LING 576 Acoustic Phonetics
Spring 2009
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Topic number 7: Acoustic Analysis of Vowels
2-3-09

Reading:

Ladefoged, Peter. 2003. Phonetic data analysis. Malden, Massachusetts and Oxford: Blackwell. Read Chapter 5.

Baart, Joan. 2002. Acoustic Phonetics. MS, SIL. Read pp. 44-61. On reserve in the CanIL library.

1. Acoustic correlates of vowel quality

Vowel formants are the main acoustic correlate of vowel quality.

Generally, only the first two formants (F_1, F_2) are relevant. However, F_3 may be relevant for languages with front rounded or r-colored vowels.

Correlations:

- Vowel height is inversely correlated with F_1.

Higher vowels have a lower F_1; lower vowels have a higher F_1.

- Frontness, backness and roundness are primarily related to F_2.

Front vowels have higher F_2; back vowels have lower F_2.

Round vowels have lower F_2; non-round vowels have higher F_2.

- Lip rounding also lowers F_3.
- [ATR] correlates mainly with F_1.

A [+ATR] vowel has a lower F_1 than its [-ATR] counterpart.

Note the connection between vowel height and [ATR] in the acoustic dimension.

"The best way of describing vowels is not in terms of the articulation involved, but in terms of their acoustic properties."

-- Ladefoged (2003:104)

2. Measuring vowel formants
Recording issues

Vowel formant measurements are more difficult than many other acoustic measurements.

In some cases, individual formants can be difficult to resolve.

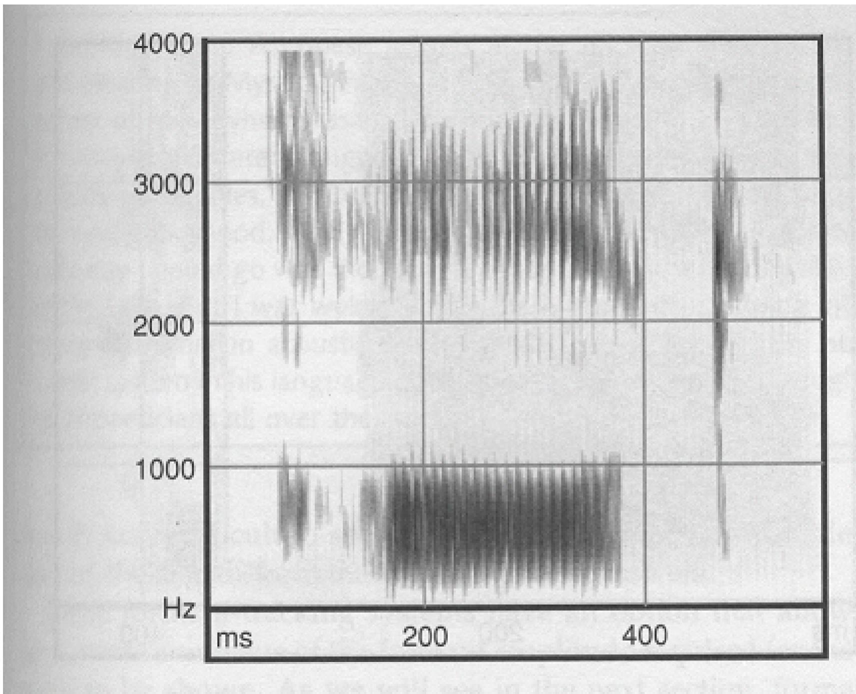


Figure 5.7 A spectrogram of the word *caught* in which the first two formants are very close together.

This means that the quality of the recordings used can be critical.

Some considerations:

- Microphone quality and placement
- Signal-to-Noise ratio
- Sampling rate

For a given sampling rate F, frequencies up to F/2 (the *Nyquist frequency*) can be effectively analyzed. Thus, the sampling rate used should be at least twice the maximum frequency of analytical interest.

For most purposes, a higher sampling rate (at least 44 or 48 kHz) is preferred.

Surprisingly, a *lower* sampling rate (e.g., 11 kHz) is generally better for looking at vowels.

Recordings made at higher sampling rates can be downsampled to some appropriate value.

Note however that for many practical purposes formant measurements can be made on recordings sampled at higher rates without major problems. The sampling rate is mainly an issue for serious and detailed acoustic studies of vowels.

Settings and displays

Primary displays for measuring vowel formants in Speech Analyzer:

- Spectrogram
- Spectrum

Spectrogram settings:

- Color vs. monochrome
- Frequency range
- Thresholds (darkness)
- Spectral resolution (wide vs. narrow band spectrograms)

Narrow band spectrograms facilitate viewing of individual harmonics.

What is this useful for?

Wide (or "medium") band spectrograms are more appropriate for formant measurements.

Spectrum display basics:

- Relationship of spectrum to spectrogram display
- Bandwidth
- Power

Issues in formant identification

A number of factors can complicate vowel formant measurement:

- Formants close together
- Spurious formants
- No harmonic in close proximity
- Effects of nasality

"You have to know where to look for the formants before you can find them."

-- Ladefoged (2003:113)

Choosing measurement points

Criteria:

- Away from consonant transitions
- Steady formant states

- Repeatable measurement procedure

This is more important if you are making measurements for a study you intend to publish.

- Average over several pitch periods?

One possible practice: "a steady state portion near the middle of the vowel."

Note Ladefoged's advice (in the reading) to make a clear record of whatever procedure you use.

Techniques for measuring formant values

There are several ways of measuring formant values:

- Manually, on a spectrogram (with cursor or printout)

"the seemingly gross visual method of formant-bar evaluation using a wideband filter can be the most accurate method, if it is performed by an experienced researcher carefully tracing the changing formant bars."

