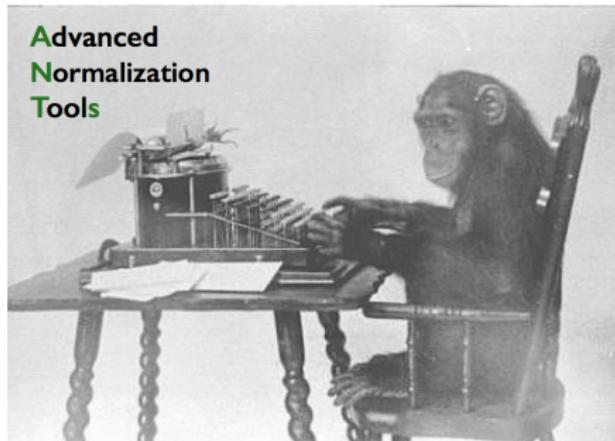


Quantitative neuroimaging with ANTs

Nick Tustison

University of Virginia



What is ANTs?

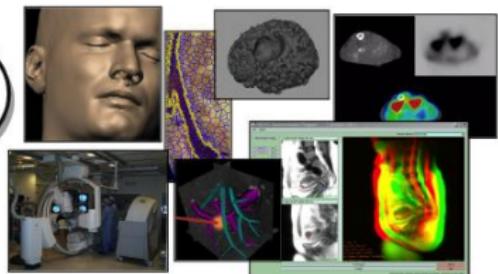
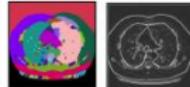
NLM's The Visible Human Project and The Insight Toolkit



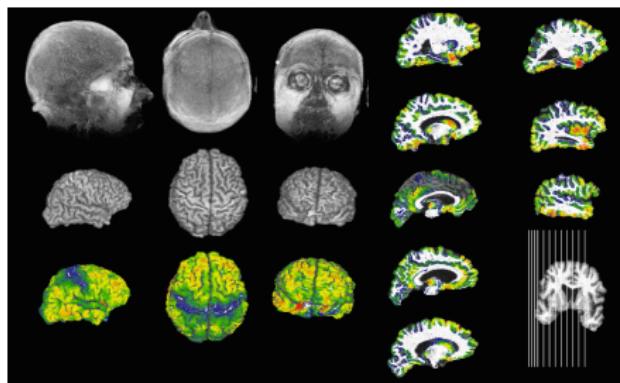
Image data



Knowledge

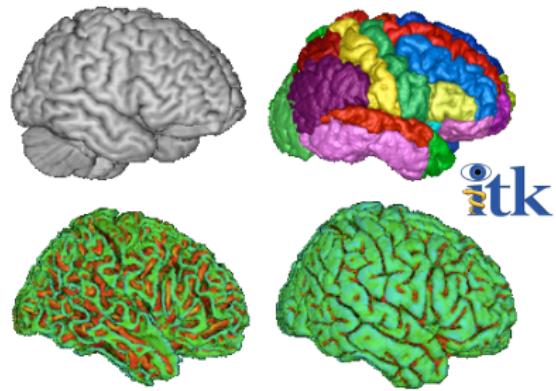


ANTs began with a clinical research need.



