A BIOMIMETIC ACTUATION METHOD FOR A MINIATURE, LOW-COST MULTI-JOINTED ROBOTIC FISH

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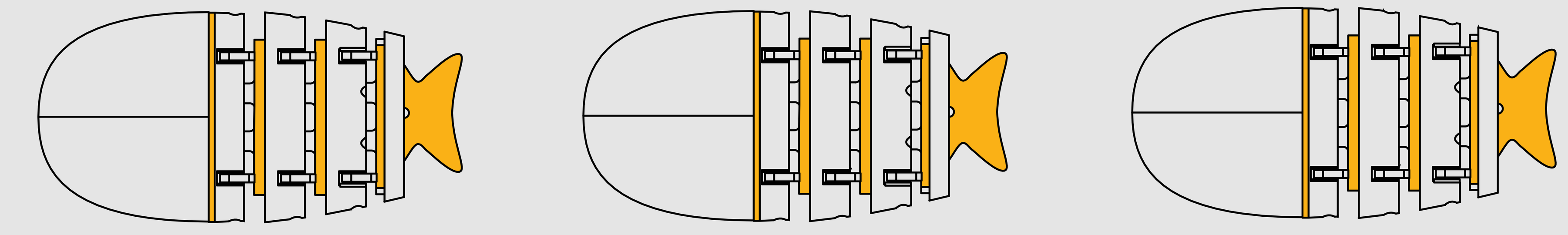

MORA (Miniature Oscillating Robot Agent) is a robotic fish designed to demonstrate a low-cost, small-scale biomimetic actuation method for efficient swimming. Our goal is to enable the development of underwater robot swarms that can access tight, fragile environments and gather data from the perspective and scale of real fish.

Miniature Low-Cost Actuator

The magnet-in-coil (MIC) actuator consists of a magnet suspended inside of a coil which aligns with the coil's magnetic field as current is alternated across the coil (Fig. 1). The MIC was developed by Berlinger et al. for swarm robotics applications that require a low cost and relatively simple actuation method.

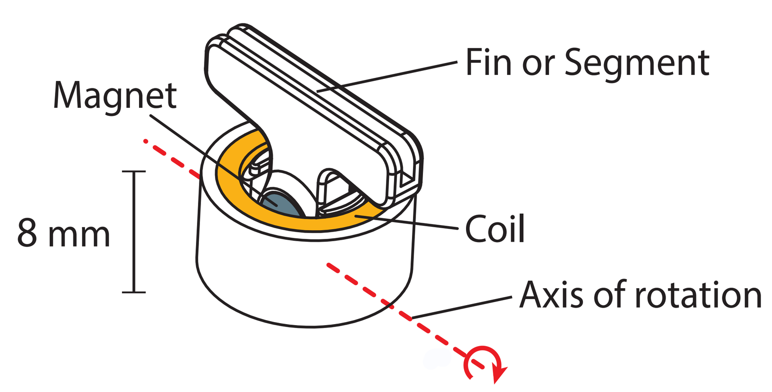

Figure 1: Magnet-in-coil actuator

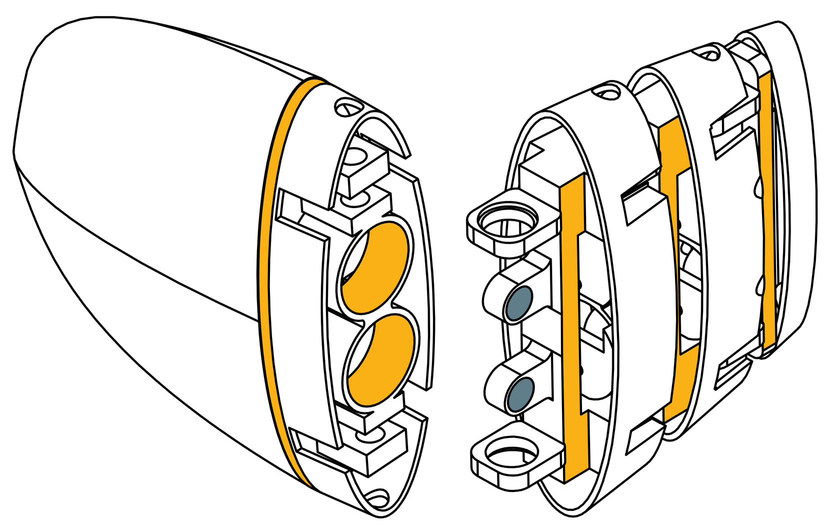

Figure 2: The actuator at each joint of the robot is constructed using two coils and two magnets.

