MUS420 Administrative Info

Center for Computer Research in Music and Acoustics (CCRMA)
Department of Music, Stanford University
Stanford, California 94305

Winter Quarter, 2007-2008

Contents

Music 420: Signal Processing Methods in Musical Acoustics

1 Course Overview

Music 420 is about computational acoustic modeling for digital audio effects, sound synthesis, and signal processing for physical modeling in general. Topics addressed include sampled traveling waves; acoustic simulation using delay lines, digital filters, and nonlinear elements; comb filters, allpass filters, and artificial reverberation; delay-line interpolation and sampling-rate conversion; phasing, flanging, and chorus effects; computational models of selected musical instruments; virtual analog modeling; and efficient finite difference schemes. Musical instruments considered include plucked, struck (piano), and bowed strings; woodwinds (primarily the clarinet); flute and organ pipes; and brasses.

Prerequisites:

1. Music 320[1] or equivalent (prior exposure to complex numbers, sinusoids, elementary linear systems theory, digital filters, and z transform analysis);
2. Physics 21 (mechanics), or equivalent experience with Newton's law of motion, "$f = ma$".

Recommended: Physics 113 (computational physics). A recommended concurrent course is Music 150[2] (introduction to musical acoustics). CS 106B[3] is a good way to learn `C++`, if you don't already know it.

Software: Basic `C++` and Matlab[4] or Octave[5] is required for homework and lab exercises.

1.1 When, Where, Who

Term:	Winter Quarter
Location:	Main CCRMA Classroom (Knoll 217)
Time:	Tuesdays and Thursdays, 2:45-4:00 PM
Instructor:	Julius O. Smith (jos@ccrma.stanford.edu)
TA:	Juhan Nam (juhan@ccrma.stanford.edu)
TA:	Nelson Lee (nalee@ccrma.stanford.edu)
TA Office Hours:	TBA
JOS Office Hours:	by appointment Tu, Th, Fri afternoons
Website:	`http://ccrma.stanford.edu/CCRMA/Courses/420/`

[1] `http://ccrma.stanford.edu/CCRMA/Courses/320/`
[2] `http://ccrma.stanford.edu/CCRMA/Courses/150/`
[3] `http://www.stanford.edu/class/cs106b/`
[4] `http://www.mathworks.com/access/helpdesk/help/techdoc/basics/getstarted.shtml`
[5] `http://www.octave.org`

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 Units

You may sign up for 3 or 4 units. Three units involves only attending classes, assigned reading, and doing the homework/lab problems. A fourth unit adds an independent project and report, which can be based on reading and/or lab work. There will be a final examination on the date specified in the class schedule (see §3 on page 5).

2.3 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 and basic `C++`.

Homework will normally be assigned on Thursday and due the following Thursday in the 420 mailbox (located in the Knoll, central wing, second floor).

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.

2.4 Final Project (4th Unit)

The purpose of the final project is to go beyond the content of the lectures and assigned reading in the direction most interesting to the student. Your project can be on any topic related to lectures and assignments. *A one-page project specification/proposal is due by the 4th class meeting*, and the final written report is due by the end of finals week. You are also invited to present your project results during the last class. There are two primary project types:

- Outside reading and report
- Programming project and report

Your project can consist of any combination of the above components. Perhaps an ideal project consists of the following roughly equal components:

Phase I:	Outside reading (explore the topic)
Phase II:	Software project (implement your best ideas from Phase I)
Phase III:	Write-up

It is usually better to iterate the above phases than to perform them entirely sequentially. Some specific project ideas are listed in the lecture overheads[6] for the first class.

2.5 Grading

Grading will be based on the homeworks/labs, and final. The weight of the final is often adjusted as we see fit, but 40% is typical.

2.6 Office Hours and Getting Help

TA weekly office hours will be announced in class and via email to the class. Meetings with JOS are arranged via email for half-hour slots on Tu, Th, and Fri afternoons. 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.

2.7 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[7] tab in the left-frame menu of the main CCRMA website to learn more about computer usage and other facilities at CCRMA.

