Homework 4
Due April 20

Task 1 of 2: Filter design.

Brain rhythms are commonly known by Greek letters, which appear here in order of their frequency ranges: Delta (1 – 4 Hz), Theta (4 – 9 Hz), Alpha (8 – 12 Hz), Beta (12 – 20 Hz), and Gamma (>30 Hz). These rhythms usually appear in the same signal and must be extracted by filtering. Your goal is to create a discrete-time (digital) finite impulse response band pass filter that will keep the beta waves (appropriate for this year, right?) and attenuate the rest of the signal.

Modified 4/18/12 to recommend using h(t) rather than h(n), and to use actual sampling rate.

Task 1 produces filter coefficients $h(n)$ or a filter function $h(t)$ on paper rather than using MATLAB. It is probably easier to work in continuous time and frequency until you have a complete filter function, and then substitute $t = n \cdot t_S$. You may write the answer to task 1 as the product of three functions. In task 2 we will apply the filter to an EEG signal.

a) Use the time values in the PhysioBank data to determine the EEG sampling frequency. You will use this sampling frequency to make the substitution $t = n \cdot t_S$, either starting in (b) or after determining $h_{\text{SMOOTH-BPF}}(t)$.

b) Create a low pass filter that has the appropriate cutoff frequency. Describe the steps you are taking in the time and frequency domain. The result should be a time-domain function $h_{\text{LPF}}(t)$ or $h_{\text{LPF}}(n \cdot t_S)$ that contains the filter function.

c) Modify the filter coefficients so that the resulting filter coefficients $h_{\text{BPF}}(n \cdot t_S)$ or $h_{\text{BPF}}(t)$ to produce a FIR band pass filter. Describe how multiplication and convolution are related in this step of the design process.

d) Modify the filter coefficients from (c) in a way that will reduce the ripple in the pass and stop bands. The result will be $h_{\text{SMOOTH-BPF}}(t)$. Describe how multiplication and convolution are related in this step of the design process.

------------------------ See the following notes and task 2 on page 2 -------------------------

1. You will want to use the relationships between a pulse and its Fourier transform:

Time domain		Frequency domain
Rectangular pulse of height 1 over $-T/2 < t < T/2$.	$\Longleftrightarrow$	$2T\dfrac{\sin(\omega T/2)}{\omega T}$
$\dfrac{\sin(a t)}{\pi t}$	$\Longleftrightarrow$	Rectangular pulse of height 1 over $-a < \omega < a$.

2. The DFT and IDFT of a pulse is not exactly the same as the continuous Fourier transform and inverse transform, but it is close enough for today. You may make the appropriate substitutions to put t and ω in terms of n and m.

Task 2 of 2. Filter application

a) Go to the PhysioBank ATM, and select the EEG Motor Movement/Imagery Dataset.   You may select any one trace you like, but I recommend Cz. Select any patient, run, and 10-second interval. Select "Export signals as CSV" in the Toolbox panel. Observe the preview trace, and notice how small the signal amplitudes are. Click the tiny "`samples.csv`" link under the "**The output below was prepared using this command:**" heading. This should allow you to open or save the data in an Excel or .csv file. Import the data into MATLAB.

b) Create a MATLAB script or function (your choice) that creates the filter coefficients $h(n)$ from the mathematical functions you generated in task 1. Use this resulting sequence of coefficients to implement a FIR filter and extract the beta waves from the downloaded signal.

c) Plot the original time-domain EEG and the filtered EEG as subplots in a MATLAB figure.

d) Plot the magnitude spectra of the original time-domain EEG and the filtered EEG as subplots in a MATLAB figure. Use a range of frequency axis that illustrates the information you wish to convey; this might be all or part of the spectrum from 0 to f_s.

Submit your work and results from Task 1 on paper no later than the 2:30 review section on April 20.

Submit your plots and MATLAB code from Task 2 no later than 11 p.m. on April 20.