Department of Electrical and Computer Engineering
College of Engineering and Applied Sciences
Western Michigan University
1903 · 2003

ECE 3800
Probabilistic Methods of Signal and System Analysis

Dr. Bradley J. Bazuin
Western Michigan University
College of Engineering and Applied Sciences
Department of Electrical and Computer Engineering
1903 W. Michigan Ave.
Kalamazoo MI, 49008-5329

Course/Lecture Overview

- Syllabus
- Personal Intro.
- Textbook/Materials Used
- Additional Reading
- ID and Acknowledgment of Policies

- Chapter 1

Syllabus

- Everything useful for this class can be found on Dr. Bazuin's web site!
  - http://homepages.wmich.edu/~bazuinb/
- The class web site is at
  - https://homepages.wmich.edu/~bazuinb/ECE3800/ECE3800_Fa16.html
- The syllabus …
  - http://homepages.wmich.edu/~bazuinb/ECE3800/ECE3800ABET.pdf
  - http://homepages.wmich.edu/~bazuinb/ECE3800/Syl_3800.pdf

Dr. Bradley J. Bazuin

- Born and raised in Michigan, Grand Rapids – Forest Hills Northern
- Education
  - Undergraduate BS in Engineering and Applied Sciences, Extensive Electrical Engineering from Yale University in 1980
  - Graduate MS and PhD in Electrical Engineering from Stanford University in 1982 and 1989, respectively.
- Industrial Employment
  - Part-time ARGOSystems, Inc., Sunnyvale, CA, 1981-1989
  - Full-time ARGOSystems, Inc., Sunnyvale, CA, 1989-1991
  - Full-time Radix Technologies, Mountain View, CA, 1991-2000
- Academics
  - Term-appointed Faculty, WMU ECE Dept. 2000-2001
  - Tenure track Assistant Professor, WMU ECE Dept. 2001-2007
  - Tenured Associate Professor, WMU ECE Dept. 2007-

Research and Technical Interests

- Wireless Communications
  - Physical Layer signal and system implementation
  - Software Defined Radios (SDR) - USRP & GNU radio
  - Xilinx with VHDL coding and Graphic processing units (GPU)
- Advanced Digital Signal Processing
  - Algorithmic techniques for processing detecting, estimating and exploiting signals (communications, electronics, and sensors).
  - Multirate signal processing, estimation theory, adaptive signal processing
- CAPE & CASSS
  - Center for the Advancement of Printed Electronics
  - Center for Advanced Smart Sensors and Structures
- Sunseeker Solar Team Adviser & WMU Educational Solar Garden Technical Director
  - Embedded processing systems (TI MSP430 based)
  - Embedded software (control, monitoring, safety, telemetry)
  - Energy conversion (solar cells, batteries, super capacitors)
- Collaborative Engineering
  - Supporting other WMU research activities where I can contribute

Required Textbook/Materials

- Henry Stark and John W. Woods, *Probability, Statistics, and Random Variables for Engineers*, 4th ed., Pearson Education Inc., 2012. ISBN: 978-0-13-231123-6.
- The MATH Works,
  MATLAB Student Version ($99) or CAE Center
  http://www.mathworks.com/
  - Learn MATLAB for free
    - https://matlabacademy.mathworks.com/
    - http://www.mathworks.com/support/learn-with-matlab-tutorials.html

Other Books and Materials

- George R. Cooper and Clare D. McGillem, Probabilistic Methods of Signal and System Analysis, 3rd ed., Oxford University Press Inc., 1999. ISBN: 0-19-512354-9.
  - Previous text used for ECE 3800
- Alberto Leon-Garcia, “Probability, Statistics, and Random Processes For Electrical Engineering, 3rd ed.”, Pearson Prentice Hall, Upper Saddle River, NJ, 2008, ISBN: 013-147122-8.
  - Graduate text used for ECE 5820
- Schaum's Outline of Probability and Statistics, 2nd Edition, M.R. Spiegel, Deceased, J.J. Schiller, R.A. Srinivasan, McGraw-Hill, 2000. ISBN: 0071350047.
- A. Papoulis, "Probability, Random Variables, and Stochastic Processes," McGraw-Hill, 1965. ISBM: 07-048448-1.

Identification and Acknowledgement

- Identification for Grade Posting,
  Acknowledgment of completing prerequisites,
  Reminder of Course and University Policies, and
  Acknowledgement and Signature Block

- Please read, provide unique identification, sign and date, and return to Dr. Bazuin.

Course/Text Overview

1 Introduction to Probability

- 1.1 Introduction: Why Study Probability?
- 1.2 The Different Kinds of Probability
- 1.3 Misuses, Miscalculations, and Paradoxes in Probability
- 1.4 Sets, Fields, and Events
- 1.5 Axiomatic Definition of Probability
- 1.6 Joint, Conditional, and Total Probabilities; Independence
- 1.7 Bayes' Theorem and Applications
- 1.8 Combinatorics
- 1.9 Bernoulli Trials–Binomial and Multinomial Probability Laws
- 1.10 Asymptotic Behavior of the Binomial Law: The Poisson Law
- 1.11 Normal Approximation to the Binomial Law

2 Random Variables

- 2.1 Introduction
- 2.2 Definition of a Random Variable
- 2.3 Cumulative Distribution Function
- 2.4 Probability Density Function (pdf)
- 2.5 Continuous, Discrete, and Mixed Random Variables
- 2.6 Conditional and Joint Distributions and Densities
- 2.7 Failure Rates

3 Functions of Random Variables

- 3.1 Introduction
- 3.2 Solving Problems of the Type $Y = g(X)$
- 3.3 Solving Problems of the Type $Z = g(X, Y)$
- 3.4 Solving Problems of the Type $V = g(X, Y)$, $W = h(X, Y)$
- 3.5 Additional Examples

Exam #1

Based on materials in the course textbook: Henry Stark and John W. Woods, Probability, Statistics, and Random Variables for Engineers, 4th ed., Pearson Education Inc., 2012. ISBN: 978-0-13-231123-6.

