

Function-Structure Integration in FreeSurfer



MASSACHUSETTS
GENERAL HOSPITAL

surfer.nmr.mgh.harvard.edu/docs/ftp/pub/docs/freesurfer.func.pdf

Outline

- Function-Structure Integration
- Function-Structure Registration in FreeSurfer
- fMRI Analysis
 - Preprocessing
 - First-Level Analysis
 - Higher-Level (Group) Analysis
 - Correction for Multiple Comparisons
 - Data Hierarchies
- FreeSurfer Functional Analysis Stream (FSFAST)
- Tutorial
- Demos

Function-Structure Integration

- Viewing Functional Maps on Structural
 - Volume, Surface
- Inter-Subject Registration
- Region of Interest (ROI) Analysis
- Retinotopy
- Structural-Functional Covariates
 - Eg, use thickness at a voxels as covariate
 - Voxel-wise design matrices

FreeSurfer Registration

FreeSurfer Subject-Specific

- Volumes
- Surfaces
- Thickness
- ROIs



Your Data/Software

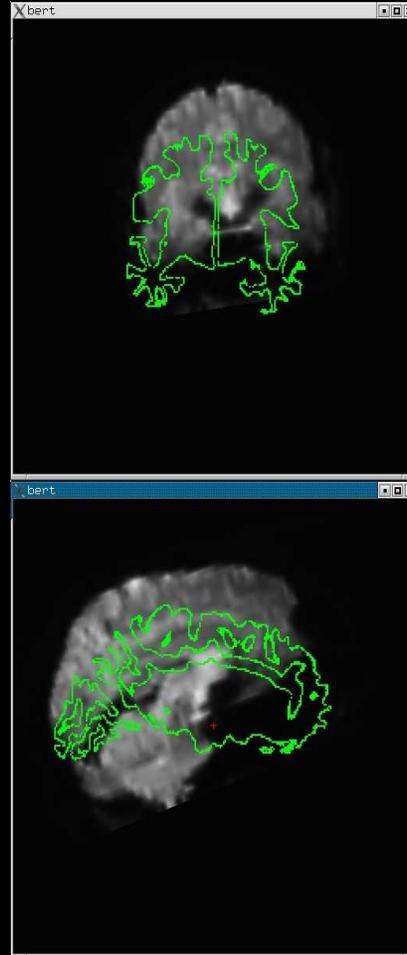
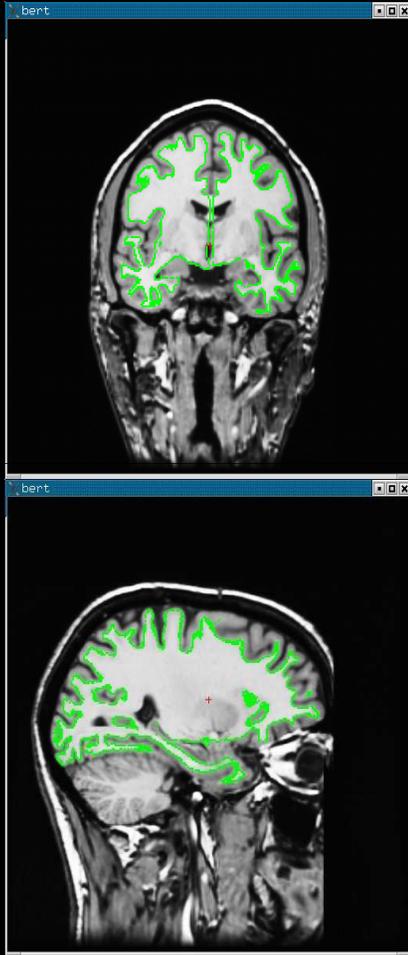
- fMRI (FSL, SPM,...)
- DTI
- PET
- EEG/MEG ...

Registration Matrix

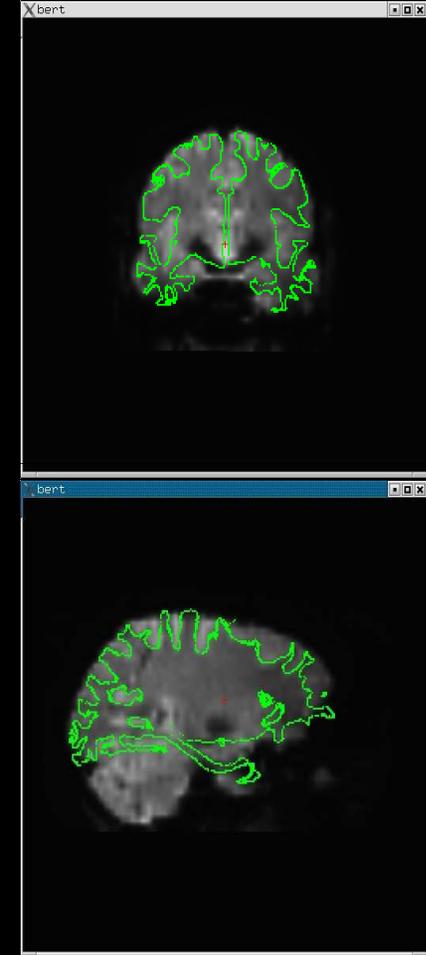
- Affine 4x4
- As many as 12 DOF (usually 6)
- Text file

Registration

FreeSurfer Anatomical
(orig)



