



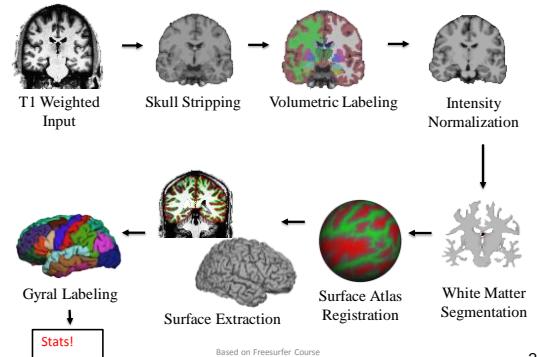
DPABISurf Advanced: More about FreeSurfer

Chao-Gan YAN, Ph.D.
严超赣

yancg@psych.ac.cn
<http://fmri.org>
The R-fMRI Lab

Institute of Psychology, Chinese Academy of Sciences

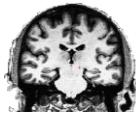
Processing Stream Overview



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Input: T1 Weighted Image

- T1 Contrast: white matter brighter than gray matter
- ~1mm³(no more than 1.5mm)
- Higher resolution may be worse!
- Full Brain
- Usually one acquisition is ok
- MPRAGE or SPGR
- 1.5T or 3T
- 7T might have problems
- Subject age > 5 years old
- Brain has no major problems (ie, tumors, parts missing)
- Non-human primates possible



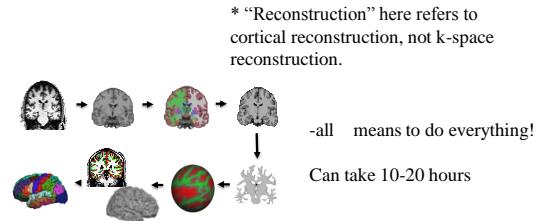
More MRI Pulse Sequence Parameter Details:
<http://www.nmr.mgh.harvard.edu/~andre>

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Fully Automated Reconstruction*

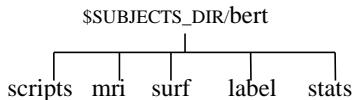
```
recon-all -i file.dcm -subject bert -all
```



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Upon Completion...

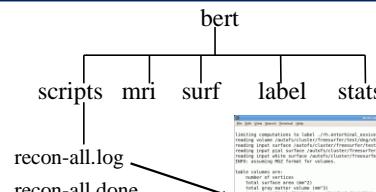


recon-all -i file.dcm -subject **bert** -all ~400MB

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Upon Completion...

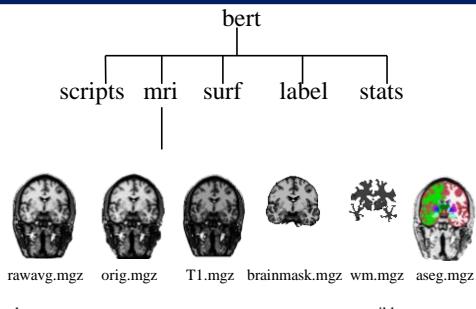


Just because it finishes
“without error” does not mean
that everything is ok!

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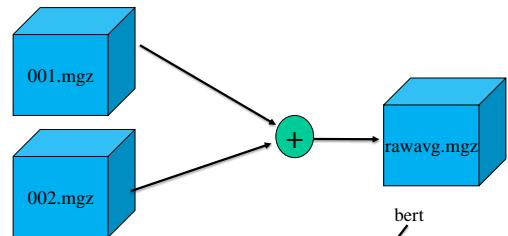
Upon Completion...



mgz = "compressed mgh" format (like nifti) unique to FreeSurfer

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Motion Correction and Averaging

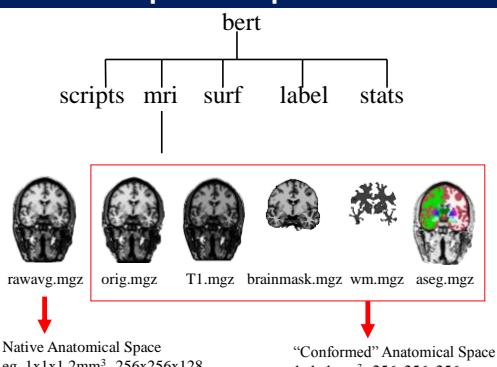


Does not change native resolution.
Usually only need one.

