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DATA-DRIVEN DESIGN AND FABRICATION METHODS

SOFT TENTACLES
Simulation and modeling for design optimization

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Reference: *Soft passive swimmer optimization: from simulation to reality using data-driven transformation*

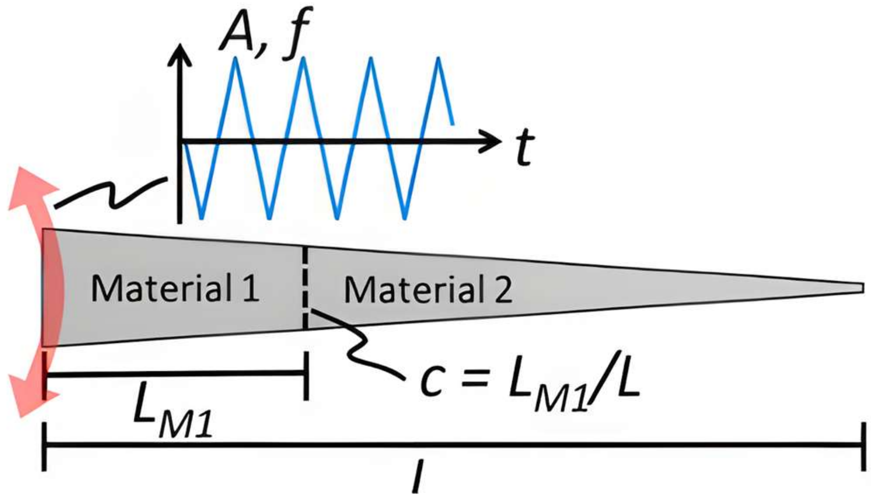
WHY DATA-DRIVEN DESIGN

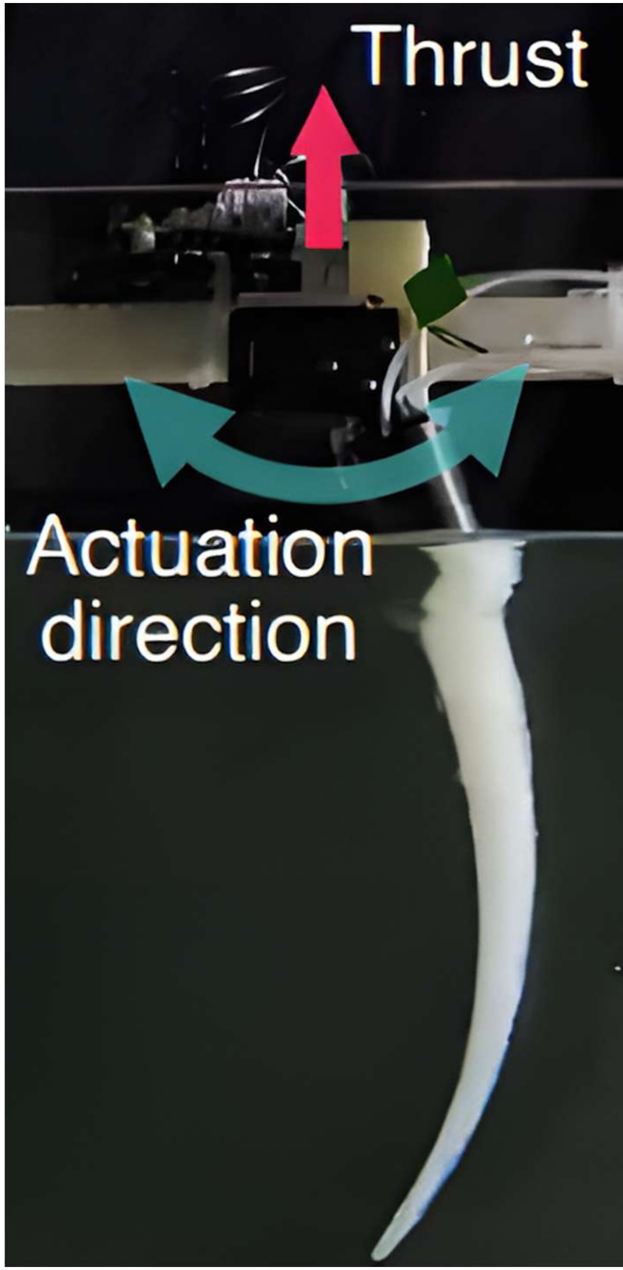
NONLINEAR DYNAMICS

- Behavior hard to model analytically
- Data-driven approach captures real-world complexity

