Grasping state sensing of soft gripper for food handling

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***Abstract*— Automatic handling of many types of food materials are required to realize the automation of production of commercially prepared box lunches. A printable soft gripper was developed for food handling which is simple to produce with a 3D printer. However, the sensing ability of the printable soft gripper was not discussed in previous research. In this paper, a novel method for estimating the curvature of a printable soft gripper using electro-conductive yarn is presented. Electro-conductive yarn is a conductive material, and the resistance of strings is changed by stretching. It is less expensive than other sensors that can be used for curvature measurement. Additionally, it is easy to assemble and disassemble by hand. The electro-conductive yarn is applied to the prototype printable soft gripper, and our proposed estimation method is experimentally verified. From results of the experiment, the estimated bending from resistance of the electro-conductive yarn was validated by the actual curvature of gripper.**

I. Introduction

Currently, several millions commercially prepared box lunches per day are consumed in Japan [1]. Therefore, automation of the production of the box lunches is required. To produce box lunches, the handling of food using a robot hand must be realized [2] [3]. Hence, a printable soft gripper was developed for food handling which can grasp foods that are soft and easily deformed [4]. It is possible to use a 3D printer to easily produce the soft gripper. However, the sensing ability of the printable soft gripper to sensing is not discussed sufficiently in previous research. Bending of the printable soft gripper was successfully measured using a strain gage [5].However, when using strain gages for measuring the bending of the printable soft gripper, the finger size of the gripper is limited by strain gage's size and the production cost of gripper increases. In this research, we propose a novel method to estimate the bending of the printable soft gripper using electro-conductive yarn [6].Electro-conductive yarn is a very low cost conductive material, and the resistance of the strings is changed by stretching. Additionally, the sensor size can be determined by users.

In this paper, a concept regarding the estimation of bending using electro-conductive yarn is proposed. Then, the calibration method is presented. Finally, the proposed estimation method is applied to prototype printable soft gripper, and estimation result is verified by experiment.

II. Estimation method for the curvature of a printable soft gripper

Our proposed printable soft gripper using electro-conductive yarn and supplementary positioning of electro-conductive yarn is shown in Fig. 1. An electro-conductive yarn is attached to a surface of a finger. When a finger bends, the yarn extends accordingly. When the air pressure is applied to the printable soft gripper, each chamber expands and the finger is bent. Then, the electro-conductive yarn is extended, and the resistance of the electro-conductive yarn is changed. The bending of the printable soft gripper can be estimated using this change in resistance.

III. Experimental verification

In this section, the electro-conductive yarn is applied to the prototype printable soft gripper. Then, our proposed estimation method is experimentally verified. The prototype of the printable soft gripper using electro-conductive yarn is shown in Fig. 2. The base and fingers of the gripper are printed by a 3D printer (Objet350 Conex3, Stratasys, USA) which can print soft material. The gripper has three fingers, and each finger is fixed to the base at even intervals. Each finger has electro-conductive yarn and each resistance is measured by the AD converter of MCU. Additionally, these values are sent to PC where the functions of the relationship between the resistance of each electro-conductive yarn. The PC estimates the curvature and tip position of fingers, then the estimated shape of fingers is displayed in real time. The measuring sampling time of the resistance is 0.5 s, and estimated curvature and tip position of fingers are uploaded in 0.5 s.

The experiment results of printable soft gripper are shown in Fig. 2. Fig. 2 (a) and Fig. 2 (b) show the estimated result of the finger's curvature. The red line shows the estimated result

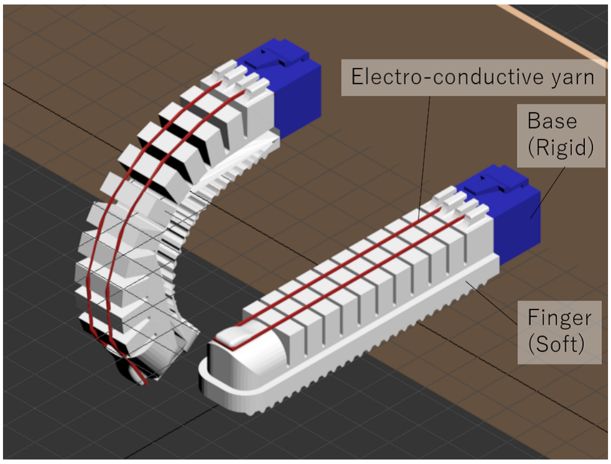

Fig. 1. Soft Gripper using electro-conductive yarn.

