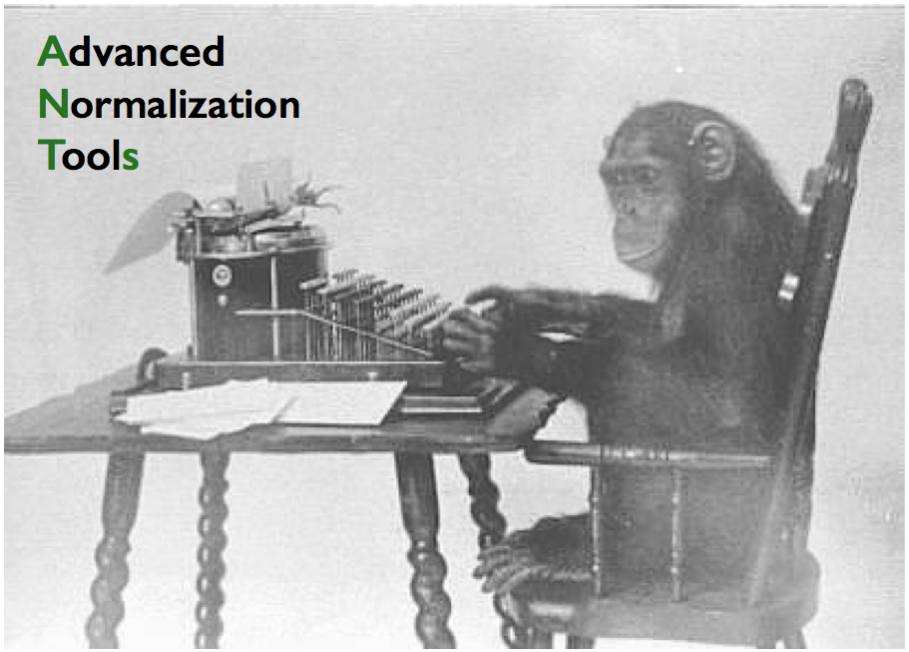
“Dr. Tustison (UVA) presentation”

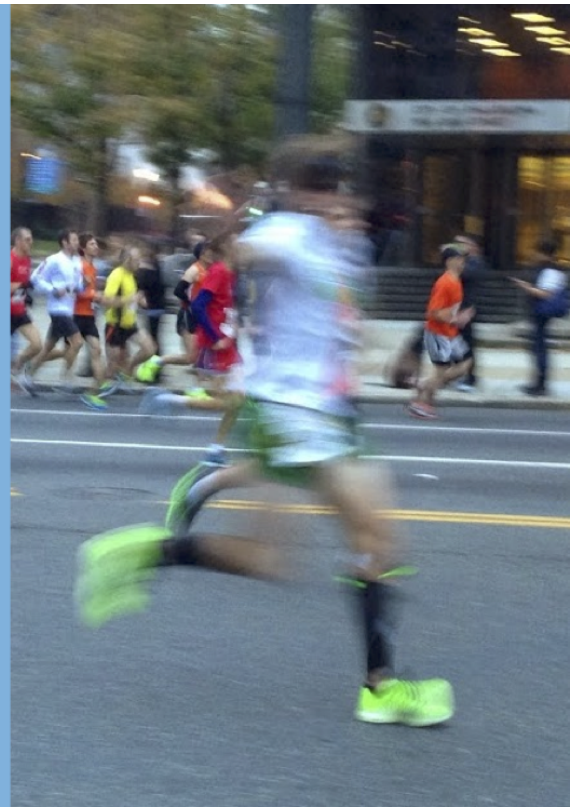
Nick Tustison

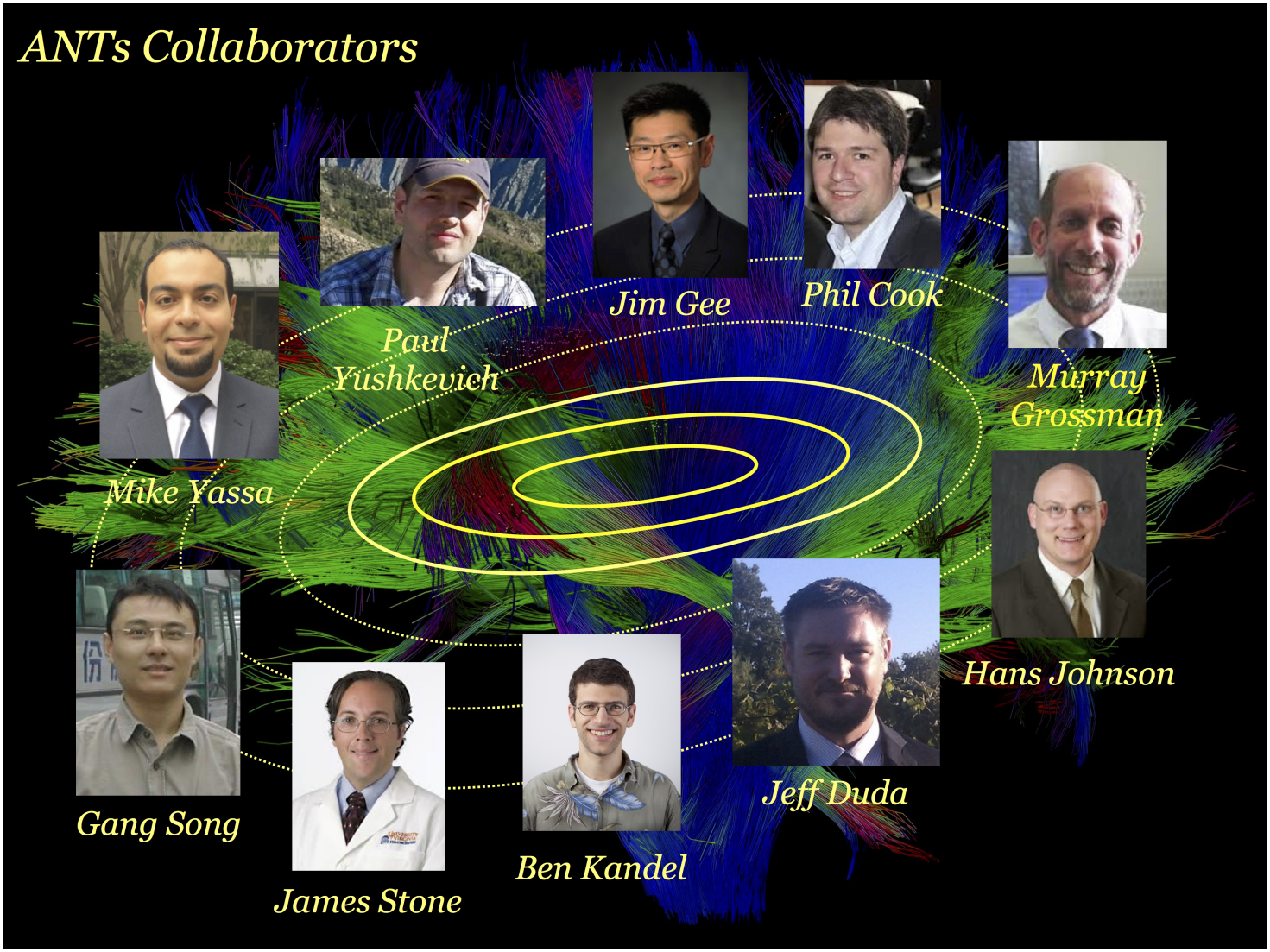
University of Virginia



Developers and collaborators

Founders: Brian and Nick





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

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*

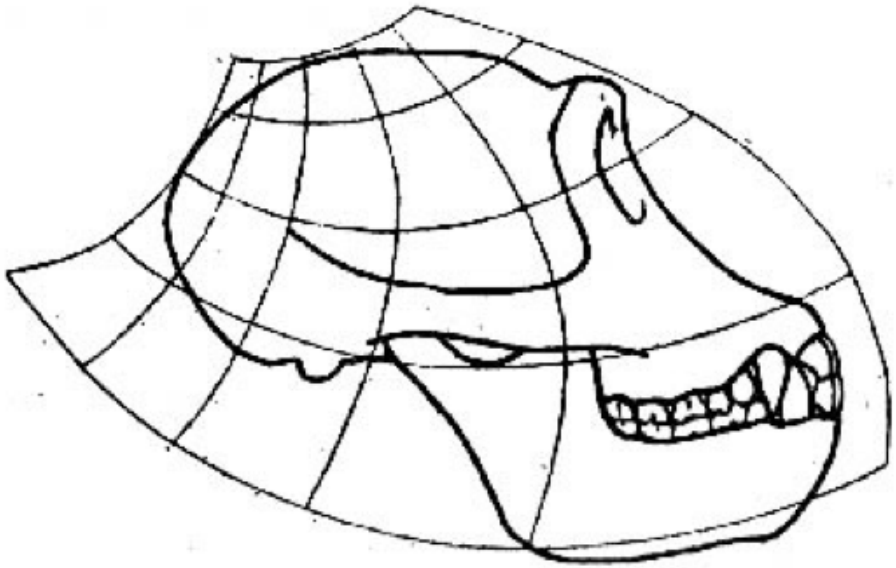


Fig. 550. Skull of chimpanzee.

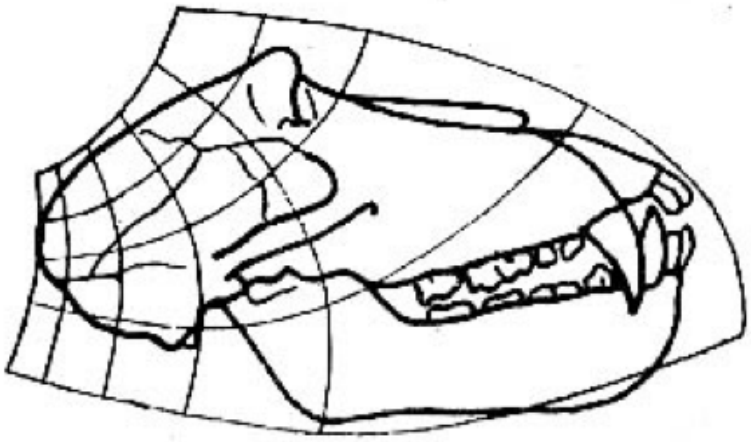
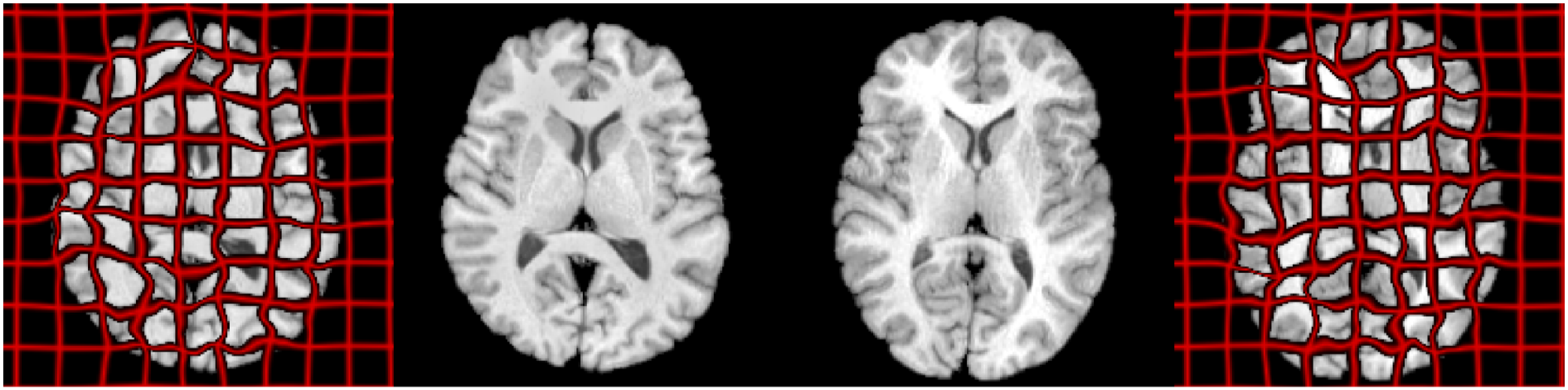


Fig. 551. Skull of baboon.

>

Image mapping & biology: Current

Look where we are now!

