Inverse Problems in Tactile Displays

Norihisa Miki[1], Hiroki Ishizuka[2]

miki@mech.keio.ac.jp
[1]Department of Mechanical Engineering, Keio University
3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa, Japan 223-8522
[2]Department of Mechanical Science and Bioengineering, Osaka Univeristy
1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan
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ABSTRACT

Tactile displays, which present virtual surfaces and tactile information to the users, can potentially augment quality and quantity of information in human-computer interaction. In this presentation, we discuss how we solve the inverse problems of the tactile displays, i.e., how to derive the control parameters of the displays when the target tactile sensations are given, in which we propose the microfabricated tactile samples to deduce quantitative correlation between the surface properties and tactile perception.

1 INTRODUCTION

Tactile displays, which present virtual surfaces and tactile information to the users, can potentially augment quality and quantity of information in human-computer interaction. Various types of tactile displays have been proposed and demonstrated [1]. Our group have developed mechano-tactile displays consisting of a large-displacement MEMS actuator array [2], electro-tactile displays with micro-needle electrodes [3], a flexible electrostatic-tactile displays [4], etc.

In the previous works, tactile sensations presented by the displays under given conditions were characterized, i.e., forward problems were solved. However, in the practical applications of tactile displays, first, tactile sensations to be presented to the users are decided and given. Then, the conditions to control the displays are to be derived, i.e., inverse problems need to be solved. In this presentation, we discuss the inverse problems in tactile displays and propose one approach for the solution.

2 CHARACTERIZATION OF TACTILE DISPLAY – LOST IN "CHARACTERIZATION"

2.1 Mechano-Tactile Display

Figure 1 shows a schematic view and a photo of the developed mechano-tactile display. It has 3 x 3 actuators, each of which consists of commercially available piezoelectric actuators and a hydraulic displacement amplification mechanism (HDAM) [2]. The actuators can push up the fingertip with a displacement upto 100 um at a frequency from 0 to 100 Hz. The driving voltage, the vibration frequency, and spatiotemporal actuation patterns of the actuators are the control parameters.

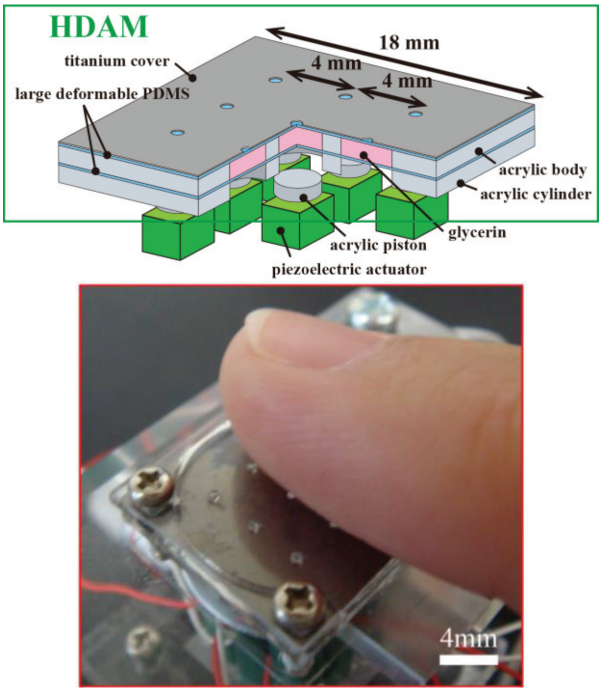

Fig. 1 Mechano-Tactile Display

2.2 Perception Test

We conducted perception tests with 8 participants, who were healthy and 20s. The tests were approved by research ethics committee of Faculty of Science and Technology, Keio University. The participants placed their index fingertips onto the display, when the conditions of the display were randomly chosen. They answered how they perceived the presented surface in their native language, Japanese.

