



Neuroconductor: An R Platform for Medical Imaging Analysis

John Muschelli

https://johnmuschelli.com/neuroc_talk/Arkansas_2020.html

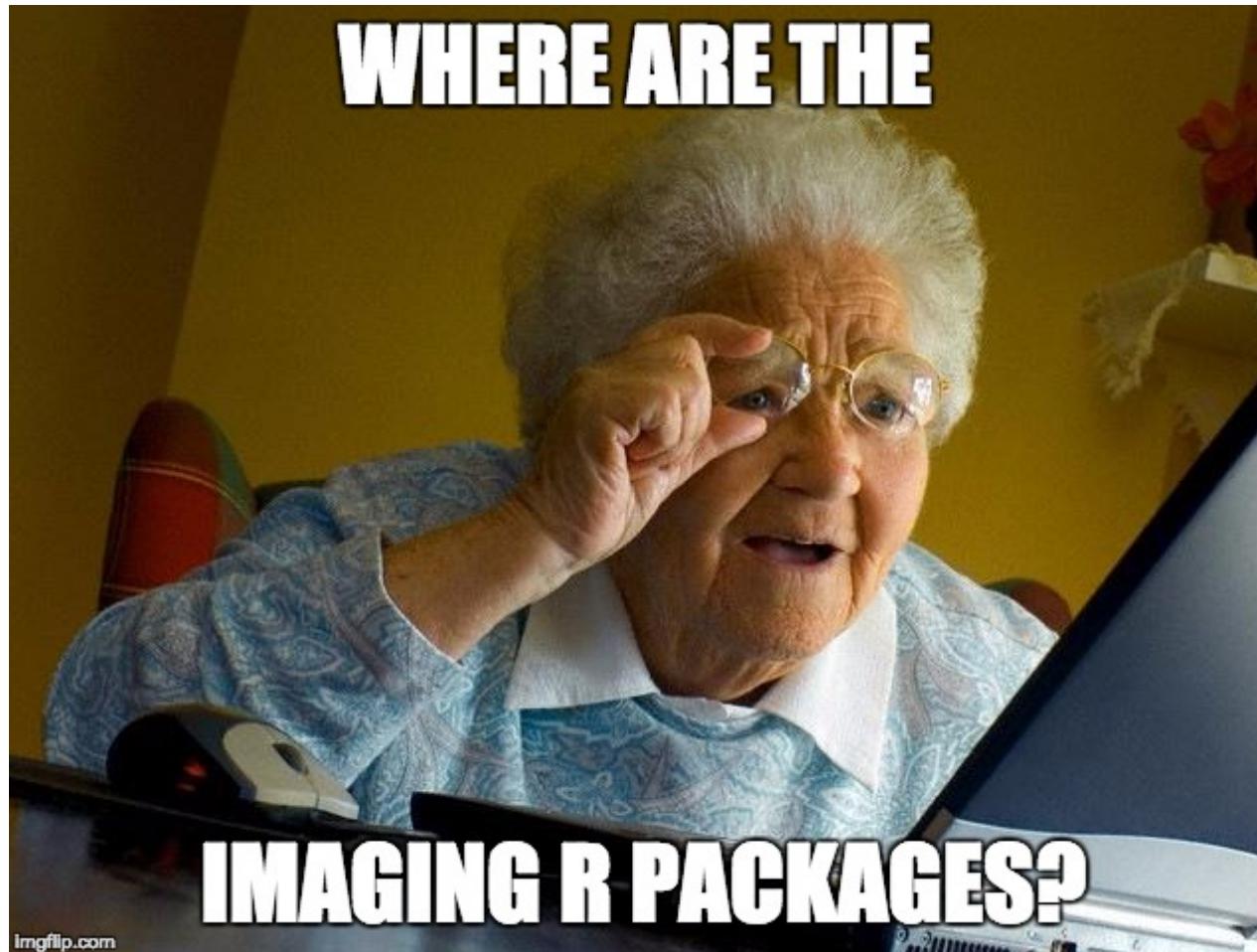
Johns Hopkins Bloomberg School of Public Health

R is a language and environment
for statistical computing
and graphics.

<https://cran.r-project.org/>

R is much more than that now,
but...

