

Quantitative Electroencephalography (qEEG) Feature Extraction utilizing Computational Intelligence

Blaine Allen, Computer Engineering Ph.D. Student

MISSOURI
S&T

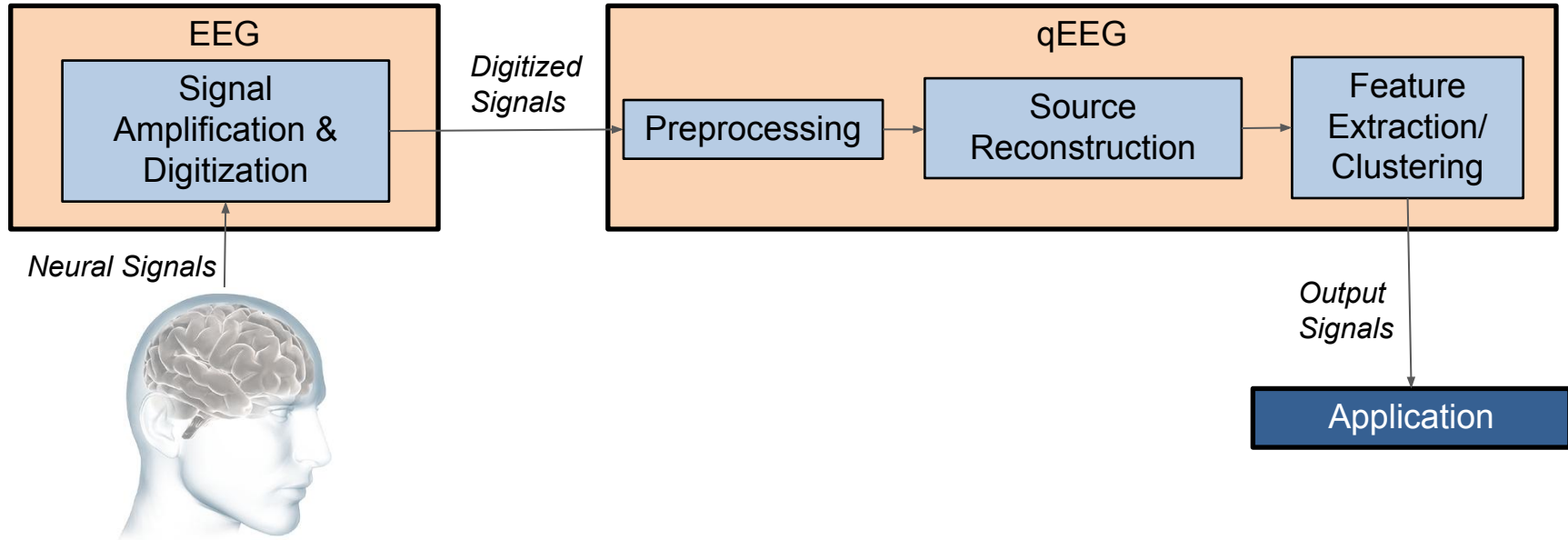
Roadmap of Discussion

- > Biological Neurons & Neuron Clusters
- > Electroencephalography (EEG)
- > Quantitative EEG (qEEG)
- > Spectral Analysis
- > Preprocessing
- > Feature Extraction

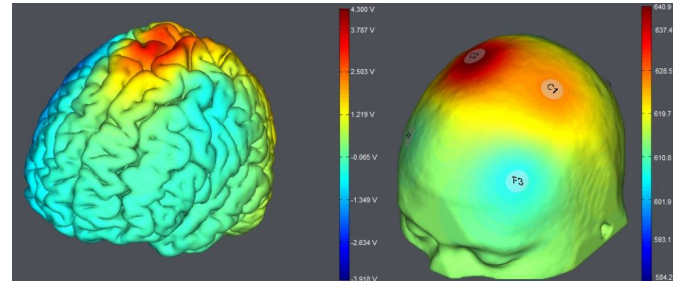


*Credit: imotions.com
Acquired: 10/10/2019*

Big Picture of quantitative Electroencephalography



What kind of applications can you imagine with neural analysis?



