Fast Aquatic Swimmer Optimization with Differentiable Projective Dynamics and Neural Network Hydrodynamic Models

ICML 2022 Short Presentation

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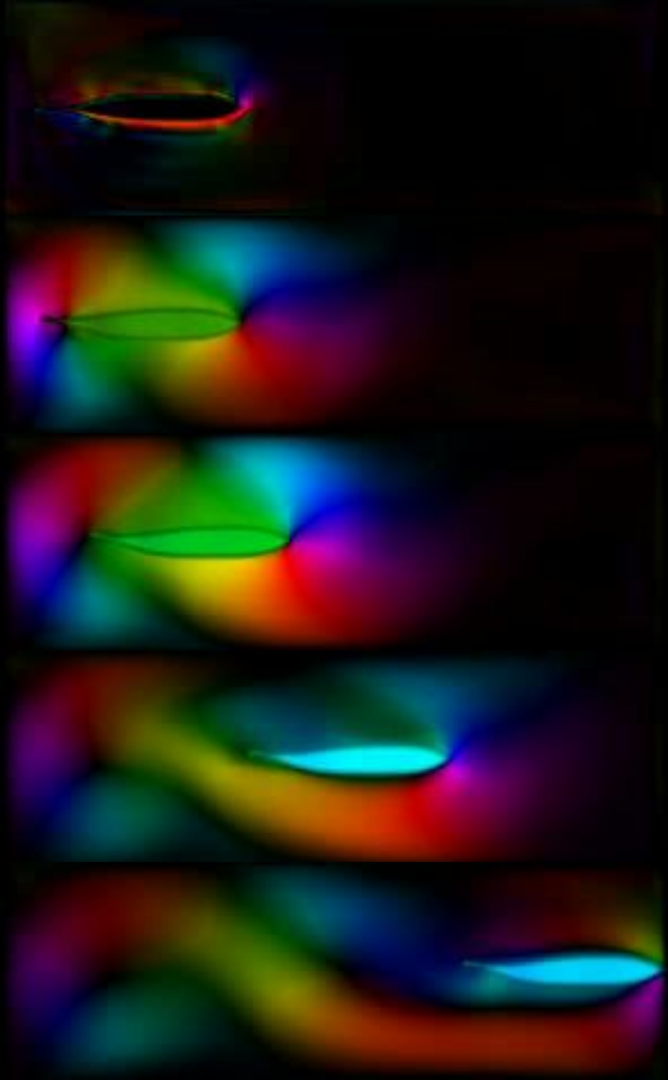
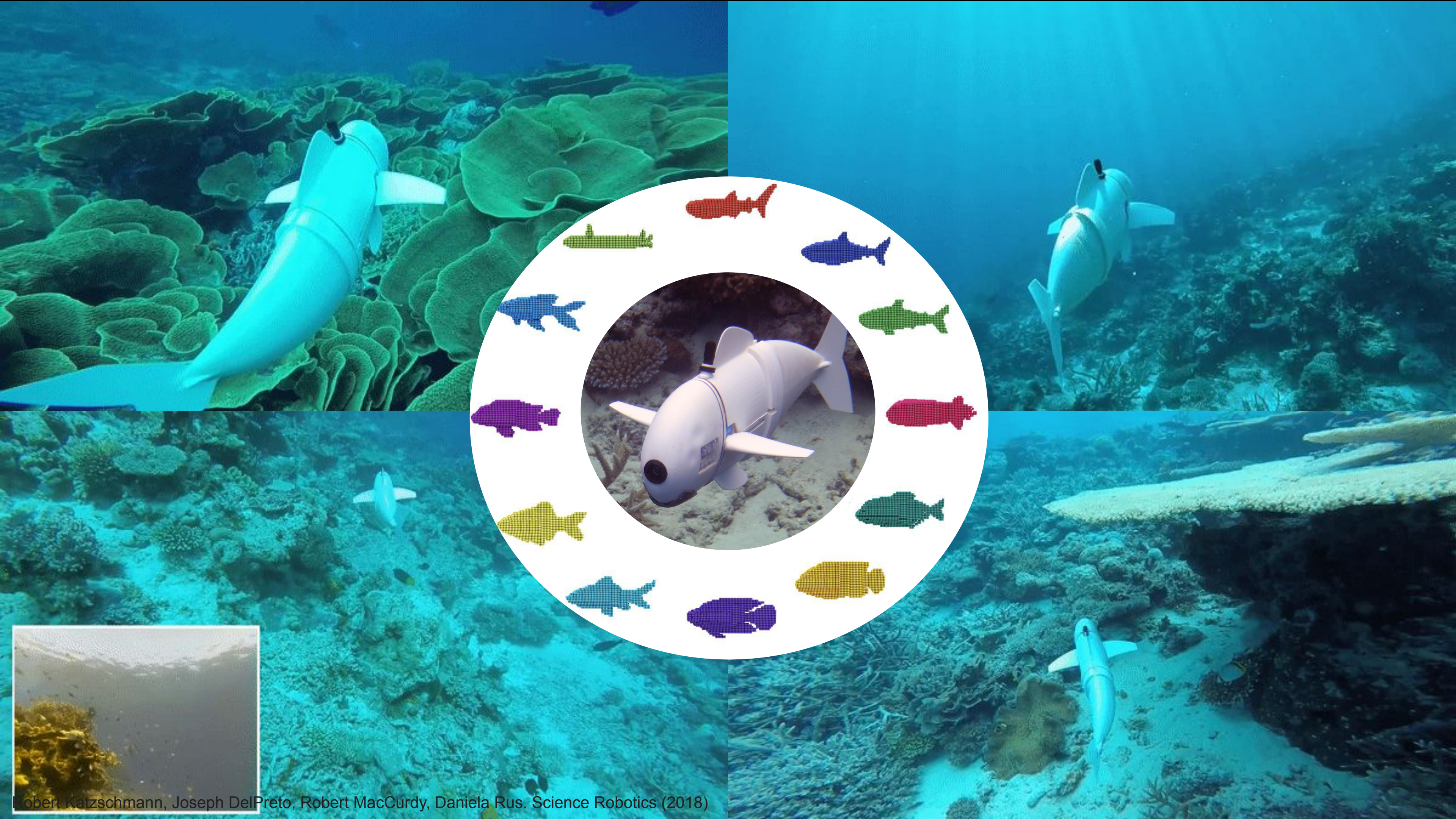
ETH Zurich, ETH AI Center, Soft Robotics Lab



