Syllabus for Randomness and Computation
Spring 2016

People

- Instructor: Prof. José Bento. **Tip:** To maximize your chances of reaching me use class time, CANVAS messaging, and office hours, where I can meet you in person, individually or in groups. I receive many emails, so using email is a bad method to grab my attention.
- TA: Minghao Liu (liunl@bc.edu).
- Extra support: **Tip**: The Connors Family Learning Center offers great tutoring services on a variety of CS related topics. I encourage you to use them if necessary. Link

Office hours

- Prof. Bento: After class, 5:00pm-6:00pm, MW, Saint Mary's Hall South, S252. I will try my best to meet with you outside this schedule if you reach out to me via CANVAS, but I cannot guarantee that I will be available.
- TA: Minghao Liu, Wed 10pm-12:00am; Fulton 160

Class schedule

Wednesday and Friday: 3:00pm to 4:15pm, 250 Fulton. During lecture time **no cellphones/computers/tablets/players/etc, and no food, are allowed**. You are, of course, very welcome to step outside for a snack, phone call, or a break, and them come back. Remember that you do not have to be in the lecture room, but if you willingly want to be there, you need to respect these minimal set of rules.

Prerequisites

Being fluid in

- Calculus (to the level of Calculus I)
- Automata (to the level of Logic and Computation)

Unfortunately, having taken and forgotten the content of these courses does not fulfill the prerequisites. I strongly recommend that you to refresh your memory. I try to make all of my lectures as self-contained as possible. **Tip**: You are

encouraged to ask questions about prerequisites during lectures, or in office hours. You can also use the TA, or the tutoring services aforementioned, to refresh those prerequisites. However, this class is not a class on calculus, or automata theory, which I assume you have already mastered. Unfortunately, I cannot devote most of my time to teach you these topics from scratch, at the expense of not teaching randomness to the students that do have the required background, and have the right to see the class topics covered in class. To help each student self-assess if he is ready to take this class, I will give a prerequisite quiz in the first lecture. Your score in this quiz **will not** count towards your class grade. Your score will help you self-assess if you are ready to take this class this year. There is nothing wrong in delaying one year to take this class.

If you understand everything that is reviewed in class sessions and you can apply all of those skills on the homework problems, you will probably do well in the class. However, you might be asked to extrapolate the main techniques and ideas learnt in class to examples or problems that you have not seen before, just like when learning e.g., English, one learns some specific words and reads some specific texts in class, but then combine these "atoms" to produce new texts.

Reading

Books are expensive, and not everyone can afford them. There is no mandatory book for the class. I try to make all of my lectures as self-contained as possible (prerequisites assumed). However, for those that do want to read a book, there are many good books on randomness and computation. A good and comprehensive one is *Probability and Computing: Randomized Algorithms and Probabilistic Analysis* by Michael Mitzenmacher and Eli Upfal, Cambridge University Pres, ISBN 978-0521835404. Link

Course topics

The level of detail with which I will cover the different class topics will vary with students' interests and time available. For each topic listed below, I include a reference to the relevant pages in the book mentioned above for those that want to do extra reading. Note that the book might not cover everything that I teach in class, or the same way that I cover it. It often goes beyond what is covered in class. To guarantee that I cover everything in the syllabus, sometimes I might record a lecture and put it online for student viewing. **Tip**: Use the list of objectives in the table below to self-assess your learning. Note: these objectives are guidelines, and are the minimum that each student should grasp for each topic.

There is more to each topic than what can be covered in a syllabus table. A high-achieving student should feel comfortable in (i) establishing connections between the different topics, not see them in isolation, (ii) applying the main ideas in each topic beyond the examples covered in class, (iii) solving the same problem in several different ways (when possible).

Week	Topics	Pages	Due dates	Objectives
1	• Course overview and syllabus • Self-assessment quiz • Pseudo-random machines		18th Jan-25th Jan	Give examples of mechanical-inspired algorithms that can generate pseudo-randomness.
2	• Pseudo-random machines (finish) • Counting ○ Permutations, arrangements, combinations	228-229	25th Jan-1st Fev	See above; Estimate the size of different types of sets and express this estimate in terms of permutations, arrangements and combinations.

3	• Counting (finish)
	  ○ Stirling's approximation
	  ○ Pigeon hole principle
	  ○ Inclusion-exclusion principle
		162, 246
		4, 16
			HW1
			1st Fev-8th Fev
				See above; Use mathematical induction, inclusion-exclusion, and bijections to count.

4	• Probability spaces and random variables ○ Sample space, sigma fields, probability measures	3-8	8th Fev-15th Fev	Apply the definition of probability spaces, random variables, and distributions to prove simple theorems.
5	• Probability spaces and random variables (finish) ○ Random variable and induced measure	20	15th Fev - 22nd Fev	See above.

