Feeling of Lateral Skin Deformation with Electro-Tactile Display*

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***Abstract*— Lateral skin deformation, which is an important cue for friction and bumps, is commonly displayed by reproducing the deformation mechanically. Our research question is whether the mechanical deformation is indispensable, or spatial-temporal pattern of tactile stimulation can substitute for the deformation. Considering skin strain energy distribution, we speculated that control of the area size and the intensity of tactile stimulation with motion are necessary to reproduce this feeling. Experimental results with electro-tactile display partly supported this consideration.**

I. Introduction

Lateral mechanical deformation of the skin is important to express friction and bumps. It is commonly expressed by mechanical devices that reproduce the lateral deformation. Our research question is whether the mechanical deformation is indispensable for the feeling, or spatial-temporal pattern of tactile stimulus can substitute for the deformation.

We use electro-tactile display to answer this question, since it does not generate mechanical deformation. There is a cathodic (negative current) stimulation and an anodic stimulation in the electro-tactile display, and it is known that each stimulation generates a different feeling particularly at the fingertip [1] [2]. Cathodic stimulation mainly produces pressure sensation, while anodic stimulation mainly produces vibration sensation.

With regard to the expression of lateral deformation using electro-tactile display, Sato et al. focused on the strain energy generated under the skin [3]. Shear deformation occurs inside the skin especially when the skin performs lateral displacement motion with respect to the contact target surface. Focusing on the change in the strain energy distribution at this time, they proposed a method of expanding the stimulation area to the direction of the lateral deformation and increasing the stimulation intensity of some electrodes, thereby presenting the direction of the force [3]. However, since the experiment was based on forced choice of two directions, it was not clear whether the stimulus was subjectively interpreted as lateral deformation. The effect of the area of stimulation on the subjective impression was also not examined.

Based on this method of Sato et al., we attempt to express haptic sense of lateral deformation by time-varying spatial pattern of pressure sense by cathodic stimulation.

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II. Concept

It is considered that the situation associated with movement of tactile pattern on the skin can roughly be classified into three situations; a case where the skin deforms laterally with frictional force (lateral deformation), and a case where the finger or contacting plate tilt (tilt), and a case where a bump moves under the skin (bump movement). As schematically shown in Figure 1, these three are distinguishable by the width and temporal behavior of the strain energy distribution under the skin. The strain energy of bump movement is narrower than the other two. In the case of lateral displacement, the strain energy distribution as a whole increases with deformation, whereas in the case of tilt, it is constant.

From the above discussion, it is presumed that the lateral deformation, the tilting motion, and the bump movement on the skin might be subjectively distinguished by the spread of the strain energy distribution and the time change, which can be mimicked by electric stimulation,.

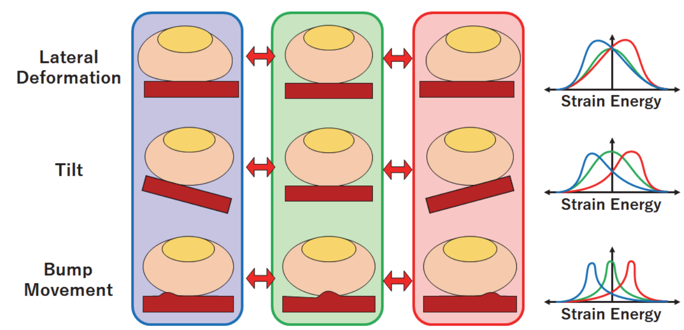

Figure 1. Classification of finger-object relationship.

III. Hardware

Figure 2 shows the electro-tactile display used in the experiment. The electrode consists of 63 stimulation points with seven rows by nine columns. We used only the middle three rows for this experiment. The cathodic stimulation is used, in which one stimulation electrode is the cathode and all the remaining electrodes are the anodes. Pattern is presented by switching stimulation electrodes at high speed. The interval and diameter of the electrodes are 2.0 mm and 1.4 mm, the pulse is

200 us, up to 3 mA, adjusted by the participants. Pulse frequency is 60 pulses per second. The electrode is placed on the mouse button and stimulation is presented when the button is pressed.

Figure 2. Electro-tactile display used in the experiment.

