Project Proposal: Soft Robotic Fish via Beam Model

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I. Problem and Motivation

Soft robotic fishes are important in terms of underwater exploration. Although rigid propellers have been widely used nowadays, they generate unwanted noises and turbulent flow. However, flexible robotic fish can adapt to the fluid forces, providing a safer and quieter actuation. However, the complex relationship between the stiffness, actuation frequency, and effectiveness has been an unsolved problem. This project focuses on modeling the robotic fish as a flexible node-spring network to simulate how different key parameters affect the bending behavior.

II. Background and Literature Review

Katzshman et al. (2018) brought up the idea of robotic fish 'SoFi. In the paper, he demonstrated a modeling of underwater exploration using different materials and finite element analysis. Esposito et al. (2012), on the other hand, focused on the study of stiffness and actuation of the soft robot fins. They have revealed a strong relationship between stiffness and thrust effectiveness. In one of the recent papers by Zhong et al. (2021), the team has shown that swimming efficiency highly depends on stiffness of the material by applying tunable stiffness.

These prior works have implemented complex analysis/ modeling of the soft fin behaviors. They have utilized different sophisticated frameworks such as fluid-structure interaction, computational fluid mechanics, etc. The scope of this project is simpler than the papers above. This project will use a Euler-Bernoulli beam model where the soft robotic fish would be discretized into a node-sprint network to model the bending behavior of the fish.

III. Propose Approach

This project models the soft robotic fish as a classic Euler-Bernoulli beam with bending stiffness. Actuation will be represented by a time-varying curvature instead of a distributed load. These replicates bending similar to an actual fish. Like the previous homework, The beam will be modeled as a discretized spring-node network. The integration would be implicit Euler method. There are several key parameters including frequency, amplitude, stiffness. The bending pattern and motion would be reproduced.

IV. Expected Contribution

The goal of this project is to provide a straightforward, lightweight model of a soft robotic fish. Key parameters such as stiffness and actuation variables would be studied to reproduce the motion. With contents from M263F, this project will focus on using Euler-Bernoulli, implicit Euler and analysis of bending and stretching energy instead of full fluid computation requirement.

References

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