Function-Structure Integration in FreeSurfer

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

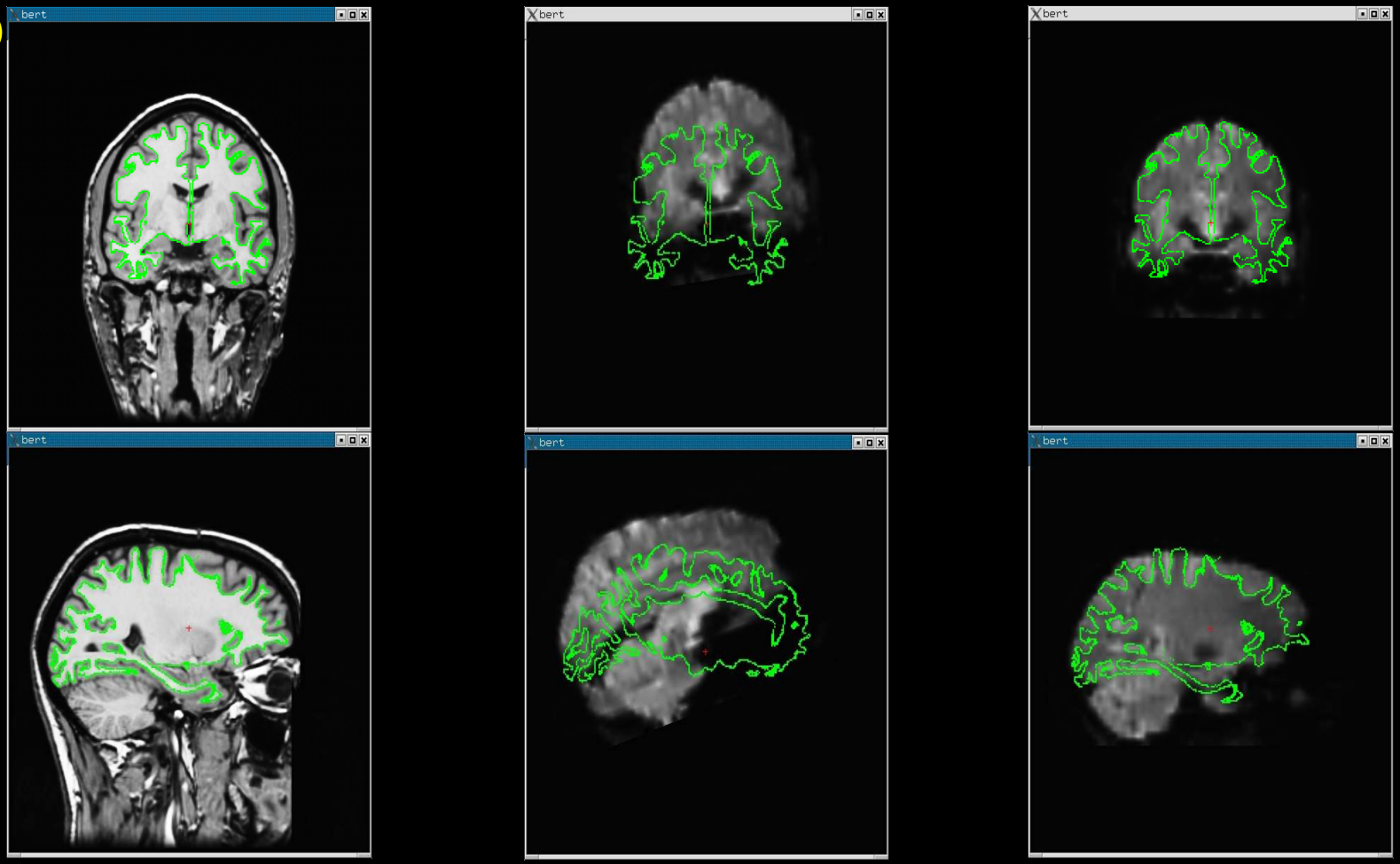
Your Data/Software
- fMRI (FSL, SPM,…)
- DTI
- PET
- EEG/MEG …

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

Registration

FreeSurfer Anatomical (orig)