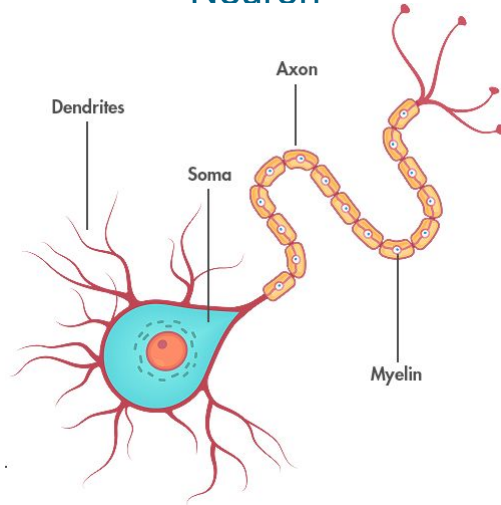
*Credit: Neuroelectrics.com
Acquired: 9/24/2019*

Neuromedical Applications

- Addiction
- ADHD/ADD
- Alzheimer's/Dementia
- Autism
- Neural Prosthetics/Robotics for Amputees/Paraplegics
- Neurofeedback/Neurostim
- Medication Reduction (Pharmaco-EEG)
- Post Traumatic Stress Disorder (PTSD)
- Seizure Disorder
- Sleep Therapy
- **Traumatic Brain Injury (TBI)**