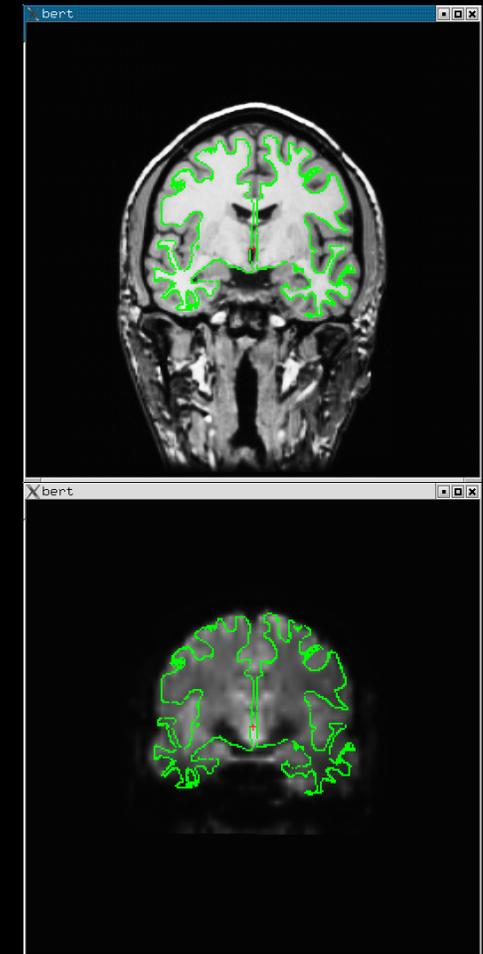
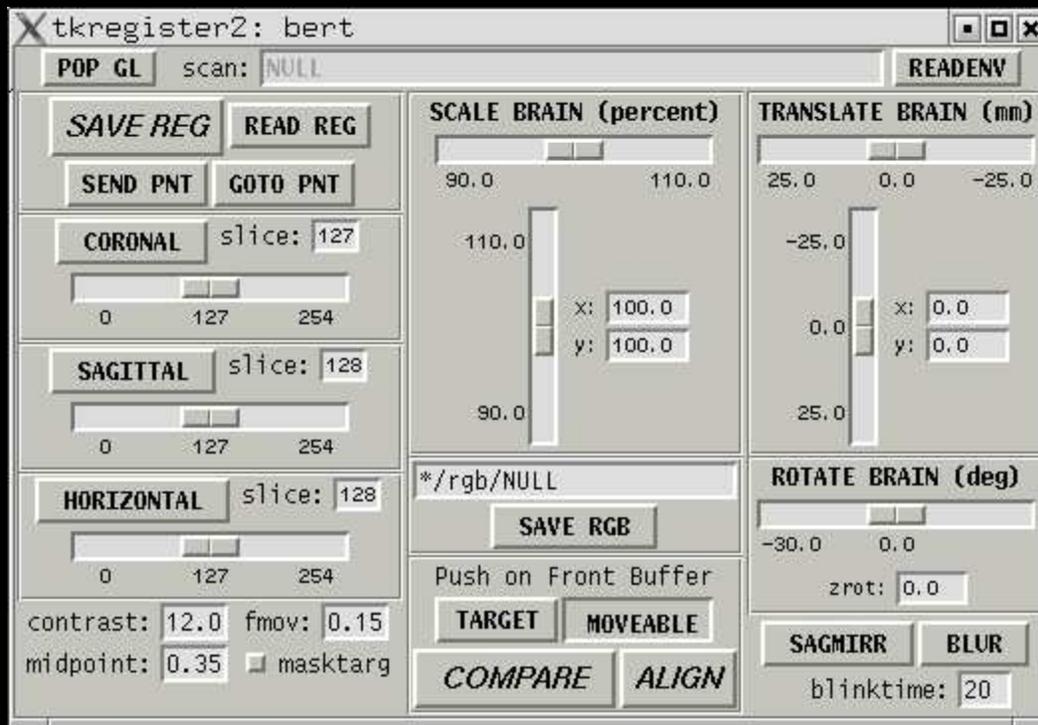
Template Functional



Note: Registering the template functional volume to the anatomical volume is sufficient to register the template to the surface.

Manual Registration

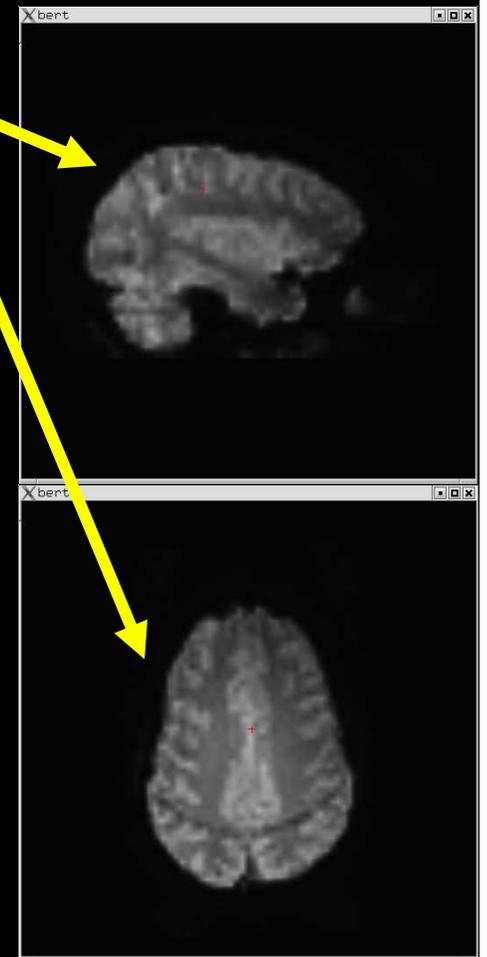
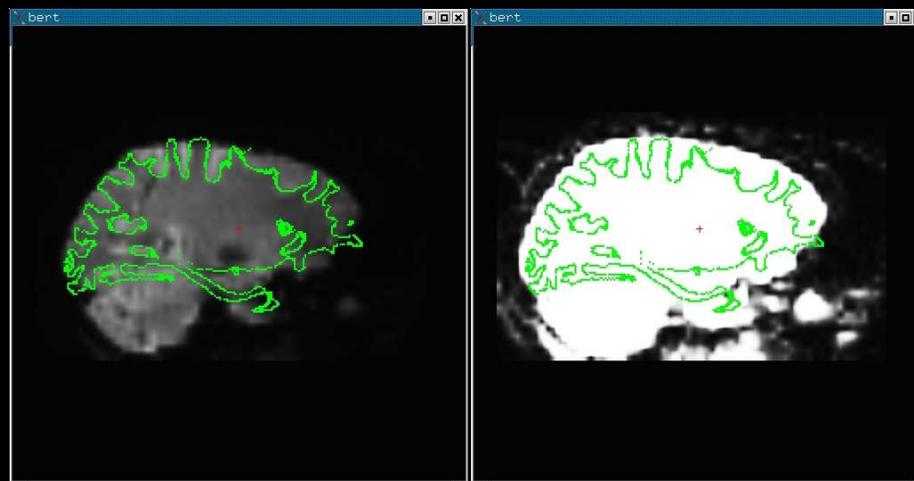
- tkregister2
- Visually inspect registration
- Manually edit registration (6 DOF)
- Cf Manual Talairach registration



tkregister2 --help

Tips

- Rigid = 6 DOF = No stretching
- Use CSF to get a sense of where the folds are
- Avoid using B0 distortion regions
- Avoid using ventricles
- Warning about “edge” of the brain
- Same Subject, Left-Right Flips



Command-line Tools

Automatic Registration:

- `fslregister -help`
 - `spmregister -help`
 - `reg-feat2anat -help`
- } FreeSurfer Scripts

