A Soft Earthworm-like Robot Targeted for *GI Tract Inspection*

Student: Ho Lam HEUNG *Supervisor : Zheng LI*
Biomedical Engineering Programme, The Chinese University of Hong Kong

Introduction

Colorectal cancer is one of the most common digestive disease around the world, accounting for 14.6% of all cancer deaths [1]. Conventionally, flexible endoscope is used for the inspection of gastrointestinal (GI) tract. However, major drawbacks are reflected in the poor patient tolerance and the risk of colon perforation during inspection. Surgeons are also required to undergo long period of training before performing GI tract inspection with traditional endoscope. Hence, capsule endoscope was introduced in 2000 by Gabbin and Idden [2, nature, 2000]. Still, it lacks an active locomotion to precisely steer the capsule, which surgeons cannot examine the suspected area repeatedly.

In this project, we present a soft earthworm robot aiming for GI tract inspection. The robot contains two inflating actuators and one extending actuator with bending function added. This allows the robot to crawl through tubular environment with sharp bends, such as colon. Pressure inside actuators are detected in real time as well, which not only enables the robot crawling autonomously, but serves as an indicator whether the robot is in well condition during operation.

Advantages of our earthworm robot: 1) Provide a complete soft and small size platform for GI tract inspection, therefore enabling intrinsic safety and improving patient's tolerance; 2) achieve active locomotion, i.e. crawling and bending, inside the GI tract, therefore allowing repeatedly examination of suspected area.

Design of our soft earthworm robot

A) Overall structure of our robot

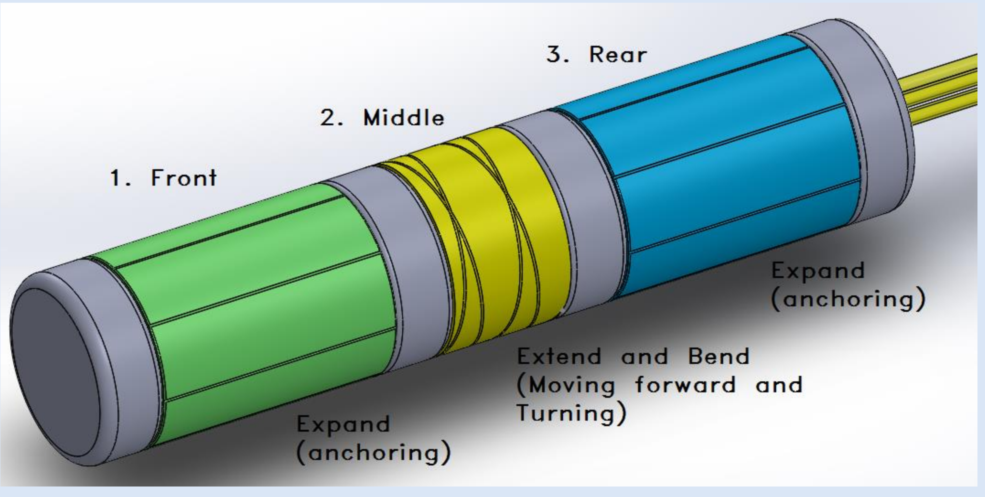


Fig 1. 3D CAD design model of our robot

Fig 2. Prototype of the earthworm-like soft robot

Our robot body consists of three sections, whereas each section is composed by silicone rubber based soft pneumatic fiber-reinforced actuator [3].