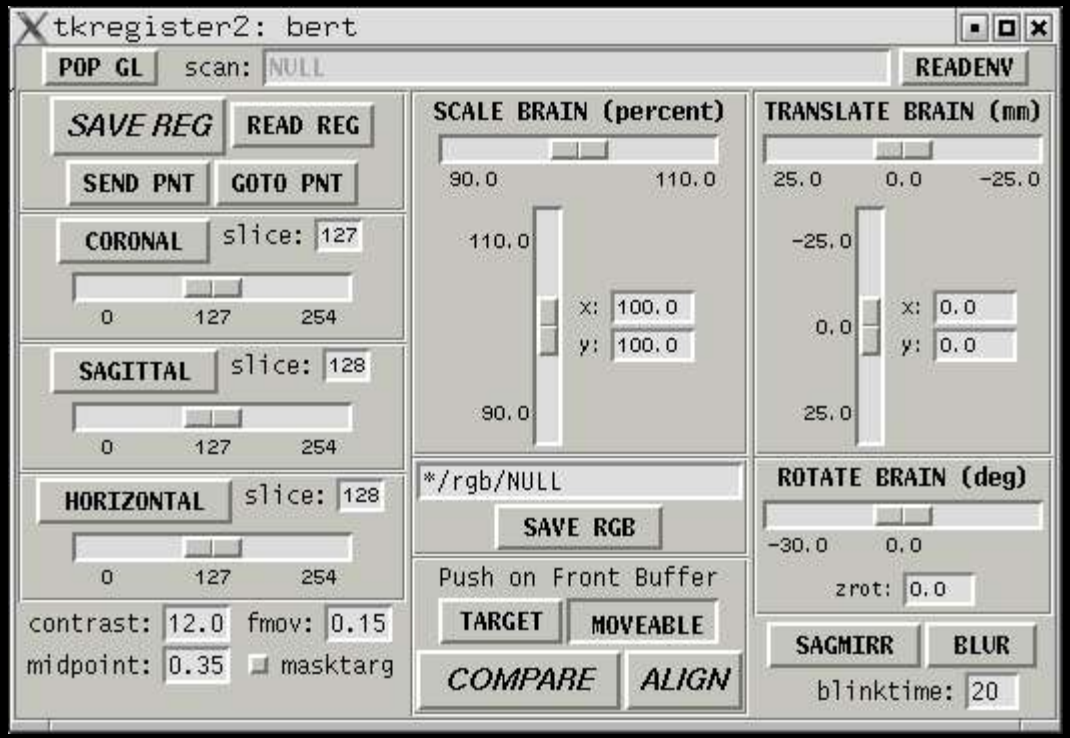
Template Functional

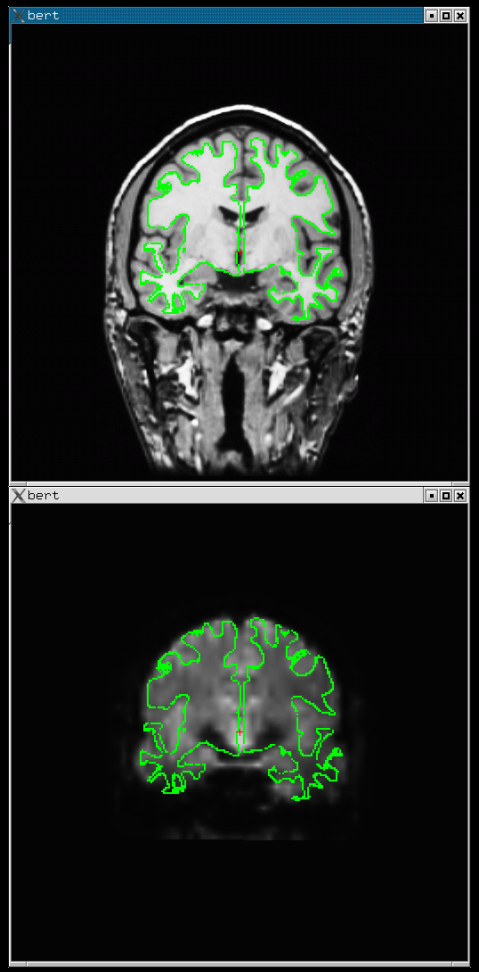


Note: Registering the template functional volume to the anatomical volume is sufficient to register the template to the surface.

Manual Registration

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

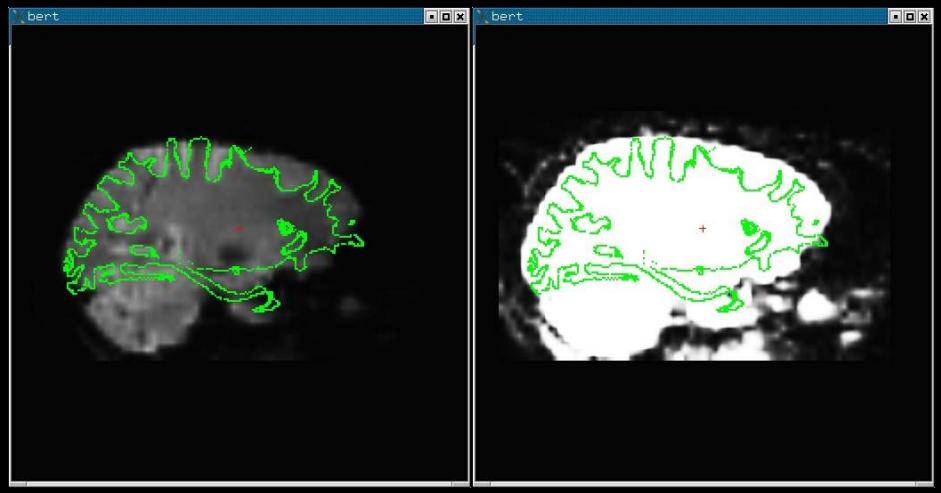




tkregister2 --help

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

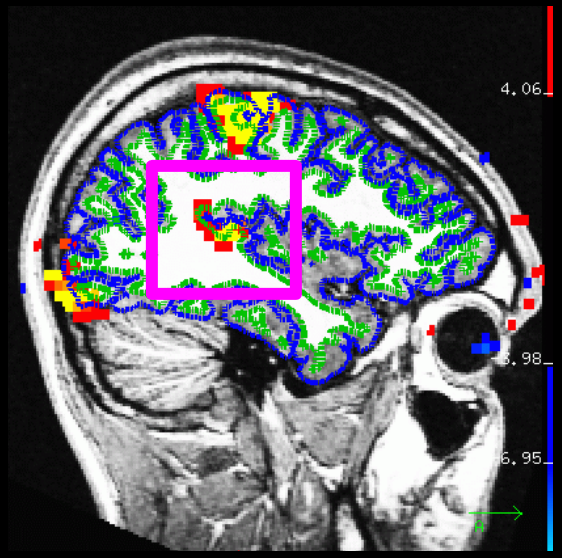
Manual Registration:

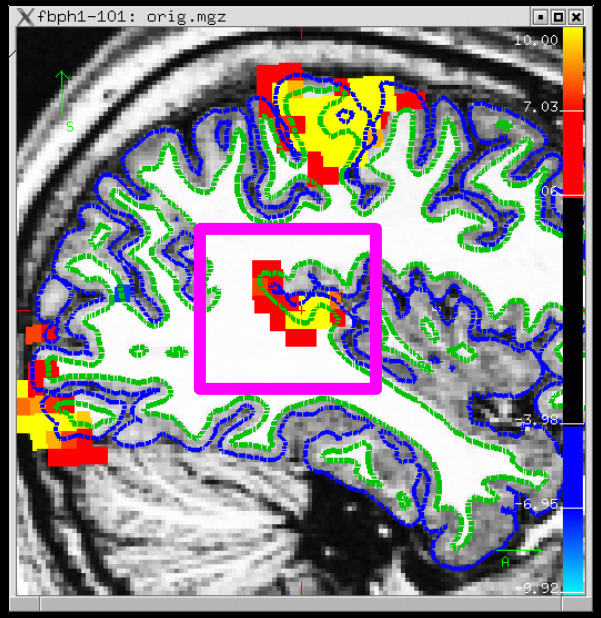
- tkregister2 --help

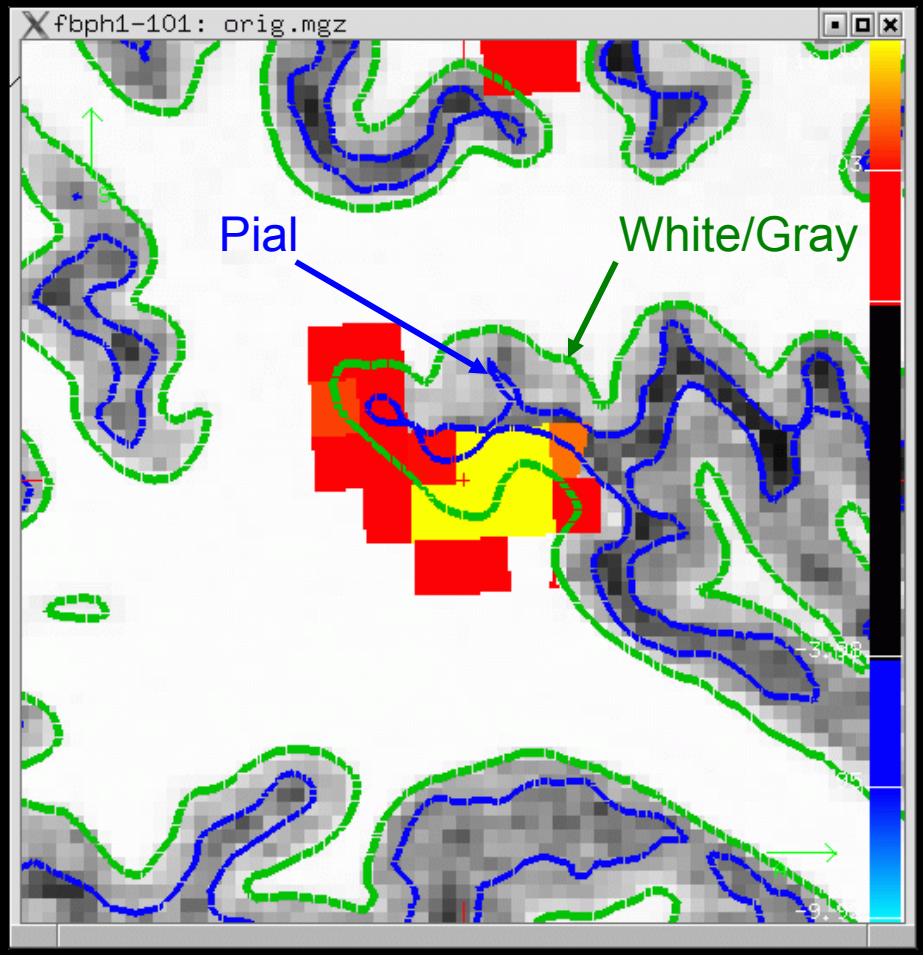
Transformations:

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

Sampling on the Surface



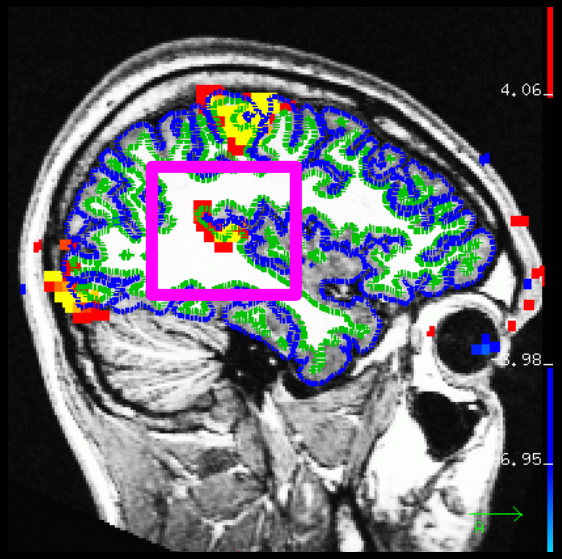


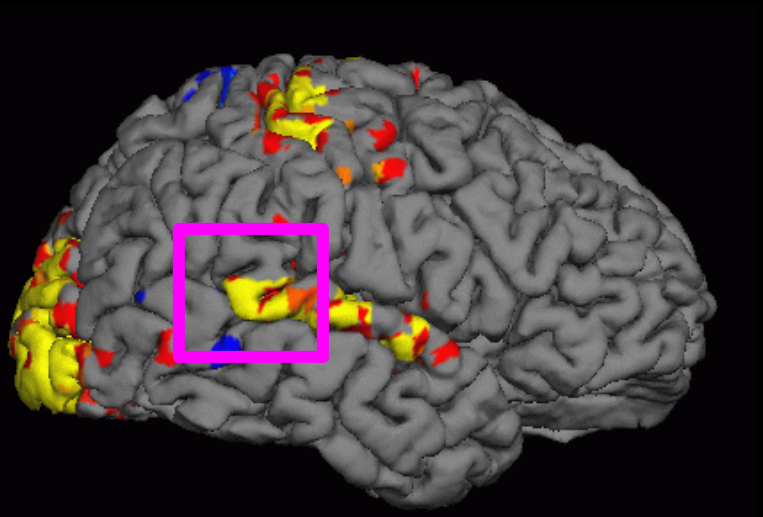


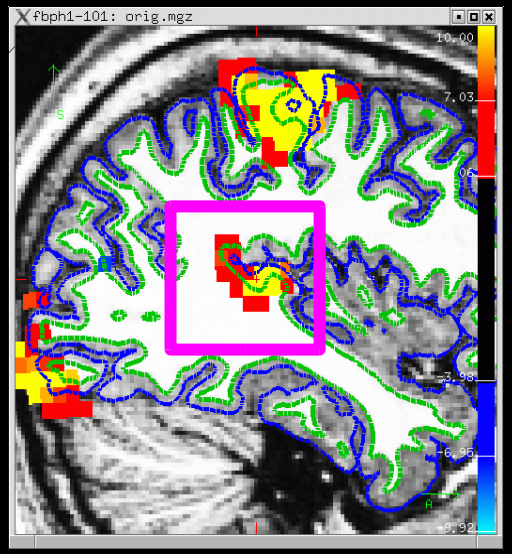
- White/Gray
- Pial
- Half Way
- Average

