Tactile Sensitivity Modulation of Elastic Skin by Change of Grasping Force

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Abstract: This paper reports the variation of the outputs of the sensors embedded in the elastic skin in incremental steps of the grasping force. The instantaneous changes of the strain gauges outputs at the moment of inpact force were recorded. Initially, the amount of the output decreased along with the increase of the grasping force. It begun to rise again, and reached the second peak.

Keywords: Grasp force, Sensing,

1. INTRODUCTION

The tactile sense plays important roles when people manipulate objects. Similarly, the tactile sense is a key for advanced robot manipulation, and it has been investigated in recent years[1]. At the same time, how robots get these information effectively from a wide variety of sensors with which they are equipped and make these tactile information available are crucial for adaptive robotic manipulation systems. In this study, we investigated the relationship between the grasping force exerted by the robot hand and the amount of information obtained from strain gauges randomly embedded in the elastic skin of the robot hand finger.

There are some studies which suggest the method that controls grasping force with sensors embedded in elastic artificial skin, in order to protect the objects from excessive grasp force and to prevent slips[6][3][5]. They described the purpose of preventing excessive force as saving energy and reducing damages. We hypothesize that minimizing grasp force is necessary to get information of events effectively in object manipulation. We examined this using the developed robot hand with sensors embedded in elastic skin randomly. In this paper, we report that the instantaneous changes of the outputs of sensors embedded in the artificial elastic skin caused by increase of the grasping force. We have proposed the method to learn optimal gasping force on the basis of previous experiences. If there are differences in the amount of information, appropriate grasping force can be learned using these variation.

2. SYSTEM DESCRIPTION

2.1 Artificial Skin and Sensors

Fig. 1 shows the artificial skin and a finger of the robot hand which were used for the experiments described in this paper. The artificial skin is a modification of the anthropomorphic robotic soft fingertip which was proposed by Hosoda et al.[5]. The skin is composed of two layers. The inner skin layer is made of soft urethane resin (Hitohada gel Hardness 0, Exseal Co., Japan). This ure-

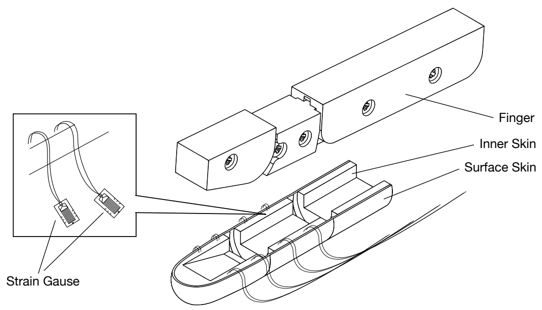


Fig. 1 A finger of the anthropomorphic robot hand and the artificial skin in which sensors are randomly embedded.

thane has softness similar to the one of human skin and its compressive elastic modulus is $11.8 N/cm^2$. The softness of the skin not only provides increase in stability of grasping but also transmits events which occur between the hand and an object to the sensors. The inner skin is wrapped in a thin outer skin which is made of relatively stiff non-foamed polyurethane (Pro-350, Temcofine Co., Japan) to prevent damages to the inner skin and sticking between the inner skin and objects, since Hitohada gel is fragile and has strong stickiness.

The eight strain gauges (KFG-1-350-C1-11, Kyowa Electronic Co., Japan) are embedded in the skin randomly. The sensors were inserted into a mold and Hitohada gel was cast into the mold of an adult finger. The strain gauges are used to measure skin strain. In this experiment, these sensors are embedded only in the index finger

2.2 Anthropomorphic Robot Hand

Fig.2 shows the anthropomorphic human scale robot hand that we designed. The robot hand feature human-like form and structure, and has five fingers which are driven by pneumatic muscle actuators through tendons. We use pneumatic muscle actuator of McKibben type. When the actuator is filled with compressed air, it contracts and force is generated. The robot hand has 16 joints which provide 16 DOF; the thumb has four joints and the

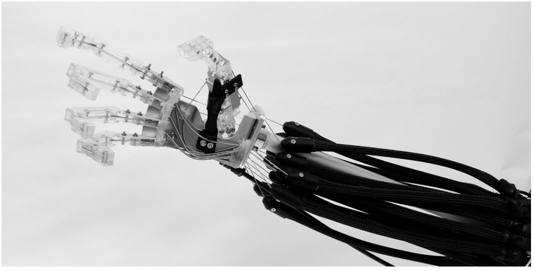
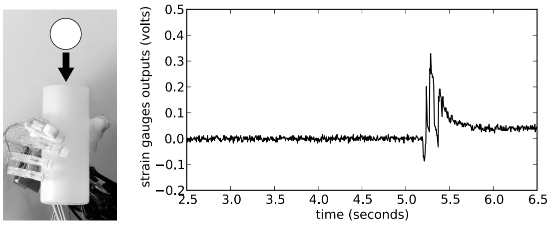


Fig. 2 Robot hand used in this experiment.



(a) (b)

Fig. 3 (a)A ball was dropped in the cup holded by the robot hand. (b)Exsample of the output of a strain gauge when the ball collided with the cup.

other fingers have three joints. The fingers and the palm are equipped with the artificial skins that we described above.

3. EXPERIMENT AND RESULT

The cylinder cup was hold by the robot hand using the index finger and the thumb with constant force (Fig. 3a). In that condition, we dropped a 50 grams ball in the cup. An example of output of one of the strain gauges is shown in Fig. 3b. We recorded the average increase of the strain gauges outputs at the moment of the collision. We repeated it in incremental steps of the grasping force. Fig. 4 shows the relationship between the average output increase in ten trials and the pressure of the pneumatic muscle attached to the index finger considered as the grasping force. Initially, the output gradually decreased along with the increase of the grasping force. The amount of the output begun to rise after the pressure reached about 0.43 MPa. Afterward, it begun to decrease again.

4. DISCUSSION

The elastic tissue in the skin of human finger has a property similar to rubber. The behavior of polymer materials is so complex that it is difficult to express its constitutive equation. Nakazawa et al.[4] has represented the dynamics of a fingertip by the Kelvin model, which is composed of a spring and a damper placed in parallel, and investigated the characteristics of the human fingertips while the shear force is being applied. They reported that the shearing stiffness increases proportionally with the contact force, while the viscosity is almost constant.

Assuming the skin of the robot hand has characteristics similar to the human skin, the reaction of the sensors embedded in elastic skin should be reduced in strength

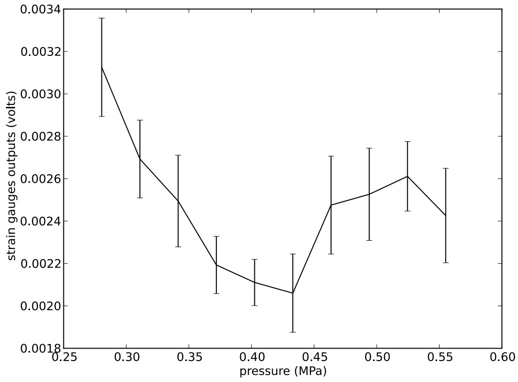


Fig. 4 Relationship between the instantaneous response of the sensors and the grasping force.

along with the skin stiffness increasing caused by the increase of the grasping force. The initial decrease of the output in Fig. 4 is believed to be due to this increase of the stiffness.

Han et al.[2] reported that the Heltz model can be used to approximate the relationship between the contact area and the load in the human skin. The increase of the outputs is suspected to be caused by the increase of the contact area between the finger skin and the object. As future work, we plan to investigate the results analytically with these models and to use this variation of information to the learning of adaptive manipulation.

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