EE 190.30F: Foundations and Applications of Intelligent and Autonomous Systems
Bourns College of Engineering, University of California, Riverside, CA 92521

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Prerequisite: EE 114 (Probability, Random Variables, and Random Processes in Electrical Engineering)

Course
Intelligent systems need to make decisions about how to interact with the physical world based on analysis of sensed data. This data is usually stochastic in nature (e.g., traffic has patterns that are somewhat, but not entirely, predictable). Modeling this uncertainty enables the design of optimal decision-making algorithms. This course focuses on the foundational principles behind engineering systems that are able to make decisions based on an understanding of this stochasticity.

Homework
Homework will be assigned weekly. Homework assigned in any given week is due before the beginning of the first class of the following week.

Studying in groups is encouraged so that you may learn from your fellow students, but materials that are turned in must be completed independently and represent each individual's own effort. *Homework that appears to be copied will be given to the Office of Student Conduct.*

Application Projects
There will be 3-4 application projects. In each, application data will be provided along with project specifications. Related solution approaches will be discussed in class. Each project will require designing and programing a solution to the problem in Matlab. You will turn in a solution description along with a discussion of your results and working code.

Projects must be *performed individually*. The report, *written individually*, is due on the date stated on the project assignment. Reports will be submitted electronically and electronically checked for copying. R*eports that appear to be copied will be given to the Office of Student Conduct.*

Grading
A letter grade (4 units) is required, and will be based on the following percentages:
Homework: 25%, Projects: 25%, Exam 25%, Final: 25%.

Sample Text Book
1. Chapters 7-11 of Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers, 3rd Edition, 2014, Roy D. Yates, David J. Goodman, ISBN: 978-1-118-32456-1
2. Chapters 6-9 of Introduction to Probability, 2nd Edition, Dimitri P. Bertsekas and John N. Tsitsiklis, ISBN: 978-1-886529-23-6, 2008.

Draft Lecture Sequence for First Offering

The goal is that most lectures start with an application[1], discusses the formulation of its problem statement, then discuss its solution and analysis using methods for random variables and stochastic processes.

Wk 1 - Introduction – Applications requiring stochastic methods. Review of random variables, expectation, covariance, correlation, estimation, and prediction. Fisher and Bayes approaches. Density and likelihood function.

WK 2 - Application: Power spectrum estimation. Problem formulation. Review of linear algebra. Stationarity, autocorrelation, frequency resolution. Linear transformation of Gaussian noise process. Covariance of the estimate by different methods. Effect of algorithm design variables on error covariance.

WK 3 - Application: Estimation of Failure Rate. Problem formulation. Bernoulli random variables. Density, likelihood, CRLB, Maximum likelihood estimate, minimum variance unbiased estimate (MVUE), covariance of the estimate.

WK 4 - Application: Fitting of linear curves to data. Problem formulation. Least squares, weighted least squares. MVUE and CRLB for linear measurement model with Gaussian measurement noise. Covariance. Confidence intervals. Bias-Variance trade-off. Residuals. Outliers. Intro to RANSAC and MSAC.

WK 5 - Application: Extraction of planes from Lidar data. Lidar data. Plane model. Problem formulation. Solution by Singular Value Decomposition and Principal Component Analysis.

WK 6 - Conditional densities, Bayes theorem, Bayes estimation. Examples. Maximum a Posteriori (MAP) estimation. Examples.

WK 7 - Application: Time series prediction. Problem formulation in Bayesian sense. Autocorrelation. Linear Minimum Mean Squared Error predictor. Issues in model selection.

WK 8 - Application: State estimation. Presentation of the application for a state estimator with constant gain L. Presentation of the Kalman Filter equations and their application to the same application. Presentation of the method to choose L as the steady-state Kalman gain. Discussion of implementation issues and tradeoffs.

WK 9 - Application - One dimensional INS with position aiding. Methods to implement Kalman filter in discrete-time for a system evolving in discrete-time. Model requirements for optimality of the Kalman filter to be valid. Problem formulation and assumptions. Kalman filter equations in different forms. Discussion of trade-offs.

WK 10 - Kalman Filter by MAP. Application of expectation and Bayes theorem in the context of state space models.

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[1] Applications are instructor dependent. Those listed in the sample syllabus are those expected for the Fall 2020 offering as **EE 190.30F.**