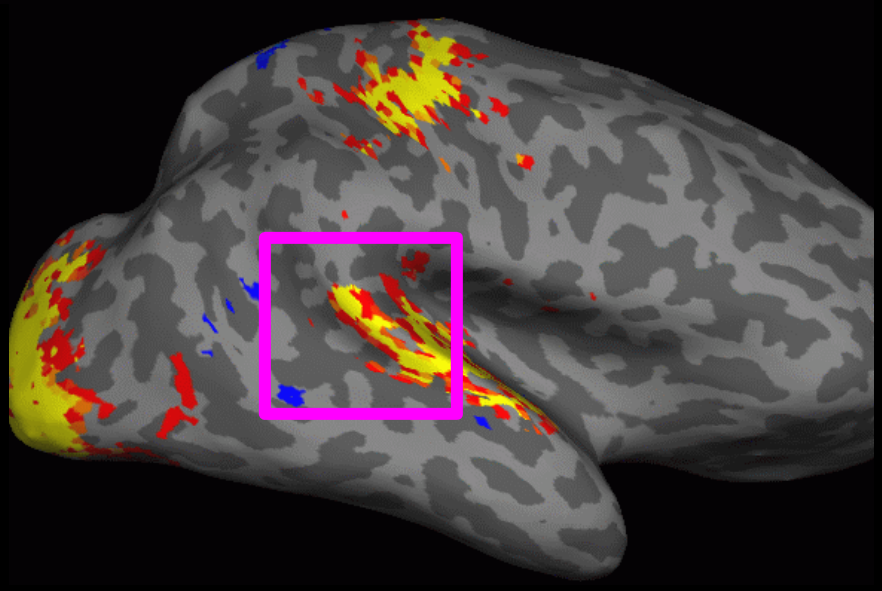
Projection Fraction
--projfrac 0.5

Sampling on the Surface

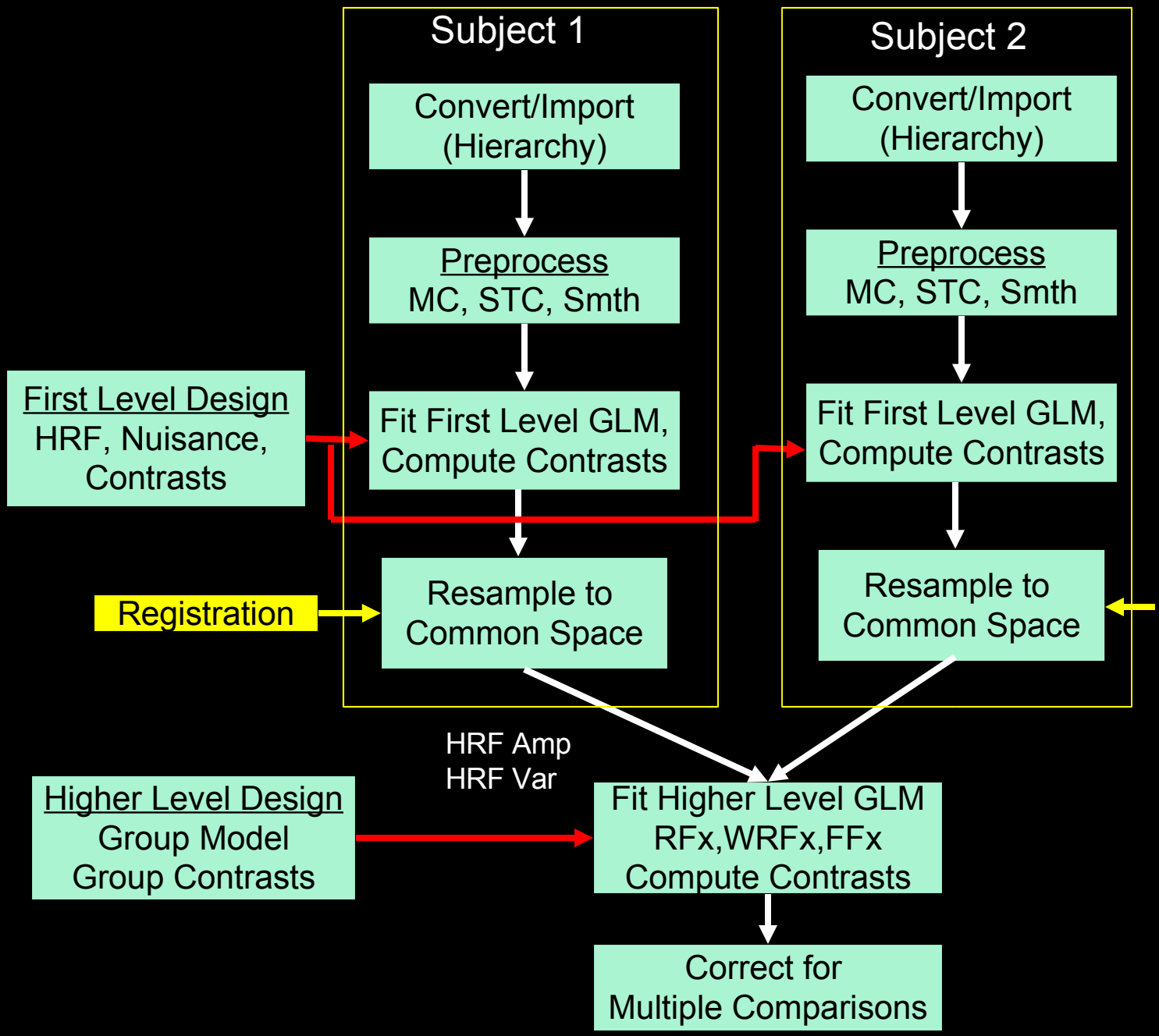








fMRI Analysis Pipeline Overview



- SPM
- AFNI
- FSL
- Brain Voy
- FSFAST
- …

fMRI Preprocessing Stages

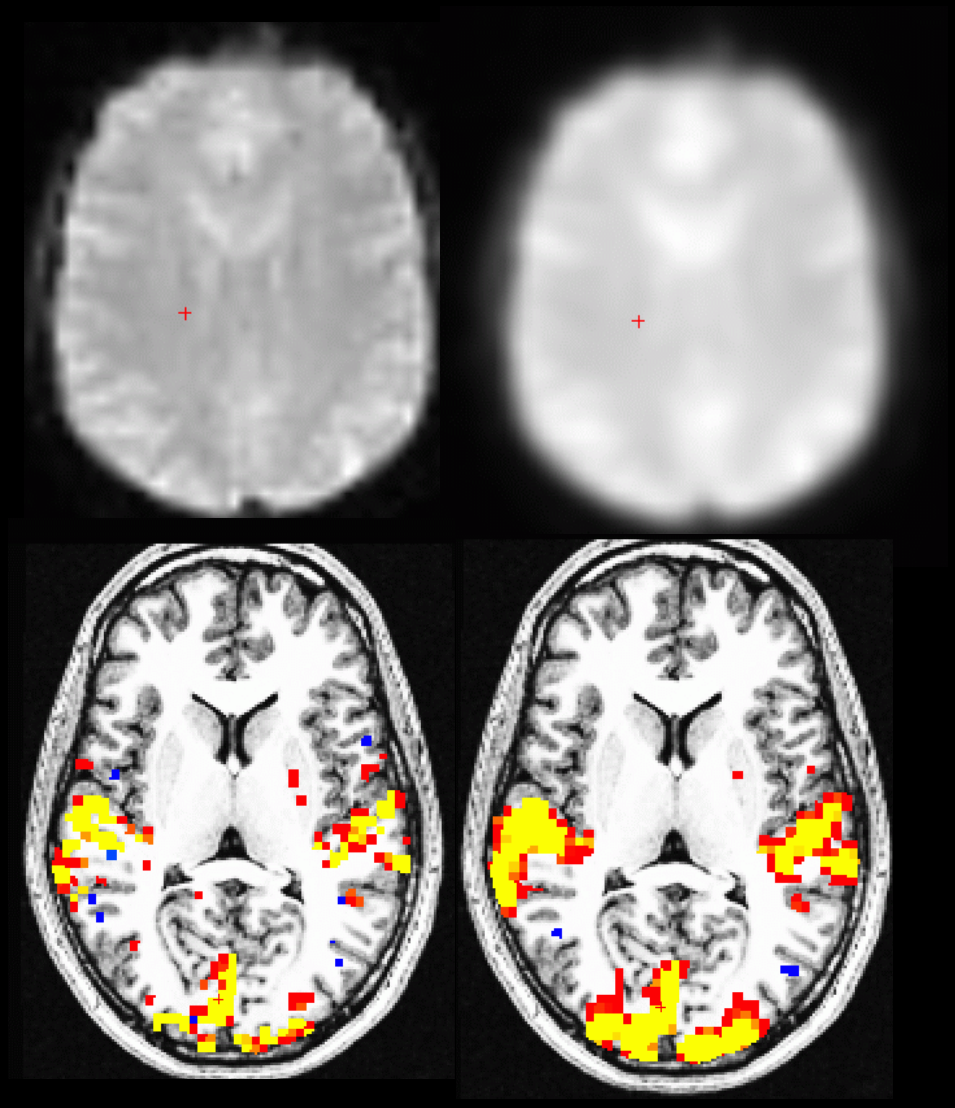
- Motion Correction
- Slice-timing Correction (Interleaved vs Seq)
- B0 Distortion Correction
