Underwater Soft Robot Modeling and Control with Differentiable Simulation

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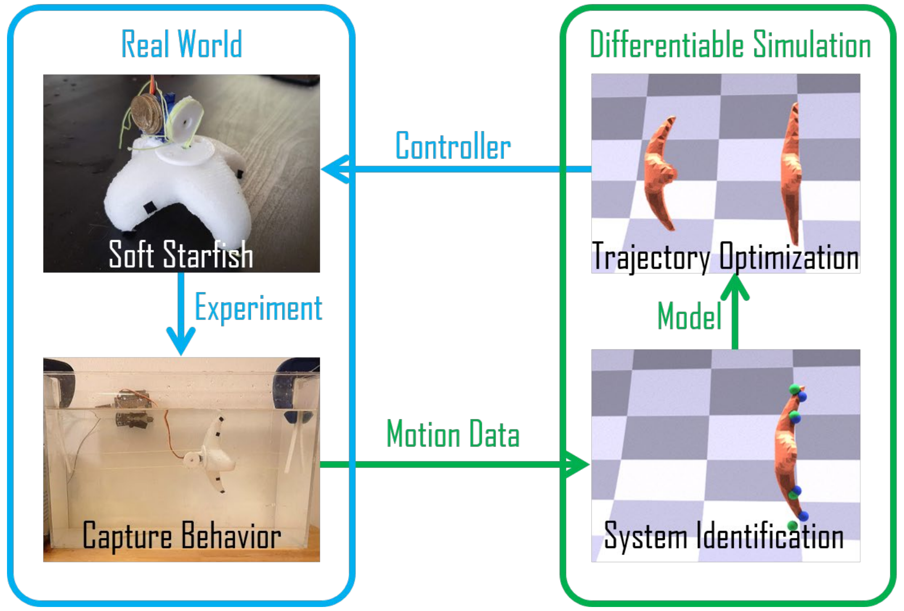
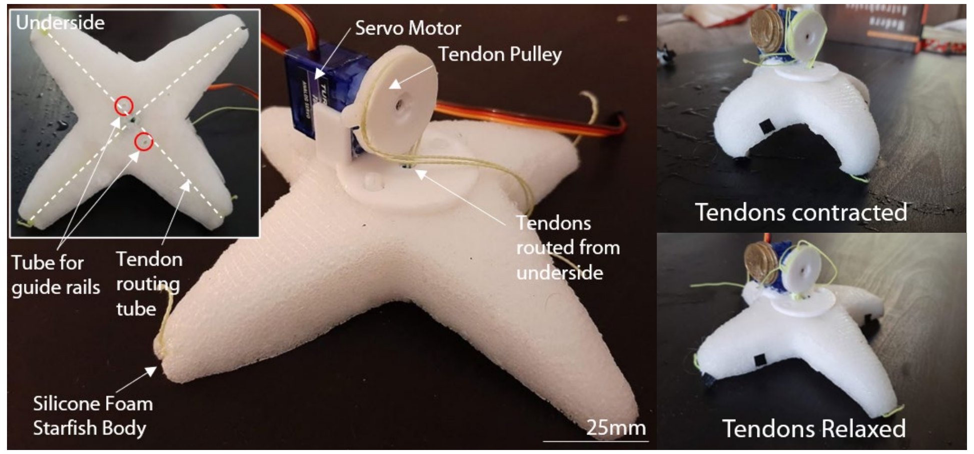
1. Overview & Summary



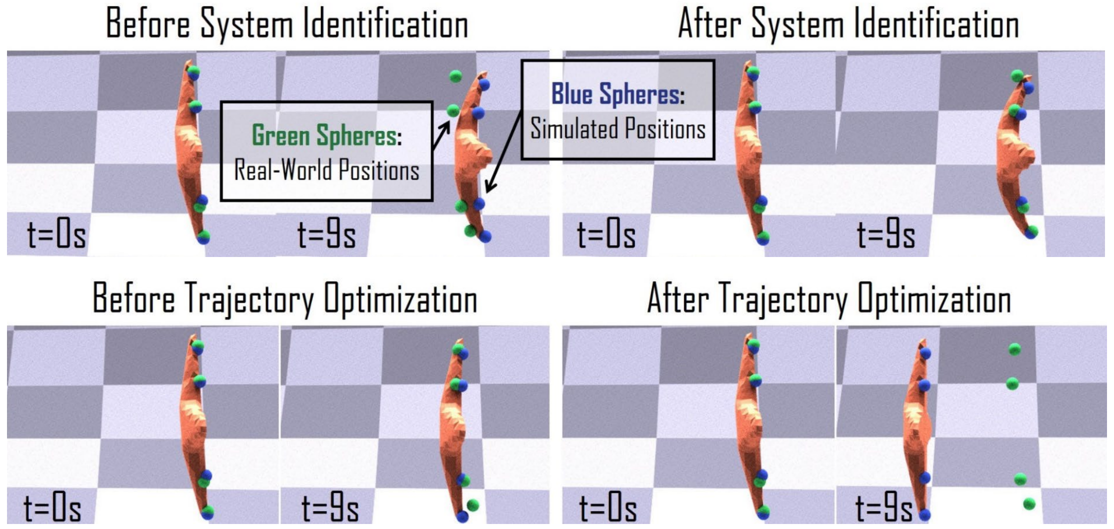
- We present a **holistic** framework for modeling and controlling underwater soft robots;
- We show an algorithm that **iteratively** solves system identification and trajectory optimization;
- We develop a **differentiable** simulation model and show its power in narrowing the reality gap;
- We demonstrate the efficacy of our method on **a real underwater soft robot**.

