

Analysis Methods in Functional Magnetic Resonance Imaging

ECE595/CS591/PSYCH650

Spring Semester, 2007

Location: ECE 310

Time: Tuesdays and Thursdays, 12:30-1:45pm

Instructor: Vince D Calhoun vcalhoun@unm.edu

Phone: 272-1817

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

Additional Reading:

- *Principles of Magnetic Resonance Imaging: A Signal Processing Perspective* (ISBN 0780347234)
 - Zhi-Pei Liang and Paul C. Lauterbur
- Joseph Hornak, "The Basics of MRI", <http://www.cis.rit.edu/htbooks/mri>
- Doug Noll, "Primer on fMRI"
- Bandettini, PA; Jesmanowicz, A; Wong, EC; Hyde, JS. Processing strategies for time-course data sets in functional MRI of the human brain. *Magnetic Resonance in Medicine*, 1993 Aug, 30(2):161-73
- McKeown MJ, Jung TP, Makeig S, Brown G, Kindermann SS, Lee TW, Sejnowski TJ. Related Articles, Spatially independent activity patterns in functional MRI data during the stroop color-naming task. *Proc Natl Acad Sci U S A*. 1998 Feb 3;95(3):803-10.
- In "Functional MRI" by C.T.W. Moonen and P.A. Bandettini, Chapter 27, "Statistical Procedures for fMRI" by Nick Lange
- Belliveau JW, Kennedy DN, McKinstry RC, Ruchbinder RR, Weisskoff RM, Cohen MS, Vevea JM, Brady TJ, Rosen BR. Functional mapping of the human visual cortex by magnetic resonance imaging. *Science* 254:716-719, 1991.
- Svensen M, Kruggel F, von Cramon DY. Related Articles, Probabilistic modeling of single-trial fMRI data. *IEEE Trans Med Imaging*. 2000 Jan;19(1):25-35.

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 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 (a standard paper will be allocated for this purpose) which will constitute 20% of the final. A standard paper has been set for all students to critique - so obviously, discussions with your classmates may help you clarify ideas. But it will be important that you don't make carbon copies of those ideas in addressing the set paper - clarity of expression (your own expression) will be considered for this assignment. The paper to critique is the following:

Plurality and Resemblance in fMRI Data Analysis **NeuroImage**, Volume 10, Issue 3, September 1999, Pages 282-303 Nicholas Lange, Stephen C. Strother, Jon R. Anderson, Finn Å. Nielsen, Andrew P. Holmes, Thomas Kolenda, Robert Savoy and Lars Kai Hansen

I encourage you to 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 15-May 12):

- 1) Jan 16: Course Intro: Overview of MRI Physics (Noll, pg 1-7)
- 2) Jan 18: Introduction to fMRI (Noll, pg 8-14)
- 3) Jan 23: Basic brain anatomy (Anatomy Primer)
- 4) Jan 25: Preliminaries (Sarty Chapter 1)
- 5) Jan 30: Preprocessing I (Sarty: 2.1-2.3)
- 6) Feb 6: Preprocessing II: Anatomic transformation to standard brain spaces
- 7) Feb 8: Preprocessing II
- 8) Feb 13 Paradigm design (blocked and event-related)

- 9) Feb 15: The GLM-univariate approaches
- 10) Feb 20: Modeling the physiology of the hemodynamic response
- 11) Feb 22: NO CLASS
- 12) Feb 27: (quiz handed out) Other parametric methods
- 13) Mar 1: (quiz due) Data Collection at the MIND Institute
- 14) Mar 6: Discussion of project details
- 15) Mar 8: Bayesian methods
- 16) Mar 13: NO CLASS (Spring Recess)
- 17) Mar 15: NO CLASS (Spring Recess)
- 18) Mar 20: Nonparametric methods
- 19) Mar 22: Fourier methods
- 20) Mar 27: Repeatability and comparison of methods
- 21) Mar 29: Real time and comparison of methods
- 22) Apr 3 (term paper due): The GLM-multivariate approaches
- 23) Apr 5: Principal and independent component analysis
- 24) Apr 10: Wavelet methods
- 25) Apr 12: Clustering methods
- 26) Apr 17: Functional connectivity (correlation)
- 27) Apr 19: Effective connectivity (SEM/DCM)
- 28) Apr 24: Integration with other modalities: EEG
- 29) Apr 26: Integration with other modalities: DTI, genetics
- 30) May 1: (projects due): Student Presentations
- 31) May 3: Student Presentations
- 32) May 8: Student Presentations
- 33) May 10 Student Presentations