1DOF Sensor and Display system of Haptic and Temparature Sensation

Hiroaki Yano[*] University of Tsukuba
Itsuro Hayashi[†] University of Tsukuba
Hiroo Iwata[‡] University of Tsukuba

ABSTRACT

This paper describes development of a sensor and display system that is sensing hardness and temperature of a real object simultaneously and displaying them as a virtual object. The sensor system consists of a force sensor, a linear-encoder, and a thermistor. And the display system is composed of a DC motor, a rotary-encoder, and a planer end effector which mounts a peltier device. The display system presents the hardness and temperature that are measured by the sensor system to the user's fingertip.

Index Terms: H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems—Artificial, augmented, and virtual realities; H.5.2 [INFORMATION INTERFACES AND PRESENTATION]: User Interfaces—Haptic I/O;

1 INTRODUCTION

By the latest rapid growth of the performance of network technology and computer, a huge quantity of digital data can be exchanged between remote users. Information of visual and auditory sensation such as pictures or video data is mainly exchanged now. By the above technical progress, the haptic sensation will be able to exchange between remote users. We will be able to touch remote objects and get haptic information.

In such situation, it is quite natural for users to use a rich haptic interface such as 6 DOF (Degree Of Freedom) force feedback interface and a tactile interface. However, as the other way, we can acquire much information by using simple 1 DOF interface like a communication with Morse code. For example, we can recognize the material of a object by feeling its hardness and temperature. In communication between remote user especially, we can feel as if he/she exists by feeling not only the proprioceptive sensation of a remote user but also remote user's warmth. Furthermore, the 1DOF simple interface can be manufactured with low cost. Many temperature displays had been developed and some of them combined with tactile interface [4]. However, there is no display combined with proprioceptive display and temperature display.

In this study, we developed a 1 DOF haptic interface that can display proprioceptive sensation and temperature simultaneously to a user. Also, we developed data acquisition system of hardness and temperature, of a remote object simultaneously.

2 SYSTEM CONFIGURATION

This system consists of a sensor system, a display system and their control PC (DELL DIMENSION 8250) (Figure 1).

2.1 Sensor system

The sensor system composes of a hardness sensor and a temperature sensor (Figure 2).

[*]e-mail: yano@iit.tsukuba.ac.jp
[†]e-mail:hayashi@vrlab.esys.tsukuba.ac.jp
[‡]e-mail:iwata@kz.tsukuba.ac.jp

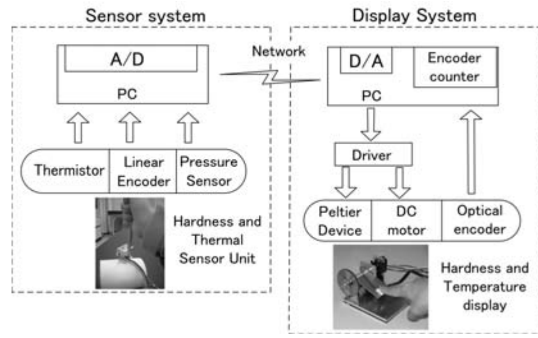

Figure 1: Basic configuration of this system.

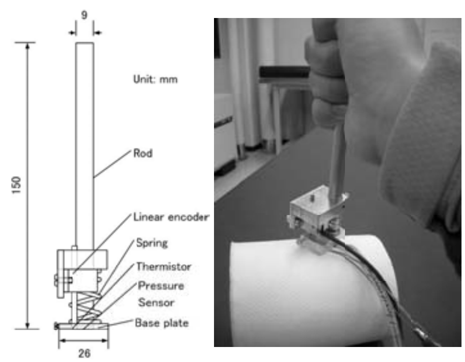

Figure 2: Basic configuration of the sensor system.

2.1.1 Hardness sensor

As hardness parameters of a object, there are a Young's modulus, a Poisson ratio and Brinell hardness, Shore hardness, etc. Among these, Young's modulus can be considered the most fundamental parameter in case of use with a haptic interface. In this research, we decided to implement equipment for measuring a Young's modulus.

There are several methods to measure a Young's modulus such as a method by using high frequency vibrator [1]. In this study, considering easy to fabrication at low cost, we use two sensor, a displacement sensor and pressure sensor. By calculating a value of pressure over displacement from the object's surface, we can get a Young's modulus.

A prototype hardness sensor was developed. It has a base plate and a rod which are made from aluminum. The rod connects with the plate by a spring coil and it can be put in a hole on the plate. In an initial state, the underside of the rod and the underside of the plate are the same height. A pressure sensor (FlexiForce made by NITTA Corporation) is attached to the underside of the rod. A linear encoder (LIC-0308, made by Murata Manufacturing Company, Ltd.) connects the base plate and the rod. When a user puts the underside of the sensor to an object, the plate contacts the object surface. And the object caves in according to displacement between the rod and the plate. The Young's modulus of the object can be calculated with the pressure and the displacement measured by the pressure sensor and the encoder. The resolution of the encoder is 0.125 micro meter. The resolution of the pressure sensor is 100 gf/cm^2.

2.1.2 Temperature sensor

Temperature can be measured by using an infrared camera, a thermoelectric couple or a platinum resistance temperature detector. However, since the sensor attaches to a target object, it is difficult to use a camera system. Also to avoid deformation caused by the sensor shape, it has to be thin and light and flexible. Considering above, we use thermistor as a temperature sensor.

