Brain Signal Processing and Applications (Fall 2023, BME/ELE 473/573)

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3rd homework, 10/13/23 (The homework, is due by Oct 26th, 11:55 pm).

Instructions: All the data details are the same as homework 1.

a) Create a family of complex Morlet wavelets, ranging in frequencies from 2 Hz to 30 Hz in five steps (for more details, carefully read lecture 3 and Mike Cohen's book, Chapter 12). Consider the number of cycles to use as a fixed number of 4 cycles.

b) Convolve each wavelet with EEG data from all electrodes and from only the first trial

   Hint:
   - The wavelet needs to be symmetric; start from -1 sec to 1 sec; NOTE: sampling rate needs to be the same as the EEG data.
   - Instead of convolution in time domain, you can get the fft of both the EEG signal and the wavelet and multiply them in the frequency domain; NOTE: the size of the fft of both EEG signal and the wavelet will be the same as the size of the convolved data in the time domain i.e., length (convolved data) = length (signal) + length (wavelet) - 1.
   - Get ifft to return back to the time domain.
   - Cut the convolved data in order to make the convolved data the same length as the original data. To do this, cut out the beginning and the end of the convolved data with the length of the cut segments equivalent to half of the wavelet length.

c) Extract power and phase from the result of the complex wavelet convolution and store in a time x frequency x electrodes x power/phase matrix (thus, a 640 x 5 x 64 x 2 matrix).

d) Make topographical plots of power and phase at 180 ms at all frequencies

   Hint:

   - You may need to use the "squeeze" Matlab function to remove singleton dimensions.
   - Arrange the plots in one figure with five columns for frequency and two rows for power/phase (using the "subplot" Matlab function).
   - Put labels in the plot so it is clear which topographical maps correspond to which frequencies.
   - Make sure that all power plots use the same colorbar axis limits. Repeat for the phase plots.

e) Repeat step (d) for activity at 360 ms, and 650 ms.

f) Are there any prominent topographical features in power or in phase? Do these differ for different frequencies? Do power and phase have similar topographical distributions? Is there any reason to suspect that they might have similar or different topographies?

g) **Mandatory for 500 levels and extra credit for 400 levels (20 points)**: Now consider that the frequency range of interest varies between 2Hz to 40Hz in 2Hz steps. Instead of the constant number of cycles equivalent to 4 used in part b), consider variable cycles ranging between [3 10] cycle. Based on your total number of frequencies, you can define constant steps for your cycles that start from 3 cycles and end at 10 cycles. 3 would correspond to the minimum frequency (i.e. 2 Hz) and 10 would correspond to the maximum frequency (i.e. 40 Hz). Considering only channel 'FCz', now follow the following steps:

- For each frequency, obtain the power for all the trials (i.e. 99).
- Get the average of the powers over all the trials.
- Apply baseline correction by dividing the obtained results by the average baseline power (i.e. [-500 -200 ms]). The resulting matrix size would be 20 x 640.
- Plot the time-frequency map where the x-axis is the time [-200 1000 ms], y-axis is the frequency [2 40 Hz], and color corresponds to 10log10 (power). (Hint: use the imagesc() Matlab function).
- Make the colormaps in 'jet' format and the color-limit to [-3 3].
- Repeat the same process with fixed cycle 4 for all the frequencies.
- Compare your results between two conditions of fixed and variable cycles and explain your observations.