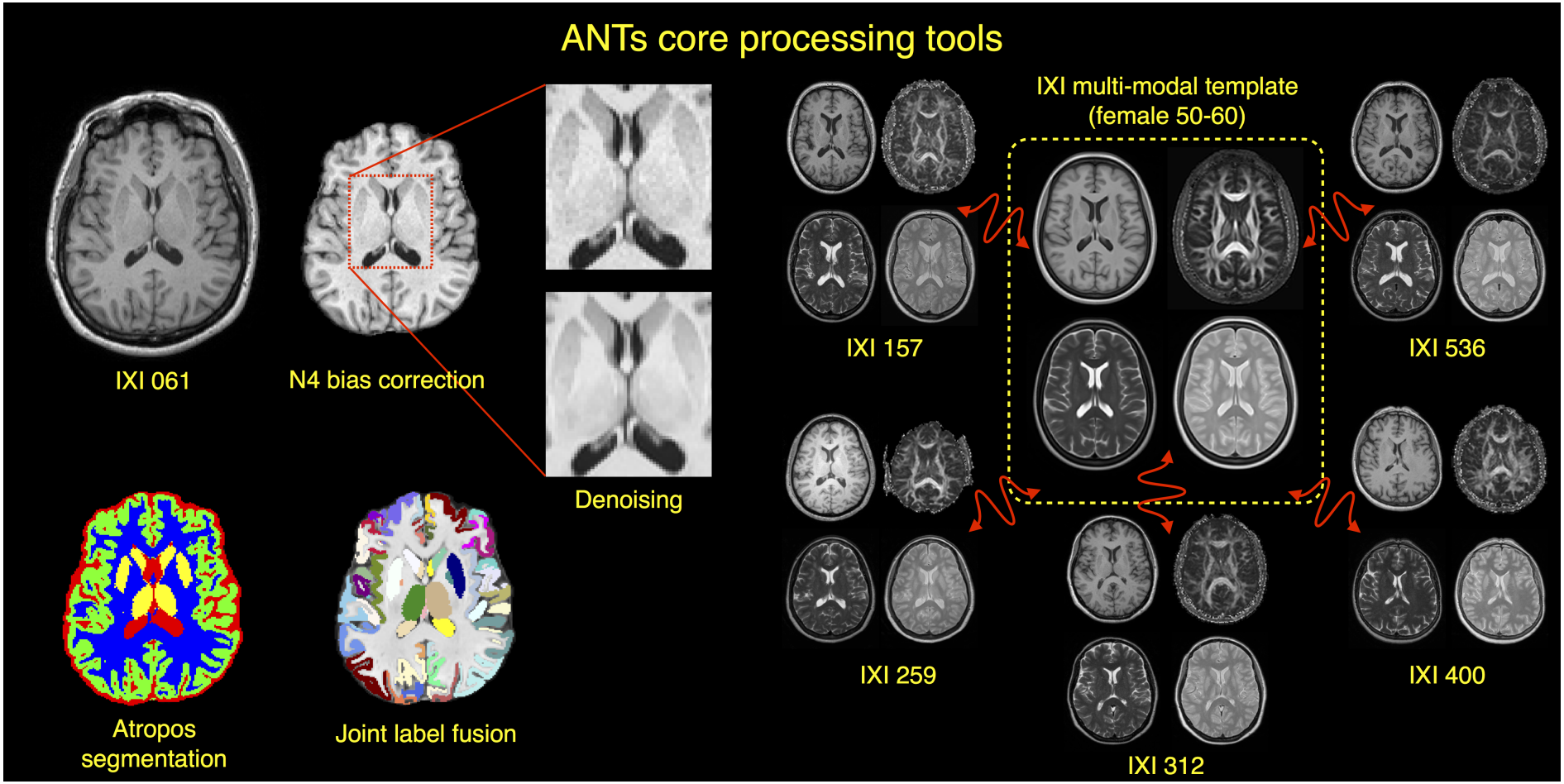


Major ANTs utilities

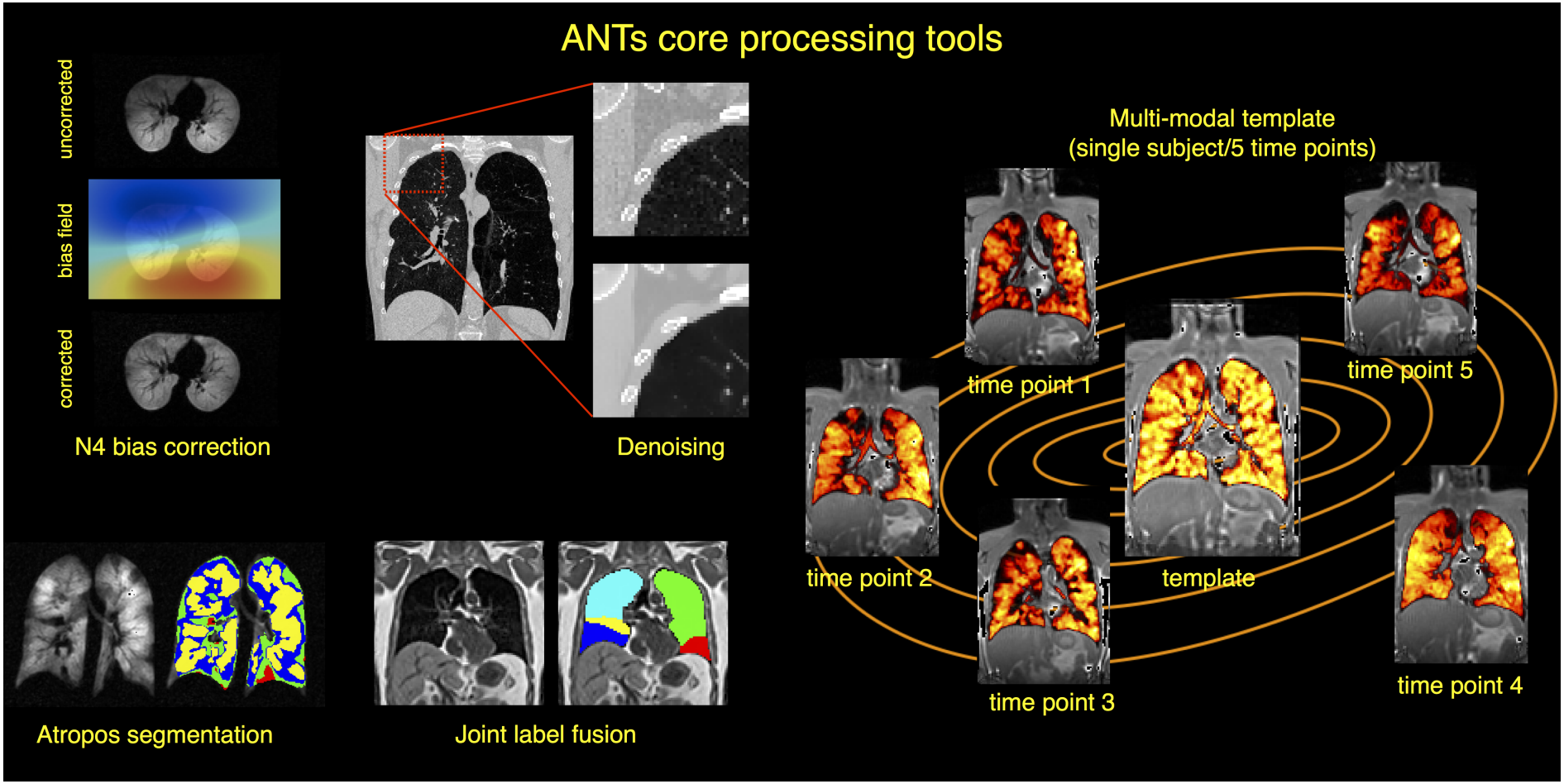
Donoho?

"Papers are just advertisements for the science."

Neuro tools

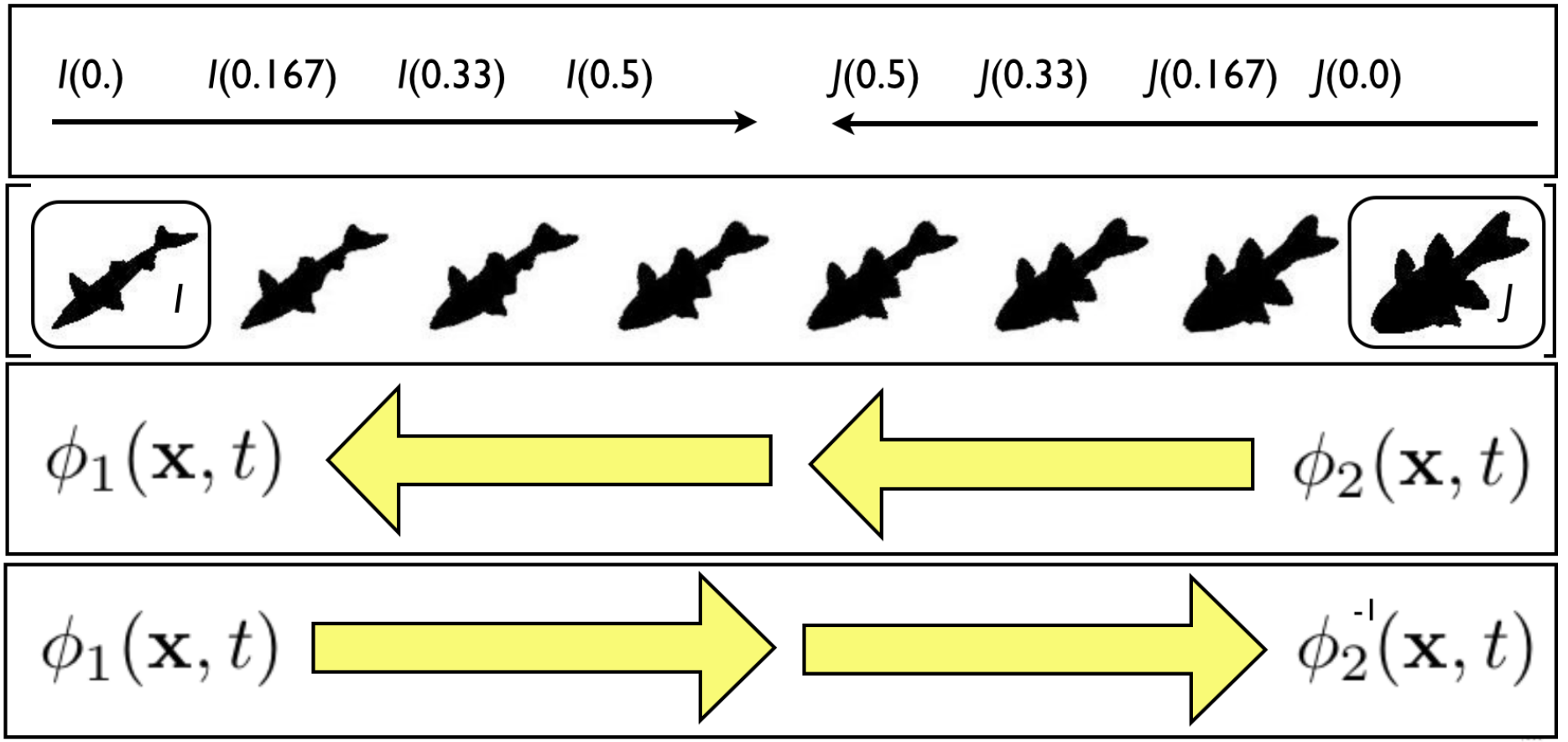

ANTs core processing tools
IXI 061
N4 bias correction
Denoising
Atropos segmentation
Joint label fusion
IXI multi-modal template (female 50-60)
IXI 157
IXI 536
IXI 259
IXI 400
IXI 312

Pulmonary tools



Symmetric Normalization (SyN)

