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:
press, 2013. (available as e-book through NJIT library)
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

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:

<table>
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<tr>
<th>Week &amp; date</th>
<th>Lecture Topic</th>
<th>Reading Material</th>
<th>Assignment</th>
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<tbody>
<tr>
<td>Week 1</td>
<td>Acoustic Fundamentals; dB SPL</td>
<td>AN ch 1</td>
<td>Acoustic Recordings</td>
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<td>Week 2</td>
<td>Review of DSP, time scale modification</td>
<td>Loizou ch 2</td>
<td>Emotion in music</td>
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<tr>
<td>Week 3</td>
<td>Auditory perception fundamentals: the ear,</td>
<td>AN ch 2</td>
<td>Plucked String synthesis</td>
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Week 4 | Modulation spectrum. Hilbert transform. Speech. | Loizou ch 3 | Chimaeric Sound
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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 individual 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.