Suppression of Deformation for Gripping Soft Objects Using Miniature Tactile Sensor with Hemisphere PDMS
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In this study, the proximity and tactile combination MEMS sensor with PDMS as a contact part was attached to an electromotive manipulator, and gripping of soft objects was controlled using sensor output. It is demonstrated that soft object can be gripped without large deformation by the manipulator controlled using output from the sensor with hemisphere PDMS and gripping force can be adjusted automatically when the object is lifted up.

In recent years, introduction of robots has been advanced in various fields, including agriculture and service industries other than manufactures. In the case of robotic applications in these industries, target object to grip is not limited to have a rigid body and a definite shape, such as fruits and human body. To dexterously grip objects with soft body and indefinite shape, information for proximity, contact, hardness and slippage of the object is required, otherwise the object may be damaged [1]. We have already constructed a grasping control system using a proximity and tactile combination MEMS sensor [2][3]. In this study, we report gripping control to lift up the soft objects without large deformation and slipping.

Figure 1 shows a chip of proximity and tactile sensor with cylindrical and hemisphere PDMS as a contact part and the manipulator (Koganei) for gripping. Durometer hardness (DH) of soft objects as a gripping target is shown in Table 1. Detection of the contact state was performed by measuring the applied load to the sensor in contact with the object. Fingers of the manipulator are automatically moved closer to or away from each other controlled by a programmable logic controller according to sensor output. The manipulator was mounted on a vertical movable stage to lift up the object after gripping.

Figure 2 shows the dependence of deformation amount and ratio of it to the initial thickness on DH of soft objects gripped by the manipulator with a constant contact force. In the case of the sensor with cylindrical PDMS, deformation ratio of objects with DH of less than 20 exceeds 10%. On the other hand, in the case of that with hemisphere PDMS, the deformation ratio is less than 10% for all used objects.

Figures 3 and 4 show chronological change of sensor output from the sensors with cylindrical and hemisphere PDMS when the object is gripped and then lifted up. In the case of the hard object (acrylic), sensor output increased, according to the contact force by gripping at around 30 s and then stable gripping with almost constant output was observed, as shown in Fig. 3. Around 40 s, sensor output instantaneously dropped down according to shear load by gravity force after lifting up the object, however, quickly recovered because of controlling to enhance grip. On the other hand, in the case of the soft objects (silicone rubber), although similar stable gripping was performed, output from the sensor with cylindrical PDMS decreased continually after lifting up the object. It means that gripping control did not work well and thus the soft object slipped due to its weight. It is assumed that the reasons for gripping failure are deformation by gripping as shown in Fig. 2 and partial contact between sensor surface and the object. In contrast with the cylindrical PDMS shown in Fig. 3, output from the sensor with hemisphere PDMS successfully recovered without slipping after lifting up the all soft objects (silicone rubber and urethane elastomer), as shown in Fig. 4. Therefore, it is demonstrated that hemisphere PDMS is more suitable than cylindrical one as the contact part of the sensor.
REFERENCES


(a-1) Cylindrical PDMS. (c) Figure 1. Photographs (a) and schematic illustrations (b) of the developed sensor and a photograph of the manipulator with the sensor (c).

(a-2) Hemisphere PDMS. Figure 2. Dependence of deformation amount and ratio on durometer hardness of soft objects.

Table 1 Hardness of soft objects as gripping target.

<table>
<thead>
<tr>
<th>material</th>
<th>Silicone rubber</th>
<th>Urethane elastomer (※3)</th>
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<tbody>
<tr>
<td>No.</td>
<td>1   (※1)</td>
<td>2   (※2)</td>
</tr>
<tr>
<td></td>
<td>1+c</td>
<td>a</td>
</tr>
<tr>
<td>DH A</td>
<td>51</td>
<td>32</td>
</tr>
<tr>
<td>E</td>
<td>42</td>
<td>38</td>
</tr>
</tbody>
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(※1)...Dow Corning Toray, (※2)...Shin-Etsu Silicone, (※3)...EXSEAL Co.,Ltd.