Music 103 - Sound Analysis, Synthesis, Perception, and Aesthetics
Prof. Michael Casey - Dartmouth College

Learning outcomes
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At the end of this course students will be able to:

* critically evaluate historical and contemporary sound research
* critically evaluate audio and music perception literature
* critically evaluate use of sound materials in musical compositions
* apply sound manipulation and synthesis techniques to research/composition
* synthesize new speculative audio processing techniques in Matlab/C/Python

ASSESSMENT
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1.	Weekly exercises in sound analysis/synthesis	30%
2.	Weekly discussions on reading/listening assignments	15%
3.	A mid-term paper/presentation to the class	15%
4.	An end-of-term project and presentation	40%

=== 1 === Wednesday 09/21

Introduction to Signal Processing

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Vector representation of signals operations on vectors
Elementary signals: definitions, construction d[n], u[n], imptrain[n]
Implementation in common digital music and programming environments
frequency representation of elementary signals
periodic, quasi-periodic, and inharmonic tones
sampling theorum, sample rate, nyquist frequency, multirate systems
Sinusoids, sums of sinusoids
Vector representation of signals
    phasor, amplitude, radian frequency, phase
Applications of simple signals
    Beating, difference tones
    Additive synthesis
    FM synthesis
    Waveshaping synthesis
Impulses, pulse trains, canonical signals
Complex exponential representation of signals
Alternate basis functions: wavelets and local support
A Universe of basis functions: sound atoms
Noise, band-limited noise, intro to to filters: LP, HP, BP
    White noise
    Colored noise
    Gaussian noise
    Perlin noise
Control:
    Envelopes
    Modulators
    Phasors
Lookup tables and interpolation
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Excercise: Manipulating and synthesizing signals using basic operations, sinusoids, frequencies, amplitudes, decibel scales
Listening: early computer music, early analogue synthesis, additive synthesis examples, FM syntehsis examples
Varese-Edgard-and-Le-Corbusier_Poeme-Electronique_1958
Category:

Xenakis: "Analogique A + B" (1958 1959), cut up sine waves
Music Varese-Edgard Le Corbusier Poeme-Electronique 1958: Oscillators
John Chowning: Stria: FM
Risset: Mutations: FM and Waveshaping

=== 2 === Wednesday 09/28

Hearing Science I

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  Helmholtz's classical view
    Application: Bell/Edison early telephony
  Dynamic signals / spectral envelopes
    Risset and Mathews - dynamic spectral envelopes
  Mel / Bark / Constant-Q frequency scales
  Decibel representation of amplitude
  Fletcher-Munsen equal loudness curves
  Limits of hearing: JND, thresholds of hearing / pain
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  Critical bands, critical band masking, non-simultaneous masking
  Frequency masking
  Temporal masking and the precidence effect
  Forward and Backward masking
  Psychological effects: linear-dimension rescaling, size, distance confusion

Reading: chapters from:
        Helmholtz: On the Sensations of Tone as a psychophysical basis for music theory
        H. Fastl and E. Zwicker, Psychoacoustics:facts and models. Springer-Verlag 2007
        B. Moore, Introduction to the Psychology of Hearing, 5th Edition

Listening: auditory demonstrations
Excercise: construct a psychoacoustic demos in Max/MSP (shepherd tones, critical band masking, threshold of hearing, ...)