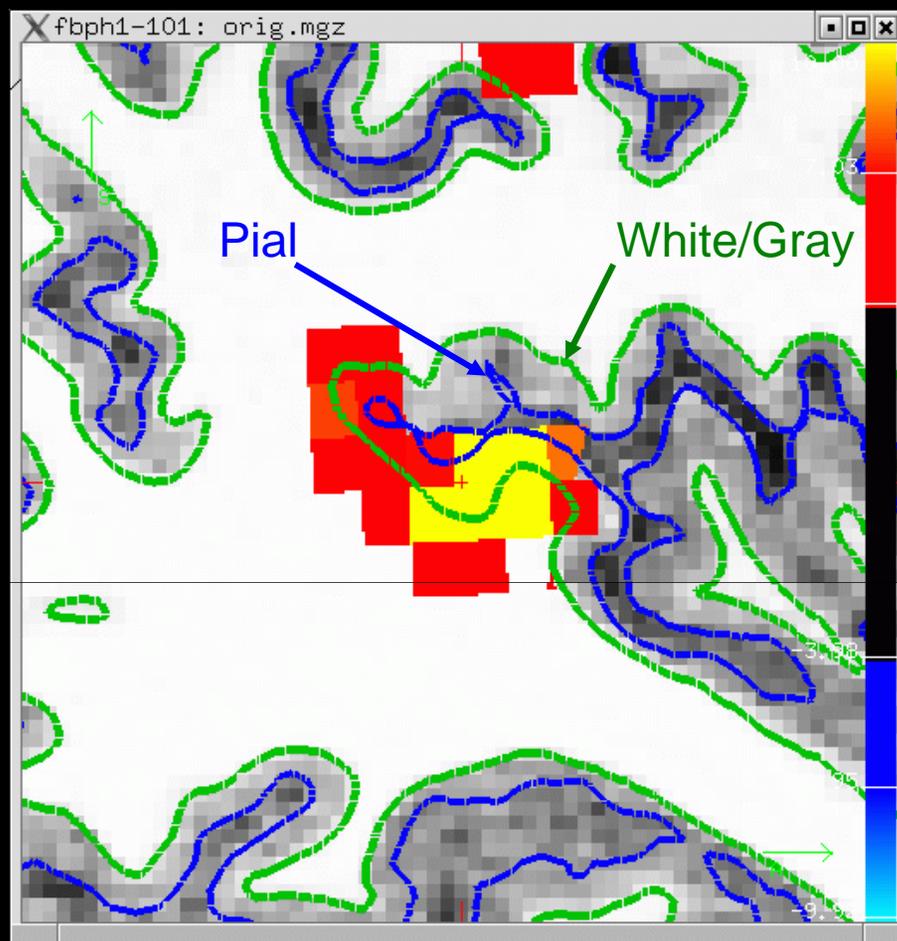
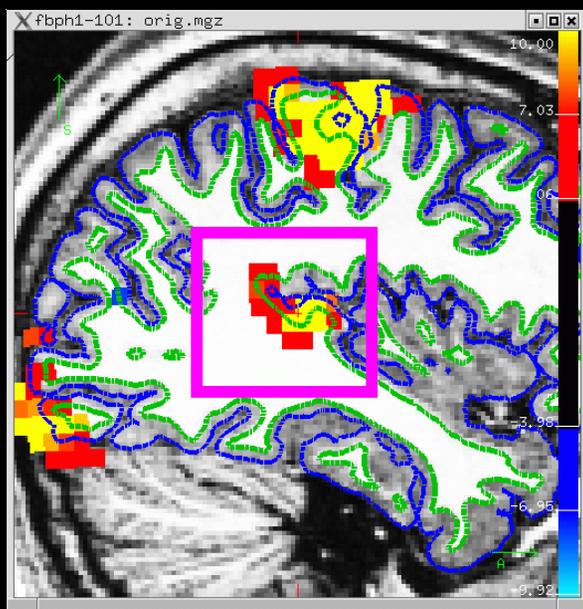
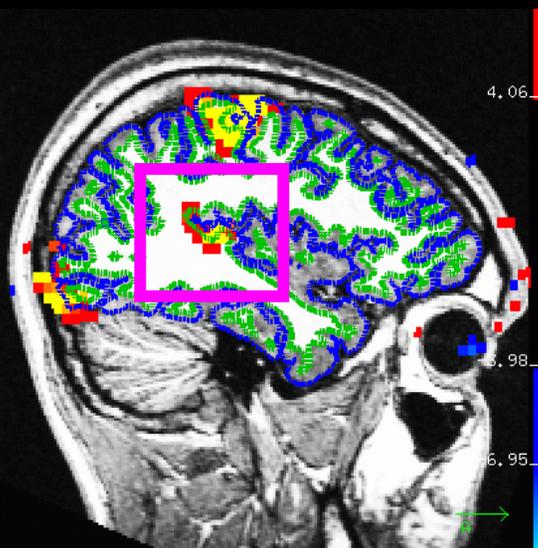
Manual Registration:

- `tkregister2 --help`

Transformations:

- `mri_vol2surf --help`
- `mri_vol2vol --help`
- `mri_label2vol --help`
- `mri_surf2vol --help`