What did R have for medical imaging?



<https://imgflip.com/memegenerator/Grandma-Finds-The-Internet>

What did R have for medical imaging?

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CRAN Task View: Medical Image Analysis

Maintainer: Brandon Whitcher

Contact: bwhitcher at gmail.com

Version: 2016-12-30

URL: <https://CRAN.R-project.org/view=MedicalImaging>

Data Input/Output

DICOM

The industry standard format, for data coming off a clinical imaging device, is [DICOM](#) (Digital Imaging and Communications in Medicine). The DICOM "standard" is very broad and very complicated. Roughly speaking each DICOM-compliant file is a collection of fields organized into two four-byte sequences (group,element) that are represented as hexadecimal numbers and form a *tag*. The (group,element) combination announces what type of information is coming next. There is no fixed number of bytes for a DICOM header. The final (group,element) tag should be the "data" tag (7FE0,0010), such that all subsequent information is related to the image(s).

- The packages [oro.dicom](#), [divest](#), [fmri](#) and [tractor.base](#) (part of the [tractor](#) project) provide R functions that read DICOM files and facilitate their conversion to ANALYZE or NIfTI format.

ANALYZE and NIfTI

Although the industry standard for medical imaging data is DICOM, another format has come to be heavily used in the image analysis community. The [ANALYZE](#) format was originally developed in conjunction with an image processing system (of the same name) at the Mayo Foundation. An Anlayze (7.5) format image is comprised of two files, the "hdr" and "img" files, that contain information about the acquisition and the acquisition itself, respectively. A more recent adaption of this format is known as [NIfTI-1](#) and is a product of the Data Format Working Group (DFWG) from the Neuroimaging Informatics Technology Initiative (NIfTI). The NIfTI-1 data format is almost identical to the ANALYZE format, but offers a few improvements: merging of the header and image information into one file (.nii), re-organization of the 348-byte fixed header into more relevant categories and the possibility of extending the header information.

- The packages [RNifti](#), [AnalyzeFMRI](#), [fmri](#), [tractor.base](#) (part of the [tractor](#) project), [oro.nifti](#), and [neuroim](#) all provide functions that read/write ANALYZE and NIfTI files.

Magnetic Resonance Imaging (MRI)

Diffusion Tensor Imaging (DTI)

- The R package [dti](#) provides structural adaptive smoothing methods for the analysis of diffusion weighted data in the context of the DTI model. Due to its edge preserving properties these smoothing methods are capable of reducing noise without compromizing significant structures (e.g., fibre tracts). The package also provides functions for DTI data processing from input,

Envy: Bioconductor



- centralized bioinformatics packages (> 1300)
- large community/developer team
- published tutorials and workflows
- additional requirements to CRAN (e.g. packages need vignettes)