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

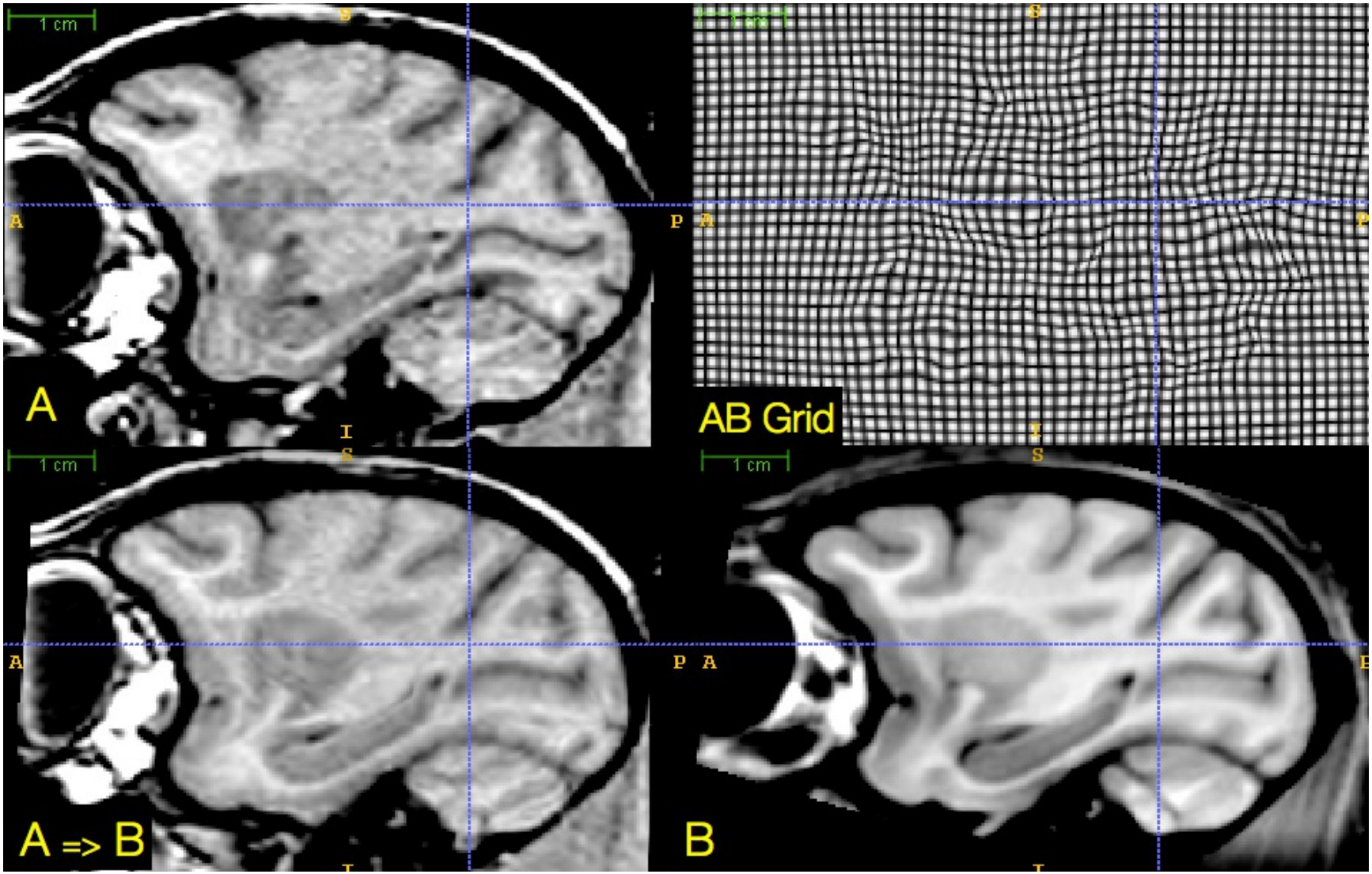


–>

NOtes: * Previously discussed Brians work * The variant most widely used

–>

Diffeomoprhisms: 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. Tustison[2], Michael Stauffer[1], Gang Song[1], Baohua Wu[1] and James C. Gee[1]

[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

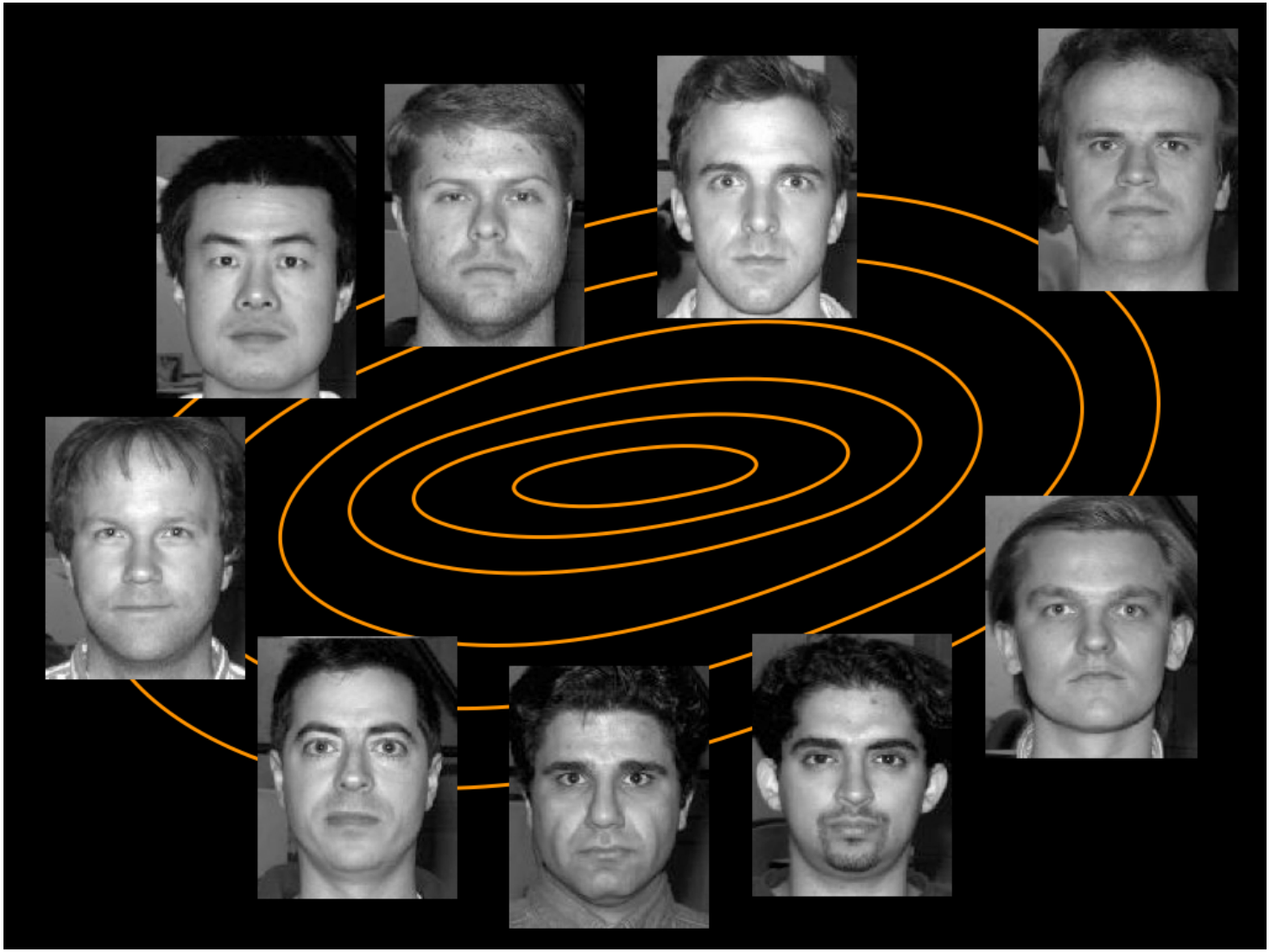
Explicit B-spline regularization in diffeomorphic image registration

Nicholas J. Tustison[1]* and Brian B. Avants[2]

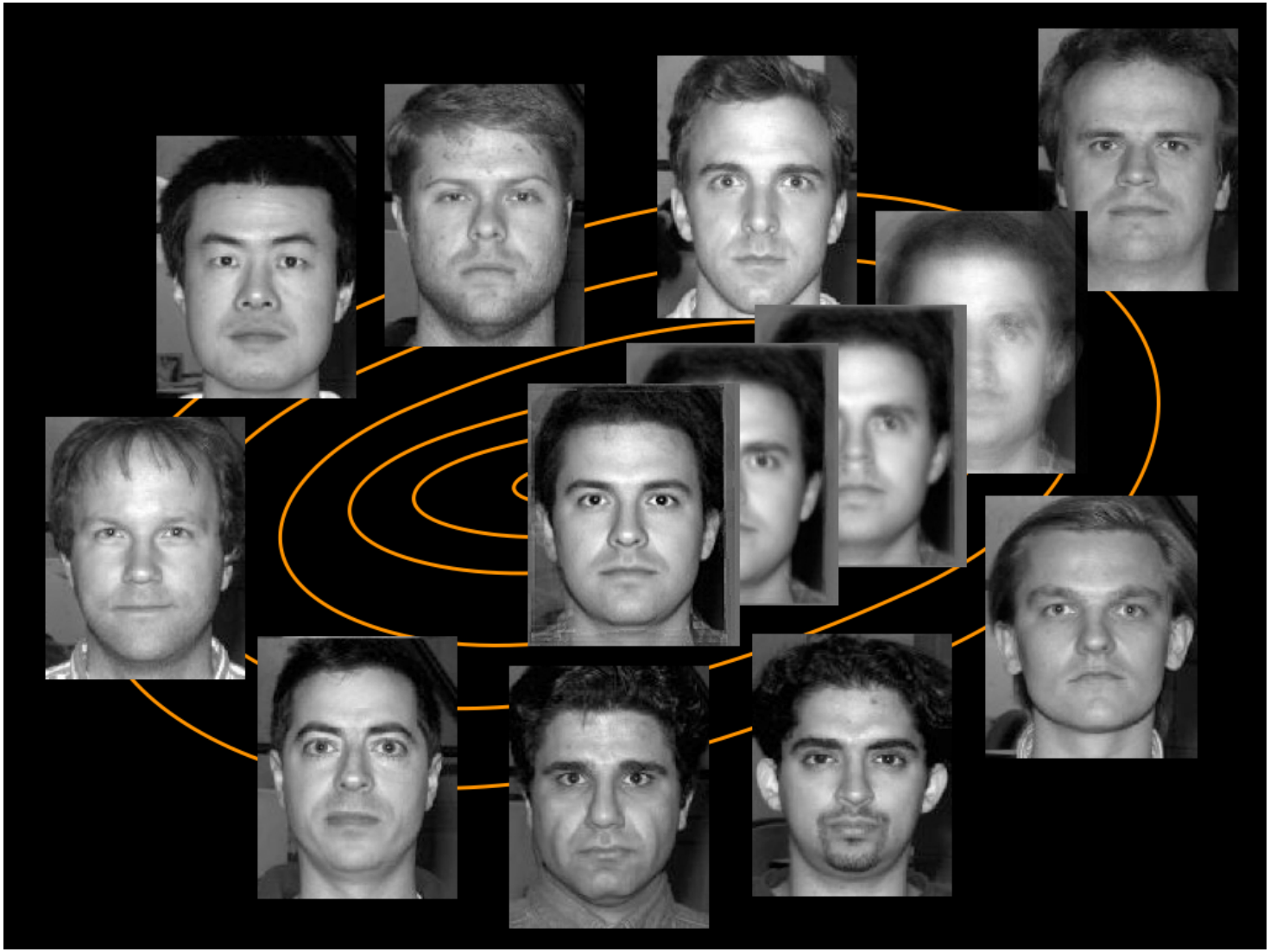
antsRegistration

```
$ antsRegistration --help

COMMAND:
     antsRegistration
          This program is a user-level registration applicatio
          ITKv4-only classes. The user can specify any number
          consists of a transform; an image metric; and iterat
          smoothing sigmas for each level.Note that dimensiona
          output, convergence, shrink-factors and smoothing-si
          mandatory.

OPTIONS:
     --version
          Get Version Information.

     -d, --dimensionality 2/3
```