B) Locomotion adopted

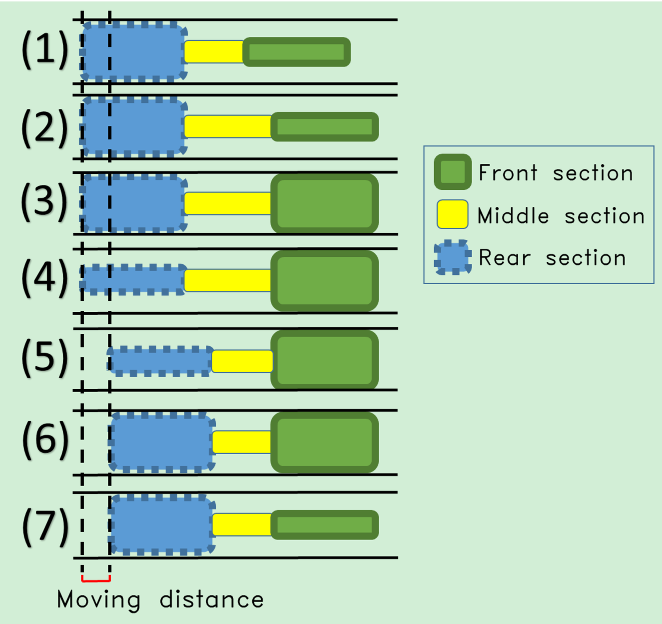


Fig 3. Locomotion

1) Rear section expands to anchor.
2) Middle section extends.
3) Front section expands to anchor.
4), 5) Rear and middle sections relax. Rear section remains to be expanded.
6) Rear section expands.
7) Front section relaxes and back to step one.

C) Fiber wrapping and Internal structure

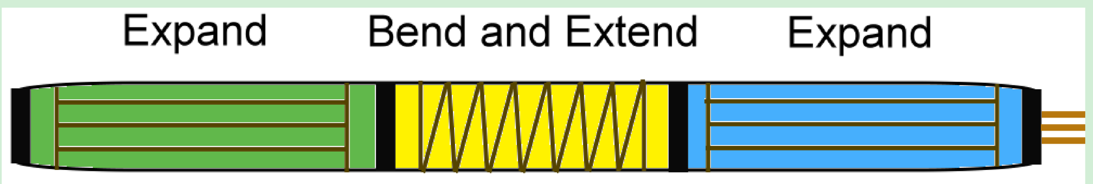


Fig 3. Fiber reinforcement of our robot

For expanding, fiber wrapped around the front and rear sections is arranged in parallel to the robot body.

For bending and extending, we made the wrapping to be double helix and modified the internal structure of middle section from the flexible micro actuator [4].

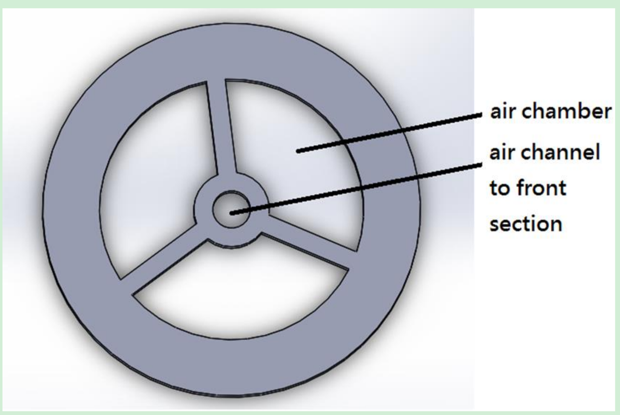


Fig 4. Cross-section of middle section

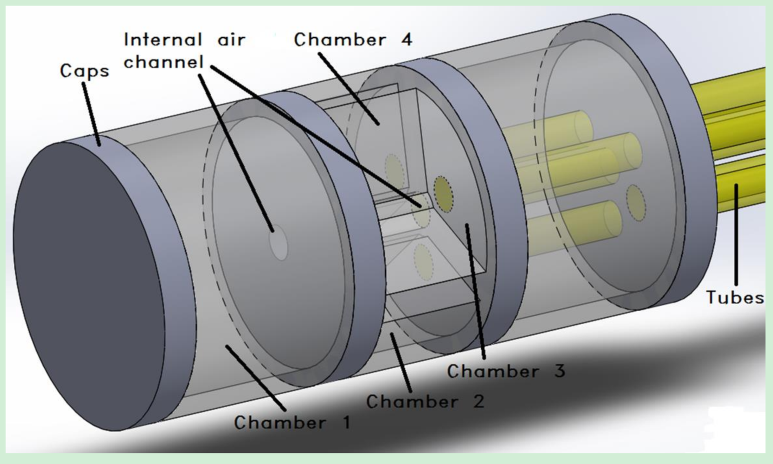


Fig 5. Complete internal structure of our robot. Middle section consists of three air chambers, while others remain one simple chamber without any modification.

