جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Stochastic Processes - AMCS 241

Division	Computer, Electrical and Mathematical Sciences & Engineering
Course Number	AMCS 241
Course Title	Stochastic Processes
Academic Semester	Spring
Academic Year	2017/2018
Semester Start Date	01/28/2018
Semester End Date	05/24/2018
Class Schedule (Days & Time)	09:00 AM - 10:30 AM | Sun Wed

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Ahmed Sultan Salem	Ahmed.Salem@kaust.edu.sa	+966128080416		Office: 3134 Khawarizmi West Office hours: Wednesday 12:30 PM—4:30 PM, Thursday 10:00 AM—1:00 PM

Teaching Assistant(s)

Name	Email

Course Information

Comprehensive Course Description	This course presents the fundamentals of probability theory and random processes. Contents of this course are relevant but not limited to: communications and information systems, computer engineering, signal processing, machine learning, bioinformatics, econometrics and mathematical finance. Contents: Selective review. Complex random variables (RV's) and vectors, proper/circularly symmetric RV's. Minimum mean-squared error (MMSE) estimation. Moment generating Function (MGF). Characteristic function (CF), central limit theorem (CLT) for i.i.d. RV's and Lyapunov CLT for independent, but nonidentically distributed RV's. Berry-Esseen Theorem. Inequalities: Jensen, Kolmogorov's maximal inequality, Hájek-Rényi inequality, Hoeffding inequality, Bernstein inequality, Kolmogorov submartingale inequality, Vapnik-Chervonenkis inequality. Chernoff bounds and exponential tilting (large deviation theory). Convergence of random variables: mean-square, probability, distribution and with probability one. Borel-Cantelli lemma. Strong and weak laws of large numbers. Consistency of estimators. Random processes: definitions, correlation function, power spectral density (PSD) and linear time-invariant (LTI) filtering. Poisson process: properties, conditional distributions, current and residual lifetimes. Renewal processes: generalizing Poisson process, renewal function and renewal equation. Discrete-time Markov chains (DTMC): definitions, computation of state probabilities and classification of states. Continuous-time Markov chains (CTMC) and Chapman-Kolmogorov's forward and backward equations. Random Walks: properties and relevant distributions. Gambler's ruin and Wiener process (Brownian motion) Vector Cramer-Rao lowerbound and the efficiency of estimators. Hypothesis testing: Bayesian risk minimization, Neyman-Pearson hypothesis testing and generalized likelihood ratio test (GLRT). A very brief introduction to minimax and sequential hypothesis testing.
Course Description from Program Guide	Topics include probability axioms, sigma algebras, random vectors, expectation, probability distributions and densities, Poisson and Wiener processes, stationary processes, autocorrelation, spectral density, effects of filtering, linear least-squares estimation and convergence of random sequences.
Goals and Objectives	AMCS 241 is an introductory graduate course. Students will learn the fundamentals of probability theory and stochastic processes. The main goal is for the students to thoroughly understand the covered topics and be able to apply them. The course prepares the students for more advanced and specialized courses.
Required Knowledge	**Prerequisites:** Adequate background in basic probability (including random variables and distributions), linear algebra, multivariate calculus, Fourier transform, z-transform and Laplace transform. Students should be competent in writing rigorous proofs and should understand terms such as 'if and only if', sufficient conditions, necessary conditions, etc. **Important note:** The course may be time-demanding, especially for those without the required background and mathematical fluency. A student who has deficiencies in his or her background can still take the course. However, the price will be more time spent on the course, or less acquired knowledge, or both. Students should, given their learning priorities and other commitments, decide for themselves whether or not to take the course and what policy to adopt to handle course material and requirements. In addition to two lectures per week, there are 8—10 tutorial sessions whose attendance is mandatory. These are typically held on Tuesdays. This course involves significant self-study and reading from handouts and references.
Reference Texts	**Textbook:** Probability, Random Processes, and Statistical Analysis by H. Kobayashi, B. L. Mark and W. Turin. Textbook is available at: http://ebooks.cambridge.org/ebook.jsf?bid=CBO9780511977770 **References:** Geoffrey Grimmett and David Stirzaker, Probability and Random Processes, 3rd Edition, Oxford University press, 2001. (The exercises in the book are solved in another book by the authors titled One Thousand Exercises in Probability. This book has numerous solved exercises covering all the topics we do in AMCS 241.) Gallager, Stochastic Processes: Theory for Applications, Cambridge University Press, 2014. Sheldom Ross, Stochastic Processes, 2nd Edition, John Wiley & Sons, 1996. Papoulis, Probability, Random Variables, and Stochastic Processes, 4th Edition, Mc-Graw Hill, 2002. Leon-Garcia, Probability, Statistics, and Random Processes for Electrical Engineering, 3rd Edition, Prentice-Hall, 2008. **Advanced References:** Patrick Billingsley, Probability and Measure http://www.colorado.edu/amath/sites/default/files/attached-files/billingsley.pdf Rick Durrett, Probability: Theory and Examples https://www.cambridge.org/core/books/probability/81949AABAA8B3A8411CB88402F0F05C9 David Williams, Probability with Martingales https://www.cambridge.org/core/books/probability-with-martingales/B4CFCE0D08930FB46C6E93E775503926 René L. Schilling, Measures, Integrals and Martingales https://www.cambridge.org/core/books/measures-integrals-and-martingales/7BEE19069C88A1376AEB988487D4131C

