

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

6.041x: Introduction to Probability - The Science of Uncertainty Spring 2016

WHAT TO DO AFTER THIS COURSE ?

Many of you have asked us about possible follow-ups to this course. There are many different choices, depending on the directions that interest you; for example, random processes, machine learning, theory, etc. In order to give you a sense of the overall landscape, we provide you with the descriptions of various courses that are available at MIT. As a rule of thumb, any class with a zero following the dot (e.g., 6.041) is an undergraduate class.

1 Systems and Signal Processing :

- **6.011 Introduction to Communication, Control, and Signal Processing:** ([OCW link](#))

Syllabus: This course examines signals, systems and inference as unifying themes in communication, control and signal processing. Topics include input-output and state-space models of linear systems driven by deterministic and random signals; time- and transform-domain representations in discrete and continuous time; group delay; state feedback and observers; probabilistic models; stochastic processes, correlation functions, power spectra, spectral factorization; least-mean square error estimation; Wiener filtering; hypothesis testing; detection; matched filters.

- **6.341 Discrete-Time Signal Processing:** ([OCW link](#)) ([edX link](#))

Syllabus: This class addresses the representation, analysis, and design of discrete time signals and systems. The major concepts covered include: Discrete-time processing of continuous-time signals; decimation, interpolation, and sampling rate conversion; flowgraph structures for DT systems; time- and frequency-domain design techniques for recursive (IIR) and non-recursive (FIR) filters; linear prediction; discrete Fourier transform, FFT algorithm; short-time Fourier analysis and filter banks; multirate techniques; Hilbert transforms; Cepstral analysis and various applications.

2 Deeper into Theory:

- **6.436 Fundamentals of Probability:** ([OCW link](#))

Syllabus: This is a course on the fundamentals of probability geared towards first- or second-year graduate students who are interested in a rigorous development of the subject. The course covers most of the topics in 6.041 (sample space, random variables, expectations, transforms, Bernoulli and Poisson processes, finite Markov chains, limit theorems) but at a faster pace and in more depth. There are also a number of additional topics, such as language, terminology, and key results from measure

theory; interchange of limits and expectations; multivariate Gaussian distributions; deeper understanding of conditional distributions and expectations.

- **Good references:** We list here a few great references. Those books are much more advanced and would require a serious background in analysis.
 - **Probability: Theory and Examples**, *Rick Durrett* ([Amazon link](#))
 - **Probability with Martingales**, *David Williams* ([Amazon link](#))

3 Statistics, Machine Learning, Inference:

- **6.008 Introduction to Inference:** ([class link](#))

Syllabus: Introduction to probabilistic modeling for problems of inference and machine learning from data, emphasizing analytical and computational aspects. Distributions, marginalization, conditioning, and structure; graphical representations. Belief propagation, decision making, classification, estimation, and prediction. Sampling methods and analysis. Introduction to asymptotic analysis and information measures, and applications.

- **18.443 Statistics for Applications:** ([OCW link](#))

Syllabus: This course offers a broad treatment of statistics, concentrating on specific statistical techniques used in science and industry. Topics include: hypothesis testing and estimation, confidence intervals, chi-square tests, nonparametric statistics, analysis of variance, regression, and correlation.

- **6.036 Introduction to Machine Learning:** ([class link](#))

Syllabus: Machine learning methods are commonly used across engineering and sciences, from computer systems to physics. Moreover, commercial sites such as search engines, recommender systems (e.g., Netflix, Amazon), advertisers, and financial institutions employ machine learning algorithms for content recommendation, predicting customer behavior, compliance, or risk. As a discipline, machine learning tries to design and understand computer programs that learn from experience for the purpose of prediction or control. In this course, you will learn about principles and algorithms for turning training data into effective automated predictions. We will cover concepts such as representation, over-fitting, regularization, and generalization; topics such as clustering, classification, recommender problems, and probabilistic modeling; and methods such as on-line algorithms, support vector machines, hidden Markov models, and Bayesian networks.

- **6.867 Introduction to Machine Learning:** ([OCW link](#))

Syllabus: 6.867 is an introductory course on machine learning which gives an overview of many concepts, techniques, and algorithms in machine learning, beginning with topics such as classification and linear regression and ending up with more recent topics such as boosting, support vector

machines, hidden Markov models, and Bayesian networks. The course will give the student the basic ideas and intuition behind modern machine learning methods as well as a bit more formal understanding of how, why, and when they work. The underlying theme in the course is statistical inference as it provides the foundation for most of the methods covered.

- **6.438 Algorithms for Inference:** ([OCW link](#))

Syllabus: This is a graduate-level introduction to the principles of statistical inference with probabilistic models defined using graphical representations. The material in this course constitutes a common foundation for work in machine learning, signal processing, artificial intelligence, computer vision, control, and communication. Ultimately, the subject is about teaching you contemporary approaches to, and perspectives on, problems of statistical inference.

- **Good reference:** An excellent and concise introduction to all of the basic topics in statistics is:
 - **All of Statistics**, *Larry Wasserman* ([Amazon link](#))

4 Random Processes:

- **18.445 Introduction to Stochastic Processes:** ([OCW link](#))

Syllabus: This course is an introduction to Markov chains, random walks, martingales, and Galton-Watson tree. The course requires basic knowledge in probability theory and linear algebra including conditional expectation and matrix.

- **6.262 Discrete Stochastic Processes:** ([OCW link](#))

Syllabus: Review of probability and laws of large numbers; Poisson counting process and renewal processes; Markov chains (including Markov decision theory), branching processes, birth-death processes, and semi-Markov processes; continuous-time Markov chains and reversibility; random walks, martingales, and large deviations; applications from queueing, communication, control, and operations research.

- **6.265 Advanced Stochastic Processes:** ([OCW link](#))

Syllabus: This class covers the analysis and modeling of stochastic processes. Topics include measure theoretic probability, martingales, filtration, and stopping theorems, elements of large deviations theory, Brownian motion and reflected Brownian motion, stochastic integration and Ito calculus and functional limit theorems. In addition, the class will go over some applications to finance theory, insurance, queueing and inventory models.

5 Decision Making in Uncertain Dynamic Environments:

- **6.231 Dynamic Programming and Stochastic Control:** ([OCW link](#))

Syllabus: The course covers the basic models and solution techniques for problems of sequential decision making under uncertainty (stochastic control). We consider optimal control of a dynamical system over both a finite and an infinite number of stages. This includes systems with finite or infinite state spaces, as well as perfectly or imperfectly observed systems. We also discuss approximation methods for problems involving large state spaces. Applications of dynamic programming in a variety of fields will be covered in recitations.

6 Applications:

Everywhere; look for them and enjoy! ☺ Having mastered the material in 6.041x, you already have the tools to deal with many of the applications that arise in different fields.