Project: Smart three-sphere swimmer near a wall

1. Description of the project

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Swimming at low Reynolds number

Reynolds number

$$Re = \frac{Inertia}{Viscosity} \propto \frac{\rho L^3 U}{\mu L^2}$$

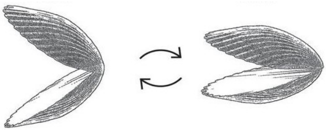
ρ: Density L: Length
μ: Viscosity U: Speed

Swimming at low Reynolds number

Reynolds number

$$Re = \frac{\rho L U}{\mu} \approx 10^{-4} \text{ (for a sperm cell)}$$

ρ: Density L: Length
μ: Viscosity U: Speed



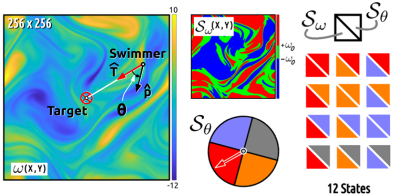
Source: Nat Commun 5, 5119 (2014)

Figure: Scallop Theorem

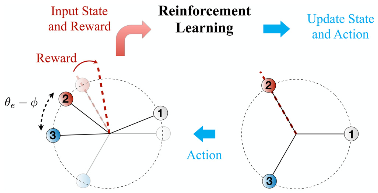
Fluid equations: Stokes equations

$$-\nabla p + \mu \Delta u = 0$$
$$\nabla \cdot u = 0$$

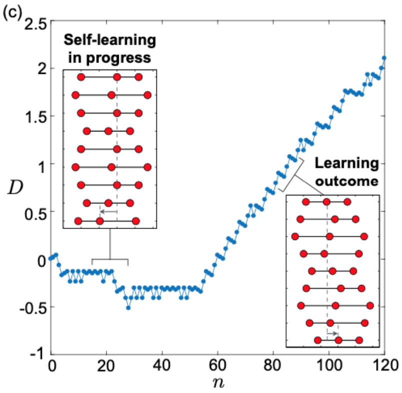
Micro-swimming and reinforcement learning: a recent encounter



Alageshan et al. (2019)

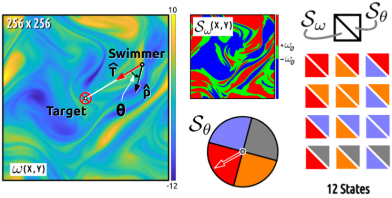


Liu et al. (2021)



Tsang et al. (2020)

Micro-swimming and reinforcement learning: a recent encounter



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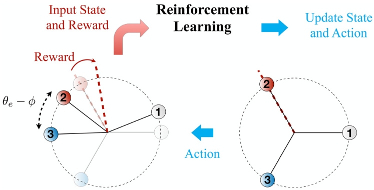

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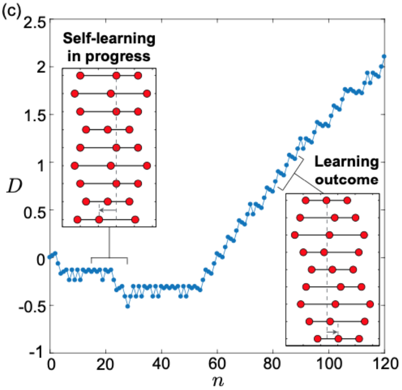

Tsang et al. (2020)
We could reproduce the results of Tsang during a master thesis internship this summer.

Roadmap

1. Understanding Reinforcement learning for the case of a three-sphere swimmer far from walls

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2. Model the problem of three-sphere swimmer/wall in terms of state, actions and reward
3. Choose the appropriate reinforcement learning approach to model the problem at hand
4. Launch the simulations and analyse the results

Some references on reinforcement learning applied to micro-swimming

- Alageshan Jaya Kumar, Akhilesh Kumar Verma, Jérémie Bec, and Rahul Pandit. (2019) *Path-Planning Microswimmers Can Swim Efficiently in Turbulent Flows* https://doi.org/10.1103/PhysRevE.101.043110.
- Liu Yuexin, Zonghao Zou, Alan Cheng Hou Tsang, On Shun Pak, and Y.-N. Young (2021) *Mechanical Rotation at Low Reynolds Number via Reinforcement Learning*, https://doi.org/10.1063/5.0053563.
- Tsang Alan Cheng Hou, Pun Wai Tong, Shreyes Nallan, and On Shun Pak (2020) *Self-Learning How to Swim at Low Reynolds Number* https://doi.org/10.1103/PhysRevFluids.5.074101.