Brain Image Analysis with SPM (VBM) and Freesurfer

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Outline

Voxel-Based Morphometry

- Sequence of processes
- 1. Co-registration
- 2. Segmentation
- 3. DARTEL
- 4. Normalization
- 5. Stats
- Freesurfer
 - Recon-all
 - Segmentation
 - results

Measuring differences with MRI

- What are the significant differences between populations of subjects?
- What effects do various genes have on the brain?
- What changes occur in the brain through development or aging?
- A significant amount of the difference (measured with MRI) is anatomical.

Voxel-Based Morphometry

- Based on comparing regional volumes of tissue.
- Produce a map of statistically significant differences among populations of subjects.
 - e.g. compare a patient group with a control group.
 - or identify correlations with age, test-score etc.
 - The data are pre-processed to sensitise the tests to regional tissue volumes.
 - Usually grey or white matter.
- Suitable for studying focal volumetric differences of grey matter.

Volumetry





T1-Weighted MRI

Grey Matter



Voxel-based morphometry – preprocessing overview



Slide from Hobbs & Novak, MfD (2008)

VBM (Procedure in SPM 12)

Requires MATLAB (Commercial software)

SPM Dartel VBM analysis (1)

- INPUT IMAGE FILE FORMAT: NIFTI (.nii)
 - (SPM can import a various of file formats, like DICOM)
- Quality check of the images using Freesurfer's "slicesdir"
 - Working Folder with all images to process > slicesdir *.nii
 - Inspect Working Folder\slicesdir\index.html



Check Reg – Inspect multiple images

SPM12 (6685): Menu 🔶 🗕							
Realign (Est. Coregister (Smooth Segment						
Model specification review and estimation Specify 1st-level Review							
Inference Results							
	Dynamic Cau	ısal Modellir	ng				
S	SPM for fur	nctional M	IRI				
Display	Check Reg	Render	. 🔻 FMRI 💌				
Toolbox: 👻	PPIs	ImCalc	DICOM Import				
Help	Utils 👻	Batch	Quit				







1. Coregister (estimate and reslice (3rd option))

SPM12 (6685): Menu + 🛛 🗠 🖉							
Realign (Est •Slice timingSmoothCoregister (•Normalise (•Segment							
Model specification review and estimation Specify 1st-level Review Specify 2nd-level Estimate							
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Display	Check Reg	Render	. 🔻 FMRI 👻				
Toolbox: 👻	PPIs	ImCalc	DICOM Import				
Help	Utils 👻	Batch	Quit				

Select TPM Template as Reference Select NIFTI (T1W MRI) as Source

Module List	Current Module: Coregister: Est	imate & Reslice
Coregister: Estimate 8▲	Help on: Coregister: Estimate Reference Image Source Image Other Images Estimation Options . Objective Function Separation	& Reslice /spm12/tpm/TPM.nii, 1 0006-000001-01.nii, 1 ed Mutual Information
	. Tolerances . Histogram Smoothing Reslice Options	1x12 double [7 7]
	. Wrapping . Masking . Filename Prefix	Dont mask images r
	Current Item: Source Image	
	/scratch/marco/s100940460V	-0601-00006-000001-01.nii,1
	Specify	

After coregistration (rFilename.nii)



2. Segment (From SPM menu) Select rFilename as Volumes

Module List	Current Module: Segment	
Segment	Help on: Segment Data . Channel	•
	b0V-0601-00006-000001-01.nil,1 Bias regularisation Bias FWHM Save Bias Corrected Save Nothing Tissues	3000
	Insue I	
	Current Item: Volumes	
	/scratch/marco/rs100940460V-0601-00006-000001-01.nii,1	•
-	Specify	

Check Reg results (Binary images, unwarped)



3. Run Dartel (create Template)



Select rc1rFilename as first image Select rc2rFilename as second image

Module List	Current Module: Run Dartel (creat	e Templates)
Run Dartel (create Ter	Help on: Run Dartel (create Temp Images . Images . Images Sattinges	olates) 0006-000001-01.nii,1 0006-000001-01.nii,1
	. Template basename . Regularisation Form . Outer Iterations	Template Linear Elastic Energy
	Inner Iterations Reg params Time Steps Smoothing Parameter Outer Iteration	3 [4 2 1e-06] 1 16
	Inner Iterations Reg params Time Steps	3 [2 1 1e-06] 1
	Current Item: Images	
	/scratch/marco/rc2rs100940460)V-0601-00006-000001-01.nii,1▲
	Specify	

nages

Select a set of imported images of the same type to be registered by minimising a measure of difference from the template.

