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How Human can Discriminate between Convex and Concave Shape from the Tactile Stimulus

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Introduction

Computational model of how vision system reconstructs the world information from visual stimulus has been studied so far (Marr 1982). Many of the famous achievements done by David Marr have been applied to the computer vision studies in the engineering field. On the other hand, little is known about how people can reconstruct 3D information from 2D stimulus distribution in the sense of touch. In vision, shape recognition has been revealed to depend on information such as stimulus intensity difference, texture, contour, or shading. Analogous to vision, a candidate for understanding the shape in touch can be the contour or edge location of an object.

In tactile sensation, contour or edge locations are represented by the information on pressure (nominal to human body) or that on friction (tangential to human body). Take Braille (embossed dots on paper or metal plate) as an example of a tactile shape with 3D information. When a reader's finger strokes over Braille, the nominal force (pressure) and the tangential force (friction) are presented according to the nominal force which the reader applies. However, it has been demonstrated that both of these two kinds of forces are not necessarily required to recognize Braille. For example, Optacon (Bliss, 1970) is the first device that enables the user to read the characters by using vibrating pins which move only up and down at high frequency. Hayward et al (2005) found that horizontal force applied to the finger can give bumpy sensation, and they developed a tactile display with this principle. Although this is a good compromise to develop tactile display, there remains a possibility that presenting only nominal or tangential force can be ambiguous, resulting in incorrect interpretation. One evidence for such possibility was found by Nakatani et al.(2005); they found that convex or concave judgment with a pin type tactile stimulator can be less accurate if the displacement of the pin is 0.1 mm. This perceptual discrepancy can be a possible way to understand the mechanism of tactile signal processing in human. Therefore, we conducted the experiment to examine how frequently such convex and concave inversion occurs.

Materials and Methods

We used a passive high density pin matrix (Nakatani et al., 2005) as a stimulator of subjects' finger. This passive device is composed of steel pins (0.3, 0.8, 1.3, 1.5 mm, respectively

in diameter) with various center-to-center spacing (0.5, 1.0, 1.5, 2.0 mm) (Figure 1). The pins' movement is constrained by close-tolerance holes in fiberglass boards to allow free movement in the vertical direction and essentially prohibit motion in the vertical direction. Users place the index finger on top of the pin array grasping the boards with thumb and middle finger, then stroke the array over the test surface. Each pin samples the height information from the surface pattern and relays it to the finger tip. Subjects (N=9, eight males and two females, averaged age was 24.6) evaluated whether the contact surface contained raised or indented surface in two-alternative forced choice procedure. Subjects stroked their bare finger or their finger with pin matrix over the stimulus(0.1 mm raised or indented circle (diameter = 25 mm) embossed on an aluminum plate).

Results and Discussion

The result is shown in the right side of Figure 1. All subjects could correctly answer whether the surface was convex or concave with over 90 % accuracy with their bare finger. On the other hand, when touching the convex surface with the pin matrix of 0.5 mm or 1.0 mm spacing, two of seven subjects could not correctly answer (less than 75 %) the geometry. This implies that high spatial frequency component disturbed the interpretation of a shape in touch.

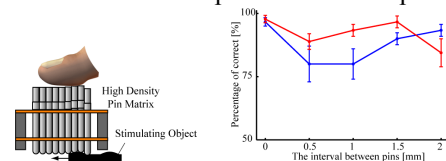


Figure 1: Schematics of pin matrix and the result.

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