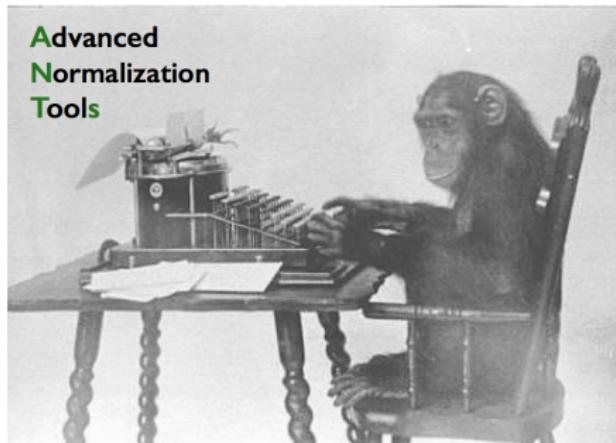


“Dr. Tustison (UVA) presentation”

Nick Tustison

University of Virginia

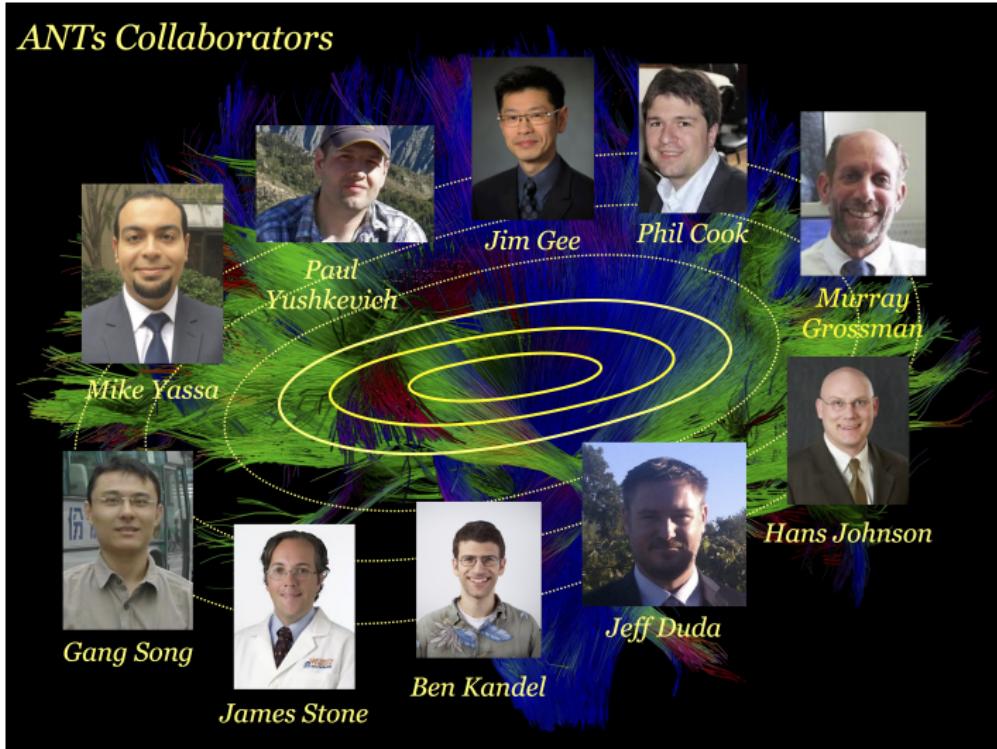


Developers and collaborators

Founders: Brian and Nick



ANTs Collaborators



+ neurodebian, slicer, brainsfit, nipype, itk and more . . .

Why would you care?

“Free beer”



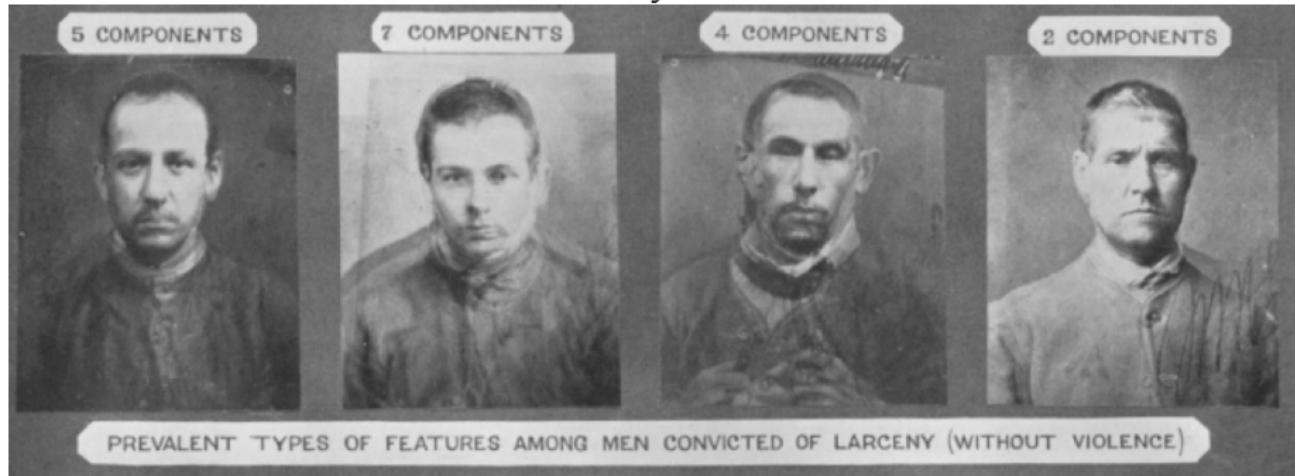
Software for medical image analysis

- FSL
- SPM
- FreeSurfer
- MIPAV
- AFNI
- Slicer, Elastix, SimpleITK, ANTs \longleftrightarrow Insight Toolkit
- Many more at idoimaging.com

ANTs lineage

Image mapping and perception: 1877

Francis Galton: *Can we see criminality in the face?*



What about syphilis, mental illness?

Speaking of criminality...

Can we say anything about the U.S. Congress?



Naive

Affine

SyN

Maybe they should have used ANTs?

Image mapping & biology: 1917

D'Arcy Thompson: *Comparison of related forms*

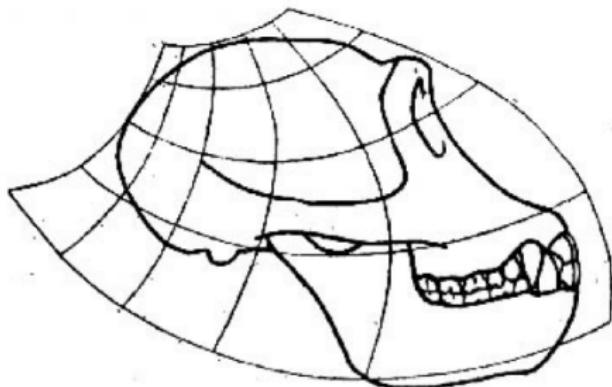


Fig. 550. Skull of chimpanzee.

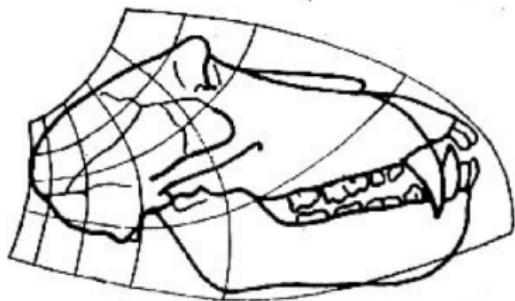
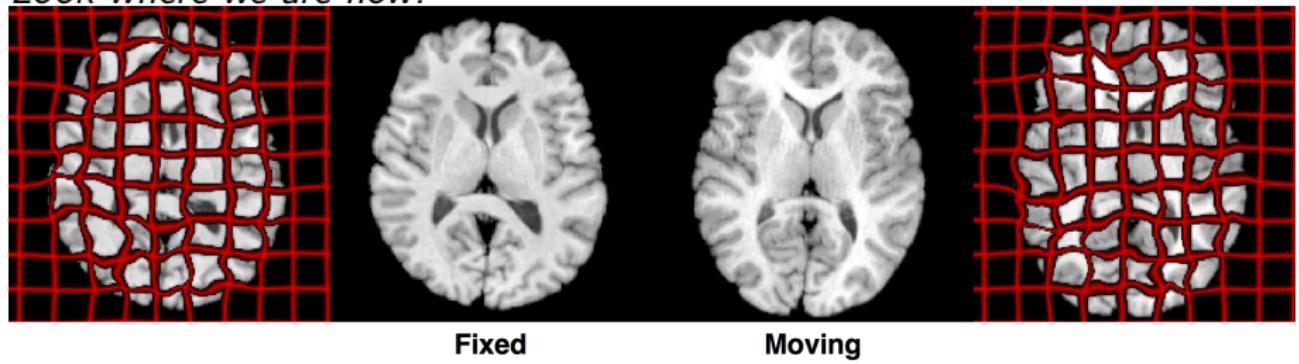


Fig. 551. Skull of baboon.

>

Image mapping & biology: Current

Look where we are now!