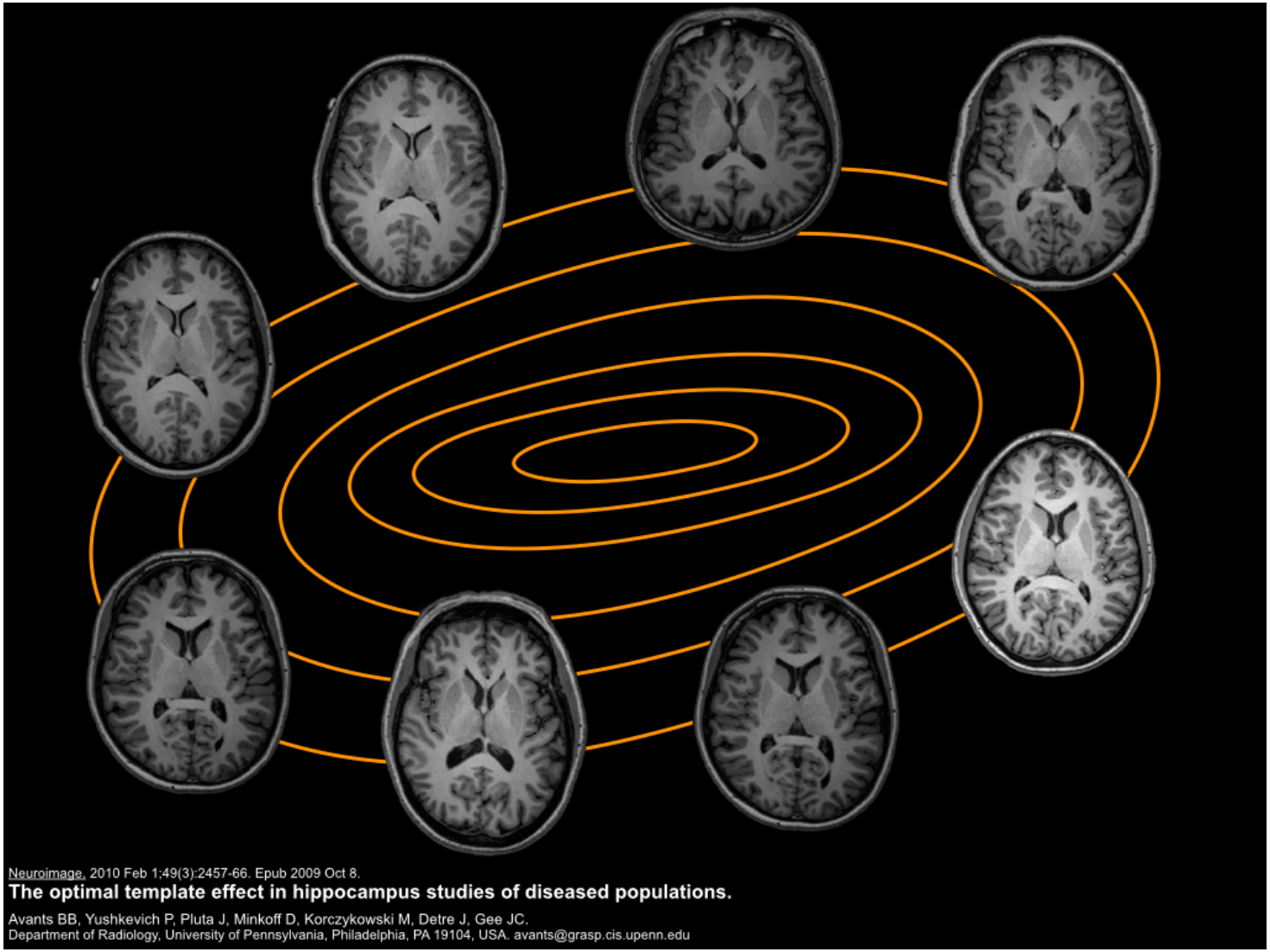
Template building: creating the average Joe



"Attractiveness" $\rightarrow$ mental processing?

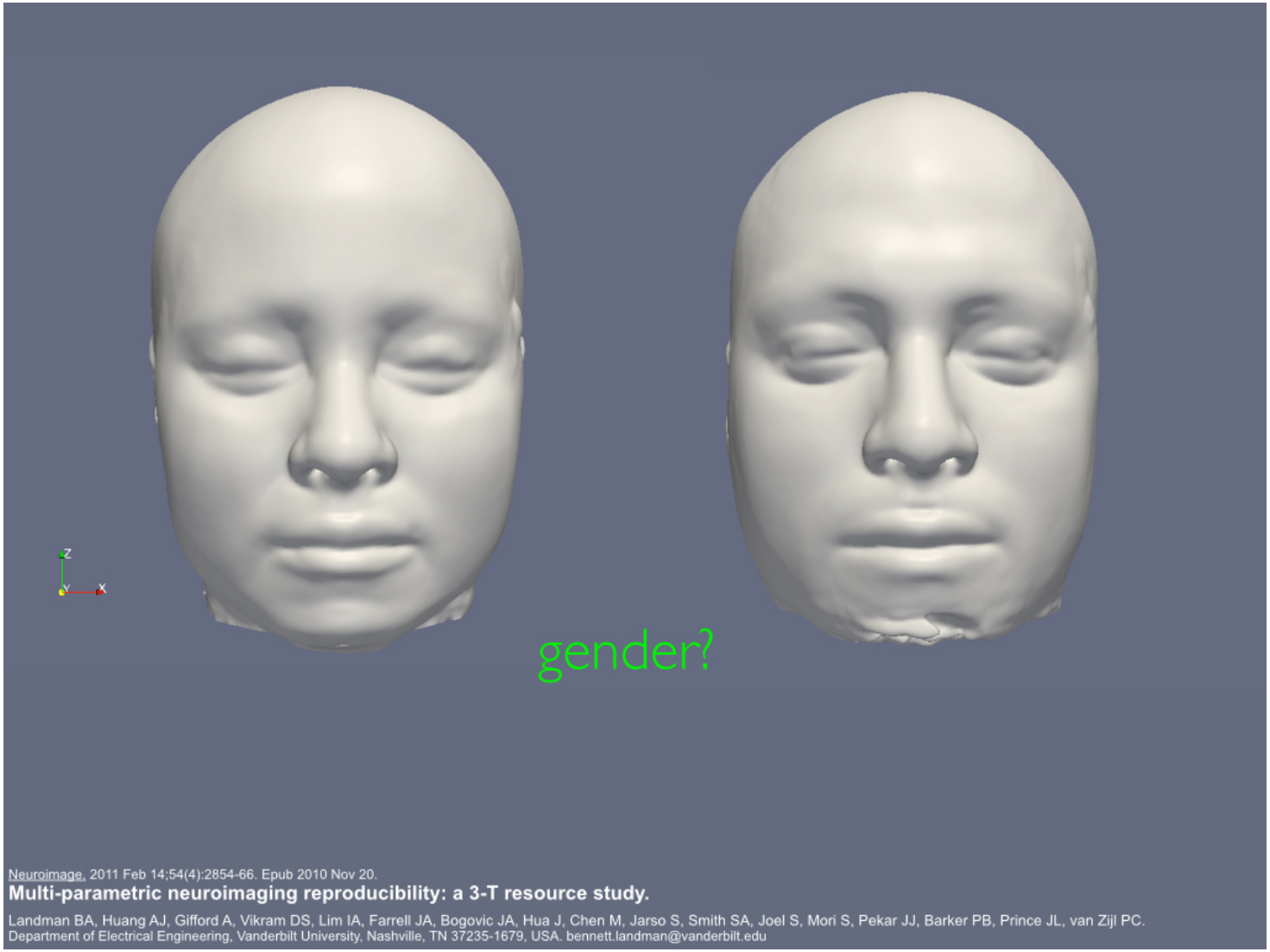


What about brains?



Templates facilitate computation

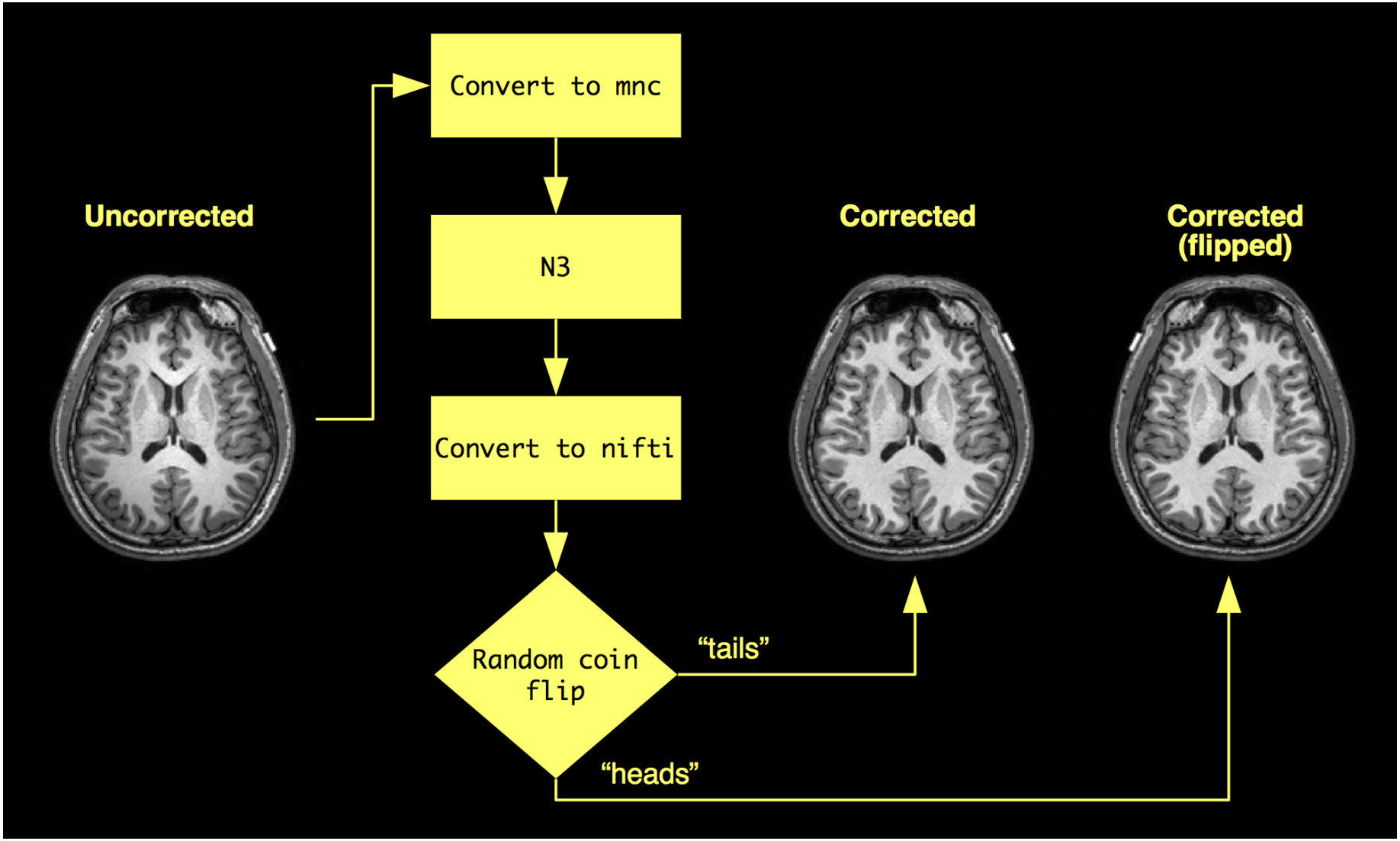
Gender?


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)

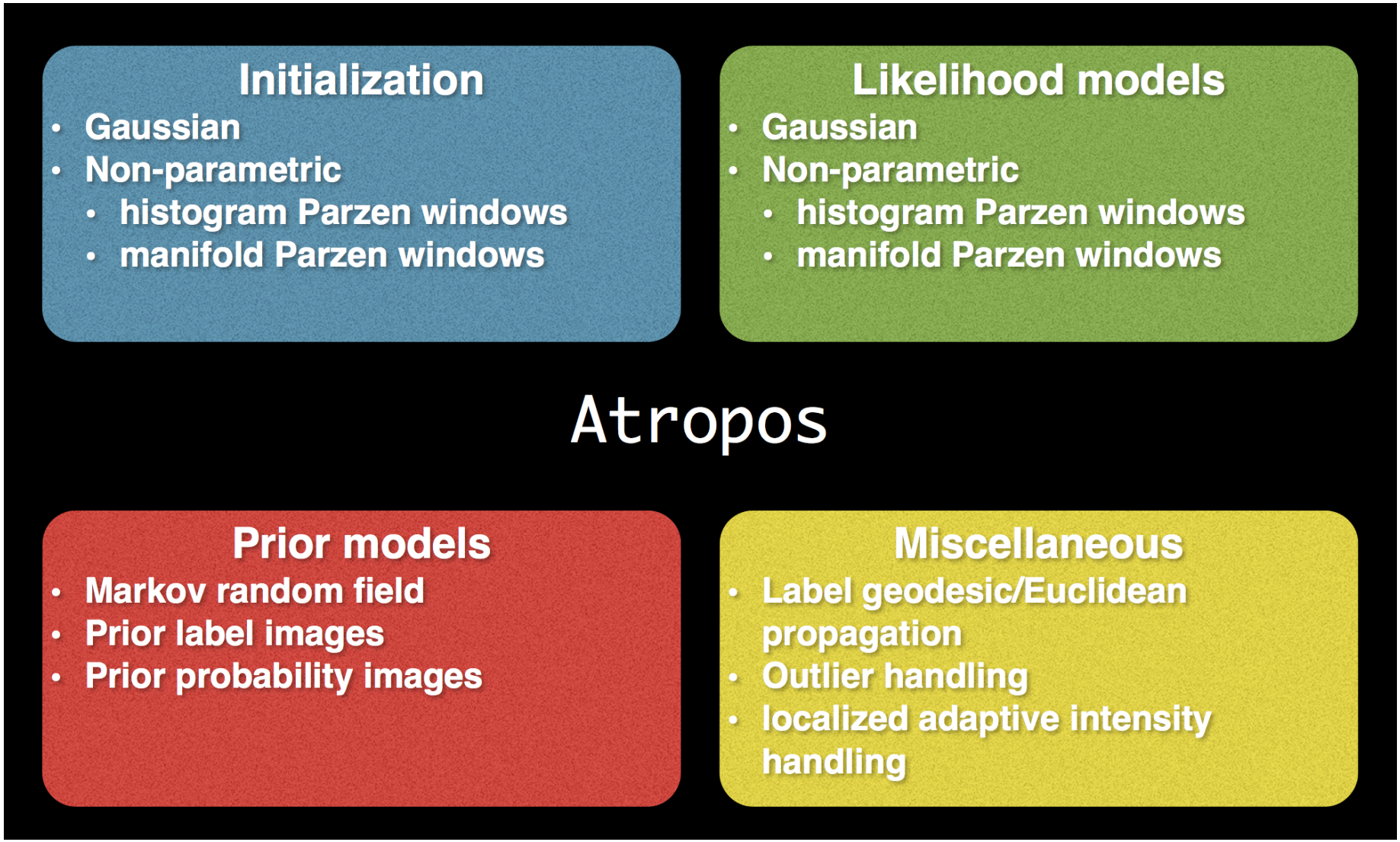


N4 ("Nick's N3")