[6] `http://ccrma.stanford.edu/~jos/Intro420/`
[7] `http://ccrma.stanford.edu/guides/`

2.8 Required Software

Laboratory assignments in this course will require basic `C++` programming, on the level of the Synthesis Tool Kit[8] (STK). Also, for sound analysis and display, proficiency with (and access to) Matlab or Octave is assumed.

2.9 Important Pointers

The *course schedule and outline*[9] in §3 on page 5 (also reachable from the class home page[10]) lists the following information:

- *Assignments!*
- Latest schedule of lectures
- Pointers to all lecture overheads and the online text.

The course web site[11] further contains pointers to

- Programming examples
- Sound examples
- Related items of interest online

2.10 Required Reading

The text for this course is Physical Audio Signal Processing[12] by J.O. Smith. It is available online in HTML format, and hardcopies are available from the TA. All reading assignments will be specified in the course schedule and outline.

2.11 Prerequisite-Level References

This course assumes the student is familiar with elementary signal processing on the level of the following textbooks:

- **Mathematics of the Discrete-Time Fourier Transform (DFT)**[13] — prerequisite material pertaining to the DFT (Music 320 text)
- **Introduction to Digital Filters**[14] — prerequisite material in the area of digital filtering and linear systems theory (Music 320 text)
- J. McLellan, et al., **DSP First: A Multimedia Approach**, Prentice Hall, 1998 (TK5102.M388). (Former Music 320 text.) The book CD-ROM is installed at CCRMA in the directory `/usr/ccrma/courses/320/dspfirst/`.

[8] `http://ccrma.stanford.edu/software/stk/`
[9] `http://ccrma.stanford.edu/~jos/intro420/Schedule_Assignments.html`
[10] `http://ccrma.stanford.edu/CCRMA/Courses/420/`
[11] `http://ccrma.stanford.edu/CCRMA/Courses/420/`
[12] `http://ccrma.stanford.edu/~jos/pasp/`
[13] `http://ccrma.stanford.edu/~jos/mdft/`
[14] `http://ccrma.stanford.edu/~jos/filters/`

2.12 Recommended Supplemental Reading

The lecture overheads and reading assignments in the text provide ample reading for this course. However, for independent project work and/or future related research, additional reading may be found in "Bibliography: Physical Modeling of Musical Instruments."[15]

3 Schedule and Assignments

Below is our current schedule, with pointers to *all* reading assignments, lecture overheads, and homework/lab assignments for the course.

> *Please bookmark this page*[16] *(reachable from the class home page*[17]*) and check it at least weekly for updates.*

