Modelling and simulation
of slender locomotors in environments with memory effect

PhD thesis in applied mathematics and robotics

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Context. Over the last twenty years or so, robotics has drawn inspiration from animal locomotion to produce a new generation of autonomous, self-propelled systems that are more maneuverable and compact. Examples include snake robots deployed for rescue operations in rubble or medical micro-robots for targeted drug delivery [1]. These robots generally move in complex environments with physical properties halfway between fluid and solid (sand, tissue or biological fluids). Modeling these robots in complex rheologies is a major challenge in robotics, requiring fast algorithms for real-time control. The main challenge is to model the memory effect induced by the viscoelastic properties of the medium [2]. The most promising way forward is to produce reduced models of interactions with these media, dedicated to the generation of control laws for robot locomotion.

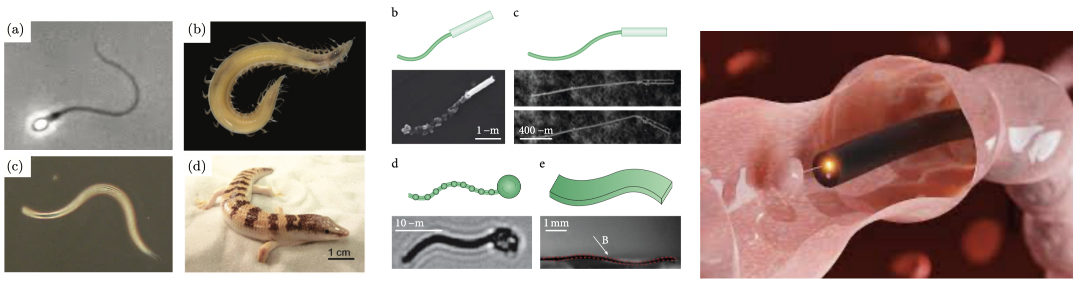

Figure 1: Left: examples of slender locomotors in complex environments. Center: examples of swimming micro-robots. Right: artist's view of a medical micro-robot.

Problem statement. In this thesis, we aim to produce new reduced models of fluid-robot interactions in memory-effect environments such as viscoelastic fluids, with the aim of designing control laws for slender robots.

Proposed research program. Based on existing models of locomotion at low Reynolds numbers, we first describe the interaction between a locomotor and a viscoelastic fluid using direct simulation data. Secondly, control laws based on these models will be proposed to ensure efficient locomotion of slender robots. This work will be based on the following methodology:

1. Production of a finite element simulator for fluid-structure interactions between the robot and a viscoelastic fluid (Maxwell or Oldroyd-B model) [3].

2. Force modeling based on these simulations. The aim is to produce extensions of mobility matrices at low Reynolds numbers, taking into account the memory effect associated with the fluid.

3. Development of internal motor activation laws for the locomotor in open or closed loops. These will be inspired by bio-inspired laws based on sensory feedback [4].

Application. Interested candidates are invited to submit their CV, cover letter and letters of recommendation to clement.moreau@cnrs.fr and johann.herault@imt-atlantique.fr.

References

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[4] Ishimoto, K., Moreau, C., & Herault, J. (2024). *Robust undulatory locomotion via neuromechanical adjustments in a dissipative medium.* arXiv preprint *arXiv:2405.01802.*