EEG and Chaotic Time Series Analysis

Adam Jump
Salisbury University

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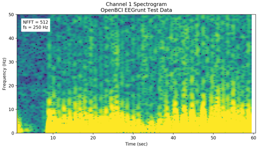
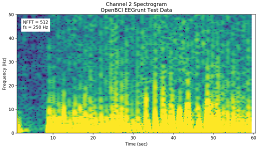
WHY ARE WE INTERESTED?

- Brain Computer Interfacing
- Accessibility
- Applications in Artificial Intelligence
- Prediction of Chaotic Time Series





Preliminary Information

- *Electroencephalography*: the measurement of neuronal function given by the *ionic gradient* of neuronal membranes
- *The Neuron*: Composed of a cell body (*Soma*), signal receptors (*Dendrites*), and signal transmitters (*axon*)
- *Excitatory Postsynaptic Potentials* (ESP) and *Inhibitory Postsynaptic Potentials* (ISP)

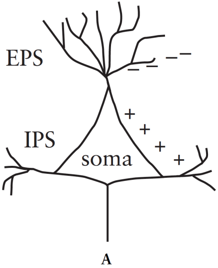
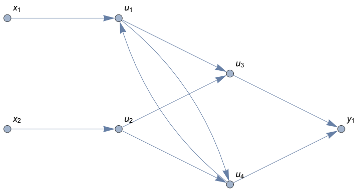


Figure: Sample Neuron

Artificial Neural Networks (ANNs)

- *ANN*: information processing system composed of *perceptrons*
- *Directed Graph*: ANNs are represented using directed graphs and adjacency matrices



	x_1	x_2	u_1	u_2	u_3	u_4	y_1
x_1	0	0	2	0	0	0	0
x_2	0	0	0	2	0	0	0
u_1	0	0	0	0	4	0	0
u_2	0	0	0	0	3	3	0
u_3	0	0	0	0	0	0	1
u_4	0	0	2	0	0	0	0
y_1	0	0	0	0	0	0	0

Figure: Sample Network and Network Structure

Translation from the Time Domain

- 8 electrodes giving us row vectors,

$$f(t) = (x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8),$$

$$x_i = x(t + i\tau)$$

- Utilizing the *Discrete Fourier Transform*,

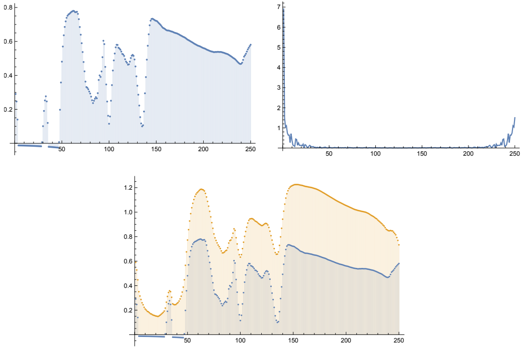
$$F_n = \sum_{k=0}^{N-1} X_k \cdot e^{-2\pi i n k/N}$$

- Multiplying by low and high pass filters,

$$\frac{t}{\tau + t}, \frac{\tau}{t + \tau}$$

Frequency Domain

- Why look at frequency?



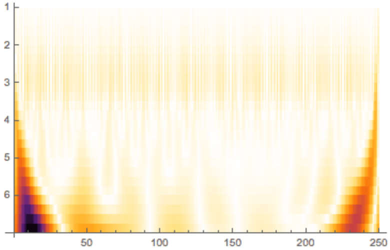
TIME-FREQUENCY DOMAIN (WAVELETS)

- The individual wavelet defined as,

$$\psi^{a,b}(x) = |a|^{-1/2}\,\psi\left(\frac{x-b}{a}\right)$$

- which gives,

$$W_\psi(f)(a,b) = \frac{1}{\sqrt{a}}\int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right)dt$$



ARTIFACT REMOVAL AND RETURN TO LINEARITY

- For all $f(t)$ we want to find $\mathbf{M}$ such that $f(t)\mathbf{M} = \mathbf{s}$ where all $\mathbf{s}$ are maximally independent
- Generally referred to as an *independent component analysis* and used in unsupervised machine learning

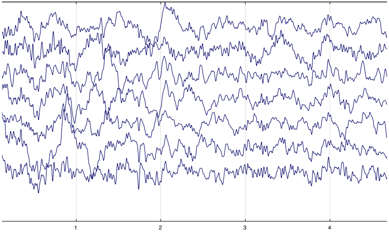
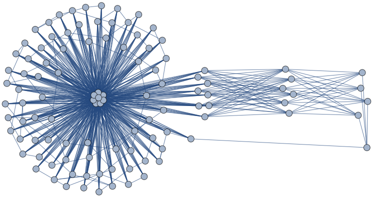


Figure: Processed Time-Series Data

CHAOTIC TIME-SERIES PREDICTION

- Nonlinear autoregressive exogenus model (NARX)
- Algebraically stated as
  $y(t) = N[y_{t-1}, y_{t-2}, y_{t-3}, \ldots, u_t, u_{t-1}, \ldots] + \epsilon_t$



References

- Christian Andreas Kothe, Scott Makeig, and Julie Anne Onton.
  Emotion recognition from EEG during self-paced emotional imagery.
  In *Affective Computing and Intelligent Interaction (ACII), 2013 Humaine Association Conference on*, pages 855–858. IEEE, 2013.
- Sophocles J. Orfanidis.
  Introduction to signal processing.
  Prentice Hall signal processing series. Prentice Hall, Englewood Cliffs, N.J, 1996.
- Germn Rodrguez-Bermdez and Pedro J. Garcia-Laencina.
  Analysis of EEG signals using nonlinear dynamics and chaos: a review.
  Applied Mathematics & Information Sciences, 9(5):2309, 2015.
- Sarit Shwartz, Michael Zibulevsky, and Yoav Y. Schechner.
  ICA using kernel entropy estimation with NlogN complexity.
  Lecture notes in computer science, pages 422–429, 2004.
- J. Ulbikas, A. Cenys, and O. P. Sulimova.
  Chaos parameters for EEG analysis.
  Nonlinear Analysis: Modelling and Control, 3:1–8, 1998.
- Yan Xiu and Wei Zhang.
  Multivariate Chaotic Time Series Prediction Based on NARX Neural Networks.
- Longhao Yuan and Jianting Cao.
  Patients EEG Data Analysis via Spectrogram Image with a Convolution Neural Network.
  In Ireneusz Czarnowski, Robert J. Howlett, and Lakhmi C. Jain, editors, *Intelligent Decision Technologies 2017*, volume 72, pages 13–21. Springer International Publishing, Cham, 2018.
  DOI: 10.1007/978-3-319-59421-7_2.
- Erim Yurci.
  Emotion Detection From EEG Signals: Correlating Cerebral Cortex Activity with Music Evoked Emotion.
  Universitat Pompeu Fabra, Barcelona, 2014.