IV. Experiment

As described in II, the situation associated with movement of the stimulation can be lateral deformation, tilt, and bump movement, and they might be distinguished by the width of the stimulation and change of intensity in accordance with movement. To examine this hypothesis, we conducted two sets of experiment.

In the first set, there was no change in the stimulus intensity accompanying the movement of the presented pattern. There were five conditions for stimulation width, from one to five columns (Figure 3), and the pattern moved left and right at a cycle of 1 Hz.

In the second set, the stimulation pattern was the same as the first set, but we gave a linear change in stimulus intensity with movement of the presented pattern. The stimulus intensity was set to half when the the stimulation pattern was at the center.

The participants were instructed to place their right index fingers at the center of the electrode. After adjusting the volume, they were asked to answer the clearness of subjective feeling of "lateral deformation", "tilt" and "bump movement" in 7 levels of Likert scale (1: I do not feel at all, 7: I feel it clearly).

We recruited ten participants, all men aged 21 to 33 years old, and performed one trial for one stimulation width, giving five total trials in one set. The order of the trials was randomized.

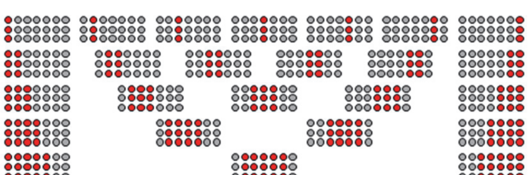

Figure 3. Stimulation pattern of two experiments.

V. Result and Discussion

Results are shown in Figure 4. Since the number of participants is small, we did not conduct statistical test.

As shown in Figure 4 (a), when the stimulation intensity was constant, the feeling of “lateral deformation” merely occurred. On the other hand, the feeling of “tilt” becomes stronger with wider stimulation, whereas the feeling of “bump movement” becomes stronger with narrower stimulation.

On the contrary, as shown in Figure 4 (b), when the stimulation intensity was modulated with pattern movement, the feeling of “lateral deformation” has relatively larger score when the stimulation width is wide, implying that the feeling of lateral deformation became clearer by increasing the stimulus intensity according to the movement of the stimulation pattern. The feeling of tilt and bump movement became relatively small, implying that these two feelings require constant intensity.

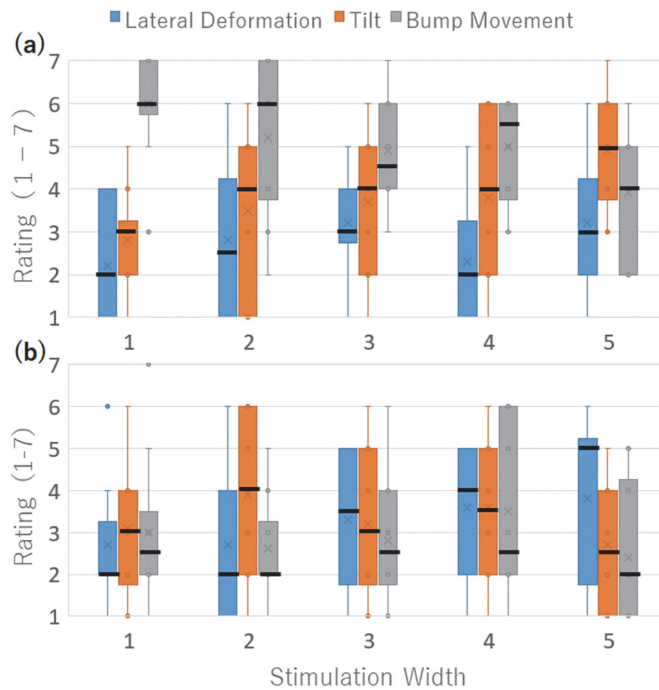

Figure 4. Experimental results with (a) constant and (b) varying stimulation strength. Thick bars indicate median.

VI. Conclusion

Our research question was whether mechanical deformation is indispensable for the presentation of the feeling of lateral skin deformation. We hypothesized that area size and change of stimulation intensity associated with pattern movement are dominant factors of the feeling of lateral skin deformation. Experimental results partly supported this hypothesis.

There are several limitation in the current study. Skin strain outside the contact area was not presented, which might play a role for the feeling of lateral deformation, and “static” case was not investigated. They will be addressed in the future research.

References

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