NEUROCONDUCTOR

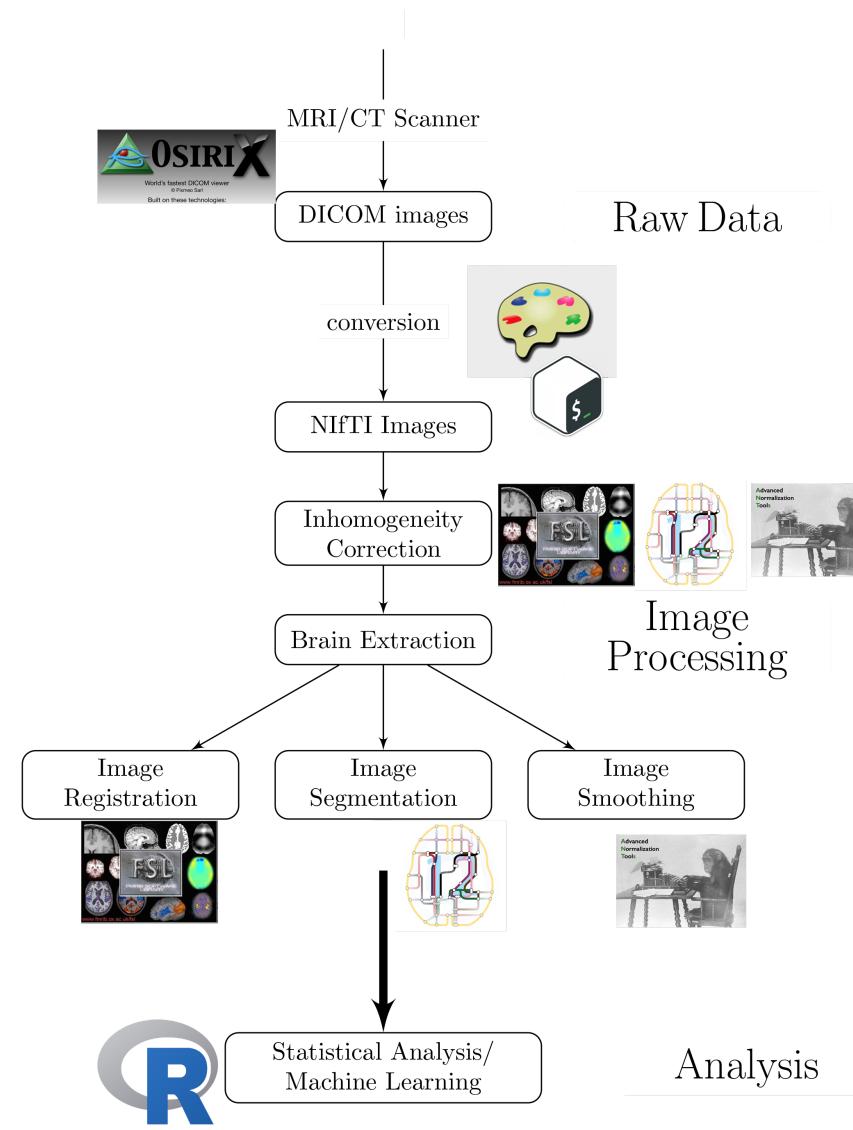
An R Platform for
Medical Imaging Analysis

What is Neuroconductor?

1. A centralized repository of packages (N = 101)
2. A community of developers (N = 27) and users
3. A website [https://neuroconductor.org/.](https://neuroconductor.org/)
 - with tutorials and help
4. A team helping developers and users (John, Adi Gherman, Ciprian Crainiceanu, Brian Caffo)
5. Set of packages to allow R to perform processing.

Workflow for an Analysis

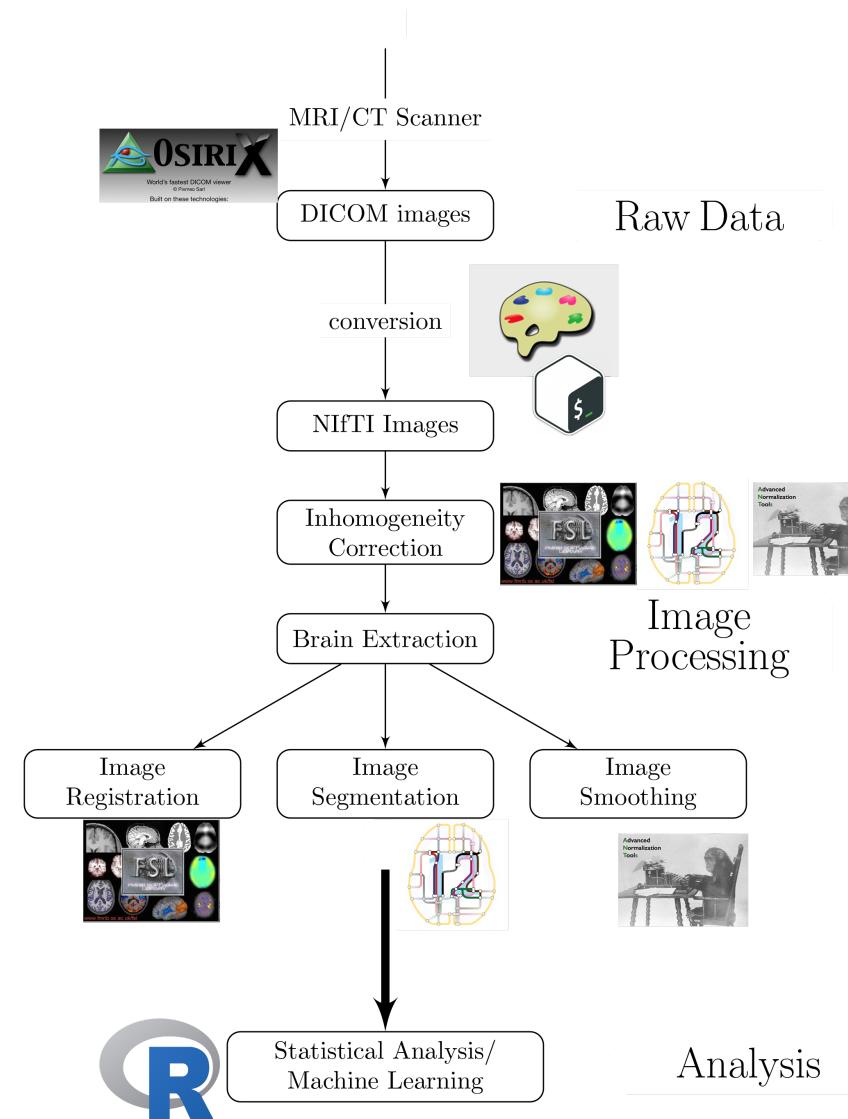
- bash 
- FSL 
- ANTs 
- MRIcroGL 
- OsiriX 
- SPM 12 