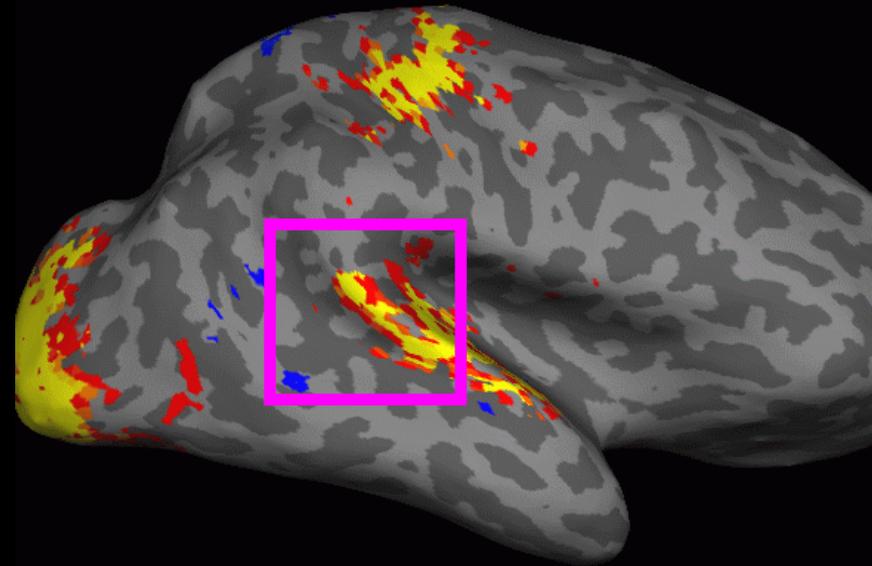
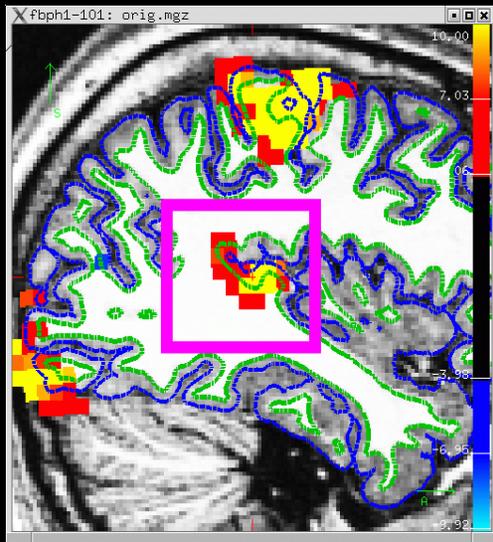
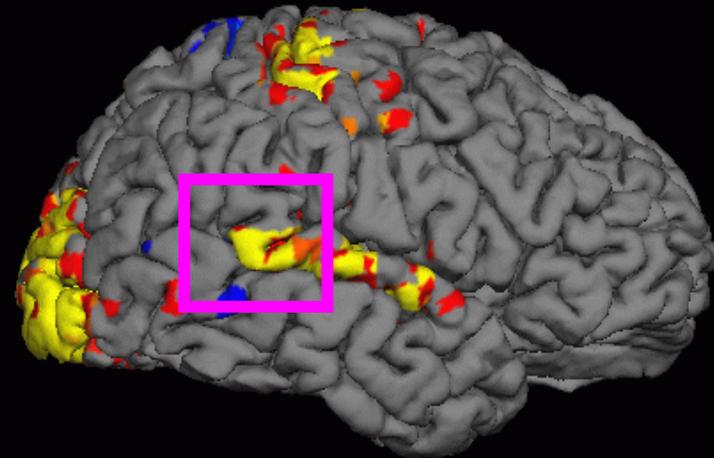
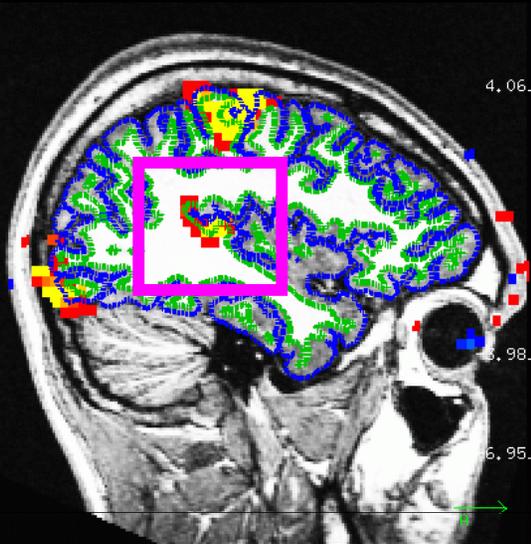
Sampling on the Surface



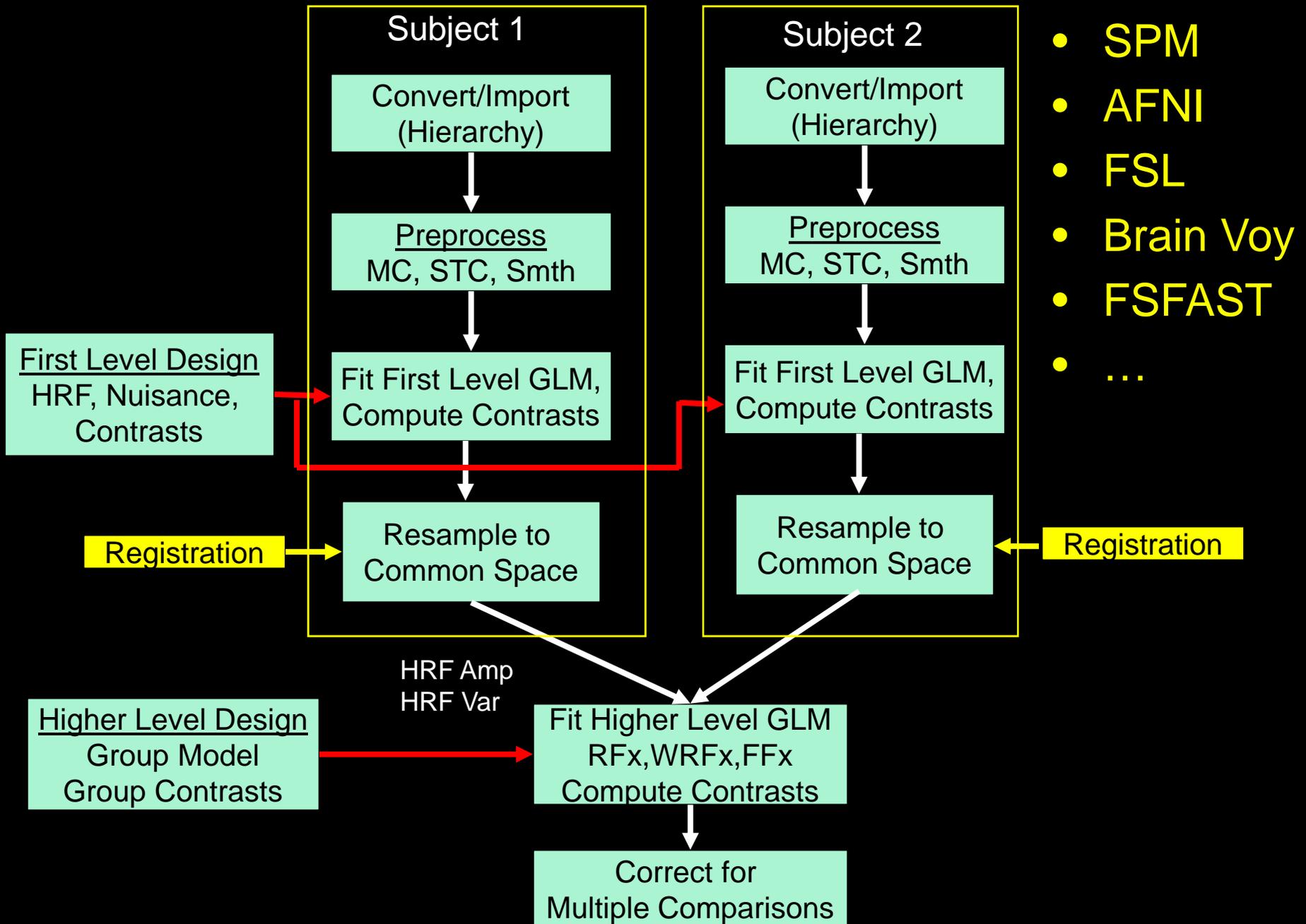
- White/Gray
- Pial
- Half Way
- Average

Projection Fraction
--projfrac 0.5

Sampling on the Surface



fMRI Analysis Pipeline Overview



fMRI Preprocessing Stages

- Motion Correction
- Slice-timing Correction (Interleaved vs Seq)
- B0 Distortion Correction
- Intensity Normalization: 4D or 3D?
- Masking – zeroing non-brain
- Resampling to Common Space
- Spatial Smoothing – 3D or 2D?
- Temporal Filtering is NOT Preprocessing!

