The Speech Chain

ECE 598, Section AL, Fall 2006

Instructor: Mark Hasegawa-Johnson, jhasegaw@uiuc.edu
Web Page: http://www.isle.uiuc.edu/tsc/

The goal of this course is to give students of speech, hearing, and language sciences, phonetics, and psychology the tools they require in order to quantitatively model speech production and perception. This course is designed to satisfy two specific curricular goals, and one research goal. (1) ECE 598AL satisfies the ASHA Audiology certification requirement for curriculum in the "Physical characteristics and measurement of acoustic stimuli" and the "Principles, methods, and applications of psychoacoustics." (2) ECE 598AL provides, to linguists, the physical and psychophysical foundations upon which to build future courses and research. (3) In addition to its curricular goals, ECE 598AL is explicitly designed to facilitate inter-disciplinary research by providing a common vocabulary.

We will start out by discussing basic acoustics: you will discover that any sound can be represented as the sum of sine waves at different amplitudes, frequencies, and phases. On this basis, you will see how to construct, manipulate, and sequence acoustic filters, including such filters as a pipe organ, a human vocal tract, a reverberant room, the outer ear, and the inner ear. The particular sources and filters used to produce and perceive the sounds of English will be treated in great detail. You will discover that humans are sensitive to something similar to the logarithms of both frequency and amplitude, and that human sensitivity has been formalized in measurement systems such as the decibel, the sone, the Bark, and the mel. By modeling this processing as a series of filters, you will discover quantitative measurements of speech intelligibility, and the ways in which such quantitative models can be used to explain the results of listening experiments and the the distinctive features of language.

Pre-Requisites

SHS 301 or Linguistics 401, or equivalent understanding of speech physiology.

Schedule

Lectures will be Monday 1:00-4:00 PM, Siebel 1105. Office hours are every weekday from 9:30-11:00 in 2011 Beckman, and Mondays after lecture (4-5 PM) in the Siebel cafe. Labs (2 hours/week) will be arranged in lecture. Credit: 4 hours (1 unit graduate credit).

Text

No text will be required for this course. All new material will be introduced via powerpoint slides, which will be available on the web. Homework assignments and labs will be self-contained. If you can do the homework and labs, then you can do the exam.

Recommended text, pre-calculus: *Pre-Calculus (Quickstudy Reference Guides - Academic)*, Lisa Drucker and Kaaren Ashley, Academic Press, 2003 ($4.95 on line).

Recommended text, Fourier decomposition and fundamental acoustics: *Fundamentals of Acoustics* by Lawrence Kinsler, Austin Frey, Alan Coppens, and James Sanders, John Wiley and Sons, 2000 ($113.51 on line; available used from $53.50).

Recommended text, speech acoustics: *Acoustic Phonetics* by Kenneth N. Stevens, MIT Press, 1999. Recommended readings from this text will be specified by page number ($43.01 on line; available used from $34.50).

Other recommended texts in speech science: *Acoustic and Auditory Phonetics*, Keith Johnson, 2003. *Speech Science Primer: Physiology, Acoustics, and Perception of Speech*, Gloria Borden, Katherine Harris, and Lawrence Raphael, 2002. *Acoustic Analysis of Speech*, Raymond D. Kent, 2001. *Elements of Acoustic Phonetics*, Peter Ladefoged, 1995. *The Speech Chain*, Peter Denes and Elliot Pinson, 1993. *Speech Physiology, Speech Perception, and Acoustic Phonetics*, Philip Lieberman and Sheila Blumstein, 1988.

Labs and Homework

Labs will include hardware labs (e.g., working with a sound pressure level meter), and labs using standard acoustic analysis software (including Praat).

Homework will be due weekly.

Both labs and homework will be graded based primarily on completion, using the following ABCD scale: A=mostly complete, B=about 2/3 complete, C=about 1/3 complete, D=less than 1/3 complete. Homework solutions and quiz solutions will be posted on the web after each lecture, so that you can study them for the final.

Quizzes and Exams

All exams and quizzes in this course are open book, open notes. You are welcome to use any material that is helpful to you except a friend. Some equations and constants will be provided, with the quiz, on a formula sheet; if there's something you want me to include on the formula sheet, send e-mail. You are welcome to use a calculator if you find it helpful. Anyone caught using wi-fi or any other medium to exchange ideas with another student during a quiz will be withdrawn from the course.

Weekly quizzes (30 minutes) will be designed to mirror, as closely as possible, the content of the homework assignment due the same day. For this reason I recommend that you finish your homework early, then verify it with me or with a friend.

The final exam will be comprehensive.

Grading

Grades will be assigned as a weighted average of scores in the following parts of the course:

Homework	20%
Labs	20%
Weekly Quizzes	30%
Final Exam	30%

Lecture Topics

1. Historical Overview; Units; Measurements
2. Stiffness, Mass, and Resonance
3. Acoustic Waves
4. Room Acoustics; Impulse Response and Frequency Response
5. Fourier Decomposition of Signals; Spectrogram
6. Acoustic Theory of Speech Production: Vowels
7. Speech Sources: Burst, Turbulence, Voicing
8. Acoustic Theory of Speech Production: Consonants
9. Place and Manner of Articulation; International Phonetic Alphabet
10. Auditory Physiology: Systems, Micromechanics, Neural Pathways
11. Psychoacoustics: Loudness, Masking, Upward Spread of Masking
12. Information, Entropy, and Markov Models of Language
13. Human Speech Recognition; Articulation Index, Speech Transmission Index
14. Confusion Matrix; Human and Machine Recognition of Phonemes
15. Grammatical and Semantic Context Effects on Speech Recognition