Math 5: Music and Sound. Homework 7

due Fri May 18 . . . but best if do relevant questions after each lecture

For formant analyses you will want to use `praat` with spectrogram settings 0-4000 Hz range, window length 0.01 s (this is short to blur the harmonics of the spoken pitch together but leave the overall vocal tract response shape), dynamic range 60 dB. You should also experiment with `Show formants`.

1. Download the file `noise_bottle.wav` which is recorded from a microphone being lowered into a bottle, while a stereo system emitted a constant random background noise at all frequencies.

   (a) Looking at the spectrogram, describe the change in the frequency spectrum. Why does this happen? What is responsible for the strongest peak that appears at low frequency?

   (b) We defined the width Δf of a resonance peak as the size of the frequency interval where the response amplitude is at least half its peak. What dB change does dropping to half the amplitude correspond to? (Review)

   (c) Use this to estimate the Q factor, and therefore the decay time τ, for this low frequency resonant mode. (Bring up a spectrum graph for the entire in-bottle part. Ignore the other nearby noisy peaks and use the width of the central one)

2. Consider a closed-open pipe of length 0.17 m, a model for the vocal tract. Assume initially the pipe has constant width and there's no end correction.

   (a) Compute the formant frequencies F1 and F2.

   (b) If the mouth is opened, what happens to F1? F2?

   (c) If the pharynx is constricted about 6cm up from the vocal cords, what happens to F1 (note it's nearer an antinode)? F2?

3. Download the file `ee_aa_both.wav`, which I made with my own vocal instrument.

   (a) Measure the pitch (fundamental frequency) and frequencies of formants F1 and F2 for the two spoken vowels.

   (b) For the same vowels whispered, is there a pitch? Are there formants? If so do they have similar frequencies to the sung case? (give only a qualitative discussion)

4. Record your own voice speaking three vowels 'ee', 'aa', and 'oo'[1]

   (a) Print out a spectrogram of your recording, label F1 and F2 for each vowel, and list their frequencies.

   (b) Now draw a new pair of axes: horizontally F1 (on a range 0-1000 Hz), vertically F2 (a range 0-3000 Hz), and plot the points giving the first two formants of each vowel (each vowel gives one point).

   (c) Apply `Convert - Change gender...`, choosing `Formant shift ratio` to be 1.3 if you're male or 0.7 if you're female . . . or subvert the concept of gender entirely and become a chipmunk. Examine the new spectrogram: Did the pitch change? What happened to the formants?

[1] Hold each for at least a second, and if you want, rather than changing suddenly, slide between them to watch formants change gradually. You will want to put the mic close to your mouth but not get crackle or noise from air blowing on it; experiment until you get a clean signal.

If you produce something entertaining, upload it.

5. Read the links on *overtone singing* and *Tuvan throat singing* on the website.
   (a) How far up the harmonic series (approximately what n) do you need to go so that adjacent harmonics are separated by a whole tone? By a semitone? Since melodies usually involve scales in which such intervals appear, this tells you typical Tuvan harmonic numbers.
   (b) A Tuvan singer wants to tune a formant to resonate at the 12th harmonic, but to give less than 1/4 that intensity for both neighboring 11th and 13th harmonics. What Q factor do they need to produce for this formant? (Assume their vocal cords produces equal intensities for all harmonics).
   (c) Draw a spectrum that could be observed if a Tuvan singer sings a fundamental of 100 Hz and tunes a formant as in part b).
6. A room has dimensions $4 \times 6 \times 10$ m^3. Compute the reverberation time T_{60} in the following situations:
   (a) The room is perfectly reflective (impossible in reality) but has windows open totalling area 5 m^2.
   (b) The room is everywhere lined with wood (use the absorbtion coefficients on p.222 at 1000 Hz) and the windows are closed (treat them the same as wood).
   (c) The room is lined with wood everywhere except 5 m^2 of windows are opened.
7. Measure the reverberation time T_{60} of the Kemeny stairwell from the sound of a clap: `Kemeny_stairwell_clap.wav` I suggest you use the `Show intensity` feature of `praat` and compute it from the time to drop by 30 dB. Quote your answer with an estimate on accuracy, *e.g.* 5 ± 0.7 sec.
8. A shower cabinet has acoustically-reflective walls and dimensions $2 \times 1 \times 1$ m^3. Compute the frequencies of the seven modes labelled 000 through 111. Sketch the resulting spectrum if they all were excited. These are the pitches that you hear resonate when singing in the shower. What is the musical interval between the frequencies f_{011} and f_{111} ?