Flexible Manipulator Inspired by Octopus

Development of Soft Arms Using Sponge

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***Abstract*—In this study, we focus on the intelligent behavior of an octopus and describe the development of a flexible manipulator. By using the developed manipulator, we show that grasping behaviors similar to those of an octopus can be realized by the dynamics of the body without computation in its brain.**

Keywords-flexible manipulator; octopus; many degrees of freedom; grasping.

I. INTRODUCTION

In general, it is difficult to control a robot with many degrees of freedom. An advanced complex controller is required for controlling a robot. However, it is reported that some creatures—for example, a snake and an octopus—can exhibit complicated behavior such as locomoting, jumping, and grasping. A snake can locomote on rubbles using its many degrees of freedom [1]. Also, an octopus, for instance, is able to grasp various objects [2], [3], [4].

In our previous work to develop intelligent robots, we focused on the dynamics of the creature's body. In [5], we proposed a snake-like robot that has flexible joints. Due to the flexibility of the joints, the snake-like robot could work on rubbles without complex control.

In [6], we considered grasping by an octopus-like manipulator. An octopus has many degrees of freedom in its arms and can realize various intelligent behaviors. However, the brain of the octopus is very small, and how the octopus achieves intelligent behavior is currently an open question. Various studies about an octopus are currently being carried out [2], [3], [4]. Then, we focused on the dynamics of the arms of an octopus and hypothesized that some intelligent behaviors are realized by its dynamics instead of being controlled by its brain. We demonstrated that an octopus-like manipulator can grasp various objects without controlling each joint. However, as the links of the robot in [6] were rigid, it is difficult to grasp three-dimensional objects.

In this study, we extend our previous work. We develop a simple flexible manipulator for grasping three-dimensional objects on the basis of the fundamental behavior of the octopus [2] and demonstrate that the grasping task can be realized very easily without a controller.

This report consists of the following parts. Section II introduces the behavior of an octopus. Section III describes the proposed octopus-like manipulator. Section IV demonstrates that the proposed manipulator can grasp various unknown objects. Section V concludes the report.

II. FUNDAMENTAL BEHAVIOR OF AN OCTOPUS

It is reported that an octopus can stretch its arm from the root to the tip in sequence while keeping its curved shape, as shown in Figure 1(a). When the curved point contacts an object, the arm wraps around the object [2], [3], [4].

This fundamental behavior is effective in grasping unknown objects. In other words, if the arm stretches from the tip and the tip contacts the object first, the arm cannot wrap around the object, as shown in Figure 1(b).

The important question in this research is how we design the robot in order to realize octopus-like behavior. We focus on the dynamics of the flexible arm and hypothesize that the arm moves and wraps around the obstacle passively by simply adjusting the compliance of the muscles of the arm. In other words, the arm can grasp the unknown obstacle without a complex control signal from the brain [2], [3], [4], [6]. The grasping behavior is realized by the dynamics of the flexible arm [6].

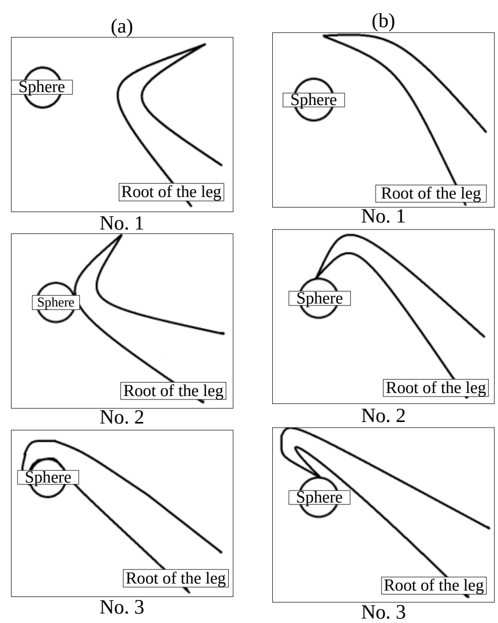

Figure 1. (a) Effective strategy of an octopus and (b) failure mode.

