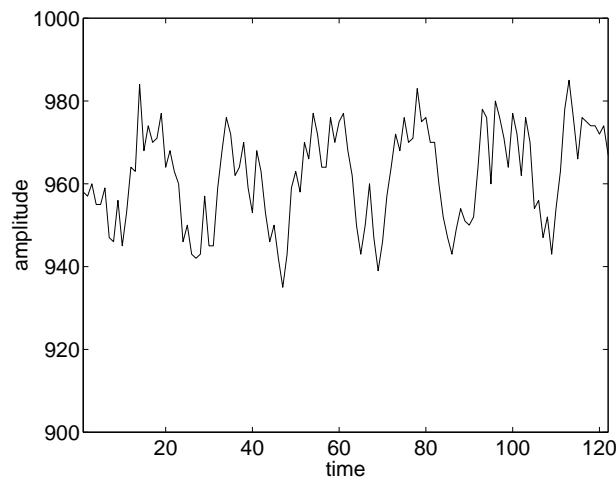


ELEC 431
Digital Signal Processing
Homework 5 — fMRI and the FFT

Due Friday, October 13, 2006

The signal depicted below comes from a functional magnetic resonance imaging (fMRI) brain mapping experiment (see <http://en.wikipedia.org/wiki/Fmri> for more information). The signal reflects the variation of the blood oxygenation level in a certain region of the brain over time. This variation is correlated with neural processing. In this case, the subject being studied was performing repetitive finger tapping, and the oscillation in the fMRI signal (recorded from a region in the motor cortex) correlates with this repetitive exercise. A Matlab file containing signal, called `fmri_sig.mat`, is available at the course website.



Analyze the spectral content of the fMRI signal using the DFT (more specifically, use Matlab's FFT function to compute the DFT of the signal).

- a. Plot the magnitude of the DFT.
- b. Identify the dominant sinusoidal component.
- c. Assuming a sampling rate of 4 samples/sec, what is the frequency (in Hz) of the dominant sinusoidal component?
- d. Find a good DC offset plus sinusoidal fit to the data using the magnitude *and* phase of the DFT coefficients associated with the dominant component. Plot and compare your fit with the raw data.

Next, we will use the results above to map neural activity in the brain using fMRI. In fMRI, a series of MRI brain images are collected over time. Because oxygenated and deoxygenated hemoglobin have slightly different magnetic characteristics, variations in the MRI intensity indicate areas of the brain with increased blood flow and hence neural activity. The central problems in fMRI is reliably detecting neural activity at different spatial locations (pixels) in the brain. The data are noisy and the variation in intensity due to activation is very subtle. Consequently, statistical signal detection methods are routinely used to derive an “activation” map; a 2-d binary image of active and non-active brain regions.

The objective of this problem is to develop an FFT-based procedure for producing an “activation” map. To get you started, I have written a very crude program that inputs the images called `fmri.m`, which is available at the course website. The data file `fmri.mat`, which contains the fMRI images, is also available at the website. The basic idea is to compute the FFT of each pixel’s time-series, and then check/detect the presence of a peak at the frequency corresponding to the period of the activation signal. In this case, the person was periodically tapping their finger, as above, and a representative response from an activated pixel is given in `fmri_sig.mat`.

In developing your brain-mapping scheme, I would like you to address/consider the following issues.

- e. Determine an appropriate “threshold” for deciding whether or not a pixel is active. Discuss how and why you selected a particular threshold.
- f. Discuss other variations in the pixel signals (DC offset, slowly varying drifts, noise) and their impact on your mapping procedure.
- g. Produce a map of activated pixels by superimposing (in color) the activated pixel locations on an image of the brain.