2. Robot Setup & Fabrication



3. Simulation & Optimization

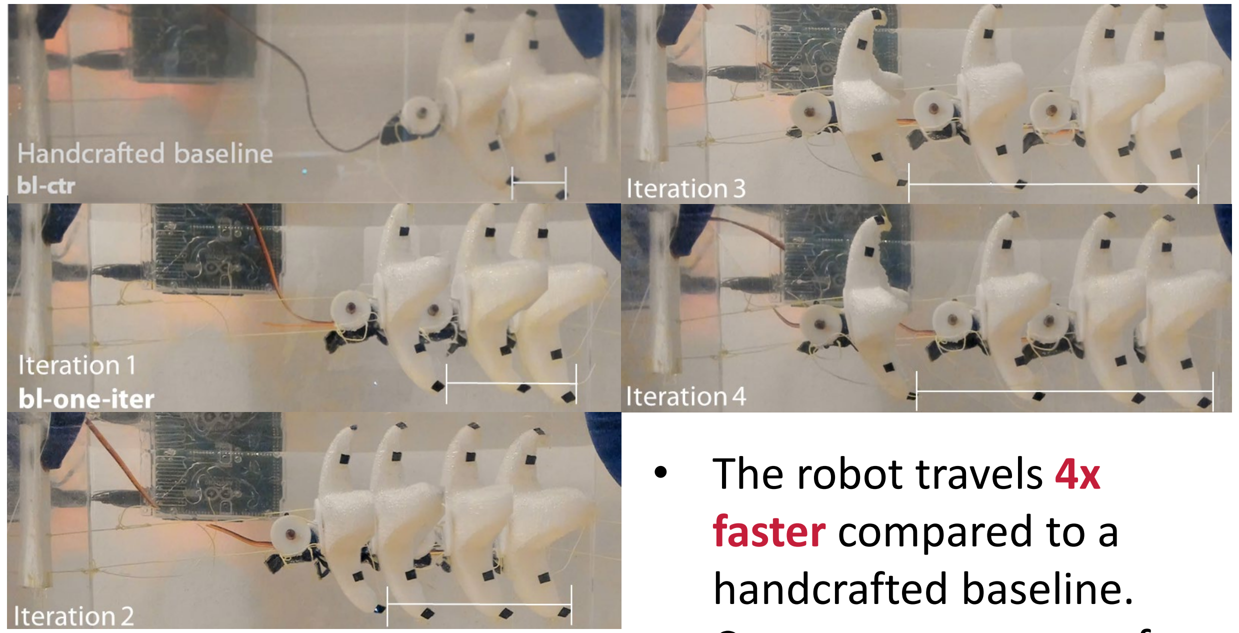
- We simulate a **differentiable** soft body and hydrodynamic model.
- We use **gradient-based optimization** in system identification to narrow the reality gap and in trajectory optimization to improve the controller.

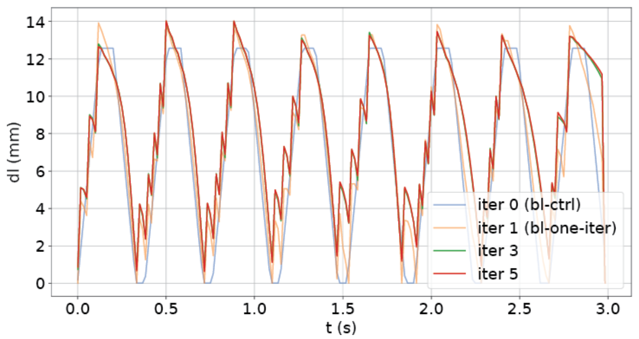


- Summary of optimization: Vs: predicted velocity; Vr: actual velocity; Orange: system parameters. Goal: 1) maximize Vr and 2) minimize the difference between Vs and Vr.

Iter.	Vs (cm/s)	Vr (cm/s)	E	w	|Cd|	|Ct|
0	0.01	0.21	9.0e5	2.0e6	4.2	3.9
1	0.83	0.48	5.0e5	4.1e6	2.5	4.5
2	0.68	0.56	1.0e6	1.4e6	3.5	4.4
3	0.66	0.67	4.3e5	4.8e6	3.4	4.1
4	0.77	0.75	4.0e5	5.7e6	3.0	4.3
5	0.75	0.75	3.8e5	5.8e6	3.0	4.3

4. Experimental Results





- The robot travels **4x faster** compared to a handcrafted baseline.
- Convergence occurs after **four iterations**.
- Control signal shows addition of **high-frequency** components (See left).

5. Conclusion & Future Work

- Our pipeline allows for significantly improvement in performance and **narrowing of the sim-to-real gap**.
- The pipeline can be used interchangeably with **other simulators (hydrodynamic models)** and **robot systems**.

6. Acknowledgments

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