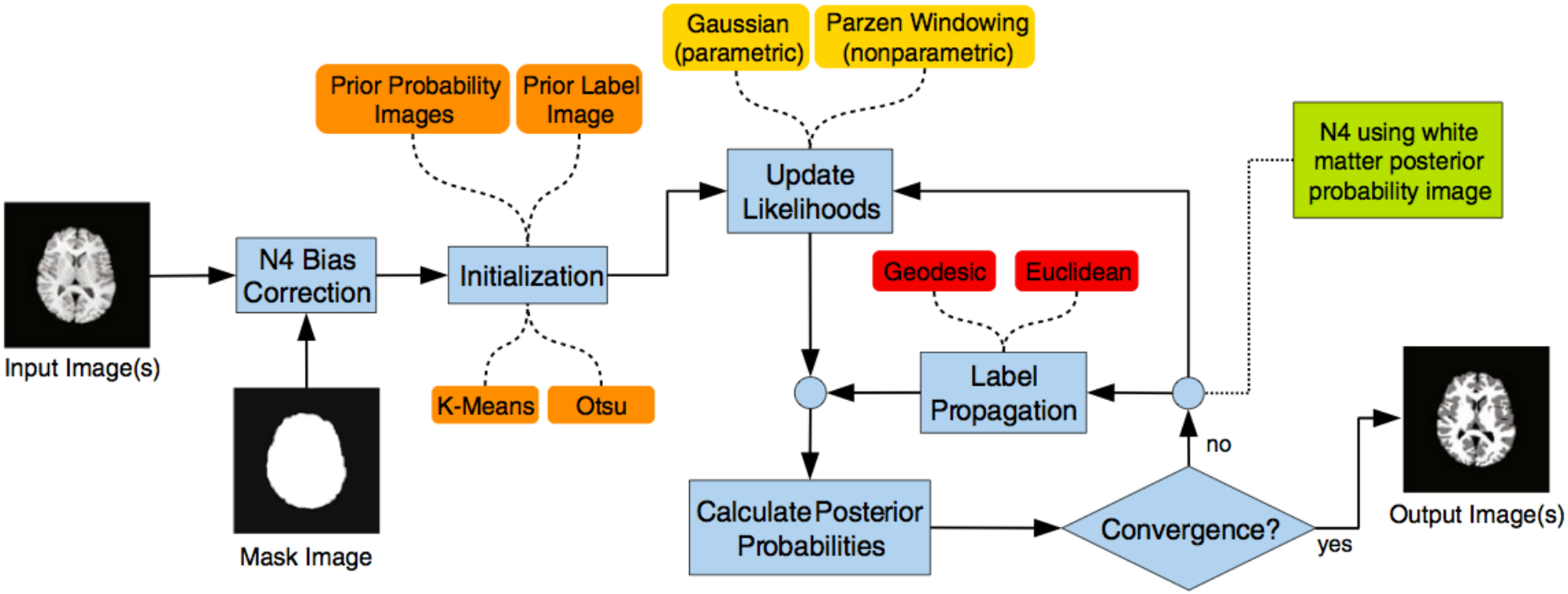
- comparative evaluation
- small spline distances (useful for higher magnet strengths)
- multiresolution
- weighted regional mask (used in `antsAtroposN4.sh`)
- fast execution times
- *publicly available*
- tested nightly within the ITK dashboard system

Atropos: flexible code base

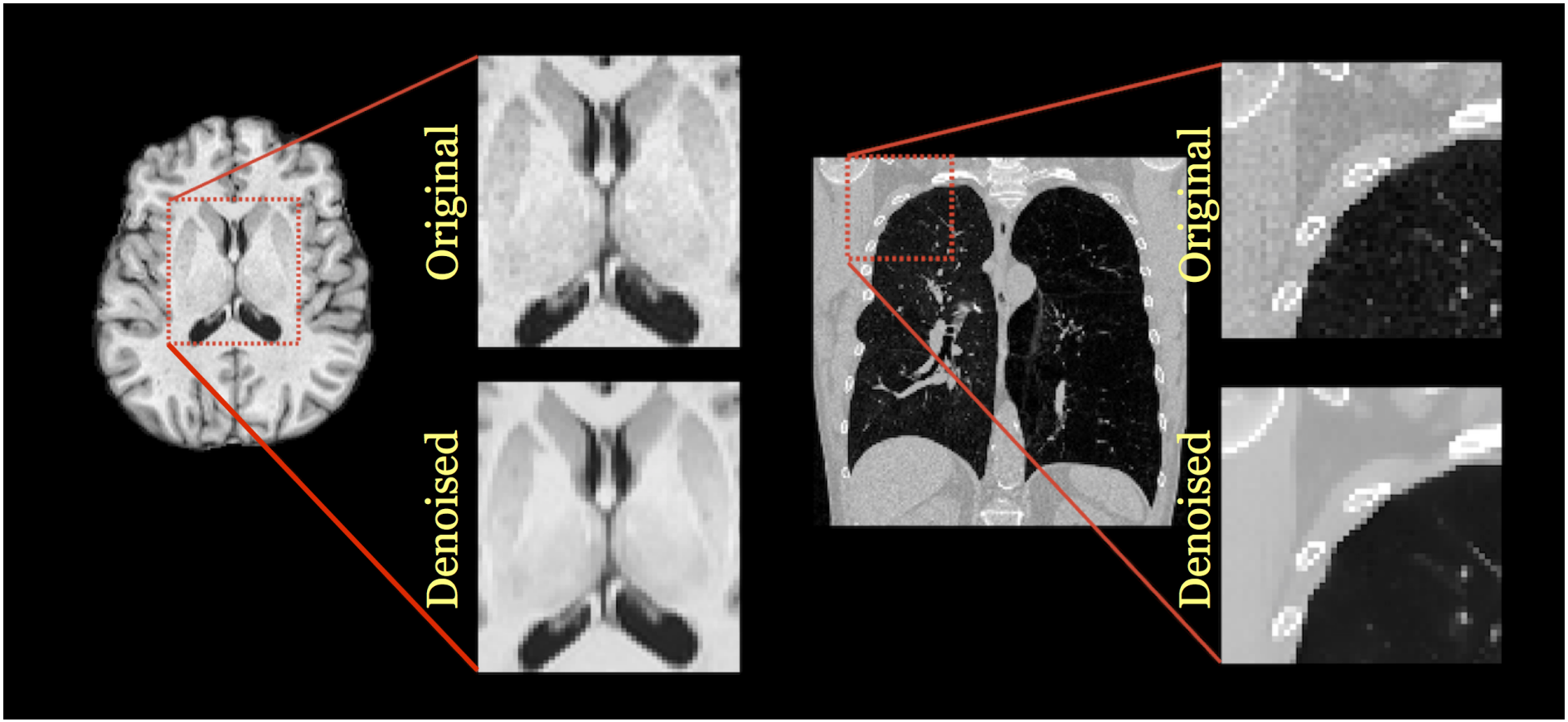
"20+ years of development. *Show me the code!*"



Atropos + N4 → antsAtroposN4.sh



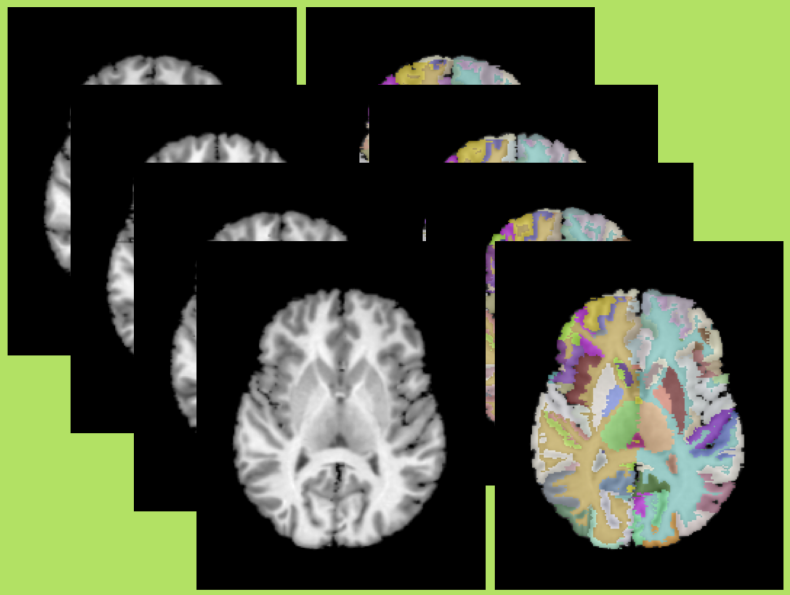
DenoiseImage — contribution from Jose Manjon



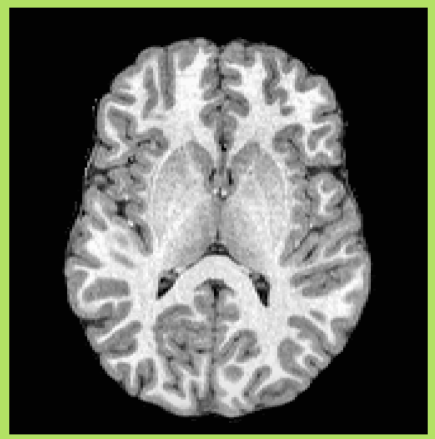

```
$ DenoiseImage --help


COMMAND:
```

Multi-atlas segmentation

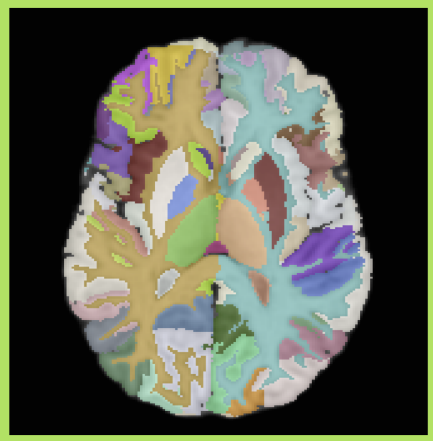
Joint label fusion



Atlases
(grayscale + segmentation)



