Measuring Vowel Formants

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Introduction

Vowel quality is based (largely) on our perception of the relationship between the first and second formants (F1 & F2) of a vowel in combination with the third formant (F3) and details in the vowel's spectrum. We can measure F1 and F2 using a variety of tools. A researcher's auditory impression is the most important qualitative tool in linguists; we can transcribe what we hear using qualitative labels such as IPA symbols. For a trained transcriber, transcriptions based on auditory impressions are sufficient for many purposes. However, when the goals of the research require a higher level of accuracy than can be achieved using transcriptions alone, researchers have a variety of tools available to them. Spectrograms are probably the most commonly used acoustic tool; most phoneticians consult spectrograms when making narrow transcriptions or when making decisions about where to measure the signal using other tools.

While spectrograms can be very useful, they are typically used as qualitative tools because it is difficult to make most measures accurately from a spectrogram alone. Therefore, many measures that might be made using a spectrogram are typically supplemented using other, more precise tools. In this case an LPC (linear predictive coding) analysis is used to track (estimate) the center of each formant and can also be used to estimate the formant's bandwidth. On its own, the LPC spectrum is generally reliable, but it may sometimes miscalculate a formant severely by mistaking another formant or a harmonic for the formant you're trying to find. Spectrograms together with an LPC provide a highly reliable measure of vowel formants with relatively little error, because the spectrogram helps the researcher see where the LPC is in error and the LPC gives an accurate estimate of the central value of the formant (and the formant's bandwidth).

Monophthongs are vowels that have only a single vowel quality throughout their duration. In most dialects of North American English, the vowels /a/ as in "hot" and /ɪ/ as in "hit" are monophthongs whereas /aɪ/ as in "hide" and /ɔɪ/ as in "boy" are diphthongs. On a spectrogram monophthongs typically have only a little formant movement concentrated near the very beginning and very end of the vowel (the result of consonant gestures impinging on the vowel's gestures thereby changing the vowel's resonances). Diphthongs have a lot of formant movement that starts about 30% to 40% of the way through the vowel and continues until the end. A common way of comparing monophthongs and diphthongs is to measure the vowels at the 20% and 80% points. The nucleus of the diphthong is represented by the 20% point whereas the offglide is represented by the 80% point. Diphthong nuclei and monophthongs are compared using the first and second formant values at the 20% point. The amount of offglide movement in a diphthong can be measured by subtracting the nucleus first and second formant measures at the 20% point from the same measures at the 80% point. A formula for calculating the absolute Euclidean distance between the nucleus value and the offglide value is found in the following formula (where nuc = the vowel nucleus and offglide = the vowel offglide):

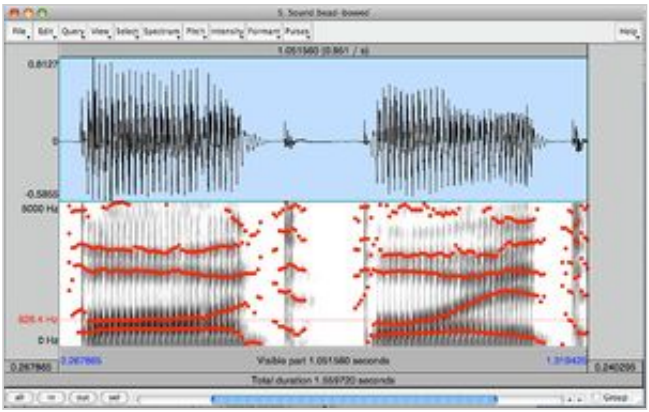
\sqrt{(F1nuc-F1offglide)^2 + (F2nuc-F2offglide)^2}

Typically monophthongs' 80% point and 20% point are very similar, while diphthongs' 80% point and 20% point are very different. The bigger the difference, the easier it will be to hear the offglide. For example, the diphthong /aɪ/ has a big difference between the 80% and 20% points, while the diphthong /eɪ/ has only a small difference. As a result, it is easier to hear that /aɪ/ is a diphthong. Many researchers prefer to measure the vowels at the 20%, 50%, and 80% points to get a clearer picture of the formant movement.

To be able to measure the 20%, 50%, and 80% points you first have to be able to measure the vowel's duration. Knowing how to compare duration will also help you measure another important aspect of vowel contrasts. If you need help measuring the vowel's duration see the handout "Measuring vowel duration".

Measuring the Vowel's Formants

1. If there are no red LPC lines the spectrogram, or if there are other lines that bug you (like the aqua "pitch" line that you see in some of my figures), or if the spectrogram is missing, you can turn each analysis on or off using pull down menus at the top of the editing window. To turn on the LPC tracking, use the "Formants" menu and select "Show Formants".
2. Make sure that both the "Spectrogram" and the "Show Formants" options are selected. If the formant tracker is having a lot of trouble, or if the spectrogram is hard to read, the last user might have been using different settings from the ones you want. Under the "Formant settings..." and "Spectrogram settings..." menus, click the "standard" button to reset the defaults. There are a variety of reasons for changing the LPC formant settings. For example, if you are measuring someone with a very short vocal tract, like a young child, you would expect to find fewer formants within a specific range than if you are measuring an adult male (who typically has 1 formant per 1000 Hz). Similarly, if you are vowel with a breathy voice quality you may need an extra formant to accommodate the sharp drop in energy in the high frequencies. Praat's settings are pretty good for most adults, male and female, but if you find that the tracker is making a lot of errors, you may want to have different settings for different speakers (but be consistent, and be sure to note the differences in your methods section).
3. Listen to the selection and write down your impressions of the vowel quality. Listening to a vowel can help head off LPC error artifacts in your data. If you hear a low back vowel and the formant measures indicate a high front vowel, the LPC tracker is probably making an error. To play a file click on the bar immediately below the spectrogram that shows the duration of the selection. To play everything in the window click on the middle bar. To hear the entire file click on the bottom bar.
4. Place the cursor at the measurement point(s) as calculated from the duration measures that you've already made. Be consistent with your cursor placement to avoid measurement error, and measurement bias.
5. At each point, use the "Formant" menu then "Get first formant" and "Get second formant" to find out the estimates of the first and second formants (alternatively you can use the F1, F2 keys or "formant report"). If it looks the LPC analysis isn't continuous through the vowel, or if there's an abrupt jump from one value to another, then there's probably an error in the estimate. Look at the spectrogram to see if the LPC lines follow the formants in the spectrogram smoothly. If it's possible, get an estimate from nearby that looks reliable. If the LPC is useless, then try to estimate the formant value from the spectrogram (from the horizontal center of the formant band).
6. Typically multiple points are measured if you are interested in comparing monophthongs to diphthongs, or if you are interested in the dynamic characteristics of vowels that are of perceptual importance to listeners (often at 20% and 80% and sometimes also at 50% of the vowel's duration). Figure 8 shows the word "baud" [bɔd] followed by the name "Boyd" [bɔɪd] to illustrate the difference between a monophthong [bɔd] and a diphthong [bɔɪd].



The words "baud" and "Boyd" illustrating monophthongs and diphthongs

In comparing the two words, note that both show formant movement throughout their durations, but note how much the first and second formants are moving in latter half of [bɔɪd] while most of the formant movement in [bɔd] is found at the very beginning and end of the vowel in the formant transitions.

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