Based on Freesurfer 001.mgz 002.mgz

8

Upon Completion...



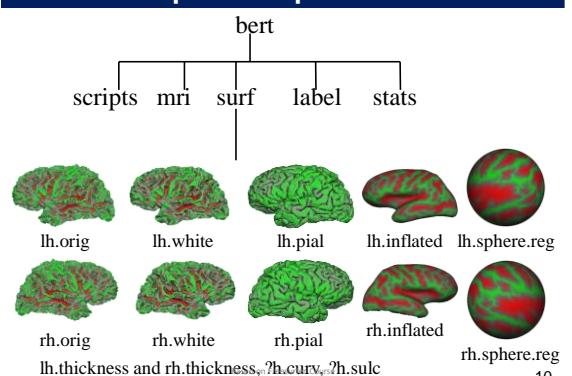
Native Anatomical Space
eg, 1x1x1.2mm³, 256x256x128

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"Conformed" Anatomical Space
1x1x1mm³, 256x256x256

9

Upon Completion...

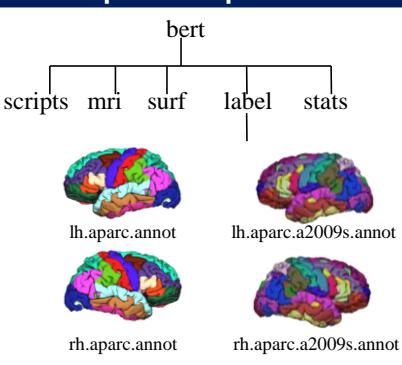


lh.thickness and rh.thickness, ?h.curv, ?h.sulc

rh.sulc.reg

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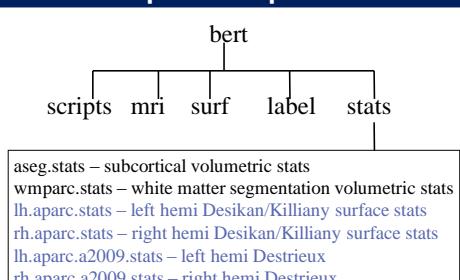
Upon Completion...



Desikan/Killiany Atlas Destrieux Atlas

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Upon Completion...



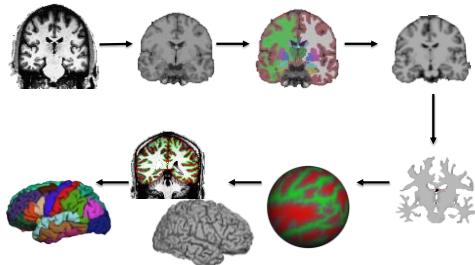
aseg.stats – subcortical volumetric stats
wmparc.stats – white matter segmentation volumetric stats
lh.aparc.stats – left hemi Desikan/Killiany surface stats
rh.aparc.stats – right hemi Desikan/Killiany surface stats
lh.aparc.a2009.stats – left hemi Destrieux
rh.aparc.a2009.stats – right hemi Destrieux

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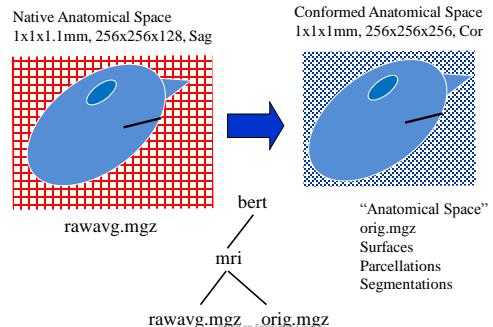
Some of the Processing Steps...



