MASSACHUSETTS INSTITUTE OF TECHNOLOGY

15.780 Stochastic Models in Business Analytics

Fall 2021

COURSE SYLLABUS

Course Website Canvas - https://canvas.mit.edu/courses/9780

Professor: Mohammad Fazel-Zarandi E62-565, fazel@mit.edu

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Class hours: MW 11:30–1:00, E62-250

Recitation hours: F 2:00 – 3:00, E62-250

Office hours: TBD

Course Objective

To provide students with concepts, techniques, and tools that will enable them to analyze and improve data-driven modeling in operations management. Special emphasis will be given to optimizing business decisions under uncertainty. In particular, some of the topics covered include: demand forecasting, choice modeling, revenue management, assortment planning, exploration/exploitation, and auction design. Many industries and application domains will be covered, such as airlines, fashion, retail, healthcare, food, online advertising, and more. A special feature of the course is a final project that provide hands-on demonstration of some of the central concepts. The course will provide a competitive edge in almost every post-graduate career path, including analytics, data science, speed dating, school choice, operations, product development, online advertising, and healthcare.

The course relies on a combination of lectures, assignments, and a final project. To pursue the course objective most effectively, you will have to:

1. Complete all homework assignments

2. Complete a final project

3. Actively engage in lectures and recitations.

Course Material

The 15.780 course packets. Course packets will be available under the "study.net" tab of Canvas.

Academic Integrity

When preparing assignments you should not receive input from anyone who has already participated in a faculty-led discussion of the same material, be it at Sloan or another school. In addition, you should work alone when preparing graded individual assignments. When preparing graded team assignments, your discussions should be strictly limited to the members of your team. When preparing any graded assignment you may *not* consult or use material not already posted on the course webpage, unless this has been explicitly authorized by the instructor. In particular, using material from previous editions of this course or courses offered at other schools is strictly prohibited. Also, no individual may be listed as a co-author of a team assignment unless that person has contributed to the work submitted in a substantial manner. Each member of the team is fully responsible for ensuring that each submitted assignment is done according to the expected professional standards and the academic integrity policy.

The academic integrity policy of this course will be enforced, and any violators would expose themselves to the most serious consequences. In addition, you will be held personally responsible for confronting and reporting any violations that come to your attention. Finally, if at any point during the course you believe that you may be violating this academic integrity policy, or if its implications in your particular situation are not completely clear, you should immediately contact the instructor for clarification.

Note that this policy implies in particular that you should:

- Never ask for/obtain/use hints or material relative to an assignment from any student or alumnus who has already taken the class;
- Never perform a search on the internet to find information relative to a graded assignment.

Team and Individual Work

- Students are allowed to form teams of up to **3** to work on team assignments. In team assignments students are allowed to discuss the assignment only with their team members. (For more details see the Academic Integrity section above.)
- In individual assignments if you consult with any other student you should indicate this on the front page. However, the work you do should be your own.
- For both team and individual assignments, you should clearly acknowledge any source of information that your work is based on.

Professional Standards and Other Important Miscellaneous Issues

- Please put your name card in front of you in every class.
- Please do not use laptops, tablets, cell-phones, or any other electronic devices during class unless given permission by the instructor.
- Attendance: We consider attending all classes as the minimum required to cover the essentials of the course materials. As per the school policy, job interviews are not a legitimate reason to miss a class. Absences, except in cases of personal/family emergencies, risk reduction in participation grades. It is difficult to receive a passing grade without regular attendance. If you do have a personal or family emergency that will require missing a class, please notify the TA prior to class. Late arrival to class will also lead to attendance/class participation penalties.
- Please be prepared for every class. It is your responsibility to **inform the TA** by email several hours before class if for any reason you have not been able to prepare adequately.
- For communications about registration status issues, swap and wait lists, attendance and absences from class, **please email your TA**. For any issue concerning access to course material (course packet, textbooks, readings), please email the course administrative assistant. For any other communication related to the course, please send an email to both the professor and your TA (unless it is of a highly personal/confidential nature, in which case you should email the professor only).

Grading and Assignments

The grading will be based on the following weights:

Class Participation	10%
Homework Assignment (individual)	40%
Global Supply Chain Simulation (group)	10%
First Deliverable of Project	10%
Final Project Report	20%
Final Project Presentation	10%

Class Participation

Class participation will be determined by your attendance, punctuality, and contributions to class discussions.