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/420/hw/hw1/hw1.pdf .
scp you@ccrma-gate.stanford.edu:/usr/ccrma/web/html/courses/420/hw/hw1/hw1sol.pdf .
```

- Week 1: Course Intro, Demos (HTML) (PDF), Delay Lines
  - Read "MUS420 Administrative Info" (this document)
  - Download the Synthesis Tool Kit[18] (STK), and install it following the directions in the online document, "Introduction to the Synthesis Tool Kit (STK)"[19] (which can be printed out if desired).
  - Read "Introduction to the Synthesis Tool Kit (STK)" (13 pp.)
  - *Optional:* Read "Signal Processing in Faust and PD" (20 pp.)
  - Review Matlab,[20] if necessary.
  - Verify that you have had adequate prior exposure to elementary spectrum analysis[21] and digital filter analysis[22].
  - Start reading Chapter 1 of **PASP**: "Acoustic Modeling with Delay."[23] (43 pp.)
  - HW#1[24]
- Week 2: Delay Lines, Comb Filters, Feedback Delay Networks, TDLs, Allpass Filters
  - Finish Chapter 1 of **PASP** entitled "Acoustic Modeling with Delay." (43 pp.)

[15] http://ccrma.stanford.edu/~jos/refs420/
[16] http://ccrma.stanford.edu/~jos/intro420/Schedule_Assignments.html
[17] http://ccrma.stanford.edu/CCRMA/Courses/420/
[18] http://ccrma.stanford.edu/software/stk/
[19] http://ccrma.stanford.edu/~jos/stkintro/
[20] http://www.mathworks.com/access/helpdesk/help/techdoc/basics/getstarted.shtml
[21] http://ccrma.stanford.edu/~jos/mdft/
[22] http://ccrma.stanford.edu/~jos/filters/
[23] http://ccrma.stanford.edu/~jos/pasp/Acoustic_Modeling_Delay.html
[24] http://ccrma.stanford.edu/~jos/hw420/

  - HW#2 — see website

- Week 3: Interpolating Delay Lines
  - Chapter 3 of **PASP** entitled "Time-Varying Delay Effects" ($47 - x$ pp.)
  - Appendix of **PASP** entitled "Higher Order Delay Line Interpolation"
  - HW#4[25]
  - Supplementary:
    - Virtual Analog and Variable Filter Design[26]
    - Papers on Virtual Analog Synthesis[27]

- Week 4: Bandlimited Interpolation and Sampling-Rate Conversion; Flanging, Phasing, Chorus, Leslie
  - HW#5
  - Supplementary:
    - DAFx06 keynote lecture II[28]
    - DAFx02 paper on Leslie modeling[29]

- Weeks 5-6: Plucked/Struck Strings, Electric Guitars
  - Read Chapter 4 of **PASP** entitled "Elementary String Instruments" through Section 4.14 entitled "Amplifier Feedback" (32 pp.)
  - HW#6
  - Supplementary: Virtual Stringed Instruments

- Week 7: Scattering Junctions; s and z planes; Laplace Transforms; Impedance and One-Ports
  - Review, if necessary, Appendix E of **PASP** entitled "Elementary Physics, Mechanics, and Acoustics" (20 pp.)
  - Review, if necessary, Appendix B of **Introduction to Digital Filters**[30] entitled "Introduction to Laplace Transform Analysis" (8 pp.)
  - In **PASP** , read the first two sections of Appendix J ("Introduction to Lumped Models"), entitled "Impedance" and "One-Port Network Theory" (9 pp.)
  - HW#7

- Week 8: Scattering Junctions; Ideal String Struck by a Mass; Commuted Synthesis
  - Read Appendix G of **PASP** entitled "Digital Waveguide Theory" (70 pp.)
  - Read section 4.10 entitled "Ideal String Struck by a Mass"[31] (10 pp.)

[25] `http://ccrma.stanford.edu/~jos/hw420/`
[26] `http://ccrma.stanford.edu/~jos/VirtualAnalog`
[27] `http://ccrma.stanford.edu/~stilti/papers`
[28] `http://ccrma.stanford.edu/~jos/pdf/DAFx06KeynoteII.pdf`
[29] `http://ccrma.stanford.edu/~jos/Doppler/`
[30] `http://ccrma.stanford.edu/~jos/filters/`
[31] `http://ccrma.stanford.edu/~jos/pasp/Ideal_String_Struck_Mass.html`

- HW#8
- Lab Reading:
  - Remainder of Chapter 4 of **PASP** regarding "Commuted Synthesis" (4 pp.)
  - Appendix of **PASP** entitled "Resonator Factoring" (11 pp.)
- Supplementary Reading:
  - Five Lectures on the Acoustic Piano[32]
  - Julien Bensa's PhD thesis on piano modeling[33]
  - Weinreich on Coupled Piano Strings

- Week 9: by senior EE graduate student David Yeh
  Currently planned lectures (subject to revision):

  1. Overview of numerical methods for solving nonlinear ordinary differential equations (ODEs)
  2. Digital audio effects based on ODE solving in real time

- Week 10 - Review

- Final Exam - Monday, March 17, 2008, 12:15-3:15 PM, in our usual classroom.
  The exam will cover

  - homework/lab assignments, and
  - assigned reading (not including "supplementary").
  - 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).
  - **Practice Questions**[34]

[32] `http://www.speech.kth.se/music/5_lectures/`
[33] `http://omicron.cnrs-mrs.fr/~bensa/`
[34] `http://ccrma.stanford.edu/~jos/fpq420/`