SimPL EEG Data Visualization

June 18, 2021

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Project mentor: Joel Ostblom

Introduction

Main Goal: Package

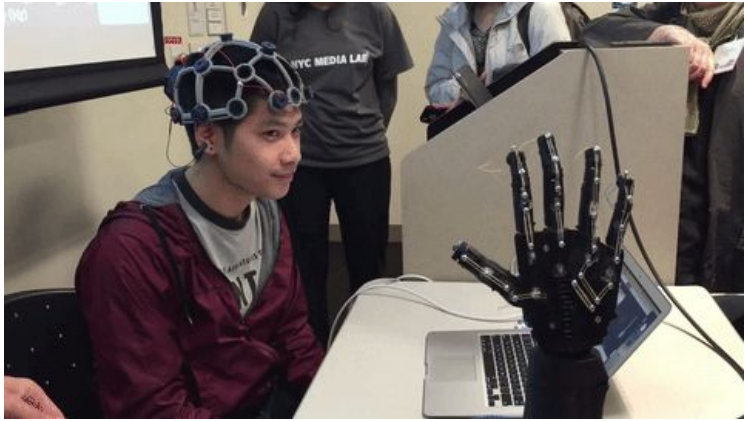
Main Goal: User Interface

Stretch Goal: Clustering

Conclusion

What is EEG?

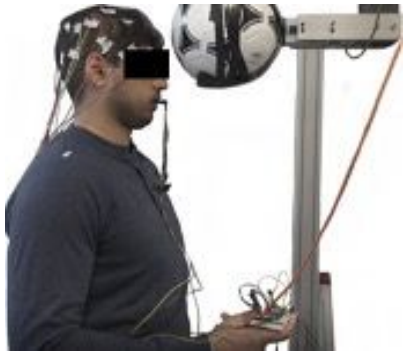
- A set of external electrodes placed on top of the skull to measure electrical potential in the brain
- Advantages:
  - High temporal resolution
  - Cheap
  - Unobtrusive



Our Capstone Partner

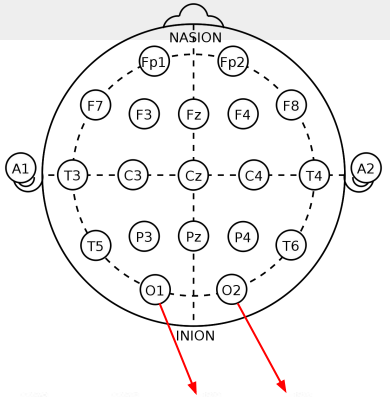
SimPL at UBC

- **S**ensing **i**n Bio**m**echanical **P**rocesses **L**ab
- Develops advanced sensing and data analytics techniques
- Focused in sport head injuries
- Employs electroencephalograms (**EEG**) for analysis
- Provided EEG data from 8 experiments



Data Provided by SimPL

- 19 electrode nodes (make 19 channels/columns)
- 1.5 hours per experiment measured @ 2048 Hz
- 33 impacts per experiment (measured in timestamps)



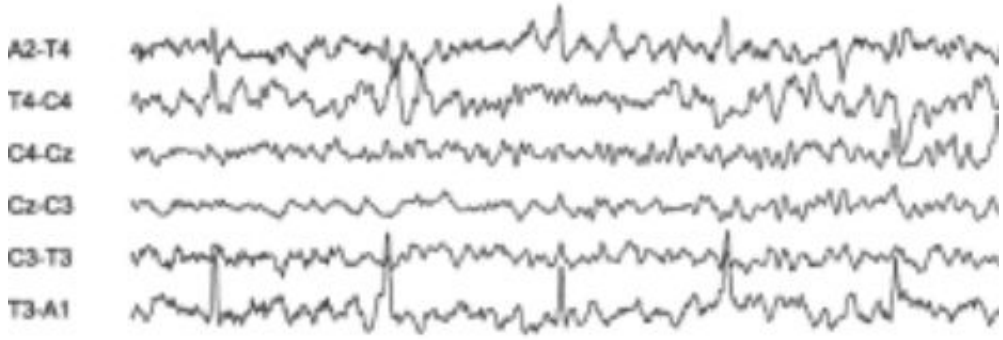
time	Fp1	Fp2	F7	T3	T5	F3	C3	P3	Fz	Cz	Pz	F4	C4	P4	F8	T4	T6	O1	O2
0	5.249967	6.655970	-4.434475	4.304095	17.676922	8.274990	5.277716	-5.298819	7.670161	-5.680321	2.303462	10.845702	1.906006	9.311716	-1.323244	6.466196	18.021606	4.767320	18.366028
0	5.278089	6.695436	-5.000164	4.084442	17.299467	8.143000	5.196838	-6.056608	7.656211	-5.643856	2.151131	11.066680	1.979347	9.305128	-1.577195	6.457521	17.939810	4.684548	18.176613
1	-0.704738	-2.400346	9.224086	4.510412	7.809945	4.485216	11.136824	20.472145	-2.422097	7.093482	12.430429	-1.899119	-0.629464	8.592073	1.141066	-2.306223	-2.914821	0.205369	-0.727486
1	-0.677084	-2.362067	8.752637	4.334788	7.497952	4.382829	11.066937	19.875942	-2.430228	7.118731	12.330954	-1.702163	-0.555030	8.585756	0.934380	-2.310043	-2.957141	0.150291	-0.842389
2	-0.871208	-3.770564	26.662954	4.588190	-3.349652	-3.055428	6.479112	19.816639	-6.230808	16.779474	15.611196	-6.215553	3.564851	10.873356	3.784559	-1.346608	-3.562572	3.920749	-6.992103
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5414299	5.882370	6.417542	3.576848	2.278841	-0.690300	6.574977	5.391859	-0.303467	9.869918	10.660233	2.687029	13.076114	14.226103	7.042773	3.503975	4.731483	2.090857	2.236192	13.754395
5414299	4.810019	5.209940	-1.924309	0.210620	-2.272475	2.603113	1.964148	-0.239862	7.261303	11.247967	3.286069	11.544709	12.174756	7.065387	1.609997	4.573243	4.996539	1.130259	16.944593
5414300	2.618884	3.422156	-2.655280	0.714436	3.448523	0.809813	4.582190	2.913018	2.620033	8.231747	5.732580	11.546264	13.648458	5.206041	-0.061993	2.883816	3.326997	2.958239	16.004593
5414300	3.358315	3.451100	1.095874	2.892261	2.921138	4.362070	4.841438	5.190645	3.713583	7.304112	7.861675	9.032394	12.721871	7.915611	1.000668	3.539896	3.228356	2.785509	8.316413
5414301	4.449532	4.165589	7.794319	2.888578	4.594507	4.161007	2.859490	4.836564	6.169818	8.420313	3.841559	7.838594	10.758005	5.795454	3.288671	4.058389	0.845247	1.097919	-0.030489

