Cornell University
Center for Advanced Computing

# CAC and Jonathan Victor

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## A Mystery of Neuroscience: How Do We See?

What features of the activity of neurons are important for visual perception?

### Finding the Answer

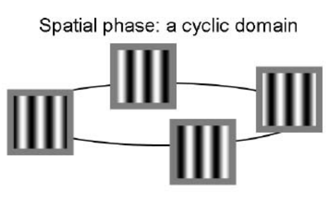
Dr. Jonathan Victor, Director of Weill Cornell Medical School's Laboratory of Clinical Neurophysiology, collaborated with the Center for Advanced Computing to reduce computing time required to analyze neurophysiologic data from several months to 1 day or less.

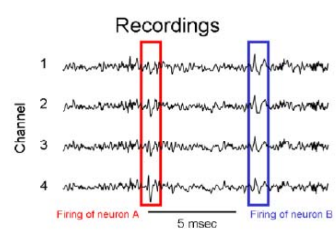
### A Mystery of Neuroscience

The human brain is made of approximately 100 billion nerve cells, called neurons, which gather and transmit electrochemical signals. While it is generally assumed that neuronal activity in the brain accounts for perception and cognition, the details of this relationship remain one of the central mysteries of neuroscience. For example, it is unclear which features of the activity of neurons are relevant to perception: the precise firing times of individual neurons, the overall firing rate of a small population of neurons, synchronization across populations, or many other possibilities.

Dr. Victor's laboratory is studying the activity of neurons in the areas of the brain engaged in visual processing, examining their responses to visual stimuli designed to determine which features of neuronal activity are relevant to perception.

Examples of those stimuli are "sinusoidal grating" patterns – patterns of equally-spaced lines – whose brightness varies smoothly from dark to light and back again. The stimuli differ in the position of the bars, referred to as the "spatial phase."




Above: Sinusoidal Grating Patterns used with Victor's research.
Right: Small Segment of the Raw Recordings.

The research team records the activity of small groups of cells that respond to these stimuli and uses statistical methods to characterize "neural coding" – patterns of neuronal activity that are reliably associated with the visual stimuli that are presented.

## Improved Research

### Research Metrics

- Speed: Optimize serial research code; parallelize for speed-up
- Scalability: Test, tune, and run code on CAC high-performance computing systems

### Research Challenge

Jonathan Victor's neuron research required the development and implementation of algorithms to characterize neural coding. Although the algorithms were efficient, the analysis of data generated from the simultaneous recording of two neurons required many hours of processing on a desktop computer. Since multiple analysis runs were required to test their research hypotheses, a full analysis would require weeks.

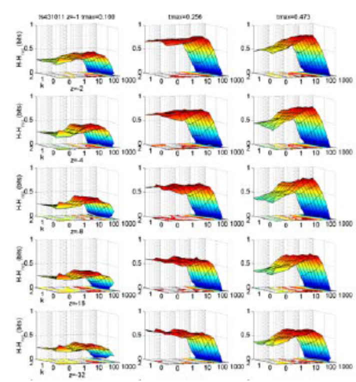
"Stepping from two neurons to three or four neurons represents a tremendous increase in the computational burden," explained Dr. Victor. "Moving to just three neurons results in an explosion in the amount of computation that is necessary, despite the use of efficient algorithms." The analysis of a "triplet" would take several months on a desktop computer.

### Solution

Dr. Victor's research group used The MathWork's MATLAB for data analysis and initially ran the computations serially. Dr. Victor and a Weill Cornell graduate student worked with a CAC applications consultant to optimize the program, first in its serial version. Performance was improved by a factor of five. However, the data generated from Dr. Victor's neuron research is numerically intense and CAC knew that performance would be further improved if the program was parallelized.

Running in parallel on CAC's high-performance computing clusters, Dr. Victor was able to do analyses that would otherwise take several months in just 12 to 24 hours.

"We gained about a factor of 100 because of the efficiencies realized through code enhancement and parallelization," said Dr. Victor. This means that we can now analyze triplets or quadruplets of neurons, and carry out variations on the analysis to ask a wider range of scientific questions. With the new analysis capabilities, we're able to move into production mode and begin analyzing large amounts of data."



### The Client

Jonathan Victor, Professor of Neurology and Neuroscience, Weill Cornell Medical College

- Director Laboratory of Clinical Neurophysiology
- Attending Neurologist
- Research on mechanisms of neural information processing and how brain diseases affect perception

## The Collaborative Relationship

"CAC's computational power allows us to ask questions that we couldn't ask before to answer a fundamental question in neuroscience."

*Jonathan Victor, M.D., Ph.D.*
*Professor of Neurology and Neuroscience*
*Weill Cornell Medical College*