ADVANCED NORMALIZATION TOOLS

HIGH PERFORMANCE METHODS FOR NORMALIZATION, SEGMENTATION & COMPUTATIONAL ANATOMY

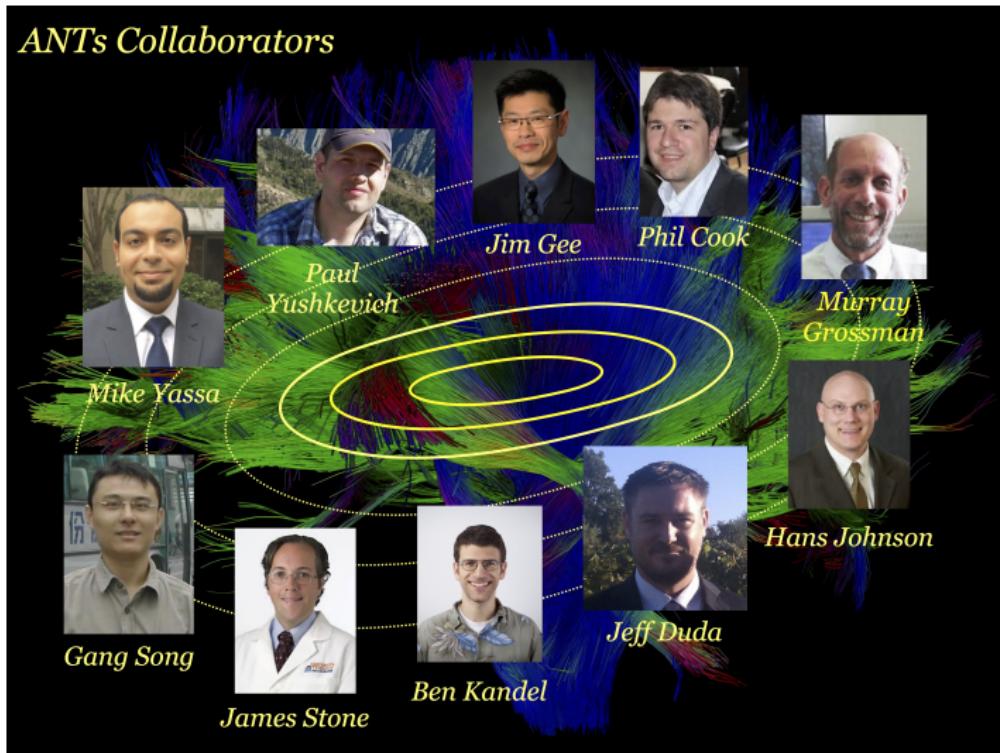


Founding developers

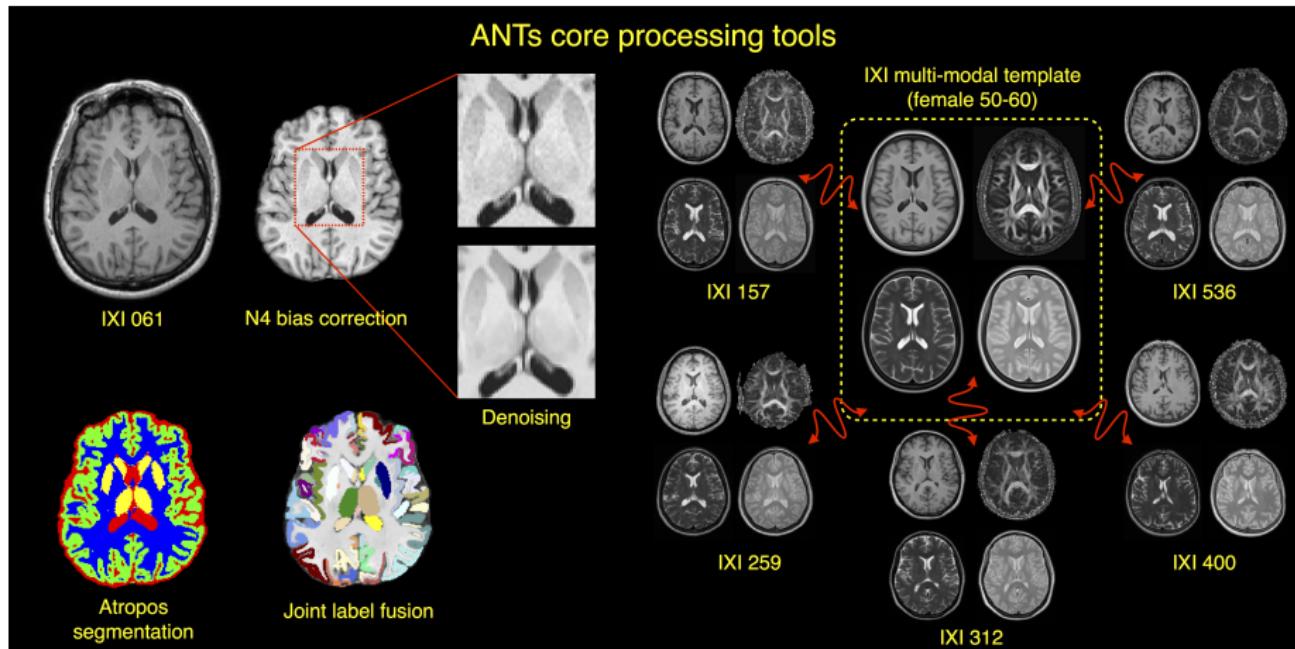


BBA & NJT

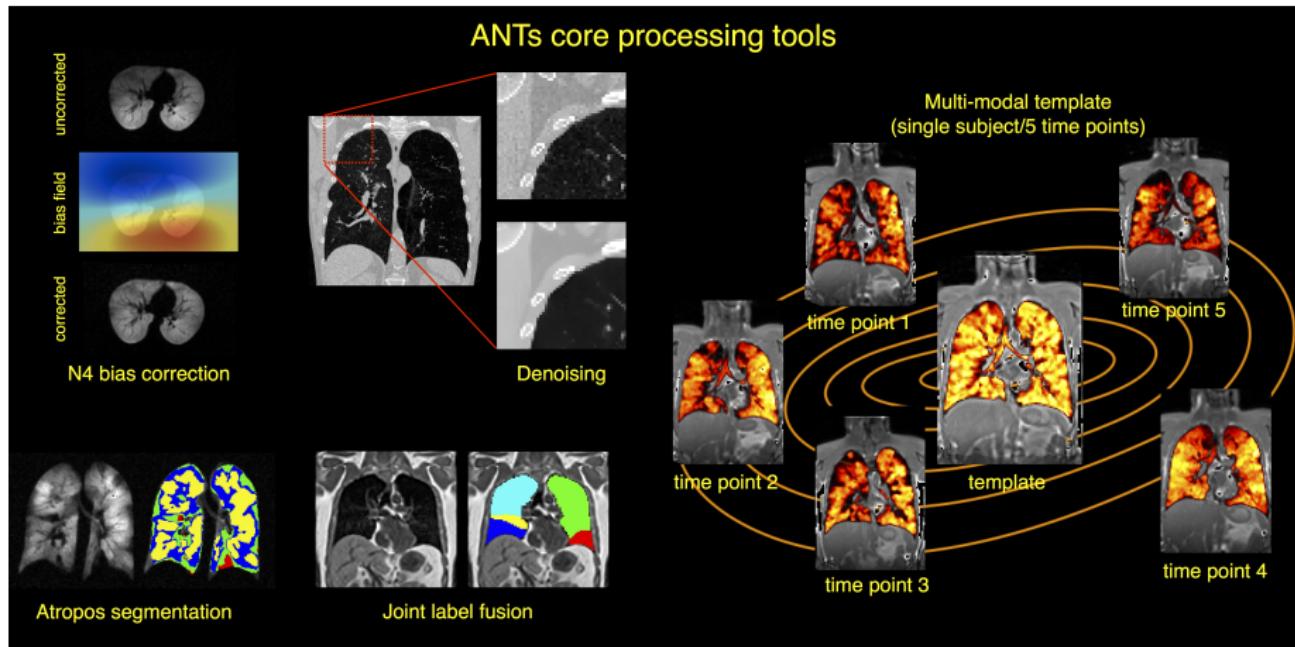
Collaborators



Advanced Normalization Tools



Advanced Normalization Tools → “ITK-Lung”



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

Donoho?

“Papers are just advertisements for the science.”

antsRegistration

```
$ antsRegistration --help
```

COMMAND:

```
antsRegistration
```

This program is a user-level registration application meant to utilize ITKv4-only classes. The user can specify any number of "stages" where a stage consists of a transform; an image metric; and iterations, shrink factors, smoothing