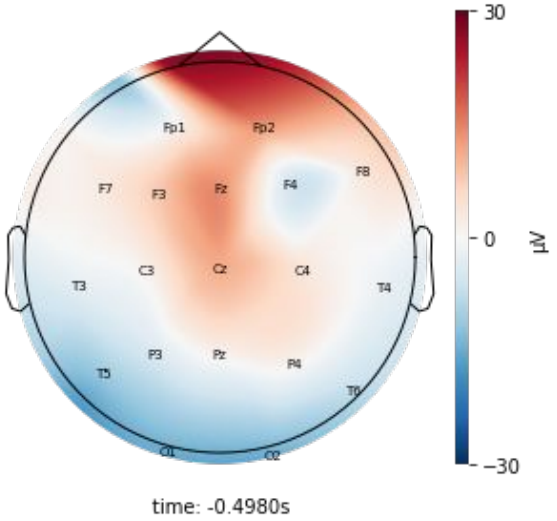
Why is visualizing EEG data important?

EEG data is complex

- Thousands of readings per sec
- Multiple channels
- Visualization tools needed to interpret

C3	P3	Fz	Cz	Pz
-0.022154	1.643101	-14.908266	-3.842329	4.032097
-2.544600	-7.484372	5.960825	-1.607204	-6.082575
-1.294117	1.392850	2.142001	-0.797354	-2.627173
-2.317574	-1.640691	2.578431	-2.599033	-1.800493
-4.060230	-0.980359	-3.455901	1.378618	3.087605

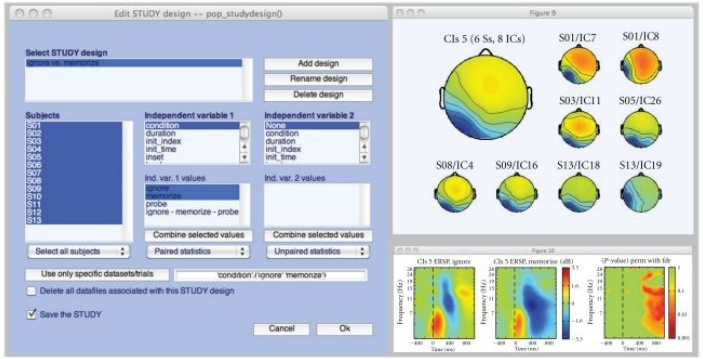




What visualization tools currently exist?

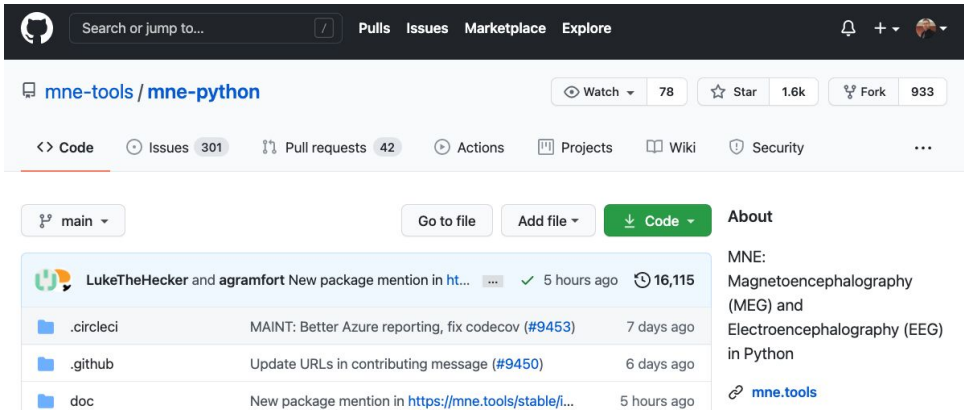
EEG Lab - Toolbox for Matlab

- Limited visualization options
- No animation capability



MNE - Python Package

- Significant pre-processing required
- EEG functionality is secondary



Other Software

- Old
- Barebones

Our Capstone Goals

Main Goals

- Python visualization and metrics package
- Interactive UI using Streamlit (no coding required)

SimPL

Stretch Goal (in progress)