FLUID-STRUCTURE INTERACTIONS

- Forces depend on shape and velocity
- Data capture realistic, time-varying effects





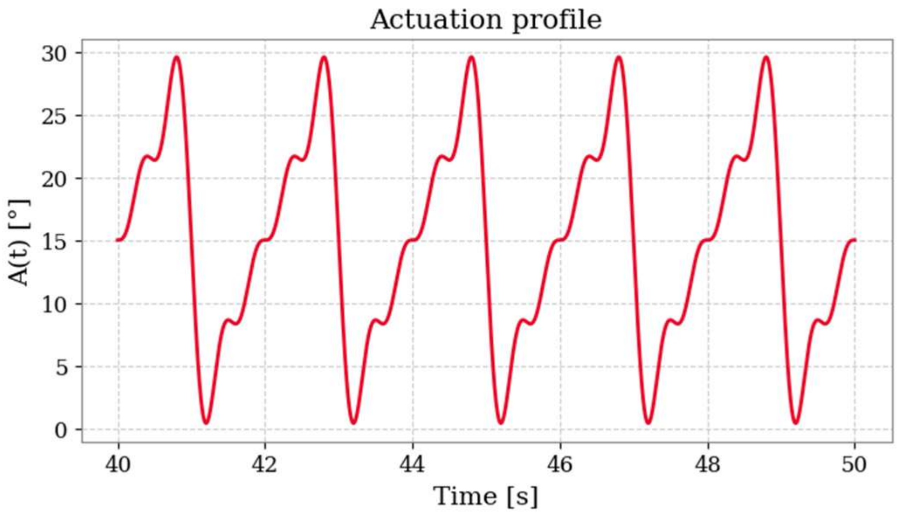
ENCODING AND OBJECTIVE FUNCTION

DESIGN SPACE

- Tentacle length $l \in [0.1; 1.5]$ m
- Material ratio $c \in [0; 1]$
- Control amplitude $A \in [5; 120]$ °
- Control frequency $f \in [0.05; 10]\ Hz$

