Effective Contact Method without Lateral Inhibition in Virtual Force Perception Device

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***Abstract*— Compared to force sense devices that reproduce reaction forces using wires and robot arms, the virtual force sense device generated from vibration illusion is not limited in work space, so it has good compatibility with virtual reality, while virtual force intensity has disadvantage that force intensity is small. In this paper, in order to transmit vibration from the virtual force device more optimally to the skin, we improved the virtual force intensity by improving the contact method. In order to simplify the contact, we aim to indicate the presentation method that is optimal for mechanoreceptors, which is one of the causes of haptic illusion by changing the point density by using pin type point stimulation.**

Keywords—haptics, force perception, asymmetric vibration, lateral inhibition

I. INTRODUCTION

For perfect virtual reality, it is necessary to reproduce the senses of all five senses. In general virtual reality technology, visual and auditory reproduction is reproduced with high accuracy, but other senses have not reached the practical stage.

In this paper, we select force sense as a target among lacked feelings, and attempt to produce a force perception device for use in virtual reality. Force sensation is a type of tactile sense, which indicates the sense of reaction force when touching an object and the sense of traction by a moving object. In the virtual reality experience, the force perception device is a technique necessary for accurate operations and realistic experiences such as reaction force and traction force due to contact with the 3D object.

II. PREVIOUS RESUARCH

Force perception devices can be classified into two types, grounded and ungrounded. The grounded type can reproduce realistic reaction forces and external forces by placing fulcrums on the ground and arms, such as Phantom Omni [1] and Spidar [2]. Meanwhile, the ungrounded type can reproduce force sense without giving an actual reaction force or external force by giving an alternative stimulus such as vibration or electric stimulation. Traxion [3], Buru Navi [4], Unlimited Hand [5] are classified this type.

Compared with the grounded type in which the working area depends on the device size, the ungrounded type has an advantage that such a problem does not occur. However, since the virtual force sense is illusionally occurred in the ungrounded type, there is a disadvantage that the force sense is small as compared with the ground type which actually gives real force. In the virtual reality experience with movement, restriction of work area is a big problem, so it is considered that grounded type device is not suitable. On the other hand, since ungrounded type device is capable of continuous force sense occurrence and small size of device, haptic illusion using asymmetric vibration is compatible with virtual reality experience.

In this paper, we aim to improve the disadvantage of small force intensity by using virtual haptic device using asymmetric vibration.

III. RESUARCH THEORY

Virtual force sense using asymmetrical vibration is perceived by illusion of vibration stimulus as a force sense stimulus. Force sense stimulus is received by a mechanoreceptor that perceives a mechanical stimulus such as a force sense, a pressure sense and a position sense. Vibration stimulus, which is one of mechanical stimulus, is also perceived as vibration sense as it is received by the mechanoreceptor. It is said that it is the cause of the virtual force sensation that the irritation by the asymmetric vibration is incorrectly perceived as the stimulus transmitted when giving the force sense.

Previous research suggested a mechanoreceptor mainly acting from the frequency band of vibration. It is stated that Meissner corpuscles occur in low frequency bands and Pacinian corpuscles occur high frequency bands. However, the magnitude of the vibration required to obtain virtual haptic sensation is very large, and there is a possibility that it acts on other sensory organs. Therefore, no accurate cause of occurrence has been found.

Mechanoreceptors have lateral inhibition. Lateral inhibition is relative edge emphasis effect by suppressing stimulus of the plane part when the compression stimulus by the cylinder is given to the skin [6]. This effect is caused by the connection of mechanoreceptors, and has been confirmed by visual sense and tactile sense that need to emphasize the edge of sensation [3] [4]. However, this effect also exists in the virtual force sense, lateral inhibition is an unnecessary suppression effect since the

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edge information of the contact surface is not useful in force sense. As shown in Fig. 1, it is hypothesized that the force sense intensity can be increased by performing the stimulation method without lateral inhibition.