- Unsupervised clustering for identifying brain states

Introduction

Main Goal: Package

Main Goal: User Interface

Stretch Goal: Clustering

Conclusion

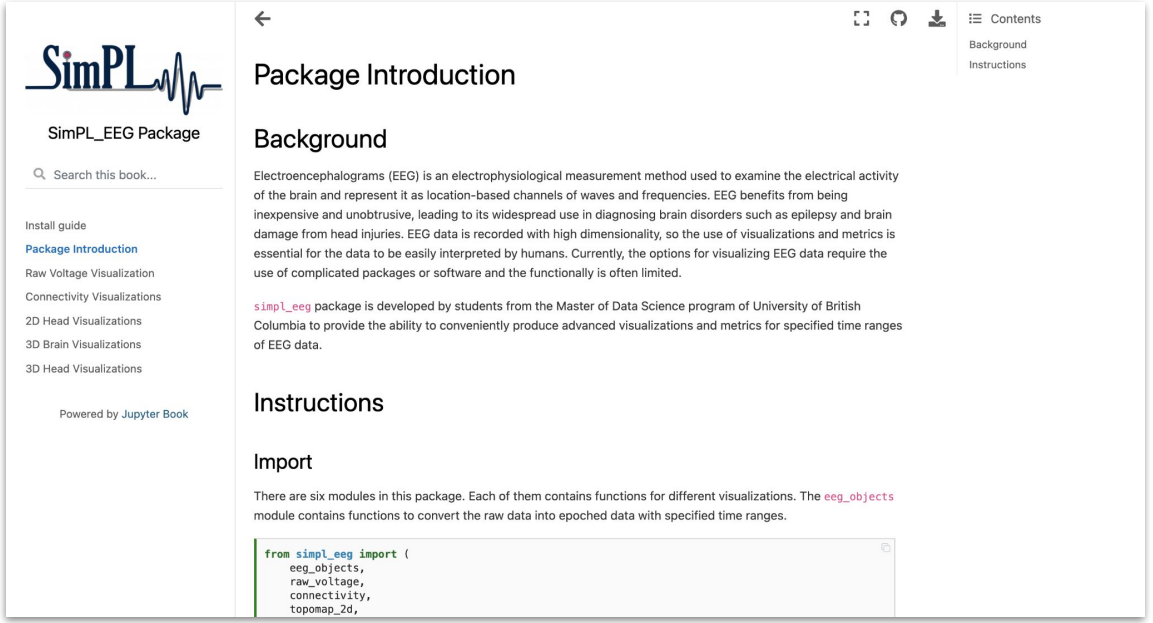
Package - Documentation

Documentation

Purpose: Communicate detailed instructions to the user on how to install and use the package

Techniques: jupyter {book}

- Jupyter Book
- GitHub Pages



https://ubc-mds.github.io/simpl_eeg_capstone/

Package - *eeg_objects* module

Custom EEG object creation

Purpose: Assist in importing EEG data and creating custom time sections

Techniques:

- Custom python classes
- Data preprocessing
- Generating event data

Drawbacks:

- Relies on MNE backend

Number of events	1
Events	5 seconds: 1
Time range	-0.488 – 0.488 sec
Baseline	0.000 – 0.000 sec

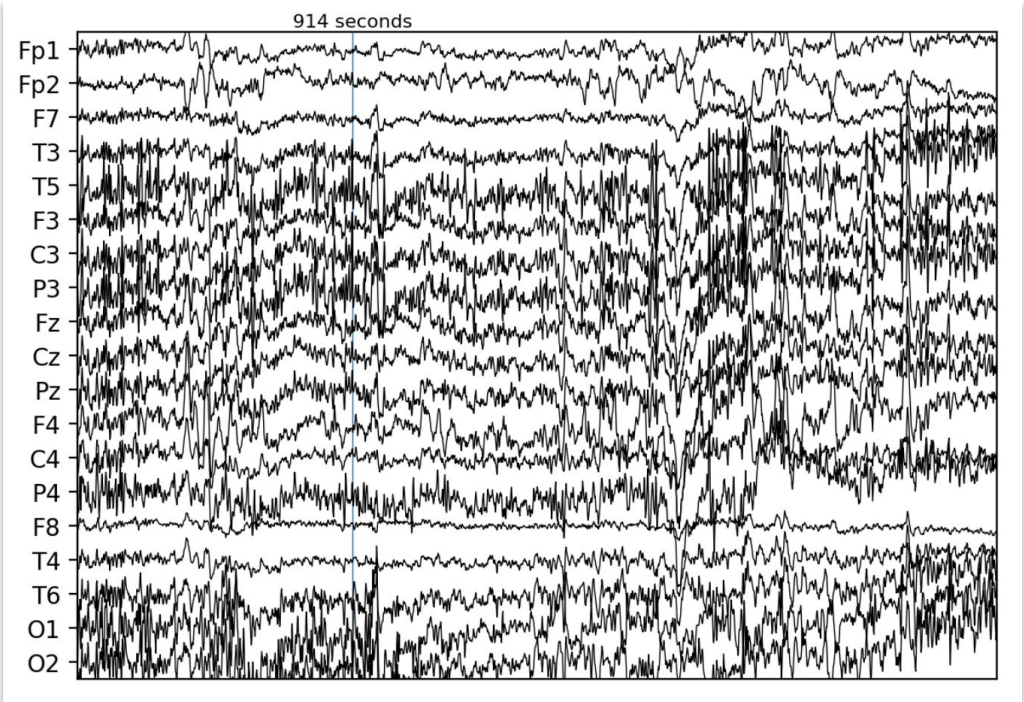
Package - *raw_voltage* module

Raw voltage plot

Purpose: To visualize raw EEG data per node over a specific time section

Techniques: MNE matplotlib

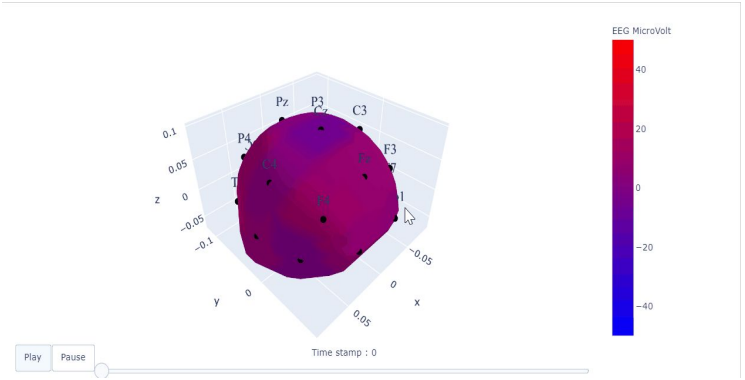
- Plotting (MNE)
- Customization (matplotlib)