- Intensity Normalization: 4D or 3D?
- Masking – zeroing non-brain
- Resampling to Common Space
- Spatial Smoothing – 3D or 2D?
- Temporal Filtering is NOT Preprocessing!

Reasons for Smoothing

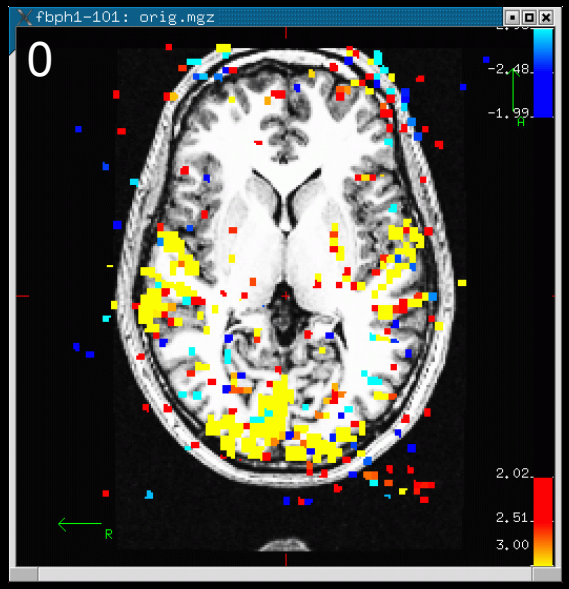
- Improve CNR/SNR
- Reduce interpolation effects
- Make statistics more valid (GRF)
- Improve inter-subject registration
- Improve function-surface registration

