F-3-4 A Study of Tactile Stochastic Resonance Using Psychophysical Experiments

Kadir BECEREN, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8601, Japan.
Tao JIN, Hitachi (China) Research and Development Co., China.
Masahiro OHKA, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, 464-8601, Japan.
Tetsu MIYAOKA, Shizuoka Institute of Science and Technology, Japan.

In the field of robotics, a tactile sensor and its data processing are very important to allow robots to perform handling objects. Especially, since some robots directly support human needs, they must sense tactile feeling caused by contact between their hand and a human. In the information processing done by biological organisms, stochastic resonance (SR) can enhance sensitivity by superimposing proper noise upon undetectable weak signals to detect the target signal. In the present research, we developed a system composed of an experimental apparatus and a computer program and have performed a series of psychophysical experiments using the different types of stimulus. Results show that the tactile sensing precision is enhanced by appropriate noise and that characteristics of normal vibration SR are quite different from those with tangential vibration.

Key Words: Tactile sensing, Psychophysical Experiments, Stochastic Resonance, Tangential.

1. Introduction

In tactile sensing, since the noise information inevitably becomes mixed during physical contact with the sensory information related to an object and a sensor’s movement on it, sensing accuracy can be increased by SR. The main purpose of this study is to investigate the mechanism of tactile SR resulting from tactile sensation using psychophysical experiments with the end goal of developing a new method of tactile data processing. We examined difference threshold (DL) variation obtained from these experiments to elucidate which condition of vibration direction and stimulus size causes the strongest SR.

2. Experimental Procedure

Many psychophysical experiments are required to obtain data on human tactile sensation. In order to measure vibrotactile thresholds presenting normal and tangential vibrations to the human hand in this study, we developed a system composed of an experimental apparatus and a computer program based on Parameter Estimation Sequential Testing (PEST) method. The experimental apparatus is composed of a piezoelectric actuator and its controller to generate a displacement step of several microns mixed with noise. The actuator is installed in a stainless steel box and equipped with a contactor (Fig.1). To change diameter of contactor, it is easily assembled and disassembled with small screws.

A half-sine pulse signal is used as tactile stimulus in these psychophysical experiments (Fig.3). Tactile stimuli and noise were generated by the PEST program and noise generator program based on the block diagram shown in Fig.2. White noise generator algorithm is used by a C-function “gasev” [1]

First, a half-sine pulse signal (Fig.3) and normally distributed random noise were calculated by computer and mixed with an adding operation. Figure 4 shows two signals with noise. The original half-sine pulse is disturbed with increase of the normal deviation of noise . The obtained digital signal is sent to the digital to analog board to transform it to an analog signal, which is sent to an amplifier (piezo-driver) to power the actuator.

Figure 1: Vibrating stimulation generator using piezoelectric actuator for (a) normal and (b) tangential vibration.

Figure 2: Schematic Block Diagram of Controller

Figure 3: Half-sine pulse signal
3. Psychophysical Experiments

The experiments were performed using the following types of stimulus: 1) normal directional vibration with a 2.5-mm stimulus point; 2) normal directional vibration with a 8-mm stimulus point; 3) tangential directional vibration with a 2.5-mm stimulus point; and 4) tangential directional vibration with a 8-mm stimulus point. We examined difference threshold (DL) variation obtained from the four experiments to elucidate which condition of vibration direction and stimulus size causes the strongest SR.

Since psychophysical experiments are conducted based on the Parameter Estimation by Sequential Testing (PEST) method, we produced a computer program that generates stimuli sequence based on PEST. A human subject touches the stimulus point with the index finger and judges a pair of vibration stimuli; one of the stimuli is a standard stimulus that is a constant during the experiment; the other is a comparison stimulus that is varied. According to PEST, if the human subject can distinguish the difference between the two stimuli, the strength of the comparison stimulus automatically decreases in order to test a greater level of sensitivity; otherwise it increases so until the subject can distinguish a difference. The experiment terminates when the increment becomes smaller than a threshold. DL is defined as the difference of the standard and comparison stimuli after the termination of experiment.

4. Results and Discussion

Figure 6 illustrates the relationship between the DL and the applied noise intensity in Experiments 1, 2, 3 and 4. These results show the average value obtained from the DL of five subjects.

The average of the experimental results produced one minimum point in the relationship between difference threshold and external noise. The minimum DL was around half of the DL under conditions of no-noise (Experiment1). Therefore, the tactile sensation’s just noticeable difference (JND) was decreased by appropriate external noise. This is to say that tactile sensing precision is enhanced by appropriate noise. However, if too much noise was applied, the DL increased again. Experimental results showed that: 1) with normal vibration the SR effect is relatively large compared to that found with tangential vibration; 2) with normal vibration SR is affected by the stimulus point size. A large stimulus point causes smaller minimum DL than the small stimulus point; 3) the minimum DL occurring with tangential vibration results in SR smaller than that with normal vibration. Tangential DL does not depend on stimulus point size.

5. Conclusion

In the present research, we performed 4 psychophysical experiments to accumulate the basic data on the SR of human tactile sensations. We examined DL variation obtained from the four experiments to elucidate the SR mechanism in tactile sensations. Results showed that tactile sensing precision is enhanced by appropriate external noise and that the characteristics of normal vibration SR are quite different from those with tangential vibration.

References