Control System – Closed loop system

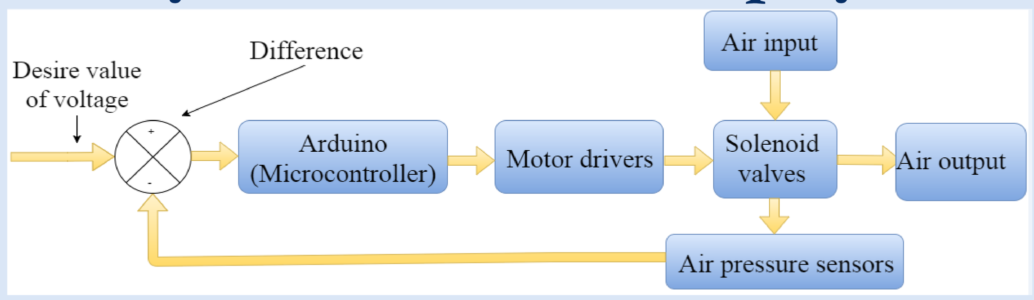


Fig 6. Block diagram of our control board

A) Solenoid valves

Air output to actuate our robot is controlled by the on-off of the valves. Default PWM signal is delivered to the valves to realize purposed locomotion on our robot.

B) L298N Motor drivers

The Arduino and valves are bridged up by L298N because of the difference in operating voltage. PWM to the valves is generated by L298N.

C) Air pressure sensors

Frequency of PWM signal delivered to the valves is regulated by the output readings from the air pressure sensors.

D) Arduino

A/D converter in Arduino can control voltage output from pressure sensors to digital signal. Calculation on difference (error) between default operating air pressure and readings from sensors can be performed. PWM will be regulated as soon as the error is out of range.