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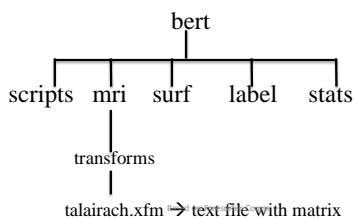
Conform Step



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Talairach Transform

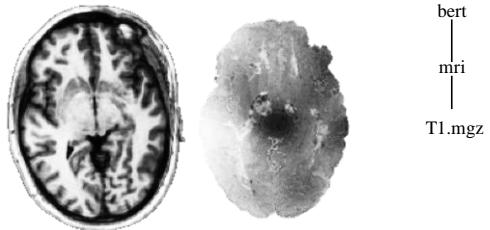
- Computes 12 DOF transform matrix
- Does NOT resample to Talairach space!
- MNI305 template
- Mostly used to report coordinates



talairach.xfm → text file with matrix

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Intensity Bias



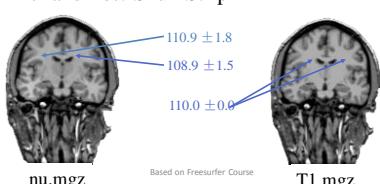
- Left side of the image much brighter than right side
- Worse with many coils
- Makes gray/white segmentation difficult

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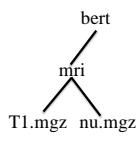
Intensity Normalization

- Removes B1 bias field
- NU (MNI) nu.mgz
- Presegmentation (T1.mgz)
 - Most WM = 110 intensity
 - Pre- and Post-Skull Strip

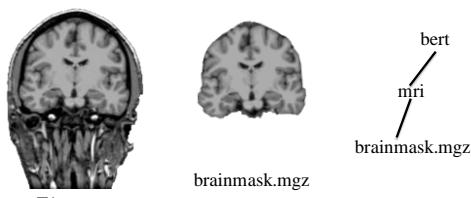


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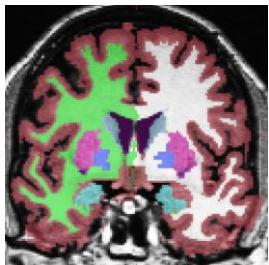
- Removes all non-brain
 - Skull, Eyes, Neck, Dura
- brainmask.mgz (cf, brain.mgz)



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Automatic Volume Labeling



ASeg Volume

Atlas: \$FREESURFER_HOME/average/RB_all_2008-03-26

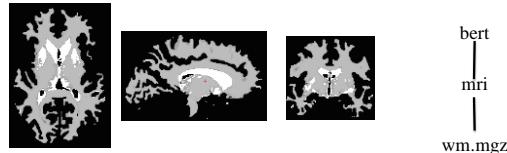
- Used to fill in subcortical structures for creating subcortical mass
- Useful in its own right
- aseg.mgz
- More in ROI Talk bert

mri
aseg.mgz

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"White Matter" Segmentation

- Separates white matter from everything else
- Uses aseg to "fill in" subcortical structures
- Cerebellum removed, brain stem still there
- wm.mgz -- "wm" not a very good name!

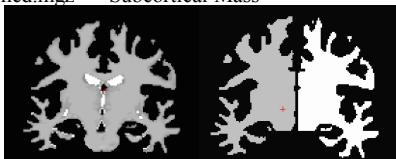


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Fill and Cut (Subcortical Mass)

- Fills in any holes.
- Removes any islands
- Removes brain stem
- Separates hemispheres (each hemi has different value)
- filled.mgz = "Subcortical Mass"

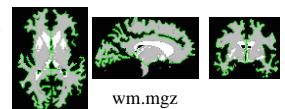
WM Volume (wm.mgz) Filled Volume (filled.mgz)
(Subcortical Mass)

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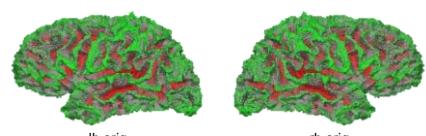
Surface Extraction

