MORA: Evolution of a Miniature Biomimetic Fish

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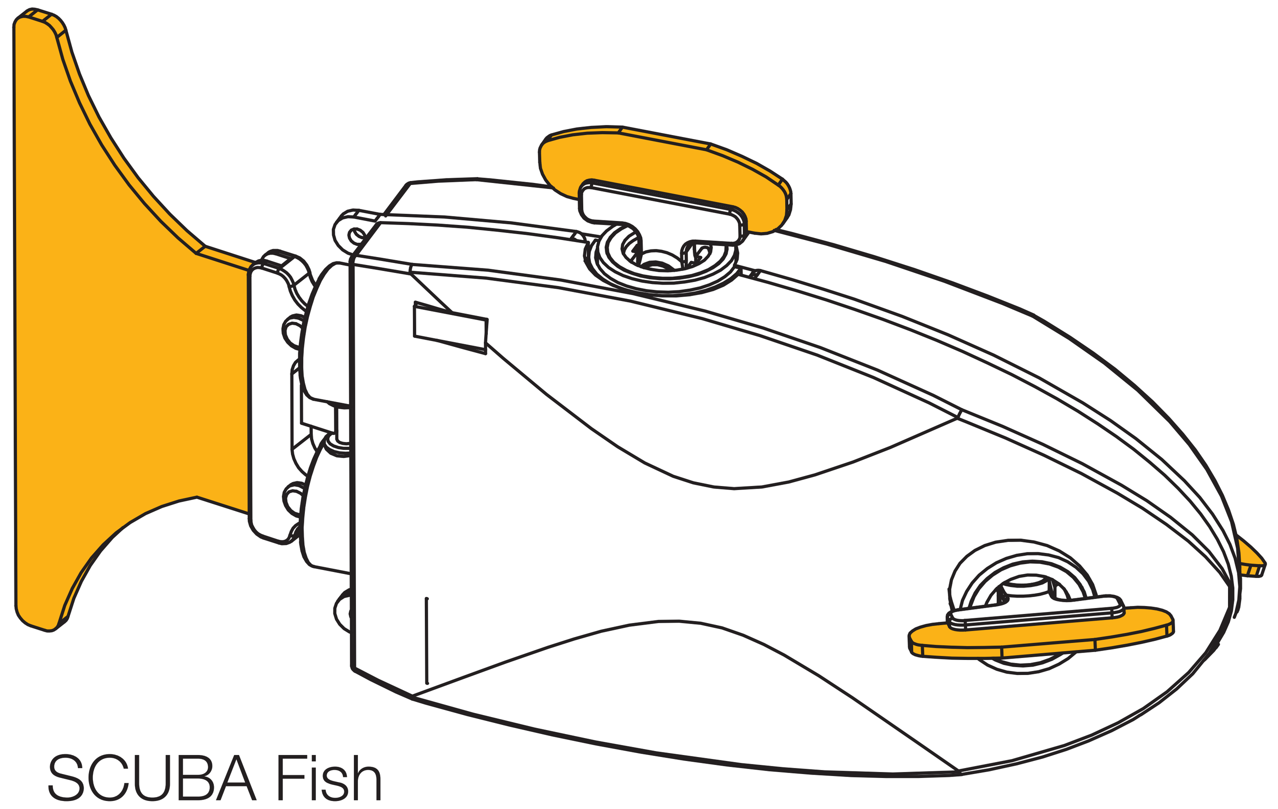
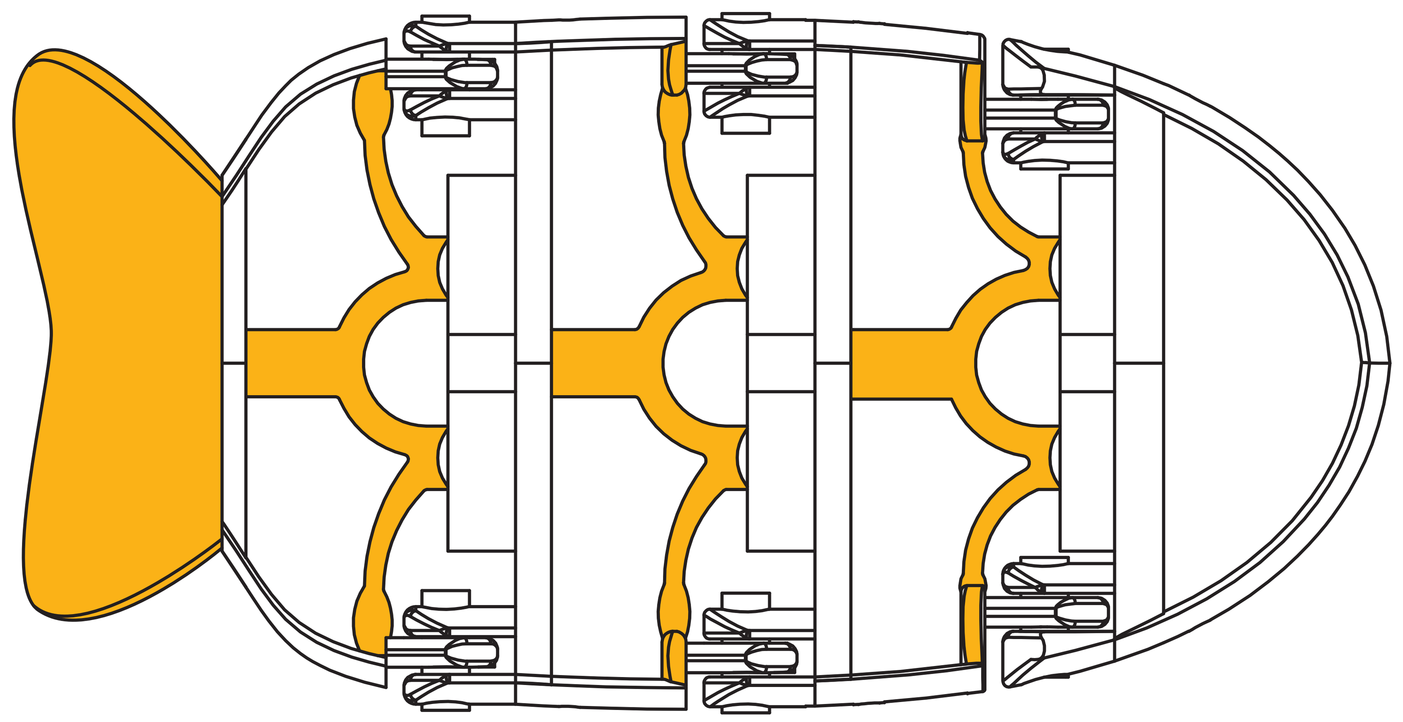
MORA
Miniature Oscillating Robotic Agent