ETH zürich SoftRobotics Laboratory



Robert Katzschmann, Joseph DelPreto, Robert MacCurdy, Daniela Rus. Science Robotics (2018)

Our Goal: **Differentiable Fast** Multiphysics Simulation for Optimization

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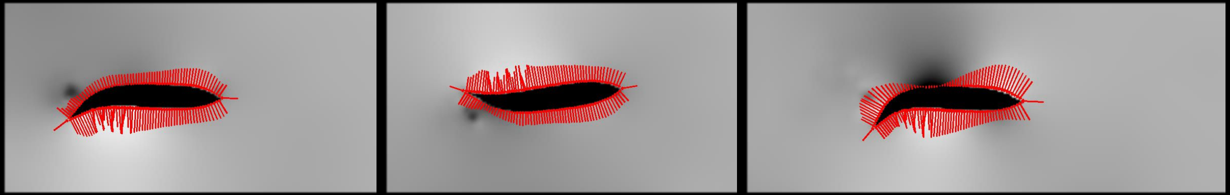
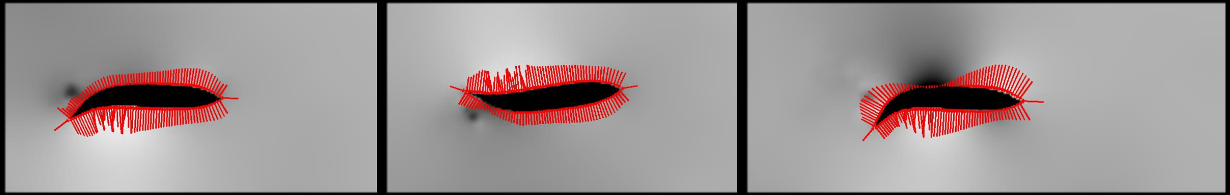


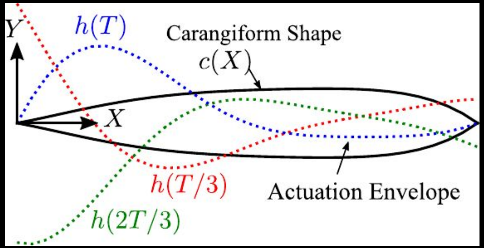
Coupling a Soft Body Simulation with NN-based Hydrodynamics