Package - *topo_3d_head* module

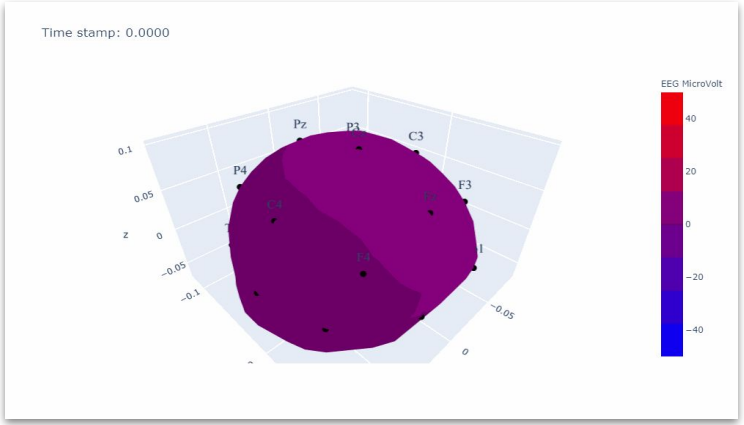
3D topographic head map

Purpose: To visualize EEG signal changes on the scalp from a 3D perspective over a given time section



Techniques: MNE MEG + EEG ANALYSIS & VISUALIZATION, plotly

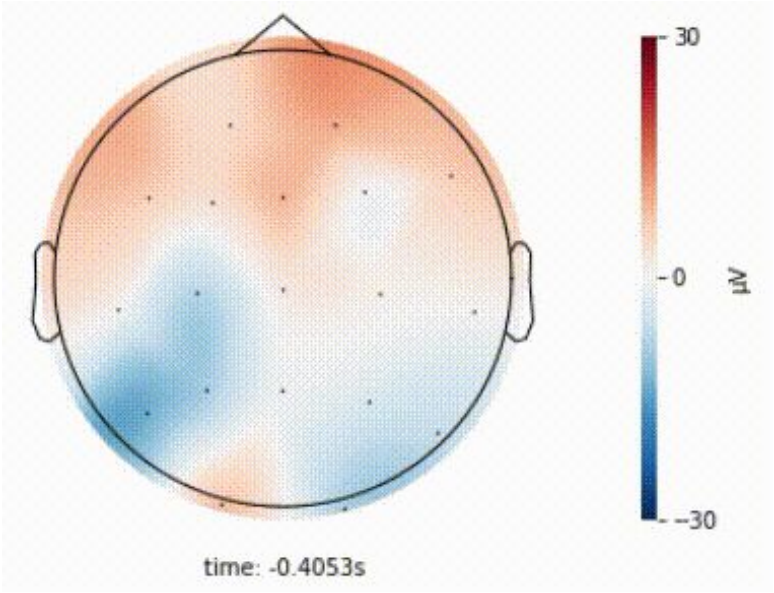
- 3D interpolation (scipy)
- 3D visualization (plotly)
- Animation (plotly)



Package - *topo_2d_head* module

2D topographic head map

Purpose: To visualize EEG signal changes on the scalp from a 2D perspective



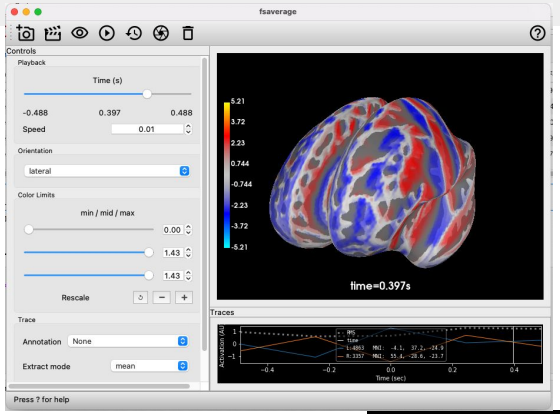
Techniques: MNE matplotlib

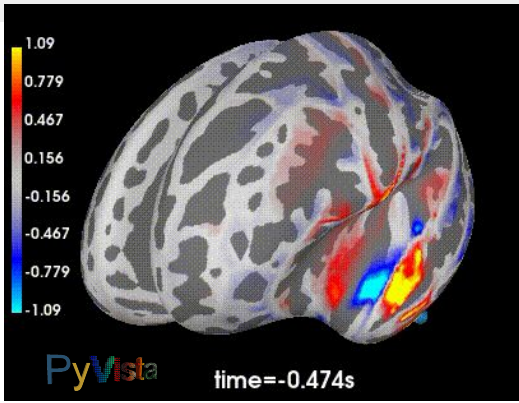
- 2D visualization (MNE)
- Customization (matplotlib)
- Animation (matplotlib)

Package - *topo_3d_brain* module

3D brain map

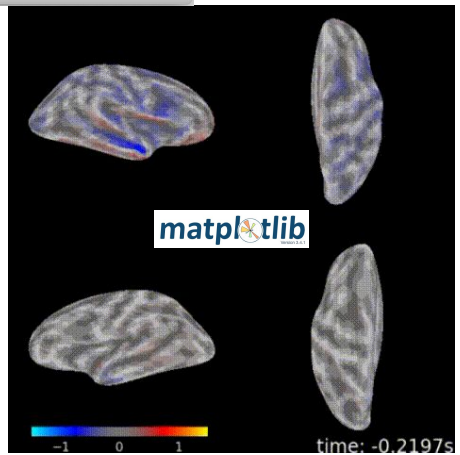
Purpose: Interpolate and visualize EEG signal changes mapped to a 3D brain to view potential brain signal changes





