Learning a curvature dynamic model of an octopus-inspired soft robot arm using flexure sensors

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OCTOPUS Inspired Soft-robot arms

Soft robot arm consisting of tendons embedded in silicone is inspired by the body properties and muscle structure of the natural octopus .

Some Open Challenges:

How to achieve planning and control of the infinite degree of freedom system?

How can we model their dynamics?

How can we sense the state of the robot's body?

What is an appropriate frame of reference in which to control?

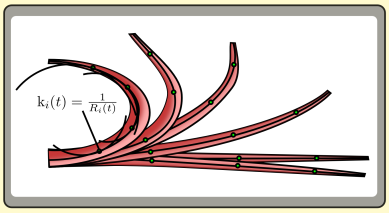
How can we exploit the passive properties of the body in the best manner?

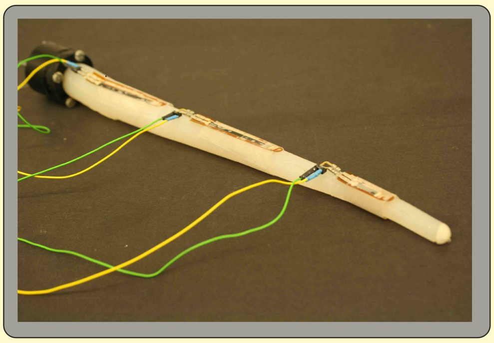
How can we develop a control scheme inspired by the natural octopus?

Continuum robotics is a challenging area of research. Soft-continuum robots - continously bending (infinite DoF), acutation embedded throughout arm.
Some problems are modeling of the dynamics, techniques for sensing, identifying appropriate frames of reference for sensing and control.
Can flexure sensing - a direct measure of local behaviour be exploited for both sensing and learning body dynamics for an octopus inspired soft robot arm?

What is Curvature and how can it be measured?

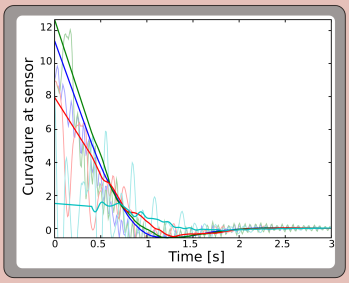
A Frenet-Serret coordinate frame can be used to describe a continuum robot arm consisting of a vector T tangent to the curve, a vector N normal to the curve, and a binormal vector B to complete the frame. For a plane curve, B=0 and the curvature k is defined on the radius of the resulting arc (shown to the right).





Advantages of measuring curvature:
1. Piecewise constant curvature assumption means that it can be measured at discrete locations along an arm.
2. It is a "situated measurement" : the value is independent of frame of reference.
3. Can be measured directly through flexure sensors such as those by Flexpoint Inc. (shown to the left) .

Simulated Curvature Dynamics



- A **simplified model** of a continuum structure in water : Dynamics may not reflect reality due to *simplicity*.

- Simulated measurement of curvature obtained at **finite set positions** along the arm (flexure sensors).

- To approximate the dynamics of real sensor readings (to be validated), **high frequency components** are filtered from the simulated data (shown to the left).

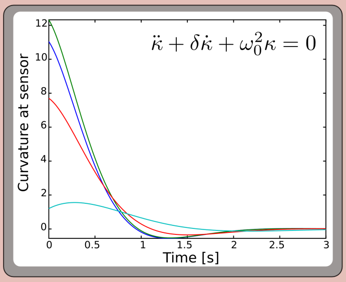
- To this filtered data, we fit different models to capture the **coupling between the sensors**. This coupling is given by the **mechanical properties** of the arm (shown below).

Ongoing Work :
Validation of these models with experimental data.

If a good model can be obtained :

- The model will be used to calculate the actuation (bending moments) required at the sensor positions, to achieve certain curvature trajectory.

- We can then apply this results to our arm simulation and verify its effectiveness.



Future Work

- Design actuators (from Input signal to bending moments)
- Identify Optimal sensor/actuator distribution in terms of trajectory tracking error.
- Potentially test biological control hypothesis (after full validation)

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