sigmas for each level. Note that dimensionality, metric, transform, output, convergence, shrink-factors and smoothing-sigmas parameters are mandatory.

OPTIONS:

```
--version
```

Get Version Information.

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

This option forces the image to be treated as a specified-dimensional image. If not specified, we try to infer the dimensionality from the input image.

```
-o, --output outputTransformPrefix
```

```
[outputTransformPrefix,<outputWarpedImage>,<outputInverseWarpedImage>]
```

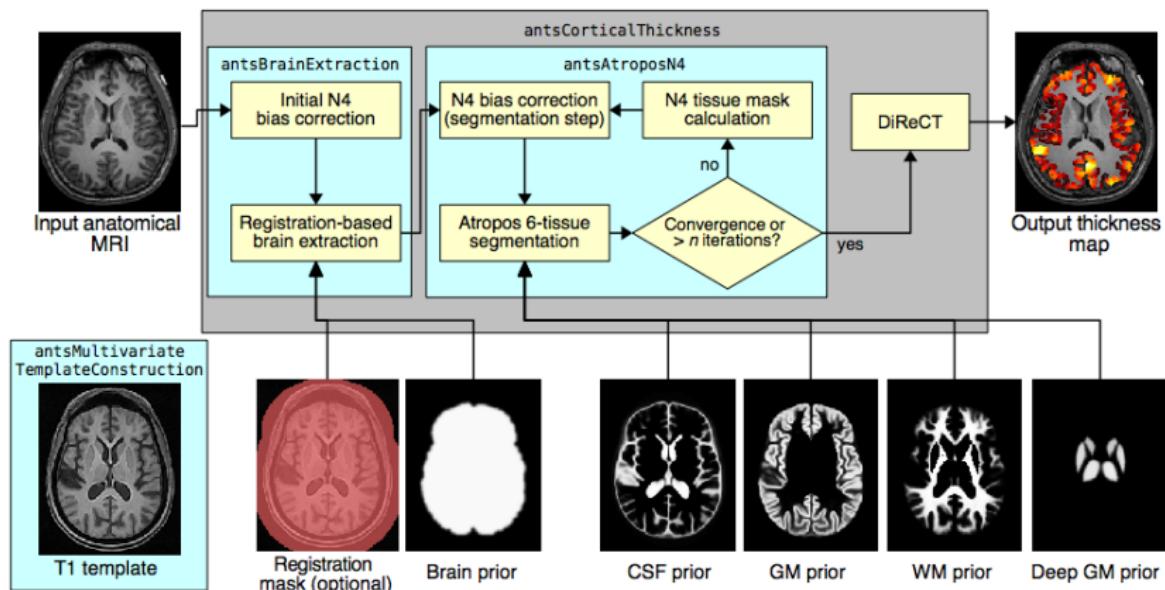
Specify the output transform prefix (output format is .nii.gz). Optional arguments include <outputWarpedImage> and <outputInverseWarpedImage>. You can choose to warp the moving image to the fixed space and, if the inverse

