Analysis Methods in Functional Magnetic Resonance Imaging
ECE595 008 (CRN 33271)
Spring Semester, 2010

Location: ECE 237
Time: Tuesdays, 3:00-5:30pm

Instructor: Vince D Calhoun vcalhoun@unm.edu
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Office: ECE 224B
Office Hours: TBA and by appointment

Text (required):
Computing Brain Activity Maps from FMRI Time-Series Images (ISBN 0521868262)
Gordon Sarty

Texts (optional):
Functional MRI: An Introduction to Methods (ISBN 019852773X)
Peter Jezzard; Paul M. Matthews; Stephen M. Smith
Functional Magnetic Resonance Imaging (ISBN 0878932887)
Scott A. Huettel, Allen W. Song, Gregory McCarthy
Nicole A. Lazar

Additional Reading:
  o Zhi-Pei Liang and Paul C. Lauterbur
- Doug Noll, "Primer on fMRI"
- In "Functional MRI" by C.T.W. Moonen and P.A. Bandettini, Chapter 27, "Statistical Procedures for fMRI" by Nick Lange

Course Description/Syllabus:
This course will be an introduction to signal and image processing methods for functional magnetic resonance imaging (fMRI) of the brain. FMRI is a widely-used brain imaging technique which produces a series of images which are sensitive to localized changes in blood oxygenation which occur in the brain while performing a task. This course will introduce the advanced undergraduate or graduate student to the analysis of the time series data produced by functional magnetic resonance imaging of the brain. Univariate and multivariate techniques will be covered. Two Matlab software packages will be used in the projects in order to demonstrate the concepts. During one of the courses, an actual fMRI scan will be performed and these data will be analyzed for the project.

Examinations and Assignments
Graduates (ECE595): Grading will be based on a take home quiz (20%) a term paper (30%) and a project (40%). The remaining 10% will be for attendance and class participation.

Quizzes: The quiz will be take-home and will be assigned on a Tuesday and due the following Thursday.
Term Paper: The term paper is an assignment to read literature on a selected fMRI method and to either critically review the method or to explore a small modification of the method under guidance. This assignment will be a 2000 word critique of an fMRI paper (paper is to be selected by the student and approved by the instructor) which will constitute 20% of the final.
You should avoid being overly critical of the small issues and rather to focus upon the big issues. Are their conclusions supported by the results? Were the algorithm comparisons fair? Are there some things they didn’t consider that might be important? These kinds of questions are more important than pointing out that they made a minor notational error (for example).

Your assignment should have the following components:
1. A brief (one paragraph) outline of the approach and the basic results and conclusions drawn.
2. A more detailed critique of the analysis (3 to 4 paragraphs) focusing on major issues as discussed above.
3. A brief (1-2 paragraphs) outline of an alternate approach to address the same question - how would your approach address your criticisms of their approach.

**Project:** Analysis of an existing fMRI data set. (5000 words – 40%). You will be provided with unprocessed fMRI data as well as pre-processed fMRI data. You should select one aspect of the processing to address (e.g. motion correction, smoothing, activity detection, estimation of hemodynamic response, functional connectivity analysis). The goal is to implement your own processing approach and apply to the data. You can compare your results to those computed using an available Matlab package, SPM5 (http://www.fil.ion.ucl.ac.uk/spm/), which we will learn during the course. This is your opportunity to be creative and also to do something which is of interest to you.

The project write-up should consist of 1) a brief introduction to the issue being addressed, 2) a formulation of the approach that will be applied, 3) a simple simulation illustrating the approach works [this should also include some quantitative comparison with the ground truth], 4) results from the method applied to fMRI data, 5) a discussion of the results (did they work? If so, what are the strengths of this approach? If not, why not?) and concluding paragraph. The code used to process the data should be included in an appendix. Students will be required to give a 15-20 minute presentation in class about the project.

**Participation:** Class participation and attendance will constitute the remaining 10% of your grade.

**Course Web Page:** Course material can be accessed at: http://www.unm.edu/~vcalhoun. Readings and course lectures will be provided at this site.

**Syllabus (Jan 20-May 5):**

1) Jan 19: Course Intro: Overview of MRI Physics & Basics of BOLD fMRI (Noll, pg 1-14)
2) Jan 26: Basic brain anatomy (Anatomy Primer, Sarty Chapter 1), basic mathematics and software tools.
3) Feb 2: Data Collection at the Mind Research Network
4) Feb 9: Preprocessing I & II: artifacts, motion correction (Sarty: 2.1-2.3)
5) Feb 16 Preprocessing III-IV: Anatomic transformation to standard brain spaces, removal of physiologic artifacts (Sarty: 2.5, 2.4, 2.6)
6) Feb 23: Paradigm design (blocked and event-related) (Sarty: Chapter 3), GLM-univariate approaches (Sarty: 4.1)
7) Mar 2: (quiz handed out [due Friday, March 5th], approval of critique paper) Random effects/multiple comparisons (Sarty 4.3)
8) Mar 9: (quiz due) Discussion of project details. Modeling the physiology of the hemodynamic response (Sarty 4.2), Bayesian & nonparametric methods (Sarty 4.4-4.5)
9) Mar 16: NO CLASS (Spring Recess)
10) Mar 23: Fourier methods/Repeatability and comparison of methods (Sarty 4.6-4.7)
11) Mar 30: Real-time fMRI (Sarty 4.8)
12) Apr 6 (term paper due): The GLM-multivariate approaches/PLS (Sarty 5.1), Principle and independent component analysis (Sarty 5.2)
13) Apr 13: Wavelet methods (Sarty 5.3), Clustering methods (Sarty 5.4)
14) Apr 20: Functional connectivity (correlation) (Sarty 5.5), Effective connectivity (SEM/DCM) (Sarty 5.6)
15) Apr 27: Integration with other modalities: EEG, DTI, genetics
16) May 4: (projects due): Student Presentations