Spectrum, Fourier Transform, Short-time Fourier Transform
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Heterodyne analysis
Filterbanks as multi-dimensional systems
    Sinusoidal filterbanks
    Classic vocoder
Gauss & Cooley & Tukey & IBM
The Fourier Transform: Discrete Fourier Series->Discrete Fourier
Transform->Fast Fourier Transform
Short-Time Fourier Transform
    Windowing, FFT size, hop size
    Phase vocoder and ISTFT re-synthesis
    Problem of phase reconstruction / synthesis
    Deconvolution of source/filter components to pitch shift
    FFT-1 synthesis algorithm
    Speculative spectral algorithms
Magniude-only Inverse Fourier Transform resynthesis (ISTFTM)
Convolution using the FFT
    Block convolution as a time-varying filterbank
Critical sampling and polyphase filterbanks
Wavelet filterbanks: pros/cons howto
Time-frequency distributions: spectral and temporal marginals
Implementation in common digital music and programming environments
Excercise: Sound design using filterbanks, modified resynthesis and
time-compression/expansion
Aural exercises: transients and the phase vocoder, identifiying vocoders
/ parameters in music

Listening: phase vocoder works, classic vocoder works, granular / spectralism
Exercise: block convolution / phase vocoder / phase vocoder / spectral transformations

=== 3 === 10/10

Hearing II: timbre perception and modeling
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Plomp - Perception of vowels -  F1/F2 space
John Gray - Multidimensional Scaling of Musical Timbre
De Chevigne - Multi-F0 estimation
McKinney - Spectral Roughness, testing Helmholtz' beating hypothesis
Plompt and Levelt, consonance, dissonance and spectral roughness
Krumhansl - relations between timbre / pitch
Perception of speech: missing phonemes, mcgurk, sinusoidal speech
Perception of Noise / environmental sounds
Cariani - Neural Coding of pitch / timbre
Patel - speech / music perception
Timbre Modeling and control:
       Forward models, Inverse models, Kalman filters
       Regression, Genetic algorithms
       David Wessel's Timbre as a Musical Control Space

Sinusoidal analysis, spectral modeling synthesis (SMS)
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Deterministic and non-deterministic signals
Common distributions and their spectral properties
Sums of sinusoids and noise signals
    noise suppression and removal
sinusoidal modeling: MQ analysis
spectral modeling synthesis: sinusoids plus noise
noise modeling
noise bandwidth and noise shaping
plosives, sibalents and fricatives in speech
noise in pitched and non-pitched timbres

Cepstrum and Quefrency Alanysis
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The Cepstrum, Quefrency, Probability, and Stochastic Signals
The complex and real cepstrum
    Timbral uses of the Cepstrum
Quefrency Alanysis, Cepstrum Liftering and Saphe cracking
Analysis of timbre using the cepstrum
Comparing cepstrum and LPC as source-filter models
Homomorphic deconvolution
Echo cancellation
Mel-Frequency Cepstral Coefficients
    Timbral similarity

Implementation in common digital music and programming environments
Excercise: Sound-design using noise bands, bandwidth and time-varying bands
Reading: William Serteis: Timbre, Tone, Pitch and Scale

Composers' use of timbre in late 20th century
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Iannis Xenakis
Pierre Boulez
Jean-Claude Risset
Philippe de Manoury
Gerard Grisey
James Tenney
Gyorgy Ligeti
Helmut Lachenmann
Louis Andriessen
Giacinto Scelsi

=== 4 === Wednesday 10/19

Hearing III: auditory scene analysis, sound textures
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Auditory scene analysis and auditory streaming
Matrix decomposition methods
    PCA, SVD
    ICA, NMF, PLCA
Machine learning decomposition methods
    The E-M algorithm and its variants, EM for PLCA
Probability and statistics - Bayes' theorem, distribution theory
Information theory, higher-order statistics, optimization
Convolutive mixtures
Shift-invariant PLCA

Excercise: using LDS and PLCA
Implementation in common digital music and programming environments
Excercise: sound-design using texture analysis, sound unmixing and
re-synthesis

Reading:
Auditory Scence Analysis - Albert Bregman, Steven Pinker, Steve McAdams
Shihab Shamma: Auditory neuroscience
Ellis/Brown/McAdams/Cooke/Smaragdis/Casey - Computational Auditory Scene Analysis
Auditory scene analysis demonstrations