4. Normalise to MNI space



Select Few Subjects, Add Subject Select u_rc1rFilename as Flow field Select c1rFilename as image

Module List	Current Module: Normalise to MNI Space		Current Module: Normalise to MNI Space	
Normalise to MNI Spa 🔺	Help on: Normalise to MNI Space Dartel Template /scratch/marco/Template 6 Select according to . Few Subjects Subject	.nii	 Help on: Normalise to MNI Space Dartel Template /scratch/marco/Template 6.nii Select according to Few Subjects Subject 	
	Flow Field 06-000001-01 Template Images <	.nii -X N] ble ns 8]		
▼	Current Item: Flow Field /scratch/marco/u rclrs100940460V-0601-00006-000001-0)1 T •	Current Item: Images /scratch/marco/c1rs100940460V-0601-00006-000001-01.nii Specify	

Dartel flow field for this subject.

Finally the result (Check Reg)

Selected 2/[1-24] files. (Added 1/1 file.) /scratch/marco/swc1rs100940460V-0601-00006-000001-01.nii,1 /scratch/marco/spm12/tpm/TPM.nii,1





Summary VBM process



Apriori

Canonical Montreal neurological institution (MNI) image



MNI Template



5. Stats – Calculation of TIV (total intracranial volume)



Select ... seg8.mat as Segm. file Results are shown in Matlab command window unless the output file is specified

Fissue Volumes Help on: Tissue Volumes Segmentation mat-files Segmentation mat-files Maximum tissue class 3 Mask image /toolbox/spm12/tpm/mask ICV.nii,1 Output file "	Aodule List	Current Module: Tissue Volumes
Current Item: Segmentation mat-files	ïissue Volumes ▲	Help on: Tissue Volumes Segmentation mat-files -0601-00006-000001-01 seg8.mat Maximum tissue class 3 Mask image /toolbox/spm12/tpm/mask ICV.nii,1 Output file "
/scratch/marco/rs100940460V-0601-00006-000001-01 seg8.m		Current Item: Segmentation mat-files /scratch/marco/rs100940460V-0601-00006-000001-01 seg8.m▲

Maximum tissue class

Specify the maximum tissue class, T, where tissues 1:T will be measured. The default of 3 corresponds to GM, WM and CSF for the default tissue prior probability maps 'TPM.nii,1' to 'TPM.nii,3'

The sum of these tissues will also be computed, which by default is the total intracranial volume (known as TIV or ICV). If T=2, the sum will by default be the total parenchymal brain values (lengues as TD) (or DD) () which is also often of interact

```
Segmentation files:
        /scratch/marco/rs100940460V-0601-00006-000001-01_seg8.mat
Volumes (litres):
    0.5838
```

0.3859

'Tissue Volumes' Done Done

0.3943

6. SPM analysis (just a teaser)



Use of covariates with VBM images. The importance of TIV.

Module List	Current Module: Factorial design specification	
Factorial design specif	Help on: Factorial design specification Directory Design	<-X
	. One-sample t-test Scans Covariates Covariate	<-X
	Vector Name Interactions	[1 35] TIV None
	Centering . Covariate	Overall mean
	Name Interactions Centering Multiple covariates	Age None O∨erall mean ▼
	Current Item: Vector	
	65	
	Specify	



Reference for VBM Dartel

Volodymyr B. Bogdanov

https://www.youtube.com/watch?v=YVDG9cjn UPU (50 min only on DARTEL VBM)

