MUS320: Introduction to Digital Audio Signal Processing

Center for Computer Research in Music and Acoustics (CCRMA)
Department of Music, Stanford University

Autumn Quarter, 2018

Contents

Music 320: Introduction to Digital Audio Signal Processing

1 Course Description

Music 320 is a first course in digital signal processing with applications in computer music.

The lectures present fundamental elements of digital audio signal processing, such as sinusoids, spectra, the Discrete Fourier Transform (DFT), digital filters, z transforms, transfer-function analysis, and basic Fourier analysis in the discrete-time case. Matlab is used for in-class demonstrations and homework/lab assignments. The labs focus on practical applications of the theory, with emphasis on working with waveforms and spectra, "getting sound", and developing proficiency in matlab.

Pre-requisites: High-school level algebra and trigonometry, some calculus, and prior exposure to complex numbers.

Time and Place

Term:	Autumn Quarter
Location:	CCRMA Classroom (Knoll 217)
Lectures:	Tuesdays and Thursdays 10:30AM–12:30 PM
Units:	4
Instructors:	Jonathan Abel (abel@ccrma.stanford.edu) and Dave Berners (dpberner@ccrma.stanford.edu)
TA:	Nolan Lem (nlem@ccrma.stanford.edu)
Office Hours:	See "Office Hours and Getting Help"[1] below
Schedule:	See "Lecture Outline, Schedule, and Assignments"[2] below

[1] http://ccrma.stanford.edu/~jos/intro320/Office_Hours_Getting_Help.html
[2] http://ccrma.stanford.edu/~jos/intro320/Lecture_Outline_Schedule_Assignments.html

2 Administrative Information

2.1 Announcements

Class announcements are often made via *email*. If you missed the sign-up sheet on the first day, please send your email address to the TA.

2.2 Weekly Homework

There will be (roughly) weekly reading and problem/lab assignments. The assignments cover a combination of theory exercises and lab work. The lab assignments typically require programming in Matlab.

Homework/Lab assignments will normally be assigned on Thursday and due the following Thursday in the mus320 mailbox (located in the Knoll, central wing, second floor). Please put your homework in the corresponding folder (e.g. homework #1 goes in folder titled *hw1*).

Lab assignments will require the use of the coursework[3] website to upload the necessary code and data.

Every student will be allowed 7 free late days to use throughout the quarter at his or her discretion. Hours are rounded up to the nearest day (e.g. 1 hour late will count as 1 day, etc.). When using late days, students must write the number of late days used at the top of the assignment, along with the date and time the homework was submitted. It is a violation of the Stanford Honor Code to write the wrong date or time for submission of late assignments.

Once all late days are used up, late homeworks will be penalized 10% per day. No homework will be accepted after the Tuesday following the due date, whether or not late days are used. Homework solutions will normally be released one week after the original due date.

Students are encouraged to discuss the homework assignments with each other. It is fine to learn from a classmate how to solve any of the homework problems, but each student is responsible for carrying out and writing up the assignments individually. It is an Honor Code violation to *copy* the work of others.

2.3 Grading

Grading will be based on the homeworks/labs, and final. The weight of the final is often adjusted, but 60% weighting on homeworks/labs and 40% weighting on the final is typical.

2.4 Office Hours and Getting Help

TA weekly office hours will be announced in class after a class poll. Office hours for the instructors are primarily Tuesdays and Thursdays before and after class. More private meetings may be arranged via email. You are also welcome, of course, to catch us whenever you see us at CCRMA. In general, email is the surest and fastest way to reach us. As a first option, please email your friendly TA regarding homework questions.

Remember that students are encouraged to freely discuss the homework assignments, but that each student is responsible for individually completing and writing up each assignment. (See §2.2 above.)

[3] http://coursework.stanford.edu

2.5 Computer Usage

Many homework and all lab exercises will be computer based. All students may obtain a computer account at CCRMA in order to use the computer facilities. It is also possible to work entirely on your own computer, as long as you have the necessary software installed on it. Since Web access to some course materials is restricted to the Stanford domain, you should have at least one Stanford computer account.

Here is how to obtain a CCRMA computer account:

1. Execute the `perl` script

   `https://ccrma-mail.stanford.edu/cgi/newuser.pl`

   from any CCRMA workstation, and enter the requested information. You need an existing CCRMA user (such as the TA) to log in for you while you complete this step.

2. Next, fill out a printed copy of the User Registration Form, available from the TA, or from `/usr/ccrma/next/Library/CCRMA-Templates` at CCRMA.

3. **Turn in the completed form** to the TA.

The TA will obtain the instructor's signature and forward the form to Fernando (nando@ccrma), who will set up your account and activate your Stanford ID cards for after-hours CCRMA access. This process should take on the order of a day.

Once you have your account, please log in at CCRMA and take a look at the User's guides[4] tab in the left-frame menu of the main CCRMA website to learn more about computer usage and other facilities at CCRMA.

2.6 Students with Documented Disabilities

Students who have a disability which may necessitate an academic accommodation or the use of auxiliary aids and services in a class, must initiate the request with the Student Disability Resource Center (SDRC), located within the Office of Accessible Education (OAE). The SDRC will evaluate the request with required documentation, recommend appropriate accommodations, and prepare a verification letter dated in the current academic term in which the request is being made. Please contact the SDRC as soon as possible; timely notice is needed to arrange for appropriate accommodations. The Office of Accessible Education is located at 563 Salvatierra Walk (phone: 723-1066; TDD: 725-1067).