In this study, we developed an octopus-like manipulator with a simple mechanism and demonstrated that this fundamental behavior can be realized by the dynamics of a flexible material and the constraints of wires.

III. Octopus-Like Manipulator

To realize the fundamental octopus behavior, we developed a simple flexible manipulator. Figures 2–7 show the mechanism of the manipulator. The manipulator consists of the sponge arms, the rubbers that simulate the compliance of the muscles, and wires to move the arms. A motor can pull the wire via pulleys, and the wires close the arms.

Note that the rubber is bonded to the sponge arm as it is stretched, as shown in Figure 2. In addition, the length of the stretching is increased from the root to the tip. From the tension of the rubber, the arm is twisted to a natural position, as shown in Figure 3.

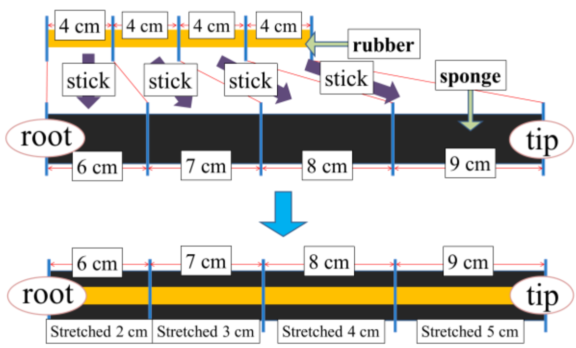

Figure 2. Rubber and sponge for an arm.

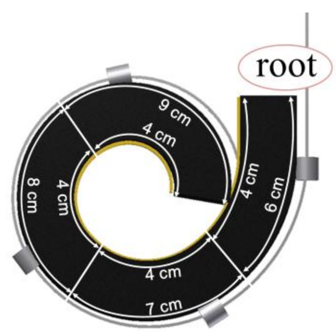

Figure 3. Natural position (open position) of an arm.

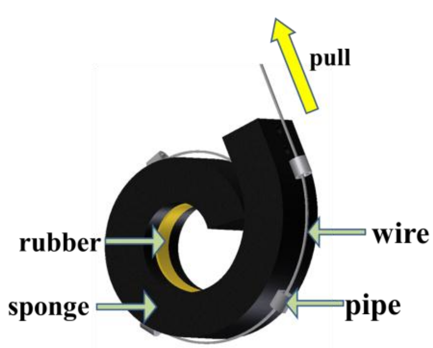

Figure 4. Structure of an arm.

With the asymmetric tension (compliance), the shape of the arm is also asymmetric. The wires are pulled by rotating a motor, and the arms move from the root to the tip like an octopus. Because the arms are flexible, the shapes of the arms adapt to the unknown objects. Figure 5 shows the developed manipulator. We designed the manipulator to grasp an object from the upper part. Active pulleys with a motor are placed in the upper aluminum frame. Figure 6 shows the top view of the arms. Three arms are installed under the pulleys via an aluminum frame at a 120° interval. Figure 7 shows the mechanism to move the arms. The wires are pulled by rotating the motor, and the three arms are closed at the same time. Then, the manipulator can grasp an object.

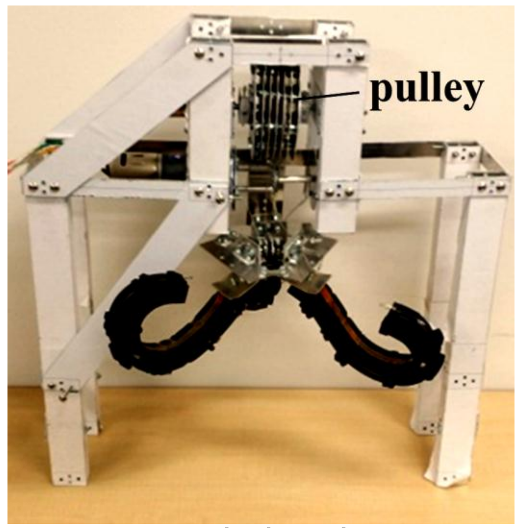

Figure 5. Developed manipulator.