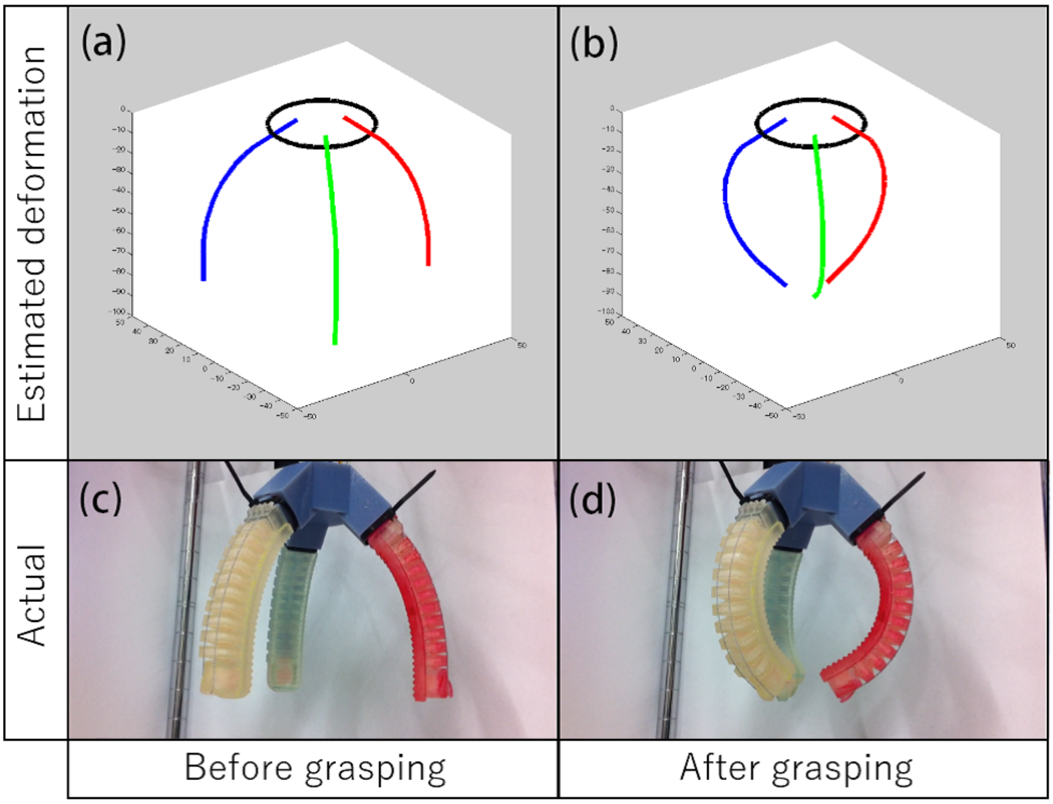

Fig. 2. Estimation of finger curvature with electro-conductive yarn.

of red finger, and green line and blue line show the estimated result for green and blue fingers, respectively. Fig. 2 (c) and Fig. 2 (d) show the actual curvature of the printable soft gripper. Fig. 2 (a) and Fig. 2 (c) show before grasping, and Fig. 2 (b) and Fig. 2 (d) shows after grasping.

From experiment results, the estimated bending from the resistance of the electro-conductive yarn are equivalent to the actual curvature of gripper. Therefore, the proposed method was successful when estimating the bending of the printable soft gripper using the electro-conductive yarn.

IV. Conclusion

In this paper, a novel method was presented for estimating the curvature of a printable soft gripper developed using electro-conductive yarn. Electro-conductive yarn is a conductive material. The resistance of the electro-conductive yarn is changed by stretching the strings. This characteristic is used for estimating the bending of the printable soft gripper. It is less expensive than other sensors for measurement and bending. Additionally, it is simple to apply and disassemble a finger. Electro-conductive yarn is applied to top surface of a printable soft gripper. When a printable soft gripper is utilized for grasping, the electro-conductive yarn extends. Then, the resistance of the electro-conductive yarn changes. In our proposed estimation method, the bending of the printable soft gripper is estimated from this resistance. The electro-conductive yarn is applied to the prototype printable soft gripper, and our proposed estimation method is experimentally verified. From results of the experiment, the estimated state from resistance of the electro-conductive yarn was validated by the actual one. It was determined that the proposed method using the electro-conductive yarn was successful for estimating the bending of the printable soft gripper using our proposed method.

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