right) Construction of haptic display.

3 User Experience and Discussion

We demonstrated TELESAR V and the haptic transmission system at an international conference [2] and a domestic conference in technical demonstrations (Figure 1 (d) and Figure 4). Participants wore the haptic display and felt haptic sensations through the system. With the use of our system, the participants touched a T-shirt, denim, a LEGO block, snake skin, a bamboo mat, hot or cold cans, and an empty cup or a cup filled with marbles. Some of the comments that we frequently received are listed below.

- The differences between the surface textures of clothes or materials can be recognized.
- The visual and haptic information are well matched so as not to cause a feeling of discomfort.
- The sensations that the participants can feel through the system are not the same as those that they feel when directly touching something with their fingers.
- It is difficult to feel a haptic sensation for very soft objects.
- Reproducing the temperature has a long delay.

As a result, it was found that our haptic transmission system could deliver haptic information that was a good match for the visual information. However, it was not able to reproduce the sensation that users can feel when directly touching an object with their fingers.

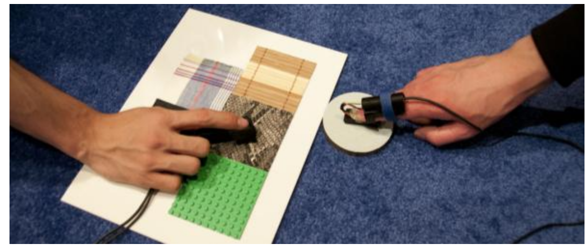

Figure 4: Haptic transmission system.

4 Conclusion

In order to realize natural interaction with objects located in remote places, we proposed a haptic transmission system that consists of the haptic scanner, haptic display, and processing block. This system can transmit pressure, vibration, and thermal sensations. The system can provide haptic sensations that are a good match to those imagined from visual information. In the future, we will construct a haptic transmission system that is also able to represent the pressure distribution on the fingertips to reproduce a more realistic haptic sensation.

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