ECE 402 Electronic Music Survey

Syllabus

Summary:

Historical survey of electronic and computer music technology; parameters of musical expression and their codification, analysis and synthesis of fixed sound spectra, time-variant spectrum analysis/synthesis of musical sound, algorithms for dynamic sound synthesis.

Learning Objectives:

To provide a familiarity with current methods of electronic/computer music synthesis and their theory of operation and design. Emphasis is on systems concepts which are not likely to change with technology, and have application in Multimedia, Sonification, User Interface, and other fields.

Prerequisites: ECE 310

Credits: 3

Lecture meeting times and location: Tu/Th 8:00-9:20am; 3081 ECEB – **note: Attendance is required and will be taken.**

Lab location: 3024 ECEB

Instructors: Prof. Zuofu Cheng

Office Hours: (posted on website)

Course website: http://courses.engr.illinois.edu/ece402

Course Materials:

- ECE 402 required readings: http://courses.engr.illinois.edu/ece402
- ECE 402 Haken Editor Tutorials (available on YouTube).

Course Topics and Assignments:
Note that some topics may be skipped or de-emphasized based on course schedule.

- Introduction to Lecture, Introduction to Lab, Choose Lab Teams and Times [Lect 1]
- An Incomplete History of Electronic Music Technology since 1900 [Lect 2]
- Telharmonium, Theremin, Reproducing Piano, Ondes Martenot
- Trautonium**,** Hammond Organ, RCA Synthesizer [Lect 3, Quiz]
- Musique Concrète, Pierre Schaeffer, Classic Studio, Edgar Varèse
- Hugh LeCaine, Robert Moog, Don Buchla, Mellotron, Walter Carlos, Isao Tomita [Lect 4]
- Lejaren Hiller, Max Mathews, Iannis Xenakis
- Phase Oscillator and Wavetable Synthesis, FM [Lect 5]
- Samson Box, Dartmouth Synthesizer, Fairlight CMI, Yamaha DX7 [Lect 6]
- IMS Synthesizer, Platypus
- Midi, Midi Sequencers and Timbre Editors, Digital Control of Analog Synthesizers

- Software Synthesis, Physical Models, DSPs – CPUs – GPUs [Lect 7]
- Music Encoding
- Kyma, Max, Reaktor
- Music Typesetting
- MusicXML
- Automated Music Transcription
- Optical Music Recognition (OMR)
- Braille Music [Lect 8]
- MusicN
- Midi Hardware Interface
- Midi Encoding, Running Mode, 14-bit Controller Fail, Control-Rate Aliasing [Lect 9]
- Four Aspects of Music: Pitch, Loudness, Timing, Timbre
- Note Name, Pitch Class, Note Number, Cents, Frequency Ratios
- Equal Tempered Scale, Just Tuning, Perfect Triads, Commas [Lect 10]
- JND, Frequency, Accuracy Requirements for Phase Oscillator
- Equal Loudness, Sones, Phons, Total Loudness, Musical Dynamic Markings [Lect 11]
- Accelerando Formulae
- Time-varying Spectral Analysis/Synthesis [Lect 12; Lect 13 Midterm]
- Pitch-tracking Analysis (Short Windows)
- McAulay-Quatieri Analysis (Long Windows) [Lect 14]
- Quadratic Phase Synthesis
- Noise Representation
- Phase Representation
- Time-Frequency Reassignment [Lect 15]
- Psychoacoustics and Signal Processing
- Outer ear - Middle Ear - Inner Ear
- Shoulder, Head, and Pinna Effects
- Place Principle
- Otoacoustic Emissions
- Critical Band, Masking Pattern, Temporal Masking Effects [Lect 16]
- Barks
- Total Excitation Pattern
- Fixed Waveform Synthesis
- No quasi-harmonic components
- Avoiding Aliasing
- Variable Duty-cycle Pulse Oscillator, Window Pulse Waveform
- Bandlimited Impulse Train, Bipolar BLIT, Leaky Integration [Lect 17]
- Phase Oscillator, Discrete Summation Formulae
- Engineer’s Sawtooth, Musician’s Sawtooth
- Additive Synthesis with Complex Basis Functions [Lect 18]
- Spectral Matching with Fixed Wavetables, Genetic Search
- Properties of Group Additive Synthesis, Morphing Implementation
- Sound Morphing and Cross Synthesis [Lect 19]
- Additive Sound Morphing, Additive Cross Synthesis
- Convolution
- Talking Guitar Effect
- Vocoder: Bandpass Filters, Amplitude Followers, Multipliers
- LPC: Transfer Function, Number of Poles, Frame Rate, Stability, Error Function

