Large Exploration with Small Payloads: Underwater Deployable via Robotic Swarms

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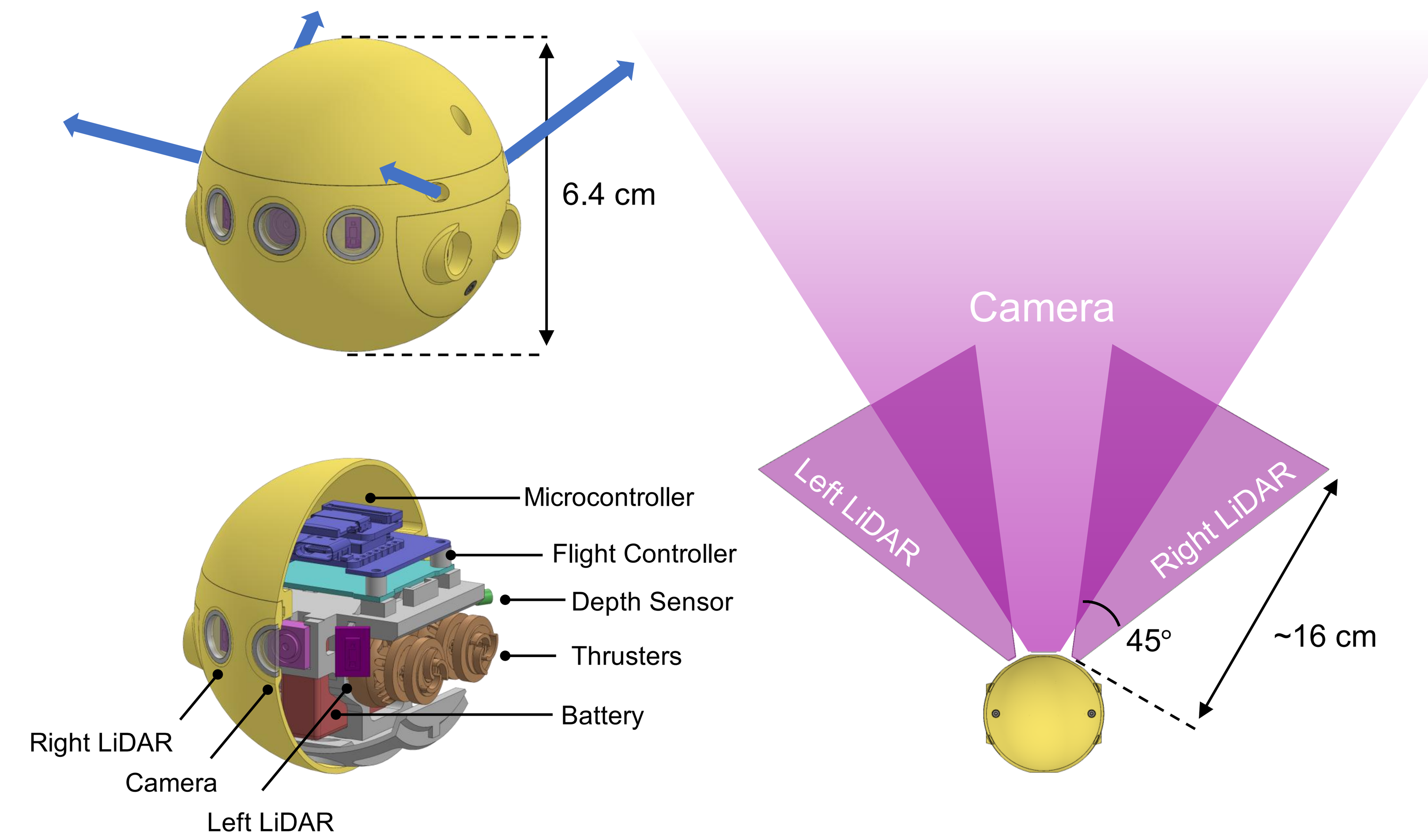
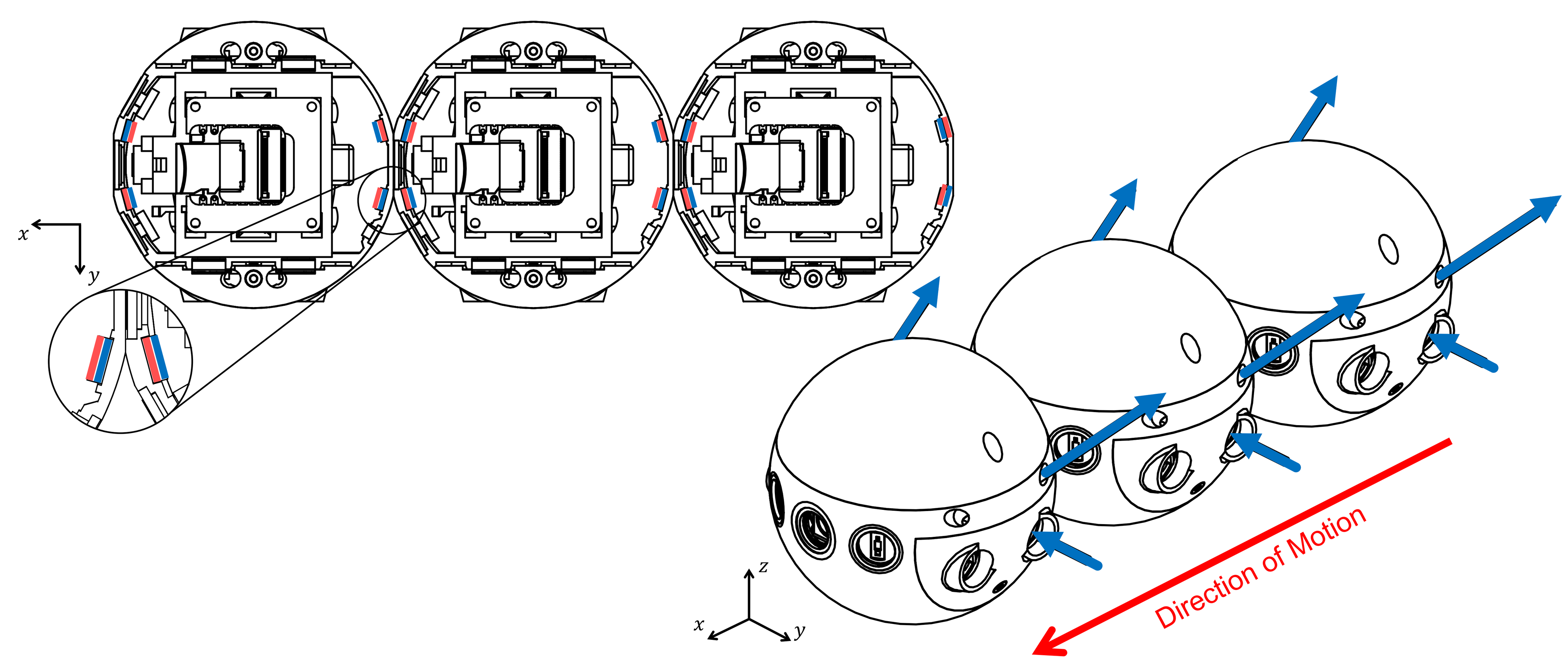
Motivation