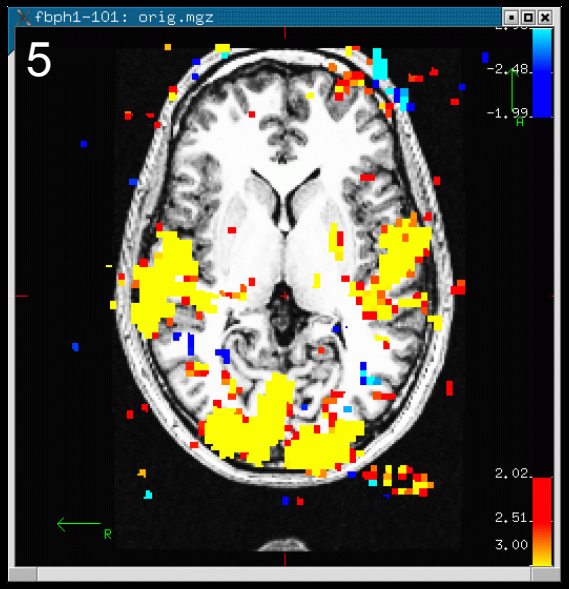
Effects of Smoothing

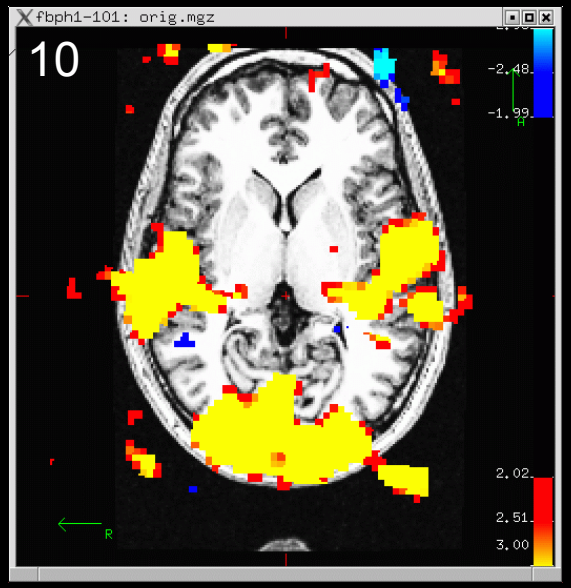
No Smoothing FWHM = 5mm

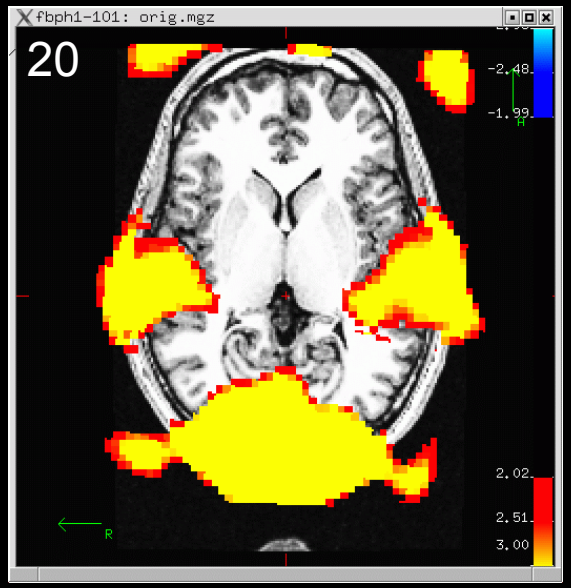


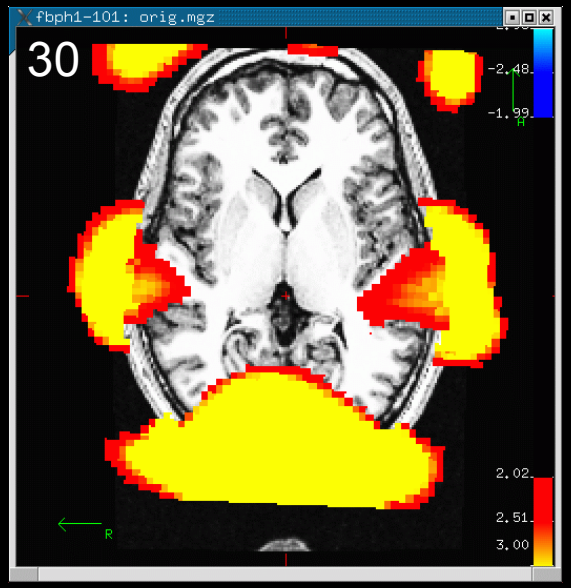
Effects of Smoothing









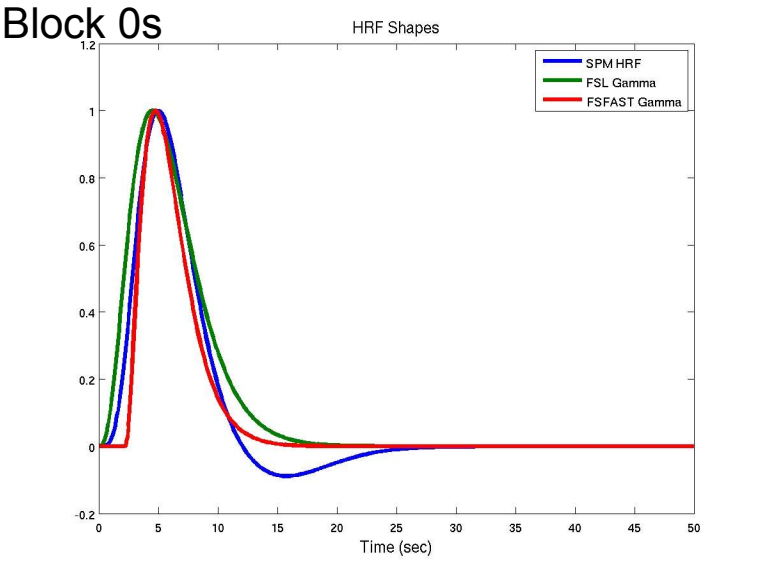


First Level Design and Analysis

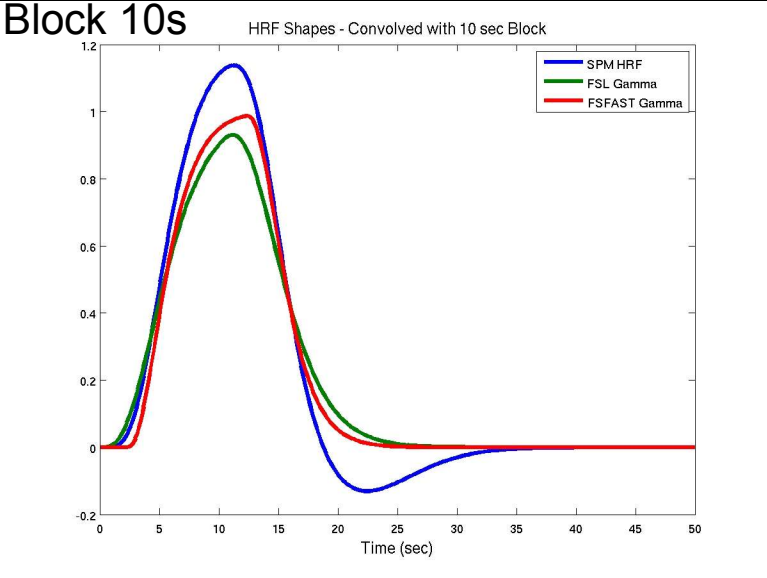
- First-Level = First Standard Deviation
- First-Level Design
  - Event Definition and HRF Specification
  - Nuisance Regressors
  - Temporal Filtering
  - Temporal Whitening
- First-Level Contrasts
  - Univariate (t) – Pass up to next level
  - Multivariate (F)
- Analysis (Voxel-wise = “Massively Univariate”)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

