world HAPTICS conference
Pisa, Italy March 18-20, 2005

GelForce:
Applying traction field sensation to Robot Finger

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Notice:
This poster is associated with a Hands-On Demo Work

• Abstract

We have developed a new type of force sensor called "GelForce", which can measure a 3D force vector field over a surface. Almost all existing force sensors that measure force distributions can obtain only magnitude of force, but not direction, and we expect that equipping robotic devices with vector field force sensors will enable more dexterous operations than previously possible. The developed sensor consists of a transparent body of silicone rubber, two layers of internal blue and red markers, and one CCD camera to capture the markers. We report the application of this vision based tactile sensor to a fingertip of a robotic hand.

1. Introduction

There has been extensive research of tactile sensors for the purpose of providing cutaneous sensation to a robot. There are two main engineering problems to overcome. The first is how to cover the whole body of a robot, the second is how to arrange sensor units at a density as high as the human. fingertip. We focused on the second problem by applying a vision based traction field sensor to a robot hand. This sensor, called "GelForce," can be easily manufactured with high sensing density and small size. From these points, we expect applying GelForce to a robot finger should allow more dexterous operation than with existing sensing techniques.

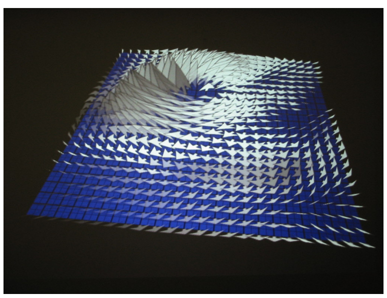

Figure 1: Calculated force vector field.

2. Principle of GelForce

The framework of the sensor, illustrated in Figure 1, is a rectangular block of transparent silicone rubber fixated by an acrylic board. We printed a collection of colored markers, 0.6 mm in diameter, inside the elastic body at approximately 3-mm intervals. We mounted a color charge-coupled device (CCD) camera 15 cm below the markers, pointed upward. When we apply force to the topmost planar surface, the camera measures the markers' displacement.

The force vector field $\boldsymbol{f}$ is calculated using the displacement of markers $\boldsymbol{u}$. By supposing that the silicone rubber is linear and using standard elastic theory, a discrete equation relating $\boldsymbol{f}$ to $\boldsymbol{u}$ and its inverse can be expressed as.

$$u = Hf$$

$$\left(H^T H\right)^{-1} H^T u = f \qquad (1)$$

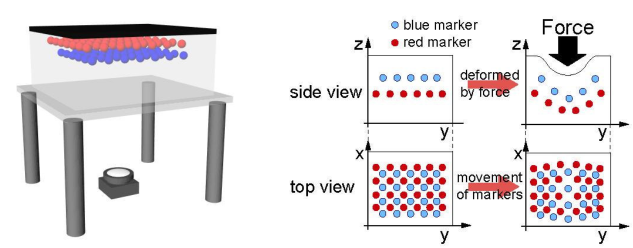

Figure 2: (left) Basic schematic of proposed sensor
(right) Representation of marker displacement

3. Design and Manufacture of Finger-shaped GelForce

The arrangement of a CCD camera and the silicone rubber is illustrated in figure 3(left). The surface of the rubber has a curved shape similar to a human fingertip. The camera is custom made with one video compression unit and 4 image capture units corresponding to each robot finger. The 4 images are captured simultaneously with a frame rate of 67-fps. The resolution of each image is 640 by 480 pixels. Marker centroids are tracked to subpixel accuracy, corresponding to about 4μm.

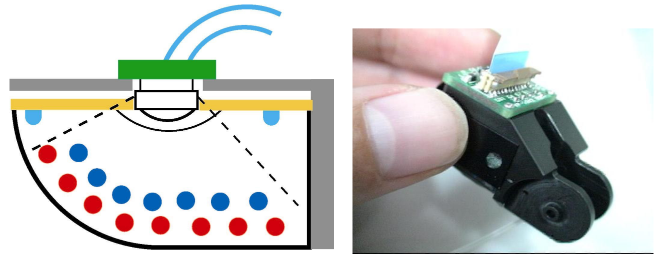

Figure 3: (left) Setup of finger-shaped GelForce
(right) Manufactured sensor.

4. Creation of Matrix and Experiment

Due to the complicated shape of the silicone rubber fingertip, it is impossible to derive the matrix H in equation (1) theoretically. Instead, we create the matrix empirically by applying known point forces to the surface and measuring the resulting marker displacement. These measurements are stored as columns in the matrix H.

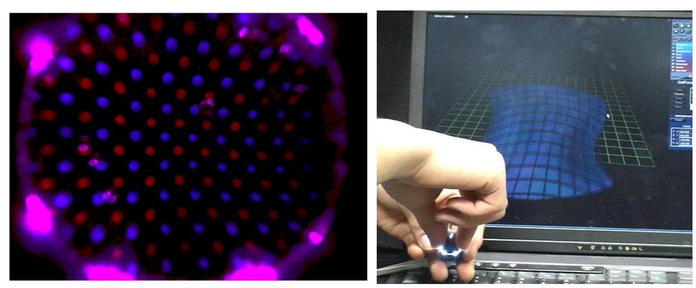

Figure 4: (left) Captured CCD image
(right) Experiment of force measurement.

5. Conclusion and Future Work

To provide tactile sense to a robot hand, we developed a finger-shaped force sensor. The sensor can detect displacement of micro-meter order and measure the corresponding traction field. We believe that the finger-shaped GelForce will lead to more dexterous robot hand operation than ever before. We are currently developing a robotic hand with 4 sensors, and implementing control methods using the measured traction field information.

References

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