Tracking and Analysis of the Motion of Ciliated Microswimmers

Amália B. Garcez[1], **Luiza Mossi**[1], **Bernardo Boattini**[1], **Roger Madena**[2], **Leonardo Brunnet**[1], **Alexandre Arenzon**[2] **and Carolina Brito**[1]

[1] *Institute of Physics, Universidade Federal do Rio Grande do Sul (UFRGS)*
[2] *Institute of Biology, Universidade Federal do Rio Grande do Sul (UFRGS)*

In this project, we investigate the motion of *Paramecia*, a unicellular ciliated protozoan, with the goal of characterizing its dynamic behavior. These microorganisms exhibit mobility driven by both physical and biological factors [1]. Additionally, given their role as fish food and their sensitivity to environmental changes, *Paramecia* may serve as effective bioindicators of water quality [2]. The main objectives of this project are to model their dynamics to understand fundamental statistical properties of these active agents and to explore how their motion patterns may reflect responses to environmental stressors, bridging basic research in active matter with practical applications in ecological monitoring.

In the initial phase of the study, we focused on low-density experimental setups and developed a method to detect and track individual *Paramecia* in video recordings. To streamline this process, we trained an artificial intelligence (AI) model capable of identifying and following *Paramecium* trajectories. The model demonstrated strong performance in 2D, low-density environments, allowing us to analyze trajectories of 1–5 individuals at a time.

Partial results presented in this talk include statistical analyses of single-*Paramecium* dynamics in a normal medium, as well as in the presence of a fish-toxic substance. We also briefly present recent developments for high-density environments, which pose additional challenges such as noise and interference from debris. These are being addressed through the implementation of an improved tracking algorithm. Preliminary results indicate a generally persistent motion pattern, occasionally interrupted by bursts of erratic behavior, which merit further investigation.

Looking ahead, we plan to explore whether *Paramecium* populations exhibit collective behavior or phase transitions, which would offer insights into emergent phenomena within active systems.

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[2] A. P. Shunmugam, G. Subramanian, and J. G. Fernandez. Measurements of the swimming speeds of motile microorganisms using object tracking and their correlation with water pollution and rheology levels. Scientific Reports, **11**:11821, (2021).