Homework 1

Background:

- Make sure you that you have the Preliminaries in Linear Algebra for this class (see materials)
- Make sure you have some knowledge of terms in Basic Neuroscience (see materials)
- Listen to the 5 Video lectures "Origins of BOLD signal"
    - Why can we use the BOLD signal to infer something about neural activity?
    - What neural processes does the the BOLD signal likely reflect in humans?
    - What do decreases in BOLD signal mean?
- Listen to lectures
    - "Convolution and Hemodynamic response function (hrf)"
    - "Transfer function and temporal resolution"
    - "Simple regression"
    - "Multiple regression"
    - "Multivariate Gaussian Distribution"
    - "Ordinary Least Square Estimation" (part 1-3)

Data homework:

In this homework we will have the first look at the analysis of fMRI time series data. The data set comes from an experiment in which a subject moved one finger at a time for 8.1s. Each of the 10 fingers was repeated 3 times per run, and 8 runs (each containing 123 images) were collected. Each image took 2.7s to acquire. The details of the methods can be found in (Diedrichsen et al., 2013, Ejaz et al., 2015). The file dataset_1.mat contains the following variables:

ANA	96x96	One axial slice through a functional image - mean signal
Y	96x96x984	Time time-series data (984 measurement points) for the slice.
run	984x 1	Indicates which time point belong to which run
Xtask	123x10x8	The task-based regressors for Left and Right fingers. column 1-5 are for D1-D5 of the left hand column 6-10 are for D1-D5 of the right hand. Each trial is already convolved with the hrf.
Xintercept	123x1x8	Intercepts for the runs
Xhpf	123x5x8	High-pass filter regressors for each run (not needed for this hw)

Note that all images (matrices of 96x96) are saved in radiological or RP convention. That means that the first index (rows) runs from Right to Left, and the second index (column) from Posterior to anterior. If you are confused, listen to Video lecture on Voxels and Affine transformation matrices.

1. First visualize (for example using imagesc in matlab) the mean T2* image (ANA). Get oriented. Where is the front and the back of the brain? Can you make out the grey matter vs. white matter?
2. Plot some of the time series. Indexing becomes slightly easier if you reshape first the 96 x 96 x 984 array into a 984 x 9216 (time points x voxels) matrix. For my model answer I used voxel 1869, 1958, & 2056. Note that the data was acquired in runs of 123 images - and between runs there was a short break. What do you notice about the time series? How should these features influence the modeling of the data?
3. *For each run separately*, set up a design matrix, consisting of the task related regressors and the intercept. Visualize these design matrices.

4. Apply Ordinary-least-squares (OLS) estimation to get a regression coefficient for each Voxel and for each run separately. Also calculate the residuals from the regression.
5. Visualize the mean regression coefficient for movements of fingers of the left and right hand (averaged over the 5 fingers and over the 8 runs). Can you see which areas are activated / deactivated for each of the hands?
6. Plot the residuals for the same voxels plotted under 2. What do you notice? How could we improve our linear model?

General Instructions

- Submit your homework as a single pdf file.
- Number the questions clearly
- For each question include the code that you are using, figures or numerical results, and provide a written answer. Do not submit figures without describing what the figure shows.
- Submit the homework on OWL before the deadline date

Bibliography

Diedrichsen J, Wiestler T, Krakauer JW (2013) Two distinct ipsilateral cortical representations for individuated finger movements. Cereb Cortex 23:1362-1377.
Ejaz N, Hamada M, Diedrichsen J (2015) Hand use predicts the structure of representations in sensorimotor cortex. Nat Neurosci 18:1034-1040.