Basics of Signal processing

General instructions

- You choose to use MATLAB or Python
- Do not use any GUI-based or higher level toolboxes

The tutorial is largely programming based and is meant to introduce you to the various concepts of signal processing and enable you to get an intuitive grasp of the methods available and the outputs they generate. Pay attention to all the questions and try to answer them.

Exercise

Plotting

1. Use the sine wave, chirp (linear, quadratic, logarithmic, concave)
    a. How does the signal look? What is on the y-axis and x-axis?
    b. Discuss Resolution of the signal, range, sampling frequency
    c. Listen to them - can you hear them? Why?

Frequency spectrum

2. Plot the spectra - Discuss their frequency content and relate to the auditory range of human hearing
3. Use the Hanning, rectangular and Hamming tapers to compute spectra
    a. Compare spectra between tapers
4. What is the sampling frequency in relation to Nyquist sampling theorem?
5. What is the wrap-around of frequency in respect of Nyquist Shannon theorem? Illustrate the phenomenon with example data.

Time-Frequency decomposition

6. Compute TFR using STFT, multitaper and wavelet decomposition
    a. What time point elicits maximal frequency and is it comparable across methods?
    b. Change the window sizes – has the frequency resolution changed?
    c. How can you find out frequency resolution from the outputs?
    d. Can you justify the change in frequency resolution?
    e. Keeping window sizes fixed, can you double the frequency resolution? How?
    f. Plot and show the results. Explain them.

Filter design

7. Design a low-, high-, bandpass and band-reject butter worth filter
    a. Use the "fdatool" in MATLAB or pyFDA in Python
    b. Filter settings
        i. LPF – 100 Hz
        ii. HPF – 0.1 Hz, 1 Hz
        iii. BPF – 0.1-100 Hz, 1-100 Hz
        iv. BSP – 45-55 Hz
    c. Change the order of the filter – how does the roll-off rate change? What is the relation between roll-off rate and order of the filter?
    d. What do the passband/stopband ripple, stopband attenuation look like?
    e. Sampling frequency – 1000 Hz
    f. Change the order of the filter – how does the roll-off rate change?
    g. What do the passband/stopband ripple, stopband attenuation look like?

   h. Look at the phase response for each of the filters. What does it indicate? Is it linear? Why is it important that it is linear? What would happen if the phase response of the filter is non-linear in the passband?
8. Phase responses
   a. Compute the response of (i) forward, (ii) reverse and (iii) forward-reverse filter for a simple Gaussian signal train. Match it with the input signal and see how response changes with mode of filtering.
   b. How can you perform a zero-phase filtering in this scenario?

Bivariate spectral decomposition

9. Coherence
   a. Generate a bivariate time series of two known common frequency contents
   b. Calculate the mean-squared coherence and plot
   c. How does it look? Have you got back the overlapping spectra?