Design and Control of Thermal SMA based small crawling robot mimicking *C.elegans*

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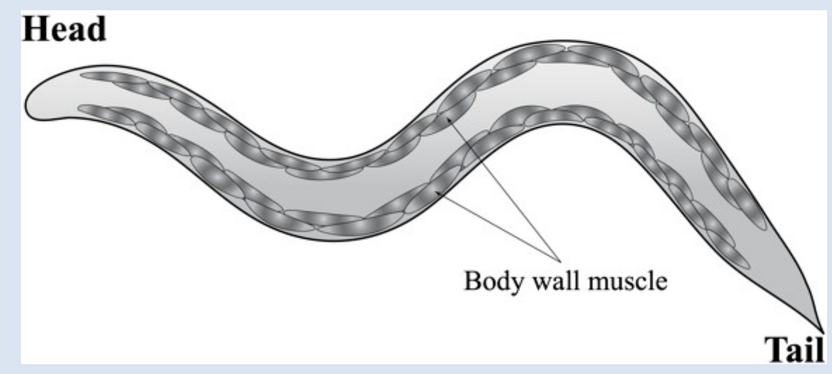
1 Introduction

Development of biologically inspired crawling robot was attempted for several decades, and many robotic applications were reported. Those crawling robots based on traditional actuator are hard to be developed in small size and low weight due to bulky actuation mechanism and complicate control method. In this research, we proposed small and simple design of crawling robot using soft actuator based on thermal SMA by mimicking *C.elegans.*

(A)



(B)

Figure 1. (A) *C.elegans* with sinusoidal body shape, (B) Body wall muscle structure of *C.elegans*.

2 Design and Control Scheme

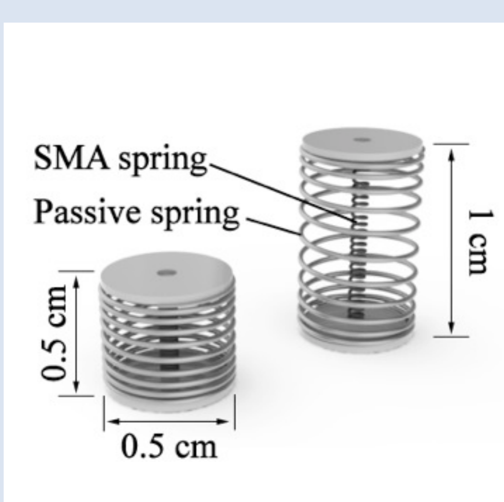
We designed small size linear actuator based on thermal SMA and passive spring, and robot body based on *C.elegans*' structure. The simple sequential code based CPG control scheme was also proposed.

A. Material Selection

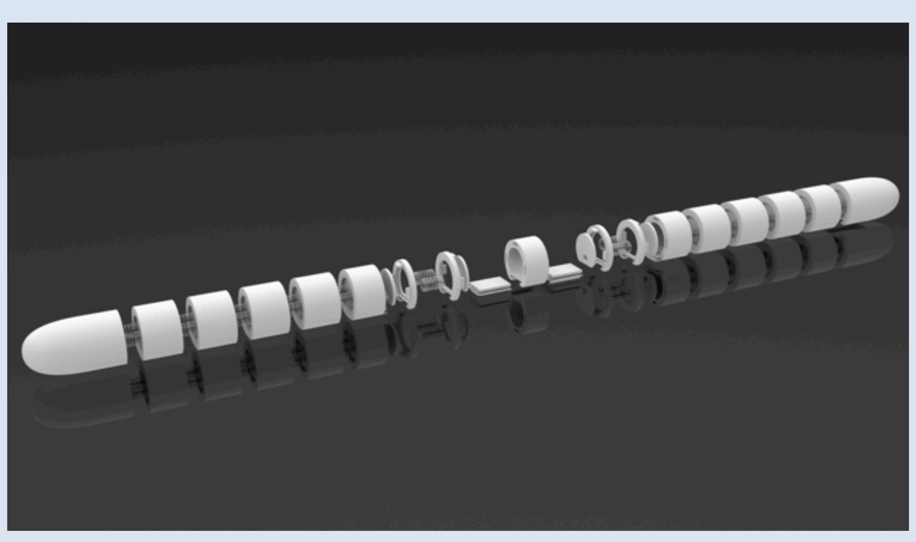
Among various smart materials, spring shaped thermal SMA was selected as an actuation material due to its large deformation (over 50% contraction), moderate force generation (< 30 gf), and similarity to actual *C.elegans* muscle.

B. Design of actuator and robot

Linear actuator was developed using thermal SMA spring and passive spring. Each linear actuator is corresponding to the body wall muscle of *C.elegans*. Entire robot consists of 12 segments and each segment has two linear actuator side by side.



(A)



(B)

Figure 2. Proposed design of (A) linear actuator based on thermal SMA, and (B) whole robot assembly.

C. Motion Control Scheme

In this research, proposed linear actuator does binary positioning. Hence, we used simplified CPG control method using sequential codes. The robot has two input signals and four different motion modes: Forward motion (11), S2 left turn (10), S1 right turn (01), and rest (00).

