Course Information (Preliminary Version)

1 Logistics

Instructor	Michael Gastpar, 265 Cory Hall, gastpar@eecs.berkeley.edu, OH Tue Thu 12:40-1:30
Lecture	Tuesdays and Thursdays, 11-12:30, 521 Cory Hall
Grading	**Project:** Proposal (5%), Review Meeting (10%), Presentation (15%), Report (20%); In-class Midterm (15%), Take-home Midterm (20%), HW (10%), Lecture Scribing (5%)
Prerequisites	EECS 123 (DSP) and 126 (Random Processes), or equivalent — contact me if in doubt.
Textbook	M. H. Hayes, *Statistical Digital Signal Processing and Modelling* John Wiley & Sons, 1996.
Project	An integral part of this a small project that involves a literature survey together with a small extension, either theoretical or via computer simulations. In small groups (1-3 students), you will select a topic and choose about 5 relevant papers. You will explore and extend their contributions in a short report (10-15 pages).
Homework	There will be a full homework set every week at the beginning of the semester. Later on, this will be reduced to allow more time for the projects. In addition, we will occasionally have "Pre-Homework:" Short problem sets intended to prepare you for lecture. *Grading:* Unfortunately, we do not have the resources to do full HW grading. Homework will therefore be graded according to "random subset grading:" we will make photocopies of the submitted HWs and hand them back to you. You will grade your HW yourself and e-mail your grade to the instructor.
Website	http://inst.eecs.berkeley.edu/∼ee225a/

2 Course Outline

With signal processing becoming ubiquitous in today's computer literate world, a large number of application areas are growing in importance, both in industry and in the research community, such as seismic signal processing, speech data processing, medical image processing, radar signal processing, and sensor network processing. These problems have many different aspects, and a corresponding number of different solutions have been explored. A mockup "general" picture is given in Figure 1: A signal source outputs a signal $s(t)$. The signal may pass through a first processor, may be subjected to noise, and may pass

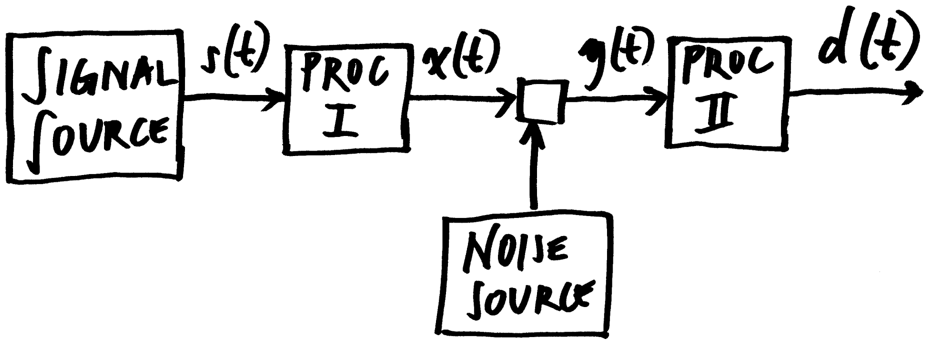

Figure 1:

through a second processor. The final output $d(t)$ is the "desired" output, revealing some fundamental insights into the nature of the signal/noise source and/or the processors.

To make a very simple example, consider the problem of determining some scalar constant, say, the coefficient of friction μ between two surfaces, from a set of noisy measurements $x_1, x_2, \cdots, x_N$. A classical way of addressing this problem is to consider the sum of squares of the discrepancy $C(\hat{\mu}) = \sum_{n=1}^{N}(x_n - \hat{\mu})^2$, and to use the μ that minimizes this as the (so-called *least squares*) estimate. This is definitely tractable, since the resulting estimate $\hat{\mu}$ is a linear function of the observations. At the same time, it makes a few implicit assumptions, including that the noise is sufficiently "symmetric" and "independent" of the signal, and that the squared error is the relevant quantity. Moreover, generally, we may have some prior knowledge about μ and some insight into the physics that generate the measurements $x_1, x_2, \cdots, x_N$ based on μ. In this class, we will see various ways of modeling the underlying signal and the involved processing, and what kind of signal processing architectures the different models call for.