2.3 Lost in Characterization

We introduce some of the answers of the participants.
(1) Rough. Feeling like a file. Slightly smaller grains than sands. (150 V_{p-p}, 70 Hz, 0.1 s of a switching time)
(2) Feeling like grains of fruits. Moist. Puni-puni. (90 V_{p-p}, 50 Hz, 0.3 s)
(3) Touching living things like sea anemone or octopus. Nume-nume. (150 V_{p-p}, 30 Hz, 0.3 s of a switching time with an overlap of 0.15 s)

Much information is lost in translation. Japanese has a variety of onomatopoeia, such as puni-puni and nume-

nume, which are quite difficult to translate in different languages. In addition, the participants cannot precisely describe their perception even in their native language and the answers were far from quantitative. There is quite a little information, which are lost in characterization.

2.4 Inverse Problem

In practical applications of tactile displays, the tactile sensation that we would like the users to have is defined first. However, as we described in 2.3, the tactile sensation that the users perceive from the display is abstract, dependent on the users, and far from quantitative. Therefore, we consider that instead of the tactile sensation, the surface properties, such as surface geometry, roughness, and stiffness, would be provided as the target.

3 SOLUTION FOR INVERSE PROBLEMS USING TACTILE SAMPLES

3.1 Sample Comparison Method

Quantitative characterization of the surfaces presented by the displays is difficult, since the surfaces are not physical but virtual. To address this problem, we proposed a sample comparison method. The users compare the presented surfaces to existing physical tactile samples such as wood, urethane foam, and sandpaper, and select the sample that provides most similar tactile sensation to the one by the display [5]. When the presented surface is perceived as identical to the physical sample (wood, foam, etc.), it could be reasonably concluded that the surface has the properties of the physical sample. With this method, we found that the developed mechano-tactile display could control roughness by driving voltage, while varying friction and dry/wet feeling was difficult with any driving parameters.

3.2 Microfabricated Tactile Samples

The proposed sample comparison method appears to be effective. However, it was impossible to characterize individual properties of the various surfaces independently, since the tactile samples that were used in the experiments—fabrics, wood, urethane foam, etc.—differed in virtually all of their properties. Ideally, if one wishes to investigate one particular characteristic (roughness, for example), the tactile samples being used should have identical properties except for the one target characteristic (e.g., roughness). To address this issue, we proposed microfabricated tactile samples, which can be made of the same material with different surface patterns or they can have an identical surface geometry but be made from different materials. Using these microfabricated tactile samples, we can directly correlate the surface property with the control parameters of the display and tactile perception of the users.

3.3 Solution for Inverse Problems

Using the microfabricated tactile samples, the properties of the virtual surfaces presented by the display

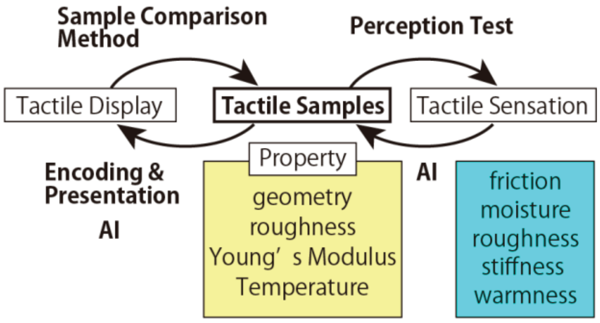

Fig. 2 Solution for Inverse Problems

can be quantified. Here, we would like to propose how to solve the inverse problems of the tactile displays.

As illustrated in Figure 2, tactile displays and tactile sensation are connected via the tactile samples. In forward problems, the displayed surfaces are quantified by the sample comparison method and the correlation between the samples and tactile sensation is deduced by perception tests. In inverse problems, machine learning can be a strong tool, where how to prepare the sufficiently effective datasets is a challenge. We can prepare a wide variety of microfabricated tactile samples whose properties are individually controlled. This enables us to conduct sufficiently large amount of experiments to have sufficient datasets. We are currently working on the machine learning and will be presenting the preliminary results in the presentation.

4 CONCLUSIONS

Inverse problems in the tactile display need to be explored for the practical applications, where microfabricated tactile samples can bridge the display and the sensation in a quantitative manner.

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