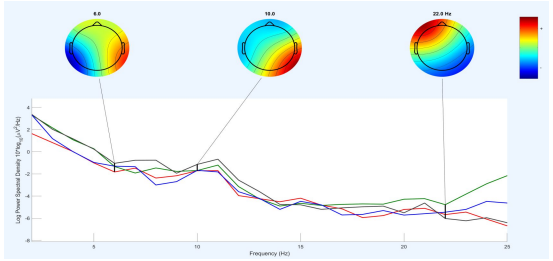
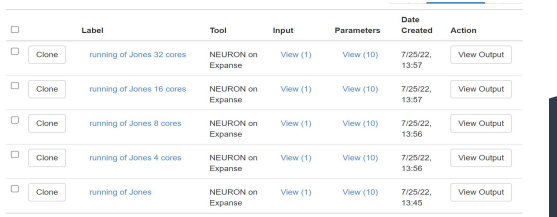
Neuroscience Gateway

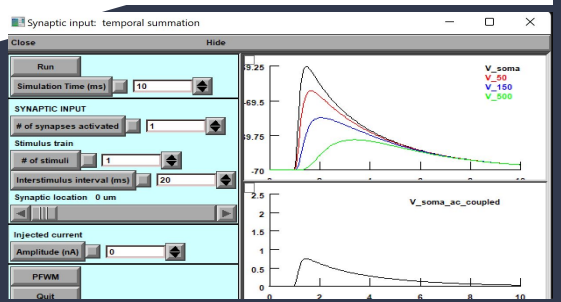
Simran Nadig – Oak Park High School
Amaia Schmitigal – Westview High School
Anika Yadav – Westview High School
Maan Patel – Rancho Bernardo High School

Mentors:
Amit Majumdar - UCSD
Dung Truong - UCSD
Ted Carnevale - Yale





	Label	Tool	Input	Parameters	Date Created	Action
Clone	running of Jones 32 cores	NEURON on Expanse	View (1)	View (10)	7/25/22, 13:57	View Output
Clone	running of Jones 16 cores	NEURON on Expanse	View (1)	View (10)	7/25/22, 13:57	View Output
Clone	running of Jones 8 cores	NEURON on Expanse	View (1)	View (10)	7/25/22, 13:56	View Output
Clone	running of Jones 4 cores	NEURON on Expanse	View (1)	View (10)	7/25/22, 13:56	View Output
Clone	running of Jones	NEURON on Expanse	View (1)	View (10)	7/25/22, 13:45	View Output

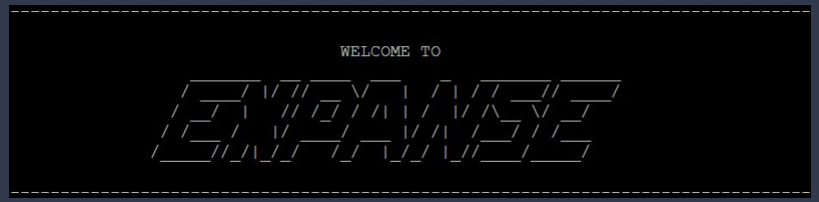


Outline:

- Parallel Computing
- EEGLAB and Processing Brain Waves
- Computational Neuroscience

What is Expanse?

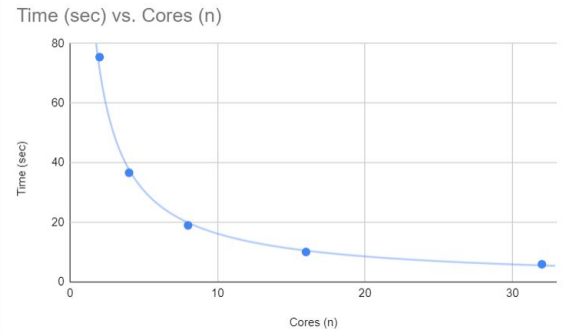
SDSC SAN DIEGO SUPERCOMPUTER CENTER
at the UNIVERSITY OF CALIFORNIA SAN DIEGO
COMPUTING WITHOUT BOUNDARIES



