Online workshop

Understanding locomotion: Nature-inspired mathematical models

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David Hockney - Portait of an Artist (Pool with Two Figures)

Schedule and abstracts

Organizers

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Schedule

(Times are in CET time zone. For Eastern Standard Time, subtract 6 hours.)

3:00pm–3:10pm *welcome remarks*

3:10pm–4:10pm Jerôme Lohéac: *Controllability of low Reynolds numbers swimmers of ciliate type*

In this talk, I will study the locomotion of a ciliated microorganism in a viscous incompressible fluid. The Blake ciliated model will be used. That is to say that the swimmer is a rigid body with tangential displacements at its boundary that allow it to propel in a Stokes fluid. This can be seen as a control problem: using periodical displacements, is it possible to reach a given position and a given orientation? I will show that when the dimension d of the space of controls is greater than 2, we have controllability, generically with respect to the shape of the swimmer and with respect to the vector fields generating the tangential displacements. The proof is based on analyticity results and on the study of the particular case of spheroidal swimmer. This work has been done in collaboration with Takéo Takahashi.

4:10pm–5:10pm Laetitia Giraldi: *Navigation of flagellated micro-swimmers*

Robotic micro-swimmers may have an impact in promising treatment and diagnosis in medicine. However, efficient actuation of these robots face numerous challenges. Hence, wireless actuation is preferable over built-in actuation sources. For example, one popular strategy is the magnetization of parts of the swimmer and its actuation with an external magnetic field. In the following study, we focus on flexible magnetic micro-swimmers that are similar to spermatozoa in their design and flagellar propulsion. A simple numerical model is provided in order to set an automated procedure for the design of optimal actuation for flagellar magnetic microswimmers based on numerical optimization. The numerical results are experimentally validated on a scaled-up flexible magnetic swimmer. More accurate simulations using Finite Element methods with an arbitrary Lagrangian framework (see Feel++ software) are discussed.

5:10pm–5:30pm *break*

5:30pm–6:30pm Daniele Agostinelli: *Peristaltic Waves as Optimal Gaits in Metameric Bio-Inspired Robots*

Peristalsis, i.e., a motion pattern arising from the propagation of muscle contraction and expansion waves along the body, is a common locomotion strategy for limbless animals. Mimicking peristalsis in bio-inspired robots has attracted considerable attention in the literature. It has recently been observed that maximal velocity in a metameric earthworm-like robot is achieved by actuating the segments using a "phase coordination" principle. In this talk we will see the main result we achieved, i.e., in fact, peristalsis (which requires not only phase coordination, but also that all segments oscillate at same frequency and amplitude) emerges from optimization principles. More precisely, basing our analysis on the assumption of small deformations, we show that peristaltic waves provide the optimal actuation solution in the ideal case of a periodic infinite system, and that this is approximately true, modulo edge effects, for the real, finite length system.

6:30pm–7:30pm Silas Alben: *Optimizing snake locomotion*

Snakes propel themselves by a variety of gaits such as slithering and sidewinding. We use a model to determine which planar snake motions are optimal for efficiency. With large friction transverse to the snake, the optimal motion is a retrograde traveling wave with amplitude scaling as the friction coefficient the $-1/4$ power. With zero transverse friction, a triangular direct wave is optimal. Between these extremes we find a variety of local optima including standing waves (or ratcheting motions).

Snakes' bodies are covered in scales that make friction anisotropic, and allow for sliding locomotion with an undulatory gait, for example. Isotropic friction is a simpler situation (that arises with snake robots, for example) but is less understood. We compute time-harmonic motions of three-link bodies and find that local optima for efficiency involve static friction to some extent. We then propose a class of smooth body motions that can achieve optimal efficiency for both isotropic and anisotropic friction.

7:30pm–7:35pm *closing remarks*