Lecture Notes 0
Course Introduction

• EE 278 in EE Curriculum

• Statistical Signal Processing

• Course Goal

• Topics

• Lecture Notes
EE 278 in EE Curriculum

- EE 278 is one of three core ISL graduate courses:
  - EE 261 and EE 263 deal with deterministic (linear) systems
  - EE 278 deals with statistical systems
- EE 278 is 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, medical devices, sensor networks . . .

- Generic signal processing problem:

  \[ X(t) \overset{\text{noisy channel}}{\rightarrow} Y(t) \overset{\text{signal processor}}{\rightarrow} \hat{X}(t) \]

  - Signal: (coded) digital data, audio, image, 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

$$Y(t) = h(t) * X(t) + Z(t)$$
- Very simple case: \( h(t) = \delta(t), \ X(t) \) binary waveform
Course Goal

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

• Courses that require EE278 as prerequisite include:
  ○ communications courses: EE276, EE279, EE376A,B and EE379A,B
  ○ signal and image processing and estimation courses: EE378, EE355, EE359, EE363, EE368, EE372

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

• EE 278 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
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.