A prototype temperature sensor consists of a thermistor (JT Thermistor 103JT, made by Ishizuka Electronics Corporation) and its driver circuit. The thermistor is attached on the underside of the base plate of hardness sensor near the rod. Since the thermistor has 1 mm height, it might cause pressure sensor error if it attached on the underside of the rod. The sensor has resolution of 0.02 [deg C].

2.2 Display system

We developed a 1 DOF multi-modal display system, which can display hardness and temperature, of a remote object simultaneously. The display system consists of a hardness display and a temperature display (Figure 3).

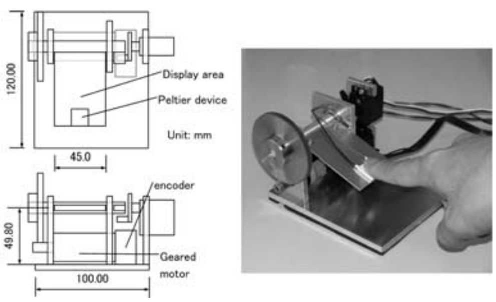

Figure 3: Basic configuration of the display system.

2.2.1 Hardness display

The hardness display consists of a linkage which rotates about a horizontal axis, and its controller. Since it is considered that deformation of a virtual object which is presented with the display is small, the pushing motion, which is a linear motion, can be approximated by the linkage. Furthermore the configuration of the linkage is easy to implement with low cost.

The linkage is 0.06 m length and is attached to a geared DC servo motor (RE25 made by Maxon motor) with an optical shaft encoder. The motor can generate a torque of 1.096Nm. Since the length of the linkage is 0.06m, the user can feel a reaction force of 18.3N. The resolution of the encoder is 0.09 [deg]. The reaction force is calculated by the Hooke's law using the Young's modulus and approximate contact area of a user's fingertip (1 cm^2).

2.2.2 Temperature display

As a temperature display, there are a resistance heating element and a heat pump system. However, they become large and it is difficult to heat user's finger or to cool it with the same equipment . Then a peltier device (T151-40-031S made by S.T.S) is used in this study. It is attached on top of the linkage of the hardness display. A user can touch it directly and feel a temperature and a reaction force simultaneously by using the display system. The peltier device is controlled at open loop control. It can present a temperature from room air temperature to 90 [deg C]. In this study since a huge cooling mechanism is required for decreasing the temperature, the target temperature is set above the room air temperature.

3 Evaluation with Paired Comparison Method

By using the prototype system, an experiment which investigates whether temperature has influence with hardness perception was conducted. Evaluation is based on the paired comparison method. In this experiment, 3 hardnesses (0.4, 1.0 and 0.2 kg/cm) and 3 temperatures (23, 32 and 45 deg C) were provided. These values were captured from a sponge, a forearm and a bean-paste bun by using the sensor system. By combining these values, a total of nine conditions were provided. Two of the nine conditions were chosen as test stimulus. Subjects answered which stimulus was hard with the values from -3 (soft) to 3 (hard). The subjects wore an eye mask and a headphone which played white noise of -20 dB , to shut out visual and auditory cues. To reset haptic sensation at the subjects fingertip, 10 seconds interval was prepared before each trial. During the interval, the subjects put his/her fingertip on a aluminium plate with the room air temperature [2]. 6 male subjects (whose ages were from 19 to 24) conducted 72 trials. The result is shown in Figure 4. The horizontal axis means average preference ratio of the 9 conditions. As a result, all subjects can distinguish 3 hardnesses, not affected by temperature. There is no significant difference between each temperature at same hardness. The system operation capability was confirmed through this experiment.

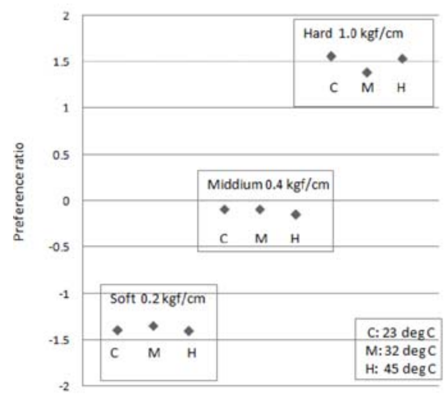

Figure 4: Average preference rate about hardness.

4 Conclusion

In this paper, a haptic sensation and temperature sensation capture and display system was developed. Through an evaluation test, the system operation capability was confirmed.

When we recognize the material of a object, we use skin temperature change after contact as a key [3]. We plan to improve the control algorithm of temperature display to present more realistic sensation.

References

[1] http://www.microphotonics.com/sonohard.html.

[2] H. Ho and L. A. Jones. Infrared thermal measurement system for evaluating model-based thermal displays. In *Proc. of World HAPTICS 2007*, pages 157–162, 2007.

[3] S. INO and et.al. A tactile display for presenting quality of materials by changing the temperature of skin surface. In *Proc. of IEEE International Workshop on Robot and Human Communication*, pages 220–224, 1993.

[4] Yang and et.al. Development of quantitative tactile display device to provide both pin-array-type tactile feedback and thermal feedback. In *Proc. of World HAPTICS 2007*, pages 578–579, 2007.