UCLA Samueli
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MAE 263F Project Proposal: Snakes in Viscous Fluids

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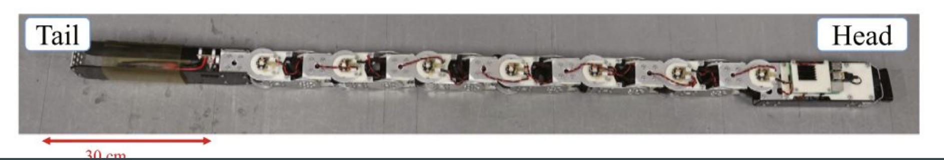
Introduction

Goal: develop an analytical approach to optimizing snake-like motion in viscous fluid

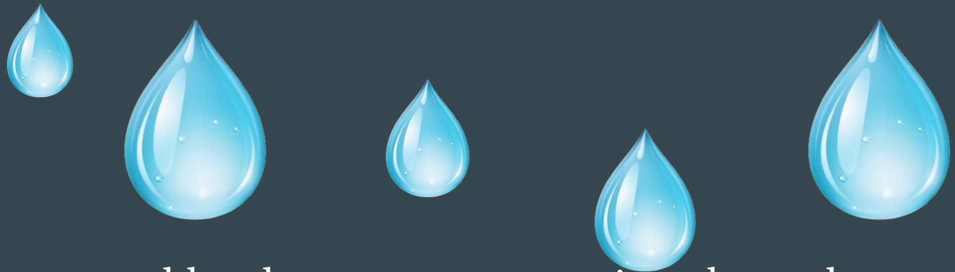
- Exploration of untraditional terrains
  - Mud, clay, etc.
- Efficiency
- Types of snake motions (undulation)
  - Pushing against surfaces



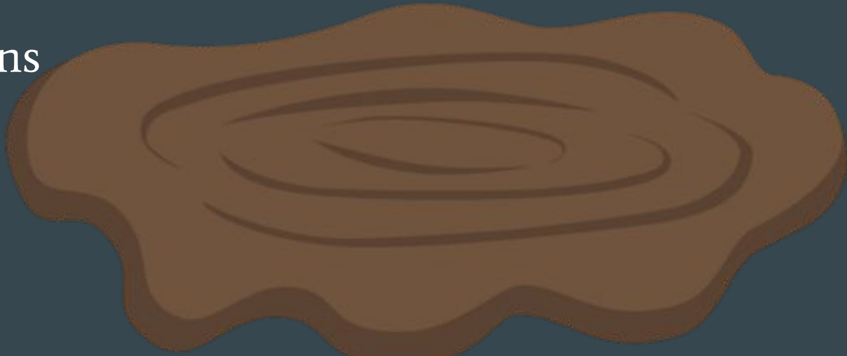
Source: Optimal swimming locomotion of snake-like robot in viscous fluids

Source: https://www.galerie.pierrewildlife.com/main.php?g2_itemId=124330

Objectives

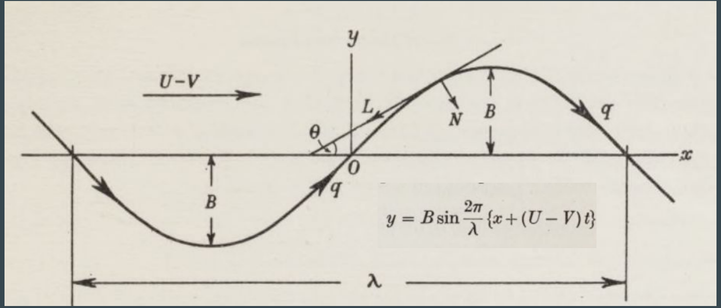


- Equations of motion for a snake are impacted by the wave propagation through the body
  - Thrust
  - Drag
  - Inertia
- Verification convergence of spatial refinement (8 nodes…?)
- Optimal motion and velocity in viscous fluids
  - Water
  - Honey
- Compare methods/results to existing solutions