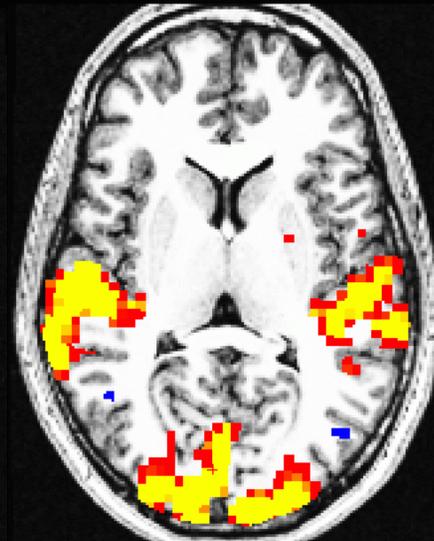
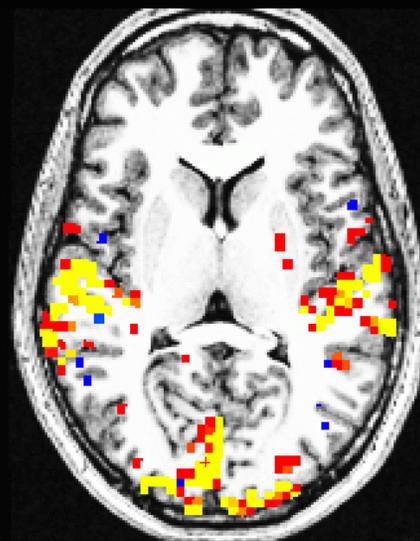
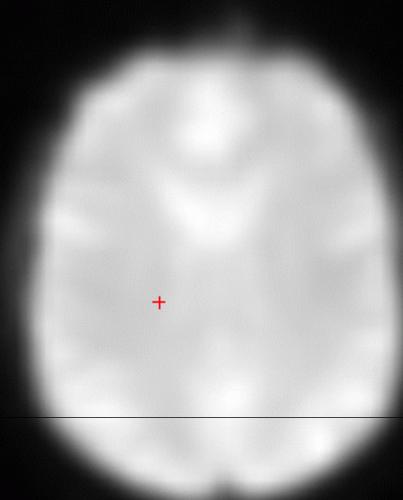
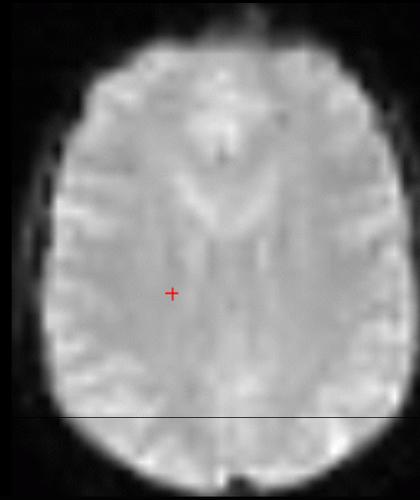
Reasons for Smoothing

- Improve CNR/SNR
- Reduce interpolation effects
- Make statistics more valid (GRF)
- Improve inter-subject registration
- Improve function-surface registration

Effects of Smoothing

No Smoothing

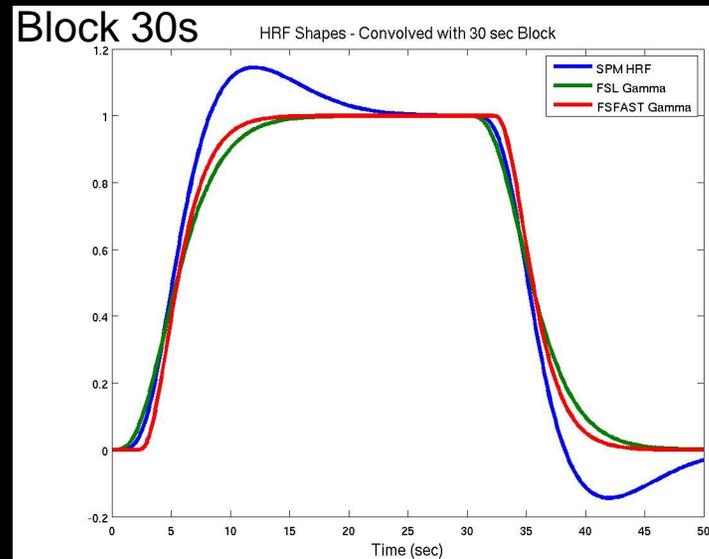
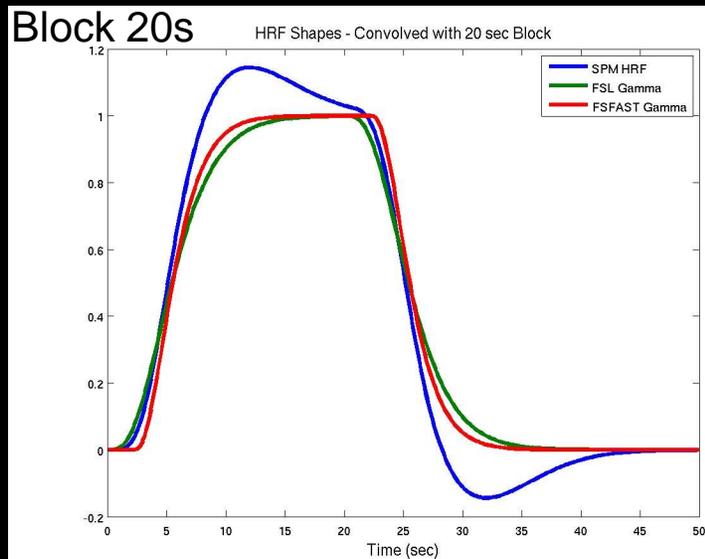
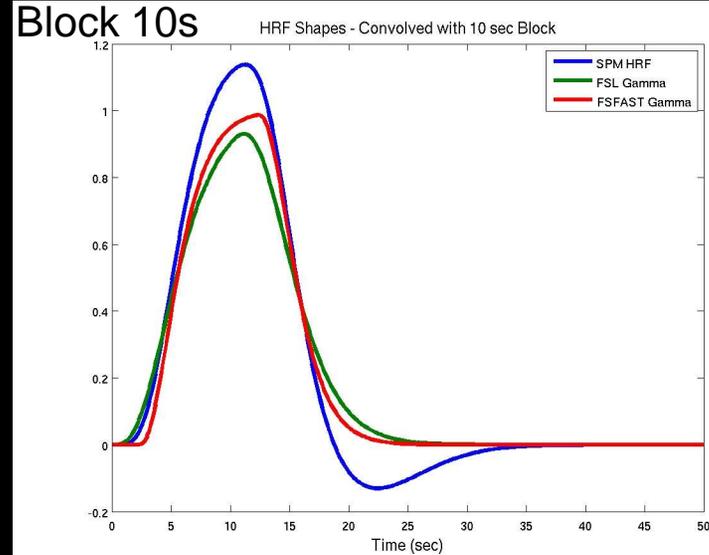
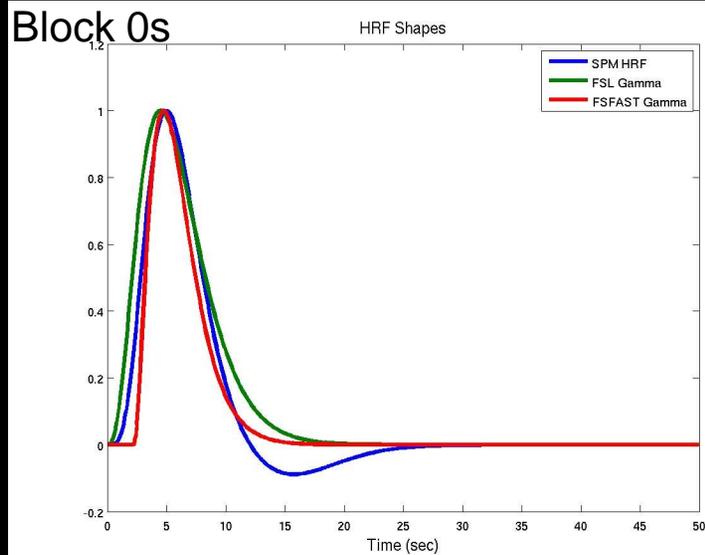
FWHM = 5mm