Workflow for an Analysis

Multiple pieces of software used

- all different syntax



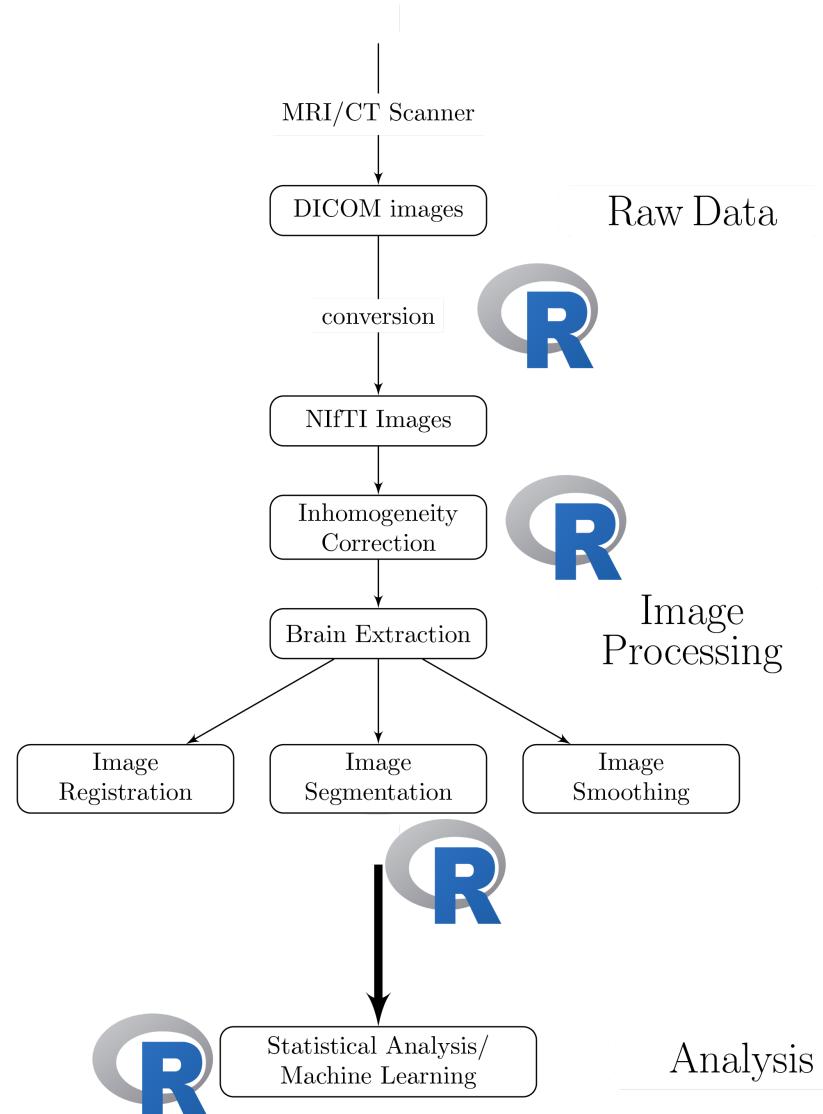
Our Goal:

Lower the bar to entry

- all “one” code (R)
 - pipeline tool
 - also “native” R code

Complete pipeline

- preprocessing and analysis



Benefits of Neuroconductor

Allow imaging to use all R has to offer:

- Statistics and Machine Learning (tensorflow)
- Versioning and testing (GitHub)
- Reproducible reports and analyses
- Shiny (web applications)
- Genomics/Imaging analysis in one platform
 - Bioconductor

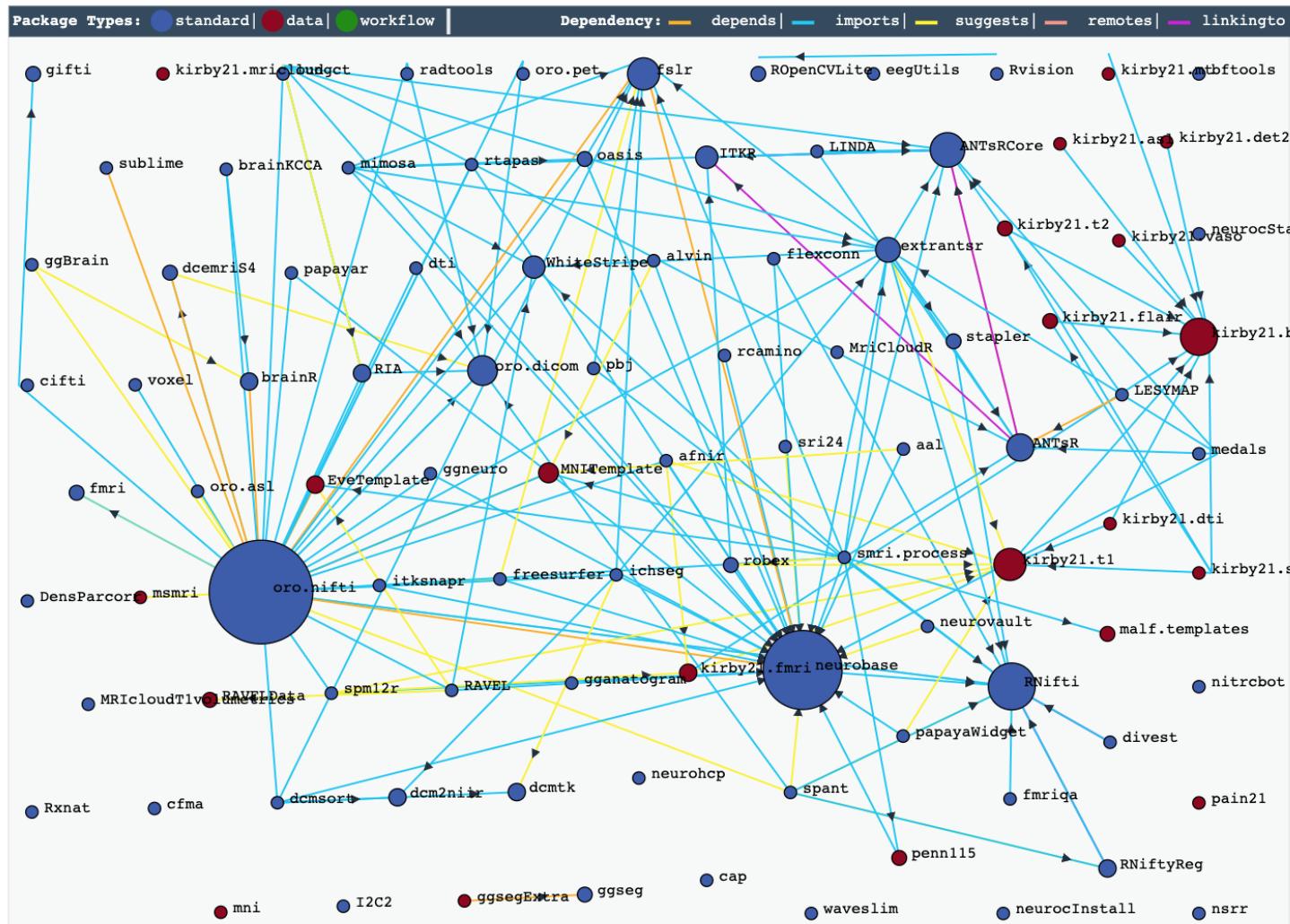
Goal: Centralize the packages (currently 101)