4

Our Goal: **Differentiable Fast** Multiphysics Simulation for Optimization



Coupling a Soft Body Simulation with NN-based Hydrodynamics



Directly Optimize Swimmer Policy Parameters

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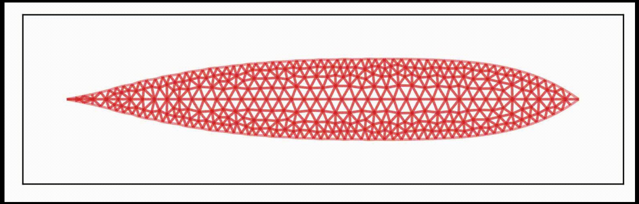
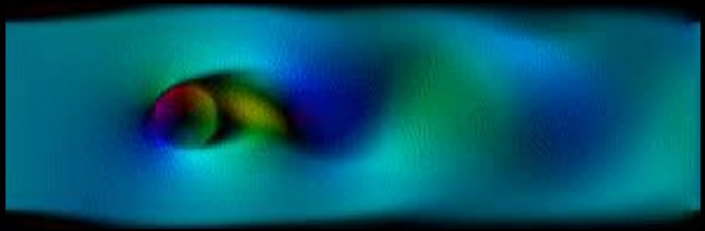
Simulation Techniques

Numerical Soft Body Simulation



Learned Physics-Informed Neural Network for Hydrodynamics



Simulation Techniques

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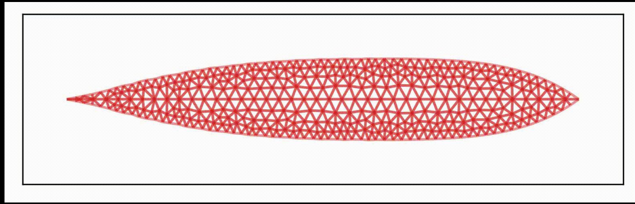

DiffPD: fast, differentiable method for soft body simulation using implicit Euler

Du, T., Wu, K., Ma, P., Wah, S., Spielberg, A., Rus, D. and Matusik, W., 2021. Diffpd: Differentiable projective dynamics. ACM Transactions on Graphics (TOG), 41(2), pp.1-21.

Simulation Techniques

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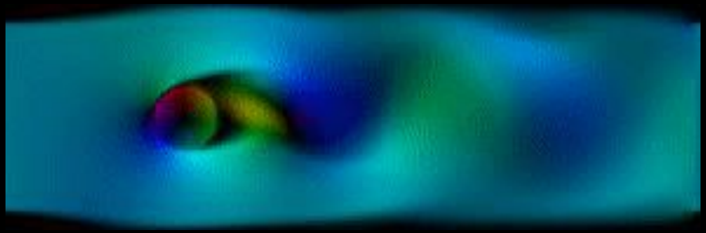


Wandel et al. surrogate method to solve Incompressible Navier Stokes with a **Physics-Constrained Loss**

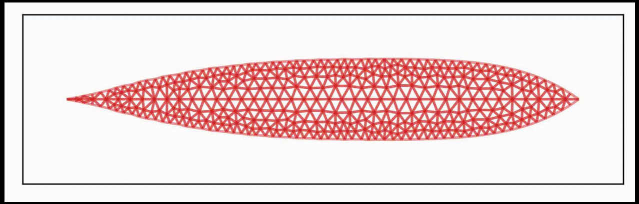
Wandel, N., Weinmann, M. and Klein, R., 2020, September. Learning Incompressible Fluid Dynamics from Scratch-Towards Fast, Differentiable Fluid Models that Generalize. In International Conference on Learning Representations.

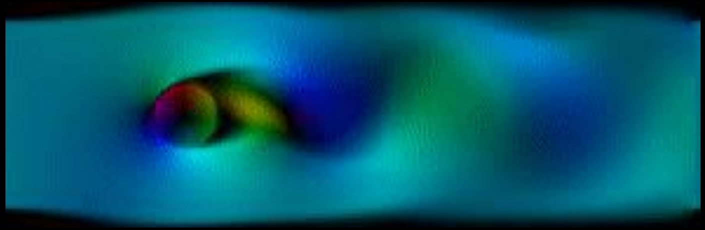
How to connect the two physical systems?
Important: **allowing gradient propagation**

