Northwestern University

Department of Electrical and Computer Engineering

ELEC_ENG 422: Random Processes in Communications and Control I — Winter 2024

Information Sheet:

Instructor:
Prof. Randall Berry
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Office Hours: By appointment

Time and Place:
TuTh 3:30-4:50 pm, Tech, Rm L160

Course Overview: Probability and random processes are central fields of mathematics and are widely applied in many areas including risk assessment, statistics, machine learning, data networks, operations research, information theory, control theory, theoretical computer science, quantum theory, game theory, finance, and neurophysiology. This course will provide an introduction to mathematical probability and random process with a focus on techniques that are useful in studying communication and control systems as well as in many other domains. We will begin with a thorough review of basic probability theory including probability spaces, random variables, concentration inequalities, and laws of large numbers. We then will study a number of basic random processes including Poisson Processes, Markov Chains and Gaussian Processes. Basics of estimation and filtering of random processes will also be covered.

Prerequisites: The official prerequisite is one undergraduate course in probability (e.g., ELEC_ENG 302). If you have not had this, then you should discuss your background with the instructor. This is a fairly mathematical course and so a degree of comfort with mathematical arguments (i.e., proofs) is also assumed. Some familiarity with linear systems and Fourier transforms is also helpful but not required (e.g., ELEC_ENG 222).

Text:
- *Stochastic Processes: Theory for Applications,* Robert Gallager, Cambridge University Press, 2014.

Reference Texts:
There are numerous books on probability and random processes. Below, I list a selected few of these that may be useful references.

1. Bruce Hajek, *Random Processes for Engineers*, Cambridge University Press, 2015.
   An on-line draft of this book is also available at:
   http://www.ifp.illinois.edu/~hajek/Papers/randomprocesses.html
   This book is a good alternative reference for many of the topics covered here.
2. Dimitri Bertsekas and John Tsitsiklis, *Introduction to Probability,* 2nd Ed., Athena Scientific, 2008.
   This book is for an introductory course on probability and is a good reference for reviewing the prerequisite material.
3. Santosh Venkatesh, *The Theory of Probability: Explorations and Applications,* Cambridge University Press, 2013.
   Another book that provides a nice introduction to probability theory with some interesting examples.

4. Geoffrey Grimmett and David Stirzaker, *Probability and Random Processes*, 3rd Ed., Oxford University Press, 2001

   An extensive introduction to probability and random processes at a slightly more mathematical level than this course.

5. William Feller, *An Introduction to Probability: Theory and Applications*, volumes 1 & 2, John Wiley and Sons, 1966.

   A timeless and comprehensive overview of probability and random processes.

6. Michael Mitzenmacher and Eli Upfal, *Probability and Computing: Randomized Algorithms and Probabilistic Analysis*, Cambridge University Press, 2005.

   This book provides some nice computer science applications of probability and random processes.

7. Sheldon Ross, *Stochastic Processes*, Wiley, 1996.

   Another well-known text on stochastic processes that focuses more on operations research applications.

Course Handouts:

Handouts and other announcements will be available on CANVAS.

Studying:

A goal of this course is to understand of probability and random processes so that you can apply the ideas to problems in a variety of different research areas. Successfully doing this requires you to develop solid intuition and insight into random process, which does not come naturally to most people. This requires you to not simply do "plug and chug" calculations, but to instead spend time understanding the concepts and proofs behind the results. In particular, you are encouraged to not simply focus on completing the homework, but to also spend time reading over and thinking about the material.

Problem Sets:

Problem sets will be assigned on a quasi-weekly schedule. In making up the exams it will be assumed that you have worked all the problems. Working together in small groups on the problem sets is encouraged, however each person should be sure to understand and write up their own solution to hand in. The problem sets are intended to help you learn the material and whatever maximizes learning for you is desirable. Problem sets must be submitted via canvas by the due date.

Exams:

There will be a one midterm exam and one final exam.

Course Grade:

Your final grade in the course is based upon our best assessment of your understanding of the material. The weightings used to determine the final grade are:

Midterm	30%
Final	35%
Problem Sets	35%

Syllabus (tentative):

- Probability review: probability spaces, axioms of probability, conditional probabilities, independence, random variables, expectation, conditional expectation.
- Concentration inequalities and limit theorems – Chernoff bounds, laws of large numbers, central limit theorems
- Poisson Process – memoryless properties, alternative definitions, combining and splitting.
- Finite and Countable State Markov chains – first passage time analysis, steady-state analysis.
- Gaussian Processes – jointly Gaussian random variables, covariance matrices, filtered processes, power spectral density.
- Bayesian Estimation – MMSE criteria, estimation and Gaussian random vectors, linear least squares estimation.

Accessibility

Northwestern University is committed to providing the most accessible learning environment as possible for students with disabilities. Should you anticipate or experience disability-related barriers in the academic setting, please contact AccessibleNU to move forward with the university's established accommodation process (e: accessiblenu@northwestern.edu; p: 847-467-5530). If you already have established accommodations with AccessibleNU, please let me know as soon as possible, preferably within the first two weeks of the term, so we can work together to implement your disability accommodations. Disability information, including academic accommodations, is confidential under the Family Educational Rights and Privacy Act.

Academic Integrity

Students in this course are required to comply with the policies found in the booklet, "Academic Integrity at Northwestern University: A Basic Guide". All papers submitted for credit in this course must be submitted electronically unless otherwise instructed by the professor. Your written work may be tested for plagiarized content. For details regarding academic integrity at Northwestern or to download the guide, visit: https://www.northwestern.edu/provost/policies-procedures/academic-integrity/index.html. Any form of cheating, including improper use of content generated by artificial intelligence, constitutes a violation of Northwestern's academic integrity policy.