ECE-GY 6183: Digital Signal Processing Lab

ECE-UY 4163 Real-Time Digital Signal Processing

Electrical and Computer Engineering
Tandon School of Engineering, New York University

Fall 2021

This course is an introduction to the real-time implementation of digital signal processing (DSP) algorithms, with an emphasis on audio signal processing and audio effects.

The course will use Matlab and Python programming. Some Matlab experience is expected. No experience in Python required; the course will introduce Python as needed. This course can be taken independently of ECE 6113 and ECE 7133 (DSP I and DSP II).

Topics include: Audio input-output and buffering. Filtering (recursive and non-recursive filters, structures). Fast Fourier transform and windowed spectral analysis. Digital audio effects (delay line, amplitude modulation, reverberation, distortion, short-time Fourier transform). Students will learn to implement these algorithms for real-time audio processing in software.

Prerequisites

Discrete-Time Signal and Systems (undergraduate level is sufficient) (ECE 3054 or ECE 6113 or equivalent)
You should know: discrete-time convolution, Z-transform, transfer function, frequency response, difference equations, pole-zero diagrams, and the discrete-time Fourier transform.

Instructor

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Texts

You can read both books online through the NYU Library for free. You will need to login to the library.

1. *Audio Effects: Theory, Implementation and Application*
   Joshua D. Reiss, Andrew McPherson
   CRC Press, 2014
   NYU library: http://bobcat.library.nyu.edu/permalink/f/ci13eu/nyu_aleph005572860
   Publisher: http://www.crcpress.com/product/isbn/9781466560284

2. *DAFX – Digital Audio Effects*
   Udo Zölzer (editor)
   Wiley, 2002 (1st edition), 2011 (2nd edition)
   NYU library: http://bobcat.library.nyu.edu/permalink/f/1c17uag/nyu_aleph004863929
   Publisher: https://www.wiley.com/en-us/DAFX%3A+Digital+Audio+Effects%2C+2nd+Edition-p-9780470665992

Outline

1. Introduction to Python
   Binary data and the pack function
   Wave files

2. The PyAudio library
   Second-order filters

Matlab examples
Graphical user interfaces (GUI) in Matlab

3. Real-time filtering of microphone signals
   The classical recursive filters

4. Circular buffers
   The vibrato effect
   Instantaneous frequency

5. Block processing for real-time processing
   The Python Matplotlib library
   Real-time plotting of audio signals

6. The Fast Fourier Transform
   The Numpy Library
   Block filtering
   Graphical user interfaces (GUIs) in Python using the TKinter library

7. FFT-based convolution and block convolution for real-time filtering
   Keyboard interactivity using TKinter
   Simulating a guitar (Karplus-Strong algorithm)

8. Complex amplitude modulation for voice transformation
   Image and real-time video processing in Python using CV2
   Processing audio from two microphones

9. Exam

10. The short-time Fourier transform (STFT)
    Audio effects using the STFT
    All-pass systems
    Fractional delay systems

11. Room reverberation
    Modeling reverberation
    Measuring room response
    Chirp signal signals and matched filtering

12. Shelving filters
    Spectral factorization
    Time-stretching and pitch shifting of audio
    Distortion effects

13. Quantization effects
    Discrete-cosine transform and PCA
    Wavelet transforms

14. Student project presentations

Project

Students will complete a real-time audio programming project and make a video presentation to be shared with the class.

Grading, Category weights

45%	Exercises
25%	Exam
10%	Paper report (ECE-GY 6183), DP2 proposal (ECE-UY 4163)
20%	Project

In the event of academic dishonesty, a score of zero may be given for the item at issue. Additionally, the grade for the course may be reduced, including a failing grade for the course.

Software

Matlab: http://www.mathworks.com
Matlab at NYU: https://www.nyu.edu/life/information-technology/getting-started/software/matlab.html
Python : http://www.python.org
PyAudio : http://people.csail.mit.edu/hubert/pyaudio/

Learning objectives

1. The implementation and design of algorithms for signal processing with an emphasis on audio processing.
2. Software-based real-time programming of signal processing functions (real-time filtering, time-varying filtering, spectral analysis, audio effects).

Learning outcomes

1. Students will be able to use Matlab and Python to perform signal processing functions (filtering, spectral analysis, filter design).
2. Students will understand constraints and parameters associated with real-time signal processing (sampling rate, latency, buffering, bits per sample).
3. Students will be able to write programs to perform audio effects (reverberation, delay line effects, amplitude modulation, distortion).

If you are ill or have a personal emergency during the semester

If you are experiencing an illness or other situation that will likely affect your academic performance in a class, please email Deanna Rayment, Coordinator of Student Advocacy, Compliance and Student Affairs. Deanna can reach out to your instructors on your behalf when warranted.
deanna.rayment@nyu.edu
https://engineering.nyu.edu/staff/deanna-rayment

Inclusion Statement

The NYU Tandon School values an inclusive and equitable environment for all our students. I hope to foster a sense of community in this class and consider it a place where individuals of all backgrounds, beliefs, ethnicities, national origins, gender identities, sexual orientations, religious and political affiliations, and abilities will be treated with respect. It is my intent that all students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. If this standard is not being upheld, please feel free to speak with me.

Moses Center Statement of Disability

If you are student with a disability who is requesting accommodations, please contact New York University's Moses Center for Students with Disabilities (CSD) at 212-998-4980 or mosescsd@nyu.edu. You must be registered with CSD to receive accommodations. Information about the Moses Center can be found at http://www.nyu.edu/csd. The Moses Center is located at 726 Broadway on the 3rd floor.

NYU School of Engineering Policies and Procedures on Academic Misconduct

Introduction: The School of Engineering encourages academic excellence in an environment that promotes honesty, integrity, and fairness, and students at the School of Engineering are expected to exhibit those qualities in their academic work. It is through the process of submitting their own work and receiving honest feedback on that work that students may progress academically. Any act of academic dishonesty is seen as an attack upon the School and will not be tolerated. Furthermore, those who breach the School's rules on academic integrity will be sanctioned under this Policy. Students are responsible for familiarizing themselves with the School's Policy on Academic Misconduct.

Definition: Academic dishonesty may include misrepresentation, deception, dishonesty, or any act of falsification committed by a student to influence a grade or other academic evaluation. Academic dishonesty also includes intentionally damaging the academic work of others or assisting other students in acts of dishonesty. Common examples of academically dishonest behavior include, but are not limited to, the following:

1. Cheating: intentionally using or attempting to use unauthorized notes, books, electronic media, or electronic communications in an exam; talking with fellow students or looking at another person's work during an exam; submitting work prepared in advance for an in-class examination; having someone take an exam for you or taking an exam for someone else; violating other rules governing the administration of examinations.
2. Fabrication: including but not limited to, falsifying experimental data and/or citations.
3. Plagiarism: intentionally or knowingly representing the words or ideas of another as one's own in any academic exercise; failure to attribute direct quotations, paraphrases, or borrowed facts or information.
4. Unauthorized collaboration: working together on work that was meant to be done individually.
5. Duplicating work: presenting for grading the same work for more than one project or in more than one class, unless express and prior permission has been received from the course instructor(s) or research adviser involved.
6. Forgery: altering any academic document, including, but not limited to, academic records, admissions materials, or medical excuses.