Info on scripting the batch files for multiple studies

Freesurfer analysis

Freesurfer in a nutshell

- Neuroimaging analysis software package (Open Source)
- Detailed characterization of anatomy (Cortex thickness, folding patterns, ROIs, Subcortical structure boundaries, Hippocampal subfields)
- Longitudinal analysis (detect changes)
- Statistical tools (GLM, LME, ...), group comparison
- Multi modal integration: MRI fMRI (task, rest) DWI Tractography PET

Freesurfer pipeline outline



T1 Weighted Input



Skull Stripping



Volumetric Labeling



Intensity Normalization





Simpler than SPM and fully automated... One command:

recon-all -i file.dcm -subject karl -all

Results will be stored in \$SUBJECTS_DIR/karl

The default directory should be set when installing the software: <u>setenv SUBJECTS_DIR /specificpath/</u>

Slower than SPM, one subject might take up to 20 hours of processing

Freesurfer terminology

ROI = Region Of Interest Volume/Image (Subcortical):

- Segmentation
 - (subcortical automatic segmentation = <u>aseg</u>)

Surface (Cortical):

- Parcellation/Annotation
 - (subcortical automatic segmentation = <u>aparc</u>)
- Clusters, Masks, Labels we created

Segmentation

- Output:
 - Volumes



• (for surfaces) Surface segmentation



- Volume-style format (mgz, nii, nii.gz)
- Each voxel has one index (number ID)
- Index List can be found in color lookup table (LUT): \$FREESURFER_HOME/FreeSurferColorLUT.txt
- aseg.mgz, aparc+aseg.mgz, wmparc.mgz

Slower than SPM, one subject might take up to 20 hours of processing

Freesurfer outputs in karl/stats the results of the segmentation, volumes and thicknesses:

aseg.stats – subcortical volumetric stats wmparc.stats – white matter segmentation volumetric stats lh.aparc.stats – left hemi Desikan/Killiany surface stats rh.aparc.stats – right hemi Desikan/Killiany surface stats lh.aparc.a2009.stats – left hemi Destrieux rh.aparc.a2009.stats – right hemi Destrieux

ROI summary example:

Ind	Index SegId NVoxels Volume_mm3 StructName normMean normStdDev normMin normMax normRange								
1	1	0	0.0	Left-Cerebral-Exterior	0.0000	0.0000	0.0000	0.0000	0.0000
2	2	265295	265295.0	Left-Cerebral-White-Matter	106.6763	8.3842	35.0000	169.0000	134.0000
3	3	251540	251540.0	Left-Cerebral-Cortex	81.8395	10.2448	29.0000	170.0000	141.0000
4	4	7347	7347.0	Left-Lateral-Ventricle	42.5800	12.7435	21.0000	90.0000	69.0000
5	5	431	431.0	Left-Inf-Lat-Vent	66.2805	11.4191	30.0000	95.0000	65.0000
6	6	0	0.0	Left-Cerebellum-Exterior	0.0000	0.0000	0.0000	0.0000	0.0000

- To generate spreadsheets of group data:
- asegstats2table –help
- aparcstats2table --help

Aseg.stats

Index	SegId	NVoxe1s	Volume_mm3	3 StructName	Mean	StdDev	Min	Max	Range
1	4	5855	5855.0	Left-Lateral-Ventricle	37.7920	10.9705	20.0000	88.0000	68.0000
2	5	245	245.0	Left-Inf-Lat-Vent	56.4091	9.5906	26.0000	79.0000	53.0000
3	7	16357	16357.0	Left-Cerebellum-White-Matter	91.2850	4.8989	49.0000	106.0000	57.0000
4	8	60367	60367.0	Left-Cerebellum-Cortex	76.3620	9.5724	26.0000	135.0000	109.0000
5	10	7460	7460.0	Left-Thalamus-Proper	91.3778	7.4668	43.0000	108.0000	65.0000
6	11	3133	3133.0	Left-Caudate	78.5801	8.2886	42.0000	107.0000	65.0000
7	12	5521	5521.0	Left-Putamen	86.9680	5.5752	66.0000	106.0000	40.0000
8	13	1816	1816.0	Left-Pallidum	97.7162	3.4302	79.0000	106.0000	27.0000
9	14	852	852.0	3rd-Ventricle	41.9007	11.8230	22.0000	69.0000	47.0000
10	15	1820	1820.0	4th-Ventricle	39.7053	10.6407	20.0000	76.0000	56.0000
11	16	25647	25647.0	Brain-Stem	85.2103	8.2819	38.0000	106.0000	68.0000
12	17	4467	4467.0	Left-Hippocampus	77.6346	7.5845	45.0000	107.0000	62.0000
13	18	1668	1668.0	Left-Amygdala	74.5104	5.8320	50.0000	94.0000	44.0000
14	24	1595	1595.0	CSF	52.1348	11.6113	29.0000	87.0000	58.0000