Course/Text Overview (2)

4. Expectation and Moments

- 4.1 Expected Value of a Random Variable
- 4.2 Conditional Expectations
- 4.3 Moments of Random Variables
- 4.4 Chebyshev and Schwarz Inequalities
- 4.5 Moment-Generating Functions
- 4.6 Chernoff Bound
- 4.7 Characteristic Functions
- 4.8 Additional Examples

5 Random Vectors (Highlights Only)

- 5.1 Joint Distribution and Densities
- 5.2 Multiple Transformation of Random Variables
- 5.3 Ordered Random Variables
- 5.4 Expectation Vectors and Covariance Matrices
- 5.5 Properties of Covariance Matrices
- 5.6 The Multidimensional Gaussian (Normal) Law
- 5.7 Characteristic Functions of Random Vectors

6 Statistics: Part 1 Parameter Estimation

- 6.1 Introduction
- 6.2 Estimators
- 6.3 Estimation of the Mean
- 6.4 Estimation of the Variance and Covariance
- 6.5 Simultaneous Estimation of Mean and Variance
- 6.6 Estimation of Non-Gaussian Parameters from Large Samples
- 6.7 Maximum Likelihood Estimators
- 6.8 Ordering, more on Percentiles, Parametric Versus Nonparametric Statistics
- 6.9 Estimation of Vector Means and Covariance Matrices
- 6.10 Linear Estimation of Vector Parameters

7 Statistics: Part 2 Hypothesis Testing

- 7.1 Bayesian Decision Theory
- 7.2 Likelihood Ratio Test
- 7.3 Composite Hypotheses
- 7.4 Goodness of Fit
- 7.5 Ordering, Percentiles, and Rank

Exam #2

Based on materials in the course textbook: Henry Stark and John W. Woods, Probability, Statistics, and Random Variables for Engineers, 4th ed., Pearson Education Inc., 2012. ISBN: 978-0-13-231123-6.

Course/Text Overview (3)

8 Random Sequences

- 8.1 Basic Concepts
- 8.2 Basic Principles of Discrete-Time Linear Systems
- 8.3 Random Sequences and Linear Systems
- 8.4 WSS Random Sequences
  - Power Spectral Density
  - Interpretation of the psd
- 8.5 Markov Random Sequences
  - ARMA Models
  - Markov Chains
- 8.6 Vector Random Sequences and State Equations
- 8.7 Convergence of Random Sequences
- 8.8 Laws of Large Numbers

9 Random Processes

- 9.1 Basic Definitions
- 9.2 Some Important Random Processes
- 9.3 Continuous-Time Linear Systems with Random Inputs
  - White Noise
- 9.4 Some Useful Classifications of Random Processes
  - Stationarity
- 9.5 Wide-Sense Stationary Processes and LSI Systems
  - Power Spectral Density
  - An Interpretation of the psd
  - More on White Noise
- 9.6 Periodic and Cyclostationary Processes
- 9.7 Vector Processes and State Equations

Exam #3

Based on materials in the course textbook: Henry Stark and John W. Woods, Probability, Statistics, and Random Variables for Engineers, 4th ed., Pearson Education Inc., 2012. ISBN: 978-0-13-231123-6.

Course/Text Overview (4)

10 Advanced Topics in Random Processes

10.1 Mean-Square (m.s.) Calculus
10.2 Mean-Square Stochastic Integrals
10.3 Mean-Square Stochastic Differential Equations
10.4 Ergodicity [10-3]
10.5 Karhunen—Lo`eve Expansion
10.6 Representation of Bandlimited and Periodic Processes

11 Applications to Statistical Signal Processing

11.1 Estimation of Random Variables and Vectors
11.2 Innovation Sequences and Kalman Filtering
Kalman Predictor and Filter
Error-Covariance Equations
11.3 Wiener Filters for Random Sequences
Causal Wiener Filter
11.4 Expectation-Maximization Algorithm
Log-likelihood for the Linear Transformation
Log-likelihood Function of Complete Data
11.5 Hidden Markov Models (HMM)
Viterbi Algorithm and the Most Likely State Sequence for the Observations
11.6 Spectral Estimation
The Periodogram
11.7 Simulated Annealing

Final Exam

Chapter 1: Introduction to Probability

- Section Headings
  - Introduction: Why Study Probability?
  - The Different Kinds of Probability
  - Misuses, Miscalculations, and Paradoxes in Probability
  - Sets, Fields, and Events
  - Axiomatic Definition of Probability
  - Joint, Conditional, and Total Probabilities; Independence
  - Bayes' Theorem and Applications
  - Combinatorics
  - Bernoulli Trials–Binomial and Multinomial Probability Laws
  - Asymptotic Behavior of the Binomial Law: The Poisson Law
  - Normal Approximation to the Binomial Law

On to the Course Material