Competitions

Algorithmic fight club



International competitions

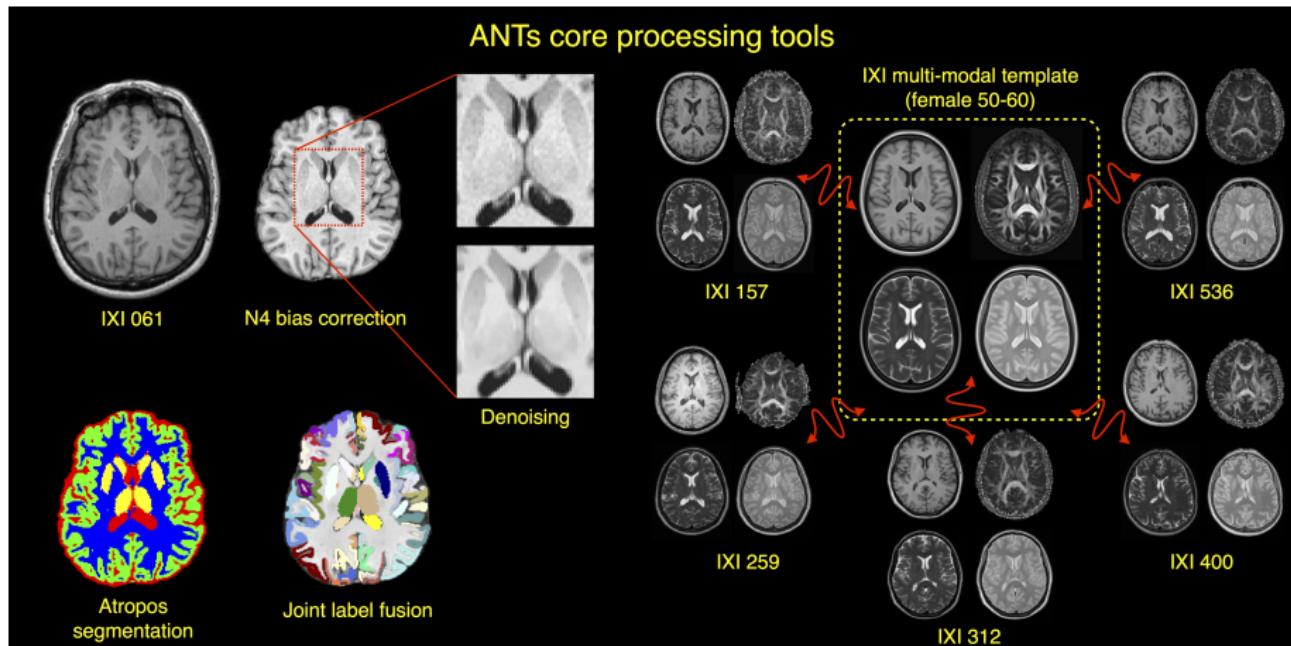
- Klein 2009: MRI brain registration
- EMPIRE 2010: CT lung registration
- Multi-Atlas Label Challenge 2012: MRI brain registration and segmentation
- SATA Challenge 2013: MRI cardiac and canine hind leg registration
- BRATS 2013: Multi-modal MRI brain segmentation
- STACOM 2014 MoCo Challenge: MRI cardiac motion estimation

Major ANTs utilities

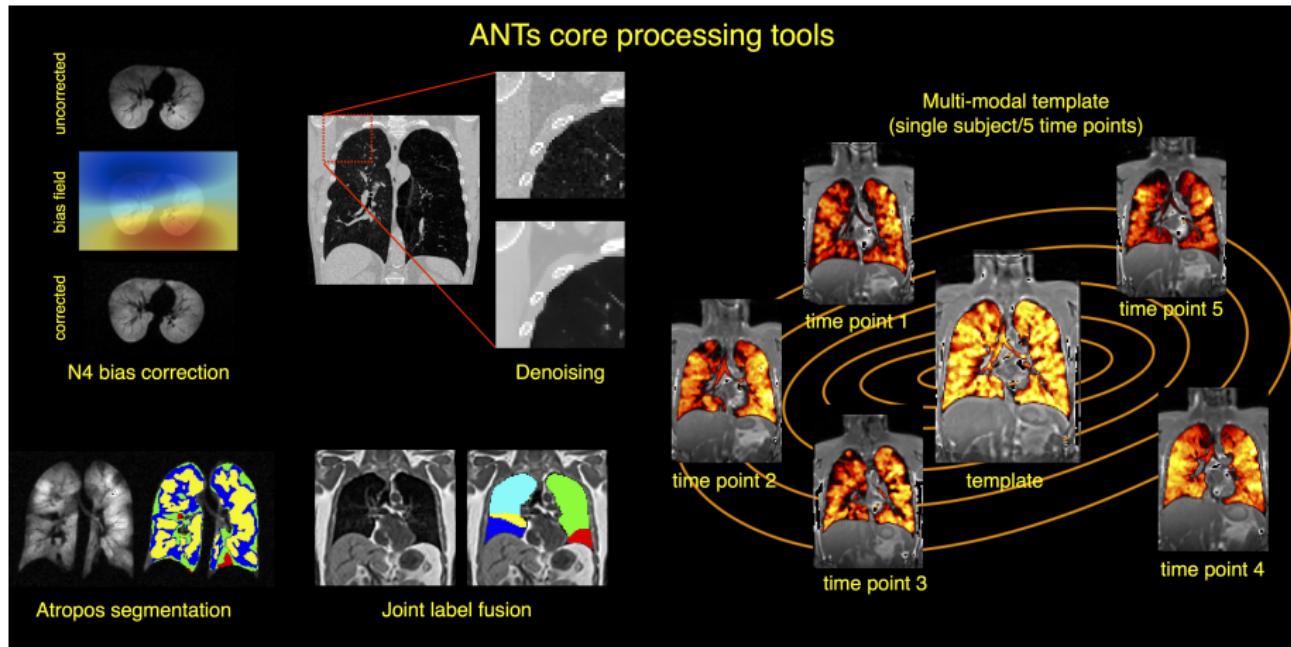
Donoho?

“Papers are just advertisements for the science.”

Neuro tools

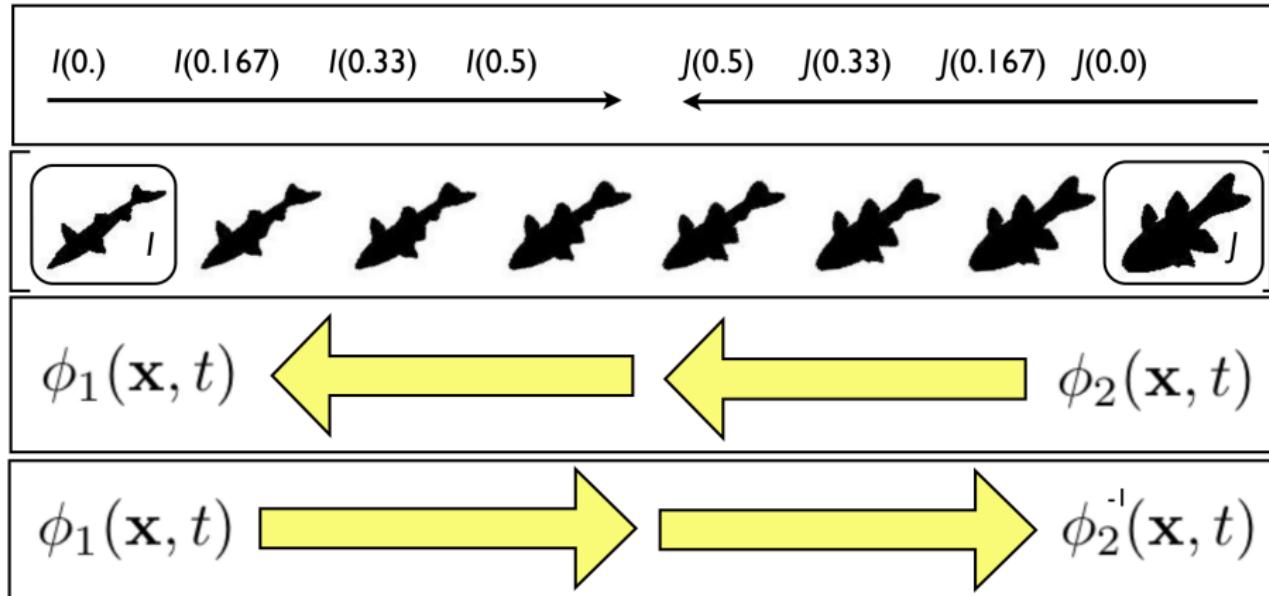


Pulmonary tools



Symmetric Normalization (SyN)

$$\int_{t=0}^{0.5} (\|\mathbf{v}_1(x, t)\|_L^2 + \|\mathbf{v}_2(x, t)\|_L^2) dt + \|I(\phi_1(x, 0.5)) - J_i(\phi_2(x, 0.5))\|^2$$