Biological Neurons

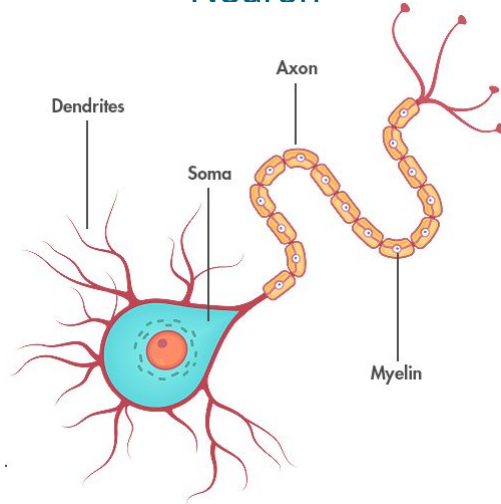
Simplified Model of Human Neuron



*Credit: Mayo Clinic
Acquired: 9/24/2019*

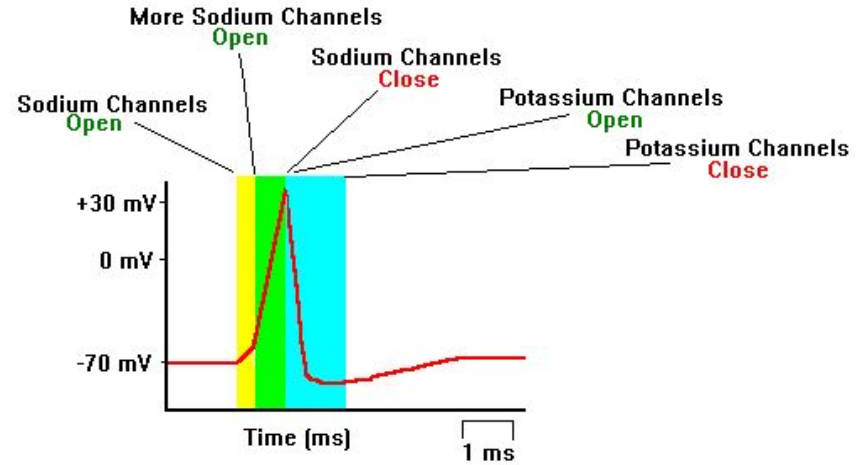
Biological Neurons

Simplified Model of Human Neuron



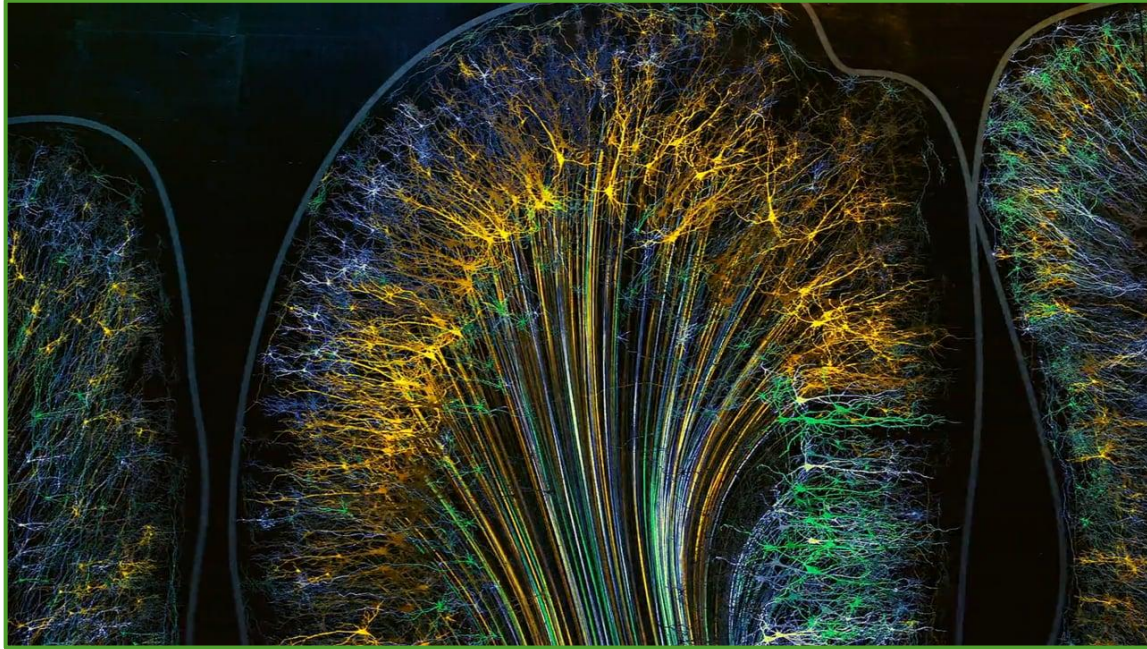
Credit: Mayo Clinic
Acquired: 9/24/2019

Action Potentials:



Credit: neuroscience.washington.edu
Acquired: 9/24/2019

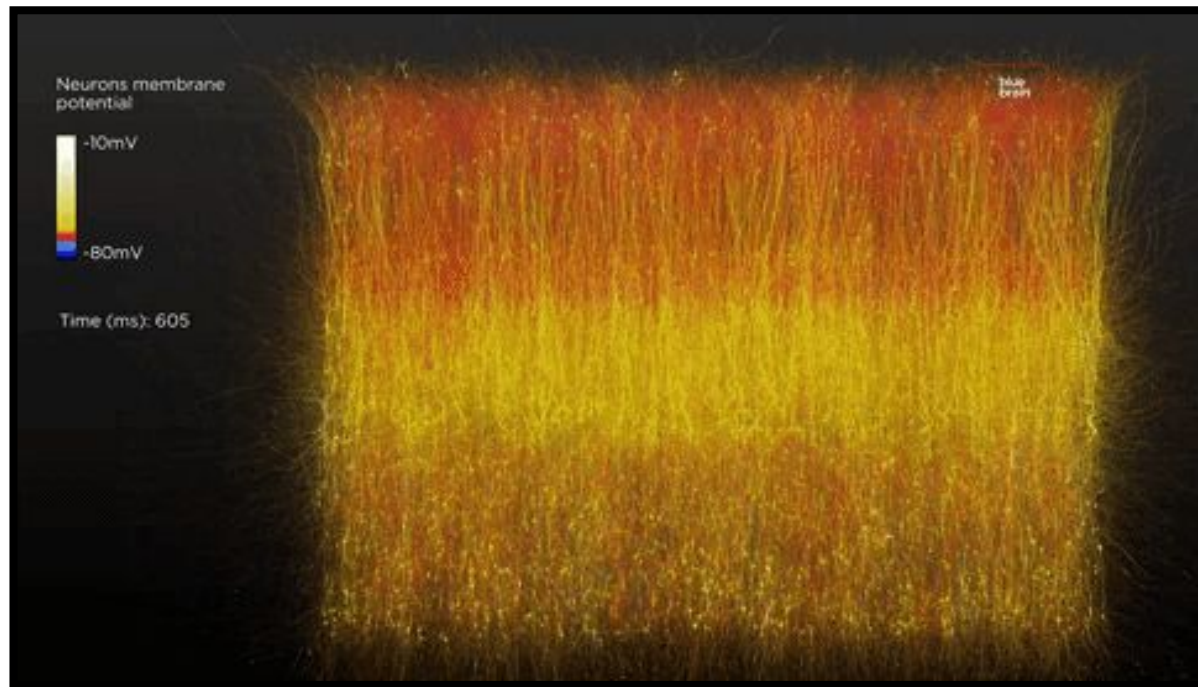
Neuronal Clusters – Spectral Visualization



