Peristalsis versus Lateral Undulation for Effective Locomotion in Soft Snake Robots

Callie Branyan, Lily Orth-Smith, and Yiğit Mengüç

Abstract

Snakes inspire the morphology of many robots, however, most are rigid with limitations for curvature dependent on the number of actuators. Soft actuators approximate continuum curvature and are therefore better suited for snake-like robots. This work presents two soft snake robots; one with an inextensible backbone and one with an extensible backbone to determine if peristalsis contributes effectively to locomotion on a flat/hard surface, and in a granular medium.

Each snake robot consists of a pair of fiber-reinforced actuators, that have been well documented in [1]. Each actuator has two air chambers for bi-directional bending, an elliptical cross-section to prevent rolling, and a double helical wrapping pattern to prevent twisting. The only difference between the two robots is that one has an inextensible layer between the air chambers to prevent elongation of the backbone, and one does not. Figure 1 shows the difference in curvature between the two robots actuated at the same pressure.

A serpenoid-curve gait, developed in [2], produces lateral undulation and was applied on each robot in order to compare total forward displacement. Peristalsis, a locomotion strategy used by earthworms, requires an extensible backbone so that it can stretch and pull itself along. However, snakes do not employ peristalsis and have an inextensible backbone that produces forward displacement through lateral undulation. We hypothesized that the addition of peristalsis to lateral undulation would lead to a larger displacement compared to a robot exhibiting no peristalsis.

We executed initial testing in a granular medium of both robots. Figure 2 shows the displacements of both the extensible and inextensible snake robots with a serpenoid-curve gait. Surprisingly, these results show that the inextensible robot moved further in the granular medium than its extensible counterpart. The testing on a flat/hard surface (Fig. 3) showed the same: that the inextensible snake was much better in producing forward locomotion than what was initially expected.

A potential reason for this outcome is that the mechanics of a serpenoid-curve gait are better replicated on a robot with an inextensible backbone. Lateral undulation requires the use of momentum produced by the propagation of a wave along the body to concentrate in a single direction to propel a body forward. The momentum of the extensible backbone robot is likely spread out in many directions and not providing as much force in a single direction. Future work will explore these differences and attempt to develop a gait that includes peristalsis to determine if a combination of both locomotion strategies produces better overall displacement.

References

[1] Panagiotis Polygerinos, Zheng Wang, Johannes T B Overvelde, Kevin C. Galloway, Robert J. Wood, Katia Bertoldi, and Conor J. Walsh. Modeling of Soft Fiber-Reinforced Bending Actuators. *IEEE Transactions on Robotics*, 2015.

[2] Suresh Ramasamy and Ross L. Hatton. Soap-bubble Optimization of Gaits. 2016.

Fig. 1: Inextensible (left) vs. extenmsible (right) backbone curvature at 0.02 MPa

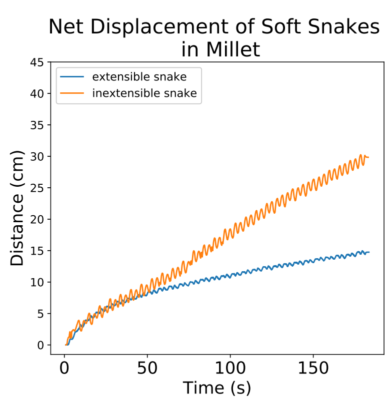

Fig. 2: Displacement in granular medium

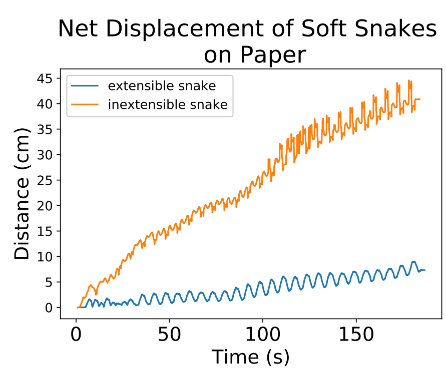

Fig. 3: Displacement on flat/hard surface