Linear Algebra for Neuroscientists

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Motivation

Neuroscience is moving towards "big data," with new and improved brain measurement technologies that acquire an ever-increasing amount of data. Examples include multichannel LFP/tetrodes, high-density MEEG, and optical imaging. Increases in the number of simultaneously recorded data allows new discoveries about the spatiotemporal structure in the brain, but also presents new challenges for data analyses. Because data are stored in matrices, algorithms developed in matrix analysis will be extremely useful. On the other hand, linear algebra and matrix analysis are unfortunately rarely taught in neuroscience/biology/psychology courses.

Purpose

The purpose of this course is to introduce you to matrix-based data analysis methods in neural time series data, with a focus on least-squares model fitting and multivariate dimensionality-reduction and source-separation methods to identify narrowband activity, task-related networks, multivariate spike-field coherence, and optimized single-trial analyses. The course is mathematically rigorous but is approachable to researchers with no formal mathematics background. The course utilizes MATLAB as the numerical processing engine but the material is easily portable to Python or any other language. The focus is on understanding methods and their implementation, rather than on using analysis toolboxes.

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 much 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 via web download. 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

Nothing about linear algebra, although it's a fast-paced course so some existing knowledge of matrix analysis will be helpful. Some background knowledge in neuroscience is useful though not crucial. 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.

How to get the most out of this course

Pay attention, take notes, ask questions, work with your fellow classmates, do the Matlab assignments, and—most importantly—have a positive and optimistic attitude!

LAN course schedule

Dates: 13-17 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: Grotius 1.176

Monday

L1: [note: starts at 11.00!] Crash-course on time-frequency analysis, part I (Fourier analysis)
L2: Crash-course on time-frequency analysis, part II (time-frequency analysis)
L3: Simulating data to evaluate multivariate analysis methods

Tuesday

L1: Vectors, matrices and multiplications, independence, rank
L2: Matrix inverses and pseudoinverse
L3: The total awesomeness of A^TA, covariance matrices

Wednesday

L1: Vector spaces and matrix spaces
L2: Linear least-squares and model fitting
L3: MATLAB work; eigenvalues and eigenvectors

Thursday

L1: PCA: quadratic form and PCA theory, applications, limitations
L2: GED theory and practice, regularization
L3: GED example applications, MATLAB work

Friday

L1: Group project results. ICA and spatial filters comparisons
L2: Multivariate overfitting and statistical evaluations