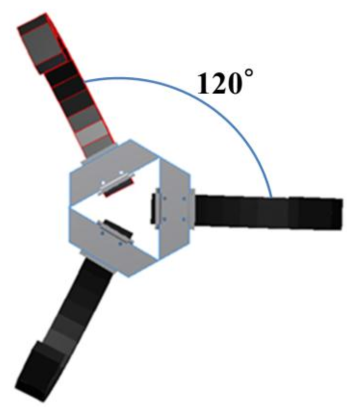

Figure 6. Top view of the arms.

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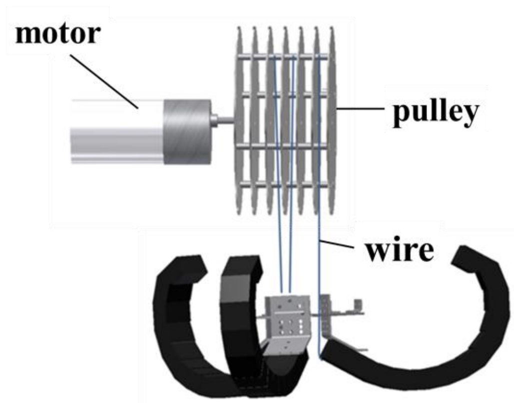

Figure 7. Mechanism to move the arms.

IV. EXPERIMENT

Figures 8 and 9 show examples of the results.

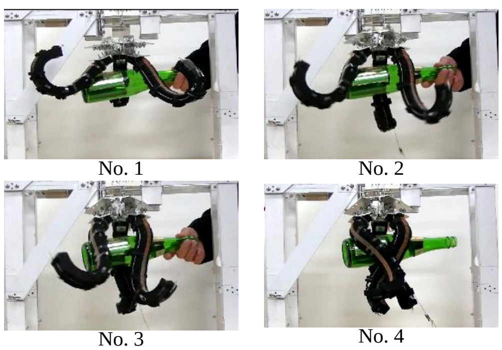

Figure 8. Structure of the manipulator.

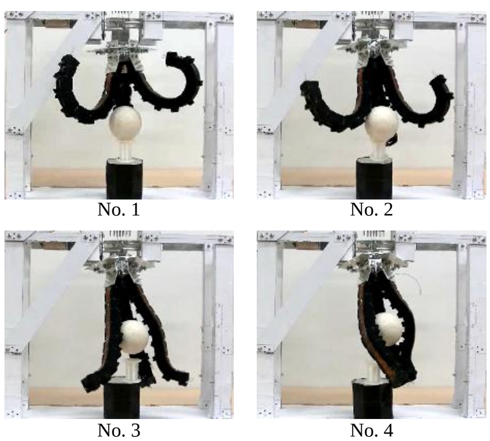

Figure 9. Experimental results of grasping a ball on the stand.

In this experiment, the manipulator worked by simple operation. An operator just turns ON the switch of the motor, and the manipulator can grasp an object. Then, the operator turns OFF the switch.

In this way, the manipulator could work only when turning the switch of the motor ON/OFF.

We confirm that the developed manipulator realizes octopus-like motion and can grasp various unknown objects. In these experiments, we simply pulled the wires using the motor, and no complex control signals were required. The grasping behavior was realized passively by the dynamics of the body.

In general, it is reported that much computation cost is required to control a robot with many degrees of freedom [7]. In contrast, the results of this research show that the proposed manipulator requires no computational cost. Necessary computation for controlling the arms was conducted by the dynamics of the arms instead of a computer.

V. CONCLUSION

In this study, we focused on the intelligent behavior of an octopus. We developed a flexible manipulator that realized octopus-like grasping behavior, and we showed that the grasping of unknown objects could be realized by the dynamics of the body without complex control signals.

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