

Internship on the locomotion optimization for micro-swimmers using machine learning

Keywords : Stokes equations, Fluid-structure Interaction, Statistical learning, Meta-modeling, Model order reduction, Micro-swimming.

Practical aspects : The internship will take place both at Institut de recherche mathématique avancée, Université de Strasbourg, and INRIA, Sophia-Antipolis within the team CALISTO.

It covers a period of 6-7 months, from March-April to August-September. The exact date of departure is quite flexible and can be adapted to the constraints of the student. This work could result in a grant for a PhD thesis.

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Subject : The internship will focus on studying the motion of micro-swimmers immersed in a fluid. The aim of the intership is optimizing the displacement of micro-swimmers using statistical learning tools, coupled with a reduced order model of the swimming problem. Numerical simulations will be performed using the open source finite element library *Feel++*¹ [2].

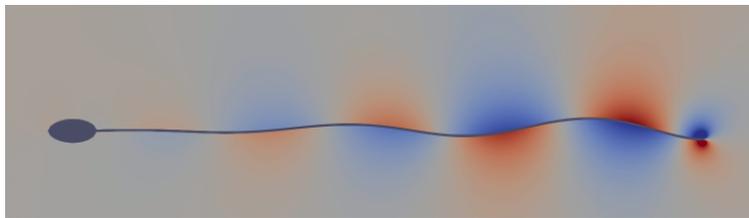


Figure 1: Simulation of a model of a sperm cell using *Feel++*.

¹<http://www.feelpp.org>

At this length scale, locomotion presents a different set of challenges compared with those encountered by macroscopic robots. Most microorganisms live in fluid environments where they experience a viscous force that is many orders of magnitude stronger than inertial forces. This is known as the low Reynolds number regime, and it is characterized by instantaneous and time-reversible flows that are described by the time-independent Stokes equations. The internship focuses on flagellated micro-swimmers which self-propel by beating their flagellum, as a sperm cell (see Fig. 1). The aim is to find the best periodic deformation which allows the swimmer to move by minimizing a certain cost (energy or speed). The results could explain the displacement of real spermatozoa and also could help to build a bio-inspired magnetic micro-robot [1, 4].

The novelty is to use learning techniques coupled with an accurate PDE-based system to optimize the swimmer's deformation strategy. The student is encouraged to write a publication at the end of the training period. The student could also compare his/her results with others approaches [1]. The internship allows the student to study machine learning techniques with model order reduction for expensive dynamical systems.

Candidate : He/She should have a background in applied mathematics (PDEs, Numerical methods, Numerical simulations, Statistical learning, Optimization). Students are encouraged to write a publication at the end of the training period. We strongly encourage motivated students to continue on a PhD thesis.

References :

- [1] Y. El Alaoui-Faris, J.-B. Pomet, S. Régner, L. Giraldi. Optimal actuation of flagellar magnetic microswimmers *Phys. Rev. E*, 2020.
- [2] L. Berti, V. Chabannes, L. Giraldi, C. Prud'Homme. Modeling and finite element simulation of multi-sphere swimmers *hal-03023318*, 2020.
- [3] V Chabannes, G Pena, C Prud'Homme. High-order fluid-structure interaction in 2D and 3D application to blood flow in arteries *Journal of Computational and Applied Mathematics* 246, 1-9, 2013.
- [4] R. Dreyfus, J. Baudry, M. L. Roper, M. Fermigier, H. A. Stone, and J. Bibette. Microscopic artificial swimmers. *Nature*, 437: 862–865, 2005.