The subsurface oceans of icy moons like Europa and Enceladus are among the least-understood and most compelling environments for future robotic exploration. However, the physics of ocean access on these bodies limits deliverable payload volume to the scale of ~ 10 L or less. What architectures enable large-scale exploration with such restrictive payload constraints?

Swarms of miniature robots like the platform shown right are a compelling architecture; the system is robust to loss of individual units, and robots can coordinate to parallelize exploration over large regions. However, one key challenge is that smaller platforms are fundamentally slower and less efficient swimmers; this places a hard limit on the speed and endurance of swarm-based exploration.



Approach



We develop a deployable-like approach that leverages self-assembly of the robots into larger, more efficient robotic structures. This work measures the scaling of swimming performance in these multirobot structures in terms of both absolute speed and dimensionless cost of transport (CoT) – which is a metric for locomotion efficiency.

The robots connect end-to-end via embedded permanent magnets, as shown left. In aggregated form, they behave as a rigid body with distributed propulsion. The robots retain the ability to self-disassemble by coordinated propulsion; thus, the system can transition between behaving as one large and efficient swimmer, or many smaller independent swimmers.

Results

We explore two propulsion strategies: all robots contributing equal thrust, or one robot generating thrust while the rest remain passive. Experiments are performed in laboratory water tanks with structures of one to eight robots.

We find that structures of eight robots can achieve a doubling in swim speed compared to an individual robot, or nearly an order of magnitude reduction in CoT depending on the propulsion strategy. The CoT-speed plot shown right visualizes performance ellipsoids corresponding to individual robots, and multirobot assemblies using the different propulsion strategies. The multirobot structure achieves a top speed of 0.41 m/s and a minimum CoT of 2 for a total volume less than one liter.