**MUS424:**
**Signal Processing Techniques for Digital Audio Effects** Handout #12
Jonathan Abel, David Berners May 2, 2019

Homework #5a: Minimum and Linear Phase, Critical Band Smoothing, and Warped Prony [30 points]
Due Date: May 14, 2019

# Minimum Phase, Linear Phase, Critical Band Smoothing, Warped Filter design

## Submission Instructions

Submit via Canvas. Create **a single compressed file** (`.zip`, `.tar` or `.tar.gz`) containing all your submitted files. Upload the compressed file to the homework submission dropbox. Name the file using the following convention:

`<suid>_hw<number>.zip`

where `<suid>` is your Stanford username and `<number>` is the homework number. For example, for Homework #1 my own submission would be named `cavdir_hw1.zip`.

For coding problems (either C++ or Matlab code), submit all the files necessary to compile/run your code, including instructions on how to do it. In case of theory problems, submit the solutions in **PDF format only**. LaTeX or other equation editors are preferred, but scans are also accepted. In case of scanned handwriting, make sure the scan is legible. Illegible homework will not be graded.

The files `Jen57Off.wav` and `Jen57On.wav` contains impulse responses of a Jensen guitar cabinet `ir`, measured with a Shure SM57 microphone placed off-xis and on-axis. The impulse responses are sampled at 44.1 kHz, `fs`. The files directory also contains a roughly 5-second-long distorted guitar snippet also sampled at 44.1 kHz. You will use these throughout this homework assignment.

### Problem 1. [7 Points]

**1(a).** [**4 Points**] Write a Matlab function that takes as input a transfer function magnitude $|H(\omega)|$ and returns the impulse response of the associated linear-phase filter. Turn in your Matlab code.

**1(b).** [**2 Points**] Use the script to convert one of the provided impulse responses to linear phase. Plot the original and linear-phase impulse responses. Plot the transfer function dB magnitude of the original and linear-phase impulse responses. Are the transfer function magnitudes the same? Turn in the plots.

**1(c). [1 Point]** Use the Matlab function `fftfilt(h,signal)` to convolve the measured impulse response with the distorted guitar, and the linear-phase impulse with the distorted guitar. Listen to the distorted guitar track, and the two processed versions, and describe the differences among them.

**Problem 2. [7 Points]**

**2(a). [4 Points]** Write a Matlab function that takes as input a transfer function magnitude $|H(\omega)|$ and returns the associated minimum phase filter impulse response. Turn in your code.

**2(b). [2 Points]** Use the script to convert the measured impulse response to minimum phase. Plot the original and minimum-phase impulse responses, and describe any differences. Plot the transfer function dB magnitude of the original and minimum phase impulse responses. Are they the same? Note what length of DFT you used. Turn in the plots.

**2(c). [1 Point]** Convolve the minimum-phase impulse response with the distorted guitar. Listen to the minimum-phase filtered distorted guitar track, and describe any differences with the linear-phase distorted guitar track.

**Problem 3. [8 Points]**

**3(a). [4 Points]** Write a Matlab function that performs critical-band smoothing on an input transfer function according to a smoothing bandwidth $\beta$ measured in critical bands and returns the smoothed transfer function, e.g., `tfs = cbsmooth(tf,beta)`. Turn in your function.

The Matlab functions `khz2erb`, and `erb2khz` (in the files directory) can be used to convert between frequency and critical band number.

**Note**: Take care to cope with frequencies that are negative or beyond $f_s/2$.

**3(b). [2 Points]** Use your script to smooth the measured impulse response transfer function. Plot the smoothed transfer function magnitude for smoothing bandwidths of 0.5, 1.0, 2.0, and 5.0 critical bands. Turn in the plots on the same axis, offset vertically.

**3(c). [2 Points]** Convert various smoothed transfer functions to impulse responses by applying the minimum-phase converter developed above, and apply the impulse responses to the distorted guitar snippet. What is the largest bandwidth in critical bands at which the nominal response and the smooth response sound the same?