Beyond the *push-me-pull-you*: computing optimal strokes for complex microswimmers using reduced order models

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There has recently been significant progress in developing robotic systems for healthcare, focusing on minimal invasiveness. This trend includes the creation of microrobots for medical interventions and targeted drug delivery, with promising applications in biomedicine and bioengineering. Microscopic swimmers operate at low Reynolds numbers, where inertial forces are negligible, requiring them to use non-intuitive periodic shape changes, known as *strokes*, to achieve propulsion. Identifying optimal swimming strategies in this regime is essential for designing effective artificial microswimmers.

Inspired by the Euglenoid movement, the so-called *push-me-pull-you* microswimmer [2], consisting of two spheres of varying volume and separation, mimics its natural shape and motion. Its geometry is described by a set of parameters, so the optimal strokes are given by the time-evolution of such parameters. The dynamics of the microswimmer are governed by the Stokes equations, and quasi-analytical methods are used to approximate its solution [1]. We propose a generalization of this microswimmer by considering ellipsoids instead of spheres. This results in a larger parametric space with more degrees of freedom that more accurately resembles the shape of the Euglenoid. However, for the ellipsoidal case, no quasi-analytical techniques are available. To overcome this limitation, the Encapsulated Proper Generalized Decomposition [3] is employed to build a parametric surrogate model of the forces involved, allowing for a real-time evaluation.

The strokes that minimize the energy expended by the microswimmer are obtained by solving the associated Euler-Lagrange equations using the surrogate model, which allows a fast and broader exploration of the parametric space. The results show that this modified microswimmer achieves better energetic efficiencies compared to the spherical model.

References

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