C. ELEGANT

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Introduction

We propose a novel program to fully model the relationship between the neural circuits and behavioral dispositions of the organism *Caenorhabditis elegans* (*C. elegans*). This program is well matched to the current level of technological development, and is poised to provide important basic insights into systems neuroscience, with likely implications for artificial intelligence research in the future. At least, it provides a unique opportunity to establish an upper bound on the level of detail in neural simulation that is necessary to make predictions about the behavior of an entire organism; as a side product, the project may also contribute some degree of understanding about intermediate levels of abstraction between neurons and organism behavior.

Initial *in silico* work

We will begin with the closest current result to our eventual goal, a 2004 paper by Suzuki and Ohtake in which 18 *C. elegans* neurons involved in gentle touch response were modeled, using a real-coded genetic algorithm to tune the unknown parameters of a very simple sigmoidal neuron model to a predetermined mathematical model of the expected system behavior. There are a number of improvements that can be made to this approach immediately: using a more principled optimization technique, a more sophisticated model of behavior, and incorporating more interneurons in the model.

Behavioral and environmental modeling

Since our goal is to replicate the behavior of an organism—its interaction with its environment—a critical component of the project is to accurately model the environment and develop a quantitative assessment of the behaviors of interest. Fortunately, the environment in which *C. elegans* is usually observed is quite simple (a dish of agar). However, a literature search and possibly some new behavioral experiments will be necessary to establish a quantitative description of *C. elegans* behavior.

Experimental technologies

Such a project as this would not have been feasible five years ago. Without the tools to directly probe functional relationships between neurons, any computer- generated theories about how behavior emerges from neural circuits would essentially be guesses. This project involves significant biological work, and the experimental tools that enable such work are briefly discussed below.

Optogenetics

In 2005, Ed Boyden and collaborators published a technique for optical control of neural potential, through transgenic rhodopsins.

Calcium dyes

Genetic mosaic

Motion tracking

Optimization and meta-optimization