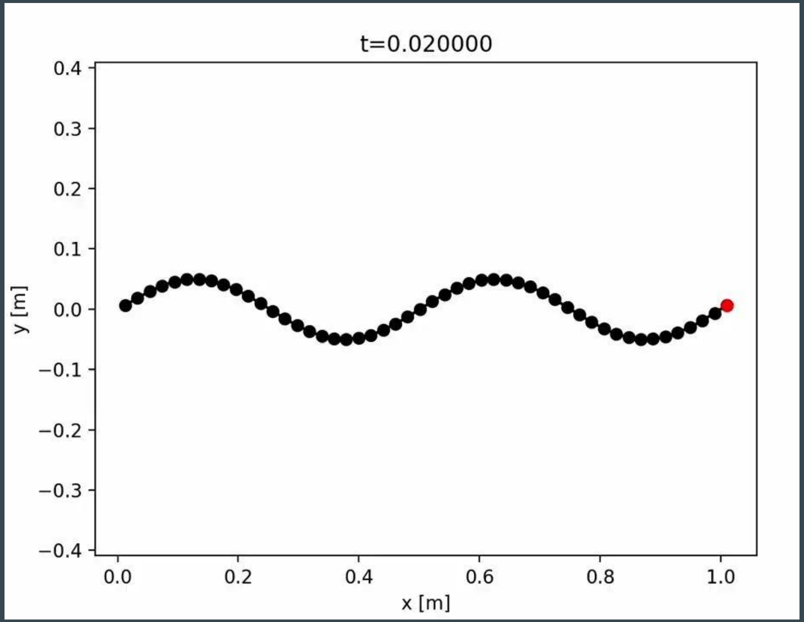


Kinematics of Undulating Motion

- Wave function idealization used to illustrate the mechanism of motion
- Body is subject additional viscous forces.
  - Damping (1st order)
  - Drag (2nd order)
  - Thrust (2nd order)
- Physical analogs for model
  - Tangential drag coefficient - roughness
  - Normal drag coefficient - shape
  - Body segment - backbone flexibility
- Assumptions:
  - 2D motion only
  - Truss-like structure (high flexural compliance)
  - Static environment (no fluid flow)
  - Buoyant force equilibrium with gravity



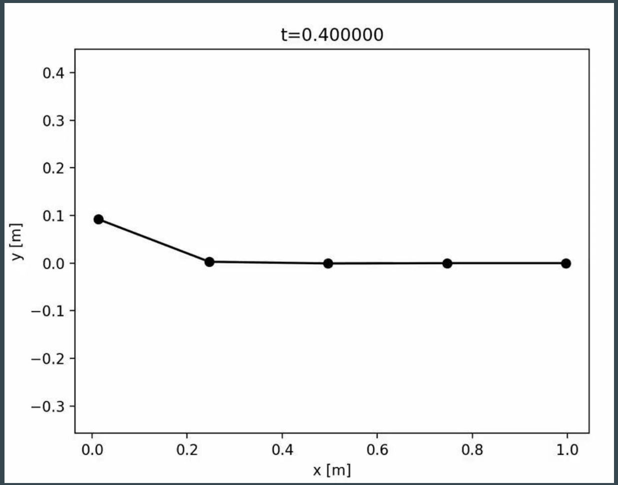
Idealization of fluid-structure interaction[6]



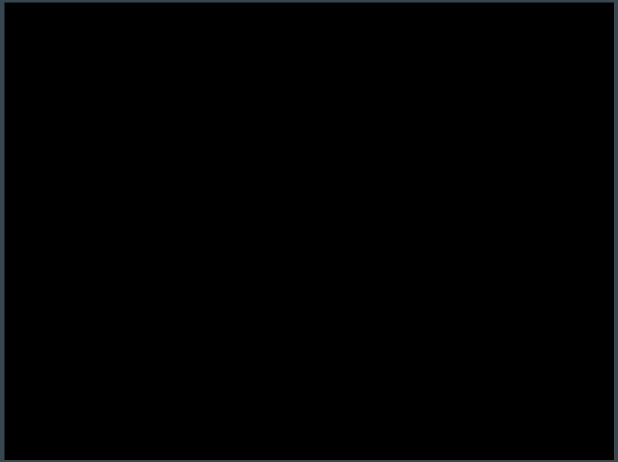
Thrust generated from body wave results in a net forward thrust.

Challenges

- Incorporating thrust and drag into equation of motion
- Representing transient response of body to single node actuation
- Defining actuation strategy and design
  - Nodal periodic torquing
  - Nodal transverse actuation
- Designing for joint stiffness and flexibility that allows for stable motion
  - Low flexural rigidity makes the design highly sensitive to spatial refinement (i.e. # of nodes)
  - Drag and inertial will contribute to segmental stretching
  - Strategy for avoiding dynamic instability will depend on the system
- Optimizing for speed, energy efficiency, and stability



Dynamic instability


Dynamics can be tuned based on nodal refinement/coarsening

Citations

A. Yamano, K. Shimizu, M. Chiba, H. Ijima, Fluid force identification acting on snake-like robots swimming in viscous fluids, Journal of Fluids and Structures, Volume 106, 2021, 103351, ISSN 0889-9746, https://doi.org/10.1016/j.jfluidstructs.2021.103351

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