SPM Introduction

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Slides adapted from T. Nichols





Software to perform computation, manipulation and display of imaging data





SPM : Overview

- Library of MATLAB and C functions
- Graphical user interface
- Four main components:
 - Preprocessing
 - Model Specification & Fitting
 - Inference & Results Interrogation
 - Supplemental Tools

承 SPM12 (6685): Menu	
Realign (E Slice timing Coregister Normalise	Smooth Segment
Specify 1st-level	Review Estimate
Results	
Dynamic Causal Model	ling
SPM for functional N	MRI
Display Check Reg Render	🔻 FMRI 💌
Toolbox: PPIs ImCa	IC DICOM Import
Help Utils Batc	h Quit
Copyright (c) 1991,1994-2016	

Preprocessing

Eliminate systematic variation before statistical modeling



After

t=10.04

Before t=5.89

Processed with slice-timing correction, motion correction, and smoothed with 5mm isotropic kernel.



SPM: Preprocessing

- Slice timing
 - Adjust for variable acquisition time over slices
 - In UM processing stream, this is already done



- "Realign"ment
 - Intrasubject registration
 - Motion correction
 - Done in UM stream



Spatial pre-processing		
Realign (Estimate)	Slice timing	Smooth
Coregister (Estimate)	Normalise (Estimate)	Segment

SPM: Preprocessing

- "Coregister" ation
 - Intrasubject, intermodality registration
 - Registration of MR images with different TR/TE
- Spatial "Normalize" ation
 - Intersubject registration
 - Register subject anatomy to atlas space



SPM T1 template MNI space

atial pre-processing		
Realign (Estimate)	Slice timing	Smooth
Coregister (Estimate)	Normalise (Estimate)	Segment

- X1 = 1.093*X -0.011*Y -0.008*Z -10.591
- Y1 = 0.010^{*}X +1.086^{*}Y -0.190^{*}Z +8.054
- Z1 = 0.001*X +0.020*Y +0.298*Z -7.243

Original Joint Histogram









SPM: Preprocessing

- Spatial "Smooth" ing
 - Blur data into submission...
 - To satisfy random field theory assumptions
 - For intersubject analyses



Before









Adapted from SPM course slides

- "Segment" ation into GM/WM/CSF •
 - Useful for structural studies

Spatial pre-processing		
Realign (Estimate)	Slice timing	Smooth
Coregister (Estimate)	Normalise (Estimate)	Segment

SPM: Model Specification

- "Specify 1st-level"
 - Specify the design, creating SPM.mat
- "Specify 2nd-level"
 - T-tests (One or two sample, paired)
 - Regression
- "Review"
 - Examine correlation of predictors
 - Power spectrum of experimental effects
- "Estimate"
 - Fit a specified model

based on a SPM.mat file

specily ist-level	Review

SPM: Inference

- "Results" button
- First brings up "Contrast Manager" Can define single (t) or sets (F) of contrasts
- Then displays MIP
 - MIP = Maximum Intensity Projection
 - Glass Brain
 - Can "surf" by dragging cursor







WhyFaceWhyHand - HowFaceHowHand - All Sessions



SPM{T_285}



SPMresults: \sub03\results\precooked\2x2 Height threshold T = 3.119073 {p<0.001 (unc.)} Extent threshold k = 15 voxels

Statistics: p-values adjusted for search volume

set-leve	el	(luster-leve				р	eak-level			mm	nm mr	и
р	с	р _{ЕЮЕ-соп}	^ф FDR-соп	k _e	р _{ипсоп}	₽ _{FME-con}	⊄ FDR-соп	T	(Z_)	Р _{ипсоп}			
0.000	15	0.000	0.000	985	0.000	0.000	0.000	9.87	Inf	0.000	30	-82	-35
						0.000	0.000	8.65	Inf	0.000	15	-88	-38
						0.000	0.000	6.75	5.50	0.000	-33	-82	-35
		0.000	0.000	8757	0.000	0.000	0.000	9.26	Inf	0.000	-9	71	10
						0.000	0.000	9.18	Inf	0.000	-54	-58	28
						0.000	0.000	9.18	Inf	0.000	-54	17	-11
		0.000	0.000	1719	0.000	0.000	0.000	7.64	7.28	0.000	-3	-49	22
						0.000	0.000	7.23	5.92	0.000	-3	-67	43
						0.000	0.000	7.04	6.75	0.000	-6	-55	37
		0.000	0.000	383	0.000	0.000	0.000	6.96	6.68	0.000	51	-64	46
						0.000	0.000	6.37	5.15	0.000	54	-61	34
						0.055	0.011	4.75	4.55	0.000	35	-58	40
		0.000	0.000	239	0.000	0.011	0.002	5.18	5.06	0.000	-9	11	10
						0.145	0.023	4.53	4.45	0.000	-3	-13	10
						0.244	0.039	4.38	4.30	0.000	15	11	16
		0.040	0.015	57	0.003	0.016	0.003	5.10	4.99	0.000	60	-46	- 2
		0.170	0.049	36	0.015	0.096	0.015	4.65	4.56	0.000	3	20	-29
		0.056	0.019	52	0.005	0.290	0.046	4.32	4.25	0.000	6	-52	-41
						0.921	0.258	3.71	3.67	0.000	-3	-55	-47
		0.000	0.000	180	0.000	0.311	0.049	4.30	4.23	0.000	30	-25	64
						0.353	0.055	4.25	4.18	0.000	24	-31	64
		0.551	0.151	19	0.064	0.394	0.060	4.21	4.15	0.000	-18	-103	-11
				table sho	ws 3 local i	maxima more t	han 8.0mm :	apart					
Height th	reshold:	T = 3.12 n =	0 001 71 000	n		Degrees	of freedom =	11.0 285	01				