=== 5 === Monday-Friday 10/24-28

GROUP TRIP
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I S M I R 2 0 1 1 - Miami, FL
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=== 6 === Wednesday 11/2

Linear Systems, Convolution, Filters
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Systems, Linearity and Time-Invariant properties
black-box representation of systems
signal->system->signal
Matrix representation of LTI systems
Convolution operator
FIR Systems: systems of delays
Fundamental Properties of LTI systems
IIR Systems: systems of delays with feedback
Cascaded systems: I am sitting in a recursive system
Z-transform and filter design
Filter Implementations
   Linear Constant-Coefficient Difference Equations
Form I and Form II digital filter lattices (CSound's filter2 unit generator)
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Source-filter models
interpolation methods
Band-limited resampling

Applications:
    wavetable synthesis and band-limited interpolation
    filters
    subtractive synthesis
    linear predictive coding (LPC)

Implementation in common digital music and programming environments
Excercise: virtual analogue synthesis, filtering, distortion, instrument
modeling and spatial audio
Aural exercises: filters, phase distortions, acoustic properties (lienar
/ non-linear), room acoustics

Virtual acoustics: environment, room acoustics and binaural audio
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Basics of room acoustics
Simulation of room acoustics
Ray-tracing model of room acoustics
Manfred Schroeder: allpass filter model of room acoustics
Jean-Mark Jot's models
Perceptual models: subjective parameterization
Binaural audio: head-related transfer functions
Transaural audio: cross-talk cancellation
Exercise: in room acoustics / 3D audio
Karplus strong algorithm
Instrument acoustics
Digital waveguide models: Julius Smith, Perry Cook, Charles Sullivan
Waveguide models: piano, guitar, clarinet, voice (similar to LPC)
The physical model paradox: acoustic tube + reed + no performer

Introduction to real-time analysis / synthesis in C (Unix/Max/PD/VST)
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tables, buffers, circular buffers
complex number representation in C/Java
indexing, interpolating, end-point protection
filters: Type-I, Type-II lattice implementation
fftw usage, fft implementation (butterflies, bit-reverse indexing)
block convolution algorithms
control pathways: OSC, MIDI
frameworks:
        Standalone UNIX
        Max/MSP
        PD
        VST

=== 7 === 11/09

Sound Texture Modeling
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Dynamical state and stochastic models
Textons - acousticons
Texture vs Noise, Mixture vs Texture
Texture analysis / synthesis
    Wavelets and grains
Linear Dynamical Systems
    Characterization of dymanical systems: differential entropy and embedding theory
    Hidden Markov models, Kalman Filters, Switching state LDS, Markov Random Fields
Control of dynamical systems (for texture synthesis)

Microsound, granularity and wavelets
Gabor vs Fourier
Granular synthesis: Rhodes, Truax, Xenakis, glitch
Curtis Rhodes - Microsound
Barry Truax - Acoustic Communication

=== 8 === 11/16

Hearing IV: everyday/musical listening, ecological acoustics
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Ecological acoustics
Everyday listening
The Schaefferian modes of listening and the timbral solfege
Aesthetics and poetics sound manipulation / synthesis
The sound object - Pierre Scaheffer
    Four modes of listening / reduced listening
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    Timbral sol-fege
    Arguments against reduced listening

Spectromorphology - Denis Smalley
Identity and structure - (detectable differences, contexts, structures)
Smalley - spectromorphology
        - refining / redefining timbre
Audiovision - Aesthetics of sound and vision

Reading:

Warren and Vebrugge - perception of breaking and bouncing events
J. J. Gibson, Ecological Approach to Perception
W. Gaver - Everyday listening (what in the world do we hear)
Schaeffer - Traites / solfege
Michel Chion - Audiovision
Denis Smalley - Spectromorphology


=== 9 === 11/23

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THANKSGIVING - NO CLASS
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=== 10 ==== 11/30


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Student project presentations (15 mins + 5 mins questions)
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