AUDL 1001: Signals & Systems for Hearing & Speech

Lab week 9: Introduction to Spectrograms

Introduction

A spectrogram is a representation of how the frequency content of a signal changes with time. We use two types of spectrogram for examining speech: one which emphasises the frequency aspects by using narrow analysis filters, and one which emphasises the temporal aspects by using wide analysis filters. Narrow-band spectrograms are convenient for investigating characteristics of the *source* of sounds for speech: they show the harmonics of the vocal fold vibration for example. Wide-band spectrograms are convenient for investigating characteristics of the vocal tract filter: they highlight the vocal tract resonances (formants) by showing how they continue to vibrate after a vocal fold pulse has passed through.

Learning Objectives

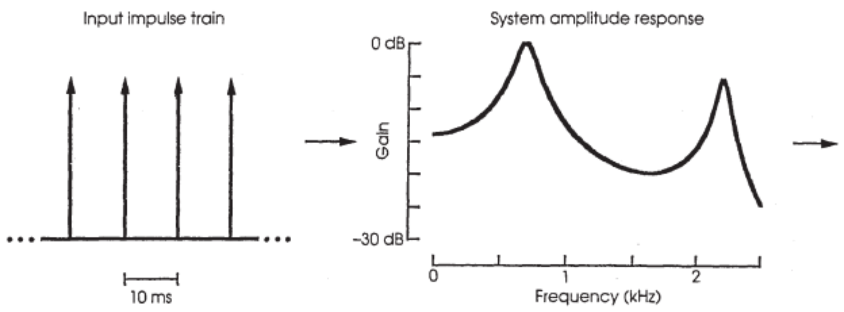
- to gain familiarity with spectrographic representations of sounds
- to appreciate the differences between narrow-band and wide-band spectrograms
- to learn how features of speech sounds appear on spectrograms
- to understand how the spectrogram can lead to quantitative analysis of the source and filter aspects of speech sounds.

Apparatus

You are provided with a program (SFS) that can display a spectrogram and a spectral cross section of a speech signal. Within the upper window you can choose to display any combination of waveform, narrow-band and wide-band spectrograms. Within the lower window you can display the spectrum between the cursors and an estimated vocal tract filter response. (http://www.phon.ucl.ac.uk/resource/sfs/)

Two versions of a very elongated diphthong (the combination of two vowel sounds at the end of the word *high*) have been generated synthetically on a computer. Each comprises only two resonances excited by a train of narrow pulses, which can be illustrated thus:

The versions are:



aimono	monotone - has a constant fundamental frequency
aifall	falling - has a falling fundamental frequency

You can also record your own versions of this and other sounds.

Method

To measure fundamental frequency from the narrow band spectrogram, find the frequency of the 10th harmonic and divide by 10. To measure the fundamental period from the wide band spectrogram, zoom the display to measure the duration of 5 periods and divide by 5. To measure formant frequencies (which are a reflection of the resonances) from the wide-band spectrogram, estimate the frequency at the centre of the main spectral peaks, or use the estimated filter frequency response.

Observations

1. Display a wide-band spectrogram of *aimono*.
   a. Make a rough, labelled sketch showing striations, formant resonances and formant movement. Make sure you label the axes.
   b. Measure the formant frequencies at the beginning and the end.

2. Display a narrow-band spectrogram of *aimono*.
   a. Make a rough, labelled sketch showing harmonics and varying harmonic amplitude.
   b. Why does a harmonic vary in amplitude over the width of the spectrogram?

3. In the graph illustrating how these sounds could be made above, it looks like both the fundamental frequency of the pulse train and the resonances in the LTI filter are fixed. What modifications would you have to make to this illustration to make *aimono*? Would the system be LTI? Explain your answer.

4. Display a wide-band spectrogram of *aifall*.
   a. Compare with the sketch you made in 1a. What differences do you observe?
   b. If this were a human speaking, what would be the cause of those differences?

5. Display a narrow-band spectrogram of *aifall*.
   a. Compare with the sketch you made in 2a. What differences do you observe?
   b. Measure the fundamental frequency at the beginning and the end.

6. What modifications would you have to make to the illustration above to make *aifall*?

7. Record your own production of the -*igh* in *high*.
   a. Measure the first two formant frequencies at the beginning and the end of the diphthong. Compare with 1b. What is the perceptual effect of these differences?
   b. Measure the fundamental frequency at the beginning and the end of your production. Compare with 4b. What is the perceptual effect of these differences?

8. Display a wide-band spectrogram of about 6 periods at the end of *aifall.*
   a. Sketch how the response of the formants is damped between one pulse and the next.
   b. How would your sketch change if the fundamental frequency were higher?
   c. How would your sketch change if the formant frequencies were higher?
   d. How would your sketch change if the damping of the formants were greater?

9. Record and print a spectrogram of your own name. See if you can find the parts of the spectrogram corresponding to elements of its pronunciation.