COMP.SGN.120 Introduction to Audio Processing

Exercise 5
Week 49

In this exercise, you will implement one of the commonly used features in audio signal processing – Mel-frequency cepstral coefficients (**MFCCs**). There are two questions with 1 point for each summing up to 2 points. Bonus question is optional, no grading, to test your skills further. **The submission should consist of a Jupyter notebook with your observations and the python code**.

Problem 1 : Mel filterbank (1 point)

a) Load the given audio file (audio.wav) to get the audio signal and its sampling rate. Hint: *librosa.load('audio.wav')*

b) Create a mel filterbank with the following settings:
- Sampling rate obtained from (a)
- N_fft = 512
- N_mel = 40

Hint: *librosa.filters.mel(sr,n_fft,n_mel)*

c) Plot the mel filterbank and report your observations. Hint: *librosa.display.specshow*

Problem 2 : MFCC (1 point)

a) Pre-emphasis the audio signal (audio.wav) with the given equation:

$$y(t) = x(t) - \alpha x(t-1)\,,\ \alpha = 0.97.$$

Hint: *np.append(x[0], x[1:] - α * x[:-1])*

b) In the **stft** loop you implemented earlier, for each frame, do the following:
- Window each frame (using hamming window) Hint: *signal.hamming*
- Calculate the fft
- Collect the power spectrum (you will get power spectrum)
- Multiply it with mel filterbank you created in Question 1 (you will get mel spectrum)
- Take log operation (you will get logarithmic mel spectrum) Hint: *20 * np.log10*
- DCT (Finally, you will get MFCC) Hint: *from scipy.fftpack import dct*

c) Plot logarithmic power spectrums, mel spectrums, logarithmic mel spectrums, MFCC.

d) Implement MFCC using librosa and compare with yours. Report your observations.

Bonus: Implement your own mel filterbank with the same setting as in Problem 1.

In Problem 1, you used *librosa* library to get mel filterbank. Now try to implement by yourself!

Hint:

- convert hz to mel using Equation $F_{mel} = 2595\ log_{10}(1 + f/700)$
- uniformly distributed on the mel scale
- convert mel to hz back using the inverse of Equation above
- Mel filter of band m:
    1. starts at 0 amplitude at $F_{mel,c}$ (m-1)
    2. has maximum amplitude 1 at $F_{mel,c}$ (m)
    3. decays to zero at $F_{mel,c}$ (m+1)

You can follow the equation below.

$$H_m(k) = \begin{cases} 0 & k < f(m-1) \\ \dfrac{k - f(m-1)}{f(m) - f(m-1)} & f(m-1) \leq k < f(m) \\ 1 & k = f(m) \\ \dfrac{f(m+1) - k}{f(m+1) - f(m)} & f(m) < k \leq f(m+1) \\ 0 & k > f(m+1) \end{cases}$$

- to have a flat spectrum in mel domain for a DFT magnitude spectrum, the mel bands need to be scaled

Plot it and compare with *librosa* implementation. Report your observations.

Useful material to read:

1. https://haythamfayek.com/2016/04/21/speech-processing-for-machine-learning.html
2. http://practicalcryptography.com/miscellaneous/machine-learning/guide-mel-frequency-cepstral-coefficients-mfccs/