Homework 1 (EAS 4803/8803: OBSERVATIONAL SEISMOLOGY - SPRING SEMESTER 2019)
Graduate Only. Total points: 100. Due 02/05/2019

Computer problem I (20 point):
Take any two time series with the same length.
1. Write a subroutine in Matlab (or any other languages) to perform convolution in the time domain.
2. Compute FFT and perform multiplication in the frequency domain.
3. Take inverse FFT back to the time domain. Compare the resulting time series with that from step 1. Comment on what you have found out.

Computer problem II (50 point):
Write a subroutine to prepare the following time series (next page), then take the fast Fourier transform (FFT) and generate the spectrogram. The subroutine should call a set of separate subroutines that perform the following operation:
1. Preprocessing (5 point)
   a. Cut the data between 300 and 1800 s;
   b. Remove the mean;
   c. Apply a cosine taper with 5% of the total length to both ends;
   d. Extend the length of time series to the nearest power of 2;

2. FFT and inverse FFT (10 point)
   e. Take the FFT the fft command in Matlab or other existing subroutines;
   f. Plot the amplitude and phase spectrum.
   g. Invert the FFT back to the time domain and plot it together with the original data.

3. Design your own filter and filter the data (15 point)
   h. Write a subroutine to filter it in the frequency domain over the following two passband (low-pass-filtered at 30 s; band-pass-filtered at 2-16 Hz), and invert the FFT to yield two filtered time series. The subroutine should have the capability to taper in the frequency domain. Plot the original and filtered time series.

4. Compute the spectrogram (20 point)
   i. Write a subroutine to compute the FFT with a window length of 256 data points, and slide the window through the entire time series with an overlapping ratio of 50% (i.e., the time window moves forward with a step of 128 data points). Generate a plot with frequency on the y-axis, time on the x-axis, and the amplitude spectra as color to show the spectrogram of your time series. You may want to change the spectra range into log10 scale in order to show the spectrogram in a wide dynamic range. (Note: you CANNOT directly use the spectrogram or specgram command in Matlab to perform this task).
   j. Please compare with the 2-16 Hz band-pass-filtered data (from step h) and comment on what you have found out.
   k. Please use any of the suggested procedures outlined in Peng et al. (SRL, 2011) paper to clean up the potential artifact.

Note:

1. Your code can be written in any scientific languages (e.g., Fortran, C, Matlab). Please make sure that the code can be compiled under standard Linux machine. Please submit your code electronically to zpeng@gatech.edu, and submit a write-up that includes all the figures.
2. You can use the existing FFT subroutine in the Stein's book or in other languages (e.g., Fortran, C, Matlab). But you should write your own filter subroutine, instead of using any existing subroutine.
3. The SAC binary format data can be downloaded from the following link: http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/BK.PKD.HHT.SAC.vel This data is generated by the 2002 Mw7.9 Denali Fault earthquake in Alaska, and recorded by the broadband station PKD around the Parkfield section of the San Andreas Fault in Central California.
4. The ASCII format data can be downloaded from the following link: http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/BK_PKD_HHT_SAC_vel.dat

   Please note that the 'instrument response' of this data has been removed, and the physical unit for the amplitude is in cm/s. The physical unit for the time is in seconds. The data started at 0 s, and with a sampling rate of 0.125 s (or 80 samples per second).
5. The MatSAC package can be downloaded from the following link: http://geophysics.eas.gatech.edu/people/zpeng/Teaching/MatSAC.tar.gz and the related examples on how to use it can be found at http://geophysics.eas.gatech.edu/people/zpeng/Teaching/SAC_Tutorial/
6. The Peng et al. (SRL, 2011) can be downloaded at http://geophysics.eas.gatech.edu/people/zpeng/zpeng_paper/Peng_etal_SRL_2011.pdf

Computer problem III (30 point):

Harmonic tremor is a continuous seismic signal accompanying volcanic eruptions with narrow, evenly spaced peaks in the frequency domain. The physical mechanism of generating harmonic tremor is still in debate. One model often invokes resonance of fluid-filled cracks, gas-filled bubbles, or vibrations of volcanic conduits. Another model utilize the so-called Dirac comb effect (https://en.wikipedia.org/wiki/Dirac_comb), where the Fourier transform of an evenly spaced signals in the time domain would produce an evenly spaced peaks in the frequency domain. See Hotovec et al. (JVGR, 2012) for additional reviews and details of this topic.

The following assignment allows you to generate synthetic tremor signals by repeating an earthquake signal many times. It also includes a subroutine to allow you to speed up the seismic data and produce audible sounds.

1. Take the seismic data of an ordinary earthquake occurred in Turkey (see below for the link). Generate a tremor signal with a total length of 200 s by repeating this earthquake signal by every 5, 1, 0.5, 0.1 and 0.05 s. (10 point)
2. Please use your updated code to compute the corresponding spectrogram for each tremor signal. Please plot it together with the time series. (10 point)
3. Please use the following subroutine to speed up the seismic data by 200 times so that it can be heard by human's ear (5 point).
4. Please comment on what you have observed, and whether the Dirac comb effect can be used to explain the gliding tremor observation (5 point).

Note:

1. The ordinary earthquake data can be downloaded from the following website
   http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/YJ.BV.EHN.SAC

2. The Hotovec et al. (JVGR, 2012) can be downloaded from the following website:

   https://earthweb.ess.washington.edu/ahotovec/pdf/Hotovec2012JVGR.pdf

3. The event 13 data can be downloaded from the following website

   http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/ev13.sac

4. The following matlab code would allow you to convert the seismic data into SAC format into an audible .wav file.
   http://geophysics.eas.gatech.edu/classes/ObsSeis/misc/misc/sac2wav.m
   usage: sac2wav(sacfile,speed_factor,scale);
   example: sac2wav('tremor.sac',200,1);
   output: tremor.sac.wav