Homework Assignment

There will be homework assignments that aims to test your understanding of some of the quantitative materials taught in the course. Assignments should be done individually and submitted online. If you collaborate on the assignment with someone, please indicate this on the front page.

Homework due dates are listed in the schedule below. All homework must be turned in online by class start time, or by midnight if the homework is due on a Friday. Specifically, if a homework is due on a Monday or Wednesday, it must be turned in by 2:30pm. If a homework is due on a Friday, it must be turned in by 11:59pm. The Canvas assignment will close at this time.

Homework assignments will be released 1 week before the assigned due date. For example, if homework is due on a Monday at 2:30pm, the homework will be released the prior Monday.

Late submissions: We will forgive two late submissions if they are submitted before the solution is posted. If you have more than 2 late submissions, **they will not be** graded. No late submissions are allowed for case preparation questions.

Global Supply Chain Management Simulation

This simulation is an assignment that allows us to manage a global supply chain and put our new knowledge to work. Each group needs to complete the simulation and submit the rational for their decisions. Turn in the assignment at the start of class on a due date.

*Final Project Report and Presentation (in teams of up to **3**)*

There will be a final project where you are required to perform an analysis of a dataset or develop an analytics based solution for a problem related to a novel application. The final project includes a proposal, a written report (10 - 15 pages, single spaced) and a final presentation at the end of the semester (10-15 minutes depending on the size of the team).

A good proposal should include the problem that they're focusing on, the importance of the problem, the dataset they want to analyze and how they want to solve the problem.

A good report will motivate the problem or application, provide an in-depth, rigorous analysis of the data, and/or present a detailed analysis of the proposed solution.

The presentation will be graded on how well it flows, how clearly it presents the results, and its general visual aesthetic quality. The projects are done in teams of up to **3**. You will be required to form teams by **October 18th**.

Further clarification and requirements for the final report:

1. **Problem description and its importance.**
    a. What is your problem?
    b. Why is this problem important?
    c. If you are partnering with a company, who is your company and what do they do?
2. **Description of the dataset.**
    a. Where did you acquire the data?
    b. What features did you have access to? How many features did you have access to?
    c. How many data points did you have?
    d. Why do you think this was a good dataset to address the problem of interest?
3. **Discussion on data quality, missing values, and outliers.**
    a. How was the quality of your data?
    b. How did you deal with missing values?

   c. How did you deal with outliers?
4. **Discussion on the predictive model and the analytics tools used.**
   a. What predictive model(s) did you use and implement?
   b. Why do you think the model(s) were the right tool to use?
   c. What results did you obtain? Present a discussion on your results.
   d. Why do you believe the obtained model makes sense and are accurate?
5. **Discussion on optimization problem and analytics tools used.**
   a. What optimization problem did you solve?
   b. Why is this problem important and/or relevant in the context of your project?
   c. Why is the way you chose to solve the problem correct?
   d. What formulation did you use? Include the formulation in your final deliverable.
   e. Did the obtained solutions make sense? Why or why not?
   f. What are the implications of your results? What do they mean in the context of your problem?
6. **Conclusion**.
   a. How can companies use your results?
   b. What future work/research could be done on this problem? What are the future directions?

Timelines:
10/18 Project team formation
11/08 Project proposal
11/21 Know who will present
12/01, 12/6 & 12/8 Project presentations (depending on number of teams)
12/08 Final report

Here're two links for public datasets:

- Kaggle: https://www.kaggle.com/datasets
- UCI ML Repository: https://archive.ics.uci.edu/ml/datasets.php