List Packages

				View Dependency Graph	View Pending Packages		
Show 50 ↑ entries				Search: <input type="text"/>			
Package Name	Version	Package Title	Maintainer(s)	GitHub URL	Last updated		
ANTsR	0.4.0	ANTs in R: quantification tools for biomedical images	Brian B. Avants	stnav/ANTsR	2017-03-18		
ANTsRCore	0.0.0	ANTsRCore: core software infrastructure for ANTsR	Brian B. Avants	stnav/ANTsRCore.git	2017-03-18		
brainR	1.4.2.1	Helper Functions to Misc3d and rgl Packages for Brain Imaging	John Muschelli	muschellij2/brainR	2017-05-26		
cifti	0.4.2	Toolbox for Connectivity Informatics Technology Initiative ('CIFTI') Files	John Muschelli	muschellij2/cifti	2017-05-26		
dcemriS4	0.57.1.2	A Package for Image Analysis of DCE-MRI (S4 Implementation)	Brandon, Whitcher	bjw34032/dcemriS4	2017-05-26		
dcm2niir	0.5	Conversion of 'DICOM' to 'NIfTI' Imaging Files Through R	John Muschelli	muschellij2/dcm2niir	2017-02-24		
divest	0.3.0.1	Get Images Out of DICOM Format Quickly	Jon Clayden	jonclayden/divest	2017-05-25		
EveTemplate	0.99.14.2	JHU-MNI-ss (Eve) template	Jean-Philippe Fortin	Jfortin1/EveTemplate	2017-05-26		
extrantsr	2.17.2.3	Extra Functions to Build on the ANTsR Package	John Muschelli	muschellij2/extrantsr.git	2017-05-26		
freesurfer	1.6.6	Wrapper Functions for 'Freesurfer'	John Muschelli	muschellij2/freesurfer	2017-05-26		
fslr	2.12.6	Wrapper Functions for FSL ('FMRIB' Software Library) from Functional MRI of the Brain ('FMRIB')	John Muschelli	muschellij2/fslr	2017-05-26		
gifti	0.7	Reads in Neuroimaging 'GIFTI' Files with Geometry Information	John Muschelli	muschellij2/gifti	2016-11-09		
ITKR	0.0.1	ITK in R	Brian B. Avants	stnav/ITKR	2017-02-24		
itksnapr	2.1.6	Package of ITK-SNAP	John Muschelli	muschellij2/itksnapr	2017-05-26		
kirby21.asl	1.5.1	Example ASL Data from the Multi-Modal MRI Reproducibility Resource	John Muschelli	muschellij2/kirby21.asl	2017-05-03		

New release (December 2019)