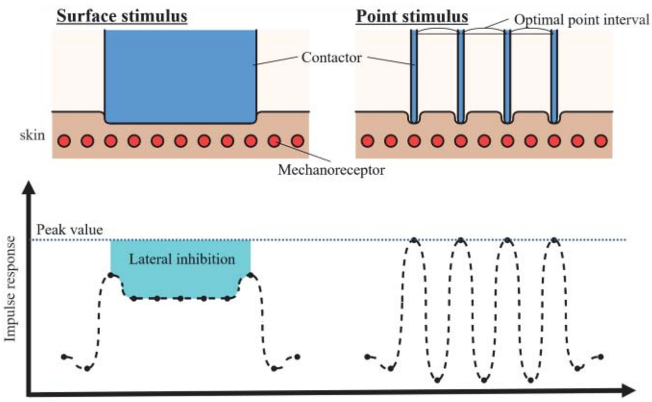

Fig.1. Surface stimulus contact with literal inhibition and point stimulus contact without literal inhibition

IV. EXPERIENCE

In this experiment, point stimulus contactors with a pin attached at a fixed point interval is attached to a contact instrument, the contact face with the skin is arbitrarily changed, and the tendency of the relation with the perceived force sense is searched.

A. Virtual Force Perception Device

The virtual haptic device used in this experiment is based on Traxion [3], and a signal with a different duty ratio is sent to the transducer and a force sense occurrence is performed. For the transducer used, Forcereactor Hybrid Tough Type of Alps Electric Company shown in Fig. 2 was used. Unlike the eccentric motor, this vibrator causes linear vibration. To control the signal, Arduino's Arduino Leonardo is used, and the signal is amplified by VMA-20 of Ave. Lab Inc. as an amplifier.

Fig.2. Forcereactor Hybrid Tough Type of Alps Electric Company

The electrical signal that causes asymmetric vibration is as shown in Fig 3. The duty ratio is 4: 12 [ms], which is the duty ratio adjusted so as to feel the most force sense in Forcereactor. The electrical signal sent to the vibrator was 0.19[A] for the current and 1.9[V] for the voltage. If the vibration is too small, the virtual force sensation be able not felt, and if it is too large, the virtual force sensation is saturated by the vibration, so the optimum electric characteristics for the subject were empirically determined. Moreover, since there is a problem that virtual sense of force is not felt when the vibration direction is only one direction in virtual force sense, by continuously changing the direction of vibration, haptic sense is generated continuously. In this experiment, a time of 1000 [ms] was given to the positive direction which is the actual measurement direction, and it was oscillated 3000 [ms] in the reverse direction.

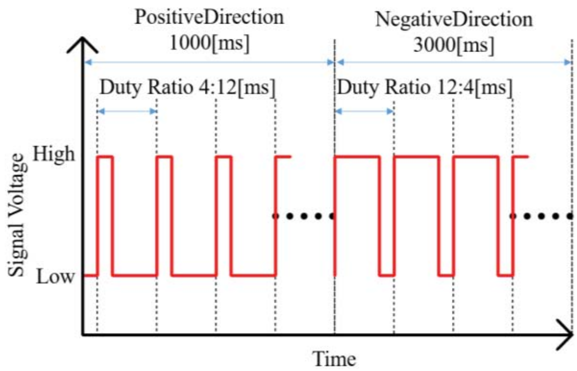

Fig.3. Electrical signal for causing asymmetric vibration in experiment

B. Mesurement Method

In the previous study [3], the measurement of the virtual force sense was made by grasping the vibrator generating the virtual force sensation and the vibrator not so with one hand. In this method, since subjective feelings of both hands are compared with each other, it is difficult for the subject to make a clear judgment, which causes a problem that the measurement time is required and paralysis caused by vibration affects the measurement result. For the measurement of the virtual force sense used in this paper, we adopted a method using a spring scale as shown in Fig 4. Connect the vibrator and the spring scale with wires, make the state of feeling the spring tension from the direction opposite to the direction in which the virtual force sensation occurs, and let the subject find the point where the forces in the two directions balance.