Putting it all together—the ANTs cortical thickness pipeline

Cortical thickness studies

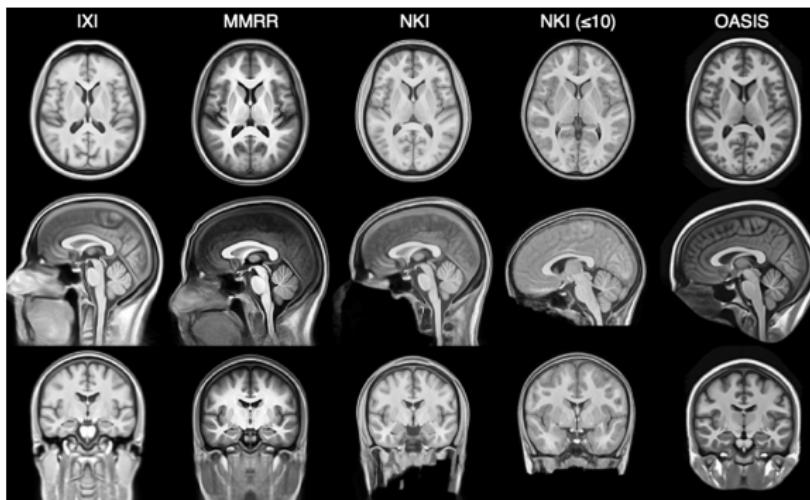
Column1	Column2
Tetris-playing ability	chronic pancreatitis
Huntington's disease	obsessive-compulsive disorder
schizophrenia	ADHD
bipolar disorder	obesity
Alzheimer's disease	heritable depression
frontotemporal dementia	elderly depression
Parkinson's disease	age
Williams syndrome	gender
multiple sclerosis	handedness
autism	intelligence
migraines	athletic ability
chronic smoking	meditative practices
alcoholism	musical ability
cocaine addiction	tendency toward criminality
Tourette syndrome in children	childhood sexual abuse in female adolescents
scoliosis in female adolescents	traumatic brain injury
early-onset blindness	untreated male-to-female transsexuality

The ANTs structural brain mapping workflow



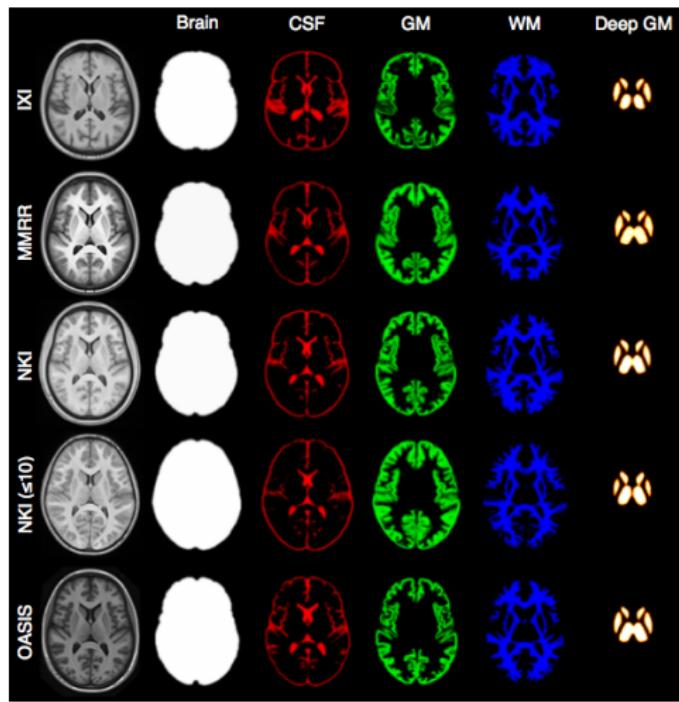
Template building

Tailor data to your specific cohort



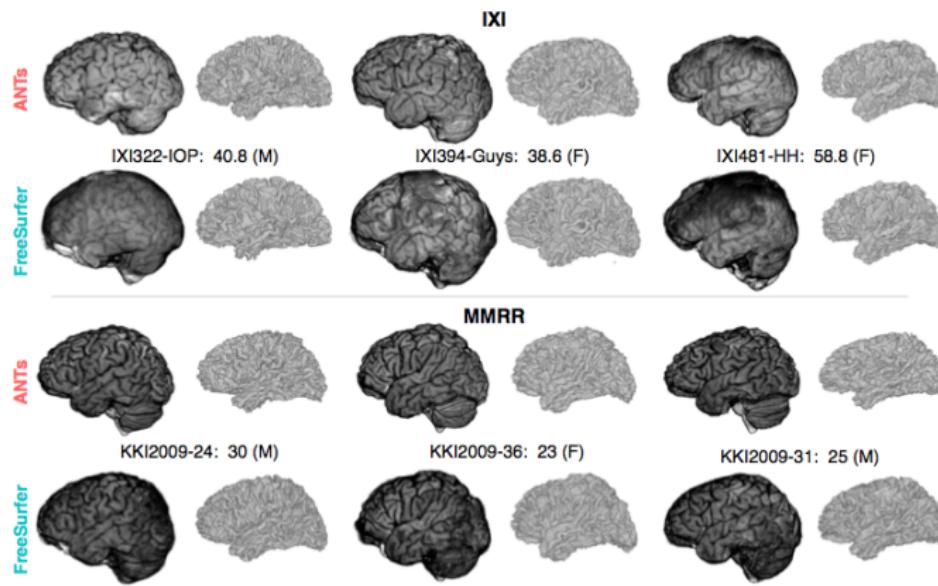
- Templates representing the average mean shape and intensity are built directly from the cohort to be analyzed, e.g. pediatric vs. middle-aged brains.
- Acquisition and anonymization (e.g. defacing) protocols are often different.