*Credit: Johns Hopkins
Acquired: 9/24/2019*

MINERS DIG DEEPER

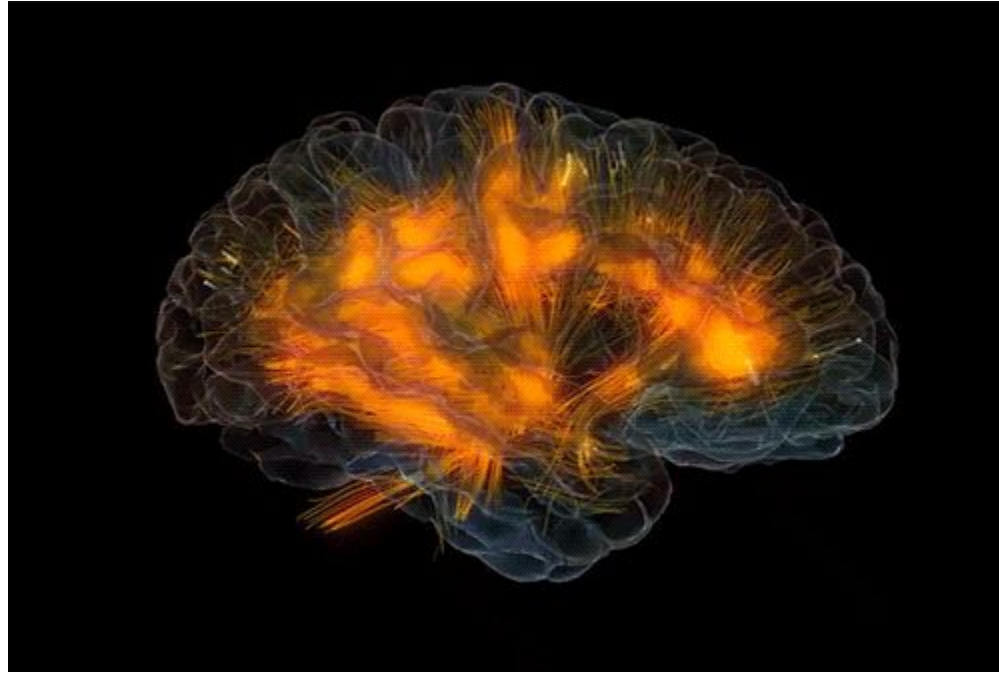
Neuronal Clusters – “Firing”



*Credit: Laboratory for Topology and Neuroscience, Brain Mind Institute, Switzerland
Acquired: 9/24/2019*

MINERS DIG DEEPER

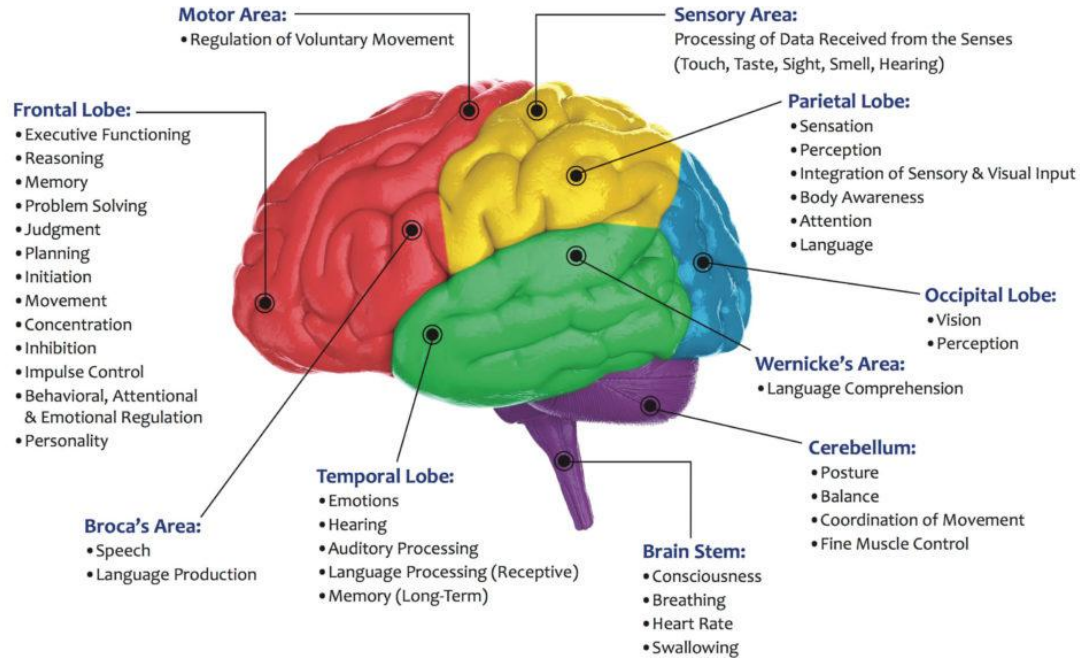
Human Brain Animation



*Credit: University of California at San Francisco Neuroscience
Acquired: 9/24/2019*