MULTI-OBJECTIVE

- Thrust
- Velocity



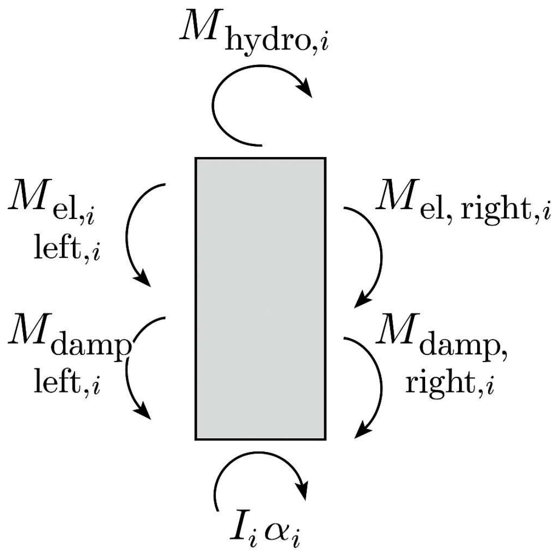
MULTIBODY MODELING

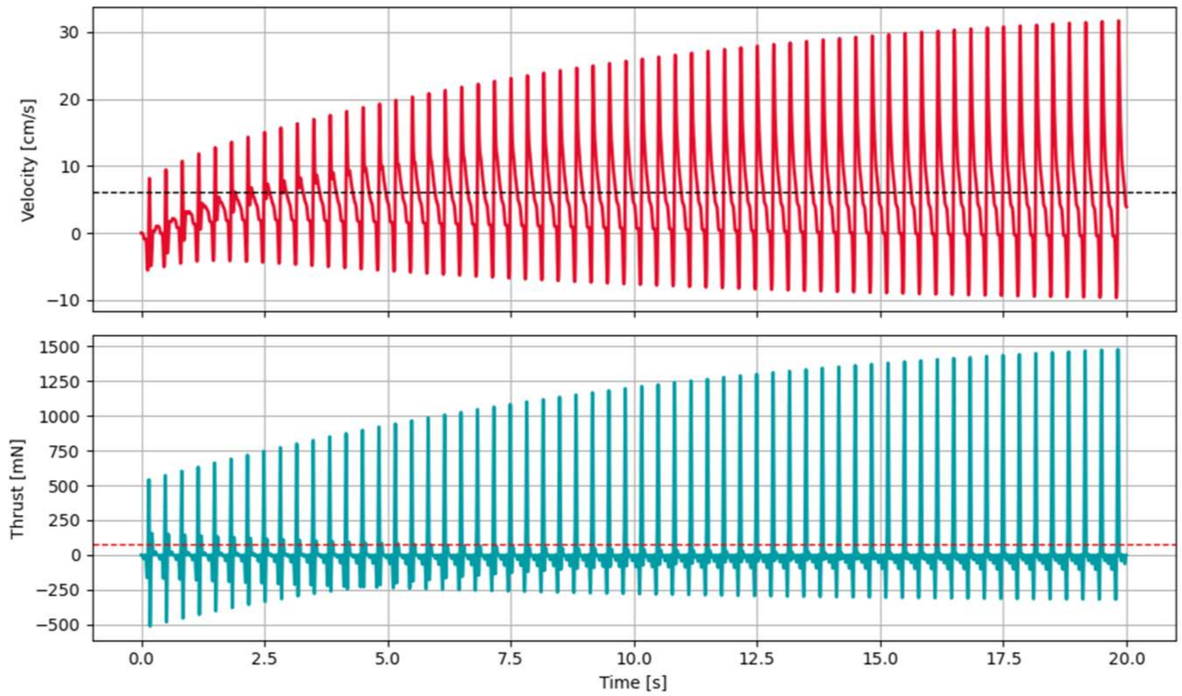
TENTACLE

- Chain of masses with spring-damper links
- Parameters from material and literature data

FEEDFORWARD ACTUATION

- Sawtooth motor input via Fourier series
- Imposed displacement on first spring





SIMULATION

- Balance of hydrodynamic, elastic, damping, and inertial moments to model complex interactions with the fluid
- 60 s simulation to capture transients
- Mean thrust and velocity evaluation

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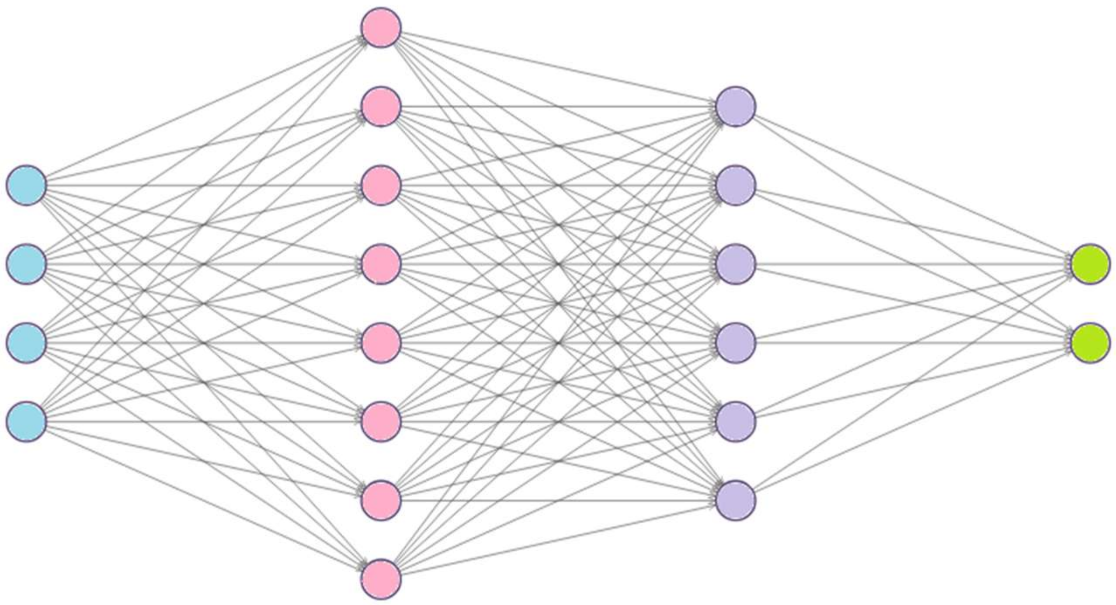

