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Gripper Mechanism Utilizing Biological Exoskeleton Structure and Movement

- Invention and Embodiment of a Gripping Mechanism
using the Opening and Closing Movements of Armadillidiidae -

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1 Introduction

1.1 Soft Robotics Initiatives

Due to their flexibility, soft robots can adapt to the shape of the contact object without complex force control, and have been studied for many years for applications in the medical and welfare fields [1]-[3]. Among them, research on robots that can be ingested or injected into the bloodstream has recently begun [4]-[6].

The authors have developed a new concept of digestible and edible actuators made of edible materials, and have so far realized a balloon-like actuator that can be inflated and deflated by air pressure, using gelatin as the main material [8].

1.2 Positioning in Robotics Research Using the Living Body as an Entity

In our research and development of edible robotic elements, we are working on a balloon actuator using sheep intestine as a natural casing from the viewpoint of using materials other than gelatin.

In terms of a reflective actuator, a gripper that uses the mouth-closing motion of the alligator snapping turtle itself could be used. The beetle is a relatively easy to obtain insect, so it was chosen as the organism for this project. We have conducted research and development on reflective drive mechanisms for arms and moving objects. In reflective actuation, it is important to convert changes in physical quantities into useful actions, deformations, and changes in properties[7][8]. Kanzaki et al. pioneered the manipulation and control of moths using light[13]. By making the contact of the moth not an input device for driving a wheel, but the handling object itself, it will lead to the creation of devices that can perform handling actions to change the orientation and position of the object through light manipulation.

From the point of view of academic fields using living organisms, there is a study by Sato et al. to control the flight and gait of a canadid using a whole body[9] and a study by Morishima et al. to extract electric power from a cockroach[10][11], a study by Takeuchi et al. using separate limbs as body parts[5], a study using sheets of sheep intestine as tissue materials, and a study by Morishima et al. using cells[12]. To the best of our knowledge, there is no example of robotics research using a living body as an entity using a 3D geometric structure as it is. Therefore, we believe that the research using the sheep intestine as it is different not only from the point of view of edible robotics, but also from other robotics research using living tissue.

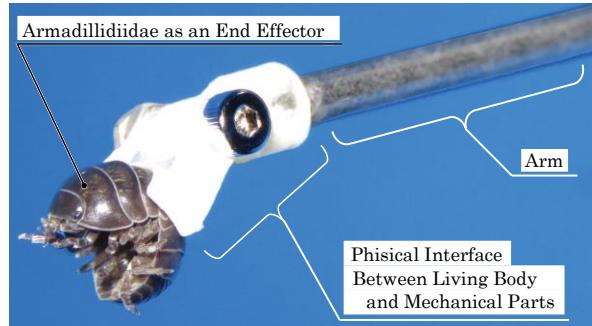


Figure 1: Overview of the First Prototype Model

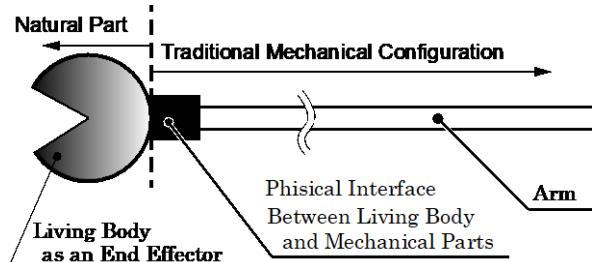


Figure 2: The Concept of the Gripper Biological Exoskeleton Structure and Movement

2 Gripper mechanism utilizing biological exoskeleton structure and motion

In this research, among the structures of the living body, we considered utilizing the skeleton and movements of the living body, especially the exoskeleton and reflexive movements, as the structure and movements of the robot. This research differs from conventional research in that it utilizes a structure and movements of a part of the body without separating them from the individual organism, while keeping the individual organism alive. As the first example of this research, we devised a gripper mechanism that uses the exoskeleton of a sow bug shown in Figure 1 and the reflex action to close the exoskeleton. As shown in Figure 2, we connect a living body to conventional mechanical elements via a physical interface and utilize part of the structure and motion of the living body.

From the viewpoint of using changes in physical quantities caused by biological structures and organisms, it is thought that it will be possible to grasp an object that is separated from the external environment and add movement by utilizing the adhesive movement of slugs and the adsorption movement of leeches, and by fixing these individuals at the edge of the mechanism. While the carrier pigeon utilizes the entire

movement of an individual, the firefly, like the light of a firefly, utilizes one of the functions of the living organism while making use of a single individual. As a part of this category, a caging mechanism utilizing the opening and closing movements of insectivorous plants and an object processing mechanism utilizing the biting force of alligator snapping turtles are also possible.

3 Realization of actual equipment

Based on the above concept, an actual device is embodied. The main body of the beetle is attached to a 3 mm diameter arm via a physical interface. A method of soft attachment with a flexible string, as shown in Figure 3, is being investigated to facilitate reflexive movement after attachment. The overall appearance of the actual device is shown in Figure 4. The width of the biological portion is 6.9 mm, the cross-sectional diameter is approximately 7.03 mm when viewed from the side of the actual device with the shell closed, and the weight of the tip including the physical interface is 0.76 g.



Number of Fixation Lines 1 Number of Fixation Lines 2
Figure 3: Fixation method for living organisms (Pill bug, Armadillidiidae)

4 Experimentation with actual equipment

4.1 Grasping motion

Figure 4 shows the grasping operation of the prototype. The object to be grasped in this experiment is a lightweight piece of cotton (0.03 g). As shown in Figure 5, we confirmed that the object can be grasped by the reflexive closing motion of the beetle. At present, the reflex action is a reflex action in which the insect is stimulated by the contact with the object itself and closes its shell. After about 115 seconds of holding, the object was released. Although the control of the low stimulus and timing to open the shell is a future issue, the possibility of grasping by opening and closing the shell was demonstrated if the object was relatively lightweight and could be held by the exoskeleton.

4.2 Handling operation

As shown in Figure 6, the walking motion of the sow bug is used to demonstrate the possibility of realizing an object-handling motion. The leg movements are shown in the forward-backward. Future work will focus on moving lightweight objects in arbitrary directions by turning and controlling them.

5 Conclusion

In this study, from the viewpoint of a mechanism utilizing biological exoskeleton structure and behavior, a grasping mechanism was devised using a pill bug, and an actual machine was realized. We confirmed that the grasping of very lightweight objects such as cotton was possible through experiments on the actual device. Future issues are to improve the minimally invasive grasping, the timing of the opening and closing of the tip, and the control of the grasping force.

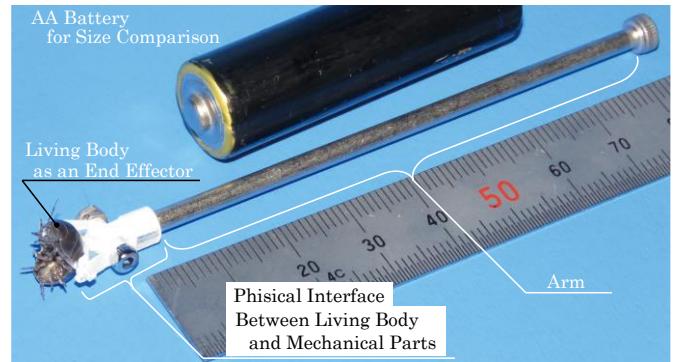


Figure 4: Overall appearance of the prototype gripper mechanism



Figure 5: Grasping operation using actual equipment



Figure 6: Handling operation using actual equipment
 (please watch the movie at the following link
<https://youtu.be/HYsTtJA19pI>)

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