ELG7172A
Multiresolution Signal Decomposition: Analysis & Applications

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Objectives of the Course

*Multiresolution signal analysis and processing* constitutes an important extension of the single-resolution analysis and processing approach studied in the basic Digital Signal Processing course. For many types of signals, this type of multiresolution processing is much more effective for accomplishing tasks such as compression, enhancement, restoration, pattern recognition, approximation, etc. The objective of this course is to introduce the fundamental mathematical and signal processing tools required for the analysis and design of multiresolution signal processing systems. Among the topics to be covered are multirate processing and sampling rate conversion, filter banks, wavelets, and time-frequency analysis. Applications will mainly be addressed through student projects.

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A basic course in Digital Signal Processing such as ELG5376 or ELG4172 is a necessary prerequisite.
What is it?

● Multiresolution signal processing is the extension of single-resolution signal processing, wherein signals of interest (generally continuous in origin) are sampled with a given fixed sampling rate (or sampling structure), and all digital processing is carried out at that rate from start to finish. This is the approach of your basic DSP course. Also called fixed-rate or single-rate signal processing.

● Examples of signals are audio, images, biomedical signals, seismic signals, radiowaves, and various other functions of time and/or space.
When is single-resolution signal processing not sufficient?

- The same signal may be required at different sampling rates.

  » Audio at 48 KHz and at 44.1 KHz; audio signals may be processed at 48 KHz in the studio, but may be required at 44.1 KHz for compact disc.

  » Video: SDTV and HDTV; HDTV signals may be sampled on an image raster of size 1920 by 1080 samples, but be required at 720 by 540 samples for transmission on standard definition TV channels.
When is single-resolution signal processing not sufficient?

- Information at different resolutions needs different treatment
- The long-term trend can be studied at low resolution
- The transient can be studied at high resolution
- Our visual system analyzes information in this way

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When is single-resolution signal processing not sufficient?

- Different frequency bands of the signal have different characteristics and importance and should be processed separately.

- Each band can be sampled at a lower rate, not necessarily the same, and be processed separately.

- This leads to the concept of filter banks and subband coding.
When is single-resolution signal processing not sufficient?

- Details can get in the way of certain analyses, for example minimum finding.
What multiresolution tools will we study?

- Sampling rate conversion - increase or decrease of sampling rate
- Filter banks - produce subband signals and reconstruct the signal
- Wavelet analysis - study long-term phenomena at low resolution and transient phenomena at high resolution
- Time-frequency analysis - short-term Fourier analysis, Wigner-Ville distributions
Applications

- Audio and video format conversion
- Compression: transform coding, subband coding, wavelet coding
- Transmultiplexing: combining many signals into one
- Noise reduction
- Secure multiple-access digital communications
Course organization

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Schedule: MON & WED 11:30-1:00  POR 105

http://cm.bell-labs.com/who/jelena/Book/

Course organization

Grading:

20% Assignments: Several assignments, to be handed in during class on the due-date specified. There will be a 5% penalty for each day late, and no assignment will be accepted after one week.

30% Project: An individual project involving either a literature review and/or some experimental work. A project report and a short presentation at the end of the course will be required. More details will follow early in the course.

20% Midterm exam: Closed-book exam, 80 minutes in length.

30% Final exam: Closed-book exam, 3 hours in length.
Course outline

**Introduction**
- scope and objectives of the course
- overview of issues in multiresolution signal decomposition
- survey of a few applications
- review of signal processing background

**Multirate signal processing**
- downsampling and upsampling
- general sampling rate conversion
- polyphase representation
Course outline

• Discrete-time bases and filter banks
  • series expansion of discrete-time signals
  • two-channel filter banks
  • tree-structured filter banks
  • multichannel filter banks
  • pyramids and overcomplete expansions
Course outline

Series expansions using wavelets and modulated bases

- series expansion of continuous-time signals
- multiresolution concept and analysis
- construction of wavelets
- wavelet series and its properties
- generalizations: biorthogonal wavelets, multichannel filter banks and wavelet packets
- local cosine bases
Course outline

- Algorithms and complexity
  - complexity of multirate discrete-time processing
  - complexity of filter banks
  - complexity of wavelet series computation

- Applications
  - projects in multiresolution analysis and processing of audio, images and other types of signals with student presentations at the end of the course
What you already know about signal processing

- Continuous-time signals, linear time-invariant systems, Fourier transform
- Discrete-time signals, linear shift-invariant systems, stability, causality
- Discrete-time Fourier transform, properties, frequency response
- Sampling of continuous-time signals
- z-transform, region of convergence, properties, inverse z-transform
- FIR and IIR filters, implementation structures, elements of digital filter design
- Discrete-time periodic signals, discrete Fourier transform, properties