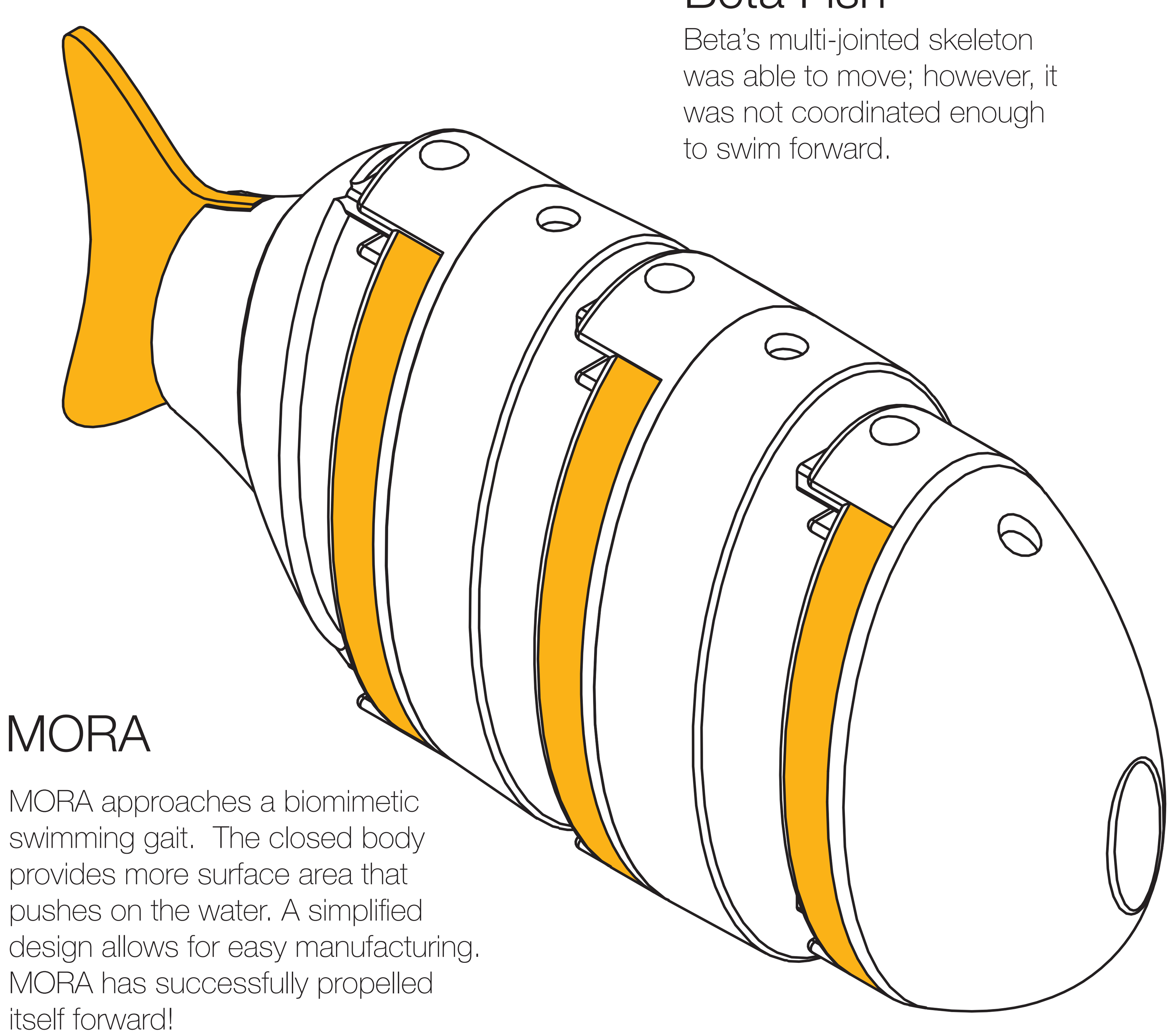
SCUBA Fish

The first iteration of the robot fish was untethered and autonomous and used one flapping fin for forward propulsion.



Beta Fish

Beta's multi-jointed skeleton was able to move; however, it was not coordinated enough to swim forward.