Differentiable Two-Way Coupling

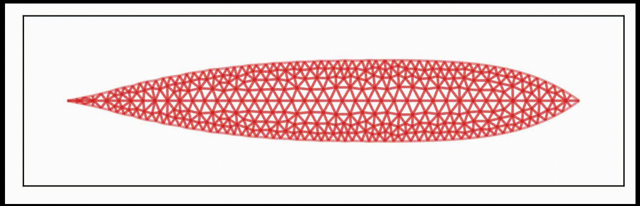
Numerical Soft Body Simulation

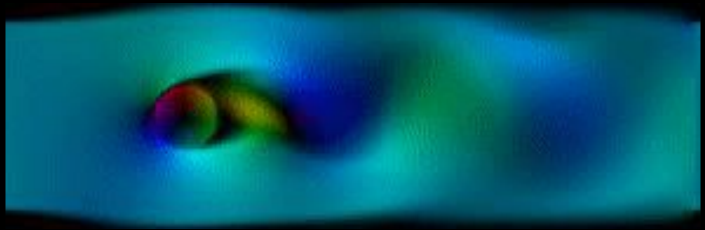
Learned Physics-Informed Neural Network for Hydrodynamics





Differentiable Two-Way Coupling





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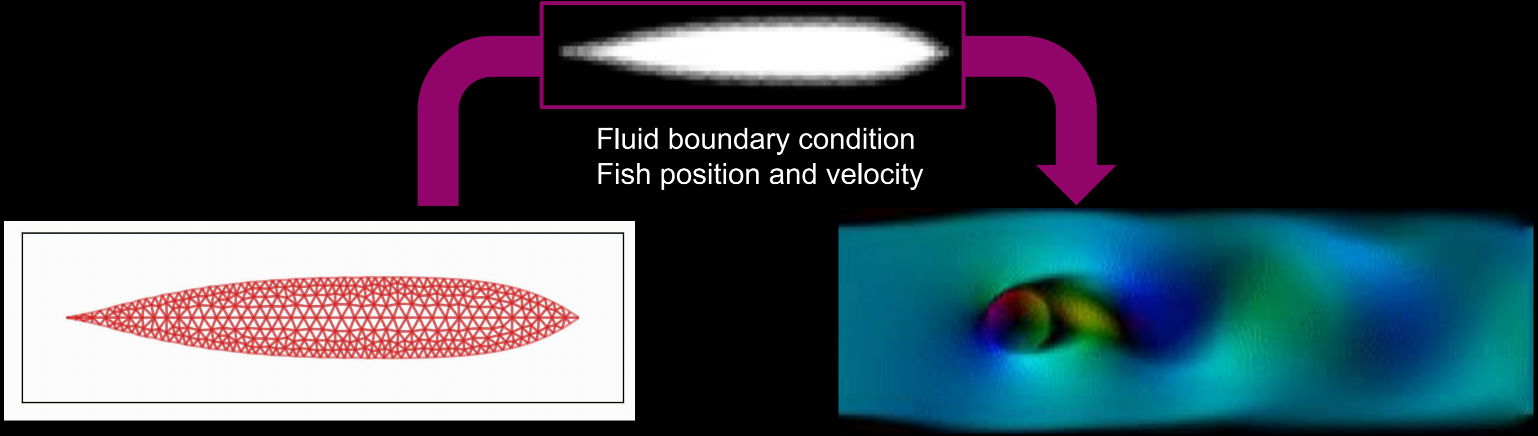