First Level Design and Analysis

- First-Level = First Standard Deviation
- First-Level Design
 - Event Definition and HRF Specification
 - Nuisance Regressors
 - Temporal Filtering
 - Temporal Whitening
- First-Level Contrasts
 - Univariate (t) – Pass up to next level
 - Multivariate (F)
- Analysis (Voxel-wise = “Massively Univariate”)
 - Contrasts of HRF Amplitudes
 - Variances of the Contrasts

First Level Design: HRF Shapes



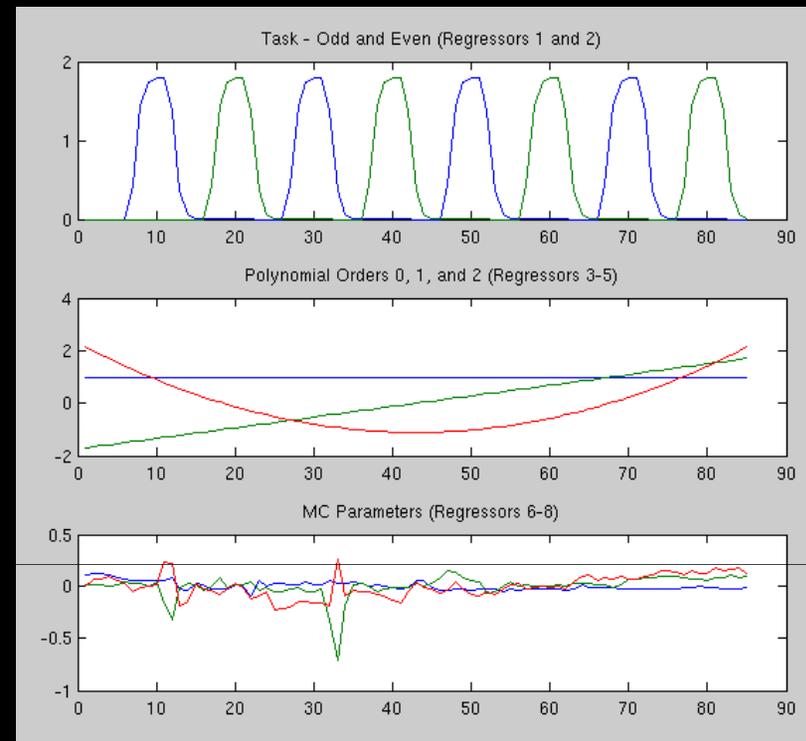
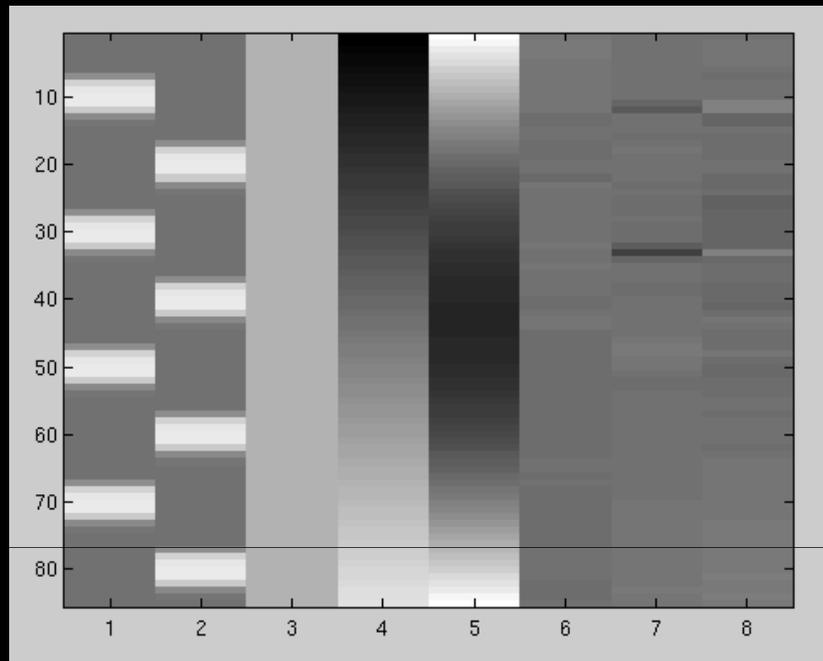
SPM
FSL
FSFAST

Stimulus Schedule/FSFAST Paradigm File

- Codes Stimulus Schedule (and Weight)
- Four Columns
 1. Onset Time (Since Acq of 1st Saved Volume)
 2. Stimulus Code (0, 1, 2 ,3 ...)
 3. Stumulus Duration
 4. Stimulus Weight (default is 1)
 5. Any other columns ignored
- Simple Text File
- Code 0 Always Fixation/NULL