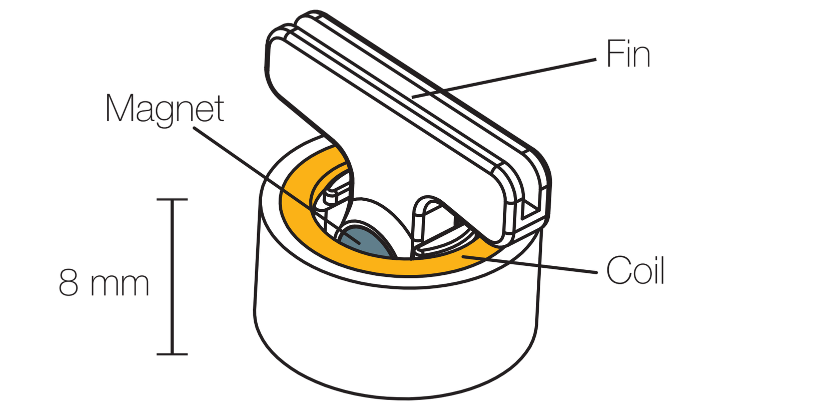


MORA

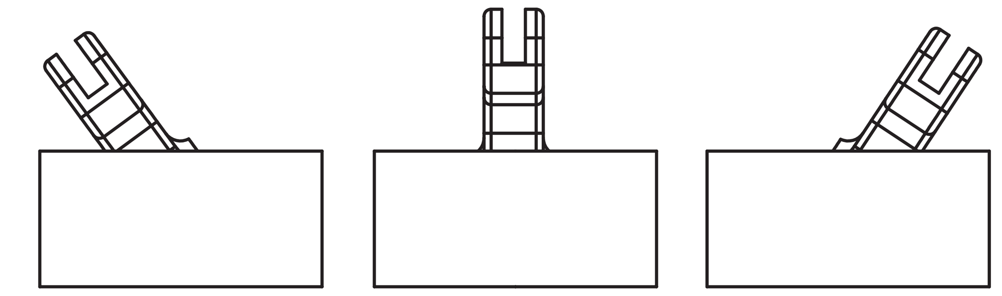
MORA approaches a biomimetic swimming gait. The closed body provides more surface area that pushes on the water. A simplified design allows for easy manufacturing. MORA has successfully propelled itself forward!

Biomimetic Robot for Swarming

MORA is an underwater robot designed to be a small, low-cost, and easily manufactured agent of a swarm, with the ultimate goal of observing fragile marine ecosystems. Its biomimetic propulsion system and size give MORA the potential to integrate into the environment it is monitoring with minimal disruption and to interact with in in a natural manner. Additionally, it provides a synthetic biology testbed for replicating collective behaviors in biological systems.

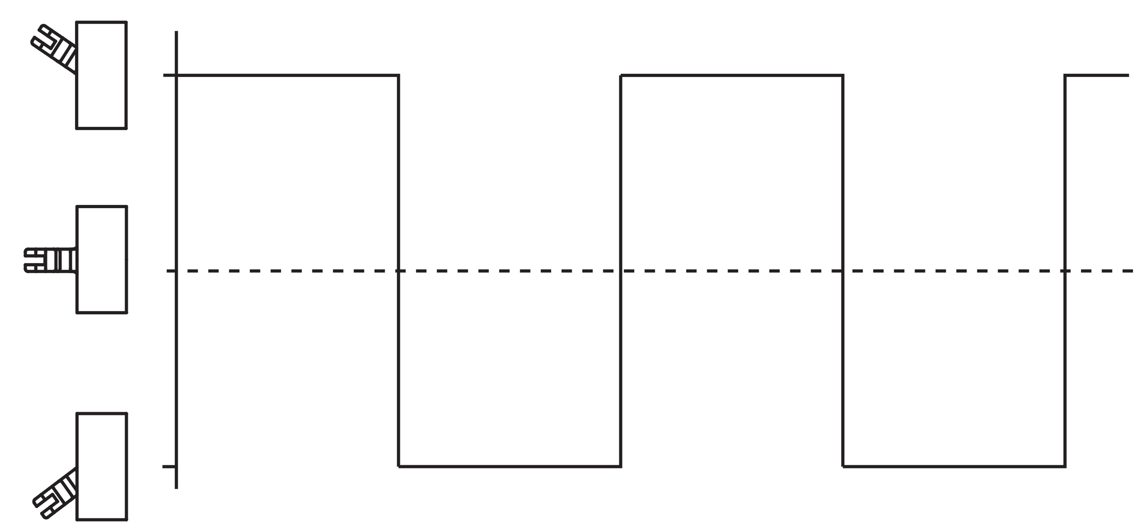


When current is passed through the coil, a magnetic field is induced, and the magnet, suspended inside, attempts to align itself with this field. As long as the current is alternating, the magnet will continue to move.