Template priors



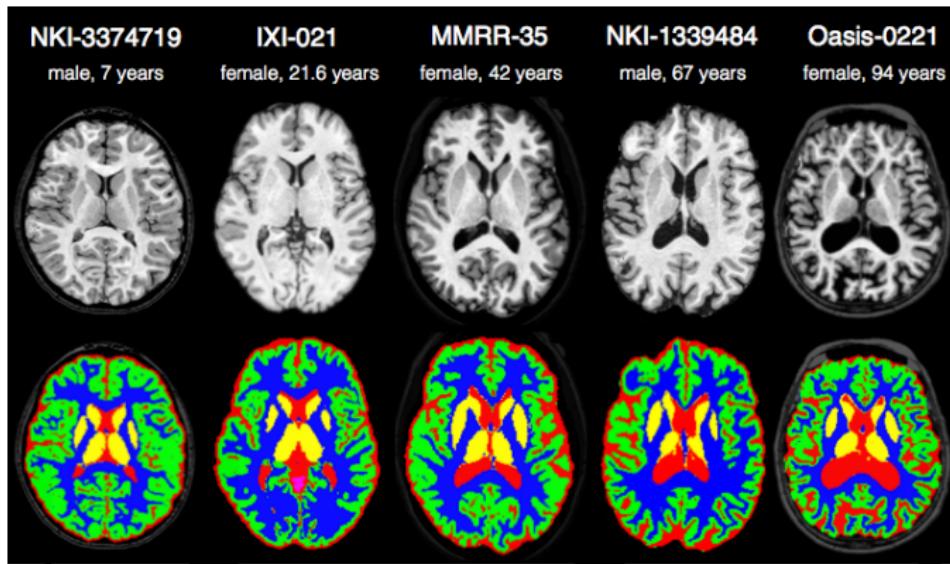
Each template is processed to produce auxiliary images which are used for brain extraction and brain segmentation.

Brain extraction comparison



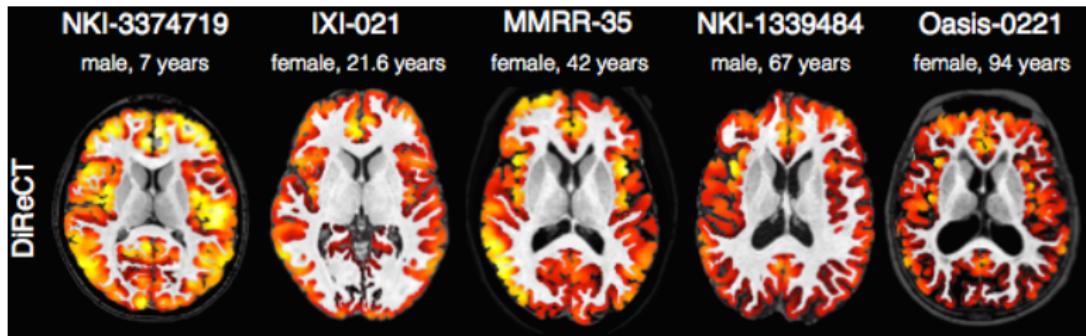
Comparison with de facto standard FreeSurfer package. Note the difference in separation of the gray matter from the surrounding CSF. (0 failures out of 1205 scans)

Brain segmentation



Randomly selected healthy individuals. Atropos gets good performance across ages.

Cortical thickness maps



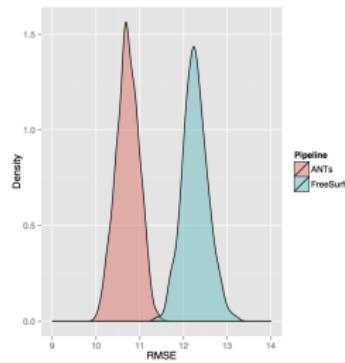
In contrast to FreeSurfer which warps coupled surface meshes to segment the gray matter, *ANTs* diffeomorphically registers the white matter to the combined gray/white matters while simultaneously estimating thickness.