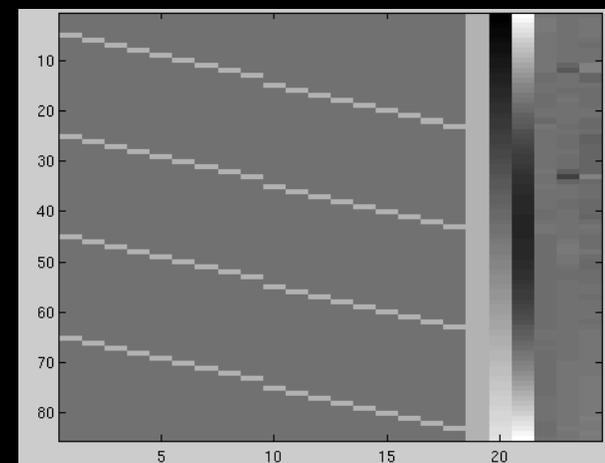
0.000	0	15	1	Fixation
15.000	1	15	1	Task-Odd
30.000	0	15	1	Fixation
45.000	2	15	1	Task-Even
60.000	0	15	1	Fixation
75.000	1	15	1	Task-Odd
90.000	0	15	1	Fixation
105.000	2	15	1	Task-Even
120.000	0	15	1	Fixation
135.000	1	15	1	Task-Odd
150.000	0	15	1	Fixation
165.000	2	15	1	Task-Even
180.000	0	15	1	Fixation
195.000	1	15	1	Task-Odd
210.000	0	15	1	Fixation
225.000	2	15	1	Task-Even
240.000	0	15	1	Fixation

First-Level Design Matrix



- Task – convolved with HRF
- Polynomial (0-2) Nuisance Regressors
- MC Parameters reduced from 6 to 3

FIR



Higher-Level (Group) Analysis

- Higher-Level Design
 - Groups and covariates
 - Contrasts
- Analysis Method
 - Random Effects (RFx, OLS = ordinary least squares)
 - Weighted Random Effects (WRFx, WLS=weighted least squares)
 - Mixed Effects
 - Fixed Effects (FFx)
- Correction for Multiple Comparisons
 - Clustering (GRF, Monte Carlo, Permutation)

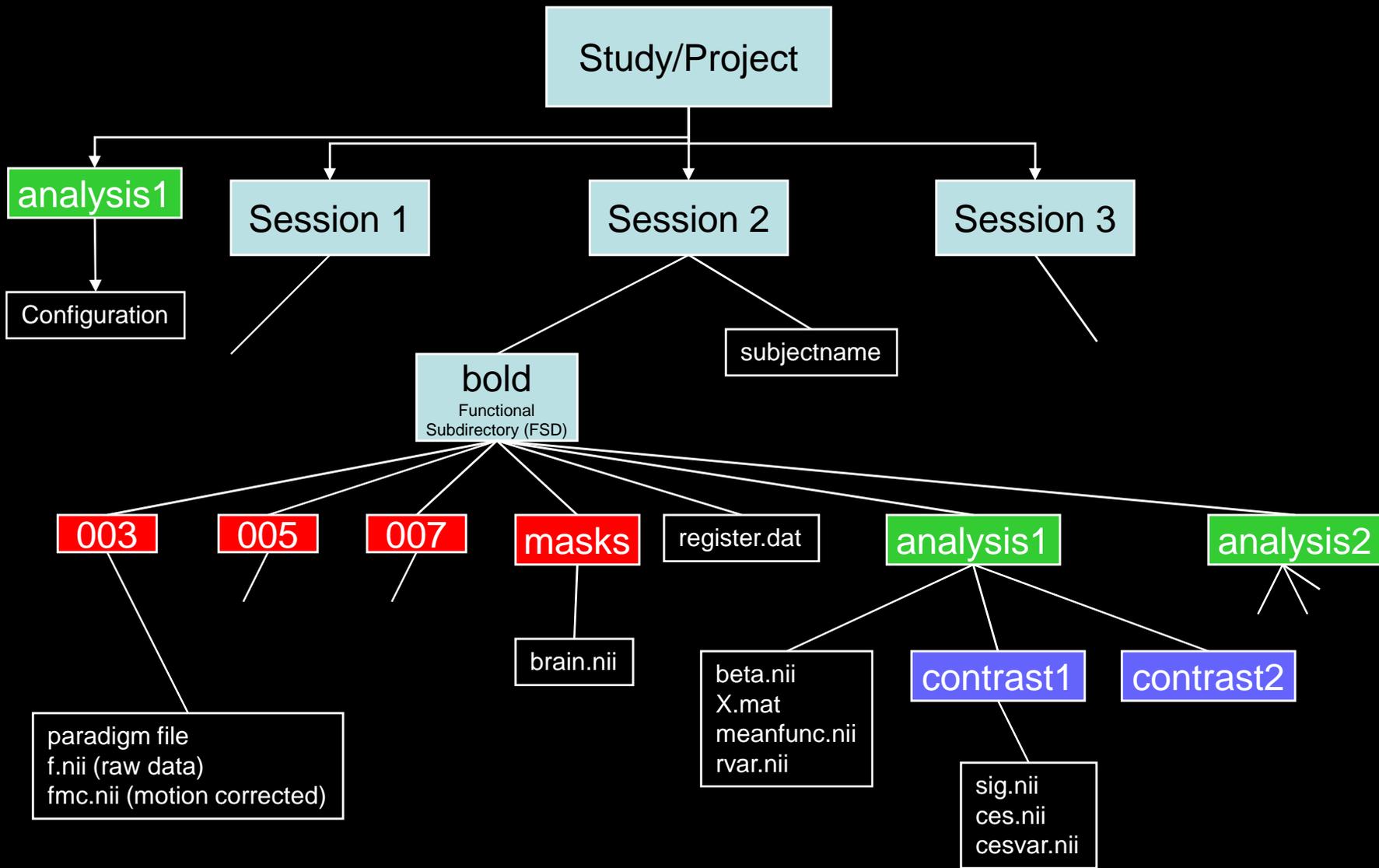
Group Effect Models

- Random Effects (RFx, OLS; WRFx, WLS)
 - Does effect exist in the general population that my subjects were drawn from?
 - Weighted – weight each subject by $1/\text{First Level Noise}$
- Fixed Effects (FFx) – Does effect exist within the group of subjects that I am studying? Like having one subject scanned multiple times.
- Mixed Effects – use First Level (within-subject) Noise AND between-subject noise to do better weighting.