Techniques: MNE MEG + EEG ANALYSIS & VISUALIZATION · PyVista · matplotlib Version 3.4.1

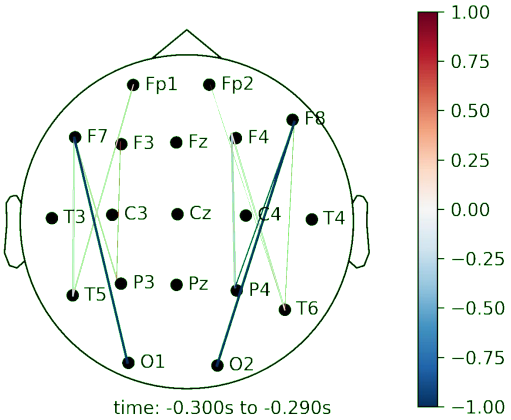
- Auto-downloads MRI brain model (MNE)
- Maps EEG data to 3D model of a brain (MNE)
- Launches interactive interface (Pyvista)
- Animation (matplotlib)



Package - *connectivity* module

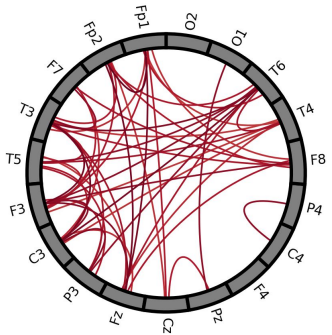
Connectivity and Connectivity Circle

Purpose: Visualize similarity in signal changes over time between nodes

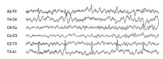
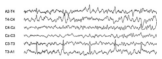
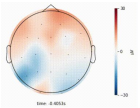
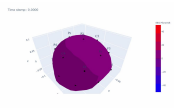
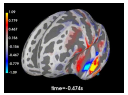
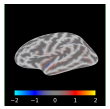
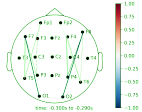


Techniques: MNE MEG + EEG ANALYSIS & VISUALIZATION matplotlib Version 3.4.1

- Correlation and connectivity calculations
- Figure modifications (matplotlib)
- Animation (matplotlib)



Advantages and Drawbacks

	Interactive Raw Voltage	Static Raw Voltage	2D head	3D head	PyVista 3D brain	Matplotlib 3D brain	Connectivity	Connectivity Circle
								
Works with UI	✗	✓	✓	✓	✗	✓	✓	✓
Viewing in true dimensions	✗	✗	✗	✓	✓	✓	✗	✗
Short rendering time	✓	✓	✓	✗	✗	✗	✗	✓
Animated	✗	✗	✓	✓	✓	✓	✓	✓

Introduction

Main Goal: Package

Main Goal: User Interface

Stretch Goal: Clustering

Conclusion

User Interface

User Interface

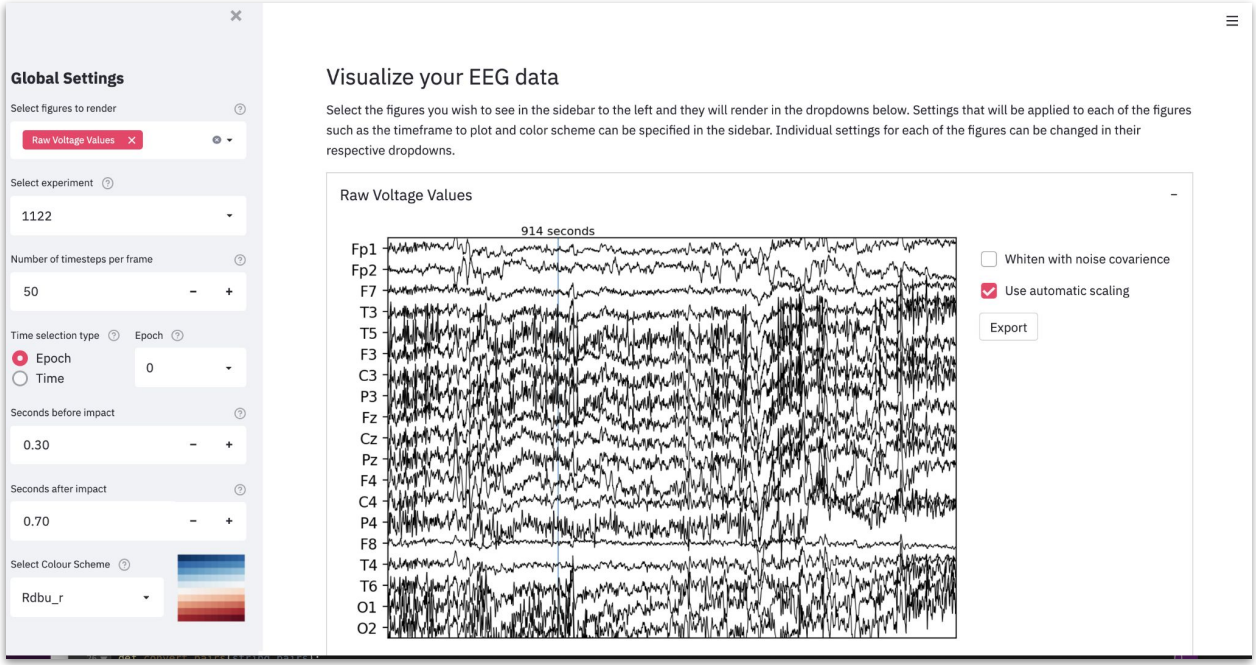
Purpose: Provide easy to use interactive access to package functionality

