Identification and Pose Estimation of a Stick-like Object by a Tactile Sensor System for a Robot Hand

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This paper describes a tactile sensor system that is aimed to be equipped on a robot hand. The proposed system consists of four pressure-sensitive sensors and a plastic board. A board with four foots is placed on the sensors. Stick-like objects are our target, and we aim to estimate object type and its grasped direction. In the estimation phase, pre-generated two discriminative functions output the two classification results. The experimental results show that the proposed system has a value as a sensor suitable to be embedded in a palm of a robot hand.

1 Introduction

Tactile sensing is an important function for robots working in daily environment. To achieve given tasks, tactile sensors have been embedded in a robot body: for instance, fingertip, a bottom of a foot, and a palm of a hand. In this paper, we aim to develop a tactile sensor system consisting of a few pressure-sensitive sensors and perception functions that enable to know the state of a stick-like object grasped by a robot hand. As we can find various stick-like objects such as stationery product, cables, and cutlery in everyday environments, a robot hand system with such recognition skill will be useful.

There have been several suggestions which might satisfy the demands described above[1][2]. One of those is sensor sheet[3]. It enables to know the shape and the pose of a grasped object from contact forces obtained from dozens of tactile sensors embedded in the sheet. On the other hand, one drawback is that such sensor is currently expensive. More reasonable sensors should become popular.

For this reason, we aim to develop a simple and cheap tactile sensor system. Fig.1 shows one of the sensor prototypes. Four pressure-sensitive sensors are installed on a solid board, and a plastic plate having four foot is put on the sensors. The plate is regarded as a palm of a robot hand, and a stick-like object is put on it. These sensors are forced by the object while grasping, and a set of temporal force data is obtained.

Based on the data, we attack a problem to know two things: the type of the grasped object and its posture. These are important to plan meaningful manipulation. However, it could not be expected that sensor data obtained from the sensors is difficult to predict from analytical model because we assume to use rapid-prototyping parts whose material property is difficult to model because of the unevenness. Moreover, above-mentioned stick-like objects commonly have irregular shape pattern that might be too much complicate to represent using only four tactile sensors.

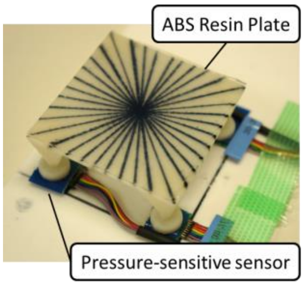

Fig.1 Tactile sensor

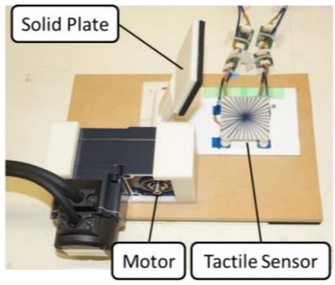

Fig.2 Experiment system

To overcome the issues, a novel method is proposed in this paper. We employ 12 series of temporal force data obtained from the four pressure-sensitive sensors, and apply machine learning technique. A dozen of stick-like objects such as cylinder, pen, and odd-shaped cylinder were used for proof experiments, and we found that the proposed sensor system achieved more than 75% success rate within whole regions which are nearly suitable to grip a stick-like object by a jaw gripper.

2 The Tactile Sensor System

2.1 The Tactile Sensor

Fig.1 shows a tactile sensor we developed. Four pressure-sensitive sensors, ShokacChip TTSI-OD10-C10 produced by Touchence Inc., are embedded in a solid board sized 50 by 50 [mm]. Rated force ranges of a ShokacChip sensor are 40 [N] for Z axis, and 8[N] for X and Y axes with 0.01[N] resolution. A plastic plate placed on the top is manufactured by a 3D printer. Silicon sheet with 1[mm] thickness was taped on the plate for anti-slip. The height of the foot under the plate was experientially defined as 19 [mm], and tactile sensors are adhered with their sole.

