UCLA
Dept. of Electrical and Computer Engineering
ECE 114, Fall 2019
Computer Assignment 2: Frequency and Time Analysis of Speech

Introduction: The goal of this assignment is to learn the purpose of pre-emphasis filters in speech analysis. Additionally, this assignment includes the estimation of speech signal parameters, such as formant frequencies and pitch period, in the frequency and time domains.

Pre-emphasis Filters:
Pre-emphasis filters are commonly used in speech processing applications to boost high frequency components, since such components may be low energy yet contain important discriminative information. The general form of pre-emphasis filters in the time domain is:

$$y(n) = x(n) - ax(n-1),$$

where a is a parameter between 0 and 1, usually set closer to 1. To display the frequency response of a pre-emphasis filter, type:

```
freqz([1 -a],1);
```

where a is the chosen parameter. A figure should appear displaying the magnitude and phase response of the given filter. Note that the parameters of the `freqz` command are the feed-forward and feed-back terms, respectively.

• Experiment with the term a. Move it closer to 1; move it closer to 0; change its sign.

• Load speech data into the current workspace by typing:

```
load_in;
```

Three variables should appear, namely "female_sentence" (a full sentence by a female speaker), "female_a" (/a by a female speaker), and "male_a (/a by a male speaker).

• Apply a pre-emphasis filter to the full sentence by typing:

```
out=filter([1 -0.8],1,female_sentence);
```

• Compare the unfiltered and filtered versions of the sentence:

```
soundsc(female_sentence,8000);
soundsc(out,8000);
```

• In addition, compare the spectrograms of the unfiltered speech in the variable female_sentence and the filtered speech in the variable out. A spectrogram can be generated in MATLAB with a command of the form:

```
spectrogram(female_sentence,100,[],[],8000,'yaxis');
spectrogram(out,100,[],[],8000,'yaxis');
```

The first input to the spectrogram() command is the variable containing the speech data, the second input is the size of the analysis window used, and the input of 8000 is the sampling frequency.

• Now inspect the spectral effect of pre-emphasis on the steady state /a sound. Type:

```
figure(1);
zpfft(female_a,8000,10);
out_a=filter([1 -0.8],1,female_a);
figure(2);
zpfft(out_a,8000,10);
```

This should display two figures: the log-magnitudes of the spectra of the unfiltered and filtered versions of the steady-state /a sound. Note that the spectra are 10× oversampled (zero-padded).

Questions:

1. Sketch three pole-zero plots for $a = 0.8$, 0.5, and -0.8. This can be done using the MATLAB command zplane(). The inputs are the same as in the freqz() command. Determine if each is high-pass or low-pass.

2. Comment on the effect of pre-emphasis on the sound and in the spectrogram of the female sentence.

3. Describe the effect of pre-emphasis on the spectrum of the steady-state /a/ sound.

Formant Frequency Identification:
In this section formant frequencies will be estimated from spectral plots. To view the spectral estimate of "male_a", type:

```
zpfft(male_a,8000,10);
```

A figure will display a windowing version of the time domain signal, along with the log-magnitude spectrum. As discussed in class, the narrowly spaced lobes are harmonics, and are due to the source signal. However, the general shaping of the spectrum is due to the vocal tract, and the peaks (resonant frequencies) of the shaping function are the formant frequencies.

Questions:

1. Determine the approximate spectral locations for the first three formant frequencies.

Pitch Period Estimation:
In this section the pitch period and fundamental frequencies of voiced speech will be estimated from time-domain signals. The steady-state /a/ sound by the male and female speakers can be plotted by typing:

```
figure(1);
plot(male_a);axis tight;
figure(2);
plot(female_a);axis tight;
```

Note the periodic nature of both signals.

Questions:

1. Determine the pitch period for the "female_a" sound in samples. Determine the pitch period in seconds. (Note that the sampling rate is $F_s = 8$kHz.) Determine the fundamental frequency of the speaker.

2. Repeat the previous question for the "male_a" sound.

3. Now use the file rex.m to record your own voice. Running the file will prompt you to speak into your computer's microphone. If your computer does not have a microphone, you may record yourself using a smartphone, save the file to your computer, and importh the audio data from the audio file as directed in the script. Say the syllable /a into the microphone for 2 seconds. The script will produce the wave form, spectrum, and spectrogram of the utterance. Use any of them to estimate your own pitch. For the waveform, you can find a segment that shows strong periodicity and estimate the period. For the spectrum, you can zoom in to estimate the distance between adjacent pitch peaks. For the spectrogram, you can estimate the distance between harmonics. You may choose your favorite method.