Neuroscience Gateway

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Abstract

Neuroscience is a vast field requiring many different methods for computation, experimentation, and modeling. To start, we investigated the applications of supercomputing and observed the benefits and limitations of parallel computing. Then we analyzed EEG brainwave characteristics in eyes open and eyes close state and what differentiated the two. Finally, we explored large scale cell modeling in NEURON.

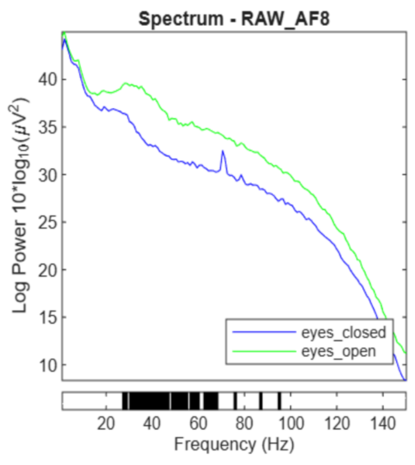
Comparing Eyes-Open and Eyes-Closed EEG Signals With Muse and EEGLAB

Introduction: EEG, otherwise known as electroencephalography, is a method for recording electrical activity stemming from the brain using electrodes placed on the scalp. EEG measures voltage changes generated by large groups of neurons. EEG is a good example of interdisciplinary neuroscience as it combines brain biology, electrical measurement, data processing, and interpretation.

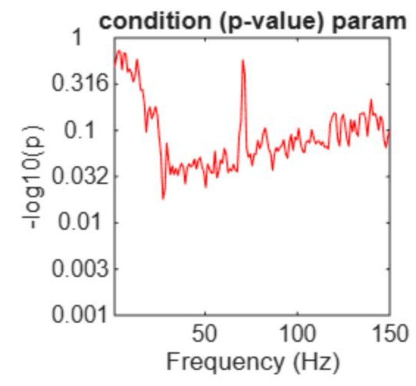
For our research, we used Muse headsets to help record large-scale neural activity. Our Muse headsets had four main EEG electrodes:

- AF7: left frontal area
- AF8: right frontal area
- TP9: left temporal/parietal area near the ear
- TP10: right temporal/parietal area near the ear

Eyes Open vs. Eyes Closed EEG/MatLab Graphical Comparisons:



P Difference Graphical Comparisons:



Results: When $p < 0.05$, there is a statistically significant difference. When evaluating the RAW AF8 Spectrum graph that compared data with eyes open and closed, a large statistical difference was observed between **20 and 100 Hz**. This range of difference matches up with **Gamma brainwaves**, which range from 30 to 100 Hz. Gamma brainwaves are usually associated with thought, focus, and cognitive functioning. Thus, the statistical difference between RAW AF8 Spectrum and RAW AF8 P Difference Graphs provides evidence of a **difference in attention** when eyes are open or closed.

Conclusion

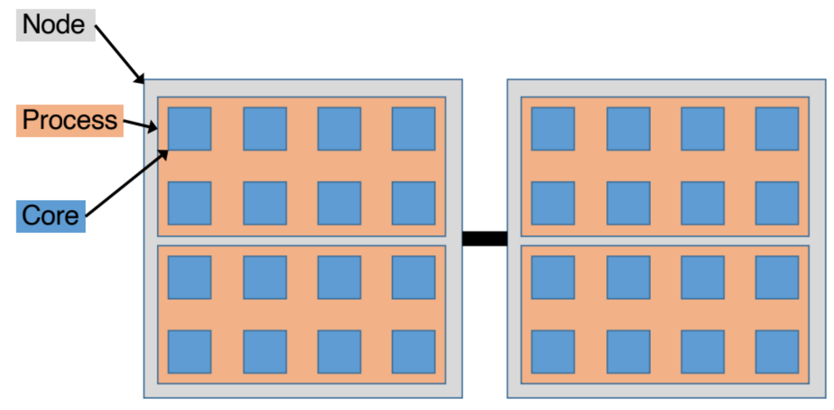
We explored several computational applications in neuroscience, including high performance computing, EEG signal analysis, and neuron modelling. We discovered how parallel computing accelerates computational tasks, how data analysis could reveal patterns in brain activity, and how cell simulations led to read world discoveries in neuron behavior. Together, they highlighted the growing role of computational tools in neuroscience, allowing us to gain a deeper understanding of the worlds diverse research to further our understanding of the human brain.