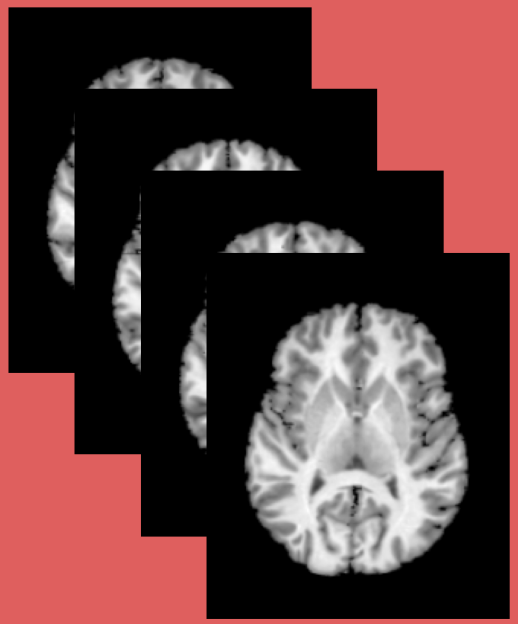
Target image



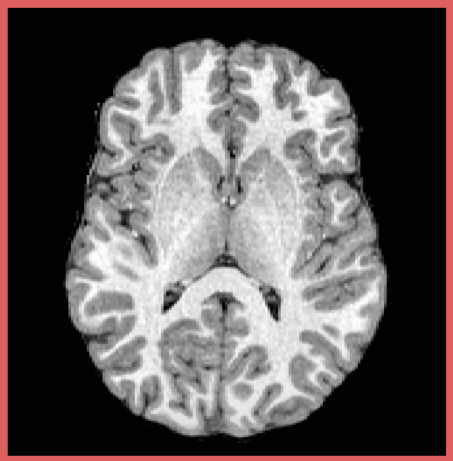
Target segmentation

New work: joint intensity fusion

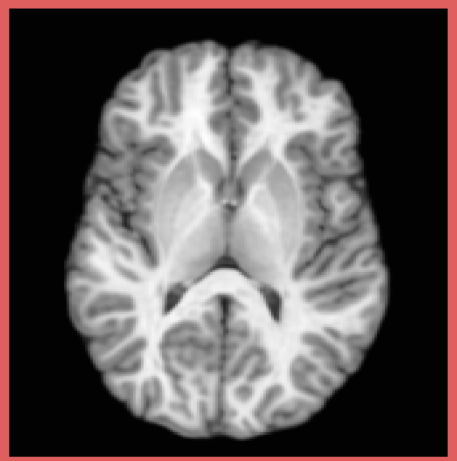
Joint intensity fusion



Atlases
(grayscale only)



Target image



Target fusion image

Possible uses

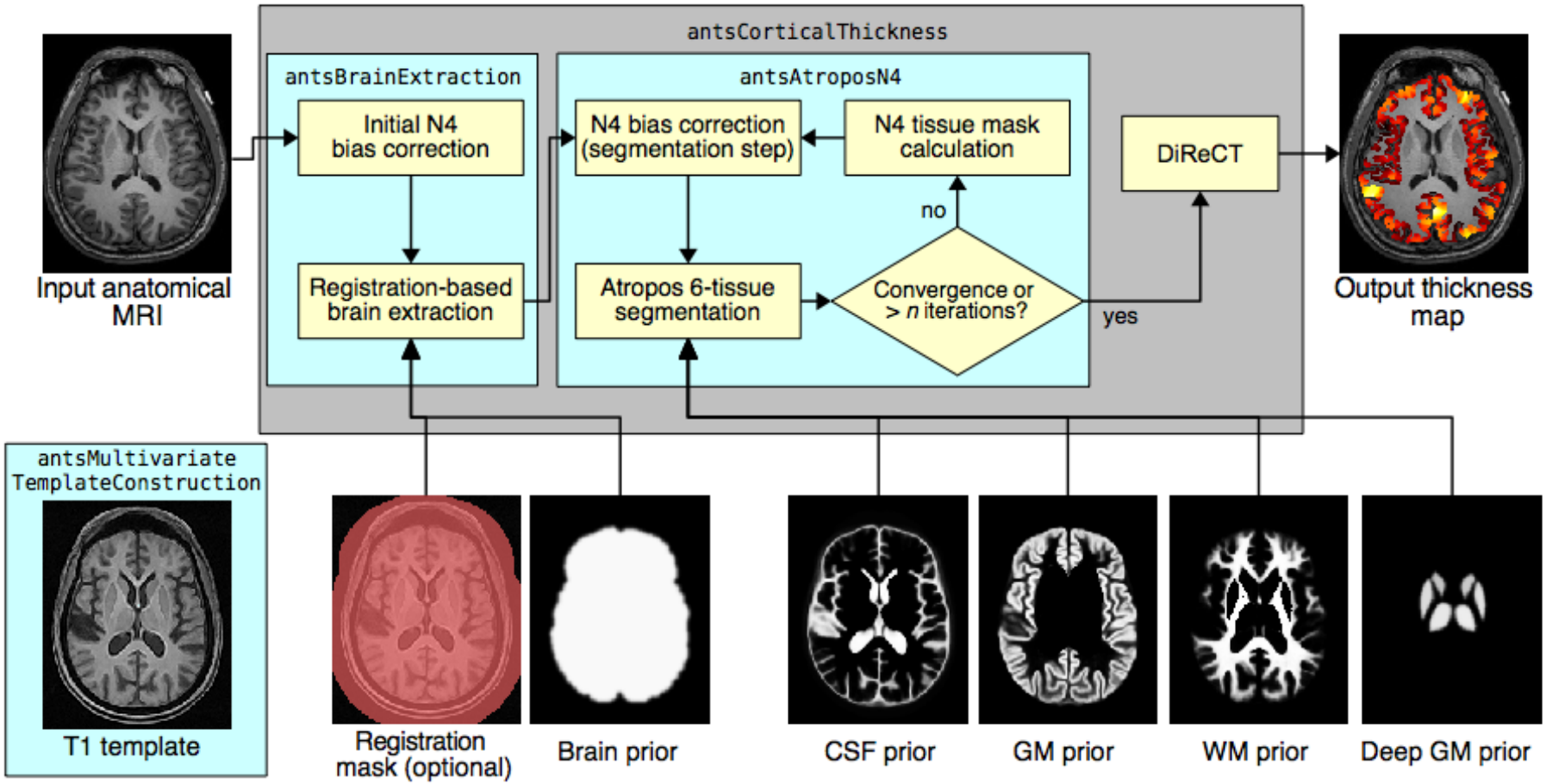
- "Correct" images
  - motion correction
  - "remove" lesions
- Project atlas set intensity signature
- Use in "corrective learning"

Putting it all together—the ANTs cortical thickness pipeline

Cortical thickness studies

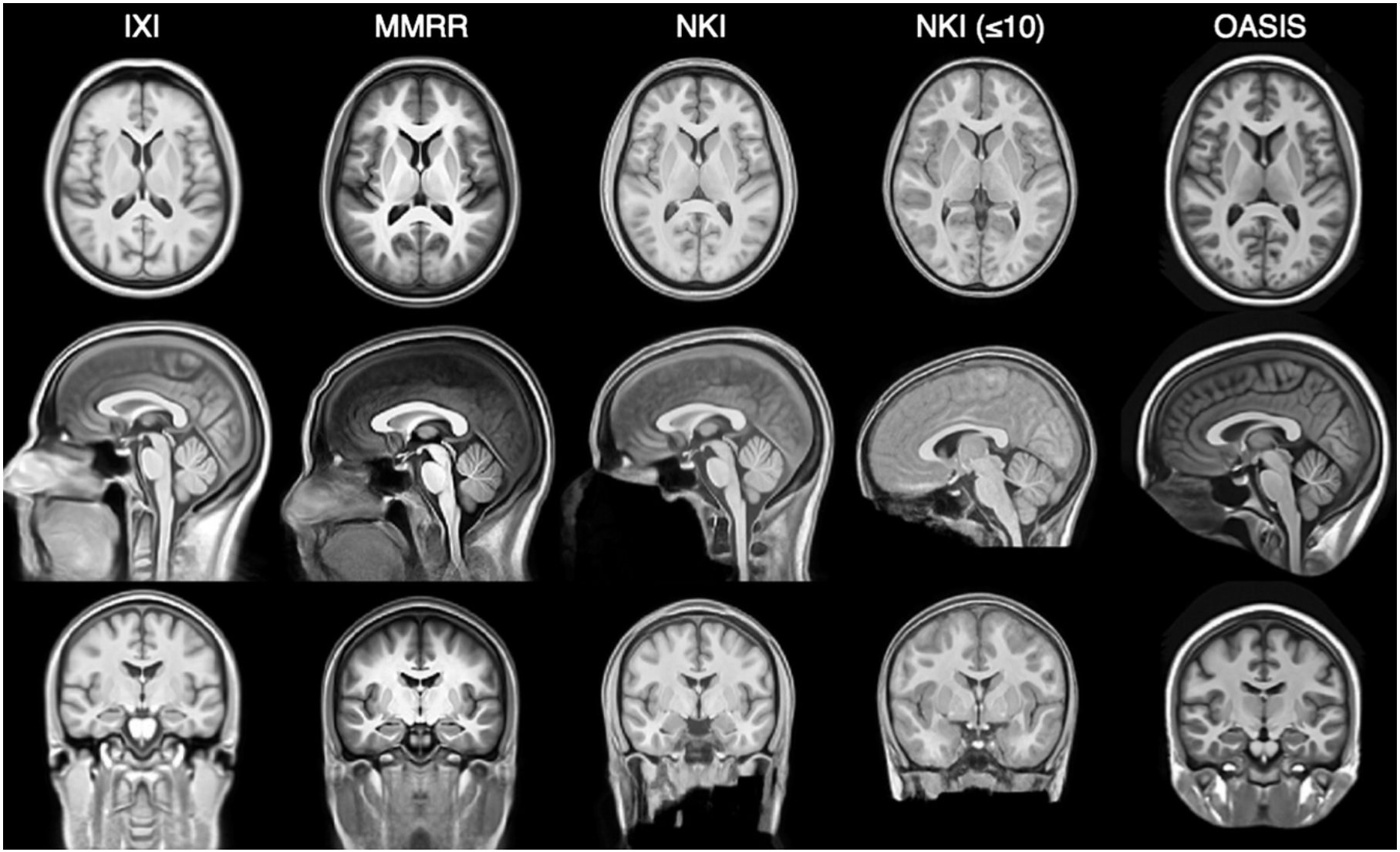
Column1	Column2
Tetris-playing ability	chronic pancreatitis
Huntington's disease	obsessive-compulsive disorder
schizophrenia	ADHD
bipolar disorder	obesity
Alzheimer's disease	heritable depression
frontotemporal dementia	elderly depression
Parkinson's disease	age
Williams syndrome	gender
multiple sclerosis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