Height threshold: 1 = 3.12, p = 0.001 (1.000) Extent threshold: k = 15 voxels, p = 0.095 (0.698) Expected voxels per cluster, <k> = 5.537 Expected number of clusters, <c> = 1.20 FWEp: 4.819, FDRp: 4.298, FWEc: 57, FDRc: 36 Degrees of freedom = [1.0, 285.0] FWHM = 11.4 11.1 10.2 mm mm mm; 3.8 3.7 3.4 {voxels} Volume: 1700352 = 62976 voxels = 1180.1 resels Voxel size: 3.0 3.0 3.0 mm mm mm; (resel = 47.92 voxels) Page 1

< >

SPM: Inference

- Interactive window
 - p-values
 - Correced for whole brain or subregion
 - Plotting of time courses
 - "Overlays"
 - Superimpose results on other images
 - Current location and value

D-values whole brain	Multivariate eigenvari	CVA	Displav plot
current cluster	multivariate	Bayes	overlay 🛟
small volume	BMS	p-value	save
	Hemodynar	mics	clear exit ?
<i>co-ordinates</i> <i>x</i> = -29.22 <i>y</i> =	-42.97 z =	-27.50	statistic 9.19





SPM: Miscellaneous Tools

- "Display"
 - Displays image with orthogonal sections
 - Check intensity values
 - Change origin
 - Change world space
 - i.e. Apply rotations/translations

SPM for functional MRI						
Display	Check Reg	Ren 🛟	FMRI 🛟			
Tool 🛟	PPIs	ImCalc	DICOM Import			
Help	Utils 🛟	Batch	Quit			
Conviriant (c) 1991 1994-2011						







Crosshair Po	Crosshair Position					
mm: 0.8 -2	2.5 4.5					
VX: 129.4 12	25.9 56.5					
Intensity: 53	Intensity: 534.268					
right {mm}	0					
foward {mm}	0					
up {mm}	0					
pitch {rad}	0					
roll {rad}	0					
yaw {rad}	0					
resize {X}	1					
resize {y}	1					
resize {z}	1					
Reorient images	. Reset					

File:8ak/anatomy/het1spgr.img
Dimensions: 256 x 256 x 106
Datatype: int16
Intensity: Y = 1 X
FSL3.2beta
Vox size: 0.94 x 0.94 x 1.5
Origin: 128 128 53.5
Dir Cos: 1.000 0.000 0.000
0.000 1.000 0.000
0.000 0.000 1.000

Full Volume	Hide Crosshairs
World Space	NN interp 🗖
Auto Window	Add Blobs

SPM: Miscellaneous Tools

- "Check Reg"
 - Display multiple images
 - Essential tool for assessing alignment of images
 All images are displayed in the space of the first image















SPM: Miscellaneous Tools

- "ImCalc"
 - Image calculator
 - Give one or more images, perform MATLAB arithmetic and write out result
- "Utils"
 - Change directory
 - Results are written to current directory!
 - Delete files, etc.

