Mechanical and actuation asymmetry in soft appendages leads to robotic propulsion in granular media

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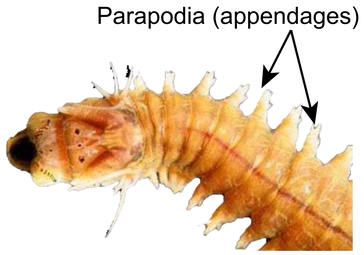
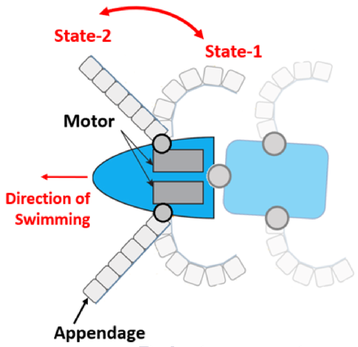
Introduction

- Soft appendage enabled granular interaction is a fundamental mode of locomotion for polychaetes or bristle worms
- Flexible appendage enabled locomotion has not been studied as well in GM as in fluids.



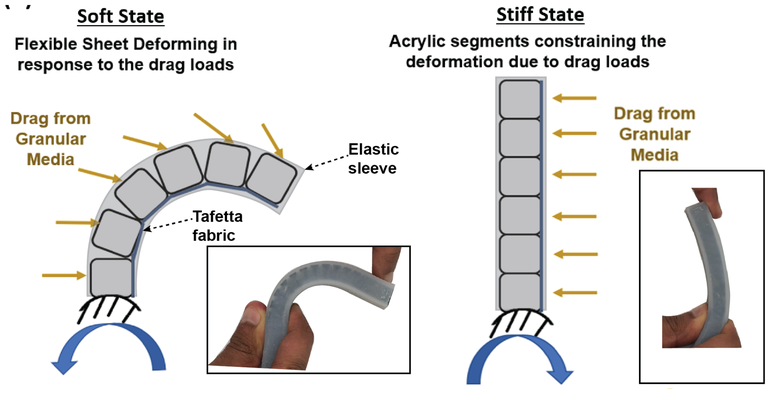
Polychaete worm



Robot concept

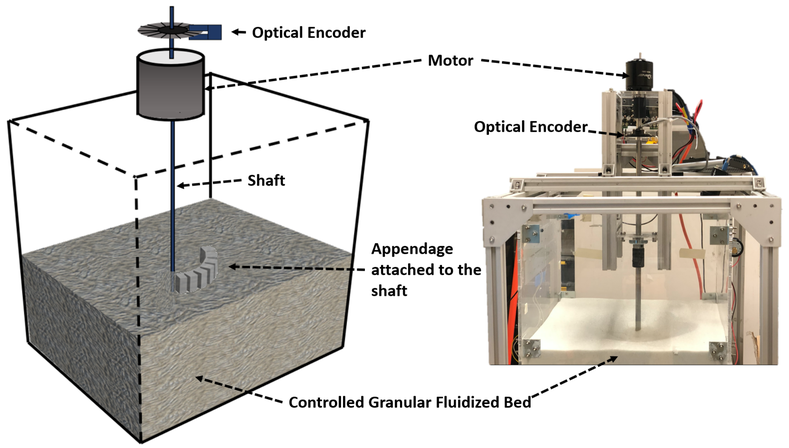
In this study,
- we designed a soft anisotropic appendage to maximize thrust
- we characterized the effect of design and actuation parameters like torque amplitude and stiffness of the appendage

Design of the appendage



- **Soft state**: drag force is minimized by bending against the direction of rotation
- **Stiff State**: acrylic segments constrain the bending in one direction which leads to anisotropic stiffness., thus maximizing the drag

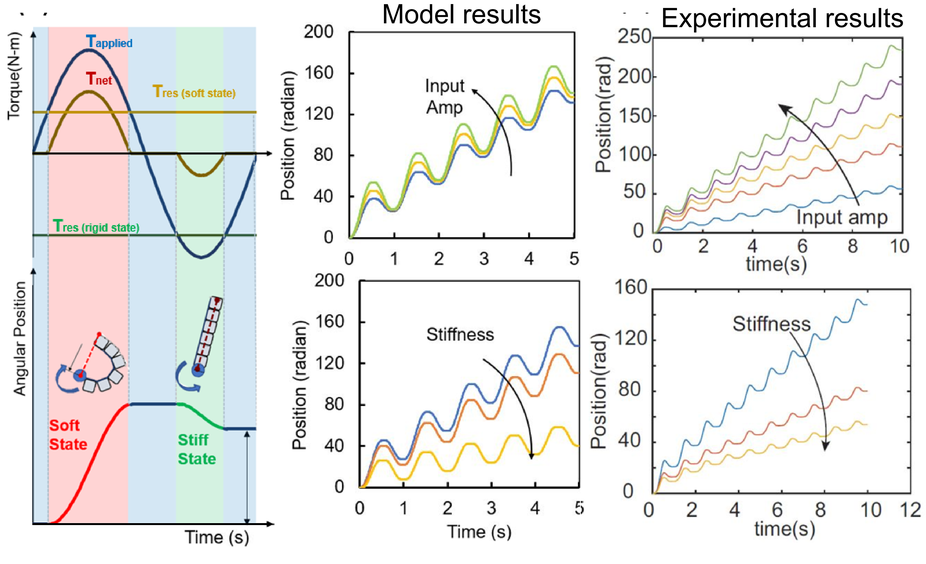
Experimental setup



Results

1) Time dependent sinusoidal torque actuation:

$$\tau = A\sin(2\pi f t)$$

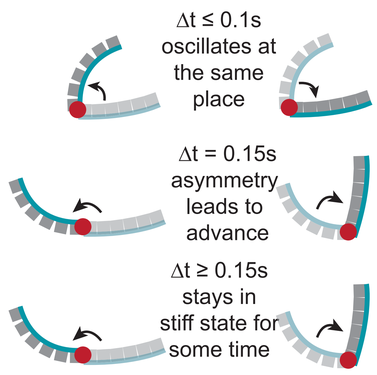


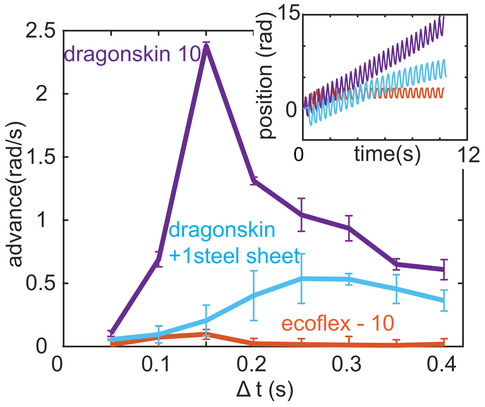
Comparison of RFT modelling results with the experiments. We tested the appendage with five input torque amplitudes. We also measured the position data for three appendages of different stiffness.

2) Time and displacement limited square-wave actuation:

$$\tau = \begin{cases} A, & \text{until } \theta = 180^\circ \text{ or } T \leq \Delta t \\ -A, & \text{otherwise} \end{cases}$$

To limit the rotation angle of the appendage to a more realitic range when considering actuation on a robot (180^0) we implemented the time and displacement dependent squarewave actuation.





Conclusion

- Increasing torque amplitude increased advance of the appendage
- Increasing stiffness of the appendage decreased advance
- Softest appendage performed the worst after limiting oscillation angle
- There is an optimum Δt for maximizing advance

Future Work

Demonstration of the appendage providing assymetric thrust on an untethered robot that can burrow and navigate in sand.

Acknowledgments

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