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

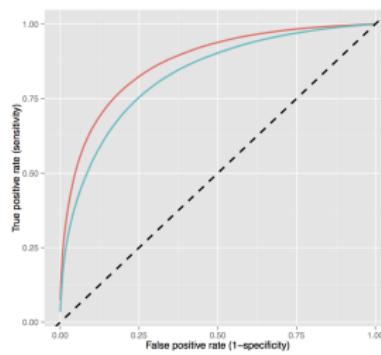
Predict age and gender

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

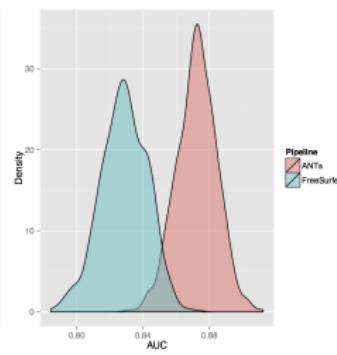
Prediction from cortical thickness data



Age



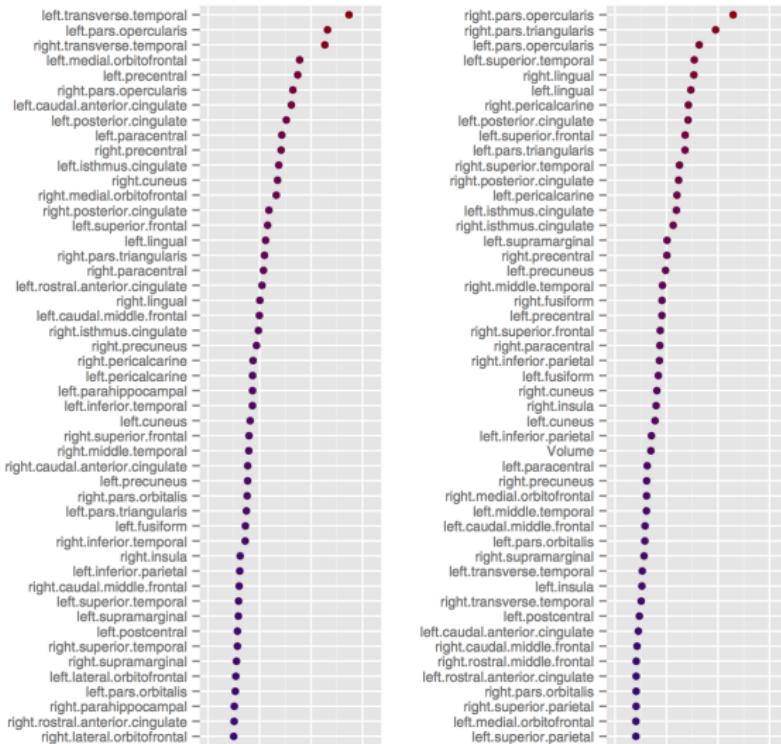
Gender



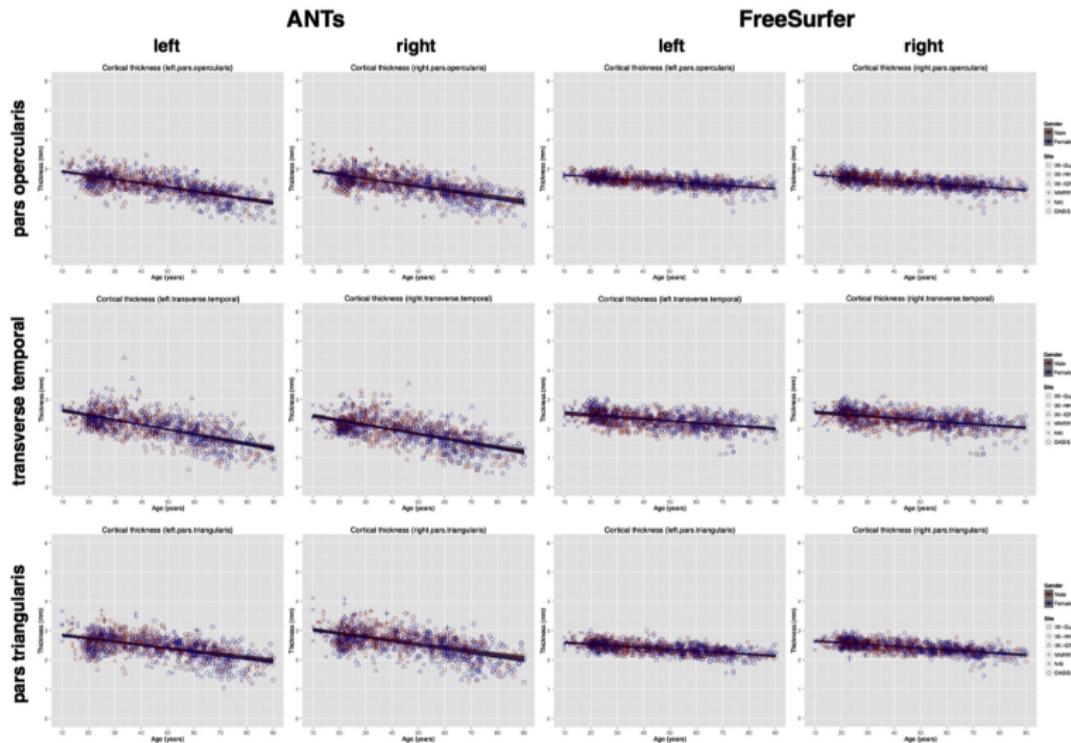
Pipeline
ANTS
FreeSurfer

Regional importance comparison

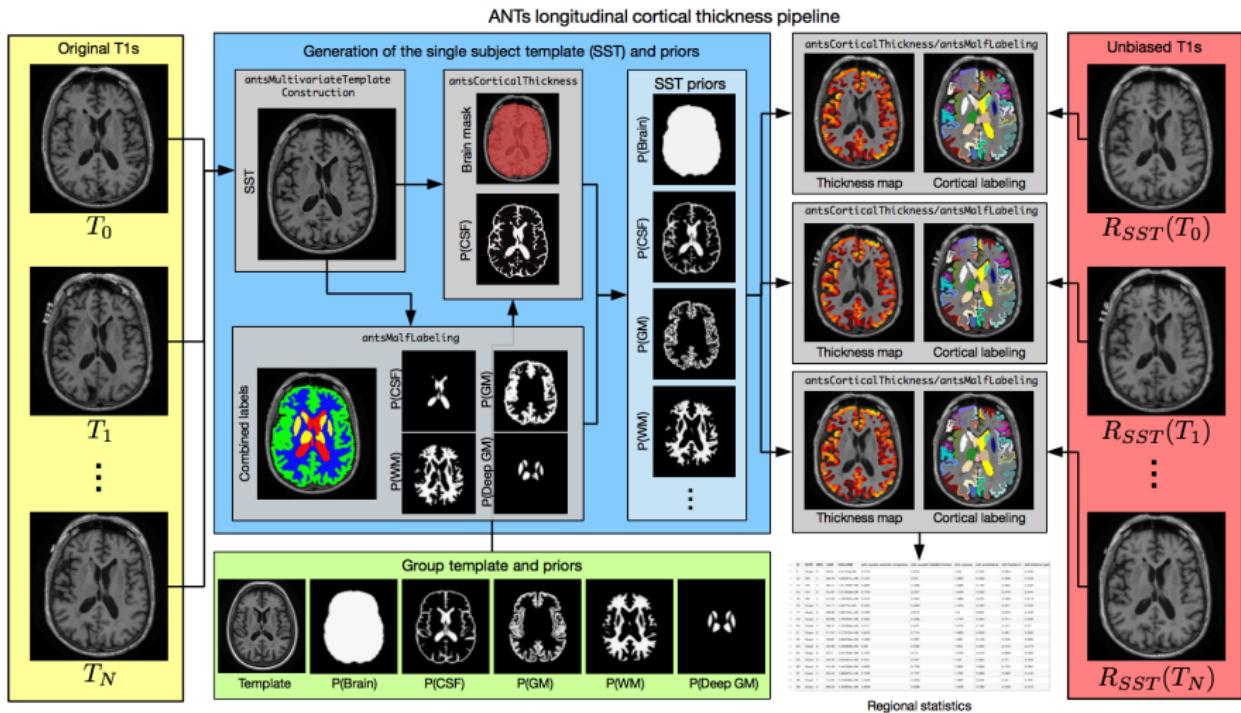
ANTs (left) vs. FreeSurfer (right)



