Towards a neuromechanical model of swimming in the jellyfish Clytia hemisphaerica

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Generating and modulating behavior are important functions of nervous systems. To understand the neural control of behavior, we study Clytia hemisphaerica, a jellyfish with a diffuse nerve net and two dense nerve rings [1]. Clytia can produce a range of internal-state-modulated behaviors, including swimming, which is controlled by a distributed network and performed by a single muscle sheet [2]. Jellyfish swimming is highly efficient, and its fluid dynamics have been well characterized [3]. Here, we examine how Clytia's nervous system coordinates swimming, paving the way for future neuromechanical computational models that integrate neuromuscular models with fluid-structure interaction models.

A key element of neural control of swimming is turning , which is dynamically modulated during behaviors like foraging. We characterized turning behavior in videos of semi-restrained, swimming jellyfish, and found that jellyfish vary the dynamics of individual swim pulses in terms of their synchrony—the difference in contraction timing—and asymmetry—the difference in contraction depth. Using a state-space reconstruction technique, we furthermore found six behavioral modes that capture the jellyfish's postural dynamics [4].

To study how Clytia's nervous system modulates swim pulse synchrony and symmetry to create turns, we next modeled the activity of the dense ring of neural pacemakers that generate swim pulses in jellyfish. We adapted a Hodgkin-Huxley-like model [5] of stable and intrinsic subthreshold oscillations. We found that ring networks of these neurons synchronize across a range of coupling strengths, and that transient asynchrony can be induced in a subset of neurons by applying external current. A network's ability to synchronize or desynchronize is critically dependent on the pacemakers' phase response curve. Taken together, our analyses suggest that our simple network can qualitatively replicate components of our behavioral data. In ongoing work, we are performing further analysis of our data and model to fully elucidate the jellyfish's behavioral dynamics and its neuromechanical control.

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