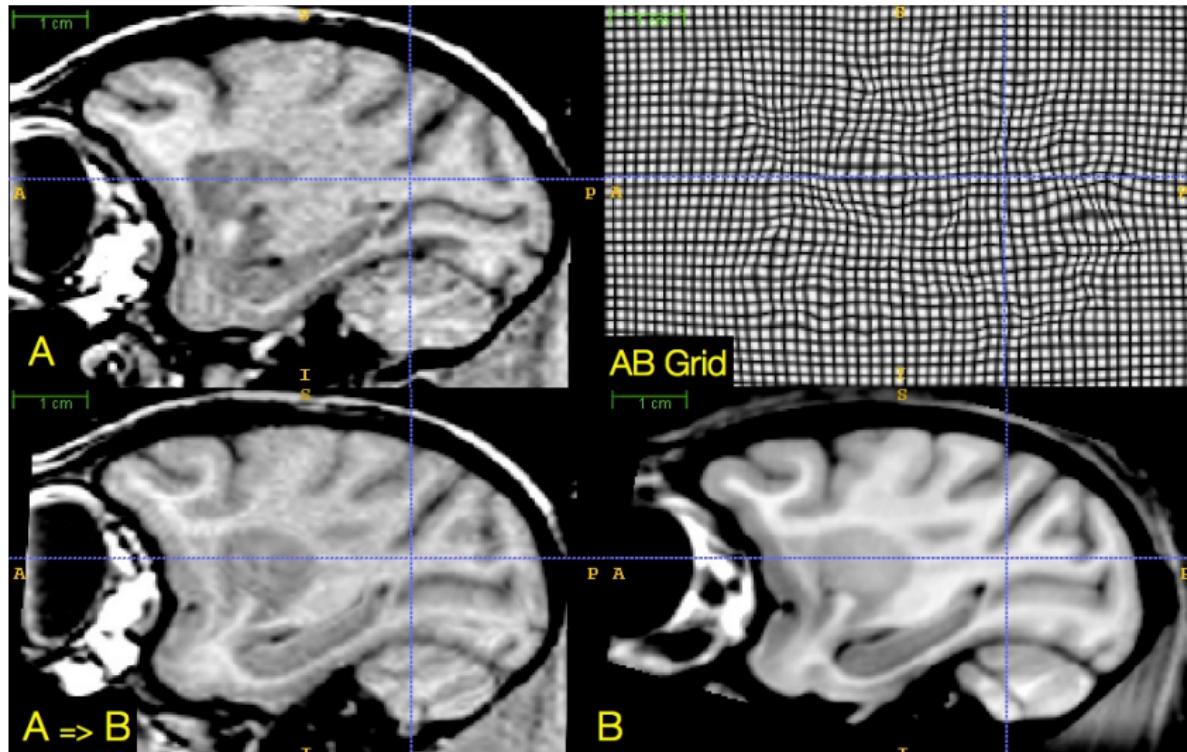


->

Notes: * Previously discussed Brian's work * The variant most widely used

->

Diffeomorphisms: differentiable map with diff. inverse



Diffeomorphisms: image parameterization in a metric space



Beyond original SyN

frontiers in
NEUROINFORMATICS

ORIGINAL RESEARCH ARTICLE

published: 28 April 2014
doi: 10.3389/fninf.2014.00044



The Insight ToolKit image registration framework

Brian B. Avants^{1*}, Nicholas J. Tustison², Michael Stauffer¹, Gang Song¹, Baohua Wu¹ and James C. Gee¹

¹ Penn Image Computing and Science Laboratory, Department of Radiology, University of Pennsylvania, Philadelphia, PA, USA

² Department of Radiology and Medical Imaging, University of Virginia, Charlottesville, VA, USA

frontiers in
NEUROINFORMATICS

METHODS ARTICLE
published: 23 December 2013
doi: 10.3389/fninf.2013.00039



Explicit B-spline regularization in diffeomorphic image registration

Nicholas J. Tustison^{1*} and Brian B. Avants²

antsRegistration

```
$ antsRegistration --help
```

COMMAND :

antsRegistration

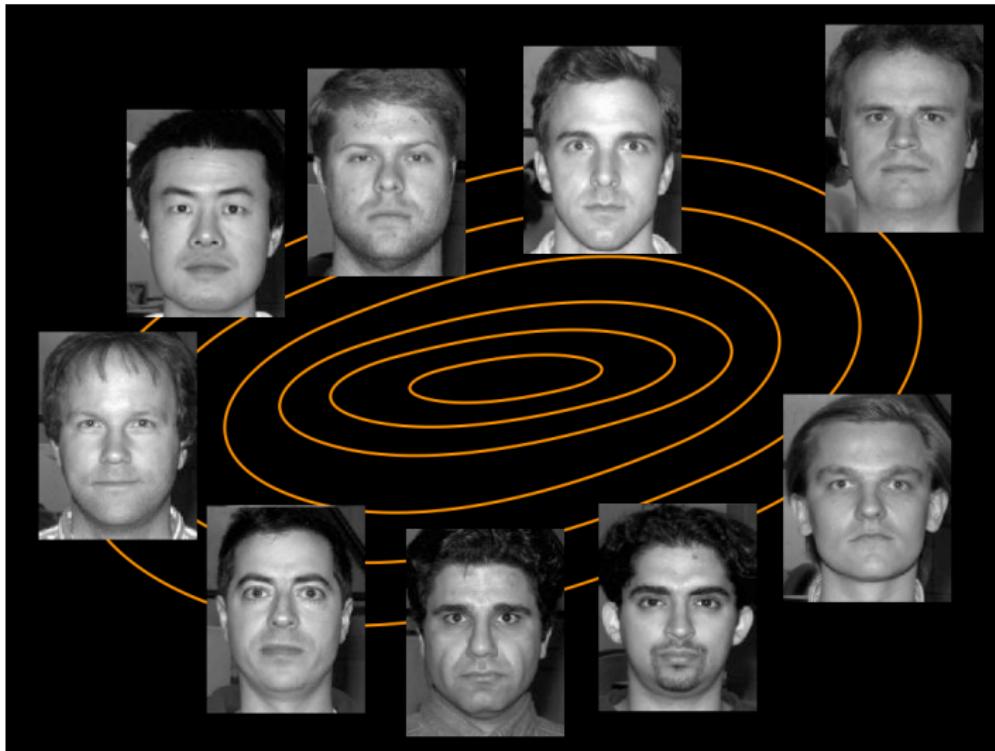
This program is a user-level registration application ITKv4-only classes. The user can specify any number consists of a transform; an image metric; and iterative smoothing sigmas for each level. Note that dimensional output, convergence, shrink-factors and smoothing-sigmas are mandatory.

OPTIONS:

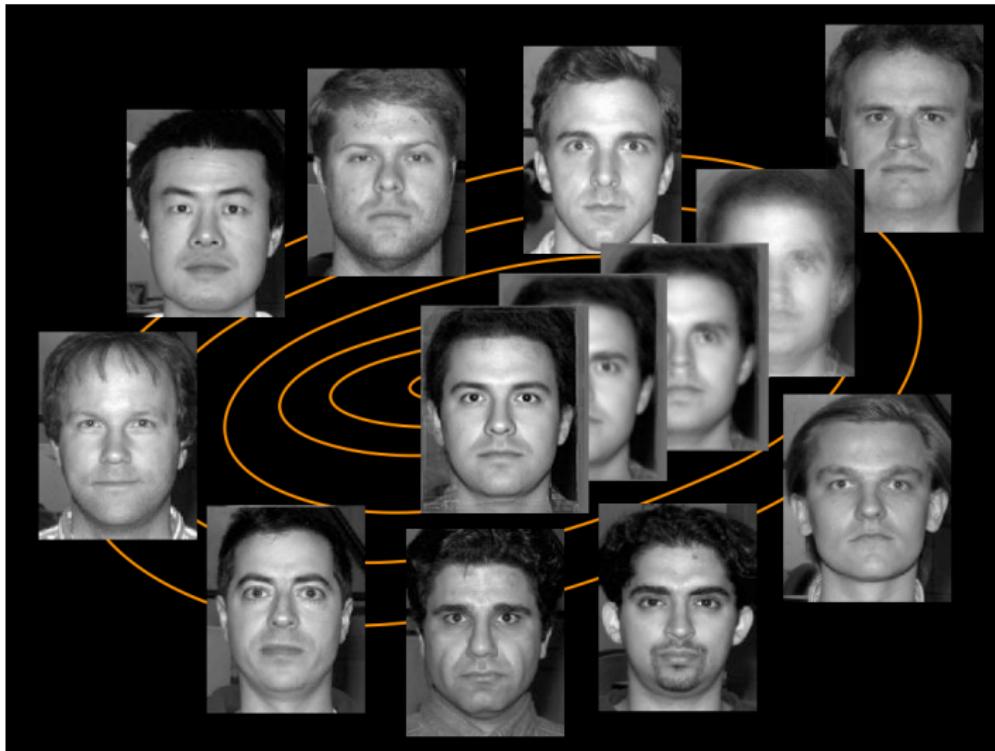
--version

Get Version Information.

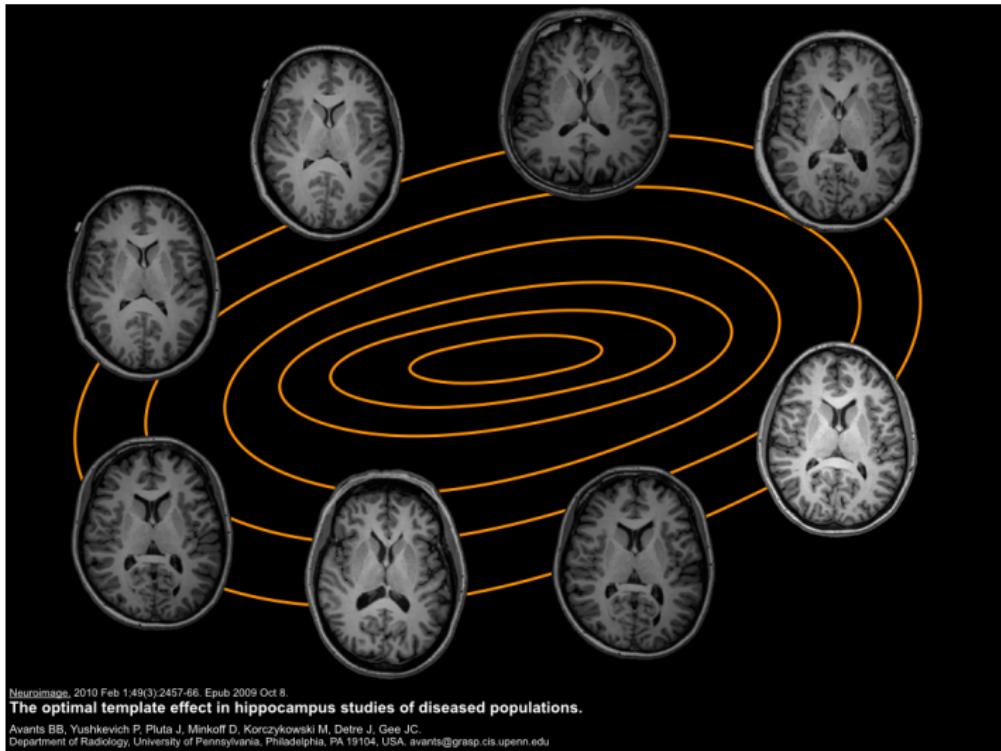
Template building: creating the average Joe



“Attractiveness” → mental processing?



What about brains?



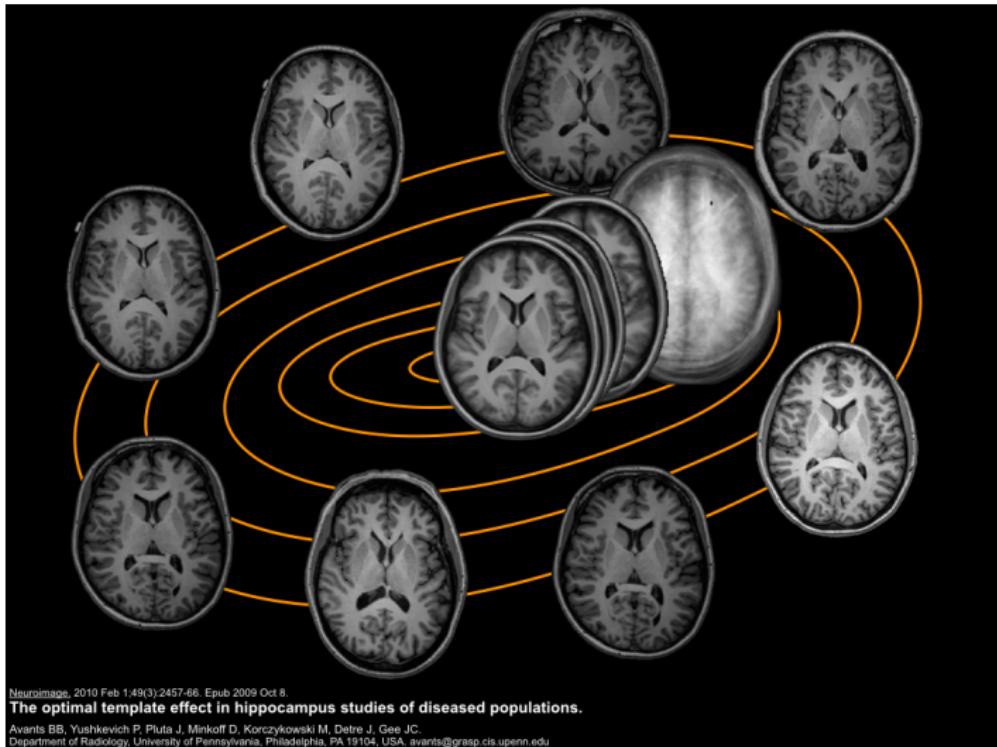
Neuroimage, 2010 Feb 149(3):2457-66. Epub 2009 Oct 8.

The optimal template effect in hippocampus studies of diseased populations.

Avants BB, Yushkevich P, Pluta J, Minkoff D, Korczykowski M, Detre J, Gee JC.

Department of Radiology, University of Pennsylvania, Philadelphia, PA 19104, USA, avants@grasp.cis.upenn.edu

Templates facilitate computation



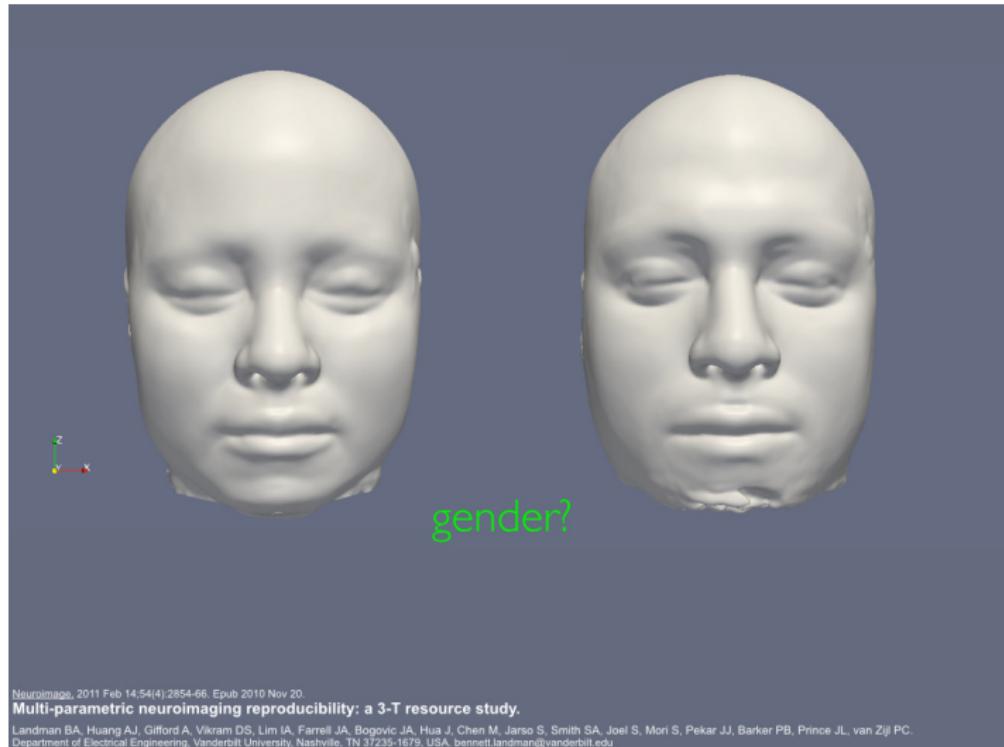
Neuroimage, 2010 Feb 149(3):2457-66. Epub 2009 Oct 8.

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Department of Radiology, University of Pennsylvania, Philadelphia, PA 19104, USA, avants@grasp.cis.upenn.edu

Gender?



Neuroimage, 2011 Feb 14;54(4):2854-66. Epub 2010 Nov 20.

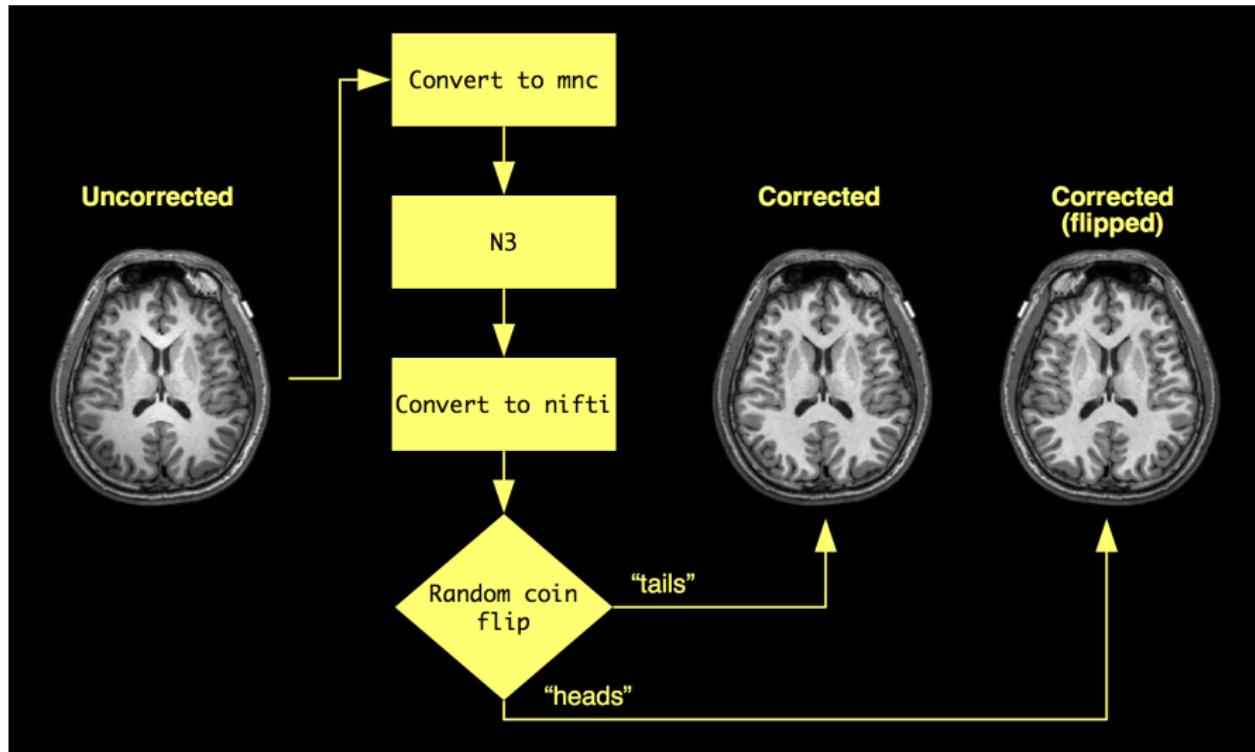
Multi-parametric neuroimaging reproducibility: a 3-T resource study.

Landman BA, Huang AJ, Gifford A, Vikram DS, Lim IA, Farrell JA, Bogovic JA, Hua J, Chen M, Jarso S, Smith SA, Joel S, Mori S, Pekar JJ, Barker PB, Prince JL, van Zijl PC.
Department of Electrical Engineering, Vanderbilt University, Nashville, TN 37235-1679, USA. bennett.landman@vanderbilt.edu

Nonparametric nonuniform intensity normalization (N3)

- Developed at the Montreal Neurological Institute (John Sled, 1998)
- Part of the standard preprocessing protocol in large scale projects such as ADNI
- The traditional de facto standard in MRI bias correction
 - good performance
 - *public availability*
- Public availability — set of perl scripts coordinating various C++ programs
- “*Let's incorporate N3 into ANTs!*”

Nonparametric nonuniform intensity normalization (N3)



N4 (“Nick’s N3”)

- comparative evaluation
- small spline distances (useful for higher magnet strengths)
- multiresolution
- weighted regional mask (used in `antsAtroposN4.sh`)
- fast execution times
- *publicly available*
- tested nightly within the ITK dashboard system

Atropos: flexible code base

“20+ years of development. *Show me the code!*”

Initialization

- Gaussian
- Non-parametric
 - histogram Parzen windows
 - manifold Parzen windows

Likelihood models

- Gaussian
- Non-parametric
 - histogram Parzen windows
 - manifold Parzen windows

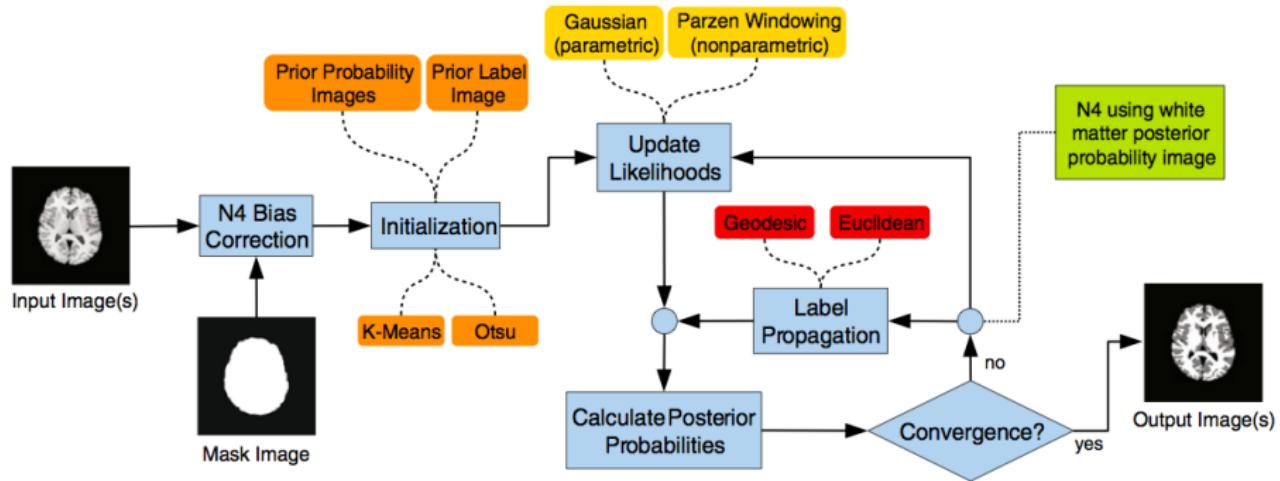
Atropos

Prior models

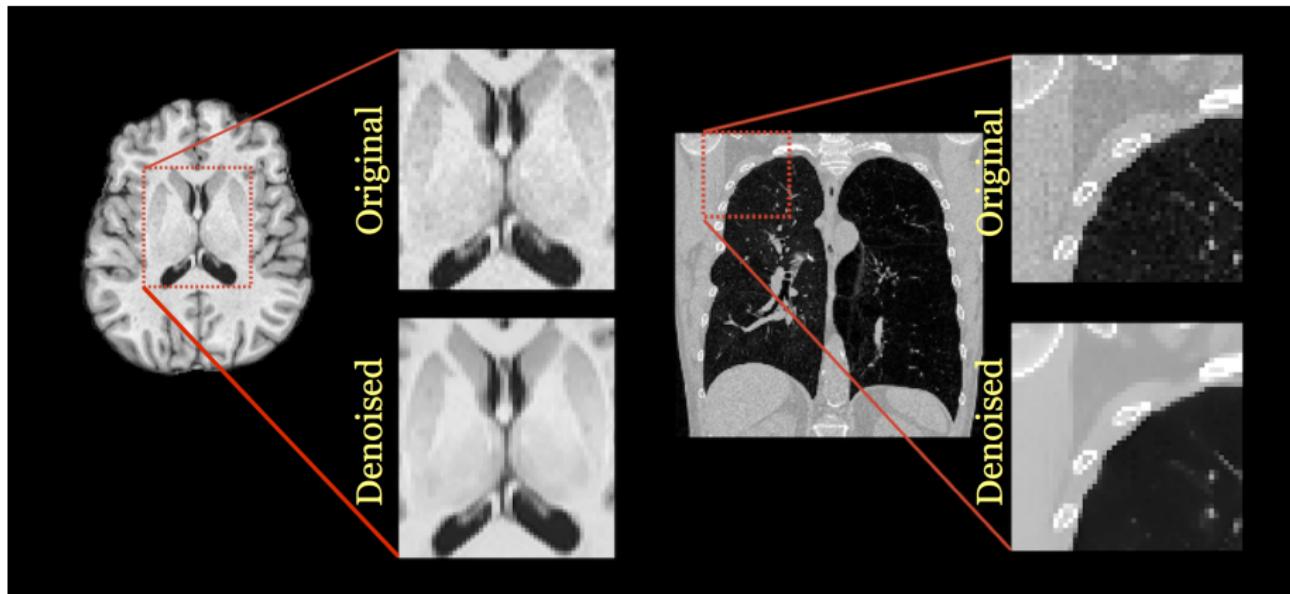
- Markov random field
- Prior label images
- Prior probability images

Miscellaneous

- Label geodesic/Euclidean propagation
- Outlier handling
- localized adaptive intensity handling

Atropos + N4 \rightarrow antsAtroposN4.sh

DenoiseImage — contribution from Jose Manjon

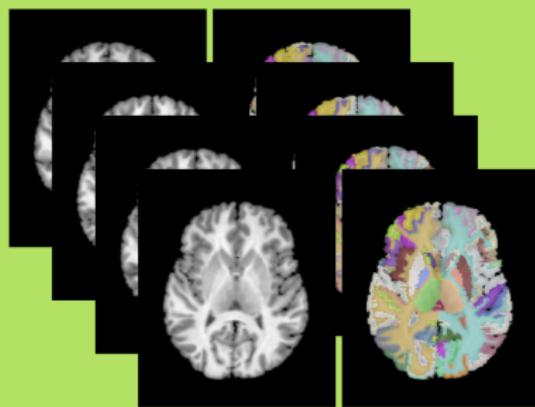


```
$ DenoiseImage --help
```

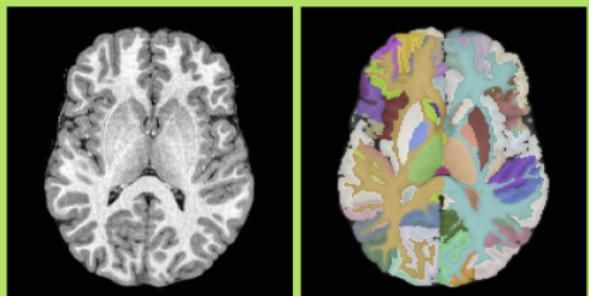
COMMAND:

Multi-atlas segmentation

Joint label fusion



Atlases
(grayscale + segmentation)



Target image

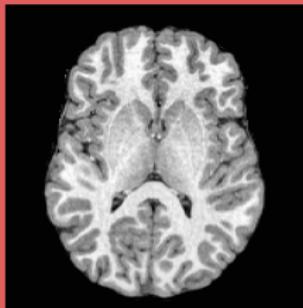
Target segmentation

New work: joint intensity fusion

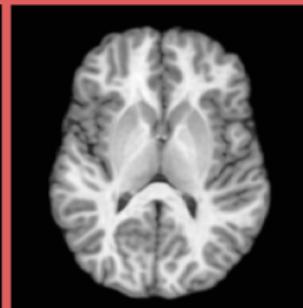
Joint intensity fusion



Atlases
(grayscale only)



Target image



Target fusion image

Possible uses

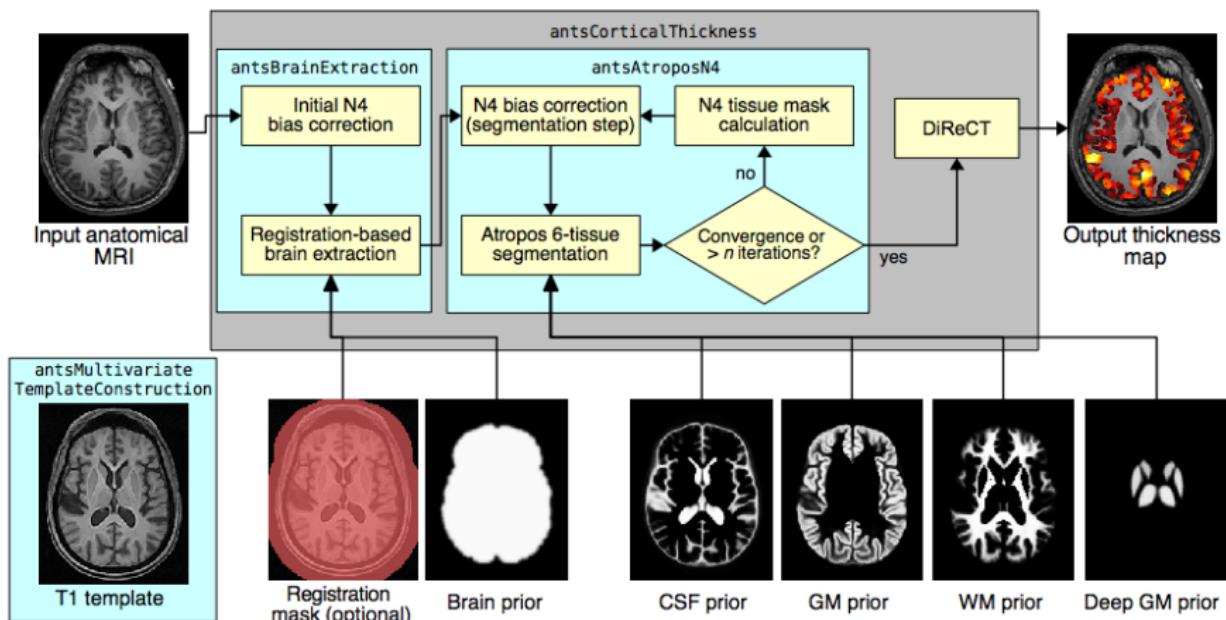
- “Correct” images
 - motion correction
 - “remove” lesions
- Project atlas set intensity signature
- Use in “corrective learning”

Putting it all together—the ANTs cortical thickness pipeline

Cortical thickness studies

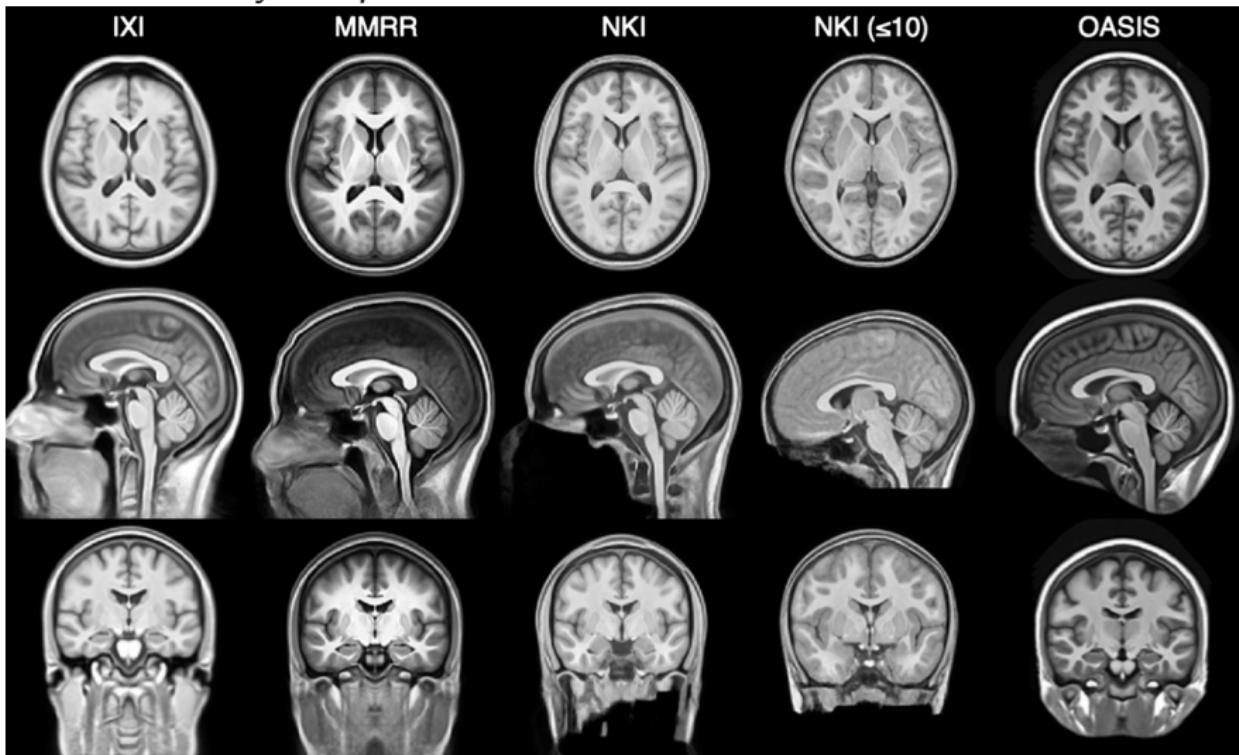
Column1	Column2
Tetris-playing ability	chronic pancreatitis
Huntington's disease	obsessive-compulsive disorder
schizophrenia	ADHD
bipolar disorder	obesity
Alzheimer's disease	heritable depression
frontotemporal dementia	elderly depression
Parkinson's disease	age
Williams syndrome	gender
multiple sclerosis	handedness
autism	intelligence
migraines	athletic ability
chronic smoking	meditative practices
alcoholism	musical ability
cocaine addiction	tendency toward criminality

The ANTs structural brain mapping workflow

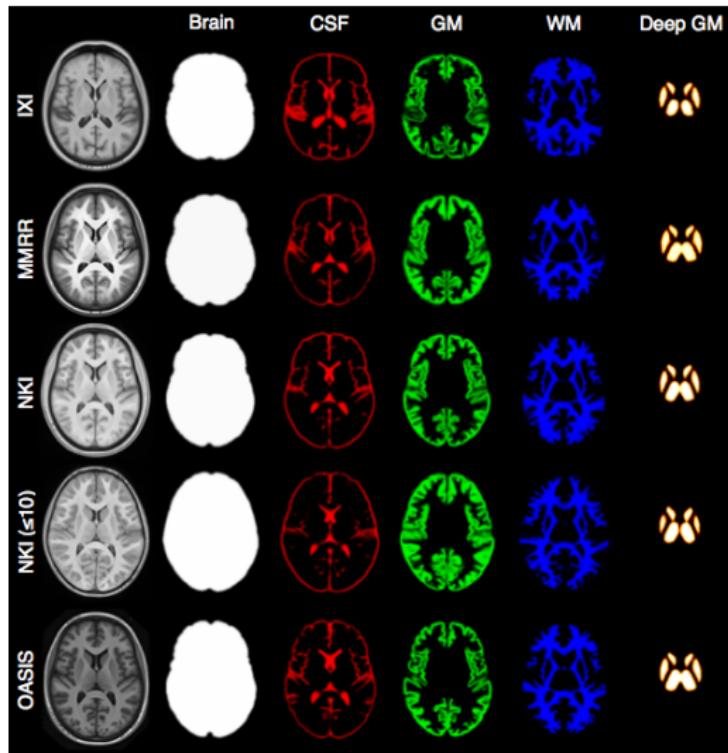


Template building

Tailor data to your specific cohort

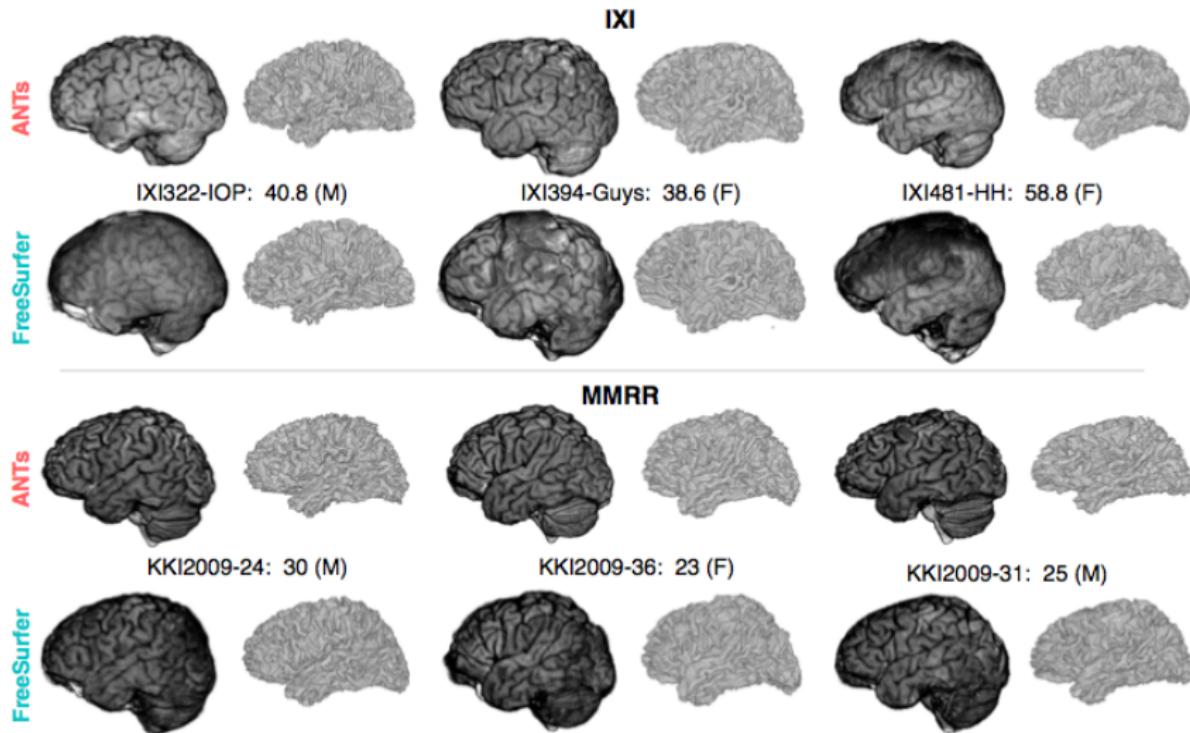


Template priors



Each template is processed to produce auxiliary images which are used for

Brain extraction comparison

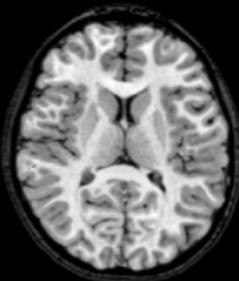


Comparison with de facto standard FreeSurfer package. Note the difference

Brain segmentation

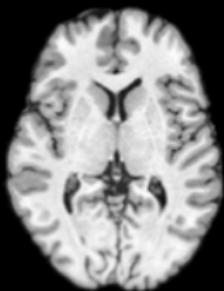
NKI-3374719

male, 7 years



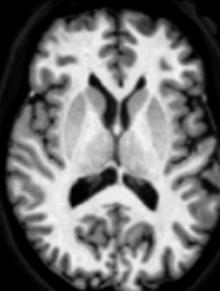
IXI-021

female, 21.6 years



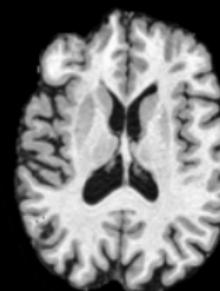
MMRR-35

female, 42 years



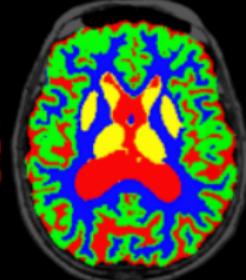
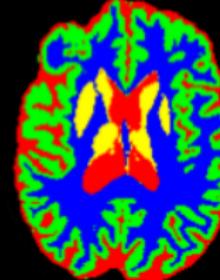
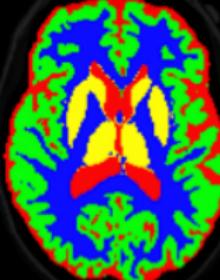
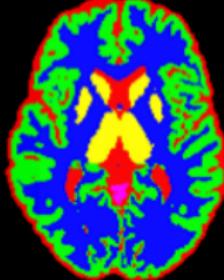
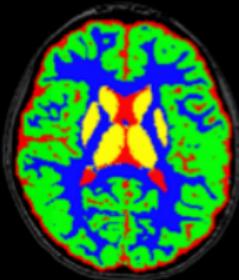
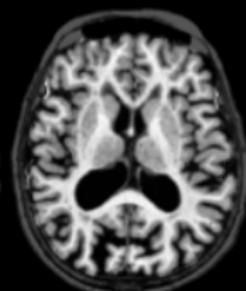
NKI-1339484

male, 67 years



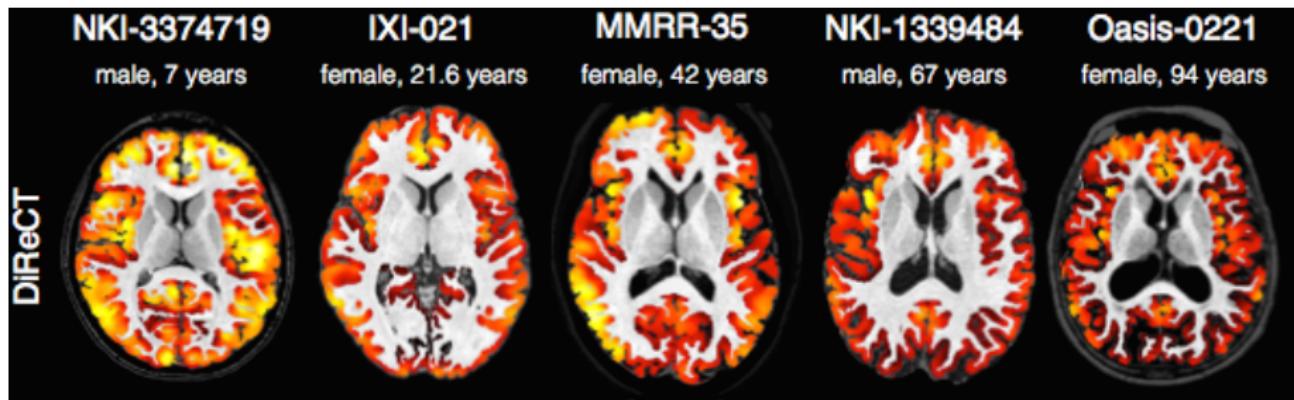
Oasis-0221

female, 94 years



Randomly selected healthy individuals. Atropos gets good performance

Cortical thickness maps



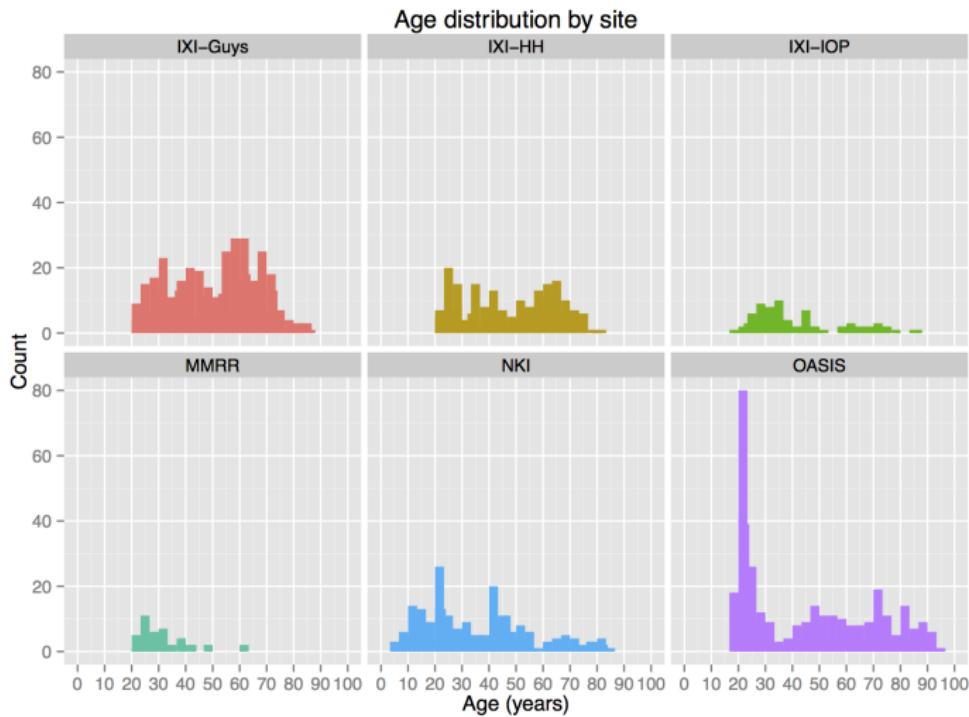
In contrast to FreeSurfer which warps coupled surface meshes to segment the gray matter, *ANTs* diffeomorphically registers the white matter to the combined gray/white matters while simultaneously estimating thickness.

But without ground truth, how does one evaluate the pipeline?

Predict age and gender

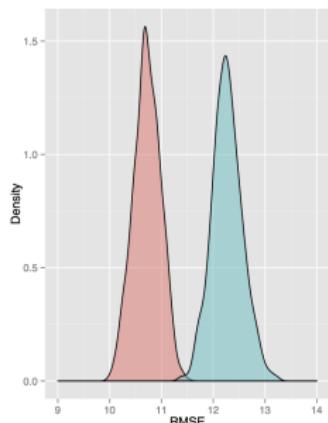
$$AGE \sim VOLUME + GENDER + \sum_{i=1}^{62} T(DKT_i)$$

Open science principles

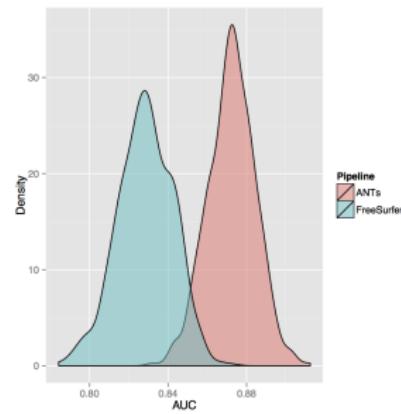
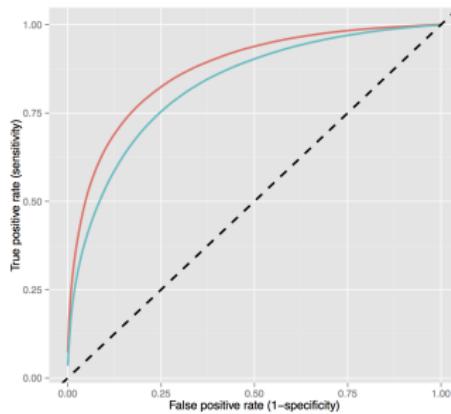


- Public data sets (IXI, NKI, OASIS, MMRR)

Prediction from cortical thickness data



Age



Gender

Age prediction per site

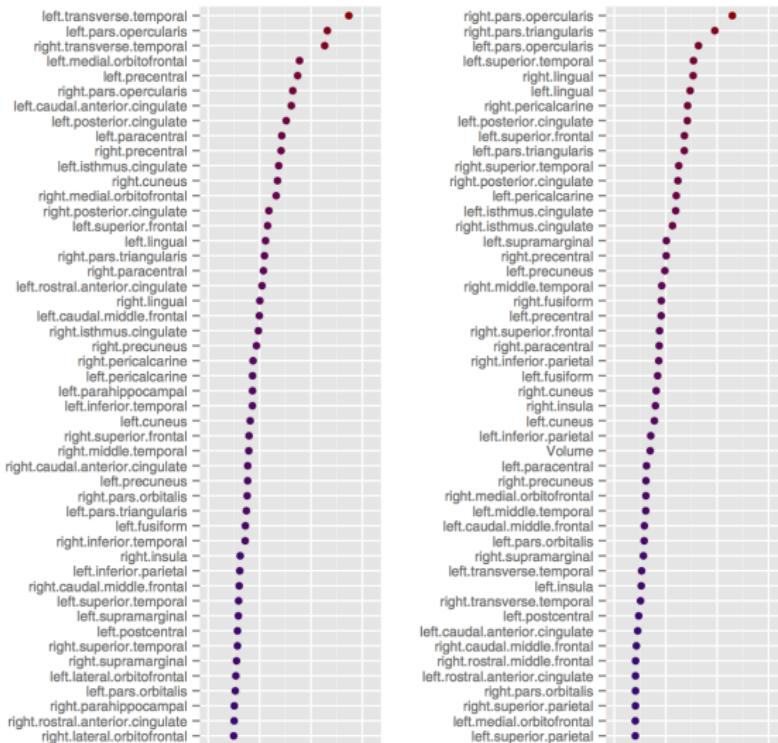
Table 3

Mean RMSE for age prediction in years.

	Linear model	Random forest
ANTs (combined)	10.7	10.2
FreeSurfer (combined)	12.3	11.9
ANTs (IXI)	9.3	8.6
FreeSurfer (IXI)	12.3	11.7
ANTs (NKI)	NA ^a	10.9
FreeSurfer (NKI)	NA ^a	13.3
ANTs (OASIS)	15.0	12.4
FreeSurfer (OASIS)	15.0	11.4

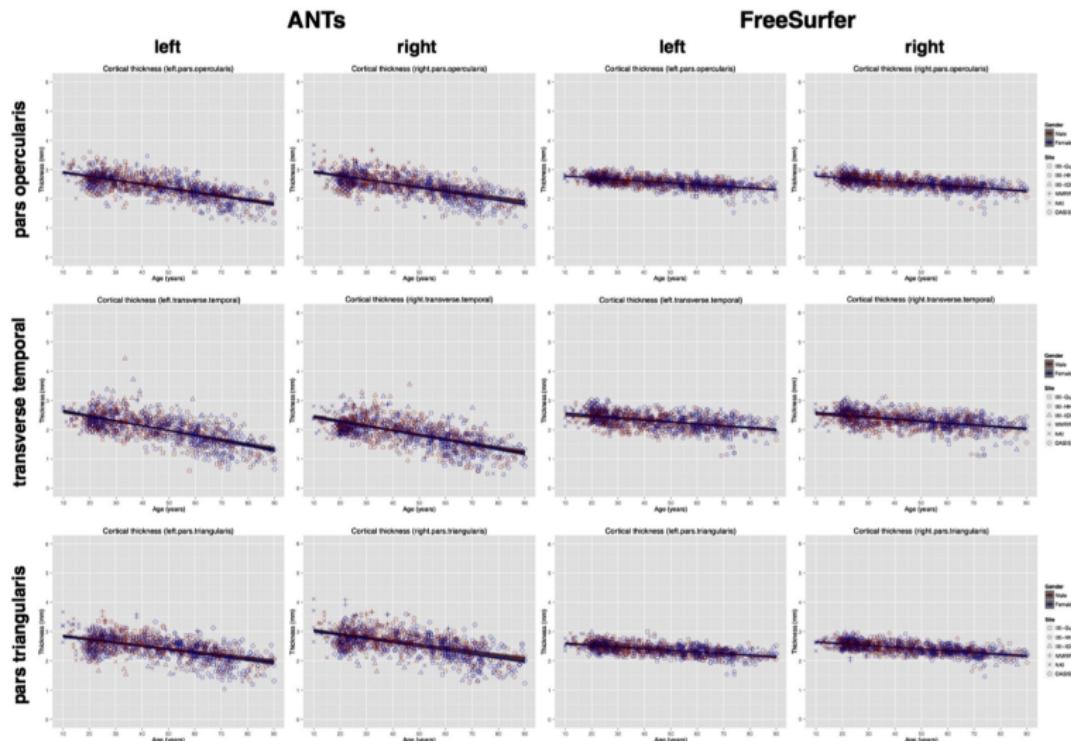
^a Fitting error.

Regional importance comparison



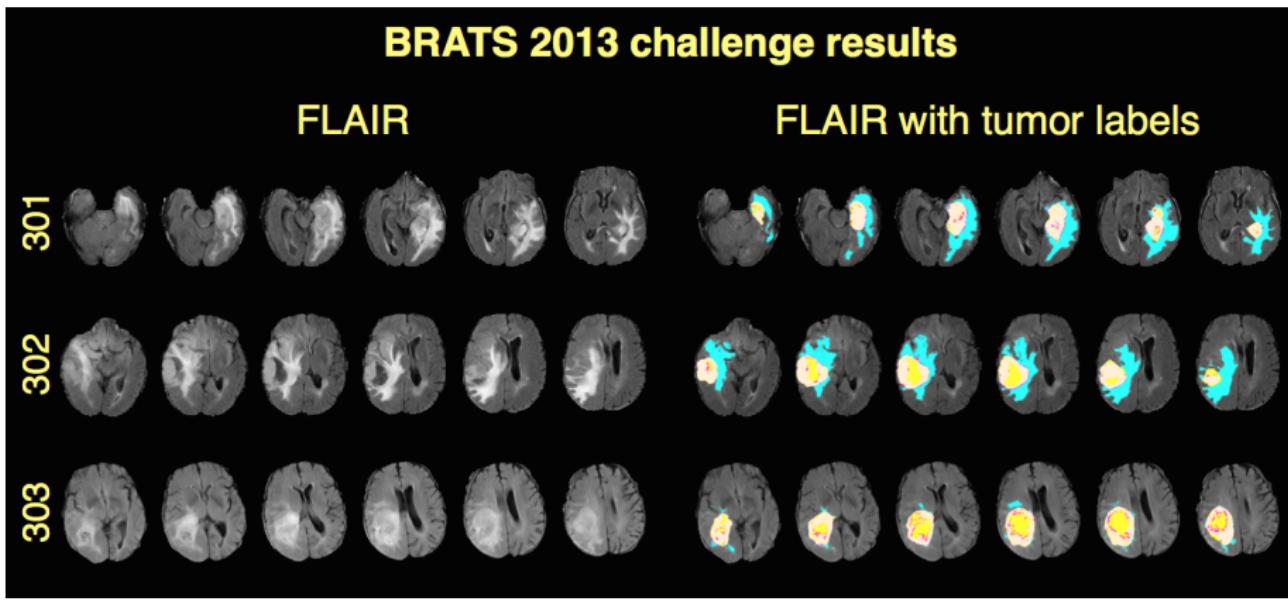
ANTs (left) vs. FreeSurfer (right)

Regional measurements



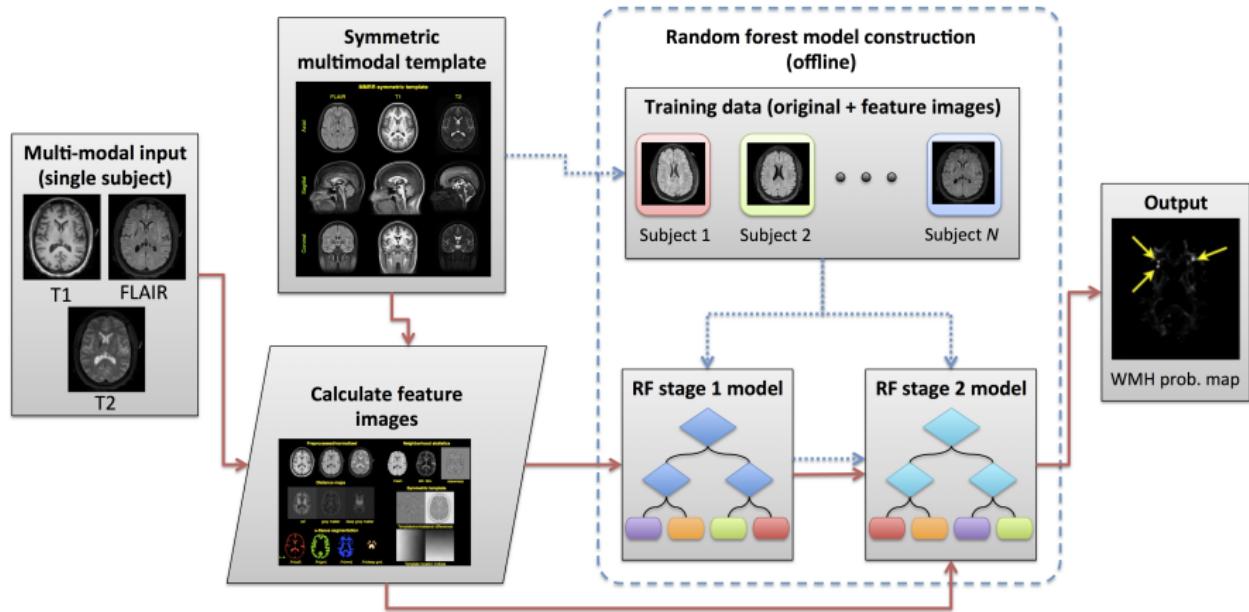
Current work and Advanced Normalization Tools in R (ANTsR)

Multimodal Brain Tumor Segmentation (BRATS 2013)

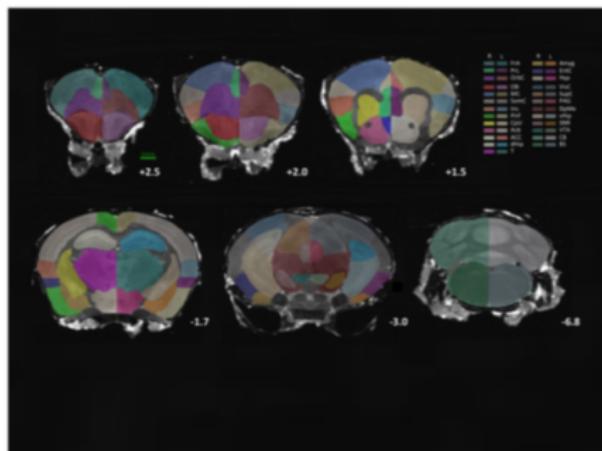
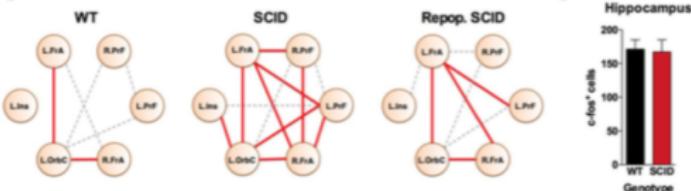


Tustison, et al., Optimal symmetric multimodal templates and concatenated random forests for supervised brain tumor segmentation (simplified) with ANTsR, *Neuroinformatics*.

White matter hyperintensities in TBI



Social behavior and immunity dysfunction in mice

a**b****c**