Observation of Finger Skin Movement on Periodical Bumps

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Abstract. Most tactile presentation methods for the touch panel present a uniform temporal signal to each finger, which hinders the expression of spatially distributed tactile information, such as information of thin lines and small bumps. To clarify the limitation of uniform presentation from the viewpoint of skin deformation, we observed the distribution of skin deformation while a finger comes into contact with periodical bumps. The measured skin deformation revealed that for bumps having an interval of less than 2 mm, the skin moved globally, which is in agreement with psychophysical and neurological knowledge.

Keywords: Texture, Fingertip, Measurement, Roughness

1 Introduction

Tactile displays that present realistic sensations have been intensively studied in the fields of virtual reality, teleoperation, and remote palpation. To realize a realistic tactile sensation, the relationship between skin displacement and associated sensation must be clarified.

In this paper, we consider the case of swiping on periodic bumps, and measures how the distribution of motion of the finger skin changes depending on the interval of the bumps using our previous research which enabled measurement of skin surface displacements on the texture surface(fig.1)[1]. Our particular interest is whether the whole skin moves synchronously or not.

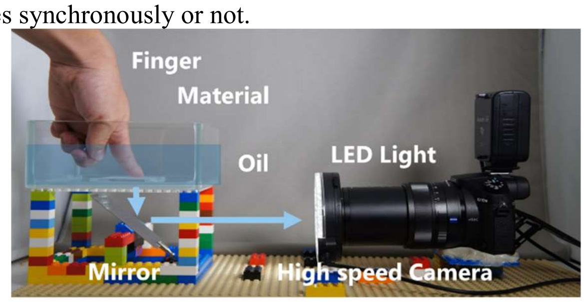

Fig. 1. Measurement System[1]

2 Method

2.1 Data collection

We recruited six participants, five male and one female, aged 21 to 23 years. Participants gave informed consent. Participants were asked to place their fingers on the textured surface and their fingers were fixed with an attachment from above.

The experiment was conducted according to the following procedure. Markers were first stamped to the fingertip skin. The finger was then placed on the textured surface submerged in oil and fixed. The subject gently touched the texture surface with a fingertip. The textured surface was moved at 4 cm/s distally, and the skin image was captured from below for 2 s, with 960 fps high-speed camera, obtaining 1940 frames.

We prepared six types of textures, all being one-dimensional gratings. The widths of grooves (concave parts) were 0.87, 1.3, 1.9, 2.9, 4.4, and 6.6 mm, the widths of ridges (convex parts) were fixed to 0.5 mm, and the heights were fixed to about 0.3 mm.

2.2 Analysis

Although markers were arranged two-dimensionally across the entire finger pad, we analyzed only one line of markers at the median line of the finger because the plate moved distally and the gratings on the plate were perpendicular to the movement, which resulted in dominant skin deformation in the distal direction.

To investigate whether the skin moved synchronously as a whole or whether the synchronization collapsed, we use the average value of the speed deviation in each frame as index. we discuss the spatial displacement distribution of fingers when tracing a certain texture plane.

The analysis procedure is as follows. First, the velocity was first calculated using the difference from the previous frame for each marker. Next, the dispersion value is calculated for the speed of the extracted marker in each frame:

$$\sigma_{\mathrm{frame}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(v_i - \overline{\overline{v_i}})^2}$$

where N is the number of extracted markers, v_i is the velocity at each marker, and $\overline{\overline{v_i}}$ is the velocity average for each marker. Finally, the average value of the velocity dispersion σ_{frame} is calculated.

$$\mu_\sigma = \frac{1}{M}\sum_{i=1}^{M}\sigma_{frame}$$

Analysis is performed for each texture and each subject, and then the obtained μ_σ is averaged for every subject's pitch width of the texture. In the actual process, 100 frames (104.16 ms) after entering the steady state were analyzed. If this index is small, it indicates that each marker faces in the same direction.

3 Result

An example of the movement of markers is shown in fig 2. This Graph shows that skin deformation speed at three adjacent points in the center of the finger in one subject. In each graph, averaging filter using every 7 frames is applied. This graph shows a vague trend that synchronicity disappears from 6.6 mm to 1.3 mm as the pitch rises. However, for the graph of 0.87 mm, it is observed that the speed varies synchronously as a whole.

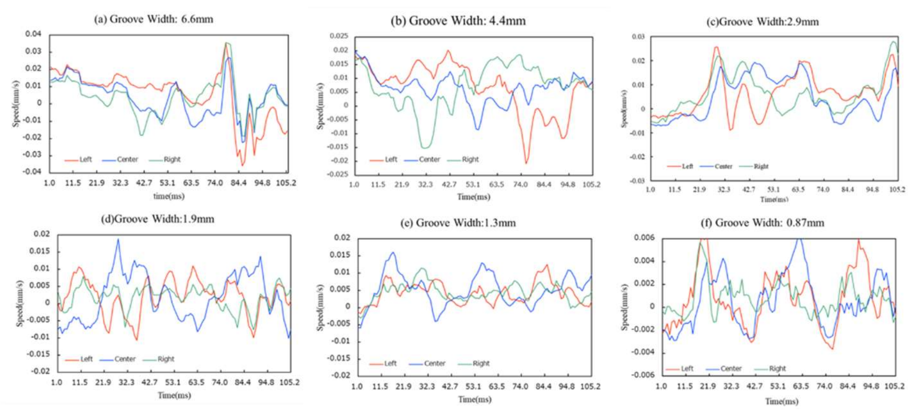

Fig. 2. Skin deformation speed at three points in the center of the finger in one subject. Applied averaging filter using every 7 frames.

Fig. 3. shows the average of every participants μ_σ. Error bars show the standard deviations. Horizontal axis gives the width of the groove and the vertical axis gives the average of μ_σ.

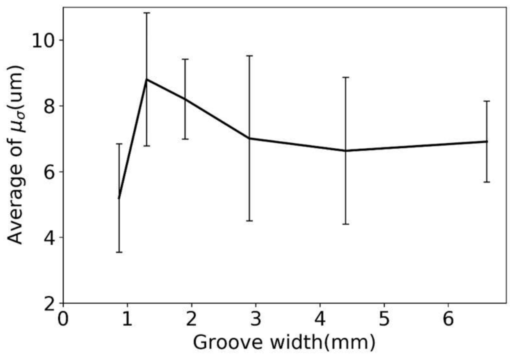

Fig.3. Average of μ_σ as a function of groove width. Error bars show the standard deviations.

4 Discussion

Experimental results suggested that the fingertip skin moves synchronously as a whole when the pitch width is smaller than 1.6 mm or larger than 3 mm. This result roughly agrees with the limit at which existing electrostatic touch display and surface vibration display can present in a realistic manner [2,3,4]. For example, a very fine sandpaper-like texture presentation or presentation of a character's edge feeling. In other words, when the entire surface is driven with the same signal (i.e., all the fingertip skin moves synchronously), there is a possibility that the tactile sensation can be presented if the texture's band is limited to less than 1.6mm, and a texture having a larger interval makes the sensation more difficult to represent.

Meanwhile, we must be careful about a large limitation of our research, is that the physical properties of the texture are different from that in the air due to the influence on oil. It is highly likely that the result obtained in this measurement is not the same as that without oil.

5 Acknowledgement

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