-- Fujimura & Erickson (1997:69-70)

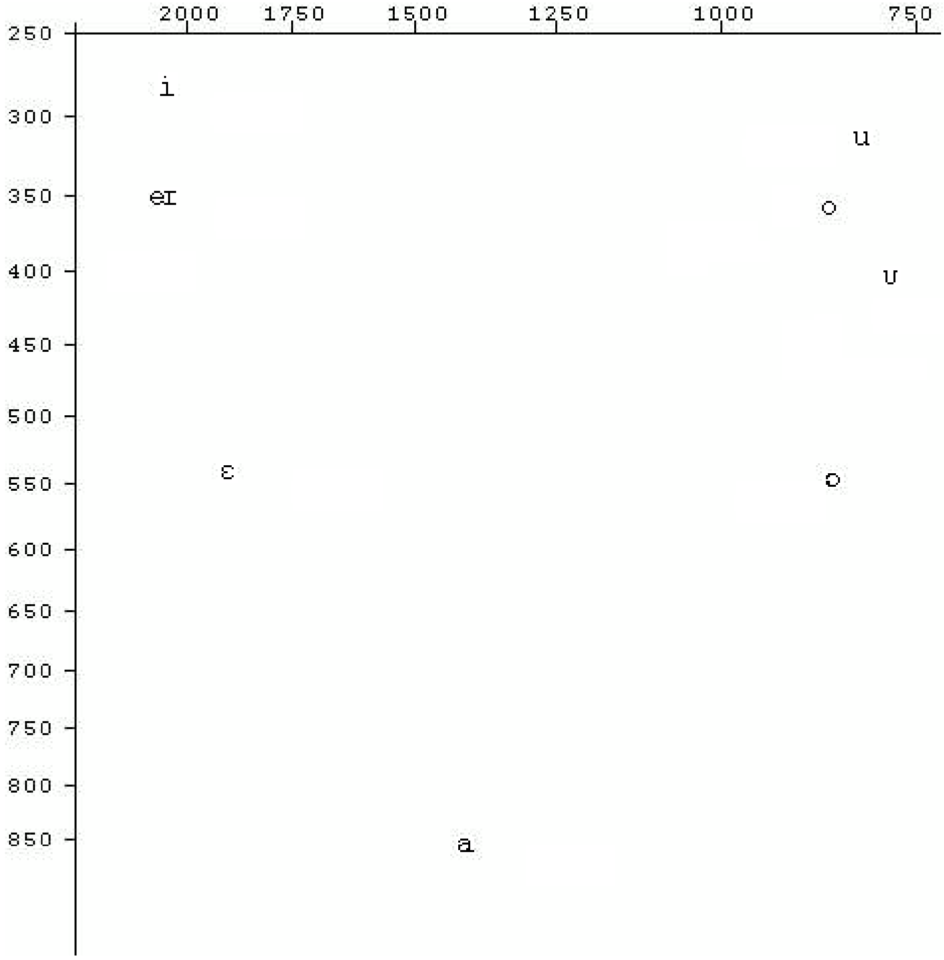
- Automatic formant tracking
- From the spectrum

Measurement practice examples

4. Vowel space plots

By plotting F_2 values horizontally, increasing from right to left, and F_1 on the vertical axis, increasing downward, we can produce a chart in which the arrangement of the vowels resembles that of a traditional vowel chart.

Nawuri example:



Some software for plotting vowel formants:

- Several programs have been developed to perform vowel plots. Links to several free programs can be found at http://www.linguistics.ucla.edu/faciliti/facilities/acoustic/acoustic.html.
- A free program (under development) called FPlot is also available at http://casali.canil.ca.

Possible modifications / embellishments to the simplest such plot:

- Some linguists prefer to use F_2 - F_1 (rather than F_2) on the horizontal axis.
- In plotting *average* formant values, it is helpful to include ellipses. (See the Ladefoged reading.)
- It is best to use a non-linear *Bark* scale to more accurately reflect how frequency differences are *perceived*.

A Bark conversion formula is given in Bladon (1986) (on reserve in the CanIL library).

The Bark scale is used in the Nawuri example above, though the values are given in Hz.

Making a vowel formant plot is a fairly simple type of acoustic study that can add value to a phonological description.

It is important to include multiple speakers if at all possible, to measure enough tokens of each vowel, and to measure the vowels in similar contexts. (Ideally, these should be contexts in which the influence of surrounding sounds is minimal.)

See the Ladefoged reading for some discussion.

5. [ATR] Issues

A major problem: In [ATR] harmony languages with nine or more vowels, F_1 and F_2 often fail to clearly distinguish all the vowels. In particular, the high [-ATR] vowels /ɪ/ and /ʊ/ often overlap heavily in their formant values with the mid [+ATR] vowels /e/, /o/.

Although F_1 is the primary acoustic correlate of ATR, other possible correlates have been discussed in the literature as well, generally with less than fully conclusive results. (We will come back to this issue later if time permits.)

Acoustic investigation of [ATR] is very challenging, and much more research is needed.

References

Bladon, Anthony. 1986. Phonetics for hearers. In Language for Hearers, ed. by Graham McGregor, 1-24. Oxford: Pergamon Press.

Fujimura, Osamu & Donna Erickson. 1997. Acoustic phonetics. In The Handbook of Phonetic Sciences, ed. by William J. Hardcastle & John Laver, 65-115. Oxford: Blackwell.

Ladefoged, Peter. 2003. Phonetic data analysis. Malden, Massachusetts and Oxford: Blackwell.