Harmonic Analysis and Signal Processing
Spring 2011 Syllabus

Summary

This course will explore the influence of ideas from the mathematical field of Harmonic Analysis on signal processing applications. The major themes are *mathematical models* for "interesting" signals, constructing *sparse representations* for these classes of signals, and exploiting this sparsity using simple but powerful *algorithms* for applications including compression, statistical estimation, inverse problems, and imaging. We will emphasize both theoretical results (mostly of an asymptotic nature) and practical techniques.

Prerequisites

ECE 6250 (advanced DSP) or equivalent, and a solid understanding of linear algebra and random processes.

Instructor

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Text

The material for this course will come from several different sources, but the required text (which covers most of what we will do) is:
S. Mallat, *A Wavelet Tour of Signal Processing*.
There are other books and journal papers of interest listed in the "Resources" section of the course web site.

Course Web Site

http://users.ece.gatech.edu/∼justin/ECE-8823a-Spring-2011

This site will host:

- general course information
- resources (links to books and papers) that augment the lectures
- homework and project assignments

Outline

- Signal decomposition using bases and frames
  - Hilbert space basics
  - orthobases
  - non-orthogonal bases
  - frames
  - reconstruction from frame coefficients, algorithms and stability
- Time-frequency bases
  - time-frequency tilings
  - the Bailan-Low theorem
  - lapped orthogonal transforms (LOT)
  - adaptive tilings using tree-based optimization
- Wavelets
  - multiresolution approximation
  - Daubechies wavelets
  - wavelets and filterbanks
  - biorthogonal wavelets
  - wavelet packets
  - wavelet frames
- Approximation theory and applications
  - linear approximation of uniformly smooth signals

  - nonlinear approximation of piecewise smooth signals
  - image approximation and compression using wavelets
  - denoising sparse signals by thresholding
  - sparse signals and linear inverse problems
  - sparse signals and data compression

- Curvelets

- Compressive sampling

  - efficient acquisition of sparse signals
  - discrete uncertainty principles
  - the (important) role of randomness in nonlinear sampling theory
  - stable reconstruction using ℓ_1 minimization
  - applications, including next-generation sensing and imaging devices

Grading

Your grade will be base on three factors:

- **Homework (50%):** There will be 6 (± 1) assignments which will be graded carefully. They will consist of exercises, proofs, and MATLAB implementations. I expect your write-ups to be very clear; I do not just want you to produce correct answers; I want you to demonstrate that you understand the material. Style is definitely important.

  You may discuss the homework with myself and other members of the class. However, **everything that you turn in must be your own work**. You must write up the assignments (and accordingly the MATLAB code) **by yourself**. Failure to do so will be considered a violation of the Georgia Tech Honor Code.

- **Final project (40%):** The course project will involve an in-depth investigation of a topic of your choice. It can be an in-depth theoretical study, or design and implementation of a cutting-edge algorithm, or a combination of both. It will be treated as a "research project", so some type of original synthesis is encouraged.

  There are four aspects to the project: a (short) proposal, a (medium-length) progress report, a (6-7 page) final report, and a 20–25 minute presentation.

- **Participation (10%):** This part of your grade is based on your engagement in the course. Part of this grade is based on attendance. Also included are the daily summaries.