- Hemispheres separated
- Fit to wm.mgz
- 1mm resolution
- Rough, jagged



wm.mgz

bert
surf
lh.orig
rh.orig



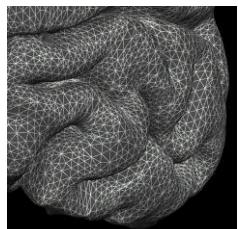
Based on Freesurfer Course

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Surface Model

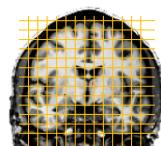


- Mesh ("Finite Element")
- Vertex = point of triangles
- Neighborhood
- XYZ at each vertex
- Triangles/Faces ~ 300,000
- Vertices ~ 140,000
- Area, Distance
- Curvature, Thickness



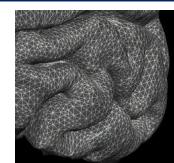
23

Volume vs Surface Model



Volume

- uniform grid
- voxel is an intersection of grid lines
- columns, rows, slices
- voxel size/distance
- voxel assigned a value
- XYZ



Surface

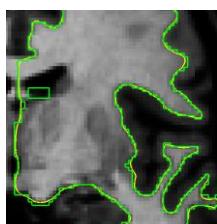
- NON-uniform grid
- vertex is an intersection of triangles
- each vertex has an index
- distance between vertices ~1mm
- vertex assigned a value
- XYZ

Vector of vertex values (~140,000)

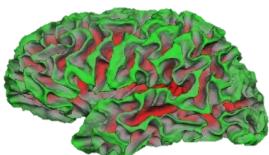
← →

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White Matter Surface



- Nudge orig surface
- Follow T1 intensity gradients
- Smoothness constraint
- Vertex identity preserved



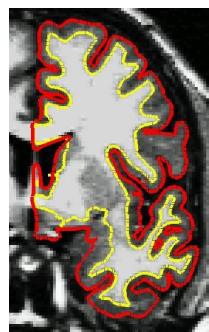
orig surface
white surface

lh.white rh.white

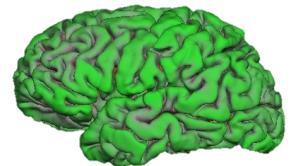
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Pial Surface



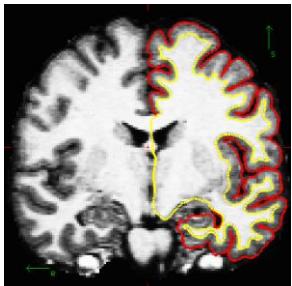
- Nudge white surface
- Follow T1 intensity gradients
- Vertex identity preserved



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Pial surf grows from white surf

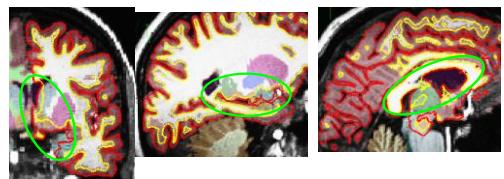


Errors in pial surface placement are typically caused by underlying errors in the white matter placement, and can be corrected by interventions such as white matter control points.

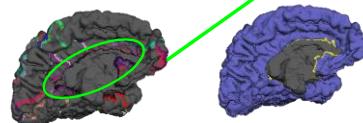
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Non-Cortical Areas of Surface



Amygdala, Putamen, Hippocampus, Caudate, Ventricles, CC

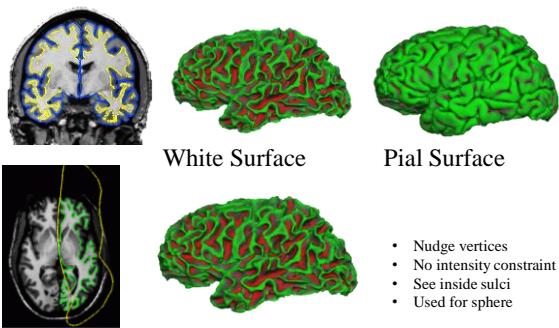


?h.cortex.label

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Inflation: 2D Surface in 3D Space