	▪ Discrete and continuous distributions			
6	• Properties of probability distributions and random variables o Independence o Inclusion exclusion formula o Marginalization		HW2 22nd Fev- 29th Fev	Use the properties of distributions to compute or estimate the probability of different events, and the expected value of different random variables.
7	• Properties of probability distributions and random variables o Functions of random variables o Density of sum of random variables o Expected value ▪ Jensen inequality	20-25	29th Fev- 7th Mar	See above.
No class on the 7th and 9th of March				
8	• Properties of probability distributions and random variables (finish) o Conditional expected value ▪ Variational definition and conditional probability o Bayes' rule o Moment bounds	26-30 10 44-52	14th Mar- 21st Mar	Prove mathematical relations involving conditional expected value, conditional probabilities, and inference; Use Bayes' rule to compute probabilities that are important in different applications.
Midterm on the 23rd of March, Fulton 250, 3pm				
9	• Classical distributions o Discrete ▪ Bernoulli	25, 30-34, 44, 95, 96	HW3 21st Mar- 28th Mar	Relate the different distributions with

	▪ Binomial ▪ Geometric ▪ Poisson ▪ Uniform			different real-life or idealized models. State and prove the main properties of each distribution.
No class on the 28th of March				
10	• Classical distributions o Continuous ▪ Normal ▪ Exponential ▪ Chi ▪ Dirichlet	188-210	28th Mar- 4th Apr	See above.
11	• Classical distributions (finish) o Continuous ▪ Normal ▪ Exponential ▪ Chi ▪ Dirichlet • Law of large numbers o Weak and strong law	60	4th Apr- 11th Apr	See above; Workout simple examples of the application of both the weak and strong version of this law; Provide simple concrete examples where the LLN does not hold.
12	• Central limit theorem		HW4 11th Apr- 18th Apr	Workout simple examples of the application of the CLT; Provide concrete simple examples where the CLT does not hold.
No class on the 18th of April				
13	• Statistical detection o Minimize error probability o Maximum likelihood o Least mean square error		18th Apr— 25th Apr	Solve simple statistical estimation problems.

14	• Random processes ○ Markov chains	153-174	HW5 25th Apr- 2nd May	Calculate the stationary distribution and return times in finite MC.

15	• Random processes (finish)
	  ○ Hidden Markov models
	  ▪ Forward-backward recursions
			HW6
			2nd May-
			9th May
				Implement a simple Kalman filter using the FB recursions.

Final on the 13th of May, Fulton 250, 3pm				

Grading

- 30% homework
  - Homework consists of written assignments. These assignments will be posted on CANVAS, where you can see their deadline, also shown in the table above.
  - No extensions or late homework are accepted.
  - Solutions to the assignments are to be uploaded into CANVAS in pdf format. You can handwrite your solution and scan them, or type them using Latex, and upload the corresponding Pdf.

- 30% midterm
  - There will be one midterm exams in this class, on the 23rd of March, Fulton 250. This date is subject to changes depending on the speed of the class. The midterm exam will cover all of the topics discussed in class, and covered in the homework, right up to the exam's date. The exam is to be hand solved/written, with no access to books, notes, computers, cellphones, or any other kind of auxiliary source of information. The duration of the midterm is 1 hour and 15 minutes.

- 10% scribing
  - Each two students will be required to scribe a lecture and generate a Power Point for the lecture. These will be made public to the class. Each pair of students should scribe their lecture within 1 week of the lecture taking place. Once the lecture is scribed, they should submit their PPT

file to CANVAS through an assignment created for them. A random pair of students will be chosen as scribes at the beginning of each lecture. If a randomly chosen student is not present when assigned as a scribe, he/she will be penalized (and a new scribe choose). The idea is to motivate you to come to lecture. **Tip:** You are welcome to ask me for last year's scribing, to have a benchmark for the quality of your scribed lecture. Copying material from last year's scribing is a violation of integrity, and will be severely punished. To get a good score in this grade component, your scribed lecture should be substantially better than the equivalent lecture from last year, specially taking into account that you have last year slides as starting point.

- The main purpose of this exercise is to teach you how to present ideas in a rigorous and clear way. The notes can also be a good way to study, but remember that you should take your own notes in class, and not trust that what other students wrote is correct. Do not trust that last year's scribing is correct either.

- 30% final
  - There will be a final exam on the 13th of May, in Fulton 250. The final exam will cover all of the topics discussed in class, and covered in the homework. The exam is to be hand solved/written, with no access to books, notes, computers, cellphones, or any other kind of auxiliary source of information. The exam's duration will be 2.5 hours.

Integrity

Do not copy your solutions for the homework from online sources or your colleagues. If you get caught, you will get into serious trouble. It is OK if you cannot solve a problem. Because of this, be careful with your collaborations. It is Ok to ask for help from a conceptual point of view. However, if you ask for very detailed help, there will be almost-equal homework solutions, and you will hurt yourself and your helping-friend. For exams and midterm, absolutely no information exchange is allowed.

Please read the following:
https://www.bc.edu/offices/stserv/academic/integrity.html