Index: nth Segmentation in stats file SegId: index into lookup table Nvoxel: number of Voxel in segmentation Volume: Volume StructName: name of structure from LUT Mean/Std/Min/Max/Range: intensity across ROI

Aseg.stats Global Measures: Cortical, Gray, White, Intracranial Volumes

Also in aseg.stats header:

- # Measure lhCortex, lhCortexVol, Left hemisphere cortical gray matter volume, 192176.447567, mm^3
- # Measure rhCortex, rhCortexVol, Right hemisphere cortical gray matter volume, 194153.9526, mm^3
- # Measure Cortex, CortexVol, Total cortical gray matter volume, 386330.400185, mm^3
- # Measure lhCorticalWhiteMatter, lhCorticalWhiteMatterVol, Left hemisphere cortical white matter volume, 217372.890625, mm^3
- # Measure rhCorticalWhiteMatter, rhCorticalWhiteMatterVol, Right hemisphere cortical white matter volume, 219048.187500, mm^3
- # Measure CorticalWhiteMatter, CorticalWhiteMatterVol, Total cortical white matter volume, 436421.078125, mm^3
- # Measure SubCortGray, SubCortGrayVol, Subcortical gray matter volume, 182006.000000, mm^3
- # Measure TotalGray, TotalGrayVol, Total gray matter volume, 568336.400185, mm^3
- # Measure SupraTentorial, SupraTentorialVol, Supratentorial volume, 939646.861571, mm^3
- # Measure IntraCranialVol, ICV, Intracranial Volume, 1495162.656130, mm^3

hCortex, rhCortex, Cortex: hCorticalWhiteMatter, ... : SubCortGray: ntraCranialVol:

tex, Cortex:surface-basedcortical gray matter volumeeMatter, ... :surface-basedcortical white matter volumevolume-basedvolume-basedsufface-based:EstimatedTotal Intracranial volume (eTIV)http://surfer.nmr.mgh.harvard.edu/fswiki/eTIV

Freesurfer upon completion, outputs the labels...

In karl/labels we can find



lh.aparc.annot



rh.aparc.annot

Desikan/Killiany Atlas





rh.aparc.a2009s.annot

Destrieux Atlas

Surfaces are extracted and saved and cortical thickness analysis can be performed on these (SURFSTAT in Matlab, for example)

In karl/surf we can find



"White matter" segmentation



- Brain stem included!
- Cerebellum excluded!
- Not like VBM segmented white matter

Freeview - Visualisation

freeview -v \ karl/mri/T1.mgz \ karl/mri/wm.mgz \ karl/mri/brainmask.mgz \ karl/mri/aseg.mgz:colormap=lut:opacity=0.2 \ -f karl/surf/lh.white:edgecolor=blue \ karl/surf/lh.pial:edgecolor=red \ karl/surf/rh.white:edgecolor=blue \ karl/surf/rh.pial:edgecolor=red

-v for volumes,
-f for surfaces



Resource for freesurfer

<u>http://surfer.nmr.mgh.harvard.edu/fswiki/</u>

 FreeSurfer Course Copenhagen 2016 https://fscph.nru.dk/programme.html



Import DICOM in SPM

SPM > Util > Dicom Import

Module List	Current Module: DICOM Import	
DICOM Import	Help on: DICOM Import DICOM files Directory structure for converted files Output directory Protocol name filter Conversion options . Output image format . Use ICEDims in filename	▲ No directory hierarchy /scratch/marco .* Single file (nii) NIfTI No
	Current Item: Output directory	
	/scratch/marco	<u> </u>
	Specify	