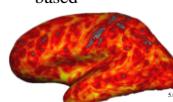


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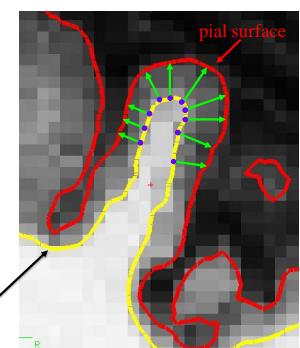
Cortical Thickness

- Distance between white and pial surfaces
- One value per vertex
- Surface-based more accurate than volume-based



"Overlay", "Heat map"

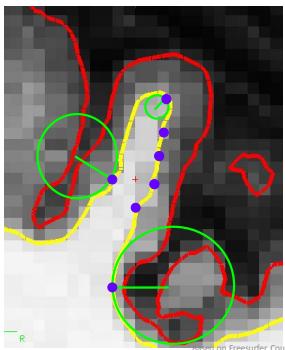
white/gray surface
lh.thickness, rh.thickness



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Curvature (Radial)



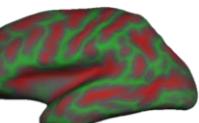
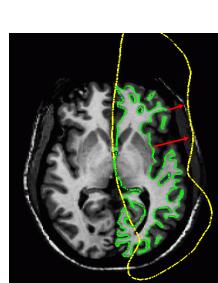
- Circle tangent to surface at each vertex
- Curvature measure is 1/radius of circle
- One value per vertex
- Signed (sulcus/gyrus)



lh.curv, rh.curv
"Overlay", "Red/Green"

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Sulcal Depth



lh.sulc, rh.sulc

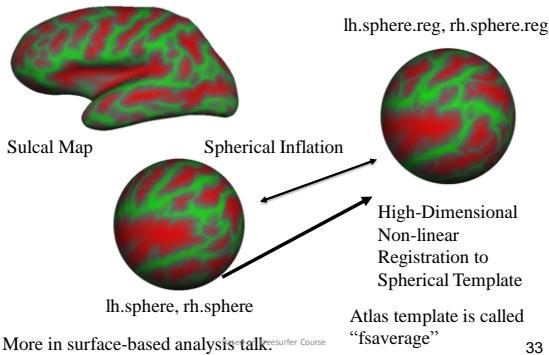


lh.curv, rh.curv

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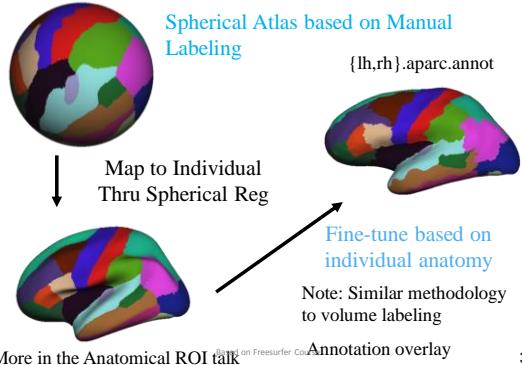
Spherical Registration



More in surface-based analysis talk:
Based on Freesurfer Course

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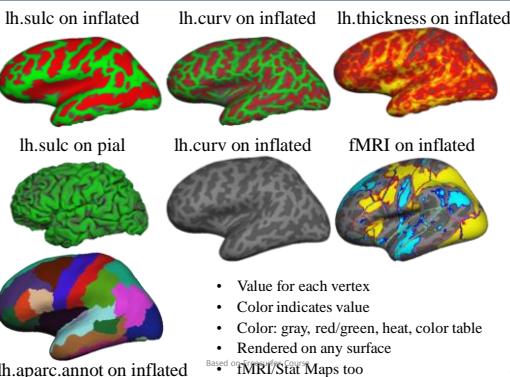
Automatic Cortical Parcellation



More in the Anatomical ROI talk
Based on Freesurfer Course

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Surface Overlays



- Value for each vertex
- Color indicates value
- Color: gray, red/green, heat, color table
- Rendered on any surface
- fMRI/Stat Maps too

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ROI Summaries:

\$SUBJECTS_DIR/bert/stats

aseg.stats – volume summaries

?h.aparc.stats – desikan/killiany surface summaries

?h.aparc.a2009s.stats – destrieux surface summaries

wmparc.stats – white matter parcellation

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-Venticle	42.5805	12.7435	21.0000	90.0000	69.0000
5	5	431	431.0	Left-Inf-Lat-Ventricle	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
...									

