Development of earthworm type robots that have a multifunction locomotion mechanism using FSB

Takahito Kubo (510032)

School of Information Science,
Japan Advanced Institute of Science and Technology

February 8, 2006

Keywords: Mobile robot, Soft actuator, FSB, multifunction locomotion mechanism, earthworm type.

Recently, various types of mobile robots are being researched and developed. For example, often introduced are humanoid robots, guard robots, rescue robots, and cleaning robots. Most of these robots have a mechanism for locomotion using wheels, crawlers and legs actuated by electric motors. However the mechanism that uses the motor has the problem in terms of the weight and cost(time and money). The motor and the aforementioned components are made of metal. So these make the total weight of the robot heavy. Increase of weight causes decrease in accessibility and portability. A lot of people and time are necessary for production(design, machining, and assembling) of a robot. Moreover, if a robot needs to be miniaturized or to implement various movements, the price of the motor and its related components raise the price of the robot. In addition, flexibility and changeability are necessary for a frame, because mobile robots might be operated in fields which are not a uniform state. But the locomotion mechanism using a motor is difficult to provide flexibility and changeability, because the metallic frame is fixed and connected to other fixed parts. Therefore, currently employed mechanisms using an electric motor will have many problems.

To cope with difficulties with the conventional locomotion mechanisms, mobile robots using soft actuators are getting increased attention. Soft

actuators are flexible actuators that exhibit passive compliance. The passive compliance has been defined in "leading edge of soft actuators development" written by Yoshihito Osada. The passive compliance allows flexibility as an elastic body like the spring, which is decided by the material property and operation medium of the actuator. Soft actuators have features that enable the robot to minimize its size and weight, as well as to provide flexibility. There are various types of soft actuators that can be made of shape-memory alloys. It is also possible to develop a pneumatic soft actuator that is made of rubber and pneumatically driven like the Mckibben type rubber artificial muscle. Mobile robots using these soft actuators can help overcome many problems with the locomotion mechanism with an electric motor. Soft actuators can function as frames whose flexibility and changeability will be exploited. Moreover, soft actuators can also cope with the problems of the weight and cost(time and money), because the robot can be easily manufactured and features a miniaturized and lightweight structure. It is pointed out that, mobile robots using a soft actuator have a number of advantages over robots that employ electric motors.

Therefore, we develop a robot that has the locomotion mechanism using a soft actuator. We use a FSB(Film Surfaced Bellows) as a soft actuator. A FSB is a pneumatic soft actuator that was developed based on the inflatable structure. It consists of a film wrapping the bellows and its terminal parts. There are air holes in the bellows, and the air inflates the film through the holes. The polyimide film is used as the film, because it shows the excellent characteristics in heat resistance, insulation properties, strength, and dimension stability. Because the FSB is operated by the pressure of about 0.1[Mpa], it can exert a high-power. And expansion and shrinkage are done only by inletting and evacuating the air, so the control is easy. In addition, a FSB possesses the rigidity before and after inletting the air, thus can function as a frame. And it has the flexibility during inletting the air, and is excellent in the adaptation to environment.

We specifically manufactured the locomotion mechanism using the FSB and suckers, and developed a mobile robot of earthworm type in this research. The high retractility and expansibility is one of the most important characteristics of the FSB. The robot is operated by a sequence control

with H8. This robot can move forward and backward like the earthworm by exploiting the suckers and expansion-shrinkage characteristics of FSB. The proposed mechanism can passively change the direction of movement conforming to the environment using the flexibility of FSB, Moreover, this robot can actively select the course by using the mechanism of a triad FSB or using the method that fixes one side of a FSB with the brake wire. Thus, this robot provides the multifunction locomotion mechanism that can change its direction both actively and passively. And it can climb a wall, because it is light and has the locomotion mechanism equipped with suckers. As a result, this robot can get over small obstacles, ditches and climb the wall from the floor. In this way, we developed earthworm type robots that have a multifunction locomotion mechanism using FSB. In addition, we applied it to an in-pipe crawling robot. The liquid such as water exists in a pipe. Therefore, it is difficult to use suckers inside the pipe. Hence, we developed a new FSB that expands in a pipe. And we used this FSB for a pipe in a vertical direction. Exploiting the intrisic function of FSB expansion, we obtain the frictional force to enable the robot to move in a pipe, and use the frictional force as a substitute for suckers.

In this work, we developed the earthworm type robot that have a multifunction locomotion mechanism using FSB that is a soft actuator. This robot has some advantages over current robots that have a conventional locomotion mechanism using a motor. First of all, it has an excellent characteristics in the adaptation to the unknown environment. Next, it is excellent in terms of the weight and cost. Lastly, it can move through territories that are quite irregular and complex. This robot can be used for in-pipe investigation, wiring LANs, and cleaning hazardous parts and play a role as a rescue robot.