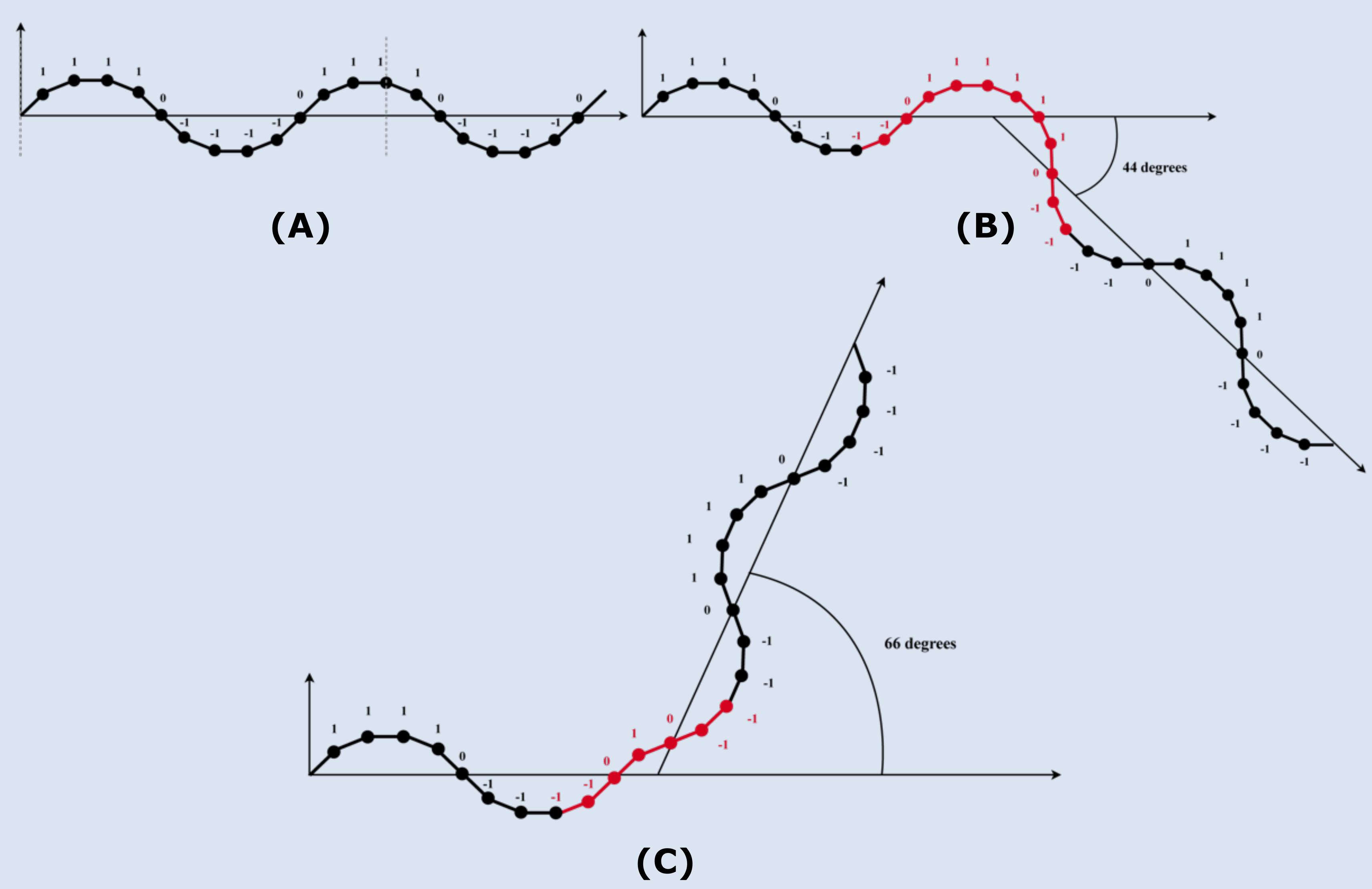


Figure 3. Sequential code for (A) Forward motion (1 1 0 -1 -1 -1 -1 0 1 1), (B) S1 right turn (1 1 1 1 0 -1 -1 -1 -1 0 1 1), and (C) S2 left turn (1 1 0 -1 -1 -1 -1 0 1 0 -1 -1 -1 -1 0 1 1).

3 Hardware Implementation

A. Hardware Implementation

Proposed simple CPG control scheme was coded in C and implemented by using microcontroller PIC12F675. Robot body parts were fabricated using RP. Implemented hardware prototype has 30 cm length, 2 cm height, 1.5 width, and 100 g weight.

B. Undulating Motion Control Verification

Undulating control based on proposed motion codes was verified with developed hardware prototype. Operating frequency of each actuator is 0.25 Hz. Supply voltage inputs are 4.5 V and 2.5 V.

Figure 4. Implemented robot hardware prototype.
(Length: 30 cm, Weight: 100 g)

4 Discussion and Conclusion

We developed design and control for thermal SMA based small crawling robot mimicking *C.elegans*. Also, hardware prototype was fabricated and verified based on proposed design. This research will be beneficial to understand *C.elegans*' motion mechanism by proposing its hardware robot application, and suggested a new approach to small sized crawling robot using soft actuator. Remaining work is developing translational motion control based on fabricated hardware prototype.