MUS424:
Signal Processing Techniques for Digital Audio Effects `Handout #15`
Jonathan Abel, David Berners `May 17, 2019`

Homework #6a: Impulse Response Measurement and Analysis [25 points]
Due Date: May 28, 2019

Impulse Response Measurement and Analysis

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.

In this problem set you will analyze the space and recordings made at Memorial Church in 2017 to characterize its reverberation.

The files provided contain the response of the church to different balloon pops and noise bursts, recorded using the AKG-414 microphones in an omni configuration, placed in two locations of the church.

The recordings are not post-processed. Each channel of the stereo file contains one of the microphone recordings. For most problems in this lab, you will likely only want to use one microphone channel. For some of the recordings, we provide two recordings. You are free to choose either as we have not evaluated which one provides a better result.

Problem 1. [9 points]

1(a). [5 points] Referring to the table of Sabine coefficients in §9 of the course notes and the air absorption decay rates a few pages later, estimate $T_{60}(\omega)$ for Memorial Church at 250 Hz, 1000 Hz and 4.0 kHz. Approximate the church as a totally enclosed shoebox, 25m wide, 40m long, 10m high. Use plywood for the ceiling and half the floor, use glass for about a tenth of the walls and plywood for another tenth, and assume marble for everything else.

1(b). [**2 points**] What if the church were half its size?

1(c). [**2 points**] What if the church floor were carpeted?

Problem 2. [**10 Points**]

2(a). [**2 Points**] Write a matlab function `[sweep] = chrpLin(duration, fs)` that ramps from 0 to $fs/2$ with a constant (linear) frequency trajectory in `duration` seconds.

2(b). [**3 Points**] Write a matlab function `[sweep] = chrpLog(f0, f1, duration, fs)` that ramps from f_0 to f_1 with a frequency trajectory that increases so it spends equal time on each octave. The total time of the sweep should be `duration` seconds.

2(c). [**3 Points**] Write a matlab function `[ir] = chrp2ir(ss, rs)` that takes a sine sweep and the response to that sweep and performs the deconvolution necessary to convert a sine sweep into an impulse response.

2(d). [**2 Points**] Write a matlab function `[env] = envergyEnvelope(sig, fs, eta)` that takes an input signal, sample rate, and smoothing time (in ms) and returns an running-RMS smoothed amplitude envelope of the signal.

Problem 3. [**6 Points**]

3(a). [**4 Points**] The Matlab function (`.p` file) `RESPONSE = hmeasure(SIGNAL)` returns the noisy response of an unknown system $h(t)$ to an input signal, clipped to have a maximum absolute level of 1.0,

$$r(t) = s(t) * h(t) + n(t). \tag{1}$$

Submit a Matlab script to measure the system $h(t)$ using linear sine sweeps of length 1/16, 1/4, $\cdots$, 32 seconds long. Turn in plots of your impulse response estimates.

3(b). [**2 Points**] Using the fact that the impulse response $h(t)$ begins with a series of zeros, estimate the signal-to-noise ratio for the sine sweep lengths above (i.e., the dB ratio of the absolute peak level to the RMS noise floor level). Compare your results to the SNR of the system measured with a unit pulse. Turn in a plot showing the SNR as a function of sine sweep length. (Note: you may need to zero pad your signals appropriately to in order to acquire a good estimate of the noise level.)

Problem 4. [**4 Points**]

4(a). [**2 Points**] In the provided files, you will find an exponential sine sweep and its response recorded in memorial church. Convert it into an impulse response. Plot the spectrogram of the computed impulse response. You may use the provided `ftgram` function. In addition to taking the signal and sample rate as arguments, it also takes a third parameter which should be either `'rir'` (which returns a log time scale) or `'music'` (which gives a linear time scale). If you type `help ftgram` you will find other parameters (like the resolution of the FFT, hop size, and waveform display) that might also be worth modifying.

4(b). [**2 Point**] Convolve a balloon pop recorded in Memorial Church and the sine sweep-converted impulse responses with a guitar track or the provided recording of Tom's Diner. Listen and comment on the differences you hear between the BP and SS processed audio track, and between the processed and unprocessed tracks.