2.2 The Experiment System

Fig.2 shows our experiment system. Above-mentioned tactile sensor is adhered on a solid base, and the same goes for a motor that is connected with a squared solid plate that is for thrusting a grasped object to the sensor. Note that this is a system simulating a jaw gripper, which can the simplest and extensively-used robot hand.

In this system, a blushless motor, TF-M30-24-3500-G15 produced by Tsuji Electronics Co, Ltd., is used. For proof experiments, we set max torque as 0.51 [kgf cm].

3 Type and pose estimation of a stick-like object

3.1 Our identification problem

Table 1 Direction estimation results

correct answer	classification result 0 [deg]	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
0	5																	
10		5																
20			5															
30				4	1													
40					5													
50					1	4												
60							5											
70								5										
80									5									
90										5								
100											5							
110												5						
120													5					
130														5				
140														1	4			
150															4	1		
160																	5	
170																		5
total recognition rate																		

A pressure-sensitive sensor we use provides temporal pressure data relevant to every three orthogonal axes *x*, *y* and *z*. That is, we obtain 12 temporal data from four pressure-sensitive sensors as one measurement. To achieve our study purpose, these data are used to distinguish the type and the direction of a grasped object.

Two discriminant functions are generated by means of a machine learning technique. First, we prepare training data. One datum, as mentioned above, consists of a dozen of temporal data obtained from the tactile sensors while a stick-like object is grasped. For various objects, the data is collected with changing its grasped direction. Each data is normalized by the maximum force value, and two discriminant functions are trained. One is intended for a use in object type estimation, and the other is for direction estimation.

We should regard this approach as multi-class recognition problem with non-linear characteristic data. For this reason, we applied random forests[4]. Random forests is a method using a set of decision trees. Each tree is generated from a part of data that are randomly selected.

4 Experiments

4.1 A fundamental experiment

To investigate the possibility of direction estimation, an experiment using a simple cylinder, which was 24 [mm] diameter and 50 [mm] length, was performed. The cylinder was thrust on a tactile sensor in training data collection phase. The direction was changed from 0 [deg] to 170 [deg] with 10 degree interval. A discriminant function was generated from 540 data. That is, 30 data was prepared for one direction. Table 1 shows a confusion matrix. If we permit 10 [deg] error as acceptable range, the direction estimation was completely succeeded. This result shows that the sensor system is suitable for knowing the direction of a stick-like object while grasping.

4.2 Experiments using several stick-like object.

Fig. 3 shows nine target objects we selected. Five of them are daily-use objects; centering punch, hexagon wrench, ballpoint pen, mechanical pen, and size AA battery. Remaining objects are artificially-shaped cylinder:

Fig.3 Target objects

a maximum of three circular rings were whipped on the cylinder. As the same way as Section 4.1, the objects were thrust on the tactile sensor with 10 degree interval while training data were collected. In this experiment, the number of data for one direction for one object was three.

Two discriminant functions were generated from these training dataset. For object identification, the dataset was divided according to nine objects, and a classifier outputting the nine numbers were generated. Meanwhile, a classifier for 18 classes was generated from the dataset divided into every 10 degree interval.

Direction estimation was about 77% success rate, and object identification was 75% success rate. In object identification, success rates were decreased for cylinder with one ring, with two rings, with three rings, and mechanical pencil (67%, 61%, 61%, and 28%, respectively). They were erroneously identified as another cylinder or centering punch. If we permit 10[deg] error as an allowable range, direction estimation was 99% success rate, and object identification was 86% success rate. These results show that this sensor system is suitable for mounting in the palm of the robot hand as we aim.

5 Conclusions

We proposed a tactile sensor system for a robot hand. Four pressure-sensitive sensors mounting a plastic board are used to estimate the state of a stick-like object. We showed an approach to the use of discriminant functions generated from temporal force data, and proved the availability by experiments using nine series of stick-like objects. The results show that the proposed sensor system has a possibility of a sensor suitable for a robot hand.

Our future work includes accuracy enhancement by both hardware and software improvement. An application to dexterous manipulation is also important.

Acknowledgement

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