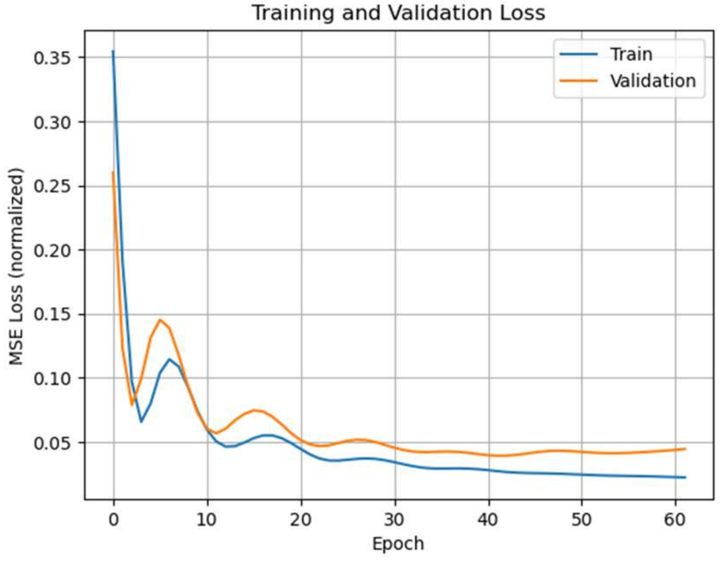

SURROGATE MODELING

GRID-BASED ACQUISITION

- Initial sampling from simulations
- Full factorial design with fixed number of levels per factor

NEURAL NETWORK

- Surrogate regression using MLP
- Maps design parameters to thrust and velocity

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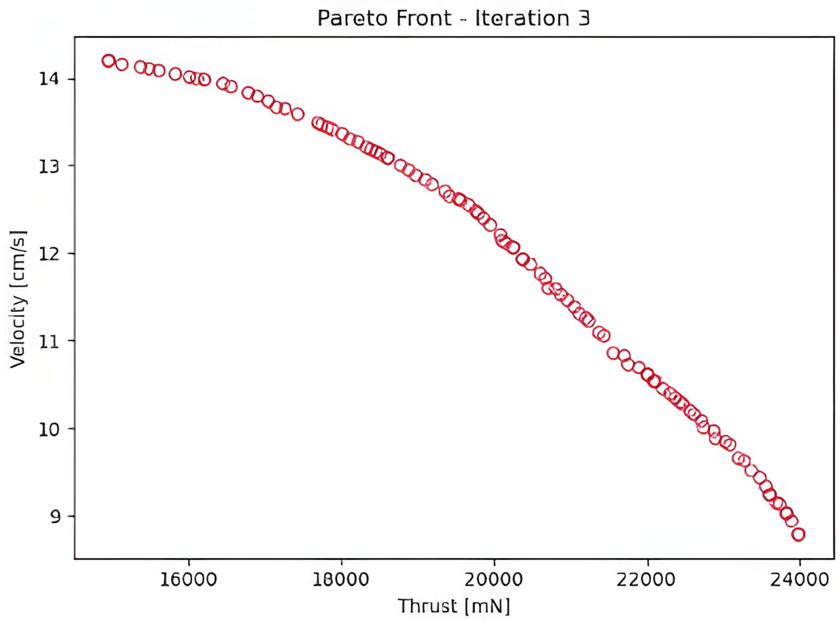

ACTIVE LEARNING WITH GA

- Genetic Algorithm (GA) used to compute Pareto front (thrust vs. velocity)
- Iterative re-sampling around Pareto to expand dataset
- Stopping criterion: improvement evaluation