In this method, as compared to the previous method, it was measured with one hand and only the balance between tension and virtual force sensation was felt, so the subject could intuitively measure and shortened the measurement time.

A pulley was attached between the vibrators so that the vibration of the vibrator was not exerted on the inner spring.

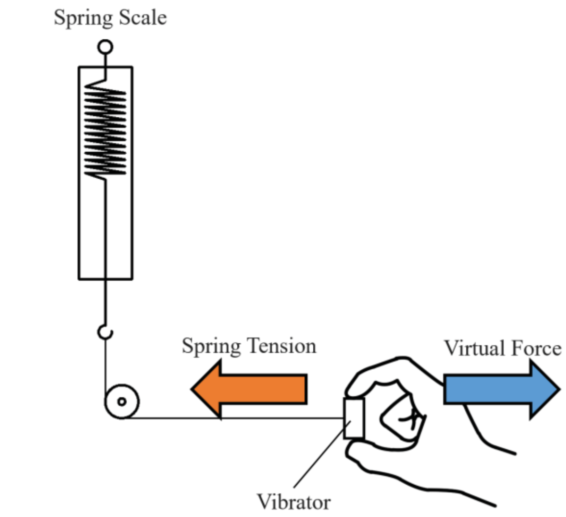

Fig.4. Schematic diagram of measurement method of virtual force sense using spring scale

C. Contactor

In order to give arbitrary vibration stimulation to the skin, a point stimulus contactor with multiple pins standing as shown in Fig. 5 and Fig. 6 was attached to the vibrator. A piano wire with a diameter of 0.5 [mm] was used for the pin of the contactor. The base of the contactor is an acrylic plate with a diameter of 20 [mm], with a hole open and the pin is fixed. In this research, we prepared five kinds of point stimulus contactors and one kind of surface stimulus contactor. As shown in Fig. 6, point stimulus contactor with point interval of 2, 3, 4, 5, 6 [mm] were prepared and surface stimulus contactor is shown in Fig. 7. Since the interval of 2 mm or less is smaller than the Two-point discrimination [7], it is not taken into consideration and it is not taken into consideration since the interval of 6 mm or more exceeds the finger width.

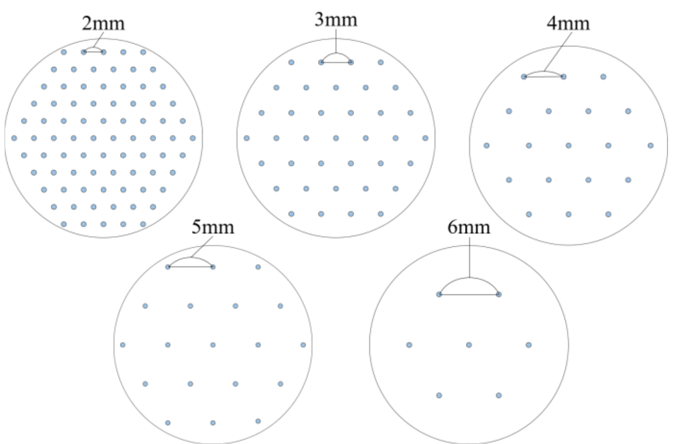

Fig.5. Point stimulus contactors with different point intervals (2, 3, 4, 5, 6 mm from the left)

Fig.6. Actual point stimulus contactors (2, 3, 4, 5, 6 mm from the left)