The ANTs structural brain mapping workflow

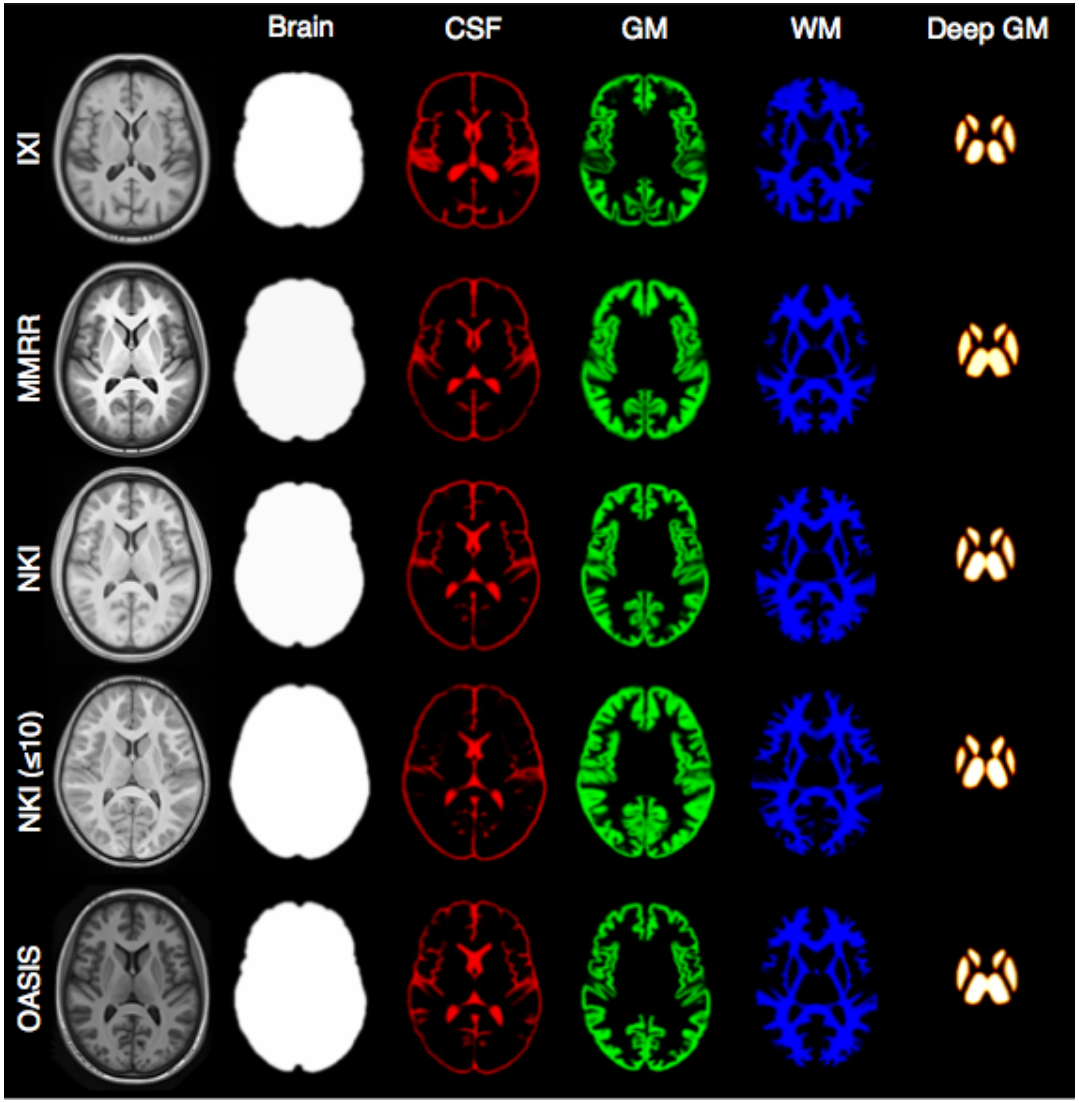


Template building

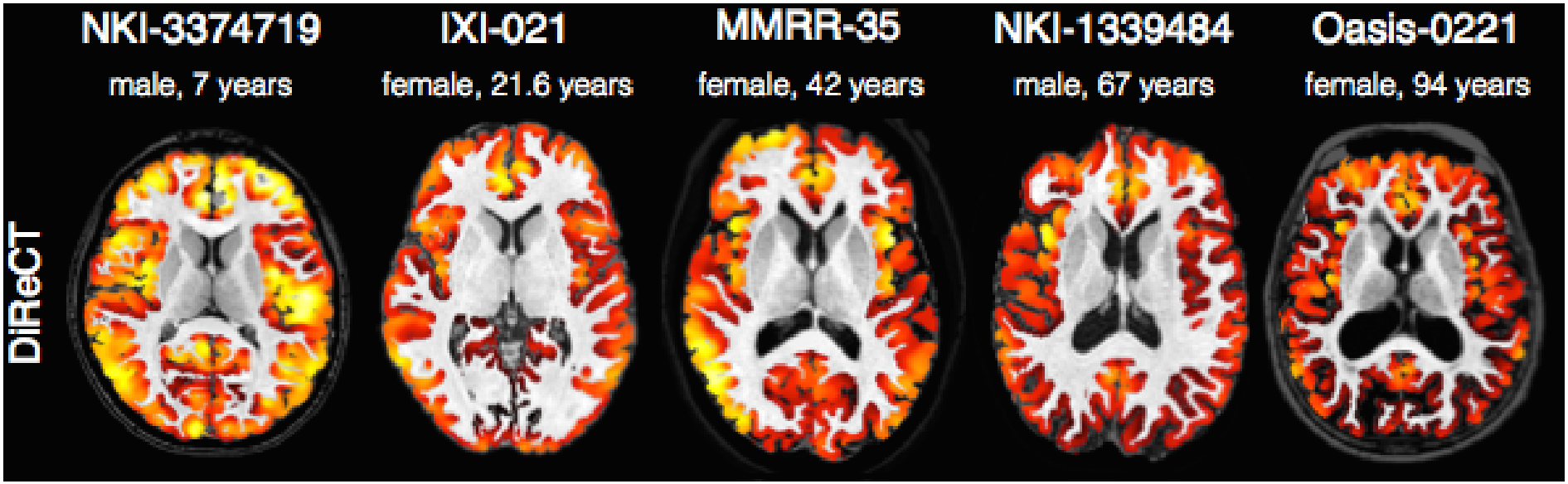
Tailor data to your specific cohort



Template priors



Cortical thickness maps



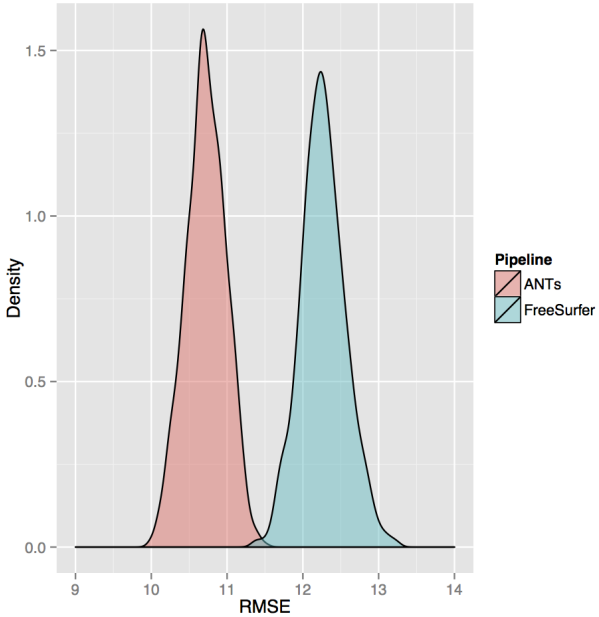
In contrast to FreeSurfer which warps coupled surface meshes to segment the gray matter, *ANTs* diffeomorphically registers the white matter to the combined gray/white matters while simultaneously estimating thickness.

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

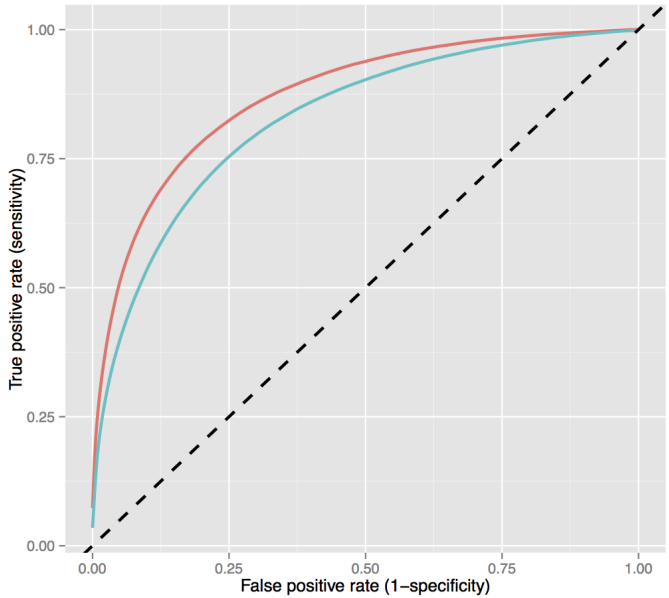
Predict age and gender

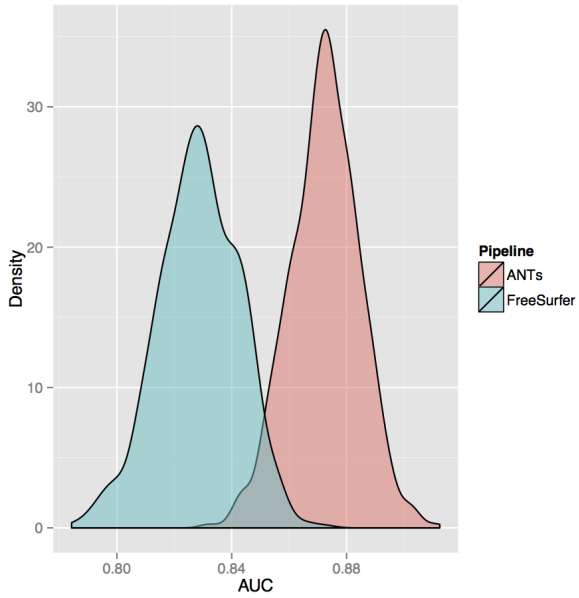
$$AGE \sim VOLUME + GENDER + \sum_{i=1}^{62} T(DKT_i)$$