TENTATIVE SCHEDULE AT A GLANCE

Session	Day	Topic (References)	HW
1	9/08	Introduction and Data Quality	
2	9/13	Regression	
3	9/15	Machine Learning and Classification	
4	9/20	Time Series Forecasting	
5	9/22	Analytics for Public Sector Operations	HW 1 [data quality] due 9/24
6	9/27	Choice Modeling	
7	9/29	Assortment Optimization	HW 2 [Regression and Time series] due 10/1
8	10/4	Assortment Optimization (Inventory Balancing)	
9	10/6	Evaluating Revenue Opportunity - Transportation National Group	Preparation question for the case study due 10/6 HW3 [Assortment Planning] due 10/8
	10/11	Indigenous Peoples Day	
10	10/13	Flashion: Art vs. Science in Fashion Retailing	Preparation question for the case study due 10/13
11	10/18	Facility location	Deadline for team formation (10/18)
12	10/20	Intro to SCM - Madurai Aavin Dairy	Preparation question for the case study due 10/20
	10/25	Sloan Innovation Period	
	10/27	Sloan Innovation Period	
13	11/1	Global Supply Chain Management Simulation	Simulation Assignment (group) 11/1
14	11/3	Guest speaker (Wayfair)	
15	11/8	Collaborative Filtering 1	First deliverable of project due 11/8
16	11/10	Collaborative Filtering 2	
17	11/15	Multi-Armed Bandits I	
18	11/17	Multi-Armed Bandits II	HW 4 [Collaborative Filtering] due 11/19
19	11/22	Vungle Case	Preparation question for the case study due 11/22
20	11/24	Online advertising (auction)	Preparation question for the case study due 11/24 HW 5 [Bandit] due 11/26
21	11/29	Guest speaker	
22	12/1	Final Project Presentations	
23	12/6	Final Project Presentations	
24	12/8	Final Project Presentations	Final Project Report due 12/8

SCHEDULE OF RECITATIONS

Date	Contents
9/10	R Tutorial
9/17	R Tutorial – Data Cleaning
9/24	Regression and Time Series
10/01	Choice Models and Optimization Tutorial
10/08	Julia Tutorial
10/15	TNG (Julia code)
10/22	ICBC Case Study
11/05	Supply Chain Examples
11/12	Collaborative Filtering
11/19	Multi-armed Bandits

References

R

Hadley Wickham's free online books, available at http://r4ds.had.co.nz/ and http://adv-r.had.co.nz/

Tim Smith's Angry Introduction to R, available at http://arrgh.tim-smith.us/

Jared Knowles' R-bootcamp, available at https://www.jaredknowles.com/r-bootcamp/

Learn X in Y minutes, available at https://learnxinyminutes.com/docs/r/

Data Cleaning

An introduction to data cleaning with R, available at https://cran.r-project.org/doc/contrib/de_Jonge+van_der_Loo-Introduction_to_data_cleaning_with_R.pdf

Missing-data imputation, available at http://www.stat.columbia.edu/~gelman/arm/missing.pdf

Regression

L. Wasserman, *All of Statistics: A Concise Course in Statistical Inference*, Springer Texts in Statistics.

Time Series

R. Shumway and D. Stoffer, *Time Series Analysis and Its Applications: With R Examples,* Springer Texts in Statistics.

Assortment Optimization

M. Fisher and R. Vaidyanathan, *An Algorithm and Demand Estimation Procedure for Retail Assortment Optimization*

Inventory Balancing

N. Golrezaei, H. Nazerzadeh, and P. Rusmevichientong, *Real-time Optimization of Personalized Assortments*, Management Science, available at http://faculty.marshall.usc.edu/Hamid-Nazerzadeh/pdf/online-assortment-planning.pdf

Facility Location

X. Wang et al., *Branch Reconfiguration Practice Through Operations Research in Industrial and Commercial Bank of China*, Interface

Multi-armed Bandits

Slivkins, *Introduction to Multi-Armed Bandits,* available at https://arxiv.org/pdf/1904.07272.pdf

Alternating minimization approach

https://web.eecs.umich.edu/~fessler/course/598/l/n-06-alt.pdf
https://arxiv.org/pdf/1709.04451.pdf

Auctions

https://web.stanford.edu/~jdlevin/Econ%20286/Auctions.pdf

Videos for auctions

https://www.coursera.org/lecture/game-theory-2/4-3-bidding-in-second-price-auctions-qQdCy?
https://www.coursera.org/lecture/game-theory-2/4-4-bidding-in-first-price-auctions-LM5LG

Display advertising

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2623163

Bandits
https://arxiv.org/pdf/1904.07272.pdf
http://katselis.web.engr.illinois.edu/ECE586/Lecture8.pdf
https://www0.gsb.columbia.edu/mygsb/faculty/research/pubfiles/3596/besbes_newsvendor_problem.pdf
https://faculty.wharton.upenn.edu/wp-content/uploads/2008/06/Dp_wo_demand_risk_ob_az_posted.pdf