16:332:521: Digital Signal Analytics
Fall 2023

Instructor Information

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Office Hours: Thursday 4:00 PM

Class Information

Time: Tuesday & Thursday 2:00PM–3:20PM
Classroom: SEC-118

Additional individual meetings to discuss course material or any other concerns can be scheduled by contacting me via email, after class, or during office hours. On occasion, if I am on campus with free time available, I will post where I can be located along with the times I will be there on my 'Office Hours' tab on my webpage.

Course Description

This course is a basic introduction to digital signal processing. It provides a solid foundation in fundamental concepts and techniques essential for analyzing and manipulating digital signals.

The course explores various essential topics, including sampling and reconstruction, antialiasing prefilters, anti-image postfilters, discrete-time signals and systems, block-based and sample-based real-time processing, circular delay-line buffers, convolution, digital audio effects, z-transforms, filter realizations, and quantization effects.

Additionally, the course delves into concepts such as DTFT, DFT, FFT, circular convolution, fast convolution, spectrum estimation, frequency resolution, windowing, periodogram averaging, smoothing, and STFT applications. Students will also learn about the phase vocoder, time and pitch-scale modification, DCT, MDCT, time-domain aliasing cancellation, Princen-Bradley windows, data compression, FIR and IIR filter design methods, normalized lattice filters, adaptive filters, neural networks, multirate systems, interpolation, decimation, oversampling, polyphase filters, sample-rate conversion, noise-shaping delta-sigma quantizers, sparse modeling, and sparse regularization methods, such as lasso/basis-pursuit-denoising.

The course covers the following key topics:

- **UNIT 01:** Sampling, reconstruction, anti-aliasing pre-filters, and anti-image post-filters
- **UNIT 02:** LTI systems review, convolution, stability, causality
- **UNIT 03:** z-transforms, transfer functions, frequency response, transients
- **UNIT 04:** filter realizations, circular buffers, audio effects

- **UNIT 05:** DTFT, frequency resolution, windowing, spectrum estimation
- **UNIT 06:** DFT, IDFT, FFT, circular convolution, fast convolution
- **UNIT 07:** STFT, phase vocoder, time & pitch scale modification
- **UNIT 08:** DCT, MDCT, data compression, time-domain aliasing cancellation
- **UNIT 09:** FIR & IIR filter design methods, normalized lattice filters
- **UNIT 10:** adaptive filtering and prediction, noise canceling, neural networks
- **UNIT 11:** multirate systems, interpolation, sample-rate conversion
- **UNIT 12:** decimation, noise-shaping delta-sigma quantizers
- **UNIT 13:** sparse modeling, sparse regularization methods

This course aims to equip students with a strong theoretical foundation and practical skills necessary to analyze, manipulate, and interpret digital signals effectively. Through a combination of lectures, assignments, and reading materials, students will gain proficiency in digital signal analysis techniques and their applications in various domains.

Prerequisites

Familiarity with the concepts of LTI systems, convolution, block diagrams, Fourier, Laplace, and z-transforms, stochastic signals, autocorrelation functions, at the level of 16:332:501-Systems Analysis, or an undergraduate linear systems/DSP course. The course emphasizes computational aspects, and familiarity with a high-level programming language, such as Python or MATLAB, is necessary. MATLAB is freely available to Rutgers students. The CVX convex optimization MATLAB package, available from http://cvxr.com/cvx/, will also be used.

Texts

The books we will be referencing in the course are:

- S.J. Orfanidis, *Introduction to Signal Processing*, Prentice Hall, 1996, available freely from: https://www.ece.rutgers.edu/~orfanidi/intro2sp/ (2010).
- S.J. Orfanidis, *Optimum Signal Processing*, online text, 2018, available freely from: https://www.ece.rutgers.edu/~orfanidi/aosp/.
- A. V. Oppenheim and R. W. Schafer, *Discrete-Time Signal Processing*, 3/e, Prentice Hall, 2009. A low-cost paperback edition is available, ISBN-13: 978-9332535039.

We will be referring to these books as I2SP, AOSP, and O&S, respectively. Additionally, slide decks will be provided through the course page on Canvas, and papers will be assigned for reading.

Course Grading

The course grade will be broken down as follows:

- Homework 10%

- Presentation 10%
- Projects 40%
- Midterm 20%
- Final Exam 20%

Class Attendance Policy

Lectures will be given in person and will not be recorded. Attendance of lectures is strongly recommended to achieve the objectives of the course. You are responsible for learning all the materials covered in class (written or orally transmitted), which can appear in examinations.

General Policies

Attendance at tests is mandatory. Absence from an examination will not be excused except in cases of an illness or other emergency. Unexcused absence from an examination will result in a grade of zero. It is the student's responsibility to see the instructor as soon as possible regarding an excused absence. All approved make-up work must be scheduled no later than the last day of classes in the semester. Students are responsible for all materials covered in lectures and announcements for homework assignments, assignment due dates, and test dates.

Academic Integrity at Rutgers

The principles of academic integrity require that a student:

- Make sure that all work submitted in a course, academic research, or other activity is the student's own and created without the aid of impermissible technologies, materials, or collaborations.
- Treat all other students ethically, respecting their integrity and right to pursue their educational goals without interference. This principle requires that a student neither facilitate academic dishonesty by others nor obstruct their academic progress.
- Uphold the ethical standards and professional code of conduct in the field for which the student is preparing.
- http://newbrunswick.rutgers.edu/chancellor-provost/academic-itegrity-students
- Please also read over the IEEE code of ethics https://www.ieee.org/about/corporate/governance/p7-8.html