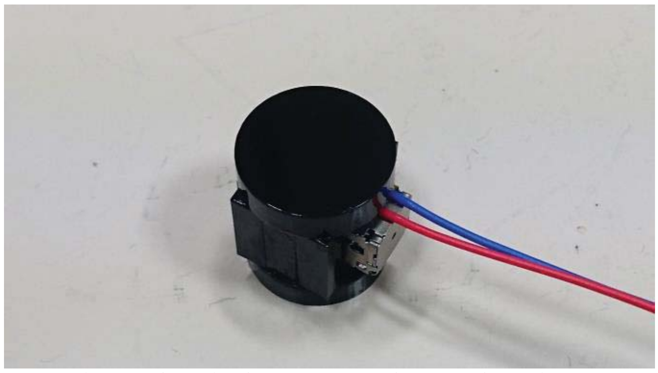

Fig.7. Surface stimulus contactor used as control experiment

V. Result & Discussion

The average value and the standard deviation of the measured data of the force intensity for 6 contactors, 5 trials was shown the Fig.8. There was no significant difference between the five kinds of point stimulus contactors and a surface stimulus contactor in all subjects. In addition, the tendency of the point stimulus contactors and the surface stimulus contactor was different for each subject. Subject C had large point stimulus, subject A and B had a large surface stimulus, subject D and E had no significant difference. In addition, the standard deviation was large as a whole, and this tendency was seen particularly in point stimulus contactors.

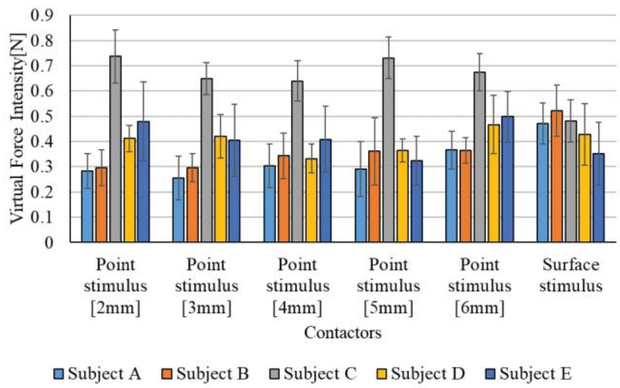

Fig.8. Comparison of virtual force intensity by each contactors

In this paper, experiments were performed assuming that the point stimulus without lateral inhibition is greater in force sense and the maximum value is shown in the point stimulus contactor with optimal point interval among the five types. However, the results did not show either effect. Therefore, it can be said that there is no lateral inhibition in the virtual force sense, or it does not significantly affect the virtual force sense.

There are two possible causes for not having a significant difference, that the measurement method is inappropriate and that the contact method is inappropriate. First, we consider the measurement method. In this measurement method, the vibrator and the spring scale were directly connected with a wire. it is thought that unexpected distortion of skin occurred due to the tension of the spring and the contact surface was adversely affect by mixed distortion due to both vibration and tension. Secondly, we consider the contact method. It was difficult to fix the pressure, friction, and the position at which the points hit at the time of gripping in the point stimulus contactor. From this, it is considered that the standard deviation of the virtual force intensity increased as the transmission of the vibration changed from each trial.

However, from these phenomena, it is conceivable that the virtual force perception is not an illusion of vibratory sense, but an illusion of deformation or compression by vibration. In the previous study, mechanoreceptors related to virtual force sensation have been considered to be Pachinian corpuscles and Meissner corpuscles involved in vibration. However, from the findings of this study, it was indicated that the possibility that the Merkel board involved in pressure sense and distortion perception is related to virtual force sense.

VI. Conclution

In this paper, we focused on the response of mechanoreceptors, which is the cause of virtual force sensation, and aimed to improve force sense by showing the relationship between virtual force sensation, mechanoreceptors and lateral inhibition. Results using surface stimulus and point stimulus contactors showed no significant difference, suggesting that there is no lateral inhibition in virtual force sense.

However, we found a new possibility of the cause of the virtual force sense occurrence. As a future work, not only the lateral inhibition but also the parameters such as friction, force and pressure are experimented. We will consider the optimum contact method to improve the virtual force sense and the cause of virtual force sense occurrence, and we aim introduction to the motion tracking controller used in virtual reality system.

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