Analyzing Neural Time Series Data

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Motivation

Rhythmic activity such as oscillations and synchronization are widespread in neural time series data, and are thought to have important roles in brain function, including providing temporal structure to shape information-processing, dynamically routing information processing, and synchronizing dynamics over multiple spatial and temporal scales. Detailed theories are important for understanding the role of rhythmic activity in the brain, but appropriate data analyses are absolutely essential. Unfortunately, there is often a gap between scientists' ideas about how to analyze their data, and their knowledge of the mathematical and practical steps to analyze the data in order to test those ideas.

Purpose

The purpose of this course is to provide a firm grounding for understanding advanced neural time series (LFP/EEG/MEG) analyses, with a strong focus on time-frequency and synchronization analyses. The course is mathematically rigorous but is approachable to researchers with no formal mathematics background. If you want to analyze your neuroscience data completely on your own, this course will certainly help get you started. It will also provide a firm basis for using analysis toolboxes such as eeglab or fieldtrip, although you will not learn how to use those toolboxes in this course.

Organization

There are 15 sessions (3x a day, 5 days), each lasting 120 minutes (with break). Each class is a mixture of lecture and hands-on work. Optional homeworks are assigned daily, and solutions are emailed the following day. Lectures cover the mathematical and theoretical bases behind data processing and analyses. "Hands-on" means you will work with real data in Matlab, programming and applying the material covered in the lecture. There is both individual and group work.

What to bring to class

Bring paper and a pen/pencil. You will need to take notes, write down equations, and draw diagrams, and paper is better than computer. **Lecture slides will not be made available.**

You should bring your own laptop with Matlab installed. Matlab scripts and sample data will be available for download from the web. Even if you have your own data, you should use the course data for assignments. You can work on your own data in parallel.

Course prerequisites

No background knowledge of spectral or time-frequency analysis is necessary. Some statistics knowledge is important (e.g., at least an undergraduate course on statistics). Knowledge of neuroscience or EEG/LFP data analysis is not necessary, but you will get a lot more out of the course if you already have some experience working with neuroscience data. However, you will need some basic Matlab proficiency. A few weeks before the course you will receive an email containing more information and a basic Matlab tutorial. There are also many introduction-to-Matlab tutorials on the web.

The trinity of EEG data analysis equations

There are three equations that you must learn by heart in this class. These form the mathematical bases of most advanced EEG data analyses. The more familiar you are with these equations, the easier it will be to learn analysis.

Sine wave: $A\sin(2\pi f + \theta)$

"Aey sine two pie eff tee plus theta"

Euler's formula: $Me^{ik} = M(\cos(k) + i\sin(k))$

"Em ee to the eye kay equals em cosine kay plus eye sine kay"

Gaussian: $e^{-t^2/2s^2}$

"ee to the minus tee squared over two ess squared"

ANTS course schedule

Dates: 6-10 August 2018

Lecture 0: 9:00 to 9:30 [note: this is an optional Q&A session]
Lecture 1: 9:30 to 12:00
Lecture 2: 13:30 to 15:00
Lecture 3: 15:30 to 17:30

Location: **TBA**

Monday

L1: [*note: starts at 11.00!*] Introduction to EEG/LFP analyses
L2: Sine waves, Gaussian tapers, noise, stationarity
L3: Simulating data to evaluate analysis methods

Tuesday

L1: Fourier transform, part I (basic mechanics and implementation)
L2: Fourier transform, part II (frequency resolution, zero-padding, etc.)
L3: Hands-on MATLAB work

Wednesday

L1: Complex Morlet wavelets, convolution theorem
L2: Getting power and phase results from wavelet convolution
L3: Parameters and their effects on TF results. Baseline normalization.

Thursday

L1: Other time-frequency methods: filter-Hilbert, STFFT, multitaper
L2: Phase-based connectivity
L3: Hands-on MATLAB work

Friday

L1: Statistics: permutation testing and multiple comparisons
L2: Within-subjects statistics
L3: Group-level analyses