First Level Design: HRF Shapes

Block 0s

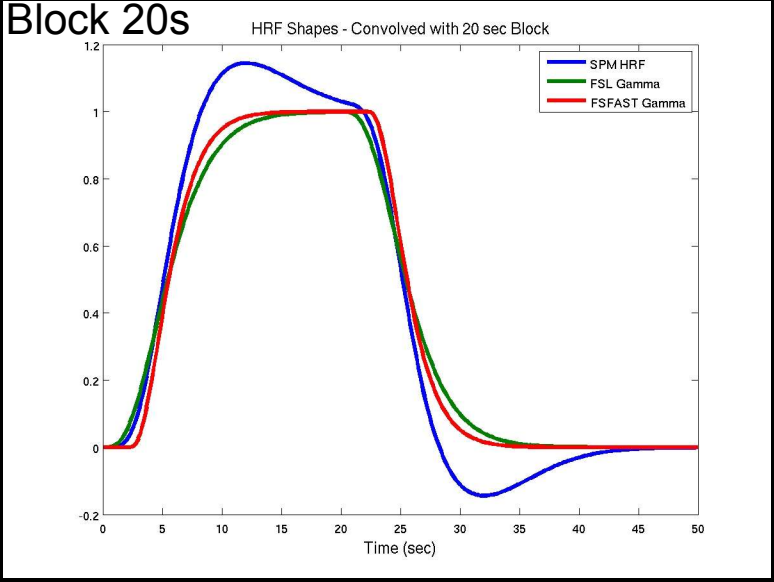


Block 10s

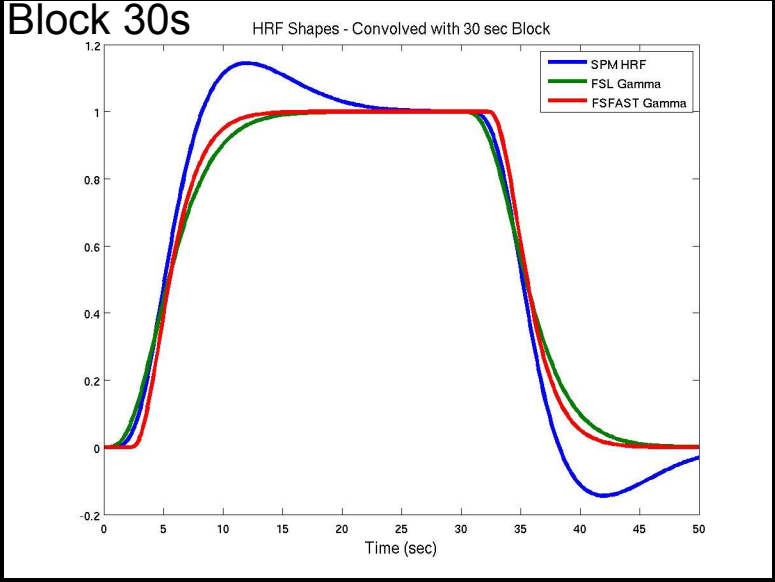


SPM
FSL
FSFAST

Block 20s



Block 30s

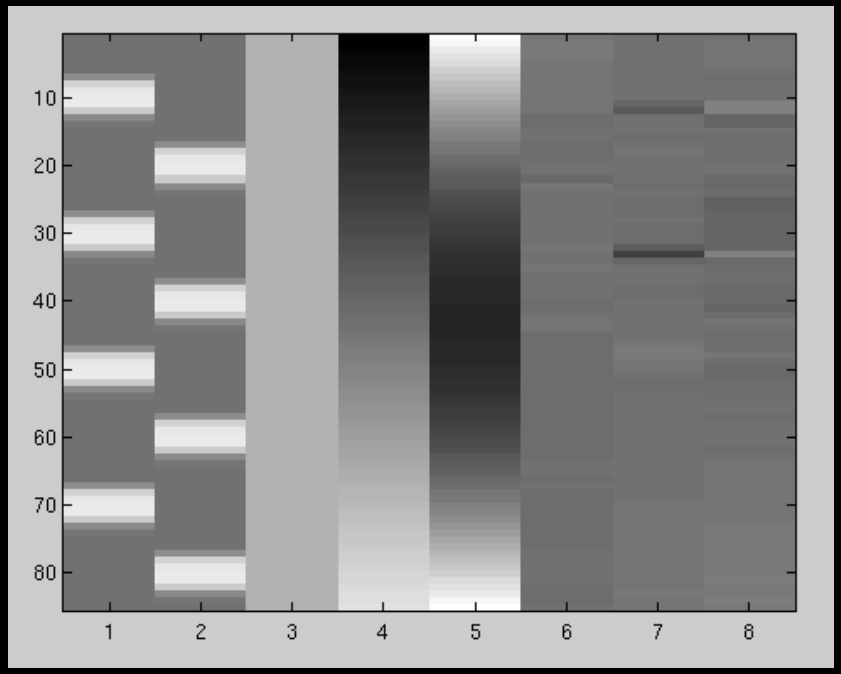


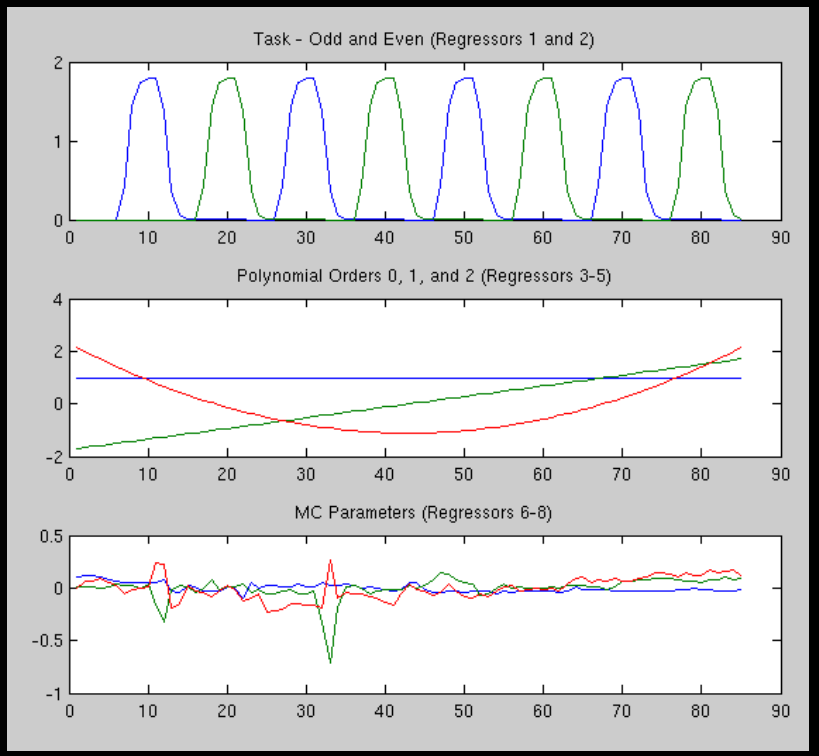
Stimulus Schedule/FSFAST Paradigm File

- 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
```

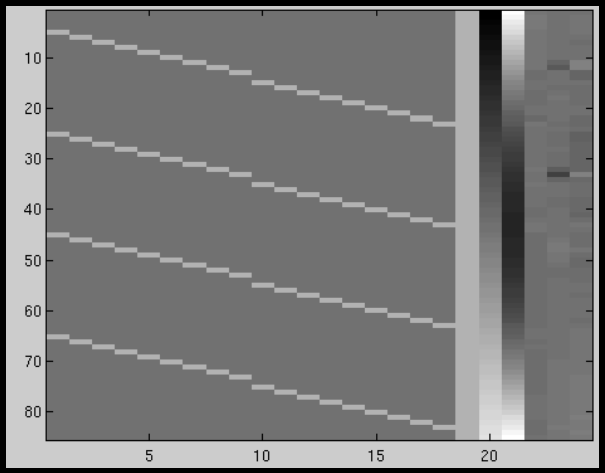
First-Level Design Matrix