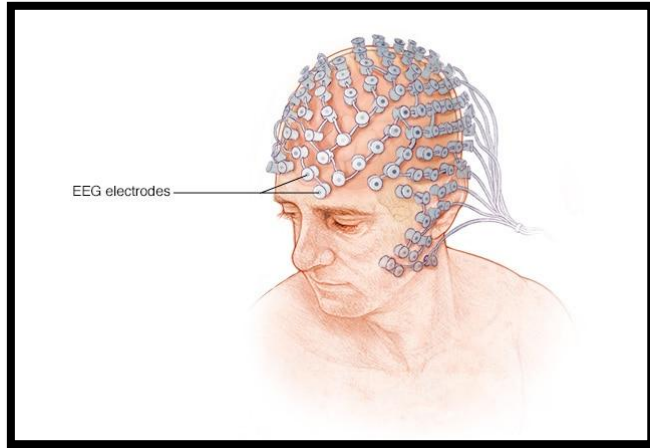
MINERS DIG DEEPER

“Some” Brain Structure & Function



*Credit: Dr. Roseann Capanna-Hodge & Associates -
drroseann.com
Acquired: 9/28/2019*

Electroencephalography (EEG) Concept



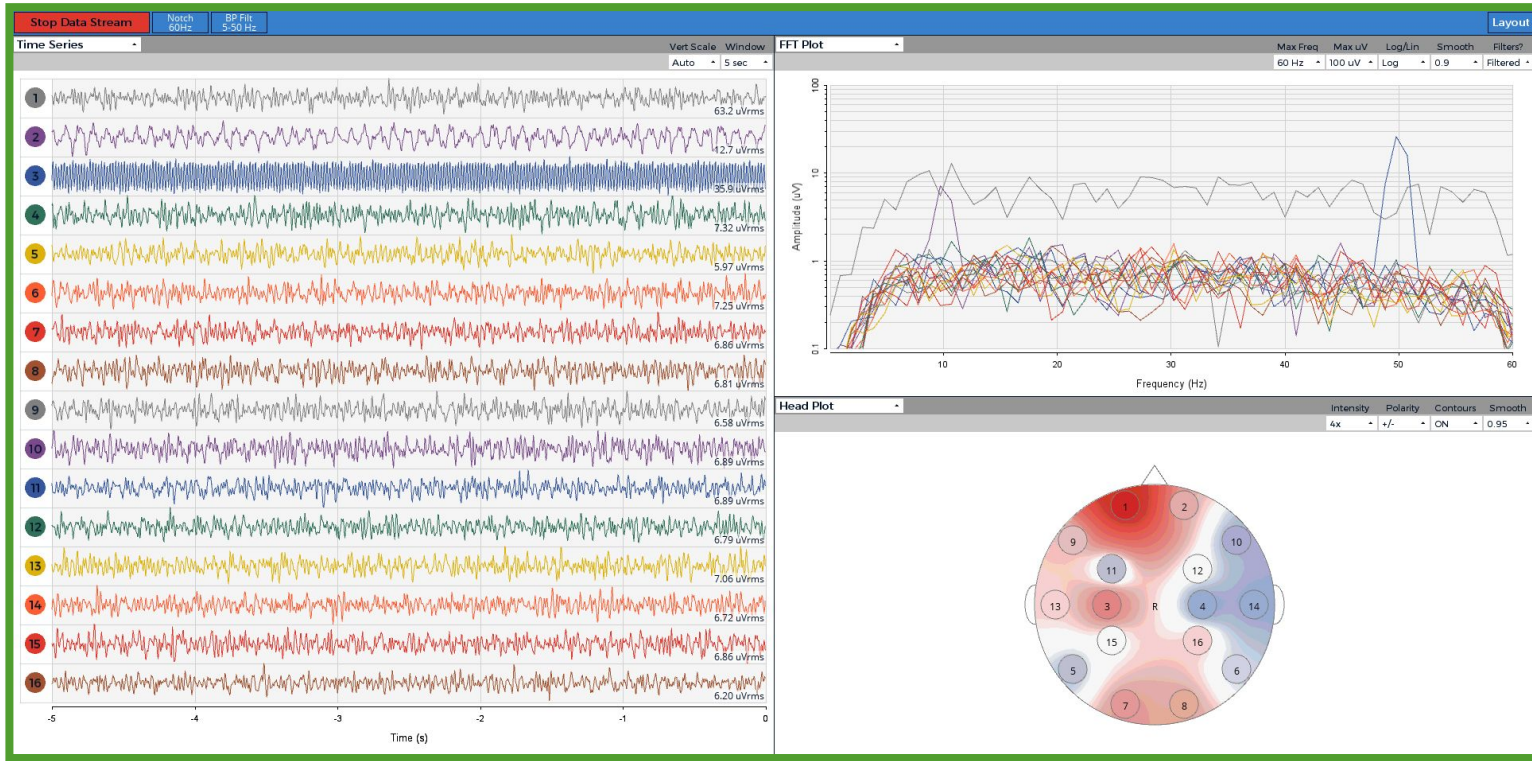
*Credit: Mayo Clinic
Acquired: 9/24/2019*

EEG is an electrophysiological monitoring method to noninvasively record the brain's electrical activity over a period of time.


EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain.

Internal electrical signals (millivolt) become diffuse and scatter through neural tissue and the skull to be observed as external signals (microvolt).


EEG Time-series Data Visualization



MINERS DIG DEEPER

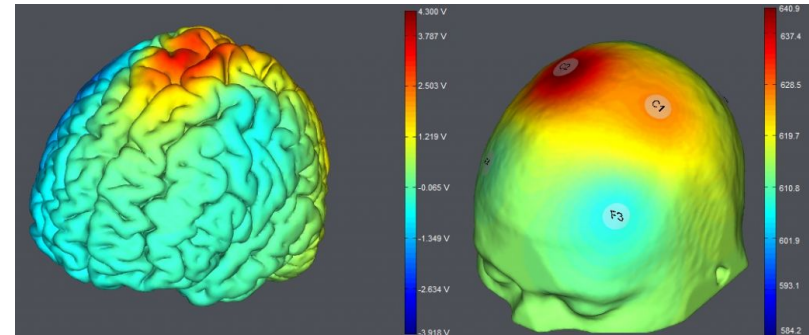
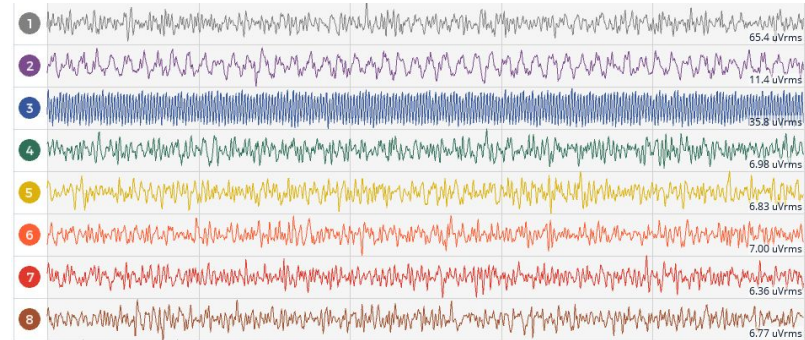


But we want computers to see
things that humans can't
identify



Quantitative Electroencephalography (qEEG)

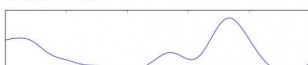
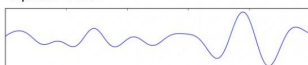
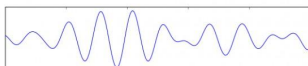
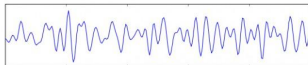
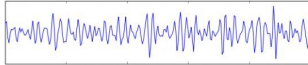
Quantitative EEG (qEEG) makes use of quantitative techniques to analyze EEG characteristics such as frequency, amplitude, coherence, power, phase, and symmetry over time independently or in combination.^[1]



Credit: Neuroelectrics.com
Acquired: 9/24/2019

EEG Neural Oscillations – Colloquially

Comparison of EEG Bands



*Credit: Neurosky.com
Acquired: 9/24/2019*

Neural Oscillations are rhythmic or repetitive patterns of neural activity in neural tissue that correspond to dominant frequency bands in the neuroimaging data^[2].



EEG Data Preprocessing

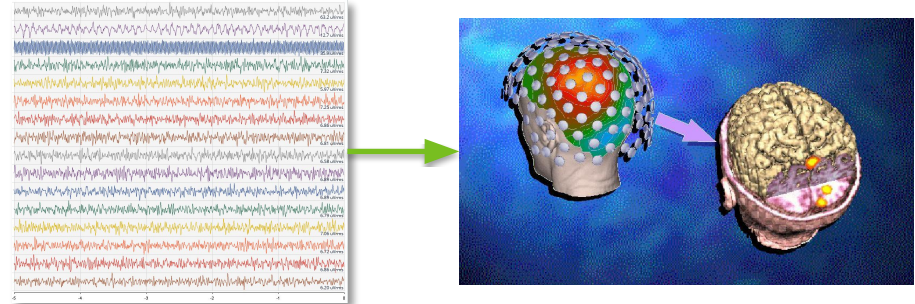
Goal:
Increase Data Quality

- Temporal Filtering
 - (Resting State vs Visually Evoked Potential)
- Down sampling (Nyquist Theorem)
- Artifact Detection
 - Electrode Interpolation
 - Independent Component Analysis
- Spatial Filtering
 - Principle Component Analysis
 - Surface Laplacian
- Artifact Epoch Removal (Noise)
 - Blink, Sneeze, Movement, etc