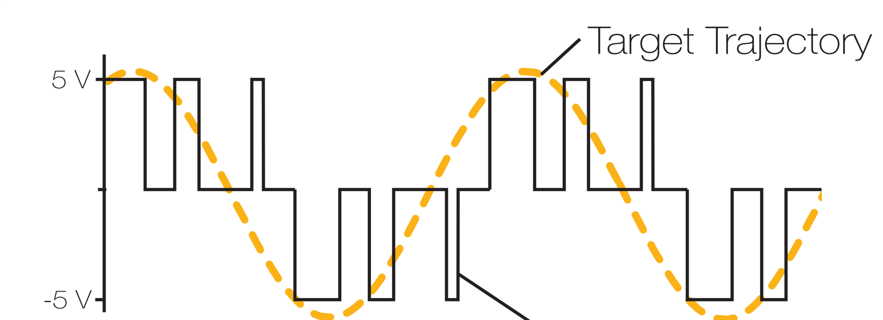
Getting Small: The Actuator

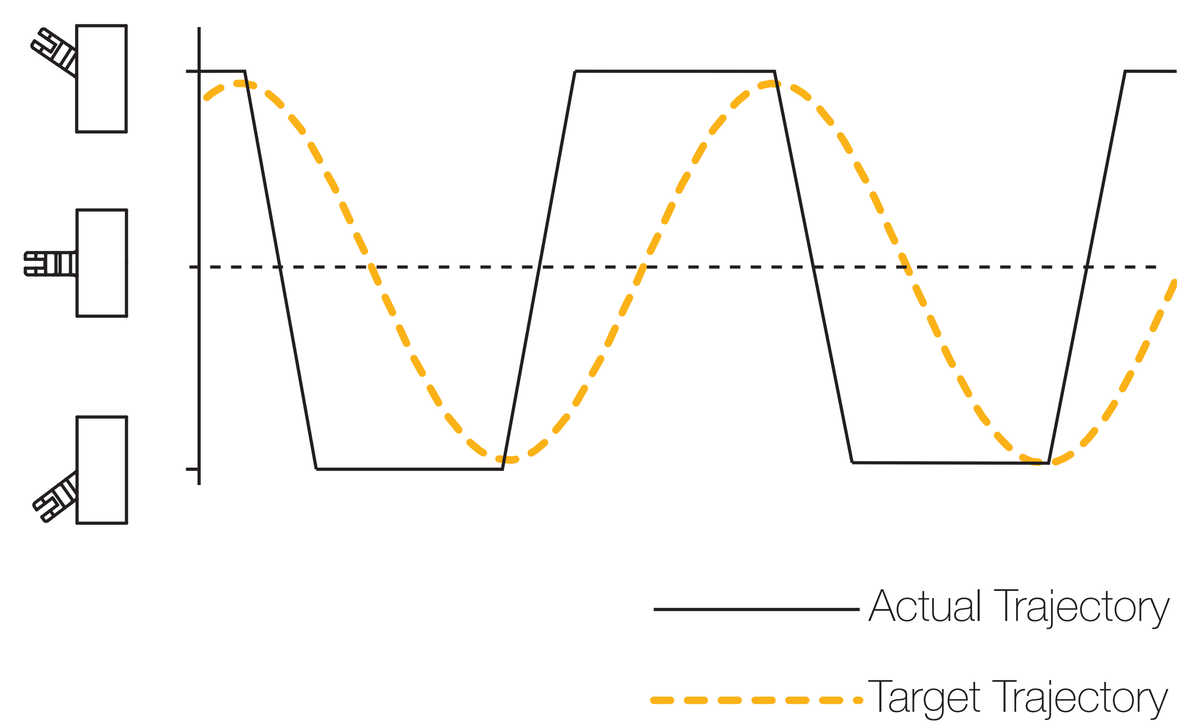
To create a miniature robot, a miniature actuator is needed. The Self-Organizing Systems Lab at Harvard University developed a simple magnet-in-coil actuator for this purpose ($1/unit), as standard motors are too large or expensive for the application. One of the limitations of this actuator is its lack of positional feedback, making it difficult to control. As the project has evolved, different control algorithms have been experimented with to produce a reliable swimming gait.