Regional measurements

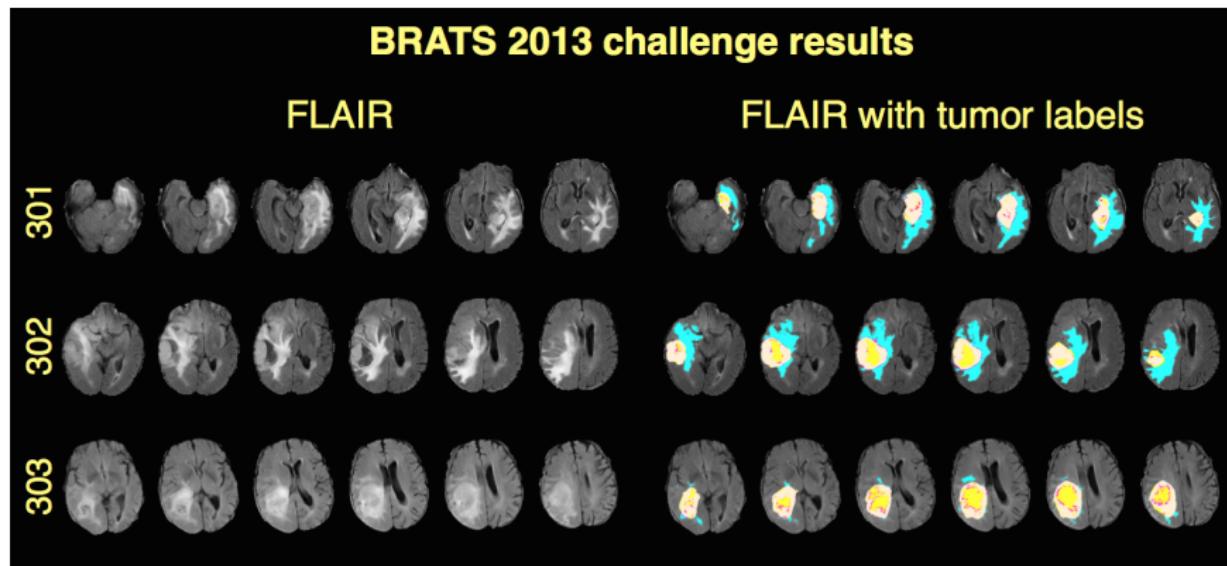


Longitudinal processing



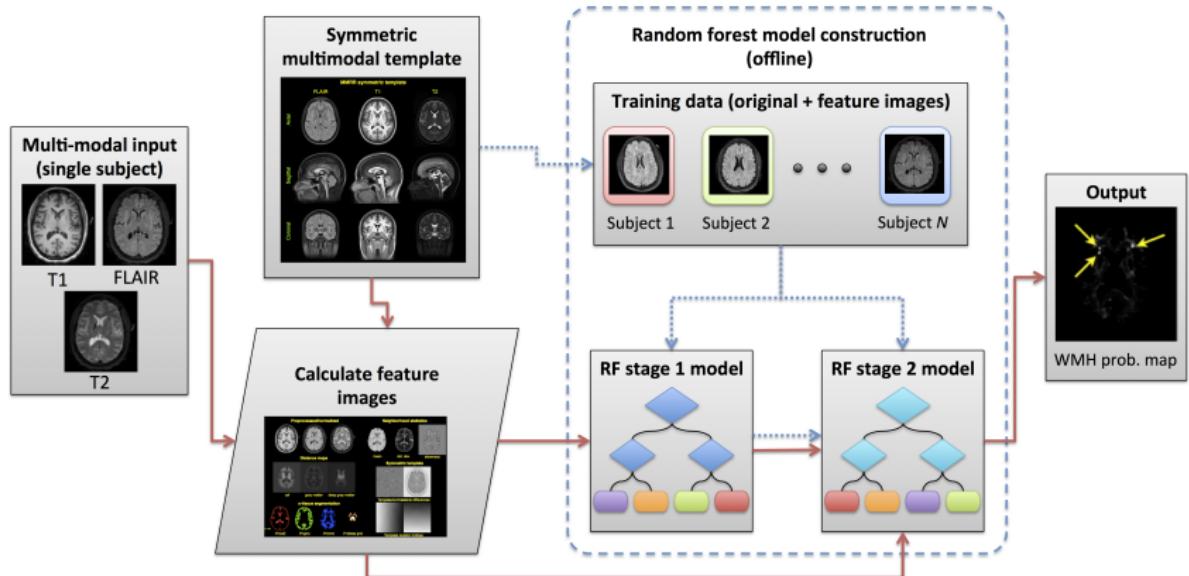
Advanced Normalization Tools in R (ANTsR)

Multimodal Brain Tumor Segmentation (BRATS 2013)



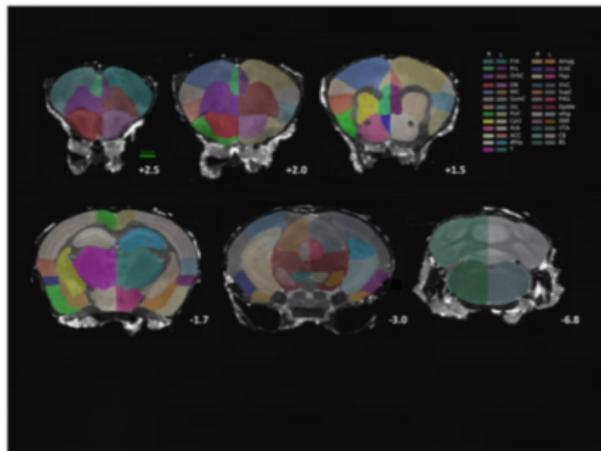
Tustison, et al., Optimal symmetric multimodal templates and concatenated random forests for supervised brain tumor segmentation (simplified) with *ANTsR*, *Neuroinformatics*.

White matter hyperintensities in TBI

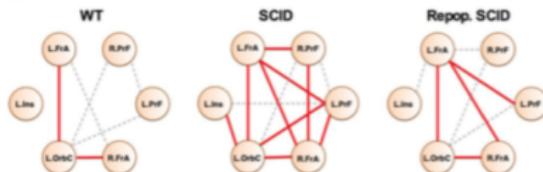


Social behavior and immunity dysfunction in mice

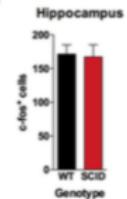
a



b



c



Other ANTsR work

- Pediatric template of brain perfusion
- Automated segmentation of chronic stroke lesions using LINDA: Lesion identification with neighborhood data analysis
- Eigenanatomy
- ANTsRNet: a growing collection of popular deep learning architectures

Open source

- <https://github.com/stnava/ANTs>
- <https://github.com/stnava/ANTsR>
- <https://github.com/stnava/ANTsRNet>