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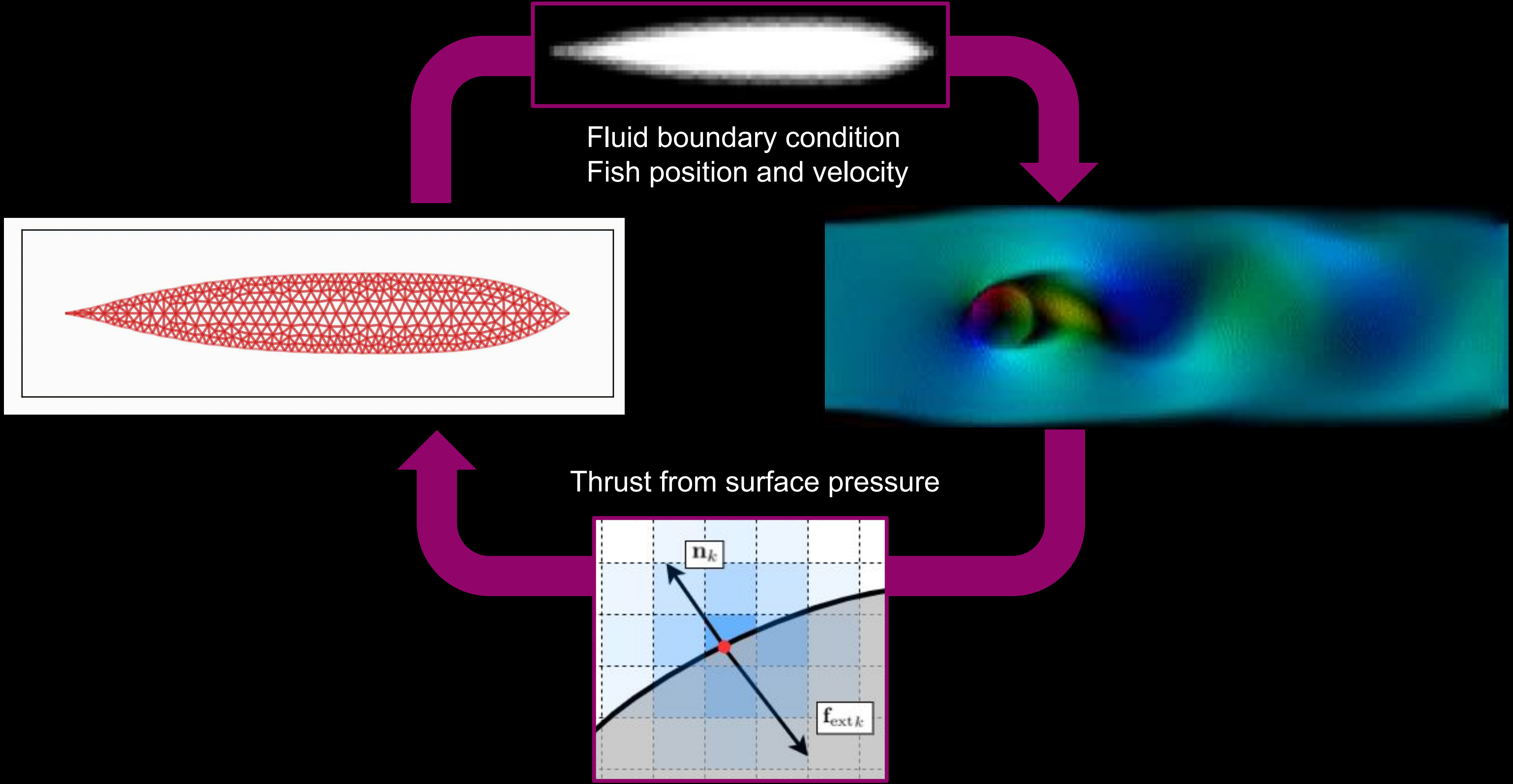
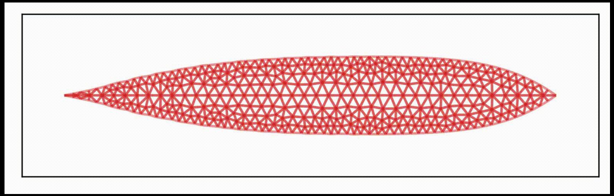
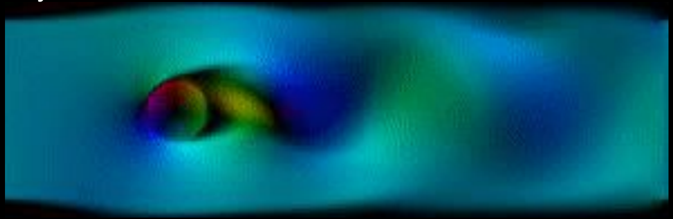


