17.806: Quantitative Research Methods IV

Spring 2024

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MIT

1 Contact Information

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2 Logistics

- Lectures: Tuesdays and Thursdays, 3pm–4:30pm (Building E53-438)
- Recitations: Fridays, TBD

Note that the first class meets on February 6. No class will be held on February 20 (Monday schedule), March 26 and 28 (Spring Break). Last day of class is May 14.

3 Course Description

This course is the fourth and final course in the quantitative methods sequence at the MIT political science department. The course covers various advanced topics in applied statistics, including those that have only recently been developed in the methodological literature and are yet to be widely applied in political science. The topics for this year are organized into three broad areas: (1) research computing, where we introduce various techniques for automated data collection, visualization, and analysis of massive datasets; (2) statistical learning, where we provide an overview of machine learning algorithms for predictive and descriptive inference as well as their applications in causal inference methods; and (3) finite mixture models (e.g., Latent Dirichlet allocation for text analysis), as well as a variety of estimation techniques such as the EM algorithm and Variational Inference.

4 Prerequisites

There are three prerequisites for this course:

2. Probability and statistics covered in 17.800, 17.802 and 17.804, including linear regression, causal inference, and Bayesian statistics.

3. Statistical computing: proficiency with at least one statistical software. We will use R in this course (more on this below).

For 1, refer to this year’s math camp materials to see the minimum you need to know; see

Math Camp 1: [https://stellar.mit.edu/S/project/mathprefresher/](https://stellar.mit.edu/S/project/mathprefresher/)

Math Camp 2: [https://canvas.mit.edu/courses/5733](https://canvas.mit.edu/courses/5733)

This class will assume that you have already had some prior exposure to the material covered and go through many concepts relatively quickly.

## 5 Course Requirements

The final grades are based on the following items.

- **Problem sets (50%)**: Six problem sets will be given throughout the semester (roughly bi-weekly). Problem sets will contain analytical, computational, and data analysis questions. Each problem set will contribute equally toward the calculation of the final grade. The following instructions will apply to all problem sets unless otherwise noted.
  
  - All answers should be typed. Students are strongly encouraged to use \LaTeX, a typesetting system that has become popular in the field (or \LaTeX typesetting in RMarkdown). Please make sure that your code follows the Google and tidyverse R style guide rules (URLs are [here](https://www.google.com) and [here](https://tidyverse.org)).
  
  - Late submission will not be accepted unless you ask for special permission from the instructor in advance (Permission may be granted or not granted, with or without penalty, depending on the specific circumstances).
  
  - Working in groups is encouraged, but each student must submit their own writeup of the solutions. In particular, you should not copy someone else’s answers or computer code. We also ask you to write down the names of the other students with whom you solved the problems together on the first sheet of your solutions.
  
  - For analytical questions, you should include your intermediate steps, as well as comments on those steps when appropriate. For data analysis questions, include annotated code as part of your answers. All results should be presented in a single document so that they can be easily understood. RMarkdown is strongly encouraged.

- **Final project (40%)**: The final project will be a short research paper which typically applies a method learned in this course to an empirical problem of your substantive interest. Students are encouraged to either collect their own data or work with non-traditional form of data for their empirical projects. Consult the instructors if you have a different idea (e.g. a purely methodological project).

Students are expected to adhere to the following deadlines:
February to early March: **Start** thinking about possible topics, strategies for data acquisition, and running simple analyses on the collected data. Run your ideas by the TA and instructor during their office hours and after classes/recitations to obtain their reactions.

March 14: Turn in a **1–2 page description of your proposed project.** By this date you need to have found your coauthor, acquired the data you plan to use at least partially, and run preliminary analysis on the data (e.g., simple summary statistics, crosstabs and plots). Meet with the instructors to discuss your proposal during their office hours. You may be asked to revise and resubmit the proposal in two weeks from the meeting.

May 9, 14: Students will give **presentations** during the regular class time. Presentations should last about 15 minutes (the exact length will be determined based on the class size, but time limits will be strictly enforced) and take the form much like presentations at major academic conferences such as the APSA and MPSA annual meetings. Performance on this presentation will be counted toward the class participation grade (see below).

May 14: **Paper due.** Upload an electronic copy of your paper along with your computer code by the end of the day to the designated Canvas page. The paper should be approximately 10 pages in length, excluding the title page and appendices. It should start with a title page containing the title, author name(s), and an abstract. The body of the paper should contain a concise statement of the research question, description of the data, empirical strategy, results, and conclusions. Literature reviews, theoretical background and motivations should be either omitted or kept to minimum. Appendices can include additional tables, figures and robustness check results.

- **Participation** (10%): Students are strongly encouraged to ask questions and actively participate in discussions during lectures and recitation sessions. In addition, there will be recommended readings for each section of the course which students are strongly encouraged to complete prior to the lectures in order to get the most out of them.

6 Course Website

You can find the Stellar website for this course at:

https://canvas.mit.edu/courses/24613

We will distribute course materials, including readings, lecture slides, and problem sets, on this website.