Prediction from cortical thickness data



Age

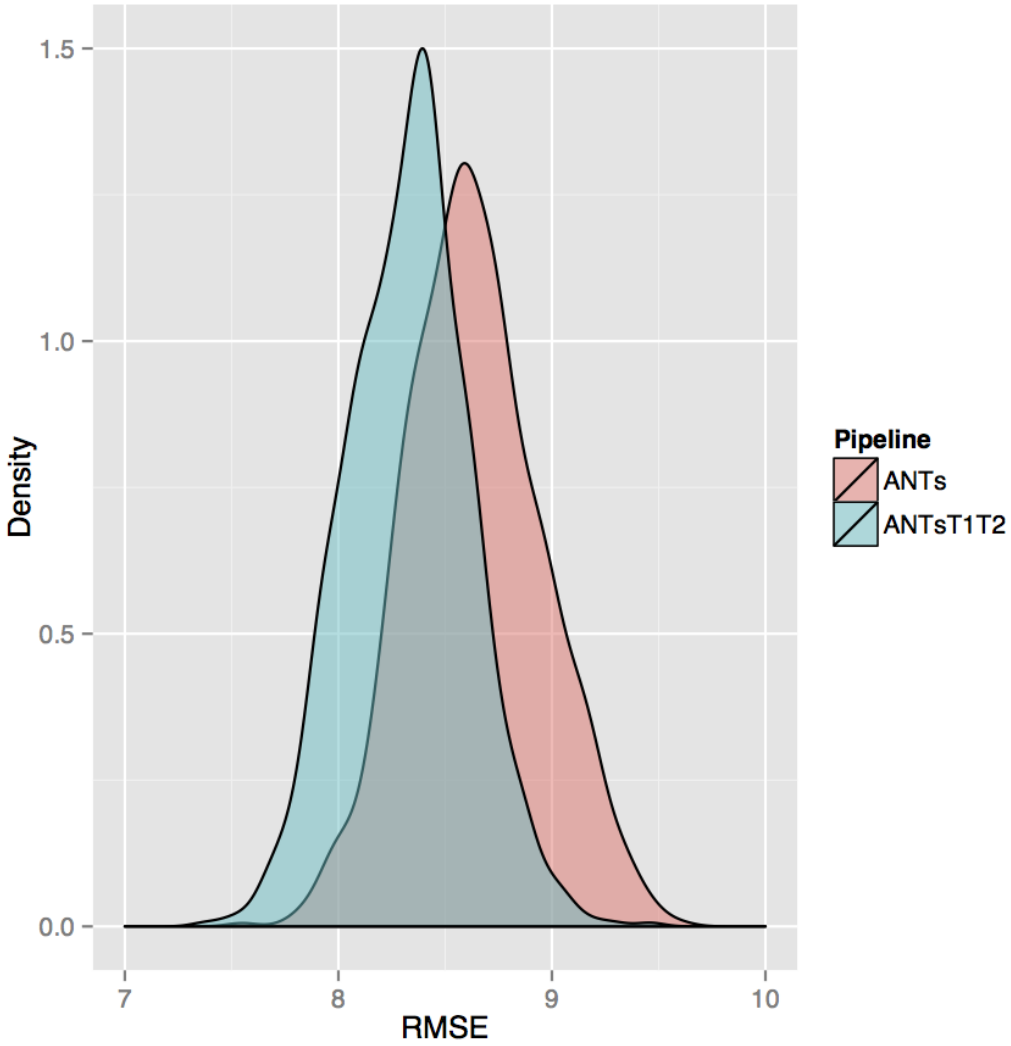




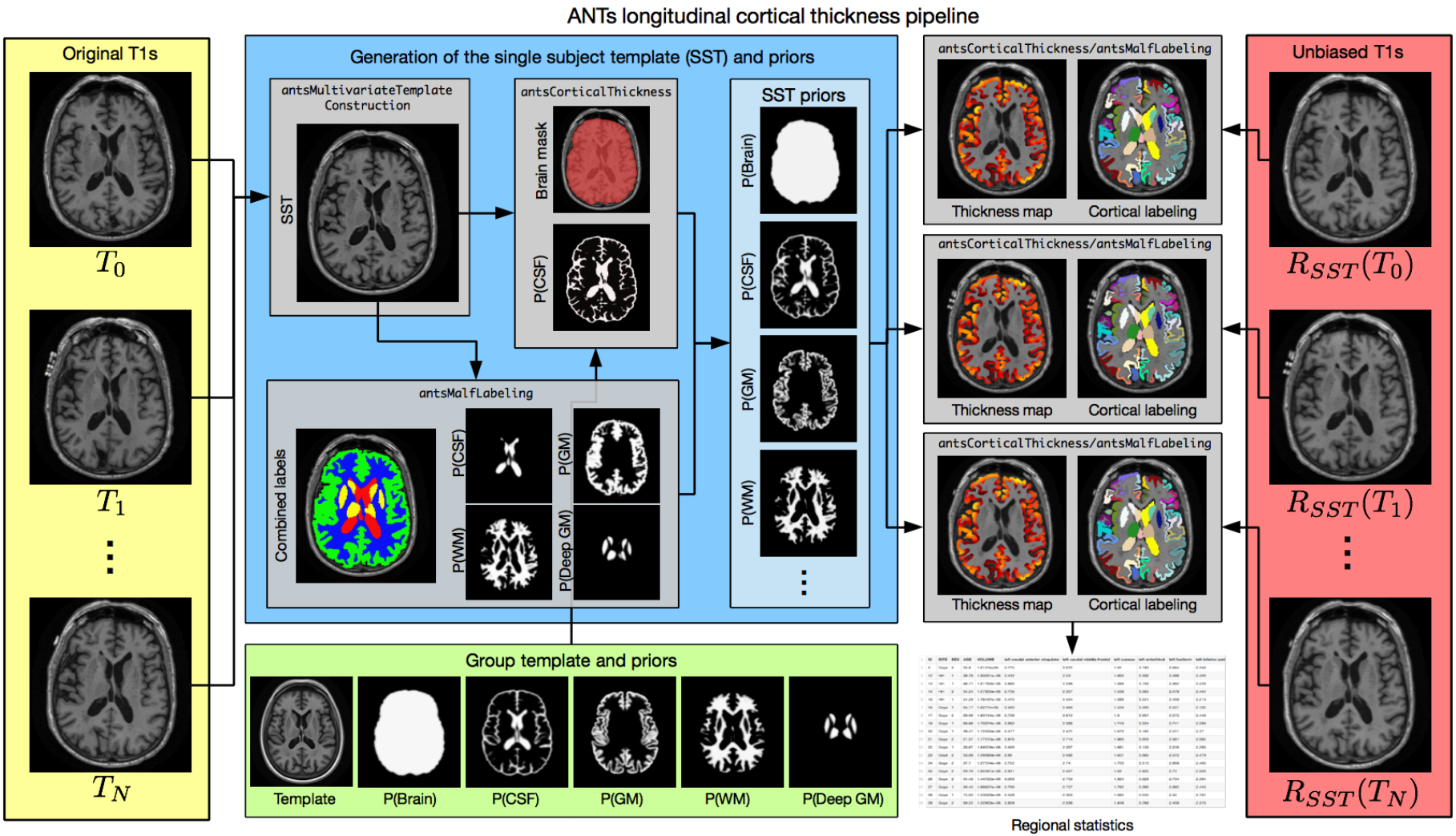
Gender

But, wait, there's more!

ANTs tools are multivariate

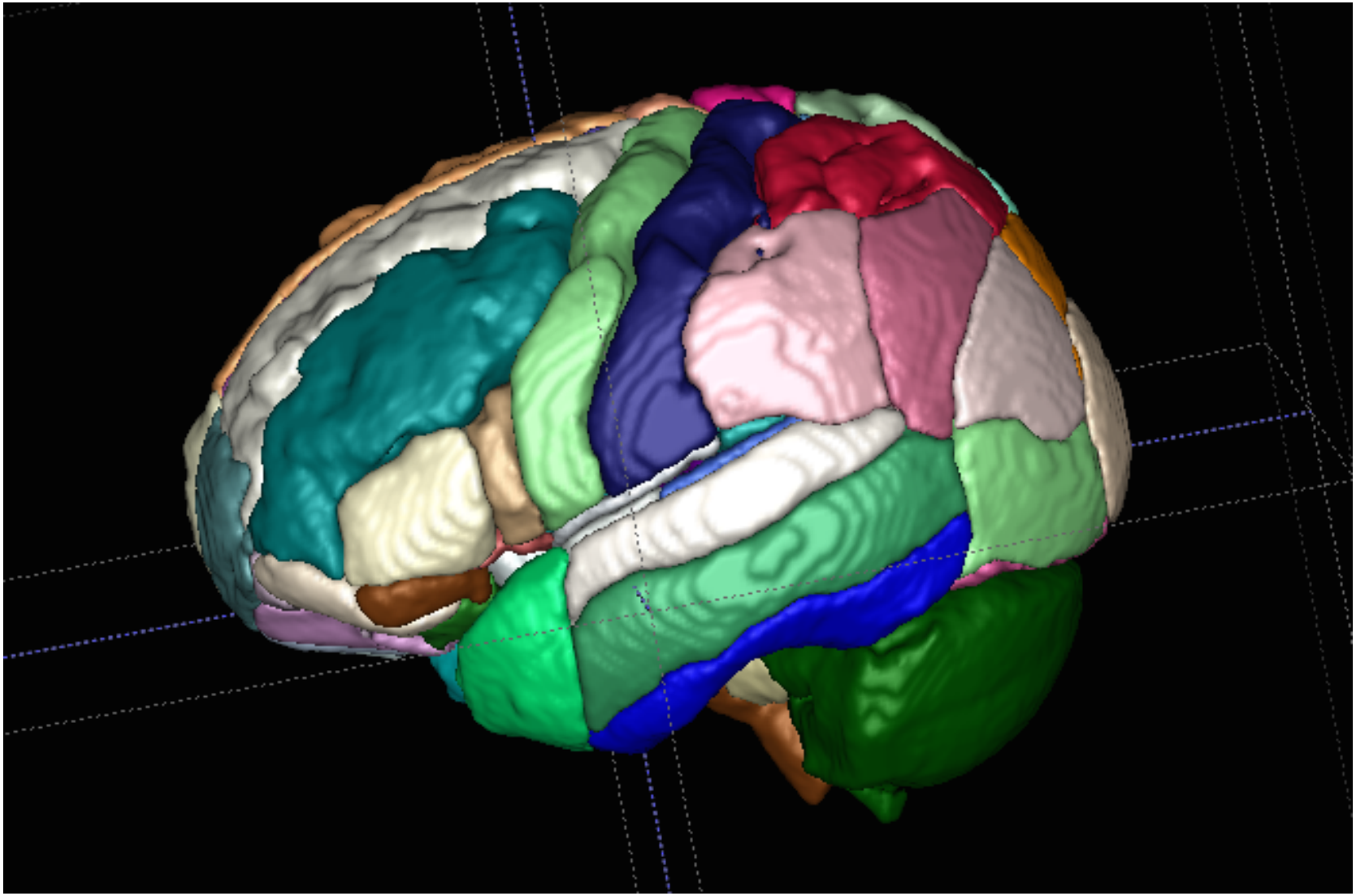


Longitudinal processing



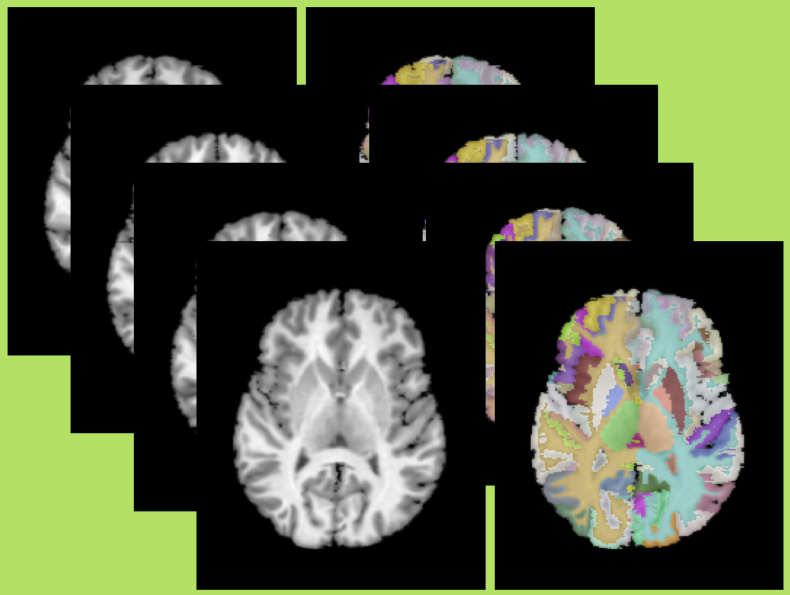
Joint label/intensity fusion

Multi-atlas labeling

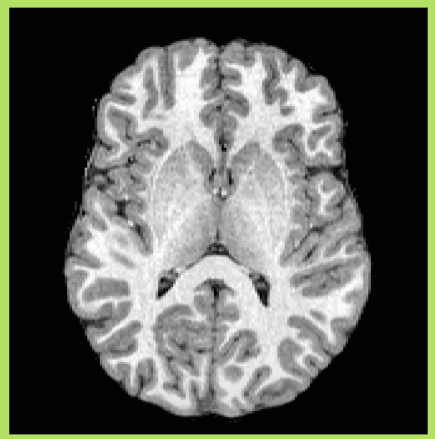


Multi-atlas segmentation

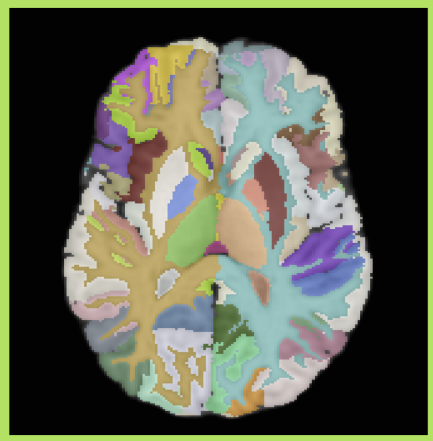
Joint label fusion



Atlases
(grayscale + segmentation)



Target image



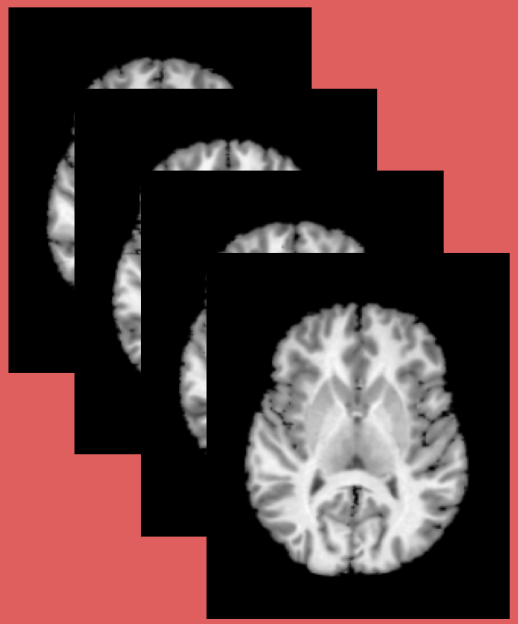
Target segmentation

Multi-atlas 2012 results

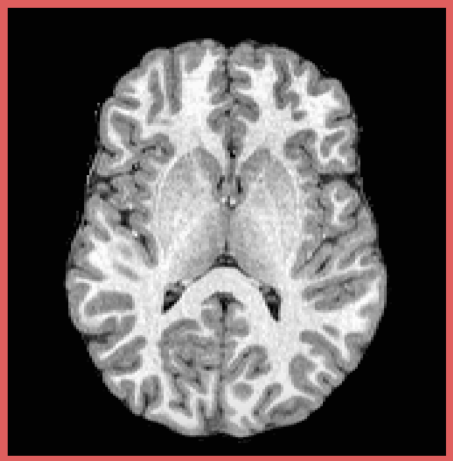
Overall Rank †	Repro. Rank‡	Team Name	Mean DSC Overall	Mean DSC Cortical	Mean DSC Non-Cortical
1	1	PICSL_BC	0.7654	0.7388	0.8377
2	2	NonLocalSTAPLE	0.7581	0.7318	0.8296
3	3	MALP_EM	0.7576	0.7328	0.8252
4	4	PICSL_Joint	0.7499	0.7216	0.8271
5	6	MAPER	0.7413	0.7144	0.8144
6	7	STEPS	0.7372	0.7107	0.8095
7	5	SpatialSTAPLE	0.7372	0.7093	0.8130
8	9	CIS_JHU	0.7357	0.7131	0.7971
9	8	CRL_Weighted_STAPLE ANTS+Baloo	0.7344	0.7122	0.7950
10	10	CRL_Weighted_STAPLE ANTS	0.7308	0.7066	0.7966

New work: joint intensity fusion

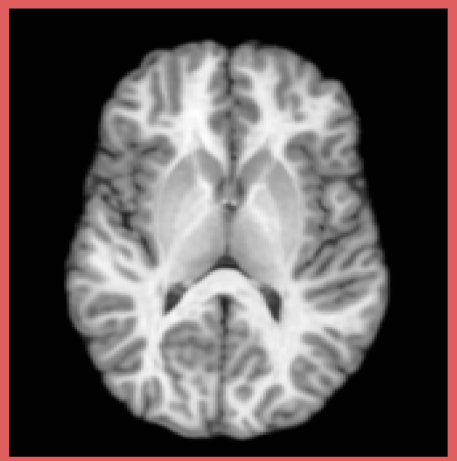
Joint intensity fusion



Atlases
(grayscale only)



Target image



Target fusion image