Mathematical Tools for Neural and Cognitive Science

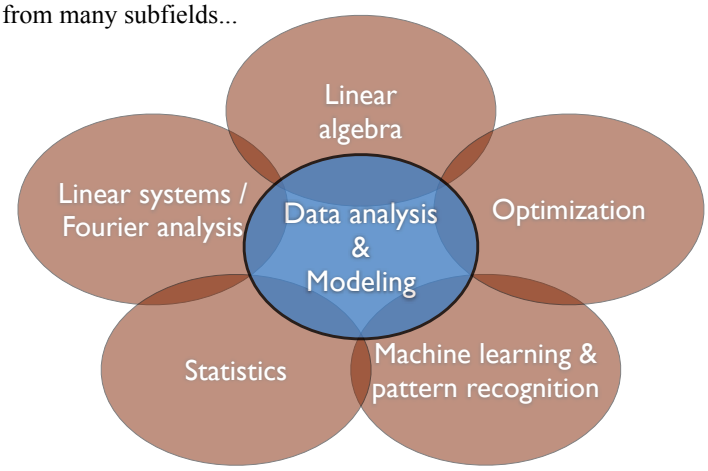
Fall semester, 2022

Conceptually motivated (not recipe-oriented)
Some equations, many pictures
Cumulative content delivery

Mathematical Tools for Neural and Cognitive Science

Goal is to be able to *use* these concepts
Lots of implementation/simulation exercises

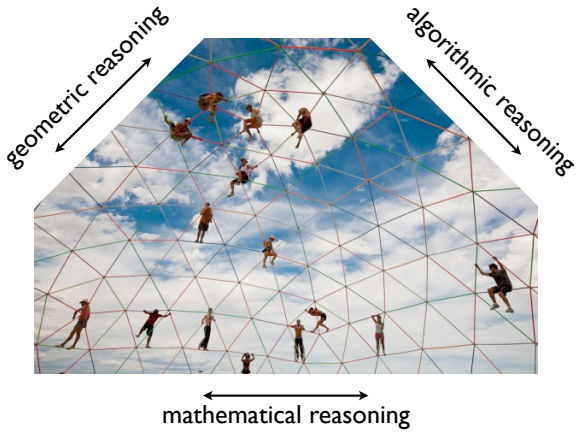
Topics: foundational material from many subfields...



Models & Data

- How do we fit the model to data?
- How well does fitted model explain the data?
- What do the best-fitting parameters tell us?
- How does model compare to other models?
- What novel predictions does the model make, and how can they be tested?
- How can we improve the model?

Active learning: We will convey concepts/facts sequentially. Your job is to connect them!



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Brief Description:	A graduate lecture course covering mathematical and computational tools for data analysis and modeling of neural and cognitive systems, including the transformations of raw data into a form in which these tools may be utilized, the choice and implementation of the tool, and the interpretation of such analyses. Lectures on each topic will include some mathematical background, derivation of basic results, and examples relevant to neural science. The course will include weekly problem sets requiring programming in either MATLAB or Python.
Audience:	The course is targeted for CNS and Psychology doctoral students, but is often attended by master's students and postdocs, as well as students from other NYU departments and other Universities.
Prerequisites:	College-level algebra, trigonometry and calculus. Linear algebra and some programming experience is helpful, but not required.
Format:	The course consists of two 2-hour lectures per week, and a computer lab session roughly every other week. The course includes a sequence of 5-6 homework assignments, primarily in the form of computer exercises, to examine the lecture topics in the context of concrete and realistic problems. These are *essential* for learning the material. Grades are based primarily on homework, but also take into account attendance and participation.

Course materials: There is no textbook. Supplementary reading materials will be handed out in class. All materials will be available from the course web site:

`http://www.cns.nyu.edu/~eero/math-tools/`

Topics:

I. Linear Algebra & Least Squares (4 weeks): vector spaces, projection, matrices, singular value decomposition, least-squares regression, Principal Components Analysis, total-least-squares regression, linear discriminants.

II. Linear Systems Theory (4 weeks): Convolution and Fourier Transforms (1D and multi-D), sampling, aliasing and the Nyquist theorem.

III. Probability & Statistical inference (5 weeks): Basic probability, summary statistics, parameter estimation, significance tests, model comparison, decision theory, clustering, model fitting, comparison, and selection.

Logistics

- Lectures: Tue/Thu, 10:00-12
- Lab: roughly every other Friday, 9:30-12:00 [Note: first two are matlab intro]
- Handouts (slides, notes)
- Homework: 6 problem sets, requiring math, computer code, visualization, short answers. Matlab or Python.
- Grading

Advice (and warnings)

- Material is cumulative. **Do not fall behind.**
- Homework will generally be due in two weeks. Ration your time - **Do not start the day before the deadline.**
- Solve problems in a way that demonstrates your understanding of the concepts/tools developed in lectures/labs. **Do not use "canned" software packages** or built-in commands that solve the problem directly (eg. the `regress` function, or the `inv` function)
- You are encouraged to discuss the problems with each other (as well as the TA's and the instructors). But you must turn in your own work. **Do not share code or text with others!**

Questions?