Method of evaluation	**30.00**% - Midterm exam **40.00**% - Homework /Assignments **30.00**% - Final exam
Nature of the assignments	Five problems per week + One bonus problem. (The bonus problem is always the 6th problem in each problem set.) No help will be provided regarding the bonus problem. The advantage of solving the bonus problems is that they can compensate for inadequate performance in some problem sets or in the exams. In a typical week, each problem is worth 20 marks for a total of 100 marks. A student can obtain up to 120 out of 100 if the bonus problem is worth 20 marks. Scoring an average of 80 marks in the problem sets is very good. Scoring above 60 is adequate. -Only the solutions to some selected problems will be posted to Blackboard.
Course Policies	-Late homework submissions are not accepted. -No collaboration between students is allowed in solving the problems. Each student must individually work on the problem sets and only ask the instructor for help. To obtain a hint, please come to the office hours with your attempts. If you cannot come, please scan or take a clear photo of your attempt at the solution, email it to the instructor, and based on your progress, a hint may be provided. -Please check the website periodically for (possible) corrections to posted homework. -To incentivize scrutiny of homework problems, extra points are given for being the first to inform me of critical errors. Also, bonus points are given to those who inform me of errors in the class handouts. -If a problem asks for a specific method to solve the problem, then solving it correctly using another method is invalid and the solution would not get any credit. -Using material from previous semesters is totally prohibited. -Cheating, copying solutions, or using previous years' solutions is a serious violation that means failing the class. -You should explicitly mention any online source you have consulted to solve any problem. -You can use software to evaluate integrals, sums, products, etc. Some problems will actually demand that you use Matlab. Note that in the exams you will still have to evaluate sums, products and integrals without the help of software. These, of course, will be chosen to be manageable and solvable using the methods that should be known by any graduate student.
Additional Information	

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Sun 01/28/2018 Wed 01/31/2018	Review. Complex random variables and vectors. PDF of quadratic forms involving projection matrices.
2	Sun 02/04/2018 Wed 02/07/2018	Moment generating function. Characteristic function. Central Limit Theorem.
3	Sun 02/11/2018 Wed 02/14/2018	Laplace transform. Generating functions. Minimum mean-squared error estimation.
4	Sun 02/18/2018 Wed 02/21/2018	Inequalities. Martingales.
5	Sun 02/25/2018 Wed 02/28/2018	Convergence of sequences of random variables. Weak and strong laws of large numbers. Borel-Cantelli lemma. Consistency of estimators.
6	Sun 03/04/2018 Wed 03/07/2018	Random processes. Power spectral density of wide-sense stationary random processes. Mean-square derivatives.
7	Sun 03/11/2018 Wed 03/14/2018	Poisson process.
8	Sun 03/18/2018 Wed 03/21/2018	Renewal processes.
9	Sun 03/25/2018 Wed 03/28/2018	Asymptotic behavior of renewal processes. Markov random processes.
10	Sun 04/01/2018 Wed 04/04/2018	Discrete-Time Markov Chains. Classification of states. Stationary distribution of irreducible ergodic chains.
11	Sun 04/08/2018 Wed 04/11/2018	Spring break
12	Sun 04/15/2018 Wed 04/18/2018	Continuous-time Markov chains. Chapman-Kolmogorov's equations.
13	Sun 04/22/2018 Wed 04/25/2018	Random walks. Gambler's ruin problem.
14	Sun 04/29/2018 Wed 05/02/2018	Wiener process (Brownian motion). ML estimation of the transition probability matrix of a discrete-time Markov chain.
15	Sun 05/06/2018 Wed 05/09/2018	Metropolis-Hastings algorithm (Markov chain Monte Carlo). Cramer-Rao lowerbound (CRLB).
16	Sun 05/13/2018 Wed 05/16/2018	Hypothesis testing.
17	Sun 05/20/2018 Wed 05/23/2018	Final
18		

Note

The instructor reserves the right to make changes to this syllabus as necessary.