3 Textbooks

The first half of Music 320 is based on assigned chapters of

Mathematics of the Discrete Fourier Transform (DFT),[5] by Julius O. Smith

The second half of Music 320 is based on assigned chapters of

[4] http://ccrma.stanford.edu/guides/

[5] http://ccrma.stanford.edu/~jos/mdft/

Introduction to Digital Filters,[6] by Julius O. Smith

See §4 for the list of assigned chapters. Both books are fully available on-line. Hardcover version are available via your TA. Softcover versions are available from Amazon.com.

[6] http://ccrma.stanford.edu/~jos/filters/

4 Lecture Outline, Schedule, and Assignments

Note: The online version[7] of this schedule contains hyperlinks to all reading and assignments.

To obtain printable versions of the assignments and solutions from off-campus locations, you can use commands such as

```
scp you@ccrma-gate.stanford.edu:/usr/ccrma/web/html/courses/320/hw/hw1/hw1.pdf .
scp you@ccrma-gate.stanford.edu:/usr/ccrma/web/html/courses/320/hw/hw1/hw1sol.pdf .
```

- Week 1 - Course Overview; Mathematics of Signal Representation; Introduction to Matlab
  - **Assigned Reading:**
    - Chapter 1 (DFT Intro)[8] of **Mathematics of the DFT**.[9]
    - Chapter 2 (Complex Numbers)[10]
    - If you are not comfortable with the decibel scale, read Appendix B (Logarithms and Decibels).[11]
    - **Optional:** Appendix H (Sampling Theory).[12]
  - **Lab presentation 0:** Introduction to Matlab[13]
    - If you do not know the rules of matrix multiplication, read Appendix H (Matrices).[14]
    - Read Getting Started with Matlab[15]
    - Read the first two sections of Appendix J (Matlab Examples)[16] in **Mathematics of the DFT**
    - Do **Lab Assignment 0**[17] if you do not know Matlab.
  - **Assignment 1**[18] (complex number problems)

    [URL footnotes are mostly suppressed below, but links persist in the online version of this page.]

[7] http://ccrma.stanford.edu/~jos/intro320/Lectures_Assignments.html
[8] http://ccrma.stanford.edu/~jos/mdft/Introduction_DFT.html
[9] http://ccrma.stanford.edu/~jos/mdft/mdft.html
[10] http://ccrma.stanford.edu/~jos/mdft/Complex_Numbers.html
[11] http://ccrma.stanford.edu/~jos/mdft/Logarithms_Decibels.html
[12] http://ccrma.stanford.edu/~jos/mdft/Sampling_Theory.html
[13] http://ccrma.stanford.edu/~jos/hw320/
[14] http://ccrma.stanford.edu/~jos/mdft/Matrices.html
[15] http://www.mathworks.com/access/helpdesk/help/techdoc/learn_matlab/
[16] http://ccrma.stanford.edu/~jos/mdft/Matlab_Octave_Examples.html
[17] http://ccrma.stanford.edu/~jos/hw320/
[18] http://ccrma.stanford.edu/~jos/hw320/

- Week 2 - Euler, Exponentials, and Sinusoids
  - Chapter 3 (Proof of Euler's Theorem)[19]
  - Chapter 4 (Sinusoids and Exponentials)[20] of **Mathematics of the DFT**
  - Assignment 2
- Week 3 - Vectors and Geometrical Signal Theory
  - Chapter 5 (Geometric Signal Theory)
  - Assignment 3
- Week 4 - Discrete Fourier Transform (DFT), Fourier Theorems, Convolution and Correlation
  - Chapter 6 (The DFT Derived)
  - Chapter 7 (Fourier Theorems for the DFT) of **Mathematics of the DFT**
  - Assignment 4
- Week 5 - DFT Applications, Spectrograms and Correlograms
  - Chapter 8 (DFT Applications)
  - Overlap Add (https://ccrma.stanford.edu/ jos/sasp/Overlap_Add_OLA_STFT_Processing.html)
  - Assignment 5
- Week 6 - Linearity and Time Invariance; Time-Domain Representations
  - Chapters 1 and 2 of **Introduction to Digital Filters**[21]
  - Chapter 4 (Linearity and Time Invariance) and
    Chapter 5 (Time Domain Filter Representations) of **Introduction to Digital Filters**
  - Optionally peruse the Music 421 overheads pertaining to acyclic convolution
  - Assignment 6
- Week 7 - Analysis of Digital Filters
  - Chapter 6 (Z-transform),
  - Chapter 6 (Transfer Function Analysis),
  - First three sections of Chapter 8 (Pole-Zero Analysis),
  - Chapter 9 (Implementation Structures),
  - Assignment 7
- Week 8 - The S-plane, Z-plane and Frequency Response.
  - Chapter 7 (Frequency Response Analysis),
  - Assignment 8

[19] http://ccrma.stanford.edu/~jos/mdft/Proof_Euler_s_Identity.html
[20] http://ccrma.stanford.edu/~jos/mdft/Sinusoids_Exponentials.html
[21] http://ccrma.stanford.edu/~jos/filters/filters.html

- Week 9 - Bode plots and Bilinear Transform canonical first-order filters.
  - Appendix I.3 Bilinear Transform
  - Appendix B.1 Elementary Filter Sections
  - Appendix B.2 Allpass Filter Sections
  - Appendix B.3 DC Blocker and
  - Assignment 9
- Week 10 - Parametric Filter Design, Catchup, Review
  - Appendix B.4 Shelving Filters
  - Appendix B.5 Peaking Equalizers
- Final Exam - Wednesday, Dec. 12, 2018, 12:15-3:15 PM, CCRMA Classroom. The exam will cover
  - Assigned readings, homework problems, and laboratory assignments
  - The exam will be *closed book*, except that you may bring an 8.5" by 11" sheet of paper, covered front and back with handwritten notes.
  - No calculators allowed (you shouldn't need one).