SPM for functional MRI						
Display	Check Reg	Ren 🛟	FMRI 🛟			
Tool 🛟	PPIs	ImCalc	DICOM Import			
Help	Utils 🛟	Batch	Quit			
	Copyright (c) 1	991,1994-2011				

SPM12 Batch Editor

- Allows jobs to be saved, re-loaded, changed
- Helps remove "Oops!" factor
- Multiple steps can be loaded, run at once

O O Batch Editor		
File Edit View SPM Basic	10	
× 🗅 🖻 🖬 🕨		
Module List	Current Module: Normalise: Estim	ate & Write
Normalise: Estimate & Wr	Help on: Normalise: Estimate & Data	Write
	Subject Source Image Source Weighting Image Images to Write Estimation Options Template Image Template Weighting Image Source Image Smoothing Template Image Smoothing Affine Regularisation Nonlinear Frequency Cutoff Nonlinear Iterations Nonlinear Regularisation Writing Options Preserve	a/060518ak/anatomy/het1spgr.img,1 O files a/060518ak/anatomy/het1spgr.img,1 Work_Scott/spm8/templates/T1.nii,1 O files 8 0 ICBM space template 25 16 1
	Current Item: Data New: Subject Replicate: Subject (1) Delete: Subject (1)	2x3 double
		Edit Value
Data List of subjects. Images of each 1 or more options must be sele * Subject Currently selected options: * "Subject"	h subject should be warped differe cted from:	ntly.

SPM: Perspective

- SPM tries to be a single solution for all fMRI processing and analysis, but there can be no such thing!
 - FMRI is a rapidly evolving field where each dataset has huge number of observations!
- Don't let SPM be a black box!
- Understand what each component does
- Understand how to get at the data
 - e.g. using 'Display', 'Check Reg'

Resources

- SPMweb site: http://www.fil.ion.ucl.ac.uk/spm/
 - Introduction to SPM
 - SPM code download: SPM12 (also older versions)
 - Documentation & Bibliography
 - SPM course videos
 - Example data sets
 - SPM extensions
 - SPM email discussion list

Other software packages can complement SPM

- MRIcron: https://people.cas.sc.edu/rorden/mricron/index.html
- Quick and easy to read, display, and convert image data



BET brain extraction		
SUSAN noise reduction		
FAST Segmentation		
FLIRT linear registration		
FEAT FMRI analysis		
MELODIC ICA		
FDT diffusion		
POSSUM MRI simulator		
FSLView		
Misc Exit Help		

Alternatives

- FSL: http://www.fmrib.ox.ac.uk/fsl
 - Open source
 - Comprehensive tools for FMRI and DTI, has nice ICA analysis tool (MELODIC)
 - Free

•

AFNI: http://afni.nimh.nih.gov

- Open source
- Active community, multiple plugins





- BrainVoyager: http://www.brainvoyager.com
 - Excellent visualization
 - Closed source, ~\$7k



SPM Spatial Transformations

Imaging data formats

- Analyze format
 - .img Raw, binary data; 3D or 4D
 - .hdr Small binary header
 - Image dimension
 - Voxel size
- NIFTI format
 - .img + .hdr
 - Like Analyze, but different .hdr definition
 - .nii Single file! Header and Image file concatenated
 - World space transformation coded in NIFTI header



Current

Is Left Right?

- Two conventions for viewing images
 - Neurological
 - On the screen, Left is Left side of subject
 - As if standing behind the head of the patient
 - Radiological
 - On the screen, Left is Right side of subject
 - As if standing at the foot of the patient



R

Nose

R

- Standard in clinical radiology is, um, radiological
- SPM always uses Neurological convention
 - Default for Analyze set by defaults.analyze.flip in spm defaults.m
 - flip = 0 ,Neuro., flip = 1 ,Rad.
 - NIFTI images allegedly have no ambiguity about left & right

Coregister & realignment

- Coregistration & Realignment are rigid body transformations
 - Subject's head doesn't change size or warp between scans
 - Well, actually...
- Each requires a "Reference" and a "Source"
 - Reference: Fixed image
 - Source: Image that is transformed
- SPM modifies the header of the *object* image
 - Unless you explicitly ask it to, it doesn't write out a new image
 - Saves lots of disk space!

Voxel space vs. world space

- Voxel Space
 - Just the original image
 - No reorientations or flips
- World Space
 - Space defined by transformation from voxel to mm matrix M
 - Let v be a voxel location indexed from (1,1,1)
 - Then w=M*[v;1] is that location in world space, in mm
 - Can represent rotations, translations and flips

Data Fresh from fMRI Lab



Template image T1.nii scalped_avg152T1.nii

Coregistration



After Coregistration



Spatial Normalization



Spatial Normalisation



After "Writing Normalized"



Group Analysis: Strategy 1 Only transform contrast img's



Group Analysis: Strategy 2 Transform all functionals



Normalization recommendations

- If not doing segmented normalization, with 'scalped' brains use 'scalped' template
 - Scalped template scalped_avg152T1.nii
 - Should give best results
 - We don't care about scalp alignment!
- Make sure WM equal in brightness
 - T1's can have inhomogeneity artifact, where center of volume is brighter
 - Should apply homogeneity correction (bias correction)
 - UM: make sure to use (e)ht1spgr, (e)ht1overlay