- 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 covriates
  - 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)

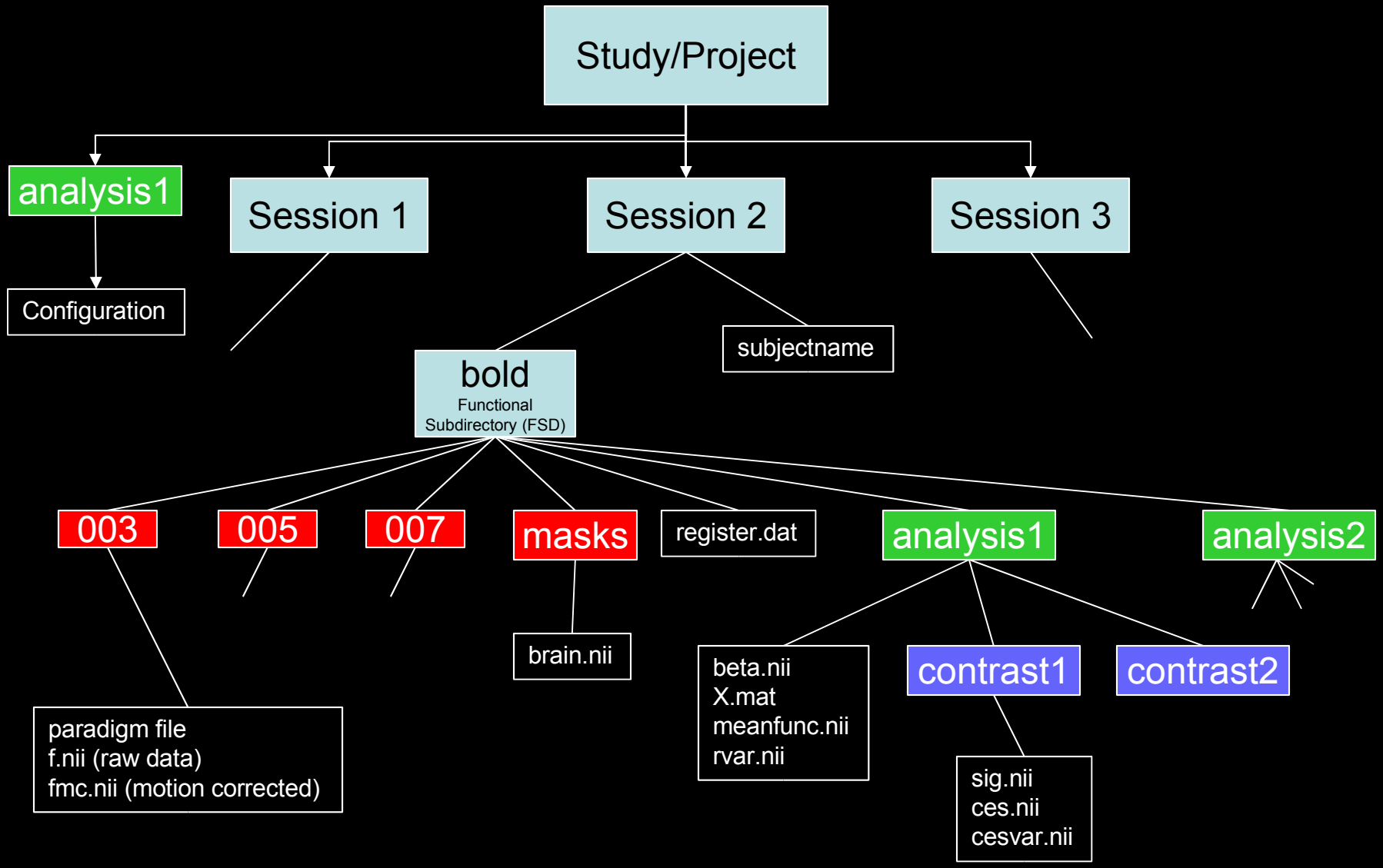
Group Effect Models

- 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/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

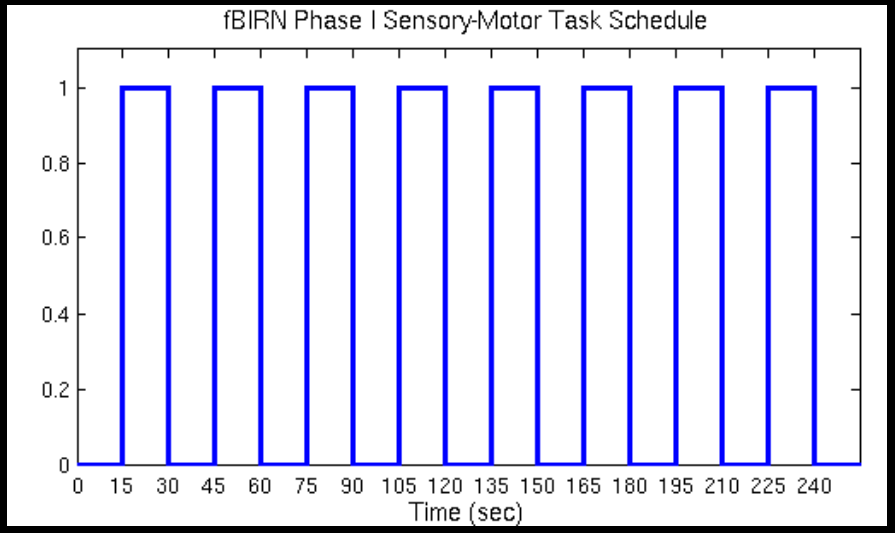
FS-FAST Directory Hierarchy



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