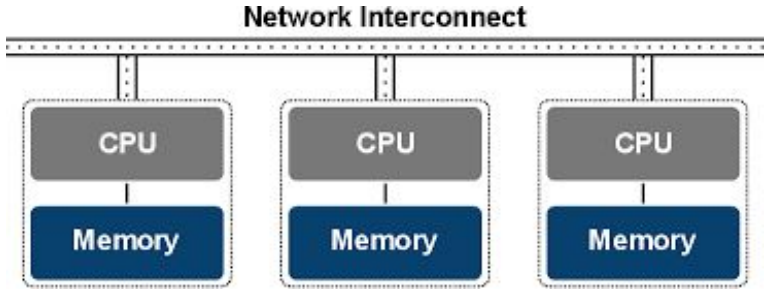
- Expanse is a supercomputer
  - Allows us to create/submit jobs that help us to solve difficult computational problems which normal computers would not be able to do
- Used Expanse to aid us with parallel computing, distributed memory parallelization using MPI, matrix multiplication, and the Jones Model.
- Submits jobs (SLURM Scripts) that allow us to get outputs.
  - We can control the number of cores that we run the code on
  - There is an optimal number of cores for each task → when choosing task, it's important to understand what a certain number of cores means in terms of speed and accuracy.

Distributed Memory Matrix Multiplication Parallelization Using MPI

Cores (n)	Time (sec)
2	75.440657
4	36.633452
8	18.977275
16	10.052567
32	5.929294



- **Distributed memory** – each processor has its own local memory. Message passing needs to be done to exchange data between processors.
- **Parallel processing** – running 2 or more processors to handle separate parts of a common task.
- **MPI (Message Passing Interface)** – allows us to utilize parallel processing, explicitly associate specific data with processes, and decrease time to run tasks
- Using MPI, we can control the data that we share between cores → each core does work parallel to the other(s).

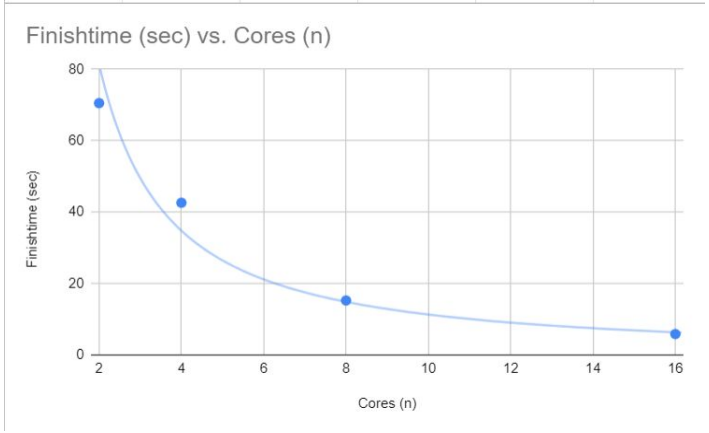


Jones Model Timing Results Using Neuroscience Gateway (NSG)

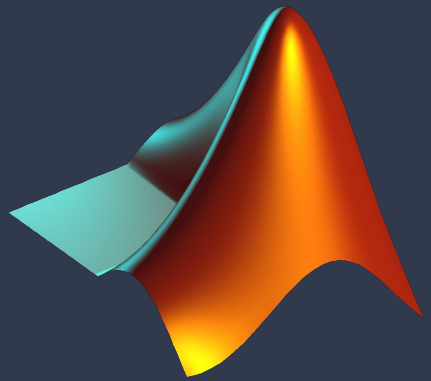
XSEDE
Extreme Science and Engineering Discovery Environment

- NSG allows us to utilize XSEDE supercomputers to help us with the computational part of neuroscience
- The Jones Model was run on NSG
  - Jones studied realistic networks in the neocortex
  - Used NEURON as his simulation environment
  - We can run it on NSG and see how long it takes a certain number of cores to run it.