Multi-Jointed Arrangement

Multiple MIC actuators ($1/unit) can be used on a single robot without appreciably increasing its cost. MORA (Fig. 2 and 4) uses three MICs in a multi-jointed arrangement to explore bioinspired swimming gaits for small robot agents. This configuration allows us to study multiple behaviors of the same robot to optimize its speed and efficiency.

Efficient, Biomimetic Swarming

Imitating the swimming motion of a real fish, who excel at underwater propulsion, provides a robot with a hydrodynamic advantage and increases its efficiency [2]. Lowering power consumption and increasing speed enables longer missions and the use of higher-power sensors for more detailed data collection. Furthermore, underwater robots with biomimetic actuation have the unique potential to integrate into ecosystems with minimal disruption to the natural inhabitants [3]. Swarms of biomimetic robots can also provide a synthetic biology testbed for swarm algorithm replication in biological systems.

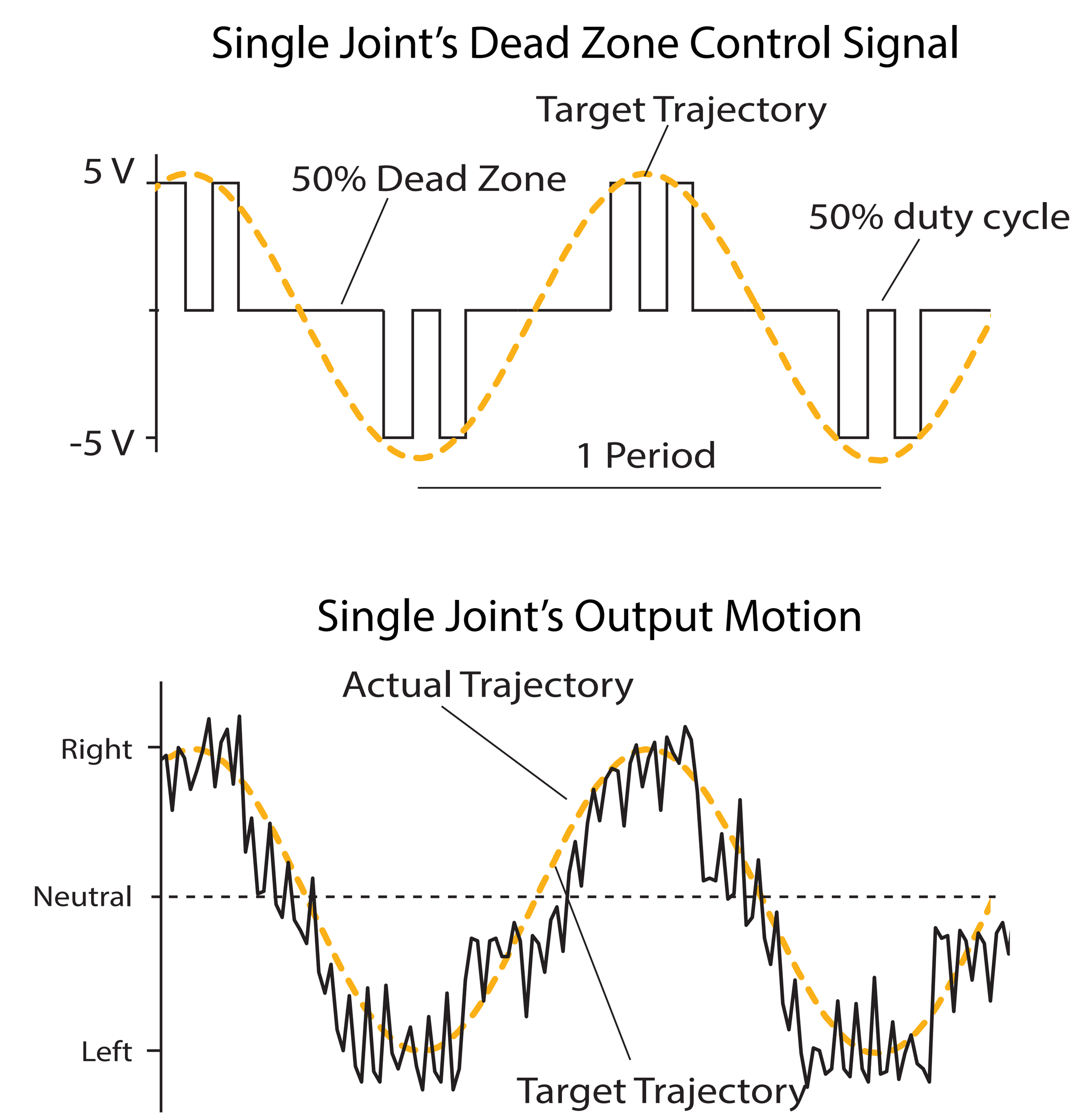

Figure 3: (top) The duty cycle and dead zone parameters are used to control when the coil receives current. (bottom) This allows the approximation of a sinusoidal trajectory.

Configuring Undulatory Motion