SCUBA Fish: Bang-Bang

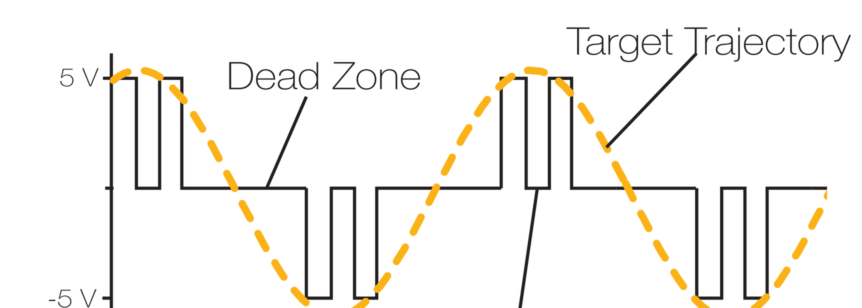
The first iteration of the fish moved the tail between two discrete states, right and left. While the SCUBA fish was able to demonstrate 3D maneuverability and autonomy, a significant area of improvement identified was increasing the robot's swimming speed and efficiency. Subsequent iterations of the robot experimented with a multi-jointed design to mimic the superior hydrodynamic performance of real fish.

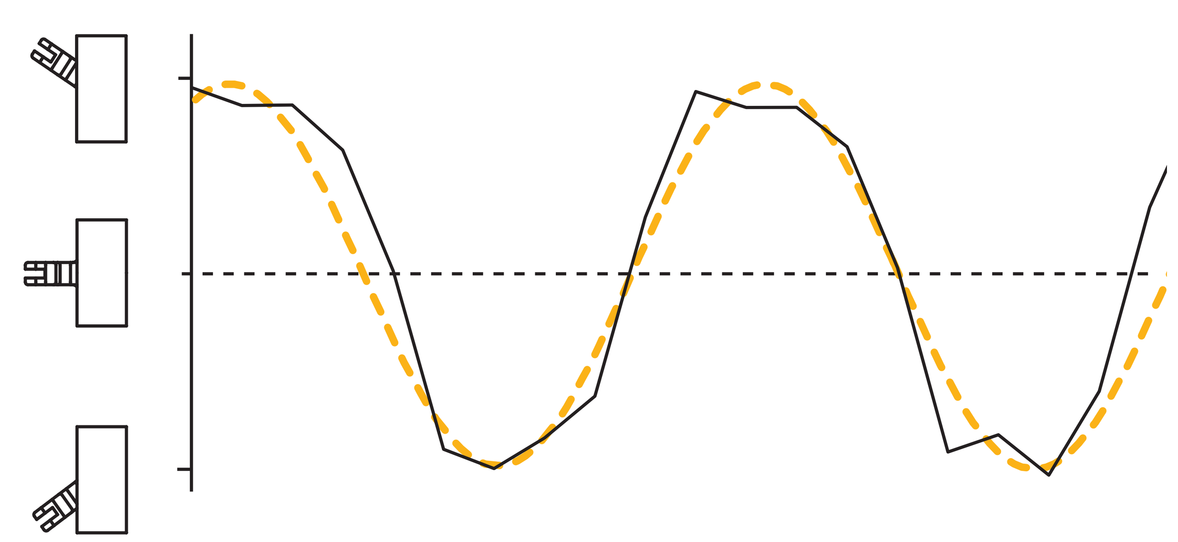




Beta Fish: PWM

Using multiple rigid joints to replicate the undulatory swimming gait of fish requires each joint to trace out a phase-offset sinusoidal trajectory. Pulse-width modulated (PWM) signals can be used to vary the perceived voltage the coil receives and thus control the torque output. The less voltage, the slower the fin moves through the water. On its own, PWM did not provide enough fine control to prevent the joint from snapping rapidly to its maximum position. The Beta fish did not achieve forward motion in the water.





MORA: PWM and Dead Zone

MORA, the current iteration of the robot, employs a dead zone in addition to PWM. The actuator is powered only during a percentage of the period, centered at the critical points of the sinusoid, to assist in changing direction. The rest of the joint's motion is smoothed and slowed by the water. This approach also provides control over the amplitude of the trajectory independent of frequency, as certain combinations of PWM and dead zone values at the same frequency will yield less or more torque.