7 Questions about Course Materials

In this course, we will utilize an online discussion board called *Piazza*. This is a question-and-answer platform that is easy to use and designed to get you answers to questions quickly. We encourage you to use the Piazza Q & A board when asking questions about lectures, problem sets, and other course materials outside of recitation sessions and office hours. You can access the Piazza course page either directly from the below address or the link posted on the Canvas course website:

https://piazza.com/mit/spring2024/17806
Using Piazza will allow students to see and learn from other students’ questions. Both the TA and the instructor will regularly check the board and answer questions posted, although everyone else is also encouraged to contribute to the discussion. A student’s respectful and constructive participation on the forum will count toward his/her class participation grade. Do not email your questions directly to the instructors or TAs (unless they are of a personal nature) — we will not answer them!

8 Recitation Sessions

Weekly recitation sessions will be held in person on Fridays. Sessions will cover a review of the theoretical material and also provide help with computing issues. The teaching assistant will run the sessions and can give more details. Attendance is strongly encouraged.

9 Notes on Auditing

In order to audit this course, one must

- Obtain the course instructor’s permission
- Complete all problem sets

10 Notes on Computing

- In this course we use R, an open-source statistical computing environment that is very widely used in statistics and political science. (If you are already well versed in another statistical software, you are free to use it, but you will be on your own.) Each problem set will contain computing and/or data analysis exercises which can be solved with R but often require going beyond canned functions to write your own program. We provide problem set solutions using R.

- We strongly encourage you to use RMarkdown. These are useful resources to learn about RMarkdown

  - Tierney, Nicholas. *RMarkdown for Scientists* [Link]
  - Xie, Yihui, Christophe Dervieux, and Emily Riederer. *R Markdown Cookbook* [Link]

- Following reference would be useful to write clean and efficient code in R

  - Google’s style guide [Link]
  - Tidyverse style guide [Link] (You do not need to use the Tidyverse but chapters 1–3 are very useful for non-Tidyverse users as well).

- If your project requires large computational resources, we recommend using xvii or Research Computing Environment (RCE) available through the Harvard-MIT Data Center (HMDC).
11 Books

- Recommended books: We will read chapters from these books throughout the course. We strongly recommend that you at least purchase Bishop. These books will be available for purchase at COOP and online bookstores (e.g. Amazon) and on reserve in the library.

  - James, Gareth, Daniela Witten, Trevor Hastie, and Robert Tibshirani. 2014. *An Introduction to Statistical Learning*. Springer.
  - Jurafsky, Daniel and James Martin. 2018. *Speech and Language Processing*. Prentice Hall. [PDF]

12 Course Outline

12.1 Introduction

1. Big Data in Political Science

   Recommended Reading:


12.2 Automated Data Collection

1. Web Scraping, Regular Expressions

   Recommended Reading:

   - Jurafsky and Martin 2.1.
   - For a basic tutorial on HTML, consult 3 sources linked from this blog post: [Three great places to start learning HTML](#).
   - Data Camp Course: [Working with Web Data in R](#).
12.3 Dimension Reduction

1. Principal Component Analysis, Factor Analysis

\textit{Required Reading:}

- Shlens, Jonathon. \textit{A Tutorial on Principal Component Analysis}. \[PDF\]

\textit{Recommended Reading:}

- Bishop Ch.12 (towards 12.2.1).
- Hastie, Tibshirani, and Friedman 14.5.

2. T-SNE

\textit{Recommended Reading:}


12.4 Supervised Learning

1. Support Vector Machine (SVM)

\textit{Recommended Reading:}

- Bishop Appendix E. Lagrange Multipliers.
- Bishop 7.1 (7.1.3, 7.1.4 optional).
- Murphy Ch.14 (optional).

2. Over-fitting (Model Selection), Cross-validation

\textit{Required Reading:}

- Hastie, Tibshirani, and Friedman Ch.7.

\textit{Recommended Reading:}

- Bishop 1.1.
3. Variable Selection (Ridge Regression, LASSO)

Required Reading:

- Hastie, Tibshirani, and Friedman 3.1–3.4.

Recommended Reading:


Recommended Reading:

- Hastie, Tibshirani, and Friedman Chs.9, 15, 16.
- Bishop Ch.14.
- Murphy Ch.16.

5. Conformal Inference

Recommended Reading:


12.5 Machine Learning for Causal Inference

1. Machine learning for Causal Inference

Required Reading:


Recommended Reading:


### 12.6 Mixture Models

1. Probability Distributions

   *Required Reading:*

   • Bishop 2, Appendix B.

2. EM Algorithm

   *Required Reading:*

   • Bishop Ch.9.

   *Recommended Reading:*

   • Murphy 11

3. Variational Inference

   *Required Reading:*


   *Recommended Reading:*

   • Bishop Ch.10.
   • Murphy Ch.21.
12.7 Text Analysis

1. Text as Data: regular expression, stemming

**Recommended Reading:**


**Required Reading:**


**Recommended Reading:**


3. Words and Votes: Scaling with Text

**Recommended Reading:**

4. Word Embeddings

Recommended Reading:

- Jurafsky and Martin Ch.6.

12.8 Causal Inference with Time-Series Cross-Section Data

Required Reading:


Recommended Reading:


12.9 Network Models (Time Permitting)

Recommended Reading:


