Contents

An introduction to the custom preprocessing pipeline built for surfaced-based analysis

1. Motivation – Why surface?
2. Overall scheme – Covering multiple softwares (e.g., FSL, AFNI, ANTs, Freesurfer)
3. Pipeline details – Comparison with existing preprocessing pipelines
4. Practical applications – Not limited to surface analysis

3. Pipeline details – Comparison with existing preprocessing pipelines

Overall scheme of this pipeline

A) Make directories for preprocessed data (r1)

B) Convert DICOM images to NIFTI format (using dicm2nii.m, which was adapted from https://github.com/xiangruili/dicm2nii) (r2-r4)

C) Basic environmental setup for preprocessing (s1)

D) Preprocessing structural data

For surface-based preprocessing:

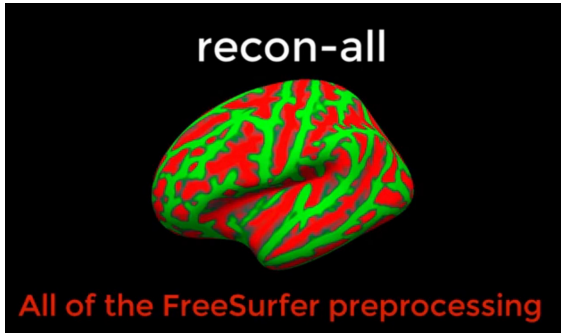
1. Use recon-all (Freesurfer) to correct bias-field, extract brain tissue, reconstruct structural images to cortical surface, and do anatomical segmentation (s2)
2. Use ciftify_recon_all (CIFTIFY, Dickie et al., 2019) to normalize structural images to MNI space, and resample native surface images onto Conte69 164k and 32k CIFTI surface (Van Essen et al., 2012) using MNI normalization parameters (s3)

For Volume-based preprocessing:

1. Use antsBrainExtraction (ANTs) to correct bias-field and extract brain tissue (s4)
2. Use antsRegistrationSyN (ANTs) to normalize structural images to MNI space (s4)
3. Use FAST (FSL) to do anatomical segmentation (s4)

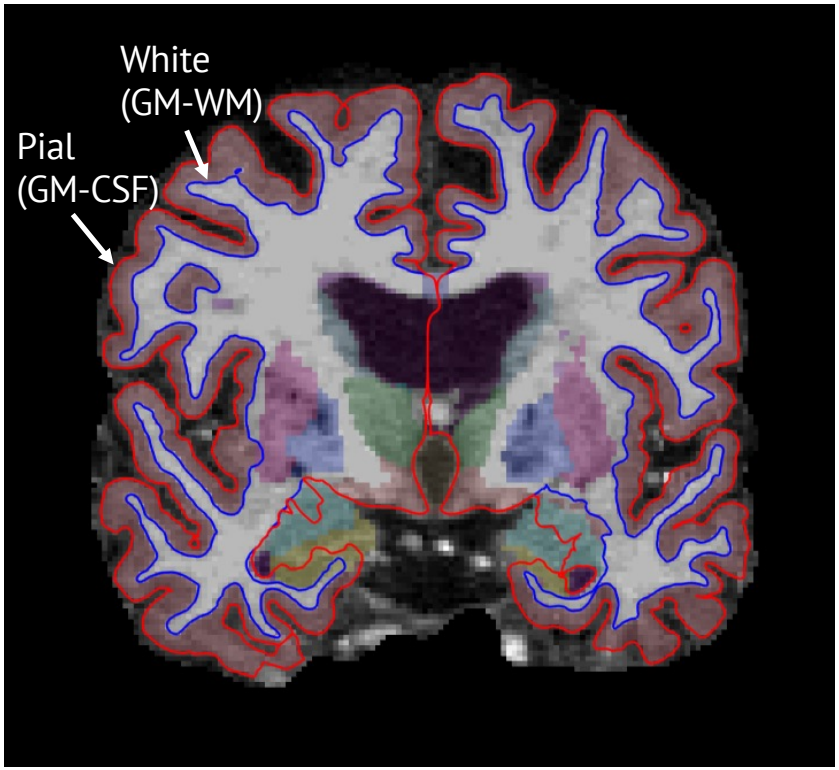
- Similar with the SPM-based COCOAN pipeline.
- For surface-based preprocessing, recon-all and ciftify was used to project structure data from volumetric space to CIFTI space.
- For volume-based preprocessing, ANTs were used.

3. Pipeline details – Comparison with existing preprocessing pipelines



https://www.youtube.com/watch?v=zeFPx0fMXRQ

1. Motion Correction
2. NU Intensity Correction
3. Talairach
4. Normalization
5. Skull Strip
6. Automatic Subcortical Segmentation
7. EM (GCA) Registration
8. CA Normalize
9. CA Register
10. Remove neck
11. EM Registration, with Skull
12. CA Label
13. ASeg Stats
14. Normalization2
15. WM Segmentation
16. Cut/Fill
17. Tessellation
18. Orig Surface Smoothing
19. Inflation
20. QSphere
21. Automatic Topology Fixer
22. Final Surfaces
23. Cortical Ribbon Mask
24. Spherical Inflation
25. Ipsilateral Surface Registation (Spherical Morph)
26. Contralateral Surface Registation (Spherical Morph)
27. Average Curvature
28. Cortical Parcellation
29. Parcellation Statistics



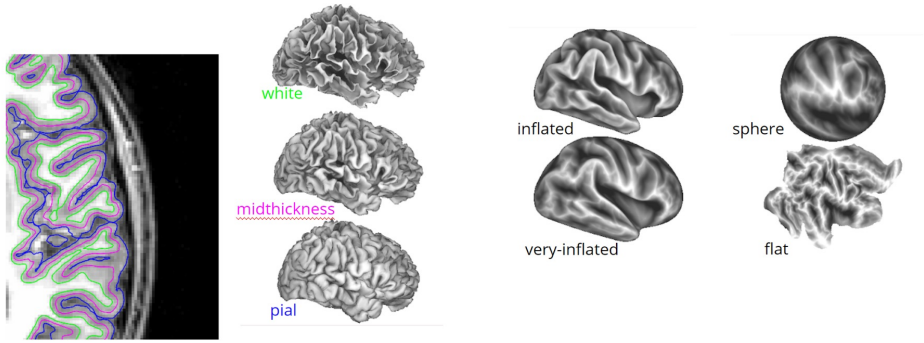
https://surfer.nmr.mgh.harvard.edu/fswiki/FsTutorial/OutputData_freeview

3. Pipeline details – Comparison with existing preprocessing pipelines

cifti-for-your recon_all outputs

ciftify_recon_all

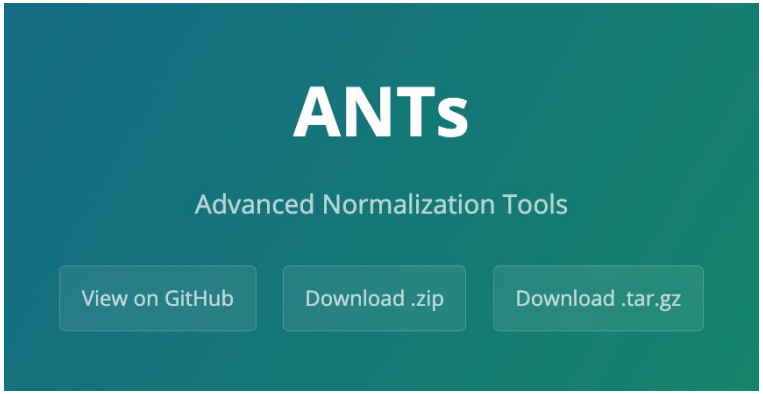
- T1w/Native: The freesurfer "native" output meshes
- MNINonLinear/Native: The T1w/Native mesh warped to MNINonLinear
- MNINonLinear/fsaverage_LR32k
  - the surface registered space used for fMRI and multi-modal analysis
  - This 32k mesh has approx 2mm vertex spacing
- MNINonLinear_164k_fs_LR (in the MNINonLinear folder):
  - the surface registered space used for HCP's anatomical analysis
  - This 164k mesh has approx 0.9mm vertex spacing



surface	description	useful for
white	The border between the gray matter and the white matter	defines the inside of the cortical ribbon
pial	The border between the gray matter and the outside of the brain (pia matter)	defines the outsite of the cortical ribbon
midthickness	The midpoint between the white surface and pial surface	measuring distance and surface area
sphere	The surface vertices as a sphere	registration and resampling
inflated	The midthickness is blown up like a balloon	visualiation
very-inflated	The midthickness is blown up like a balloon *more*	visualizations
flat	the cortex ripped apart	visualizations (one less intuitive view of the entire hemisphere)

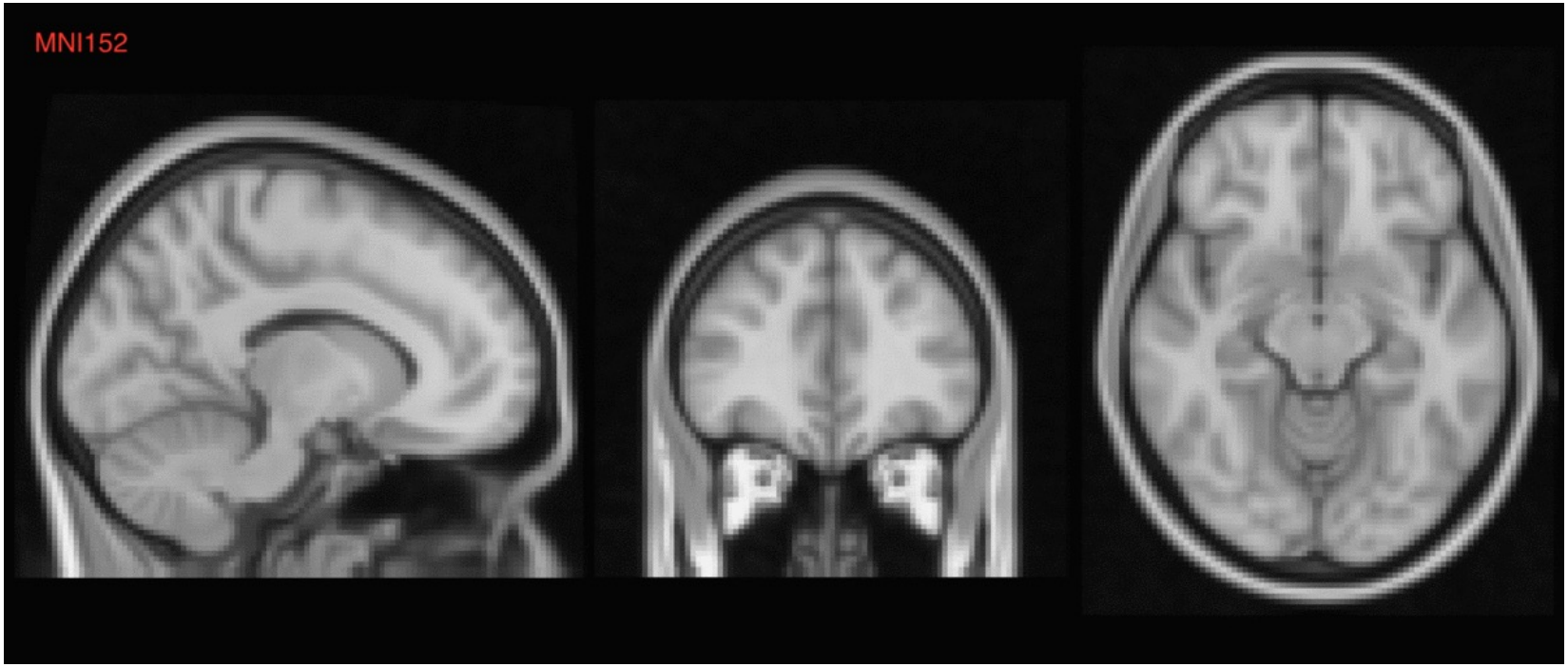
https://edickie.github.io/ciftify/#/03a_cifti-for-your_recon_all

3. Pipeline details – Comparison with existing preprocessing pipelines



3. Pipeline details – Comparison with existing preprocessing pipelines

SPM (cocoanlab) vs. ANTs



3. Pipeline details – Comparison with existing preprocessing pipelines

E) Preprocessing functional data

1. Use 3dTshift (AFNI) to do slice-timing correction (s5, if needed)
2. Use 3dvolreg (AFNI) to do motion-correction (s6)
3. Use topup/applytopup (FSL) to do distortion-correction (s7)
4. Use flirt (FSL) with BBR cost function to co-register functional images to structural images (s8)
5. For surface-based preprocessing, additionally use bbregster (Freesurfer) to refine co-registration (s8)
6. Use ICA-AROMA (Pruim et al., 2015) to remove motion-related signals (s9)
7. Use 3dTproject (AFNI) to remove nuisance signals (s10)
8. Use applywarp (FSL, for surface-based preprocessing) or antsApplyTransforms (ANTs, for volume-based preprocessing) to normalize functional images to MNI space
9. For volume-based preprocessing, use susan (FSL) to spatially smooth functional images
10. For surface-based preprocessing, use ciftify_subject_fmri (CIFTIFY, Dickie et al., 2019) to transform functional images to Conte69 32k CIFTI surface, and spatially smooth (based on both surface-based and volume-based smoothing) functional images

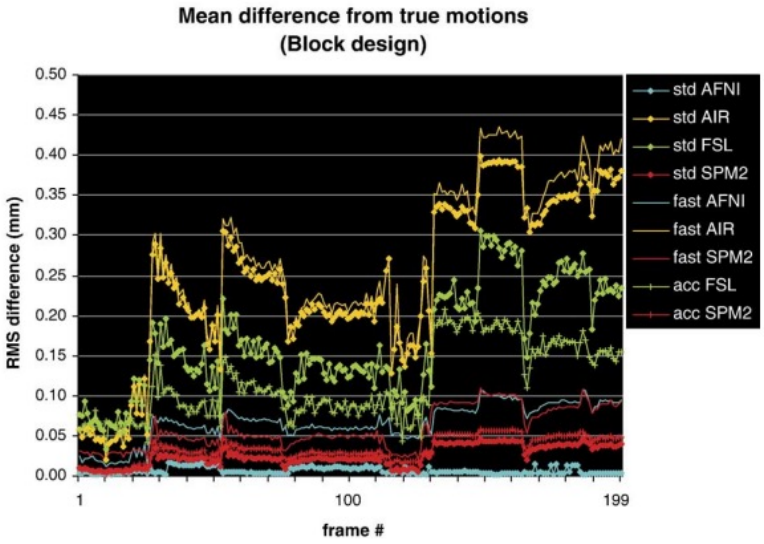
Note: 8 can precede 6 and 7. depending on your purpose.

- Similar with the SPM-based COCOAN pipeline.
- For surface-based preprocessing, fMRI volumes were projected to CIFTI surface!
- For volume-based preprocessing, outputs are almost same.

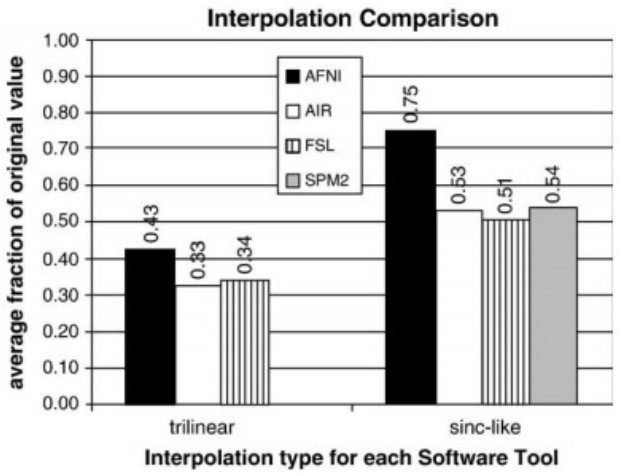
3. Pipeline details – Comparison with existing preprocessing pipelines

Motion correction: AFNI 3dvolreg

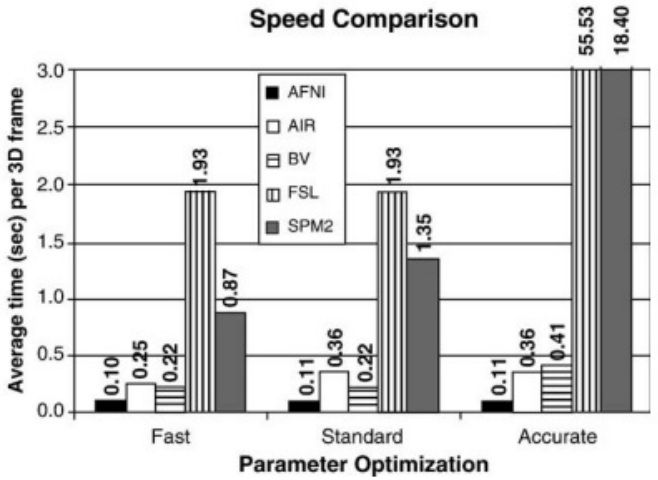
Realignment accuracy



Interpolation accuracy

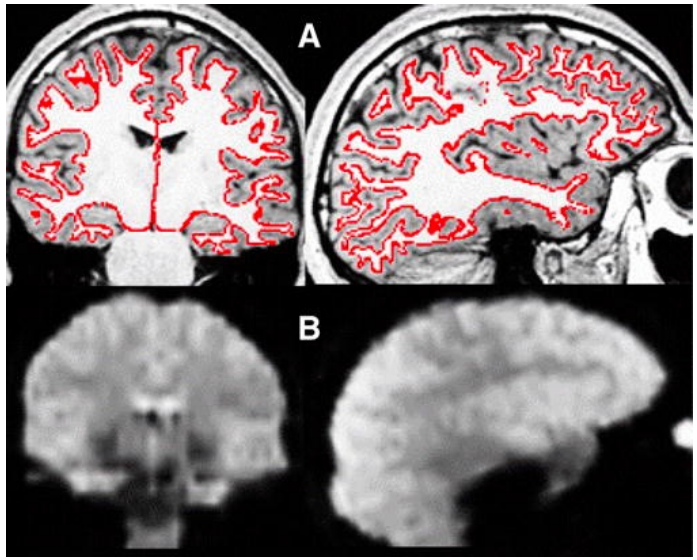


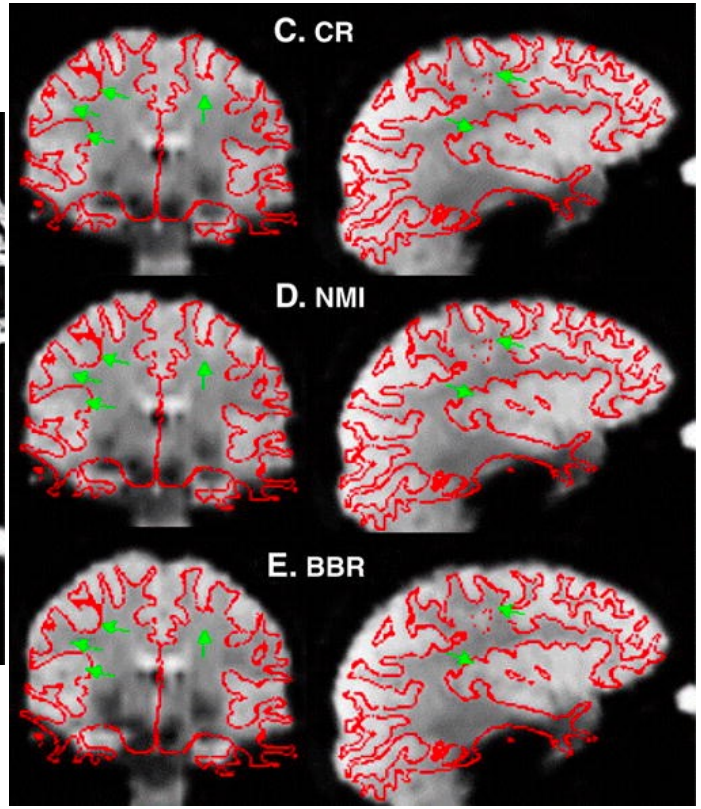
Speed



Oakes et al, 2005

Coregistration: FSL FLIRT + BBR (Boundary-Based Registration)





Greeve and Fischl, 2009

3. Pipeline details – Comparison with existing preprocessing pipelines

Coregistration: FSL FLIRT + BBR
(Boundary-Based Registration)

Pre-alignment by FSL FLIRT (cost function: correlation ratio)

↓

Alignment by FSL FLIRT (cost function: bbr)

↓

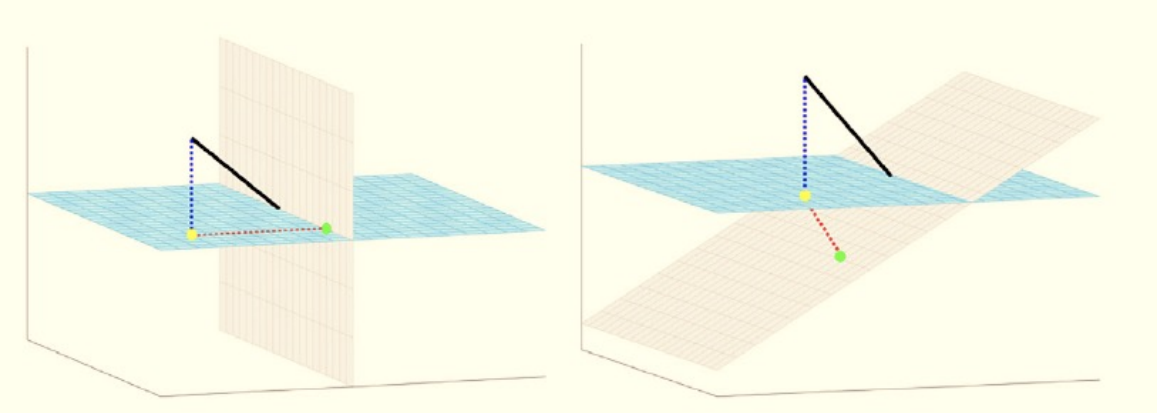
Refinement by freesurfer bbregister (cost function: bbr)

(if freesurfer reconstruction was done before)

3. Pipeline details – Comparison with existing preprocessing pipelines

Denoising: AFNI 3dTproject

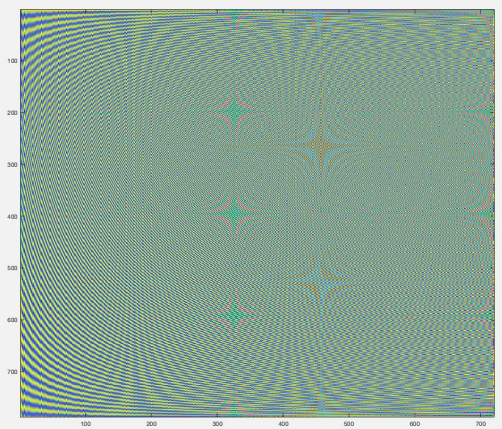
'one-step' strategy is the best!



Lindquist et al., 2019

steps within an omnibus framework. For example, it is relatively straightforward to formulate a single linear model that simultaneously performs motion regression, nuisance regression, and temporal filtering. This is an approach advocated by Caballero-Gaudes and Reynolds (2017), and implemented in Analysis of Functional NeuroImages (AFNI) (Cox, 1996) 3dTproject. In general, we believe that the

Instead of bpf -> Nuisance regression, combine them onto one matrix.



3. Pipeline details – Comparison with existing preprocessing pipelines

Normalization:
FSL applywarp (surface-based)
or ANTs antsApplytransform (volume-based)

Surfaced-based: Use pre-computed transformation parameters (FSL FLIRT+FNIRT) from ciftify_recon_all step.

Volume-based: Use pre-computed transformation parameters (ANTs antsRegistrationSyN) from normalization step.

3. Pipeline details – Comparison with existing preprocessing pipelines

Smoothing: FSL SUSAN

For volume-based analysis; Anatomically-constrained volumetric smoothing technique!

Projection to surface and Smoothing: CIFTIFY

For surface-based analysis; project fMRI volumes (in MNI space) to CIFTI surfaces (in Conte69 32k space) and perform 2D (cortex) + 3D (subcortex) smoothing!