BTP Progress Log: Microswimmer Bimotility Simulation

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Week 1: Project Initiation & Literature Review

Interval: December 15, 2025 – December 21, 2025

- **Paper Analysis:** Reviewed "Self-organization in a bimotility mixture of model microswimmers" by Adyant Agrawal and Sujin B. Babu[cite: 3, 4].
- **Model Definition:** Identified the Taylor line as a discretized model of the Taylor sheet for microswimmer simulation[cite: 20, 36].
- **Research Objective:** To study cooperation and segregation in mixtures differing in propulsion speed[cite: 8, 32].
- **Task Distribution:**
  - **Partner A:** Environment physics (Circular boundary and Steric interactions).
  - **Partner B:** Swimmer internals (Chain physics and Propulsion engine).

Week 2: Implementation of Dry Simulation

Interval: December 22, 2025 – December 28, 2025

Partner A: Boundary & Steric Interaction

- **Confinement Logic:** Implemented rigid circular boundary conditions as per paper specifications[cite: 49, 169].
- **Reflection Algorithm:** Coded velocity reflection along the normal vector for bead-boundary collisions.
- **Steric Force:** Implemented the truncated Lennard-Jones potential[cite: 62, 63]:

$$V_l = 4\epsilon \left[\left(\frac{r_o}{r}\right)^{12} - \left(\frac{r_o}{r}\right)^{6} \right] \text{ for } r < 2^{1/6} r_o$$

- **Interaction Parameters:** Set $\epsilon = 13.75$ and $r_o = a_0$ to model swimmer-swimmer repulsion[cite: 66].

Partner B: Taylor Line Internal Physics

- **Swimmer Representation:** Each swimmer is modeled as a discretized Taylor line composed of beads connected in sequence, capturing undulatory microswimmer motion at low Reynolds number.
- **Elastic Spring Forces:** Neighboring beads interact via Hookean springs

$$\mathbf{F}_s = k_s(r - l_0)\hat{\mathbf{r}}$$

ensuring inextensibility and structural integrity of the swimmer.

- **Active Bending Mechanism:** A traveling sinusoidal curvature wave is imposed along the body to generate propulsion, given by

$$c(i,t) = b\sin\left[2\pi\left(\nu t + \frac{2i}{N}\right) + \phi\right]$$

- **Bending Force Formulation:** Discrete curvature

$$\mathbf{C}_i = \mathbf{r}_{i+1} - 2\mathbf{r}_i + \mathbf{r}_{i-1}$$

  produces bending forces

$$\mathbf{F}_b = \kappa\, c(i,t)\, \mathbf{C}_i$$

- **Overdamped Dynamics:** Bead motion follows viscous-dominated dynamics

$$\gamma \mathbf{v}_i = \mathbf{F}_i, \quad \mathbf{r}_i(t+\Delta t) = \mathbf{r}_i(t) + \mathbf{v}_i \Delta t$$

- **Outcome:** The implemented internal physics yields smooth, force-free, self-propelled Taylor-line swimmers consistent with theoretical and experimental microswimmer models.