We live in a stochastic world. What we experience each moment is unique, but often we have an understanding that it is similar to other events in our lives. In nature and society what we observe is not nature/society itself but rather how we perceive them based on our methods of questioning and measuring them. How can we describe such events and experiences so that we better understand, predict and possibly optimize them?

The course aims that students develop an **understanding of the fundamentals of stochastic methods for modeling, optimization and inference in science and engineering**. It emphasizes **more the thinking and first principles** deployed in stochastic methods and less the particular details of the computer implementation. After the end of the course I hope that you can distinguish between the choice of stochastic or deterministic methods to solve a problem and have the basic tools for solving stochastic problems. I also hope that you will have acquired **a sense of critical thinking** for computing and data sciences principles, methodologies, results and the ways we interpret them.

Is this course right for me?

The class is demanding. Students must have working familiarity with fundamentals of probabilities, multivariable calculus, linear algebra, ordinary and partial differential equations and calculus-based statistics. Students are expected to be proficient in python and C++ programming, using GitHub and software libraries is beneficial.

I wish to emphasize that AM207 can be a very time consuming course, in particular if students have little background in probabilities and programming. In the previous years, students have reported to spending *15 to 20+* hours per week outside of class on class related activities (assignments and project). I expect that this amount of time will be also representative of this year.

As in previous years, students who enroll in AM207 have diverse backgrounds -- it is entirely possible to succeed in the course with gaps in your technical preparation! However, be aware that this is a course that is both demanding in time and attention, students who lack the suggested preparations typically invest many extra hours in order to pick up the required skills on the fly.

I am looking forward to seeing you in class and I will do my best to make this course a rewarding experience.

Prerequisites: It is essential that students know fundamentals of probabilities. STATS 110 is an excellent preparation. It is also important to have a good working knowledge of calculus as well as ordinary and partial differential equations. Programming proficiency is required. Languages such as C++ and object oriented python are strongly recommended. Recommended courses are CS 50 and CS 107.

Tasks & Grades

The grade is based on **homework,** a **project**, and a **midterm exam**. The midterm exam will take place in class and last 75 minutes. You are allowed to use two pages of handwritten notes.

The project will involve teams of 2 students. We hope that in addition to content the project fosters the spirit of collaboration. The grade will be the same for both team members. You may pick your team-mates. We can help with pairing of teammates in case you need to do so. More details regarding the projects will be announced later.

TASKS	% OF FINAL GRADE
Homework (4 - keep 3 best)	30%
Midterm	20%
Project - Proposal (1 page)	10%
Project - Report (up to 8 pages)	30%
Project - Poster Presentation	10%

You are permitted to use one 1-day extension (no questions asked) for a homework assignment. There are no extensions for the project assignments available. The score of submissions that are handed in late will be reduced by 20 percent for each day the submission is late.

Contact Information in case of questions:

Please use Ed Discussion or write to skaltenbach@seas.harvard.edu

Office Hours:

Office Hours will start in the second week of the semester.

Times and Dates will be announced soon.

SCHEDULE *(8/22/2024)*

- ***Introduction to AM207 (Week 1)***
  - Definition of random variables, random variables transformation theorem
  - Sampling of probability distributions: Uniform numbers, transformation method, acceptance-rejection, variance reduction and importance sampling
- ***Fundamentals of Stochastic Processes (Weeks 1 to 3)***
  - Markov Processes and Master Equation
    - The Chapman - Kolmogorov equation, Monte Carlo Algorithms
    - Stochastic Simulation - Gillespie and accelerated Algorithms
- ***Stochastic Optimization (Weeks 3 to 7)***
  - Bio- Inspired Search and Optimization
    - Differential Evolution
  - Randomized Optimization - Learning Probability Distributions
    - Probabilistic Incremental Learning
    - Covariance Matrix Adaptation
- ***Bayesian Uncertainty Quantification (Weeks 7 - 11)***
  - What is Model Uncertainty?
  - Laplace Approximation and Maximum Likelihood - Model selection
  - Markov Chain Monte Carlo Algorithms (Transitional, Hamiltonian)
  - Variational Inference
- **Generative AI (Weeks 11 - 12)**
- **Reinforcement Learning (Weeks 12 - 13)**

Note: I may change the class schedule to accommodate progress in the class.

We have already published the lecture notes from last year. Changes to the course content (especially in the 2nd half of the course), are not reflected in the lecture notes yet. We will soon provide an updated version.

POLICY FOR THE USE OF AI IN THE COURSE

This course encourages students to explore the use of generative artificial intelligence (GAI) tools such as ChatGPT for all assignments and assessments. Any such use must be appropriately acknowledged and cited. It is each studentâ€™s responsibility to assess the validity and applicability of any GAI output that is submitted; you bear the final responsibility. Violations of this policy will be considered academic misconduct. We draw your attention to the fact that different classes at Harvard could implement different AI policies, and it is the studentâ€™s responsibility to conform to expectations for each course.

IMPORTANT:

Harvard University values inclusive excellence and providing equal educational opportunities for all students. Our goal is to remove barriers for disabled students related to inaccessible elements of instruction or design in this course. If reasonable accommodations are necessary to provide access, please contact the Disability Access Office (DAO). Accommodations do not alter fundamental requirements of the course and are not retroactive. Students should request accommodations as early as possible, since they

may take time to implement. Students should notify DAO at any time during the semester if adjustments to their communicated accommodation plan are needed. **Please communicate at least three weeks before the exam if you need special accommodations.**

Midterm Exam: October 29th