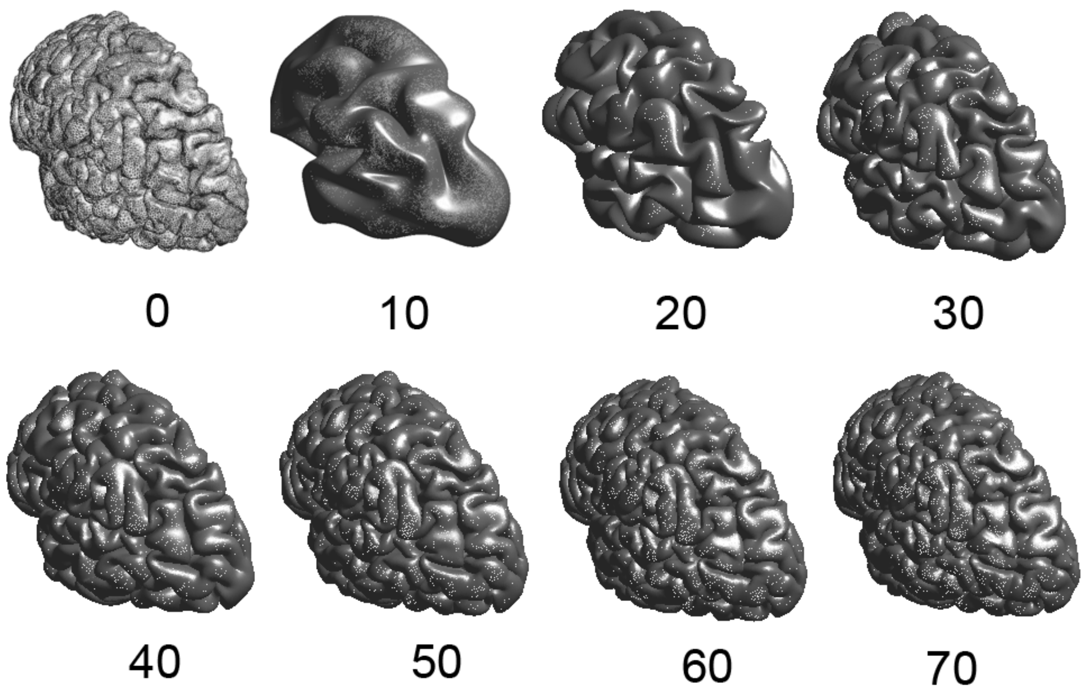
Title: Computational Methods in Neuroimage Analysis (2010 fall semester)



Multiscale modeling of cortical folding pattern using spherical harmonic representation. Does this type of cortical folding pattern differ between normal controls and clinical populations? We will study the underlying computational methods to answer this type of complicated hypotheses. The cortical surface is obtained using widely used Free Surfer package but if you want to build advanced models beyond what Free Surfer can possibly offer, you need to take this course.

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Audience: Basics on various computational techniques will be covered. The target audience is master's level graduate students. Competent senior undergraduate students can take the course as well without much difficulty. No knowledge in any sort of image analysis and computation is required and all course materials will be self-contained.

Syllabus: Various computational and numerical issues in neuroimage processing and analysis will be addressed. The focus of the course is on the algorithmic aspect of various computation intensive procedures. MATLAB will be used as a language of instruction although students can do homework and project in any computer languages of their choice. The following topics will be covered: numerical techniques for (ordinary and partial) differential equations, FEM, spectral methods (Fourier analysis, PCA, sparse-PCA, functional-PCA), optimization (least squares, multivariate general linear model (MGLM), L1-norm minimization, maximum likelihood), discrimination and classification (linear, quadratic and logistic discrimination and SVM). Geometric and topological computation (curvatures, Euler characteristics, other topological invariants).

Various applications will be covered in connection with these topics. For instance, compressed sensing will be covered as an application of L1 norm minimization problem. Brain connectivity networks will be investigated in terms of topological invariants. The multivariate version of general linear model (MGLM) will be studied as an application of the least squares method. MGLM let you to set up a statistical model that the usual F-statistic based method cannot handle. Some topics overlap with the topics covered in the previous course (Neuroimage Processing) I taught in 2009.

Textbook: Computational Neuroanatomy: The Methods. This is a preprint of book I am currently writing and it will be freely available to students.

Teaching Plan: One 3-hour lecture will be given per week. Few speakers form other universities will give guest lectures to provide additional motivation for the course. The weekly teaching plan is as follows.

Week 1: Introduction to MATLAB

Week 2-3: Least squares method, multivariate general linear model (MGLM). Maximum-likelihood methods.

Week 4-5: Ordinary and partial differential equations for image modeling and smoothing, FEM.

Week 6-7: Geometric and topological computation on cortical and subcortical structures.

Week 8-9: Spectral methods. PCA, sparse-PCA, Compressed sensing.

Week 10-11: Topological and geometric methods in brain network modeling.

Week 12-13: Discrimination and classification.

Week 14: Student presentation.

Evaluation: The evaluation is based on the successful completion of a course project based on techniques covered in class. Students are required to submit an initial report containing preliminary image analysis in the middle of semester (30%), give 20-minute oral presentation (20%) and submit the final report (50%). To avoid any possible bias in evaluation, all students are required do a project using the data set provided in the class. Last year 9 students took a similar course and the grade distribution is as follows: 1 A, 4 A-, 4 B+, 1 B.