Proceedings of 2013 ICME
International Conference on Complex Medical Engineering
May 25 - 28, Beijing, China

IPMC Actuator-based a Movable Robotic Venus Flytrap

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Abstract - **Nature is a perfect model for a robot. Besides the insects and underwater animals, some carnivorous plants which are capable of rapid movement, such as mimosa, the venus flytrap, the telegraph plant, sundews and bladderworts, are of great interest for the biomimetic robot design. Carnivorous plants, such as Venus flytrap, can be turned on in a controlled manner to capture prey by using their trigger hairs as detecting sensors. In our previous research, we designed a robotic Venus flytrap by using two ionic polymer metal composite (IPMC) actuators and one proximity sensor. To enlarge its working area in real applications, we improved it by integrating biomimetic walking and rotating motions into the previous version. First, we proposed a conceptual structure of the improved robotic Venus flytrap which consisted of two IPMC lobes, one proximity sensor, and eight IPMC legs. Then, we developed a prototype movable robotic Venus flytrap and evaluated its walking and rotating speeds by using different applied signal voltages. At last, to reduce the gaps between two IPMC lobes, we improved the robotic flytrap by using three IPMC lobes. The experimental results showed a good performance.**

Index Terms – Robotic Venus flytrap, Ionic polymer metal composite actuators, **Biomimetic locomotion.**

I. INTRODUCTION

Creature has succeeded in creating a fantastic variety of structures using an enormous amount of resources. During the long evolution history, they have evolved lots of locomotion for diversiform environments. For example, swimming, rowing, flapping, floating, and sinking motions are most used in water; crawling, walking, climbing, jumping, and rolling motions are always used on land; flying, gliding, and wafting motions are the normal ways in air. Also there are some assistant motions such as sucking, clasping, ejecting, and grasping, which are used to improve the efficient of the locomotion [1]–[6]. Besides the insects and animals, some carnivorous plants are also capable of rapid movement to trap various invertebrates, and occasionally even small frogs and mammals. Carnivorous plants obtain some nutrients by trapping and digesting various invertebrates. Most plants absorb nitrogen from the soil through their roots. But carnivorous plants absorb nitrogen from their animal prey through their leaves specially modified as traps. In the case of the Venus flytrap, the prey that is lured by the sweet nectar in the Venus flytrap pair of lobes has to flip and move the trigger hairs, which are colorless, bristle-like and pointed.

In recent years, lots of bio-inspired robots have been developed utilizing motor-actuated screw propellers as actuators [7]–[9]. However, the applicability of traditional motors is limited by their large size, high noise, and high power consumption [10]–[11]. In addition, the electromagnetic structure of traditional motors is difficult to be changed in any shapes to adapt the soft biomimetic locomotion. Thus, motors are rarely found in this type of application [12], and special actuator materials are used instead. A variety of smart materials, such as ionic polymer metal composite (IPMC), piezoelectric elements, pneumatic actuators, and shape memory alloy, have been investigated for use as artificial muscles in new types of microrobot [13]–[21]. Shahinpoor et al. have developed a robotic Venus flytrap by using two IPMC lobes and four IPMC bristles [22]. However, by using IPMC bristles to mimetic the trigger hairs, the output of IPMC bristle is too weak and unstable. The bending of bristles is also limited in two directions, which is hard to be used in real application. In addition, without characteristic analysis, it is hard to determine its grasping ability and the available distance between two IPMC actuators. So, we designed a robotic Venus flytrap by utilizing two IPMC actuators and a short-range proximity sensor [23], and designed an electromechanical model to evaluate the grasping ability of the robotic flytrap by using different voltages [24].

In this research, to enlarge the working area of the previous version, we improved it by integrating biomimetic walking and rotating motions into the robotic Venus flytrap. A prototype movable robotic Venus flytrap was developed and the walking and rotating speeds were also evaluated.

The remainder of this paper is divided into four parts. First, we review the previously developed robotic Venus flytrap and describe the proposed structure of the movable version. Second, we discuss the development of a prototype of this movable robotic Venus flytrap, together with a series of experiments to evaluate its walking and rotating ability. Third, we show the improved structure of the robotic flytrap with three leaves. Finally, we present our conclusions.

II. PROPOSED ROBOTIC VENUS FLYTRAP

Figure 1 shows the previously developed robotic Venus flytrap. It uses two IPMC actuators as pair lobes. The

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dimensions the IPMC actuators are 24 mm × 18 mm × 0.22 mm. The distance between two IPMC lobes could be adjusted. To determine the available distance between the sensor and the fly, we used one proximity sensor to mimetic the trigger hairs of actual Venus flytrap. The infrared proximity sensors used in the present research were 10 mm long and 5 mm wide, with a weight of 0.7 g. The angle measurement range for one proximity sensor was from –30° to 30°, which is enough for the robotic flytrap to detect the total space between two IPMC lobes.