- Types of Inputs Useful for Vocoder and LPC
- Pitch Processing [Lect 20]
- Zero Crossings, Peak Detection
- Comb Filter, 2nd Derivative
- Autocorrelation
- Cepstral Pitch Detection, Quefrency
- Spectral Peak Labeling, String Inharmonicity Formula
- How Not to Pitch Shift [Lect 21]
- Pitch Shifting Using Lent's Algorithm
- Synchronous Granular Synthesis
- Serialized Lent's algorithm, Time Stretching and Pitch Shifting
- Grain Spectra, Mixing, Morphing, Formant Preservation, Spectral Envelope Dilation
- Asynchronous Granular Synthesis [Lect 22]
- Sampled Grains, Granulated Sinusoids
- IRCAM Chant Synthesis
- Jenny Oscillator
- Physical Models
- Kinetic Model, Modeled Noise vs Filtered White Noise
- Karplus-Strong (Simple Waveguide Model), Fractional Sample Delay (All Pass vs. Lagrange)
- Models using Multiple Waveguides, Nonlinear Elements, Banded Waveguides, FDN [Lect 23]
- Modal Synthesis, Nonlinear Feedback
- Waveshaping (aka Nonlinear Filtering, or Memoryless Harmonic Distortion Synthesis) [Lect 24]
- Clip, Soft Clip, etc.
- Feedback Impedance Functions for Physical Models
- Polynomial Table Function, Brightness and RMS Matching
- Modulation Synthesis [Lect 25]
- AM, RM, Single-sideband
- FM, Spectral Frequencies and Amplitudes, FM Recipes
- Multi-operator FM, Formant FM
- Musician's Filters [Lect 26]
- Musician's Low Pass Filter, Half-power Excursion, Transparency
- Control Issues: Parameter Decoupling, Stability
- All-pass Lattice, Regalia-Mitra Topology, Chamberlin Filter
- AES3 Standard [Lect 27]
- Biphase Encoding, Differential (Balanced) Signals
- Block, Frame, Subframe, Time Slot, Channel Status
- Lab Demos [Lect 28 & 29]

Grading policy:

- 25% Homework, 1 Quiz (3rd lecture), and Lecture Participation
- 15% Lab and End-of-Semester Lab Project Presentations
- 25% Midterm [8:00-9:15 a.m. (13th lecture)]
- 35% Final [8:00-11:00 a.m., TBA]

General policies:

- Before taking ECE402, you should know how to read music notation and be familiar with key signatures, accidentals, the circle of fifths, major and minor triads, tempo markings, and tunings (e.g. MUS101 or MUS103).
- ECE majors should complete ECE310 before ECE402. Students who do not have ECE 310 and who are not concurrently registered in 310 will be dropped.
- Non-ECE majors are not assumed to have ECE310 and will be graded separately but must do all assignments.
- You are expected to be at ***every*** 2-hour lab assignment and attend ***every*** ECE402 lecture unless you are not well.
- Each lab team will present a project at the end of the semester showing work you did in the Sound Design lab. (PowerPoint presentations will not be permitted.)

Homework:

Homework assignments are given as weekly readings, with a combination of summary and specific questions to answer. Students are expected to spend 3-5 hours on each assignment. ***HW0 has a quiz during the 3rd lecture. All other homework assignments will be due Tuesdays before lecture; submit your answers by Gradescope*** *(see course website for access code)****.*** No late homework is accepted. Students may discuss homework, but each person hands in their own work.

Lab Policies:

At the beginning of the semester, students are to choose a 2-hour weekly timeslot to work on the Sound Design Lab. This is a series of video tutorials on the Continuum Fingerboard, EaganMatrix synthesizer, and Haken Editor. This lab will have attendance taken and be monitored by an undergraduate lab monitor. Students will sign up for their time slot on Campuswire and expected to follow their schedule (note that there are only 2 stations in the music laboratory). Students may work in groups of 2.

Resources:

Students will be responsible for attending lectures in person. Lectures will have attendance taken. Students who are sick or out of town for interviews may be excused from a lecture by emailing Prof. Cheng. **Students may <u>not</u> sign up for attendance for another student, as this constitutes an academic integrity violation.** Lectures will be recorded for the purposes of review.

Students will have a course Campuswire available, which serves as both the schedule and the message board system. Students may ask questions about the course on Campuswire, and Prof. Cheng, other students, and the TAs will attempt to answer them. In addition, students are expected to electronically submit the homework assignments on Gradescope.

Accommodations:

Students who have DRES letter of accommodations should contact Prof. Cheng at the beginning of the semester and work with Prof. Cheng to satisfy those accommodations. All students are

expected to substantially complete the same homework and laboratory assignments and satisfy the same learning objectives, but accommodations may be provided in the form of extensions and extra time on the quizzes as appropriate according to DRES. Students who have undiagnosed disabilities should seek a DRES evaluation as soon as possible, though accommodation may be given on a case-by-case basis if (for example) the student is undergoing evaluation but cannot receive a letter in time.

Students who have excused absences (illness, death in family, job interviews, etc.) must contact and work with Prof. Cheng to set extended deadlines working around their absence.