Lecture Notes 0
Course Introduction

• EE 278B in EE Curriculum
• Statistical Signal Processing
• Course Goal
• Topics
• Lecture Notes

EE 278B in EE Curriculum

• EE 278B is one of three core ISL graduate courses:
  ○ EE 261 and EE 263 deal with deterministic (linear) systems
  ○ EE 278B deals with statistical systems

• EE 278B is also a prerequisite to courses in signal processing, image and video processing, communications, stochastic control, and machine learning. It also provides a good background for other areas (e.g., noise in devices, circuits, biological systems, . . . )
Statistical Signal Processing

- Focus is on extracting information (signals) from noisy observations
- Applications are all around us—cell phones, digital cameras, base stations, digital TV, DVD, . . .
- Generic signal processing problem:
  \[ X(t) \xrightarrow{\text{noisy channel}} Y(t) \xrightarrow{\text{signal processor}} \hat{X}(t) \]
  - Signal: (coded) digital data, audio, image, video, geophysical, medical, sensor . . .
  - Channel: twisted pair, optical, wireless, satellite, computer memory, electronic circuit, layers of earth, biological, . . .
  - Channel is modeled as a statistical system—linear vs. nonlinear, time invariant vs. time varying
  - Noise (physically generated or due to interference) and often signals are modeled as random processes, i.e., sequences of random variables indexed by time

- Signal processor: attempts to recover the signal from observation via
  - estimation: find an estimate that is close to the signal \( X(t) \), for example, one that minimizes the mean square error (MSE)
  - detection: decide which signal out of a finite number of possible signals (e.g., 0 and 1) was sent—goal: minimize the probability of error
- Statistical signal processing deals with both modeling of signals and channels and design of “optimal” signal processing algorithms
- Example: many real channels (twisted pair, wireless model, . . . ) are modeled as linear time-invariant (LTI) system with additive noise

\[
X(t) \xrightarrow{h(t)} Y(t) = h(t) * X(t) + Z(t)
\]
• Very simple case: \( h(t) = \delta(t) \), \( X(t) \) binary waveform

\[
\begin{align*}
X(t) & = 1, \quad 0 \leq t < 1 \\
Y(t) & = X(t) + \text{noise}, \quad 0 \leq t < 10 \\
\hat{X}(t) & = X(t), \quad 0 \leq t < 10
\end{align*}
\]

Course Goal

• To provide the statistical signal processing background:
  o provide relevant random vectors and processes background
  o introduce statistical models for noise and signals
  o introduce detection and estimation

• Courses that require EE278B as prerequisite include:
  o communications courses: EE276, EE279, EE376A,B and EE379A,B
  o signal and image processing and estimation courses: EE378, EE355, EE359, EE363, EE368, EE372

• Prerequisites:
  EE178/278A or equivalent,
  linear systems and transforms, e.g., EE102A,B

• EE 278B may not provide sufficient background for research in communication or signal processing; more mathematical courses, e.g., Stats 217, 218, 310A,B, C may be needed
Course Topics

• Probability and random variables: Lectures Notes 1 and 2; lectures 1–4. Axioms, basic laws, conditional probability, Bayes rule, and independence. Random variables; cumulative distribution function, probability mass function, probability density function, joint, marginal and conditional distributions, functions of random variables. Applications: Generation of random variables, scalar detection. Expectation; mean, variance, covariance and correlation. Inequalities; Markov and Chebyshev. Scalar MSE estimation; linear estimation and orthogonality principle.


• Convergence and limit theorems: Lecture notes 5; lecture 10.


Lecture Notes

• Help to organize and reduce note taking in lectures
• You will need to take some notes, e.g., clarifications, missing steps in derivations, solutions to additional examples
• Slide title indicates a topic that often continues over several consecutive slides
• Lecture notes + your notes + review sessions should be sufficient. (You may want to refer to textbooks for more explanations or different approaches)
• These lecture notes are always evolving. Please give me feedback on what can be improved
References

The following books should be on reserve at the Engineering Library:

- Leon-Garcia, *Probability and Random Processes for Electrical Engineers*

In addition, the following resources are available online:

- Gray and Davisson, *An Introduction to Statistical Signal Processing*, also available through Prof. Robert Gray’s webpage and EE 278 webpage.