Techniques: Streamlit

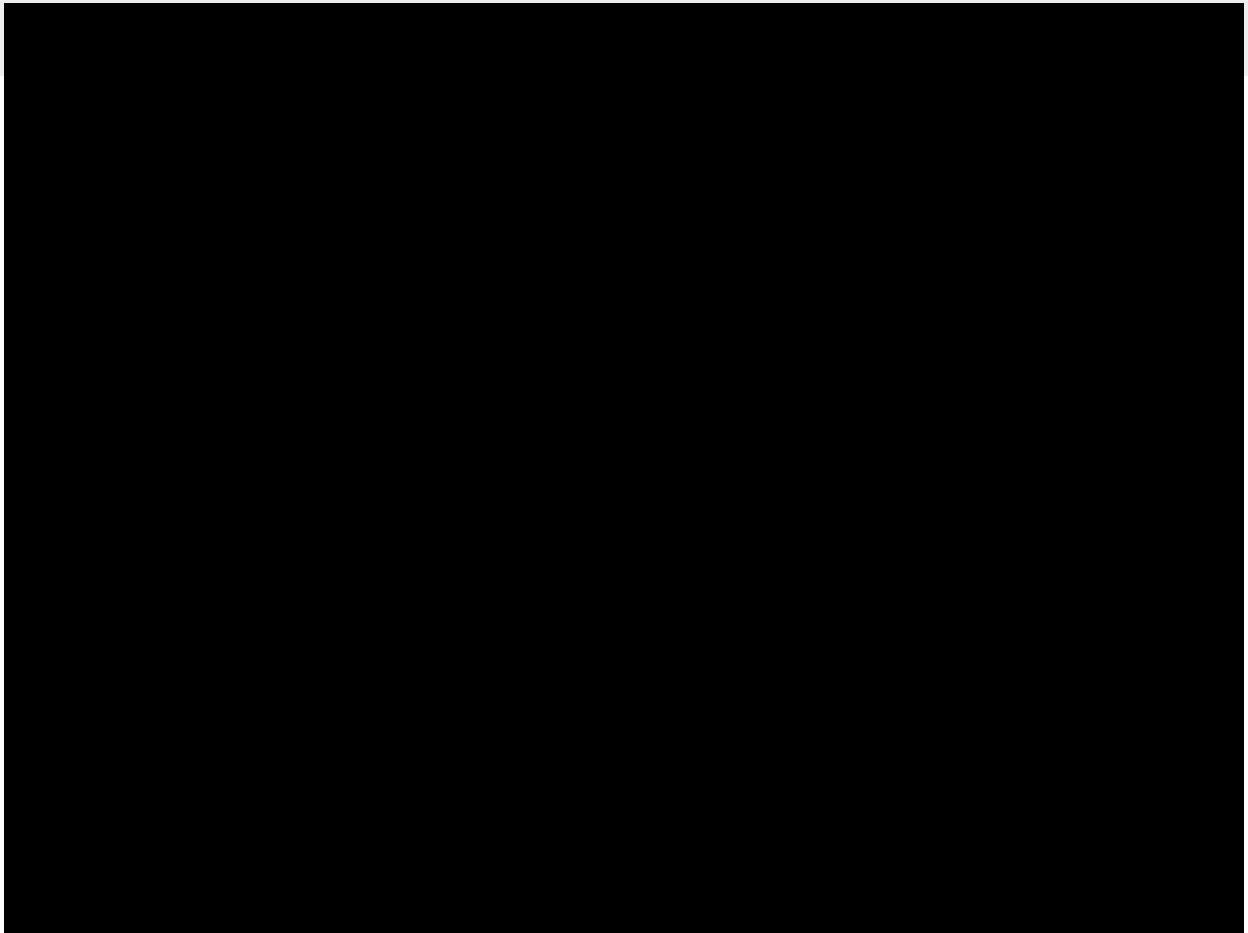
- Streamlit
- Caching
- Custom CSS

Drawbacks:

- Flexibility



User Interface Demo



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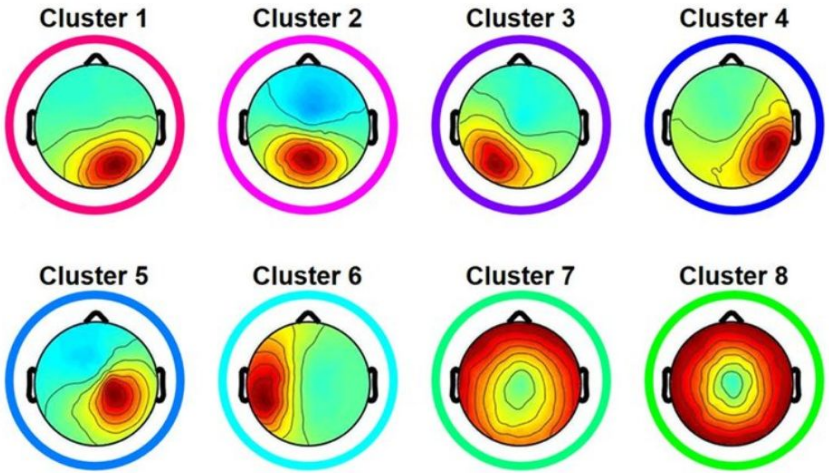
Stretch Goal - Clustering

Clustering Algorithms

Purpose: Identify potential brain states, which are considered as similar patterns of 19 electrodes over a period of time in the EEG data, with unsupervised machine learning techniques



Data attributes:

- No labels or pre-defined brain states
- High dimensionality

Stretch Goal - K-means

Finding number of clusters:

