Homework 10
Functional Magnetic Resonance Imaging

Due Thursday Oct 17 at class

This homework will count for three regular homework assignments.

In this "extra-big" homework problem you will apply many of the signal detection concepts we have looked at in this course to an exciting new brain mapping tool called functional Magnetic Resonance Imaging (fMRI). In fMRI, a series of MRI brain images are collected over time. Because oxgenated 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 homework problem is to develop your own testing/detection procedure for producing an "activation" map. To get you started, I have written a very crude program that forms a rough activation map using a simple correlation test with an ad hoc threshold `fmri0.m`, which is available at the website. The data files `fmri.mat` and `ref.mat` are also available at the website. In developing your detection scheme, I would like you to address/consider the some of following issues. Summarize your investigation in a short report, including derivations, theory, analysis, and plots of results.

1. Study the "noise" in fMRI

Is the noise white (uncorrelated)?

Is the noise Gaussian?

Is there a slowly-varying drift in the baseline?

2. Study the fMRI "response"

Is the response signal at different spatial locations similar to the reference signal?

Are some pixels *negatively* correlated with the reference signal?

Is there a possible delay in the timing of the response at different spatial locations?

3. Based on your analysis, derive a new testing procedure for fMRI using the GLRT.

- The GLRT should be invariant to uncertainties in response signal, noise, and baseline drift characteristics.
- Investigate the performance of your GLRT. Determine the distribution of the test statistic (if possible), summarize performance with ROC curves, P_D vs. SNR curves, etc.
- Discuss advantages and disadvantages of your method, and suggest avenues for future work in fMRI.