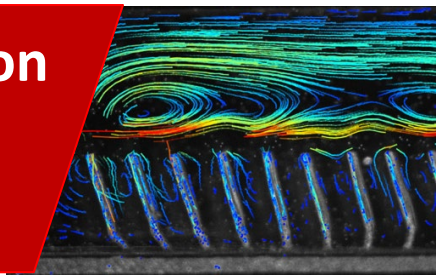
Development of a COMSOL simulation model on micro-swimming robots



Master thesis project

Introduction

Micro-swimming robots have gathered considerable attention in recent years due to their potential applications in healthcare, environmental monitoring, and industrial processes. These robots, which typically range from tens to hundreds of micrometers in size, display intricate swimming behavior influenced by factors such as fluid dynamics, material properties, and the environment. Simulations provide a cost-effective and efficient means to explore diverse design configurations, reducing the need for extensive experimental testing. By utilizing the simulation model, we can identify and optimize design parameters that have a significant impact on the performance of micro-swimmers, leading to the development of more efficient and dependable robots. Furthermore, the simulation model offers valuable insights into the underlying mechanisms governing the swimming behavior of micro-robots, facilitating the exploration of novel propulsion techniques.

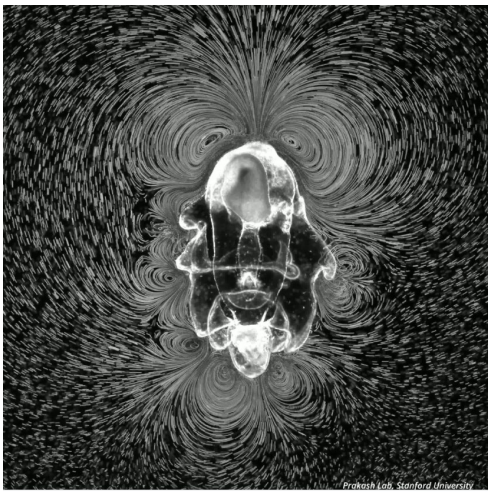


Figure 1 Bat star larvae generate complex arrays of vortices

Project

This project will focus on microswimmers based on magnetic artificial cilia. The Microsystems group has developed various magnetic artificial cilia ranging from tilted conical motion to metachronal motion mimicking the biological cilia. Fig. 1 shows the vortex structures created by a microorganism. Fig. 2 is a magnetic artificial cilia system that can generate vortex structures similar to biological cilia and can create net flow for propulsion. A COMSOL simulation model has been developed for the study of this system, which is a fully-coupled Multiphysics model containing magnetic field, solid mechanics and fluid mechanics. The student will first modify this model using the automatic remeshing function to develop a new model for the study of microswimmers. Then, the model will be used to design and study microswimmers. The design would range from single-cilia system to multi-cilia system. Various propulsion mechanisms will be discussed and finally, an optimized design of the microswimmer would be proposed.

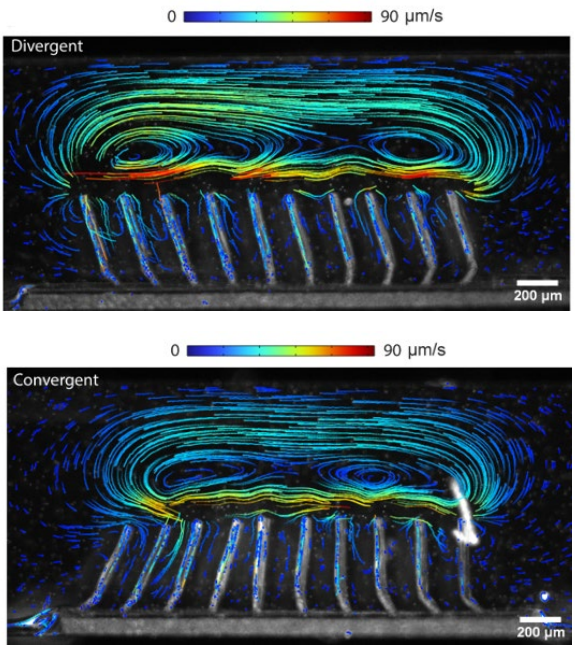


Figure 2 Vortex structures created by magnetic artificial cilia

[1] Gilpin, W., Prakash, V. N., & Prakash, M. (2017). Vortex arrays and ciliary tangles underlie the feeding–swimming trade-off in starfish larvae. Nature Physics, 13(4), 380-386.
[2] ul Islam, T., Wang, Y., Aggarwal, I., Cui, Z., Amirabadi, H. E., Garg, H., ... & den Toonder, J. M. (2022). Microscopic artificial cilia–a review. Lab on a Chip, 22(9), 1650-1679.

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