Cores (n)	Finishtime (sec)
2	70.52
4	42.61
8	15.24
16	5.84

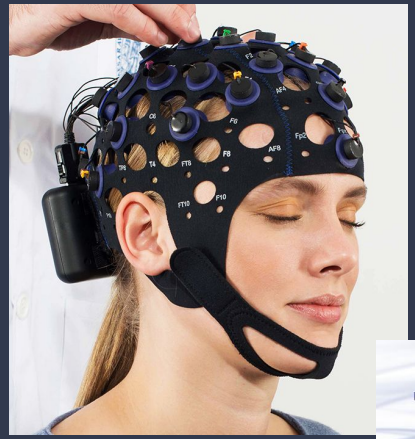


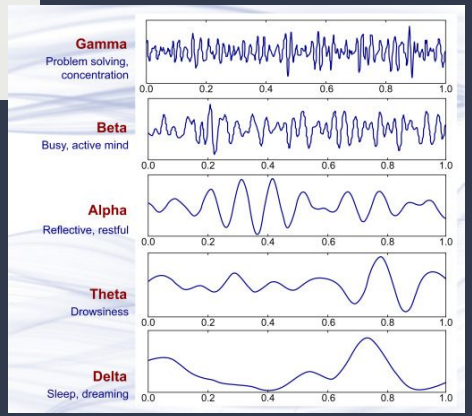
Using EEGLAB and Matlab to Process Brain Waves



Swartz
Center for
Computational
Neuroscience

What is EEG?





- EEG = electroencephalogram
- Measures electrical activity in the brain using electrodes attached to scalp
- Brain cells communicate via electrical impulses and are active all the time (+sleep) → activity shows up as wavy lines in an EEG recording
- Used to evaluate different brain disorders
  - Ex: epilepsy → seizures show up as rapid spiking waves
  - Ex: lesions (from tumors or stroke) can have slow EEG waves
- Used to measure brain waves during sleep

Using the MUSE EEG Recording Device

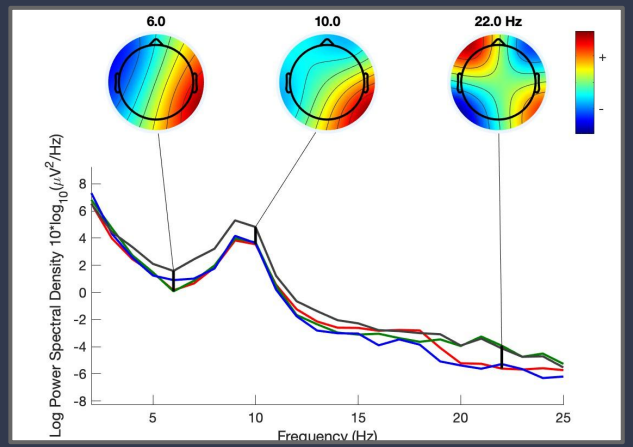
- A bluetooth EEG device in the form of a headband (6 electrodes) that senses electrical rhythms of the brain
- Coupled with an app called Mind Monitor which measures the brain waves once the electrodes are connected
- We connected it with the app and measured data when our eyes are open and when they are closed (3 minutes each)
    - We made sure that we did not move too much and stayed in a room with not many electrical interruptions so as to not disrupt the data

Step by Step:

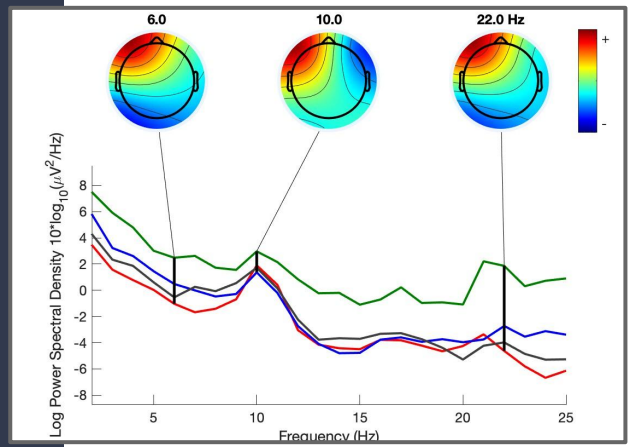
Processing Data on EEGLab

1. Emailed data from app to our computers & downloaded it
2. Using MatLab, we opened EEGLab
3. Uploaded our data to EEGLab
4. Filtered the data
    a. To remove linear trends, it is desirable to conduct a high-pass filter of the data
5. Re-referenced the Data
    a. Calculating the average reference is recommended for source localization
6. Manual Rejection
    a. Scrolled through data and identified bad channels with higher noise content
        i. Could have been an instance where we blinked, moved our eyes, repositioned our bodies etc

Results:



EYES CLOSED

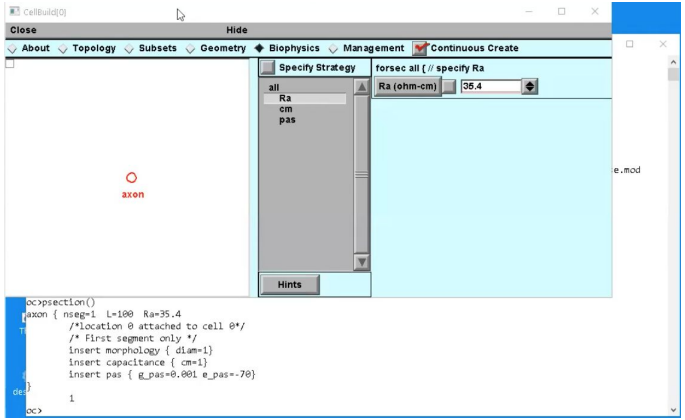


EYES OPEN

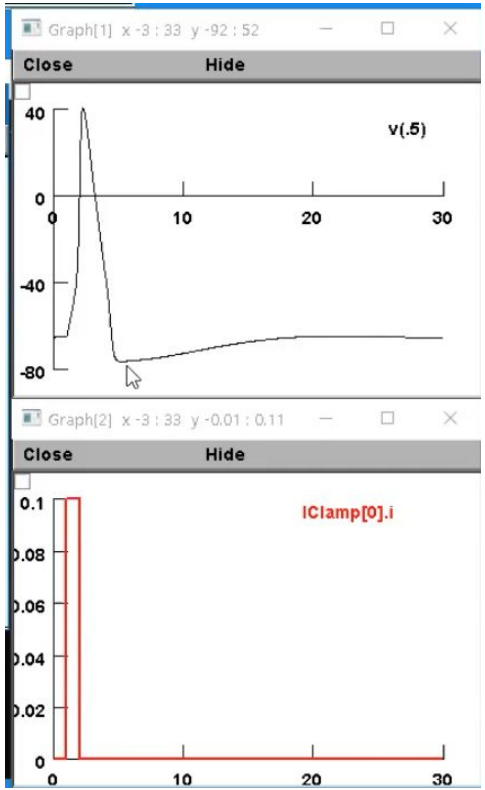
Computational Neuroscience

Neurons as Conductors of Electricity

- Neurons pass signals through the membrane that generates an impulse
- To understand this communication, knowledge of synaptic transmission and electrical currents passed along in the nerve must be understood
- A large diameter and high membrane resistance leads to current spreading farther along the neuron fiber
- The geometry of the membrane and its caricaturists can tell us its threshold potential change
- The nerve cell is covered by the myelin sheath which is an insulator and allows the signal to be passed along quicker



Creating a cell for experimentation



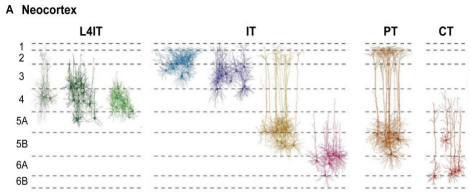
Membrane potential with current stimulus

Cell Shapes Affecting Chemical and Electrical Signals

Neocortical Laminations: Insights from Neuron Types and Evolutionary Precursors article summary:

- In the olfactory, hippocampus, an dorsal parts of the forebrain, there exists a three-layer cortex that responds to excitatory and inhibitory inputs

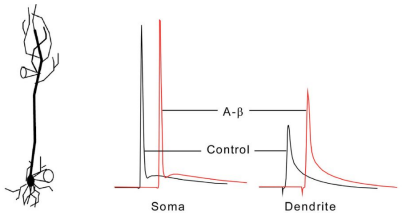
- The development of the three-layer cortex can be traced to the six-layer mammalian

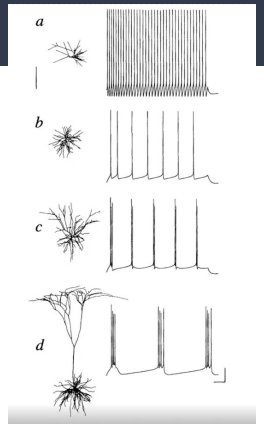


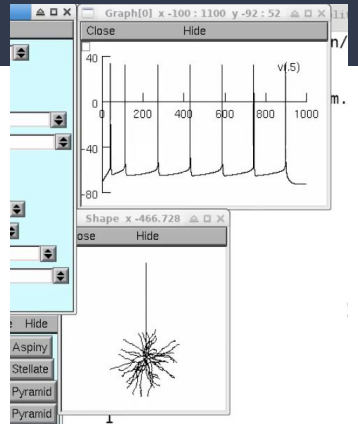
Abnormal excitability of oblique dendrites implicated in early Alzheimer's: a computational study article summary:

- This study use computational modeling to analyze hyperexcitability in distal dendrites

- The results show the action potentials create hyperexcitability and excessive calcium concentrations







Influence of dendrite structure on firing pattern in model neocortical neurons article summary:

- Density variation in ionic channels can be attributed to electrical responsivity

- Using computational models, they are able to recreate the firing patterns by neurons that share similar ion channels, but not dendrite geometry

- Results indicate a relationship between dendrite structure and firing properties

Thalamocortical Cortex

This experiment aimed to better understand thalamocortical neuronal ensembles

Created a network model containing different types of neurons

- Such as superficial pyramids (with regular spiking [RS] and fast rhythmic bursting [FRB] firing behaviors), etc.

Network examined behaviors of gamma oscillations, sleep spindles, synchronized population bursts, double population bursts, etc

Electrical coupling between axons, synaptic exicationton between spiny stellate cells, and their tendency to fire in multiple burst plays a role in epileptogenic events

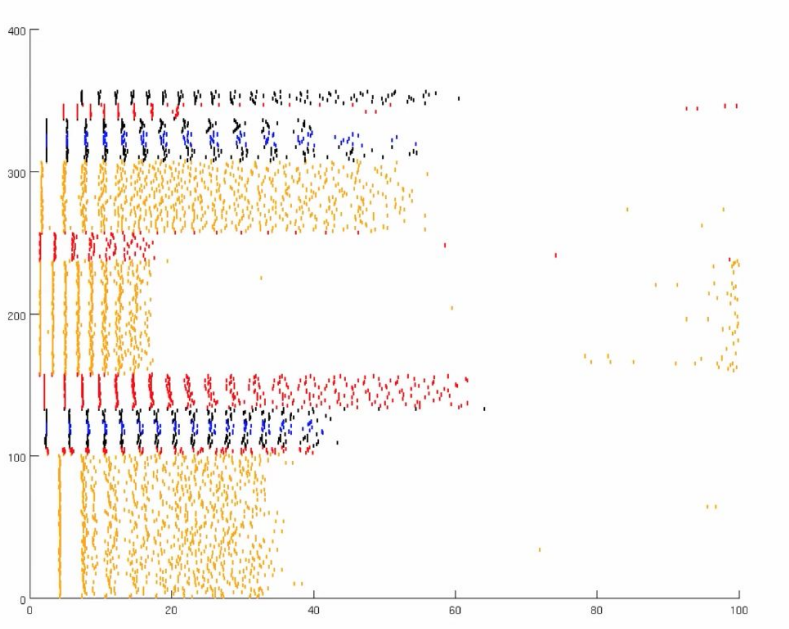
```
RunTime: 3595.53
Maximum integration interval: 1e+09
histogram of #spikes vs #exchanges
0       0
end of histogram
                    total        min        max    idmin    idmax
eqn                     0          0          0        0        0
NetCon             109982     109982     109982        0        0
deliver                 0          0          0        0        0
NC deliv                0          0          0        0        0
PS send                 0          0          0        0        0
S deliv                 0          0          0        0        0
S send                  0          0          0        0        0
S move                  0          0          0        0        0
Q insert          3398762    3398762    3398762        0        0
Q move                  0          0          0        0        0
Q remove          2591512    2591512    2591512        0        0
max sent                0          0          0        0        0
sent                    0          0          0        0        0
received                0          0          0        0        0
used                    0          0          0        0        0

setup      run        avgspkxfr  avgcomp    avgx2q     avgvxfr    avgsplit   avgcmplx
2.66       3596       0          3595       0          0          0          9.673e+05

     id   spkxfr     id   com        id   x2q        id   vxfr       id   split      id   cmplx
min  0    0          0    3595       0    0          0    0          0    0          0    9.673e+05
max  0    0          0    3595       0    0          0    0          0    0          0    9.673e+05
endtime 0.1099999
```

Bash window running experiment and results

Output data



Conclusion

- Learned about computational neuroscience through presentations and scholarly articles
- Analyzed data with Expanse, EEG, and NEURON
- Talked to computational neuroscientists about future career paths
- REHS helped introduce us to our future career/research interests