Problem 3.1

It has been said that everything that we hear may be decomposed into three types of sounds: click, hiss, and buzz.

(a) Record a click. Open Praat, and record a tongue click, or a finger snap, or a ruler hitting the table. Look at the waveform display and the spectrogram. How long is the click (in milliseconds)? What is its bandwidth, i.e., for what range of frequencies does it have energy?

(b) Record a tone that is as nearly sinusoidal as you can make it (try a sustained flat whistle). Observe the waveform plot. What is the fundamental frequency of your whistle? What is its fundamental period? Observe the spectrogram. What is its bandwidth—for what range of frequencies does it have significant energy?

(c) Now record a “buzz”—a tone that is not sinusoidal (try a /z/ sound, or perhaps an “eee”). Observe the waveform plot. What is the fundamental frequency of your buzz? What is its fundamental period? Observe the spectrogram. What is the bandwidth of the buzz—for what range of frequencies does it have significant energy?

(d) Finally, record a “hiss” (try an /s/ or an /f/ sound, or both). Observe the waveform plot and spectrogram. How long does it last? How broad is its frequency band?

Problem 3.2

In this problem, you will use matlab to construct and test a simple filter.

(a) Open matlab. Type "s=rand(16000,1);" to construct a one second hiss sound, s(t), at a sampling rate of f_s = 16000 samples/second.1 Play s(t) back using the command "soundsc(s,16000);". Verify that it’s a hiss. Type t=[1:16000]/16000; to construct a time axis, then type "plot(t,s);" in order to plot your hiss. Type "zoom on;", then use the mouse to zoom in on the waveform plot. Is it a hiss? Type "specrogram(s,16000);" to display a spectrogram. What is the bandwidth of the hiss?

(b) Type "v=wavrecord(16000,16000);" to record one second of audio from the microphone. Say something. Plot the waveform (using "plot(t,v);") and the spectrogram (using "specrogram(v,16000);").

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1Warning: if you leave off the semicolon at the end of a command, matlab will print the result of the command to your screen. If the result is a 16000-sample waveform, then matlab will print 16000 numbers to your screen. If you let this happen by accident, you can stop the display by pressing control C.
(c) Construct a very simple impulse response. Type $h=[1; 1/2; 1/3; 1/4; 1/5]$; to construct the following impulse response:

$$h(t) = \sum_{n=1}^{5} \left( \frac{1}{n} \right) \delta(t - \tau_n)$$

where $\tau_n = \frac{n-1}{f_s}$, i.e., $\tau_1 = 0$, $\tau_2 = \frac{1}{16000}$ of a second, etc. Type `stem(t(1:5),h(1:5))` to plot the impulse response. Verify that it has five impulses with successively decreasing amplitudes. What are the impulse times, $\tau_n$? Listen to the impulse response by typing `soundsc(h,16000)`; Can you hear five separate impulses, or does it just sound like one impulse?

(d) Type $x = \text{conv}(s, h)$ in order to implement the following operation:

$$x(t) = \sum_{n=1}^{5} \left( \frac{1}{n} \right) s(t - \tau_n)$$

Listen to $x(t)$ by typing `soundsc(x,16000)`. Plot its spectrogram. How does it differ from $s(t)$?

(e) Repeat part d with $v(t)$, i.e., type $x = \text{conv}(v, h)$.

(f) Create an impulse response with the same five impulses as before, but spread out over much longer delays. You can do this by typing $h=[1; \text{zeros}(1599,1); 1/2; \text{zeros}(1599,1); 1/3; \text{zeros}(1599,1); 1/4; \text{zeros}(1599,1); 1/5]$; What is the total number of samples in your impulse response? Verify your answer by typing `N=length(h)` (if you type this without the semicolon, it will print $N$ to the screen). Plot the impulse response using either `stem(t(1:N),h)` or `plot(t(1:N),h)`; Verify that it still contains five impulses, but that the impulse times have changed. Listen to the impulse response by typing `soundsc(h,16000)`; Can you hear five separate impulses, or does it just sound like one impulse?

(g) Type $x = \text{conv}(s, h)$; in order to filter $s(t)$. Listen to $x(t)$, plot its spectrogram, and plot its waveform. How does this differ from the result of part d?

(h) Repeat part g with the speech waveform. Listen to the resulting $x(t)$. Can you hear the echoes?