Source Reconstruction

- Trying to find brain areas responsible for EEG waves of interest.
- Forward Problem: Solved by starting from given electrical sources and calculating the electric potentials.^[7]
- Inverse Problem: Identifying the source of a given surface field potential.^[8]

*Goal:
Increase Feature Space*

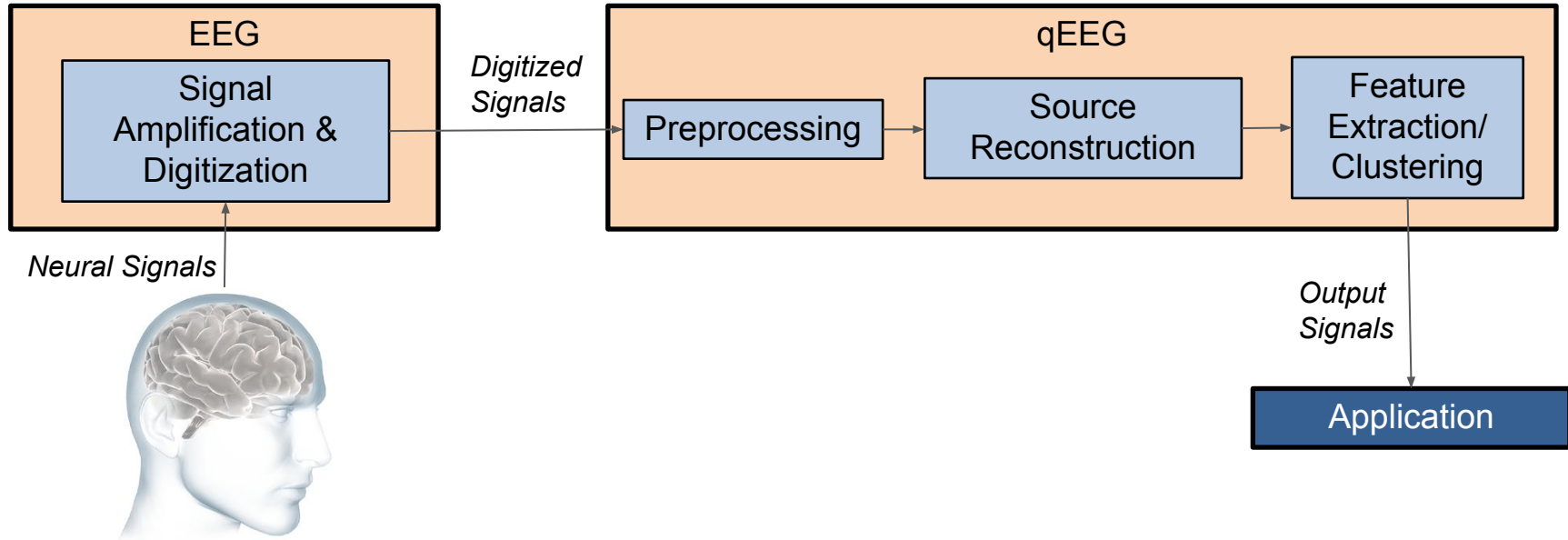


*Credit: laxtha.com
Acquired: 9/30/2019*

Feature Extraction

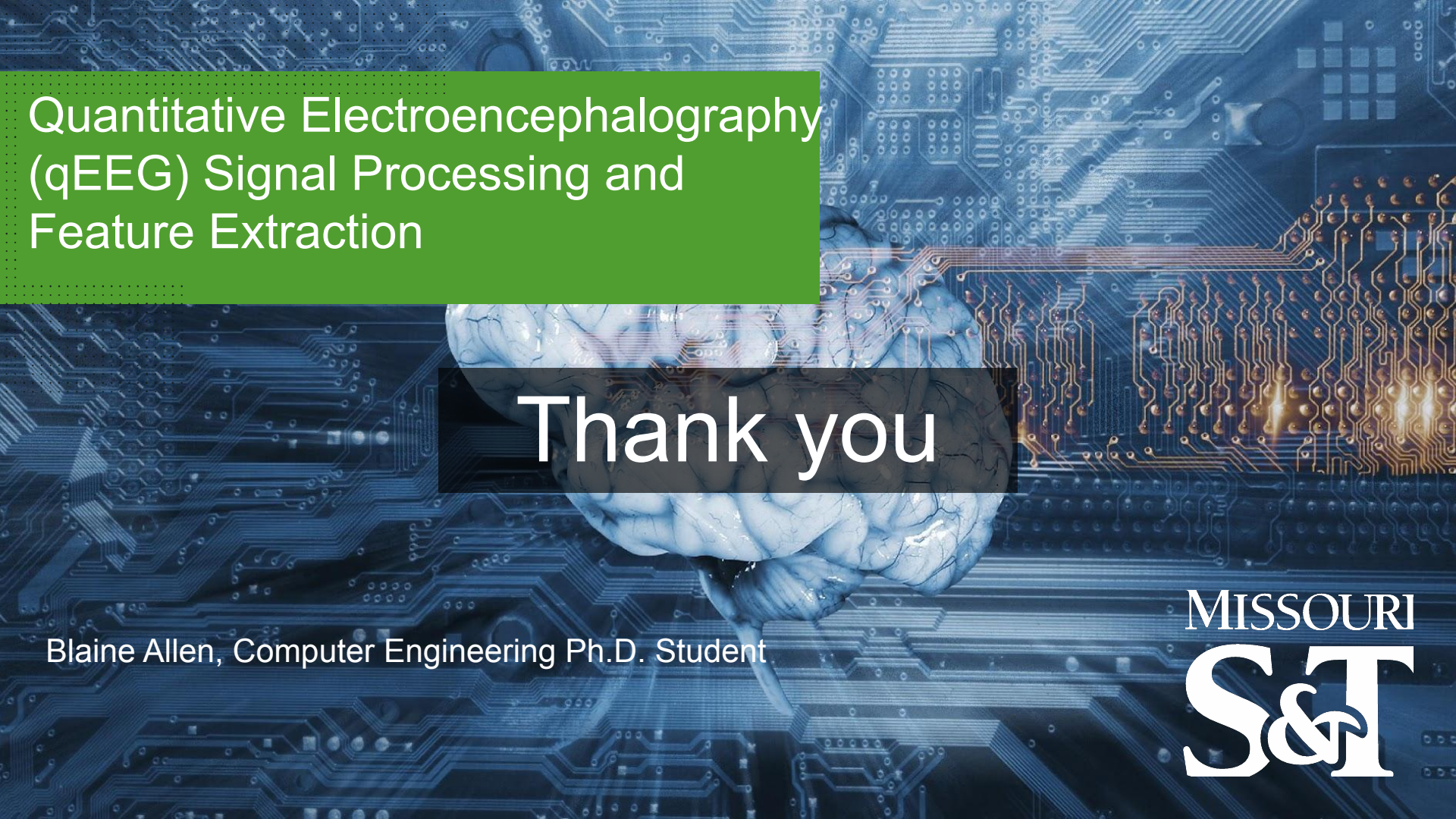
- Mutual Information
- Granger Prediction
- Deep Learning CNNs
- Non-linear Dynamics (Chaos Theory)
- Graph Theory

Quantitative Electroencephalography (qEEG)



References

- [1] Z. Haneef, H. S. Levin, J. D. Frost, and E. M. Mizrahi, “Electroencephalography and quantitative electroencephalography in mild traumatic brain injury,” *J. Neurotrauma*, vol. 30, no. 8, pp. 653–656, Apr. 2013.
- [2] “Traumatic brain injury: An EEG point of view.” [Online]. Available: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5619208/>. [Accessed: 24-Oct-2019].