One-Sample Group Mean (OSGM)

- No groups, No Covariates
- Does average = 0?
- One-sample t-test
- Group Design Matrix: Vector of All 1s

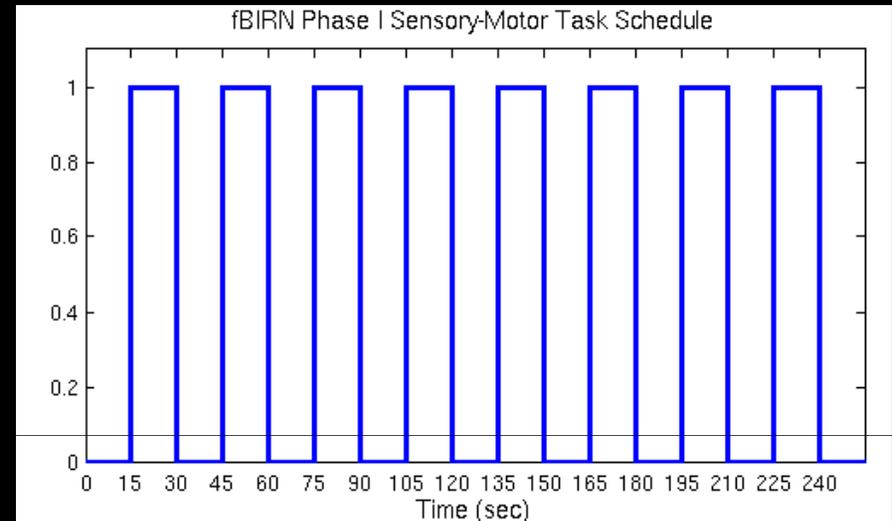
FS-FAST Directory Hierarchy



Use `unpacksdcmdir` to import Session in Siemens dicom to FS-FAST.

FS-FAST Tutorial

- Data - fBIRN
 - 5 Subjects
 - 4 Runs Each (TR=3, 85TP)
 - Sensory Motor Task
 - 15 sec Blocks
 - 9 OFF
 - 8 ON
 - Code Odd and Even Separately
 - Test Odd vs Even



surfer.nmr.mgh.harvard.edu/fswiki/FsFastTutorial

FS-FAST Tutorial Exercises

- Data setup
 - “Import” in to hierarchy
 - Create paradigm files
 - Link to FreeSurfer Anatomical Analysis
- Viewing Functional Results in TkMedit/TkSurfer
- Preprocessing – MC and Smoothing
- Registration – automated and manual
- First Level
 - Design and Contrasts: Gamma, Finite Impulse Response (FIR)
 - First Level Analysis
 - Visualization – volume and surface
- Group Level Analysis – One-Sample Group Mean (OSGM)
 - QA
 - RFX, WRFx, FFX
 - Volume (Talairach) and Surface

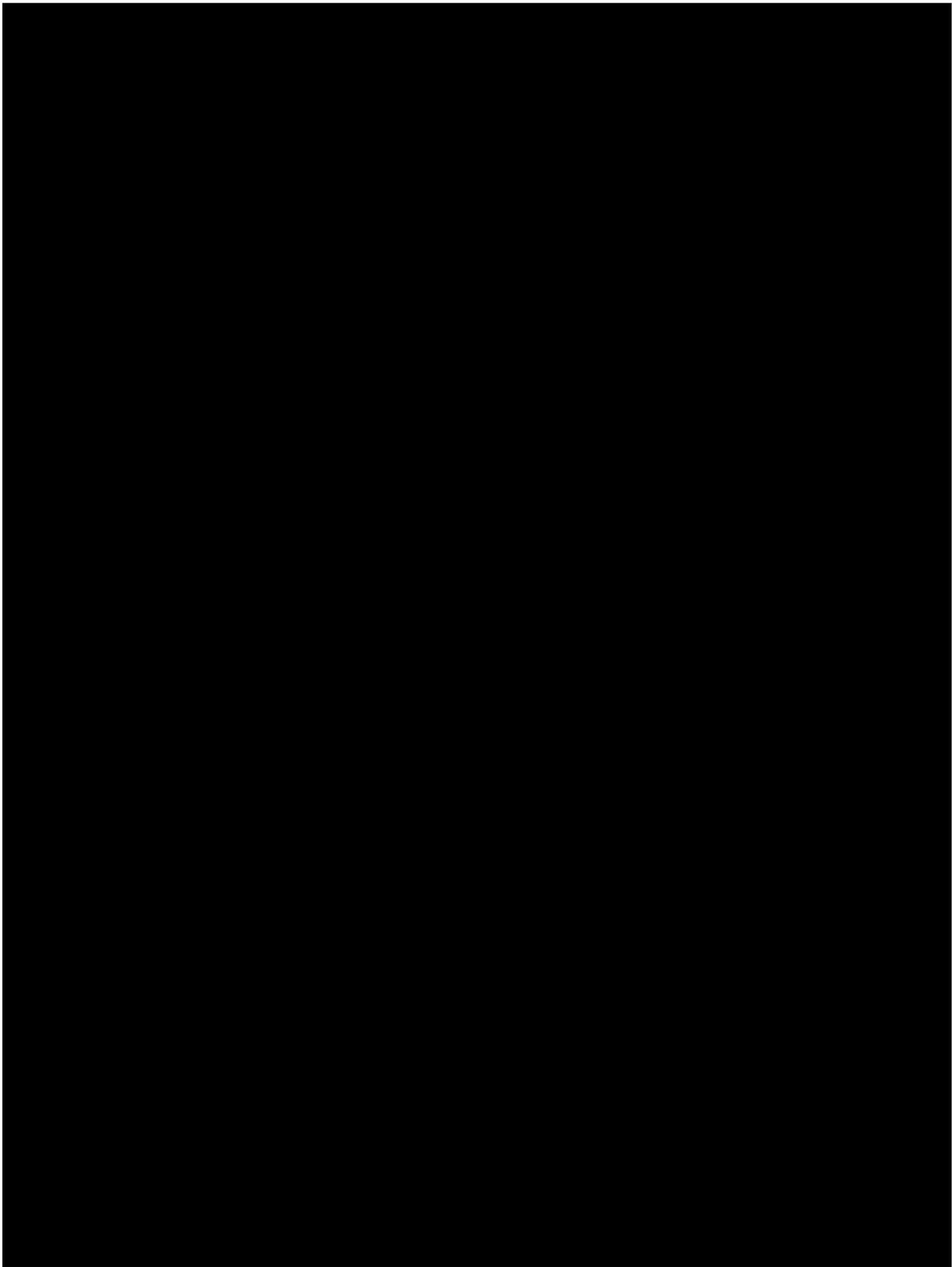
FS-FAST Tutorial Exercises

- Four main directories at various levels of processing in \$FSFTUTDIR:
 1. fb1-raw – raw data, nifti format, unorganized
 2. fb1-raw-study – raw data organized in FSFAST hierarchy
 3. fb1-preproc-study – preprocessed data
 4. fb1-analysis-study – fully analyzed
 1. First-level Analyses
 2. Group Analyses in Tal and Surf
- You don't necessarily need to run any processing – can just run visualization.

Start Terminal

firefox&

surfer.nmr.mgh.harvard.edu/fswiki/FsFastTutorial



Effects of Smoothing