We will take Figure 1 as our conceptual background, starting with the simplest version (no processing, no noise) and successively approaching the full-fledged picture:

1. **Signal Modeling.**
   (a) Stochastic signal models; WSS signals and LTI systems.
   (b) Power spectrum estimation.
   (c) Minimum description length.
2. **Signal Representation and Approximation.**
   (a) Fourier theory (Hilbert space)
   (b) Wavelets and splines
   (c) Bases and frames
   (d) Sampling and sparsity (Hilbert space perspective; compressed sensing)
3. **Signals, Systems, Noise.**
   (a) **Wiener theory** and extensions/variations
      - Wiener filter (causal and non-causal)
      - Adaptive algorithms (LMS, RLS, Neural Networks; Application to Equalization, Echo cancellation, Linear Prediction)
      - Kalman filter
   (b) **Bayes theory** and extensions/variations

- MMSE estimation
- Bayesian detection (Viterbi algorithm)
- Minimax and Neyman-Pearson (when priors are unknown)

(c) **Non-random Parameter Estimation**

- Minimum-variance (Cramér-Rao lower bound)
- Maximum-likelihood (EM algorithm)

(d) **Non-parametric techniques**

3 References

- **Linear algebra**
  - G. Strang, *Linear Algebra and Applications,* Academic Press, 1980.
  - R. A. Horn and C. R. Johnson, *Matrix Analysis.* Cambridge University Press, 1985.
- **General DSP**
  - A. V. Oppenheim and R. W. Schafer with John R. Buck, *Discrete-time Signal Processing.* Second Edition. Prentice-Hall, 1999 [Reserved]
  - J. Proakis and D. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Applications.* Third edition. Prentice-Hall, 1996. [Reserved]
  - S. K. Mitra, *Digital Signal Processing: A Computer-Based Approach.* McGraw Hill, 1998.
  - P. Brémaud. *Mathematical principles of signal processing: Fourier and Wavelet analysis.* Springer, 2002. [Reserved]
- **Adaptive filtering**
  - P. M. Clarkson, *Optimal and Adaptive Signal Processing.* CRC Press, Boca Raton, FL, 1993.
  - B. Widrow and S. D. Stearns, *Adaptive Signal Processing.* Prentice-Hall, 1985
  - S. Haykin, *Adaptive Filter Theory.* Second Edition. Prentice-Hall, 1991. [Reserved]
- **Statistical signal processing**
  - B. Porat, *Digital Processing of Random Signals: theory and methods.* Prentice-Hall, 1994. [Reserved]
  - M. Hayes, *Statistical Digital Signal Processing and Modeling.* Prentice-Hall, 1996. [Reserved]
- **Spectral analysis**
  - P. Stoica and R. Moses, *Introduction to Spectral Analysis.* Prentice-Hall, Englewood Cliffs, NJ, 1997
  - S. M. Kay, *Modern Spectral Estimation, Theory and Applications.* Prentice-Hall, Englewood Cliffs, NJ, 1988
- **Wavelets and Multi-rate Signal Processing**
  - M. Vetterli and J. Kovacevic, *Wavelets and subband coding.* Prentice-Hall, 1995. [Reserved]
  - P. P. Vaidyanathan, *Multirate systems and filter banks.* Prentice-Hall, 1993.
  - S. Mallat, *A Wavelet Tour of Signal Processing.* Academic Press, 1998. [Reserved]
- **Quantization and coding**

  - N. Jayant and P. Noll, *Digital Coding of Waveforms.* Prentice-Hall, 1984
  - A. Gersho and R. M. Gray, *Vector quantization and signal compression.* Kluwer Academic Publishers, 1992.

- **Fast algorithms**
  - R. E. Blahut, Fast algorithms for digital signal processing, Reading, MA, Addison-Wesley, 1985.

- **Probability**
  - A. Papoulis, *Probability, Random Variables and Stochastic Processes.* McGraw-Hill, 1984.
  - A. Leon-Garcia, *Probability and Random Processes for Electrical Engineering.* Addison-Wesley, 1993.
  - H. Stark and J. W. Woods, *Probability and Random Processes with Applications to Signal Processing.* Third Edition, Prentice-Hall, 2002.

- **Detection and Estimation Theory**
  - H. L van Trees, *Detection, Estimation, and Modulation Theory, Part I.* Wiley-Interscience, Reprint 2001.
  - H. V. Poor, *An Introduction to Signal Detection and Estimation.* Second Edition. Springer, 1998.
  - S. M. Kay, *Fundamentals of Statistical Signal Processing, Volume I: Estimation Theory.* Prentice Hall PTR, 1993.
  - S. M. Kay, *Fundamentals of Statistical Signal Processing, Volume II: Detection Theory.* Prentice Hall PTR, 1998.

- **Information Theory**
  - T. M. Cover and J. A. Thomas, *Elements of Information Theory.* Wiley-Interscience, 1991.