A Machine Learning Approach to Classify Microswimmers

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Background Biological and artificial microswimmers swim using various strategies. For example, bacteria *E. coli* swim by rotating a helical tail bundle at the back of the cell, algae cell *Chlamydomonas* swim by whipping two flagella in a breaststroke fashion, ciliated eukaryotic cell Paramecium swim by orchestrating the cilia carpet on the cell surface in a wave fashion. Despite the difference in the detailed locomotion strategies, if we take a step back and investigate where the activations (driving forces) concentrate, they can be classified into three main groups of microswimmers: *pushers* (activation in the back), *pullers* (activation in the front), and *neutral swimmers* (activation uniformly distributed). For a given axisymmetric shape, efficient numerical algorithms exist to optimize the slip velocity on the swimmer surface to maximize the swimming efficiency, and subsequently classify the microswimmers.

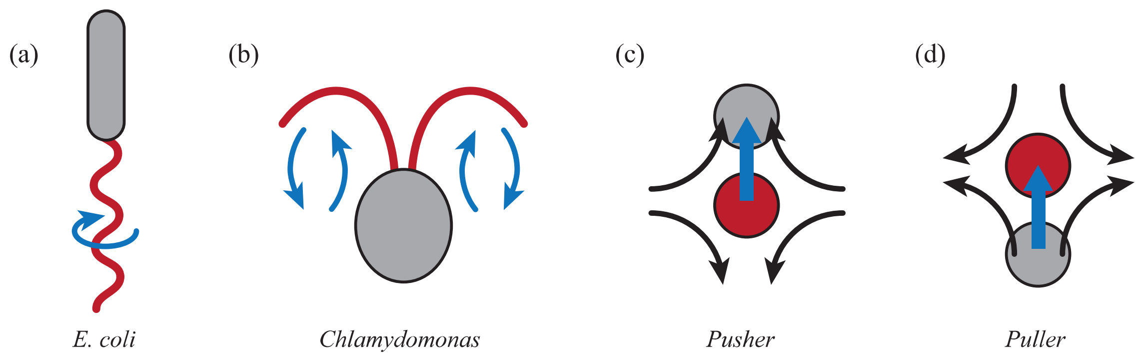

Figure 1: Examples of pusher and puller. Cartoons showing the swimming mechanisms of *E. coli* (a) and *Chlamydomonas* (b) and their reduced-order swimming types *pushers* (c) and *pullers* (d) respectively. The cell body (passive part) are depicted in grey and the flagella (active part) are depicted in red. The flagellar motion is denoted by the blue arrows.

Goals In this project, we will build a machine learning framework (most likely an artificial neural network) to classify the optimal microswimmers for a given shape, <u>without</u> actually optimizing them. In other words, we are trying to classify the optimal microswimmers based solely on their shapes. The more challenging second goal is to understand the classification results provided by the machine learning algorithm. That is, we want the machine learning algorithm to be interpretable to inform future design of microswimmers.

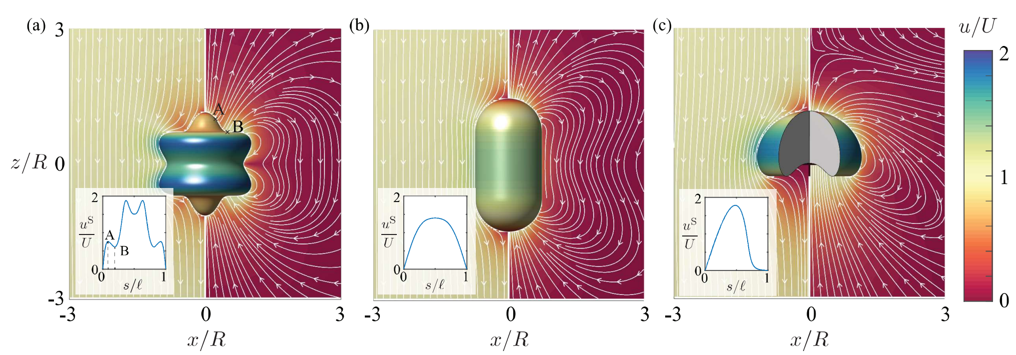

Figure 2: Optimal slip velocities of microswimmers with different shapes. (Adapted from [HG et al. JFM (2021)])

Prerequisite Linear algebra (Math 214 or equivalent) and Multivariable Calculus (Math 215 or equivalent). Coding experience (Python, Matlab) will always help.