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A Vision-based Tactile Sensor (II)

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Abstract

Receiving tactile information from a slave-robot is a necessary component of telexistence with tactile display. However, there are few tactile sensors that can measure the distribution of three-dimensional force vectors on a surface of the sensor. For this reason, we developed a sensor that provides three-dimensional force distribution by detecting movement vectors in the transparent elastic body with a video camera. In the previous report, fundamental principle was explained. In this report, we describe about downsizing of the sensor and result of evaluation experiment.

Key words: tactile sensor, telexistence,
force distribution, force vector

1. Introduction

The purpose of our research is the development of a tactile sensor for telexistence of tactile sensation. When handling an object accurately in environment of telexistence, such as telesurgery, transmission of tactile sensation is equally important as visual and auditory sensation. To realize telexistence of tactile sensation, we need both sensing device and displaying device. As a displaying device, there has been extensive research on haptic displays. As a sensing device, there also has been research on tactile sensor[1]. However, the purpose of them is not telexistence originally. Therefore, we developed a new tactile sensor specially designed for tactile display.

2. Necessary property and information

Our first step is to determine the property that the sensor for haptic display should equip. The primary difference from other sensations such as vision is the existence of interaction. When the finger contacts with an object, repulsive force causes the deformation of both finger and object. If the sensor does not deform like the finger, acquired information becomes different. In other words, same elasticity as finger is essential for the sensor body.

The second step is to determine what information the sensor should get. Several mechanoreceptors are distributed within the finger. Merkel cell perceives displacement, Meissner corpuscle and Pacinian corpuscle receive low and high frequency vibration. Combination of the activities of these receptors makes various sensations. As both displacement and vibration are generated by force applied on the surface of the skin, if we can measure the surface force distribution, we can obtain sufficient information to calculate the receptor's activities. Force is vector and has direction. Besides fingertip can measure distribution. Hence the sensor for display needs to measure distribution of force vector.

3. Method of measurement

Here, we propose a new optical tactile sensor for displaying tactile information, which can measure a three-dimensional vector distribution and have the property of elasticity. The concept of our proposed tactile sensor is as follows. The sensor consists of transparent elastic body and markers within the body. When a stress is applied on the surface, we optically measure the internal strain of the body as movement of the markers. Finally force vector is calculated from the strain using elastic theory.

3.1 Method of measuring strain

This proposed measuring method uses information of strain of an elastic body. There are many choices about what kind of strain should be measured, and our current approach is to measure the horizontal movement of small markers in the elastic body, which are located N by N at a specified depth. To gather sufficient information for the reconstruction of the stress vectors, we used two layers of markers that are located at different depths (Fig.1). These layers could be distinguished by the colors of the markers (red and blue). We set the x-y plane parallel to the sensor surface and the z-axis extending vertically on the interior. By measuring these markers from a positive z direction with a CCD camera, we could obtain two sets of two-dimensional motion vectors at different depths, so the amount of information is increased and the distribution of stress vector can be readily obtained.

3.2 Method of calculating force distribution

We assume linearity of the elastic body, so the motion of the markers is described as a simple superposition of stress distributions[2][3].

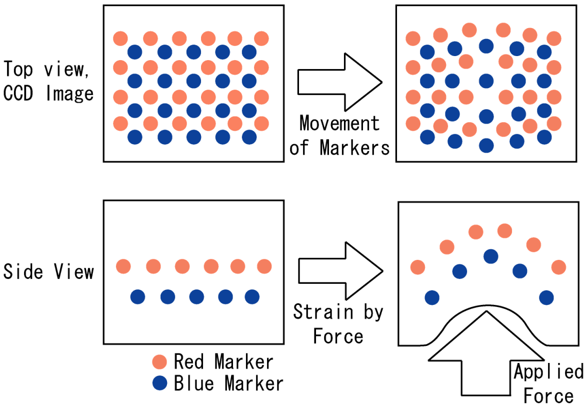

Figure1: Model of sensing

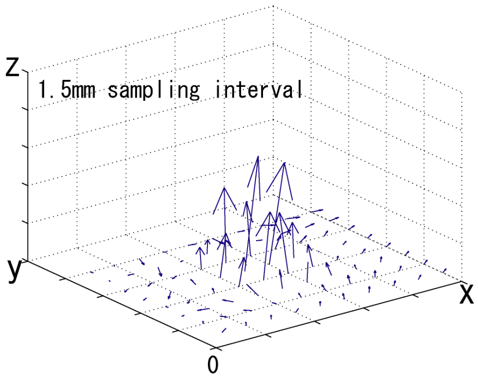

Figure3: Distribution of force vector

4. Experiment

4.1 Sensor system

Figure 2 illustrates the developed sensor system. Part of elastic body is a cylinder, which height is 10[mm] and diameter is 35[mm]. Whole size of sensor is 40[mm] by 40[mm] by 100[mm]. Red and blue spherical markers are arranged in a depth of 3[mm] and 6[mm] from the surface. Diameter of the markers is 0.6[mm]. Through transparent acrylic block with which the elastic body is fixed, the markers are captured by CCD camera.

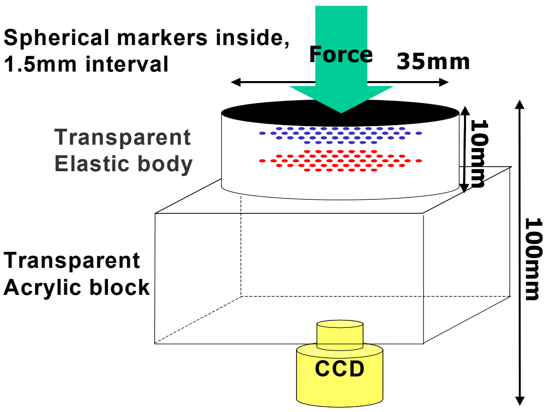

Figure2: Sensor system

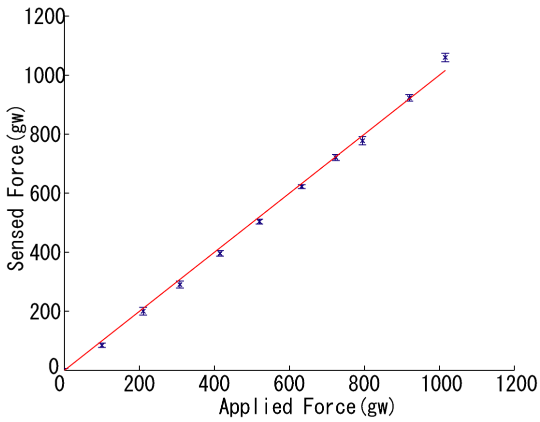

Figure4: Evaluation of linearity

4.2 Evaluation

Figure 3 illustrates calculated distribution of force vector. This distribution is resulted by applied force to z-direction using 5mm cylinder. The length and direction of arrow represents magnitude and direction of force. Additionally, Figure 4 is the result of linearity evaluation. Applying forces to z-direction using the cylinder, we summated z components of distributed forces and plotted them. This graph shows that the sensor has high linearity and accuracy of 20[gw].

5. Conclusion

Discussed at first section, our purpose is development of tactile sensor for telexistence of tactile sense. To accomplish the purpose we developed the tactile sensor, which has property of elasticity and can measure distribution of three-dimensional force vector. In this report, linearity and accuracy of the sensor is evaluated. From this result, we believe that the sensor works effective for use of telexistence. As current and future work, we are developing finger shaped tactile sensor and will evaluate in detail.

Reference

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