To enlarge the working area and reduce the number of robotic Venus flytrap in real application, we improve it by adding eight biomimetic IPMC legs that can implement walking and rotating motions, as shown in Fig. 2. Outside four legs are the drivers and inside four legs are used as supporters. The supporters lift the body up, and the drivers are off the ground to bend forward for one step. When the supporters bend upward, the drivers bend backward to move the body. The drivers and supporters are driven at the same oscillating frequency. When crawling, the phase of the supporters lags that of the four drivers by 90° [4].

By changing the bending directions of four drivers between its two sides, the robotic Venus flytrap can implement walking forward and backward, and rotating in clockwise and counter clockwise.

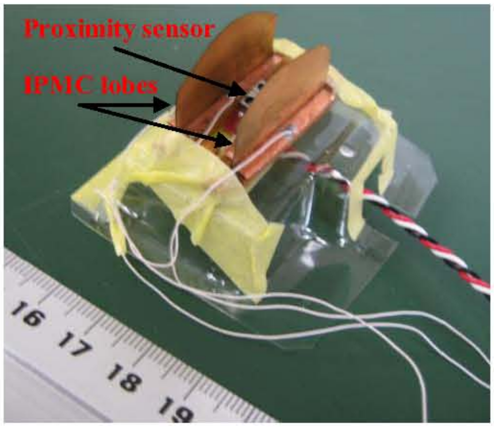

Fig. 1 Previous version of the robotic Venus flytrap [23]

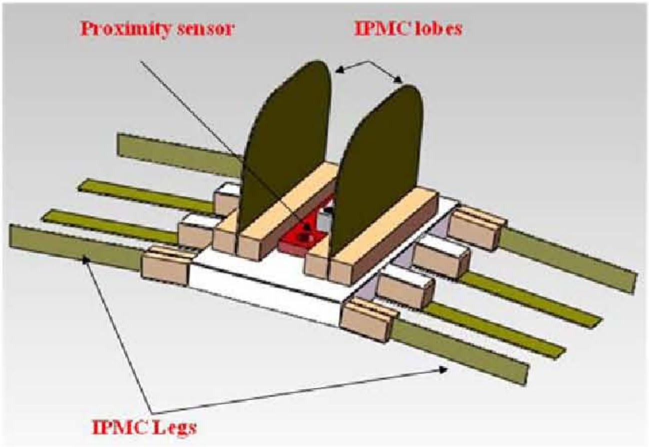

Fig. 2 Proposed conceptual structure of the movable robotic Venus flytrap

III. PROTOTYPE ROBOTIC VENUS FLYTRAP AND EXPERIMENTS

A. Prototype movable robotic Venus flytrap

Figure 3 shows the prototype movable robotic flytrap. It is 33 mm long, 58 mm wide, and 30 mm high. The weight of the body is 8.1 g. The size of the IPMC actuator lobes is $24 \times 18 \times 0.22$ mm^3 and the size of the IPMC actuator legs is $24 \times 3 \times 0.22$ mm^3. And the distance between two IPMC lobes was set as 10 mm. The control signals were transmitted by enamel-covered wires from AVR control circuit.

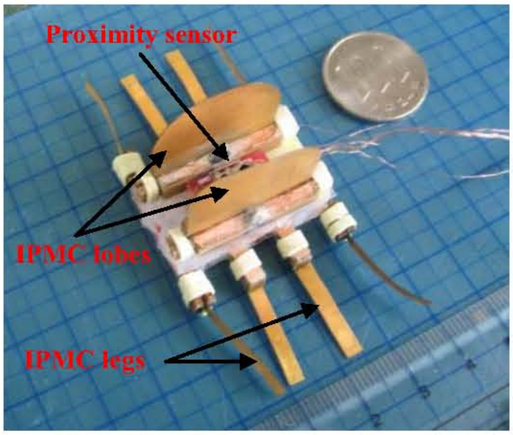

Fig. 3 Prototype movable robotic Venus flytrap

B. Walking experiment

To evaluate walking locomotion, we carried out an experiment on an underwater plastic surface. We recorded the times required to walk a distance of 100 mm using different applied signal frequencies with a voltages of 8 V. The experiment was repeated 5 times for every set of control signals to determine the average speed on the flat surface. The experimental results described in Fig. 4 show that the walking speed was nearly proportional to the input voltage, and a top speed of 15 mm/s was obtained with a control signal of 3 Hz.

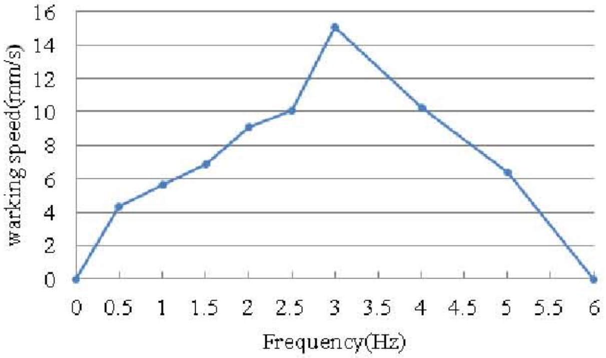

Fig. 4 Experimental speed results during walking

C. Rotating experiment

We also investigated the rotating motion on the same underwater plastic surface. We recorded the times for rotating through 90° under the influence of different frequencies of the control signal, and calculated the average angular velocity for 5 repetitions of the same experiment. The experimental results described in Fig. 5 show that the angular velocity was nearly proportional to the input voltage, and a top angular rotation speed of 20.3 °/s was obtained for a voltage of 8 V and a frequency of 3 Hz.

