263F PROJECT PROPOSAL

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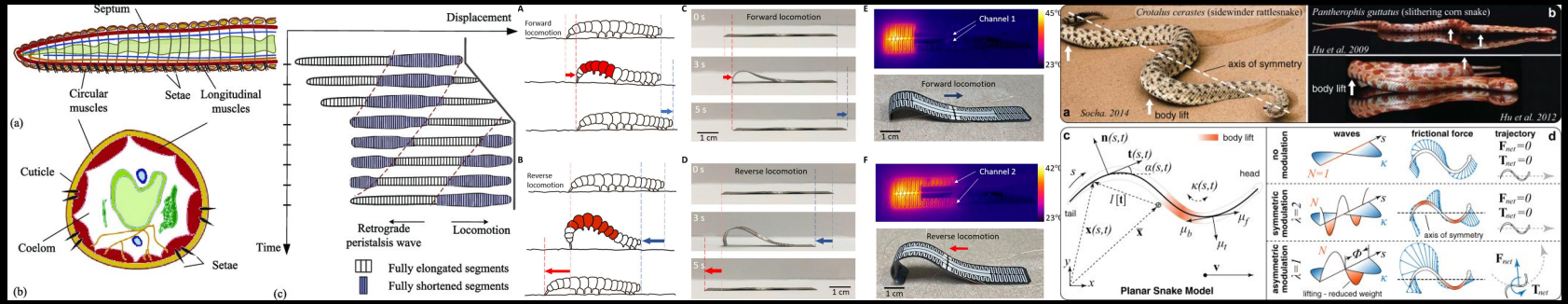
Worm Simulation

Objective: High-fidelity soft-body simulation of a worm-like robot

- Replicate biologically inspired locomotion patterns (peristaltic crawling, lateral undulation, and inching), to study forward locomotion.
- Simulate interactions with the environment: frictional contact with surroundings, to evaluate ability in different terrains.



Peristaltic crawling Inching Lateral Undulation

Worm Simulation

Goals

- Evaluate performance metrics: displacement per cycle, metabolic rate, robustness to perturbations, and control responsiveness
  - Control policies
    - segmented contraction, wave-based open-loop control, and feedback-based control
  - Actuation strategies (that control policy seeks to mimic, and also potentially informs material characteristics of the model)
    - pneumatic/hydraulic chamber actuation
    - heating element/thermal expansion
    - dielectric elastomer actuators
  - Material properties: Effects of body compliance/stiffness distribution on locomotion efficiency, maneuverability, and stability, identifying design parameters that optimize performance.

Worm Simulation

Model Progression

- Start with 2D planar soft-worm model viewed from the side
  - (discrete segment approach)
  - Actuation/Deformation pattern → forward motion
    - Segment length modulation
  - Ground friction (time-varying friction anchors)
  - Nonlinear material behavior energy add on

Consider a 3-segment worm (S1 head, S2 middle, S3 tail):

1. **Phase 1: Head contracts**
   - S1 contracts, pulls S2 and S3 toward it.
   - **Tail anchored:** friction high → doesn't slide.
   - Result: middle segment moves forward relative to tail.
2. **Phase 2: Head expands, middle contracts**
   - S1 expands → slides forward (low friction).
   - S2 contracts → pulls S3 forward.
     Tail remains anchored.
3. **Phase 3: Wave propagates down the body**
   - Each segment alternates contraction/expansion, sequentially pulling the body forward.

Worm Simulation

Model Progression

- 3d deformable body + 3d deformation pattern
  - Nonlinear Soft-Body Mechanics
  - Directional friction
- Implement control strategy + performance measuring framework
  - Changing speed of contraction
  - Pathing with directed contraction patterns.

References

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