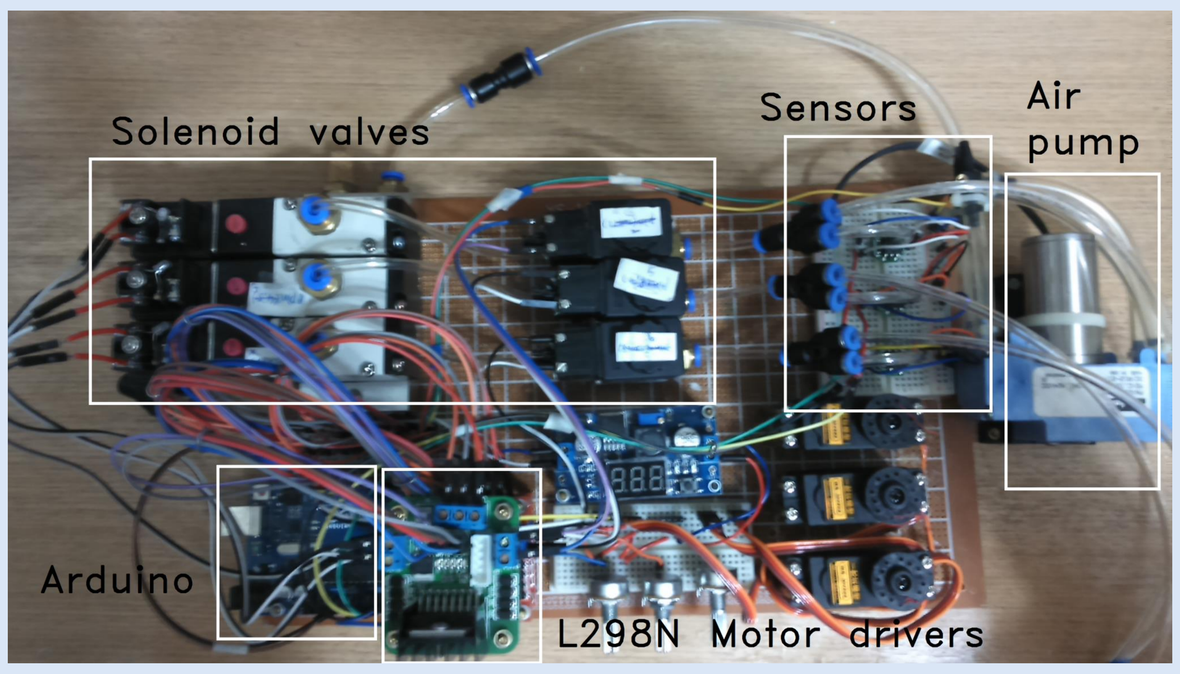


Fig 7. Real set-up of our control board

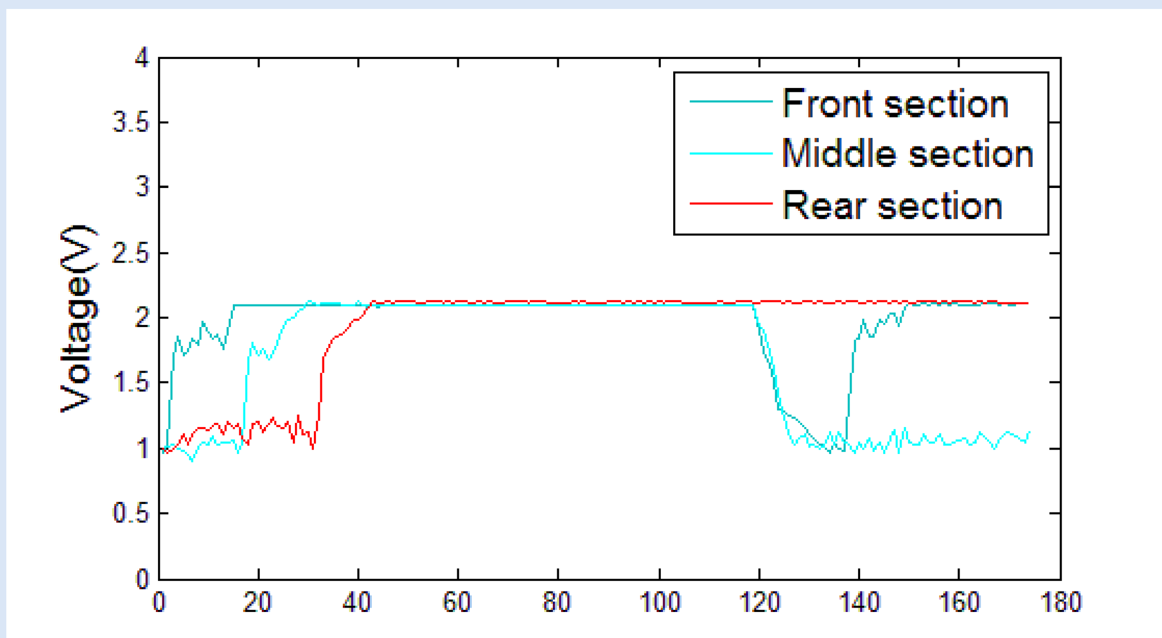


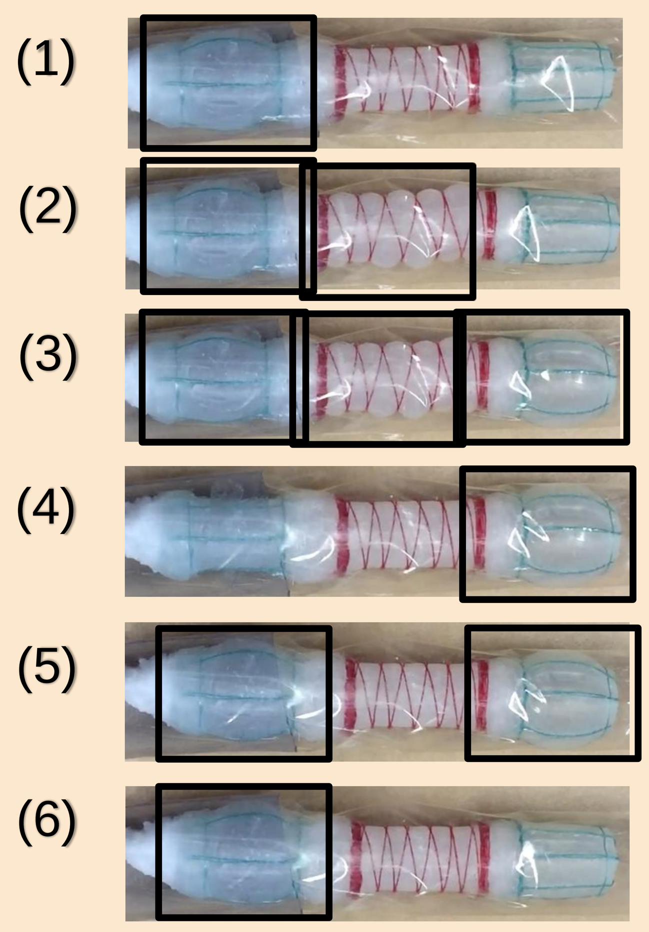
Fig 8. Pressure change inside sections during locomotion

Voltage output from sensors are monitored in time domain, reflecting the regular change of air pressure within each section of the robot.