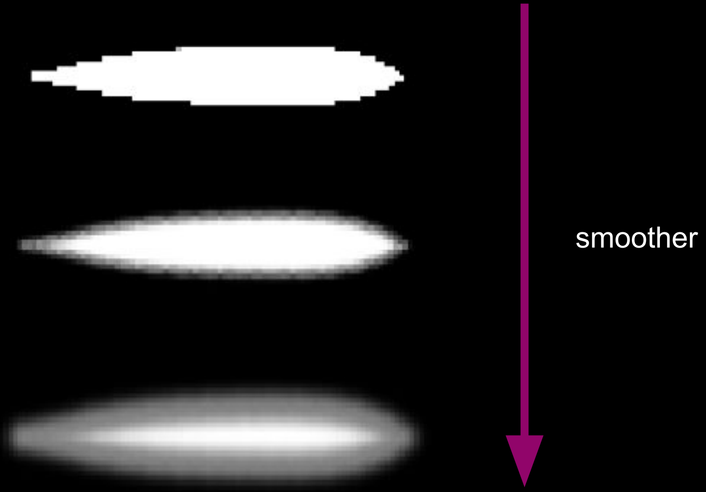
Solid to Fluid Interaction

Fluid boundary condition
Fish position and velocity





To make the boundary mask **differentiable**, we use **soft rasterization.**

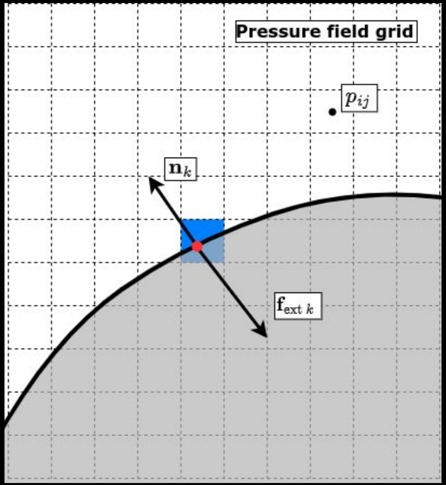


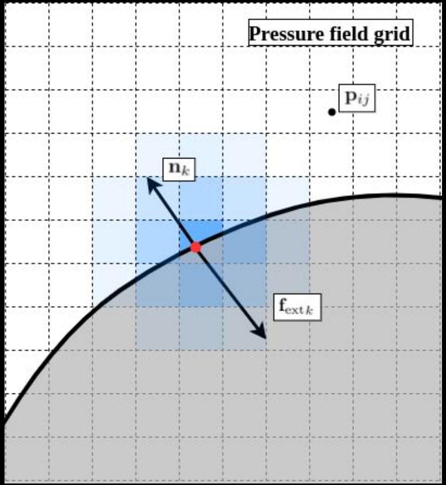
Fluid to Solid Interaction

Thrust from surface pressure

Numerical Soft Body Simulation

Learned Physics-Informed Neural Network for Hydrodynamics

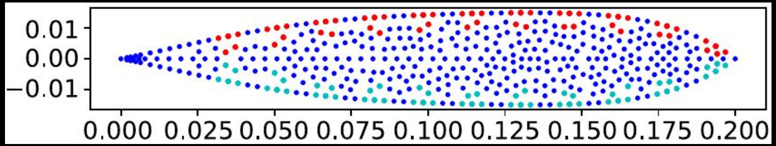




To make the computed thrust **differentiable**, we use an **Immersed Boundary Method** with Gaussian distances.

Simulated Soft Body Fish

Our method is tested on a Carangiform Swimmer, composed of discretized FEM elements.



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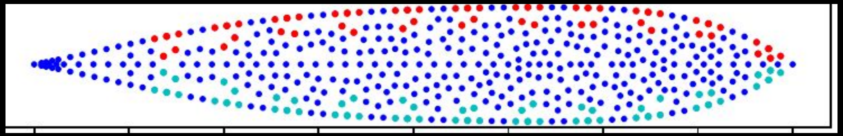
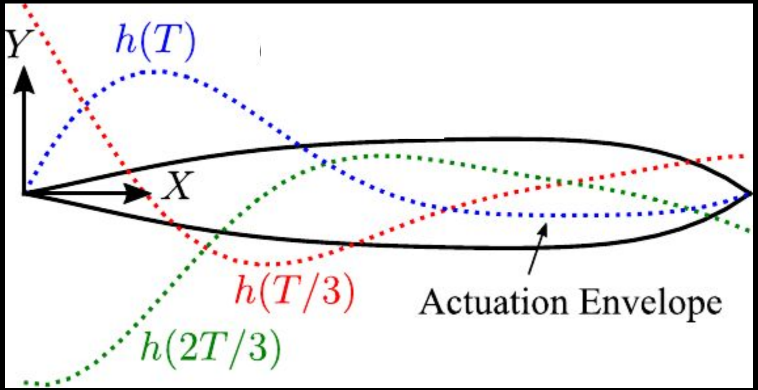


- Its actuation signal is determined by an Actuation Envelope **h(T)**.



Optimize the parameters of the actuation signal function,
To **maximize** the swimmer’s forward thrust.

Result: An optimized swimming frequency for maximum velocity