MUS320: Introduction to Digital Audio Signal Processing

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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 3:15-5:05 PM
Units:	4
Instructors:	Jonathan Abel (abel@ccrma.stanford.edu) and Dave Berners (dpberner@ccrma.stanford.edu)
TA:	Juhan Nam (juhan@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 will normally be assigned on Thursday and due the following Thursday in the TA's mailbox (located in the Knoll, central wing, second floor). Lab portions of the homeworks are due at midnight of the due date at the coursework[3] website.

Late homeworks will have a penalty of 5% per day, but no homework will be accepted after the Wednesday following the due date (or the following Monday if the homework is due on Tuesday). The solutions will normally be released the next day.

Every student can submit *one* late homework during the quarter without penalty, within the boundaries specified above.

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 40% is typical.

2.4 Office Hours and Getting Help

TA weekly office hours are Wednesday 3:00-5:00 PM in the Seminar Room (Knoll 315). Office hours for the instructor 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.

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.)

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

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

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.

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

See §4 for the list of assigned chapters. This book is fully available on-line, and printed versions[6] are available as well.

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

Introduction to Digital Filters,[7] by Julius O. Smith

This book is currently in press, and should be available before it is needed. Check the status page[8] for latest info. In the meantime, CCRMA Administrator Tricia Schroeter still has some copies of last year's version (but remember that it's all on the Web as well). Her office is on the third floor, Room 301, at the west end of the building (shared with Chris Chafe).

[4] http://ccrma.stanford.edu/guides/
[5] http://ccrma.stanford.edu/~jos/mdft/
[6] http://ccrma.stanford.edu/~jos/mdft/mdft-hardcopy.html
[7] http://ccrma.stanford.edu/~jos/filters/
[8] http://ccrma.stanford.edu/~jos/filters/filters-hardcopy.html

4 Lecture Outline, Schedule, and Assignments

Note: The online version[9] 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 .
```

Another solution is to use a Stanford proxy server such as `http://library.stanford.edu/apcproxy/index.ht`

- Week 1 - Course Overview; Mathematics of Signal Representation; Introduction to Matlab
  - **Assigned Reading:**
    - Chapter 1 (DFT Intro)[10] of **Mathematics of the DFT**.[11]
    - Chapter 2 (Complex Numbers)[12]
    - Chapter 3 (Proof of Euler's Theorem)[13]
    - If you are not comfortable with the decibel scale, read Appendix B (Logarithms and Decibels).[14]
    - **Optional:** Appendix H (Sampling Theory).[15]
    - Time permitting, start on Chapter 4 (Sinusoids and Exponentials)[16]
  - **Lab presentation 0:** Introduction to Matlab[17]
    - If you do not know the rules of matrix multiplication, read Appendix H (Matrices).[18]
    - Read Getting Started with Matlab[19]
    - Read the first two sections of Appendix J (Matlab Examples)[20] in **Mathematics of the DFT**
    - Do **Lab Assignment 0**[21] if you do not know Matlab.
  - **Assignment 1**[22] (complex number problems)

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

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

- Week 2 - Spectrum Representation; More Matlab
  - Chapter 4 (Sinusoids and Exponentials)[23] of **Mathematics of the DFT**
  - Chapter 5 (Geometric Signal Theory)
  - Chapter 6 (The DFT Derived)
  - Assignment 2
- Week 3 - The Fourier Theorems
  - Read Chapter 7 (Fourier Theorems for the DFT) of **Mathematics of the DFT**
  - Assignment 3
- Week 4 - Practical Spectrum Analysis
  - Read Chapter 8 (DFT Applications) of **Mathematics of the DFT**
  - Assignment 4
- Week 5 - Introduction to Digital Filters
  - Read Section 8.3 (Filters and Convolution)
  - Read Appendix B (Fourier Transforms for Continuous/Discrete Time/Frequency)
  - Read Chapters 1 and 2 of **Introduction to Digital Filters**[24]
  - Assignment 5
- Week 6 - Linearity and Time Invariance; Time-Domain Representations
  - Read 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
  - Read Chapter 6 (Transfer Function Analysis), Chapter 7 (Frequency Response Analysis), and the first three sections of Chapter 8 (Pole-Zero Analysis),
  - Assignment 7
- Week 8 - Elementary Audio Digital Filters
  - Read Chapter 9 (Implementation Structures), Chapter 10 (Elementary Audio Digital Filters)
  - Assignment 8
- Week 9 - IIR Filters and Transfer Function Analysis
  - Read Chapter 11 (Filters Preserving Phase), Chapter 12 (Minimum Phase Digital Filters), and

[23] http://ccrma.stanford.edu/~jos/mdft/Sinusoids_Exponentials.html
[24] http://ccrma.stanford.edu/~jos/filters/filters.html

  - Assignment 9

- Week 10 - Review, Overview, Applications, Demos

- Final Exam - Monday, Dec. 11, 2006, 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 notes.
  - No calculators allowed (you shouldn't need one).