An ideal carangiform swimming motion can be approximated with discrete joints moving in sinusoidal trajectories at various amplitudes and relative phase offsets [4]. By strategically sending pulse-width modulated (PWM) signals, we can control each MIC's sine wave output individually, allowing for a highly configurable joint arrangement (Fig. 3). Internal hall effect sensors were used to verify the sinusoidal behavior of the actuator under different settings (Fig. 3).

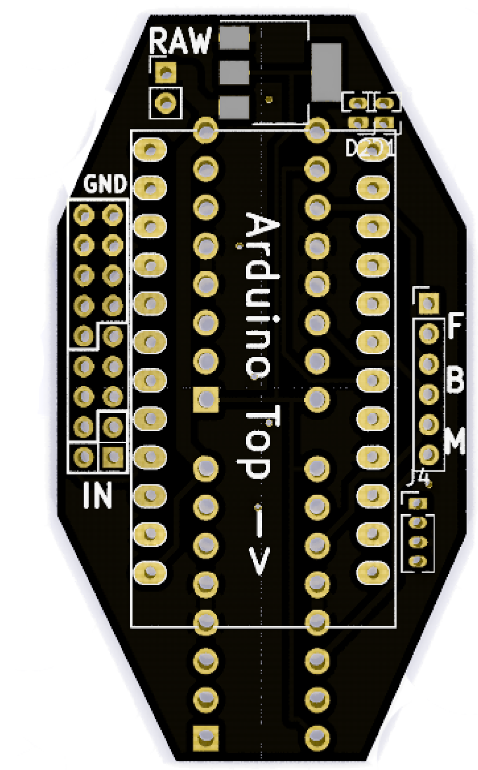

Figure 4: Printed circuit board designed to fit inside a segment of the fish.

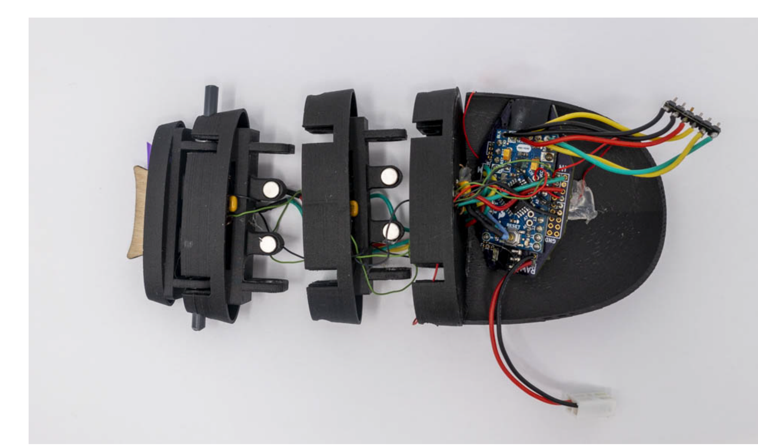

Figure 5: A fully printed and assembled fish.

Packaging and Waterproofing

Custom printed circuit boards (PCBs) were designed to reduce the form factor of the electrical components (Fig. 4). To waterproof each PCB, we coated all electronics, except the battery, in CorrosionX, a contaminant rejecting polymer coating. Electrical components were fitted throughout different 3D printed segments, making the fish fully standalone.

Future Work

Improving MORA will enable the development of miniature underwater robots which show promise as robust and efficient agents in a distributed sensing network designed to navigate small spaces and sensitive ecosystems. A closed-loop control system will be used to provide dynamic response and complex control. As we look to begin tests with multiple agents, we will research different underwater, wireless communication methods. We are currently investigating the use of an XBee to transmit data in real time between agents.

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