GelForce

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1 Introduction

GelForce is a novel type of interface that measures the distribution of both the magnitude and direction of force. The sensor is composed of a transparent elastic body, two layers of blue and red markers and a CCD camera. Force vectors are calculated from the captured movement of the markers.

The history of the force sensor is ancient, yet it has always been exceedingly difficult to obtain the distribution of force vectors, because nearly all existing sensing technologies use some sort of sensing unit for which electric resistance or capacitance depends on force. For sensors of this type intended to measure the distribution of force vectors, the wiring becomes extremely complex, and the size of the unit expands dramatically as the amount of measured information is increased. On the other hand, the optical system of our developed sensor is simple, and various applications are therefore possible such as tactile sensation for a robotic fingertip, and a versatile force-based computer interface.

2 Technical Features and Details

Nearly all force sensors fall into two categories. One measures direction and magnitude of force at a single point, but cannot measure its distribution. The other measures the distribution of the magnitude of force, but cannot measure its direction. The force sensor we have developed integrates these two types to measure the distribution of force vectors, with both magnitude and direction. The sensor consists of a transparent elastic body, and two layers of colored markers within the body. When a force is applied on the body's surface, we optically measure the internal strain of the body through the movement of the markers. Finally, force vectors are calculated from the strain using elastic theory.

The core innovation is the technique to derive a distribution of force vectors from the movement of two layers of colored markers. We wish to obtain 3-dimensional force vectors, but the movement of markers captured by a CCD camera is 2-dimensional. If there is only one layer of markers, only the magnitude of force can be measured with any degree of accuracy, or else two cameras would be necessary to measure the 3-dimensional movement of markers. Using two cameras brings about complex camera calibration and occupies a large space. These complications make downsizing the sensor infeasible in practice. To solve this problem, we use two layers of markers at different depths. Equipping the two layers is equivalent to measuring 2 times 2 dimensional movement of markers. This provides sufficient measurement depth information to readily obtain a force vector distribution.

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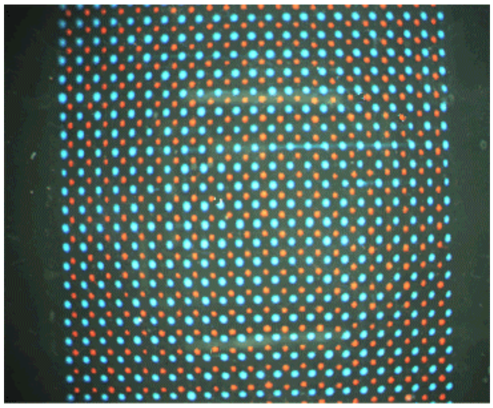

Fig.1: Video capture of markers in the elastic body

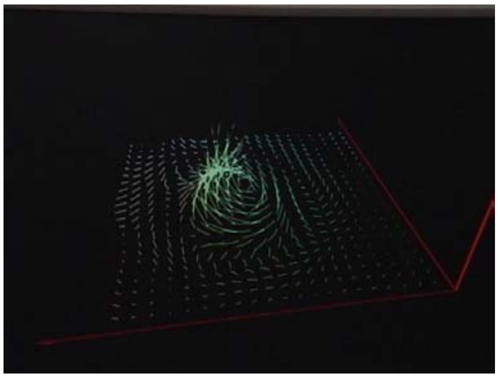

Fig.2: Screenshot of measured force vector distribution

3 Future Works

One of the goals is to develop a finger shaped sensor to equip on a robotic hand. Herewith, the robot is granted with tactile sensation and can perform fine manipulation tasks just as humans do. Existing sensors equipped on mechanical hands cannot measure sufficient force information to perform most everyday tasks, which has severely hampered the development of field robotics.

To develop a sensor with a finger shape, there are two key technical issues. One is that the sensor needs to be prepared at a small size and with high density, comparable to the layout of mechanoreceptors in human skin. The other key issue is that the force sensor must adapt to the particular form of the fingertip. The simple structure of this elastic sensor leads to an elegant solution to these two issues. The sensor does not require a complex sensing unit, but only markers within a gelatin body, which can be arranged at high density. In addition, because the sensor needs only to capture the markers, it may be crafted into any shape that allows it to do so. From these points, we are now developing the finger shaped sensor.