1) K-means using Elbow Method

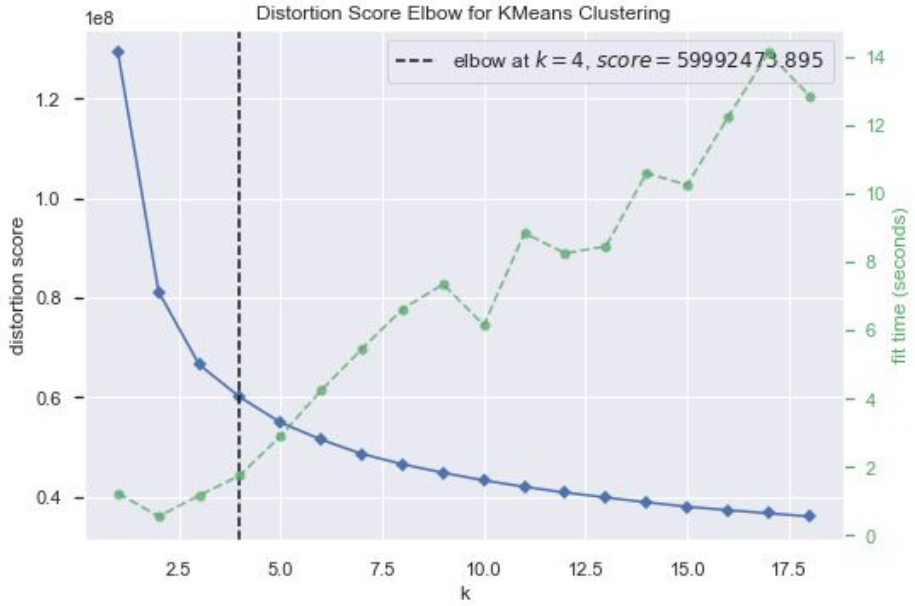
Purpose: To find the optimal value of clusters in range of K values

Techniques:

- K-means Algorithm

Drawbacks:

- Dependent on inertia



K range = (1, 19)

Stretch Goal - K-means

Finding number of clusters:

2) K-means using Silhouette Method

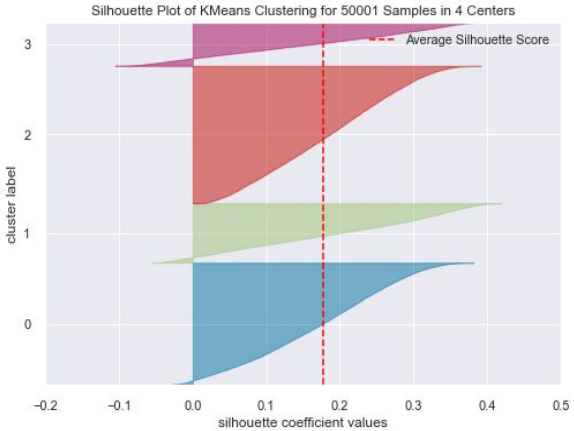
Purpose: To test and visualize the optimal value of clusters (K value)

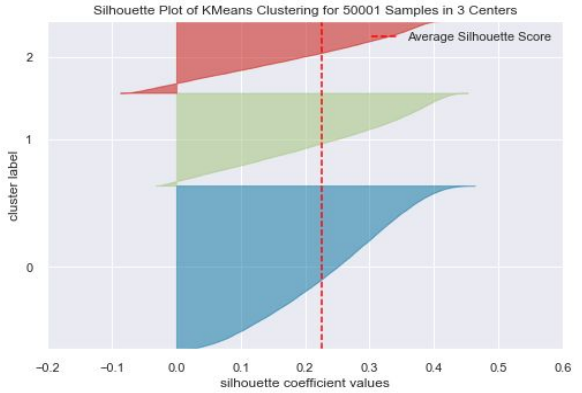
Techniques:

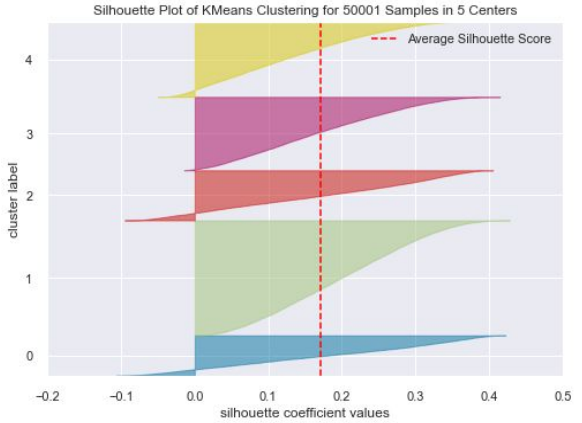
- K-means Algorithm

Drawbacks:

- Needs K as in input







Stretch Goal - Clustering

Hidden Markov Model

Purpose: Use a probabilistic model to identify similar patterns in EEG data to cluster different brain states in the likelihood sense

Techniques: **hmmlearn**

- Gaussian HMM (hmmlearn)

Drawbacks:

- Output is hard to interpret
- Difficult to evaluate performance

Stretch Goal - Range of Timestamps

What's next?

