BME: Neural models of speech, music, and hearing

3 Credits, 3 Contact hours
Instructor: Antje Ihlefeld, Ph.D.
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Overview:
This course will focus on computational techniques to model auditory function and analyze and synthesize auditory signals. The course will cover fundamentals in signal processing as it applies to acoustics, auditory perception, and auditory neuroscience. We will consider current engineering approaches that apply these methods, including psychoacoustic compression methods (such as MP3), speech processing, sound mixtures, and aural rehabilitative devices.

Textbook(s)/Materials:
Loizou, Philipos C. Speech enhancement: theory and practice. Second Edition. CRC press, 2013. (available as e-book through NJIT library)
Schnupp, J. Nelken, I., and King, A. Auditory Neuroscience. Making Sense of Sound. MIT Press, 2012.
Course materials will consist of power point handouts for each lecture, assigned readings, peer-reviewed articles, homework assignments, and occasional video lectures from MOOCs.
Course materials will be provided via the Moodle portal to this course, and can be accessed in http://moodle.njit.edu/.

Prerequisites:
The course requires familiarity with signals and systems in the discrete time domain. BME 330 is a suitable pre-requisite. Basic skills in probability, including Bayes' theorem, are also assumed.

This is an elective course for Master/graduate students to be offered in Fall 2016.

Course Syllabus:

Week & date	Lecture Topic	Reading Material	Assignment
Week 1	Acoustic Fundamentals; dB SPL	AN ch 1	Acoustic Recordings
Week 2	Review of DSP, time scale modification	Loizou ch 2	Emotion in music
Week 3	Auditory perception fundamentals: the ear,	AN ch 2	Plucked String synthesis

	auditory physiology, psychophysics		
Week 4	Modulation spectrum. Hilbert transform. Speech.	Loizou ch 3	Chimaeric Sound
Week 5	Gaussian variables and processes. Signal Detection Theory. Masking.	Loizou ch 4	Audiogram
Week 6	Denoising, Basics of Wiener filtering, Kalman filtering	Loizou ch 6	van Bekesy tracking
Week 7	Mid-term Proposals		
Week 8	Pitch 1 – perceptual phenomena	ANS ch 3	Praat
Week 9	Pitch 2 – computational models	Handout	Singing voice
Week 10	Spatial sound, Virtual Displays, Reverberation	AN ch 5	Binaural sound
Week 11	Auditory scene analysis	Loizou ch 4, AN ch 6	Binary mask
Week 12	Models of hearing loss Hearing aids Cochlear implants	AN ch 8	Cochlear implant simulation
Week 13	Speech models and speech synthesis: LPC, cepstrum, harmonic+noise	Handout	Sinewave speech
Week 14	**Final exam,** project presentations	Handout	
Week 15	*Finals weeks*		

Lecture duration: Each lecture is designed as a 3 hours class.

Course Grading:

The course consists of lectures each week, weekly problem sets, a midterm proposal, and a final project. The grade will be broken down as follows:

Problem Sets:	25%
Mid-term proposals:	25%
Project:	50%

Course Description:
This lecture series introduces neural models of sound processing that span the auditory parts of the central nervous system, and how explains how they relate to current speech and audio technologies. The primary objective is to develop an in-depth understanding of what sound attributes are perceptually important, how hearing loss reduces a listener's ability to hear those attributes, and how they can be

classified, altered and enhanced through signal processing. Moreover, many neural models are based in statistical pattern recognition, and the course introduces and applies its basic principles. Practical homework assignments and term project strongly encourage students to build up practical engineering skills in advanced signal processing.

Assignments:
Matlab homework challenges will be assigned weekly. A major part of the course will be the invidividual term project. Students are encouraged to define a project by week two or three of the semester, and to document progress on the project on their personal website. All projects must be approved via email by the instructor.