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Lab 2 *09/11/01*

Spectrographic and Spectrum Analysis of the English Vowel System

The main purpose of this laboratory is to get you familiar with some of the speech analysis and editing tools that are available in the Speech Group. You will digitize some more of the utterances that you recorded in Lab 1, and you will use various analysis methods to examine the sounds. Then you will do more detailed analysis of some of the vowels from the utterances in Lab 1.

On the VAX computers, you can log in as LABCOURSE. Each laboratory has a subdirectory in this account, named group1, group2, etc. To get in your subdirectory after logging in, type *set def [.groupx]* or *cd groupx*. You can create further subdirectories under [.groupx] by typing *cre/dir [.name]*. For example, you may want to set up a subdirectory [.lab2].

Part 1. Spectral analysis and editing with the Klattools.

In this part we will do several kinds of spectral analysis on the vowel [ʌ] and consonant [Σ] in **shutter**. Log in to a UNIX terminal as labc (password =). Create a directory for your group, as you did on the VAX. Convert the waveform **shutter** from the VAX to UNIX. (See attached instructions.)

To get into the spectral analysis program, type *xkl shutter*. You will see displays of (1) the waveform, (2) the waveform with an expanded time scale, in the vicinity of a cursor, and (3) a window that will display the spectrum. Type *i* to include a fourth window with a spectrogram.

(a) Isolate one portion of the waveform (say the vowel [ʌ]) and play it back. This is done by placing the cursor (left mouse button) at the beginning of the portion, typing *w*, and then placing it at the end of the portion, and typing *e*. To play, type *p* or press middle button. Try other portions of the utterance.

(b) Default spectrum. Locate the middle of the vowel and place the cursor there. Look at the spectrum (with a smoothed version overlaid over the discrete Fourier transform). What is the

fundamental frequency? What are the frequencies of the first three formants? (The duration of the time window for this spectrum is about 26 ms.) Print the spectrum. (See attached instructions.)

(c) Spectrum with a short time window. Change the window size to 6.4 ms. To look at the spectrum type *d* and give the time. With the mouse, adjust the location of the window to different times within a pitch period. Note the variation in the spectrum. The best location is centered on the first part of a pitch period. Measure the frequencies of the first three formants. If you type /, it will automatically find the frequency of the peak nearest your click. Print the spectrum.

(d) Use of averaging. Calculate the average spectrum over a time interval of 15 ms. (Type *a* and follow instructions.) Again measure the formant frequencies. Print the spectrum. (To print spectra, *lpr* the ps file.)

(e) Look at (and print) the spectrum in the middle of [ʃ] with the same window sizes of 26 and 6.4 ms. To obtain the average spectrum (as in (d)), use a longer averaging time, such as 50 ms. Print some relevant spectra.

(f) Comment on the advantages and disadvantages of the different analysis methods for examining vowels and fricative consonants.

Part 2. Measurement of American English Vowels.

References

Peterson, G.E., and Barney, H.L. (1952) *Control Methods Used in a Study of the Vowels*, **J. Acoust. Soc. Am. 24, 175-185**. Also in R. Kent et al. (1991) **Papers in Speech Communication: Speech Production**, Acoustical Society of America, Woodbury, NY., 585-594, and in J. Hillenbrand et al. (1995) *Acoustic Characteristics of American English Vowels*, **J. Acoust. Soc. Am. 97, 3099-3111**. See also pp. 257-322 of Chapter 6 of **Acoustic Phonetics**, K.N. Stevens.

Procedure

Spectrograms of stored waveforms can be calculated and printed out using the computer in the lab. Broadband spectrograms are to be made of each of the word pairs containing examples of English vowels. Select the *best* speaker among the lab partners (other speakers may be analyzed, if desired). You can use either the VAX or the UNIX systems. You will need to digitize the words with vowels, and, if you use UNIX, you will need to convert the files.

Determine the midpoint in time for each simple vowel. Select two measurement points for diphthongized vowels, but try to exclude formant motions associated with consonantal transitions. Measure and tabulate the frequencies of the lowest three resonances of the vocal tract (formants). Plot each vowel as a point or as a trajectory (with two points) on the attached graph paper. From this plot, formulate the simplest possible acoustic relationships between the first two formant frequencies and the distinctive features that were described in lecture:

1. Raise tongue body to a HIGH position

2. Lower tongue body to a LOW position

3. BACK tongue body

4. Make TENSE (non-LAX) articulation

5. Round lips

For two of the vowels, use the xkl program to obtain spectra sampled at the midpoint. It is best to use preemphasis to calculate the spectrum. (Parameter *p* should be 100.) In each case, display three spectra: (1) using the S command, a dft and a smoothed spectrum superimposed on the dft; (2) using the l command, a dft and an lpc spectrum superimposed; (3) setting the dft window to 6.4 ms (wd = 6.4 ms), placing the window on the first part of a pitch period, and clicking on the peaks to get the frequencies. Compare the estimated values of F1, F2, and F3 obtained from the spectra and from the spectrograms. You can create a printout with up to four spectra per page.

The lab report should include (1) spectrograms with the measurement points marked in pencil, (2) the plot of F1 vs. F2, (3) your acoustic definitions of distinctive features, and (4) spectra and observations concerning formant frequencies obtained from the spectra.