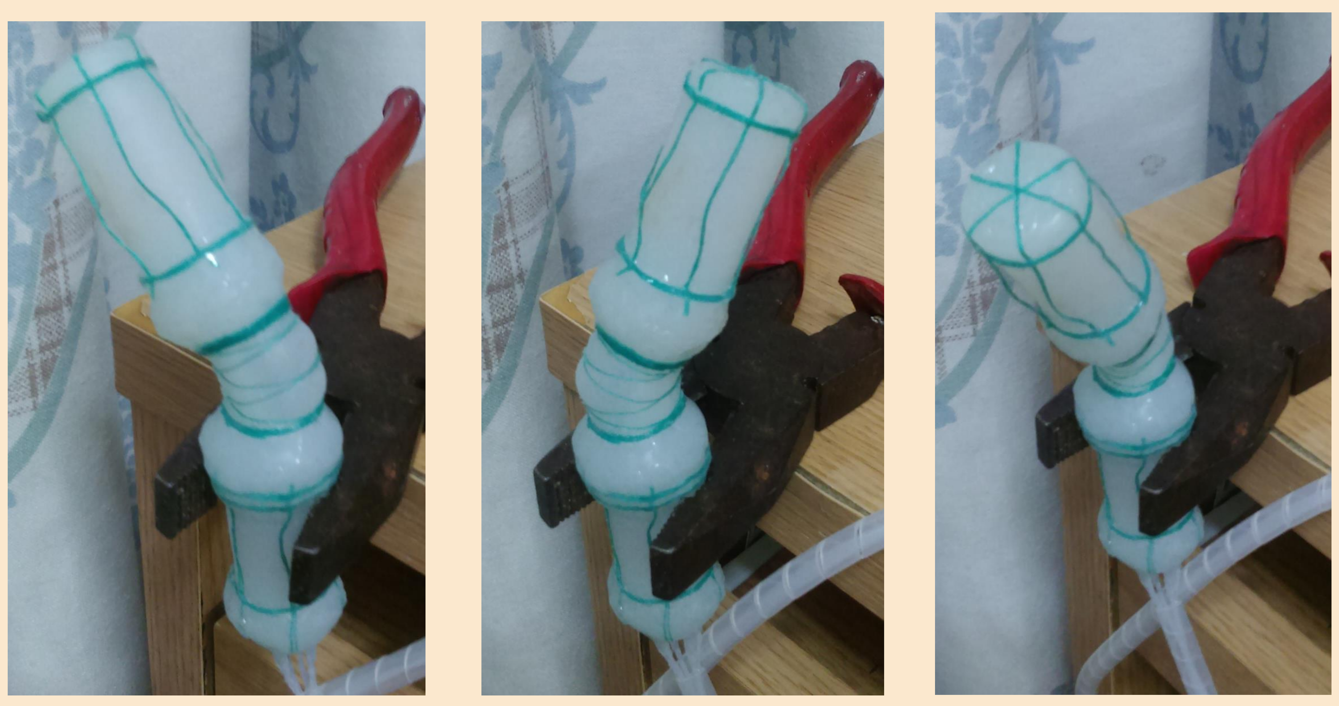
Results

Demonstration

Crawling motion (Our first prototype)



Bending motion



Conclusion and Future development

We have successfully developed a soft earthworm robot which is able to perform crawling and bending. With these functions, the robot is expected to function inside real human GI tract, e.g. colon. Therefore, future works involve designing real GI tract model for assessing the ability of our robot to move inside tract with contraction exhibited continuously, which is much more similar to real human GI tract.

Acknowledgement

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References

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Our project is also submitted to the EMedic Global competition and the IEEE BIOROB 2016 conference.