- [3] “Spectral Analysis - an overview (pdf) | ScienceDirect Topics.” [Online]. Available: <https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/spectral-analysis/pdf>. [Accessed: 30-Oct-2019].
- [4] Y. Li, P. T. Wang, M. P. Vaidya, Y. Charles Liu, M. W. Slutzky, and A. H. Do, “A novel algorithm for removing artifacts from EEG data,” in *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2018, pp. 6014–6017.
- [5] M. R. Nuwer, D. A. Hovda, L. M. Schrader, and P. M. Vespa, “Routine and quantitative EEG in mild traumatic brain injury,” *Clin. Neurophysiol.*, vol. 116, no. 9, pp. 2001–2025, 2005.
- [6] O. M. Bazanova and D. Vernon, “Interpreting EEG alpha activity,” *Neurosci. Biobehav. Rev.*, vol. 44, pp. 94–110, Jul. 2014.
- [7] H. Hallez *et al.*, “Review on solving the forward problem in EEG source analysis,” *Journal of NeuroEngineering and Rehabilitation*, vol. 4. 2007.
- [8] R. Grech *et al.*, “Review on solving the inverse problem in EEG source analysis,” *Journal of NeuroEngineering and Rehabilitation*, vol. 5. 2008.



Quantitative Electroencephalography (qEEG) Signal Processing and Feature Extraction

Thank you

Blaine Allen, Computer Engineering Ph.D. Student

MISSOURI
S&T