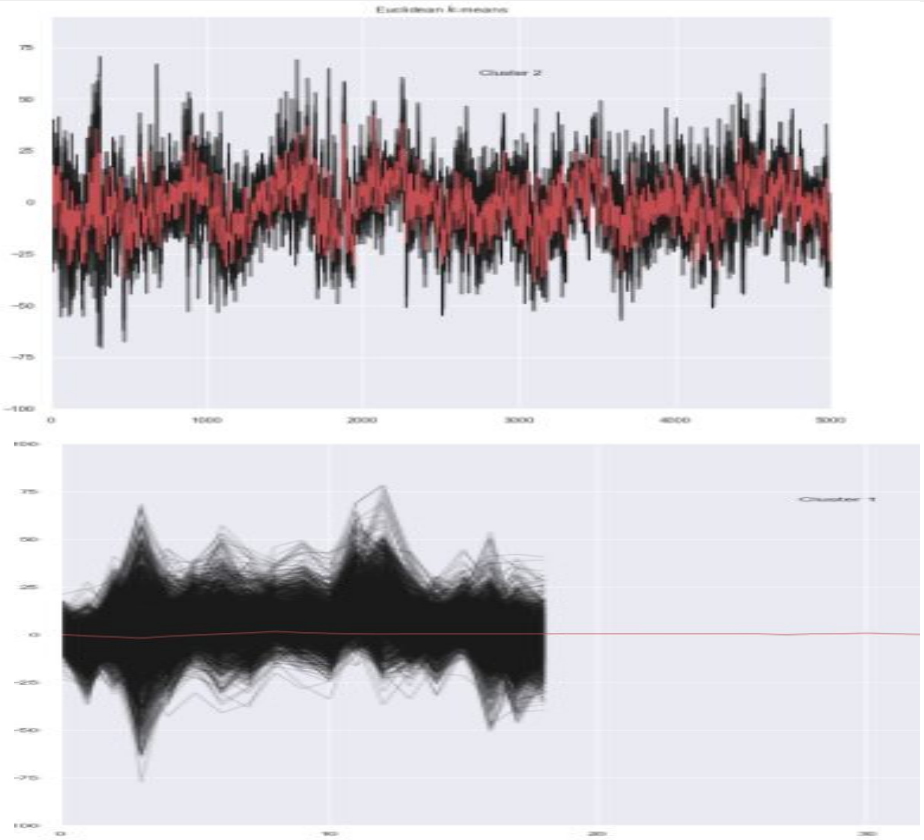
Range of timestamps:

Techniques:

- Self Organizing Map (SOM)
- Soft-DTW K-means
- Time Series Kernels and Time Warping

Drawbacks:

- Beyond the scope of MDS



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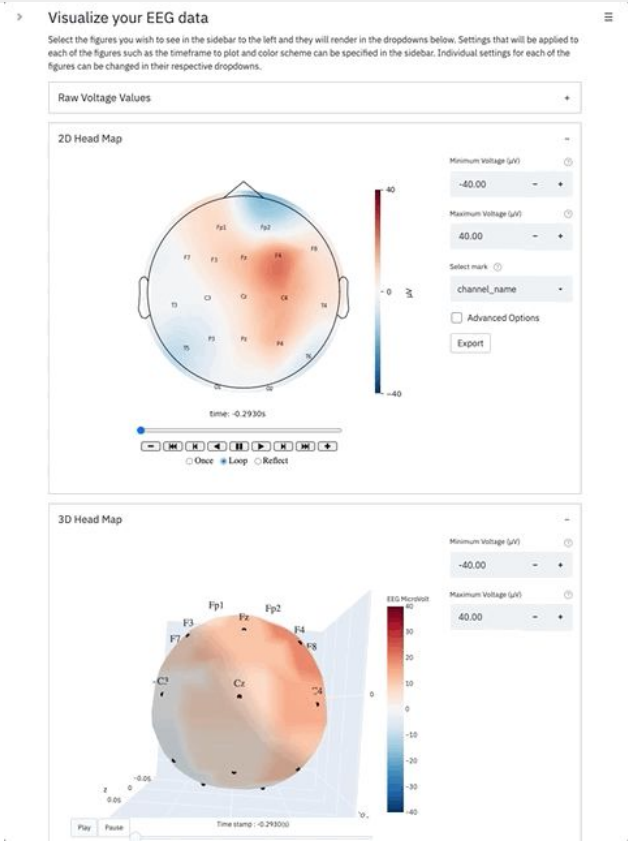
Conclusion - Project Overview

Summary

- ✓ Completed both main goals and started stretch goal
  - ✓ Package with 6 modules
  - ✓ Interactive User Interface
  - ✓ Preliminary clustering analysis and recommendations for next steps
- ✓ Created detailed step-by-step instructions
- ✓ Issue tracker on GitHub contains a record of known bugs and suggested improvements

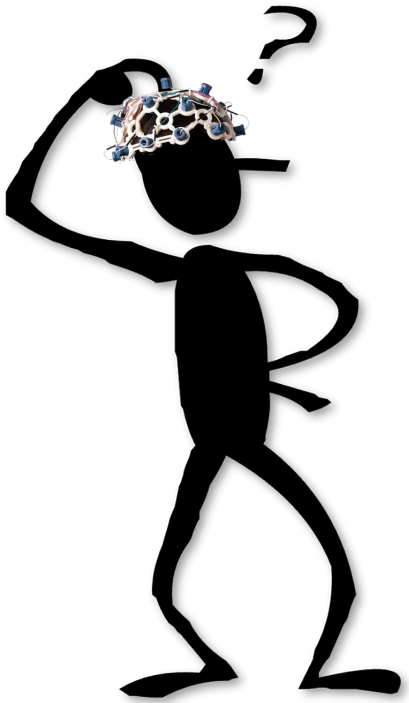


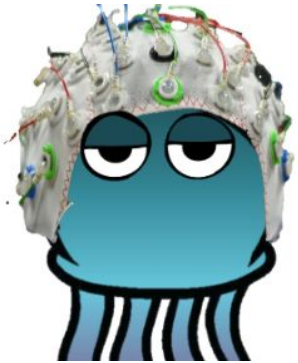
Conclusion - Future Improvements

Ideas for next steps

- Package: Extend functionality (e.g. accept different file types)
- UI: Deploy app to make use of shared caching
- Clustering: Expand upon techniques - our stretch goal is just a starting point

Questions?





Attributions

- EEGLab
- MNE
- Plotly
- JupyterBook
- Netflix (Firm),. (2017). Stranger things: Season 1.
- Man moving hand with EEG
- Confused Scientist
- UBC SimPL Lab
- Future image
- EEG Koala
- EEG Squid
- EEG Figure from paper
- EEG Cluster Figure