Fig. 6 shows hybrid motion of developed robotic Venus flytrap. First, it walked forward to desired position. Second, it rotated by 45° to adjust it moving direction. Third, it walked forward again to reach the working area. At last, it bent two IPMC lobes to grasp some imaginary flies.

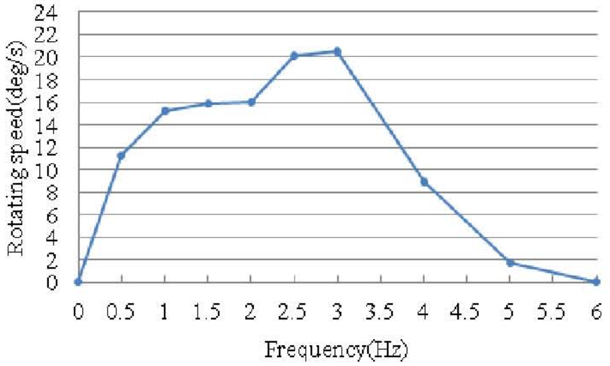

Fig. 5 Experimental angular velocity results during rotation

(a) Walking (b) Rotating

(c) Walking (d) Grasping

Fig. 6 Hybrid motion

IV. IMPROVEMENT

Though we developed this movable robotic Venus flytrap, some problems still existed. For the structure limitation, it was hard to close without gaps between two IPMC lobes. To obtain maximal closing deformation, we had to increase the driving voltage of IPMC actuators, which would destroy them. To conquer this problem, we improved the robotic flytrap, as shown in Fig. 7. Three lobes were used to reduce the gaps. Also, we used three proximity sensors to detect the fly in the whole inner space of the leaves. Three proximity sensors were more sensitive than one sensor.

Based on the improved structure, we developed a prototype robotic flytrap with three IPMC leaves, as shown in Fig. 8. The distances among three leaves could be adjusted. It opened and closed like a flower, which could be carried by a walking microrobot to extend the trapping area.

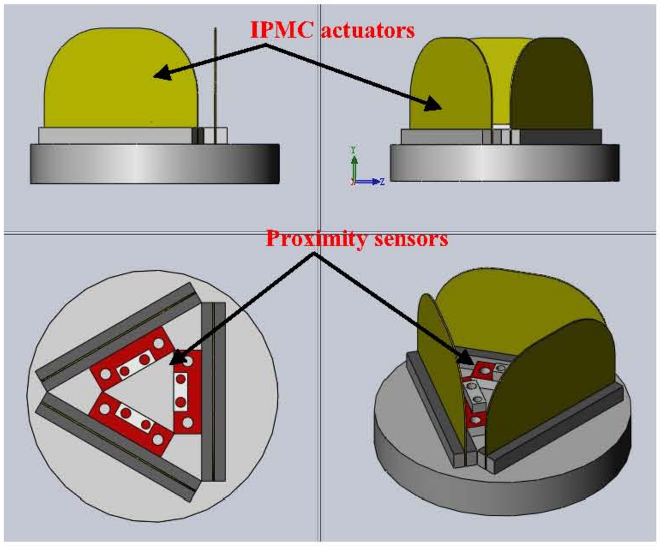

Fig. 7 Improved structure of the robotic flytrap

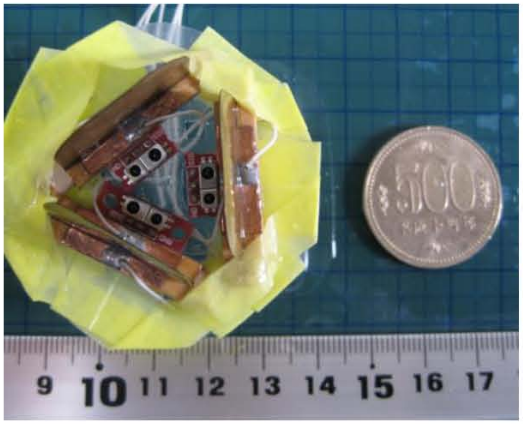

Fig. 8 Improved prototype robotic flytrap

V. CONCLUSIONS

In this paper, in order to improve the detecting and grasping performances of the previous developed robotic flytrap, evaluate its grasping ability and enlarge its working area, a new movable robotic Venus flytrap was proposed and developed. First, we proposed conceptual structure of a movable robotic Venus flytrap. Then, we developed a prototype robotic flytrap and carried out experiments to evaluate its walking and rotating speeds. The experimental results showed a good performance of the robotic Venus flytrap. The robotic flytrap could walk with a maximal speed of 15 mm/s and rotate with a maximal speed of 20.3 °/s. At last, we improved the robotic flytrap by using three IPMC lobes as leaves. Three proximity sensors were utilized to detect the fly in the whole inner space of three leaves. It shows the potential application of detecting and trapping the flies outdoor or on the surface of shallow water.

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