Cornell University
Center for Advanced Computing

Red Cloud with MATLAB case study

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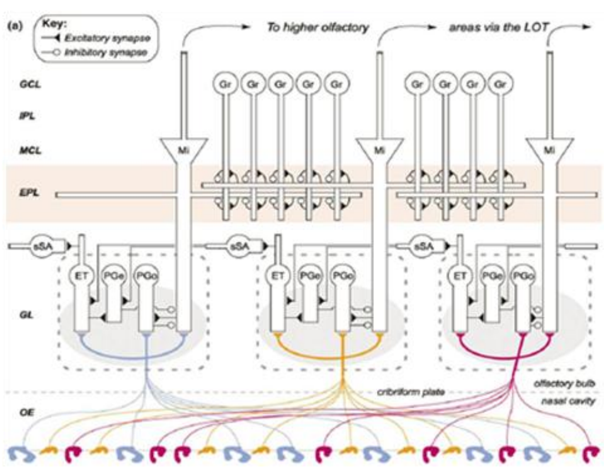
Thomas Cleland – Neural Algorithms: Understanding the Complex Computations of Brain Circuitry

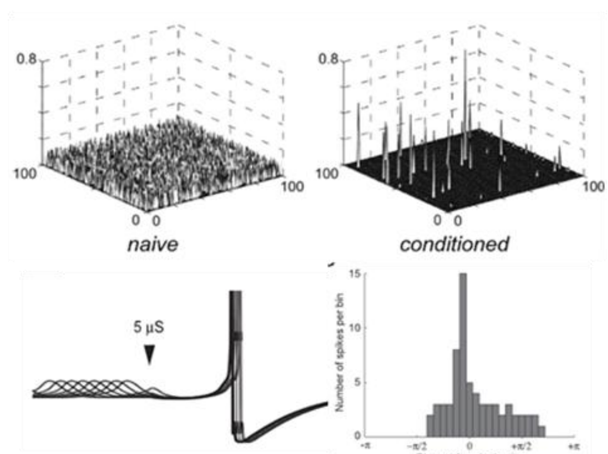
Neural circuits in our brains learn from our experiences in order to better predict the future. But how?

Finding the Answer

The olfactory bulb is a physically segregated region of the cerebral cortex that acquires and processes sensory information about odor, and also learns from experience. It also is a convenient microcosm of the larger brain for understanding the mechanisms of learning and memory in the brain, and how they adapt to the statistics of personal experience.

Thomas Cleland and his colleagues in Cornell’s Department of Psychology and Program in Neuroscience are studying the neural circuitry of the olfactory bulb, focusing on how these “wetware” circuits construct representations of odors, how these learned representations adapt according to experience, and how cellular and circuit mechanisms determine the form and longevity of the resulting memory. Algorithms developed in the lab have illustrated how high-dimensional, similarity-dependent transformations can be computed using established olfactory bulb circuitry, how subthreshold voltage oscillations in principal neurons can regulate spike timing in the network, how neurons in the bulbar network can learn about the statistics of odor presentations based on this spike-timing regime, and how ascending neuromodulatory pathways can govern bulbar circuit plasticity based on the behavioral state of the organism. Some of these algorithms, first developed as traditional computational models, now are being instantiated in hardware devices.





Improved Research

Research Metrics

- Efficiency: Time-varying needs for burst computing resources and commonly requested software, e.g., MATLAB, make it most efficient to outsource to a cloud computing provider that also offers consulting and turnkey HPC cluster hosting and maintenance services.
- Speed: CAC resources enable rapid, interactive parallel simulations for exploratory modeling as well as speed-optimized large-scale simulations.

Research Challenge

Reverse-engineering neural circuitry requires a great deal of exploratory modeling, for which interactivity and ease of use are priorities. Although occasionally it is necessary to set up large parameter searches, it is more typical that many simulations of moderate complexity need to be performed interactively. These simulations often are too large to execute effectively on desktop workstations (requiring hours to days to weeks to complete), but can be completed in an interactive timeframe (minutes to hours) on Red Cloud with MATLAB. The results from these moderately complex simulations then often guide the construction of larger-scale simulations for which efficient parallelization and high-end computational resources are absolute necessities.

Dr. Cleland's research group models the biophysics of single neurons as well as networks of thousands of neurons, and sometimes models networks comprising large numbers of biophysically complex neurons. These simulations simply cannot be performed without high-performance computing resources. Fortunately, they are often quite amenable to both trivial and nontrivial parallelization.

Solution

Red Cloud with MATLAB enables MATLAB-based models to scale up to the levels necessary for useful neuronal network simulations, enabling substantially complex models to be run on an interactive timescale. Consequently, it is excellent for exploratory MATLAB modeling; from the user perspective, it is quite like working directly on an unreasonably powerful desktop workstation. Its characteristic ease of use also facilitates the inclusion of undergraduate students in computational modeling research.

For network models based on Python, the simulator NEURON, and/or other source languages, we use CAC's v4/v4dev Linux cluster. The v4dev cluster enables rapid exploratory and pilot modeling without complicating the allocation of resources in v4 proper.

The Clients

Thomas A. Cleland, Dept. Psychology and Program in Neuroscience, Cornell University

- Computational Physiology Laboratory co-director.
- Research in systems neuroscience, learning and memory, focusing on the olfactory system. The Cleland group studies how learning, memory, expectation, and like processes shape the transformations performed on sensory inputs by relatively peripheral (i.e., experimentally accessible) cortical circuitry, and how these different transformations in turn influence behavior and subsequent learning.
- Undergraduate, graduate, and postdoctoral researchers such as Anuttama Sheela Mohan, Guoshi Li, Pavel Sountsov, Licurgo de Almeida, and Pedro Rittner.

The Collaborative Relationship

"Our need for computational power is substantial but uneven. Computing in the cloud with Red Cloud with MATLAB and leveraging other CAC computational resources when we need them is an ideal solution for us. CAC's flexibility and willingness to support the multiple configurations we need enables us to work effectively without assuming the complex burden of cluster hosting and maintenance."

Thomas A. Cleland
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