Routines to generate spread sheets of group data

• asegsstats2table --help

• aparcstats2table --help

More info in Anatomical ROI talk
Based on Freesurfer Course

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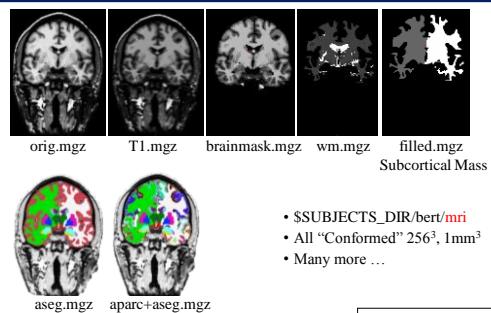
Results

- Volumes
- Surfaces
- Surface Overlays
- ROI Summaries

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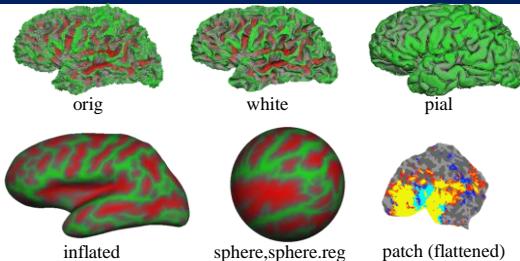
Volumes

Volume Viewer:
tkmedit

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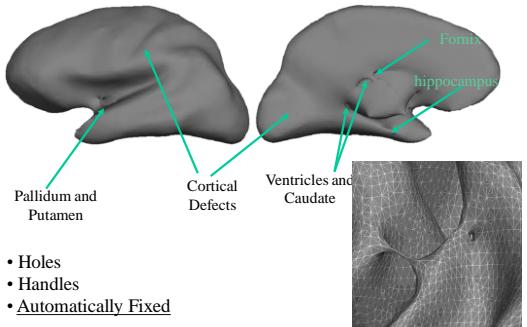
Surfaces

Surface Viewer:
tksurfer

- \$SUBJECTS_DIR/bert/surf
- Number/Identity of vertices stays the same (except patches)
- XYZ Location Changes
- Flattening not done as part of standard reconstruction

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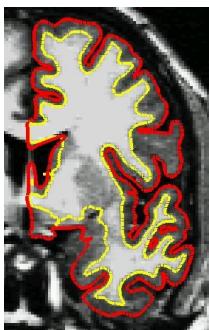
Topological Defects



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Find “Subcortical Mass”

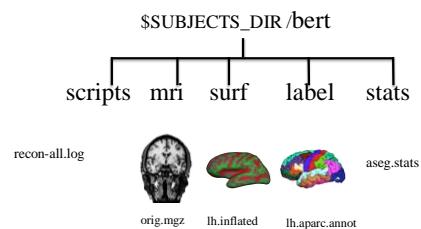


- All White Matter
- All Subcortical Structures
- Ventricles
- Excludes brain stem and cerebellum
- Hemispheres separated
- Connected (no islands)
- Many Stages ... More Later ...

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Overview



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

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Surface Reconstruction Overview

- Input: T1-weighted (**MPRAGE,SPGR**)
- Find white/gray surface
- Find pial surface
- “Find” = create mesh
 - Vertices, neighbors, triangles, coordinates
 - Accurately follows boundaries between tissue types
 - “Topologically Correct”
 - closed surface, no donut holes
 - no self-intersections
- Generate surface-based cross-subject registration
- Label cortical folding patterns
- Subcortical Segmentation along the way

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Thanks for your attention!

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