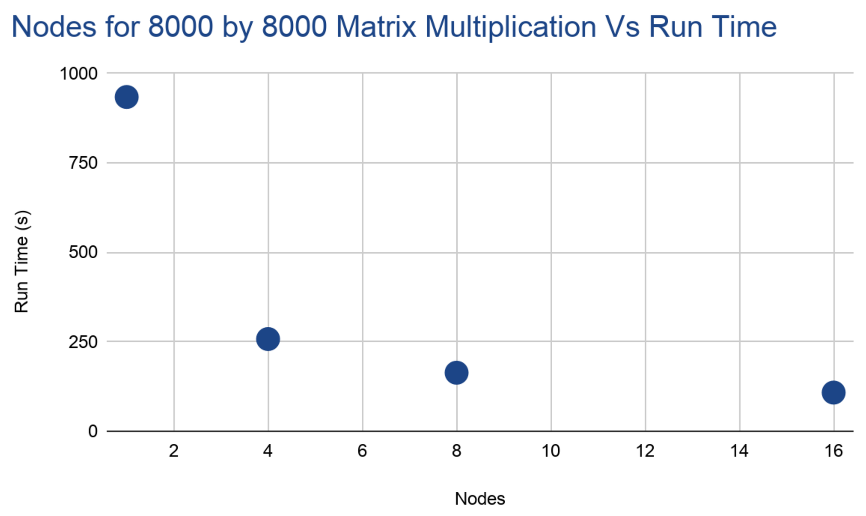
Expanse High Performance Computing Using OpenMP and MPI

Introduction: With the power of supercomputing, researchers are able to run models at a massive scale with the help of the Expanse machine and Neuroscience Gateway. With the sheer scale of computation required for these experiments, we explored the methods and tools that have been adapted to speed up each job. To start, we utilized SLURM batch job manager to run parallel jobs and explored timing optimization across different cores and thread variations

Method:

- Ran batch jobs through UCSD Expanse Supercomputing machine and SLURM
- Tested increase in cores to productivity in MPI Matrix Multiplication





Using parallel computing, at a certain number of nodes allocated for the job, run time no longer significantly decreases

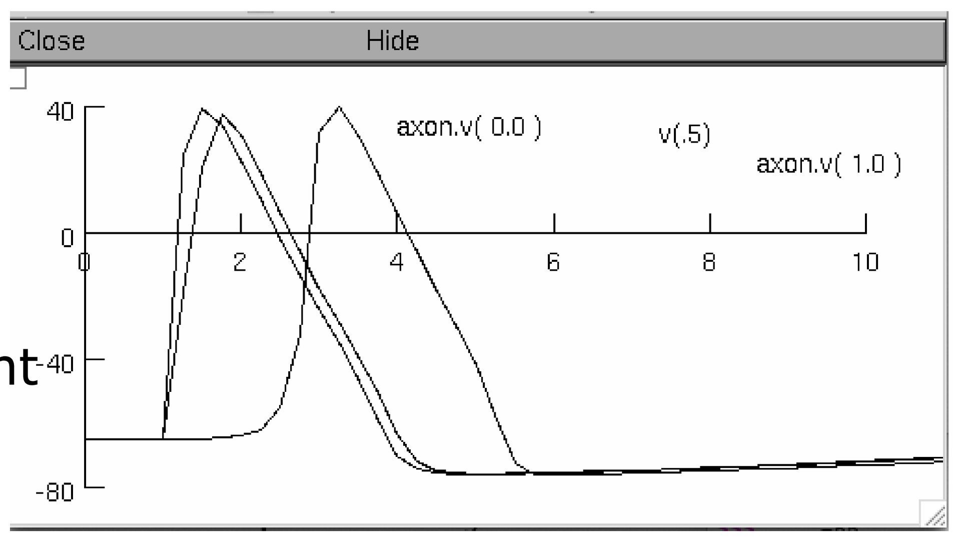
Computational Neuroscience: Running Models with NEURON

Introduction: With the microscopic scale of neuroscience and the yet unknown properties of the brain, it is especially hard to run live experiments.Thus computer simulations and modeling are especially handy. Using NEURON, a software tool that creates models of biophysically detailed neurons and runs simulation, we explored various models and simulations.

Experiments:

Squid axon:

- This model represents the measured voltage at different points in the axon
- Each location has the same action potential but at different times, meaning the electrical signals are regenerated as it moves along the axon, doesn't weaken over distance
- Demonstrates how voltage gated ion channels generate and propagate action potentials



Can a nerve impulse still travel across an axon if its myelin sheath is damaged?

Waxman and Brill built a computer model containing 11 nodes of Ranvier with 10 myelinated internodes between them (each node w/ voltage gated sodium and potassium channels). The internodes didn't have ion channels and action potentials jumped from node to nod, **proving conduction velocity is constant.** Then, they replicated this experiment with one damaged internode (myelin removed). Without myelin, current leaks out of the membrane, therefore spike either gets delayed or completely dies before reaching next node, concluding that **demyelination disrupts nerve conduction.**

References

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