NSF/NIH Collaborative Research In
Computational Neuroscience Workshop
Spring 2005 Principal Investigators' Meeting

Modeling and Analysis of Neuronal Circuits
(1R01NS046057-01-FY02)
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The broad aim for this project is to enhance the understanding of biological information processing mechanisms. The immediate goals are to uncover the fundamental roles of sensory feedback mechanisms in the neuronal control of animal locomotion and to establish mathematical models that predict the dynamical behavior of and supply missing information about the biological system. More specifically, the aims are to I) perform biophysical and physiological experiments on leech preparations to collect neuronal and mechanical input/output data needed for quantitative models, II) develop a mathematical model of the neuronal control system for leech swimming that includes sensory feedback, III) predict the effects of sensory feedback through numerical simulations of the model, and IV) test these predictions through physiological experiments on leech preparations. The project develops dynamical models of the leech locomotion control system, consisting of the central oscillator, muscle actuation by motoneurons, body-fluid interactions, and sensory feedback from stretch receptors, through parameter identifications based on experimental observations. So far a systems-level model of the central oscillator has been developed. We have found that the topology of intersegmental connections, determined from physiological data, allows for generation of stable phase-locked oscillations with intersegmental phase lags close to biophysical observations *without fine parameter tuning*. The model is shown to correctly capture the relation between the intersegmental phase lags and several crucial parameters including the intersegmental coupling strength and the intrinsic periods of segmental oscillators. A model has also been developed for the passive dynamics of leech longitudinal muscles. The length-tension data have been obtained through two types of experiments: the length is changed in multi-step (or piecewise constant) and sinusoidal manners. Models determined from the multi-step data are found capable of reproducing the tensions observed in the sinusoidal experiment on the same muscle. These models for the muscle and central oscillator are to be combined with models for fluid mechanics and body biomechanis through sensory feedback. Insights gained from the proposed research on leech swimming are expected to increase our general understanding of neuronal control systems.

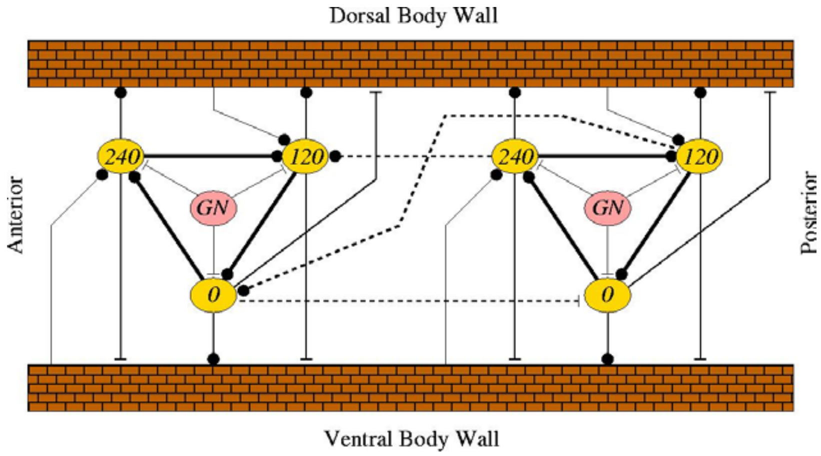

Figure: Systems-level model of the leech central oscillator with muscle activation and sensory feedback. Each circle represents a group of neurons. The connections with filled circles are inhibitory and those with bars are excitatory.

PI Website

http://www.people.virginia.edu/~ti3q

Publications

We have the following conference papers supported by NIH:

T. Iwasaki and M. Zheng, "What makes biological oscillators achieve robust self-excitation?" American Control Conference, 2003.

T. Iwasaki and B. Liu, "Feedback control with central pattern generator for decentralized coordination of prototype mechanical rectifier," American Control Conference, 2004.

M. Zheng, T. Iwasaki, and W.O. Friesen, "Systems approach to modeling the neuronal CPG for leech swimming," The 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2004.

The journal version in preparation:

M. Zheng, W.O. Friesen, and T. Iwasaki, "Systems-level modeling of neuronal circuits for leech swimming locomotion," J. Neurophysiology (in preparation).