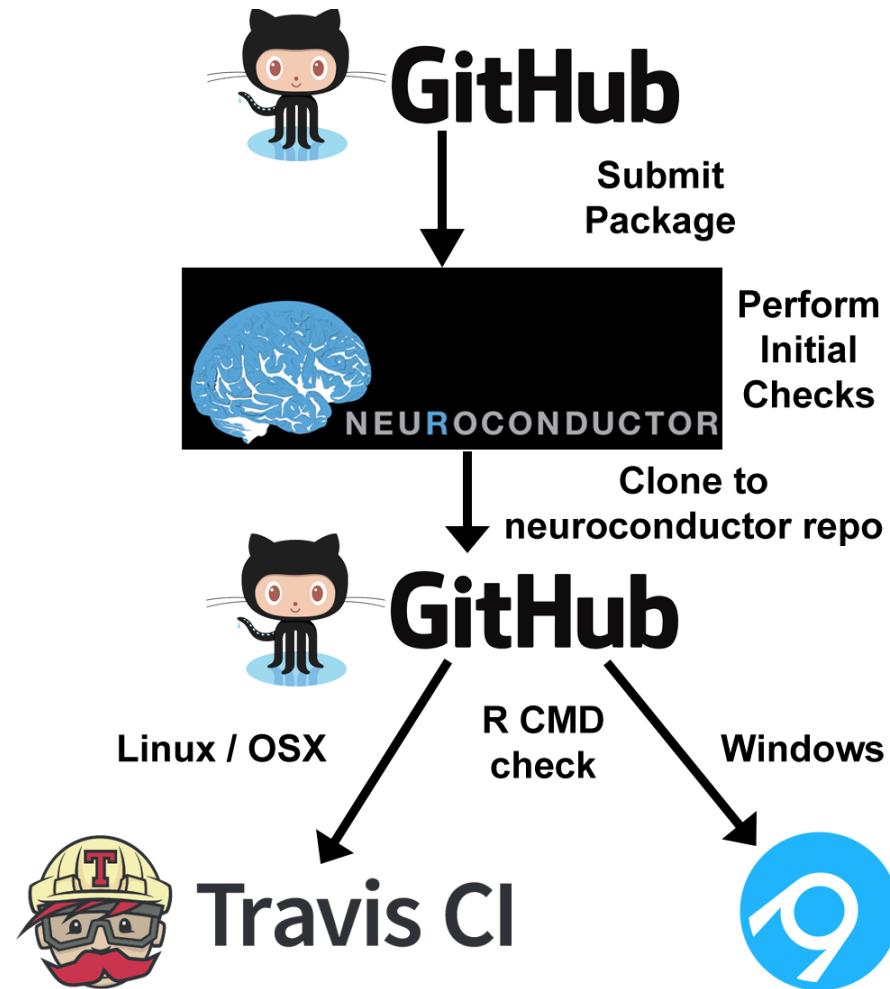
Neuroconductor Package Dependency Graph



Development Pipeline:

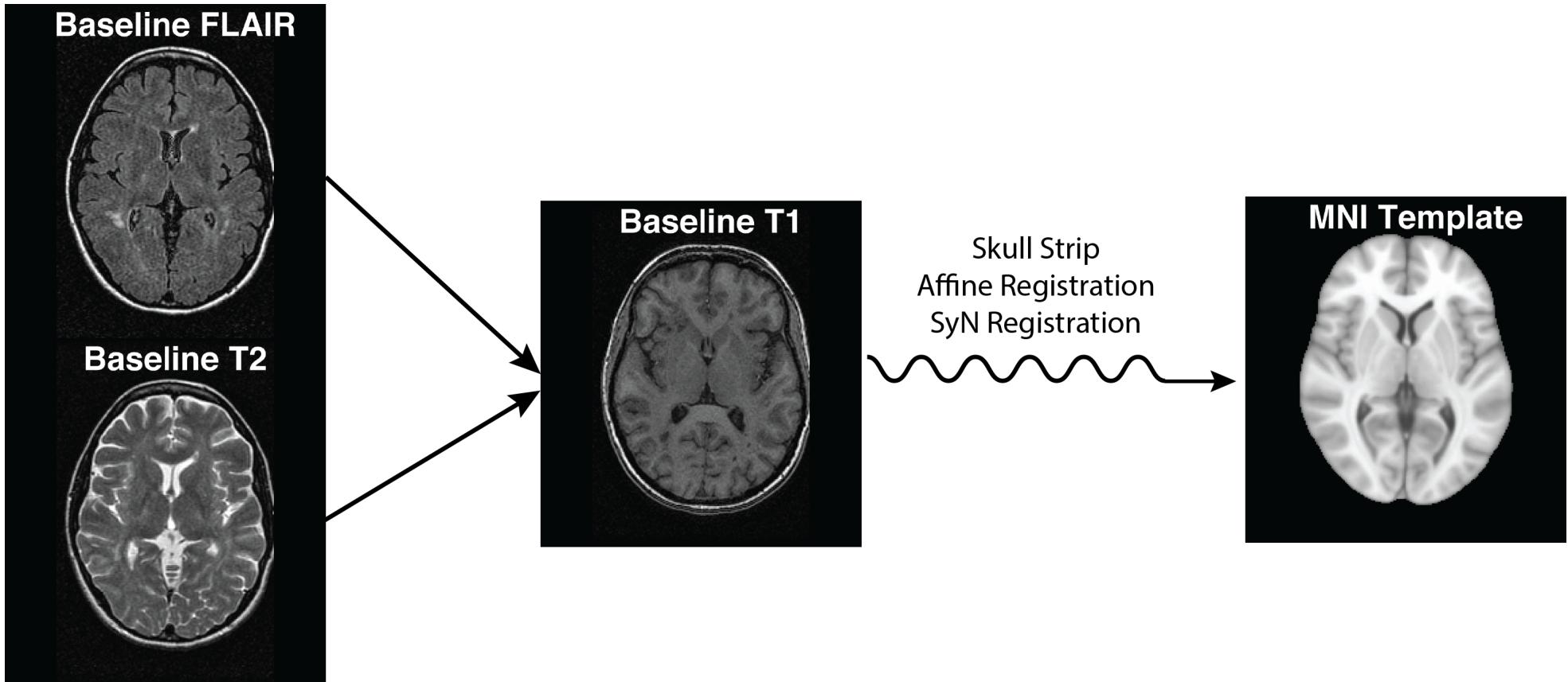
Check the package for stability

- check against other imaging software (e.g. FSL)



Package Features: Image Registration

- ANTsR, RNiftyReg, fslr



Package Features: Inhomogeneity Correction

- ANTsR, fslr

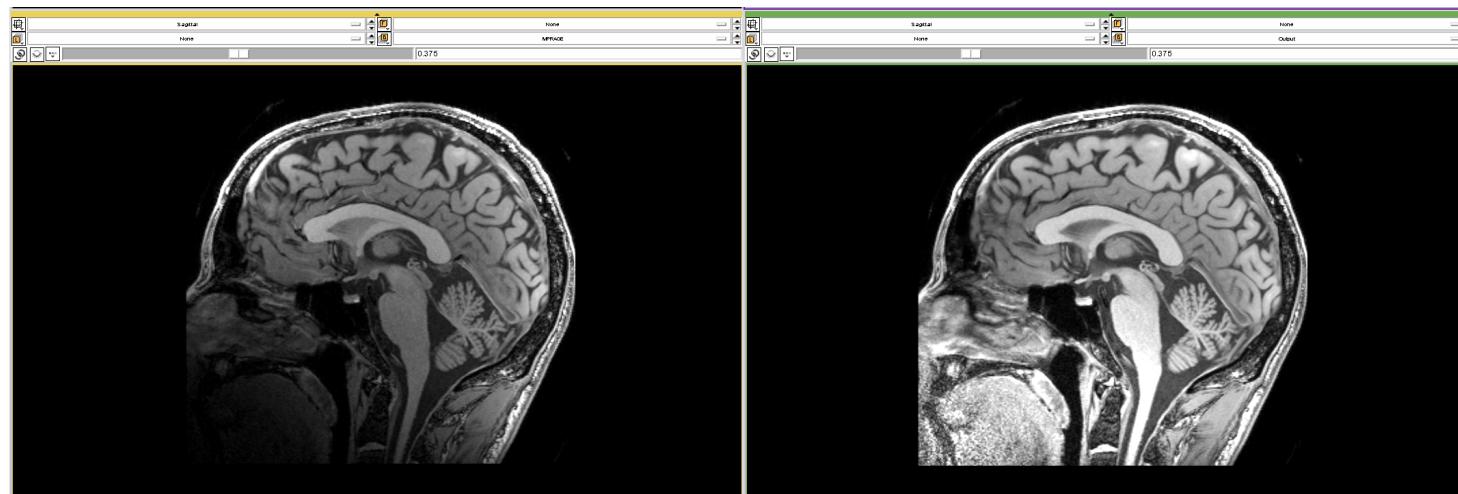


Image From https://www.slicer.org/w/images/7/77/MRI_Bias_Field_Correction_Slicer3_close_up.png

Package Features: Intensity Normalization

- WhiteStripe -
<https://github.com/muschellij2/whitestripe>
- RAVEL -
<https://github.com/Jfortin1/RAVEL>
- ComBat (adapted from genomics) -
<https://github.com/Jfortin1/ComBatchHarmonization>

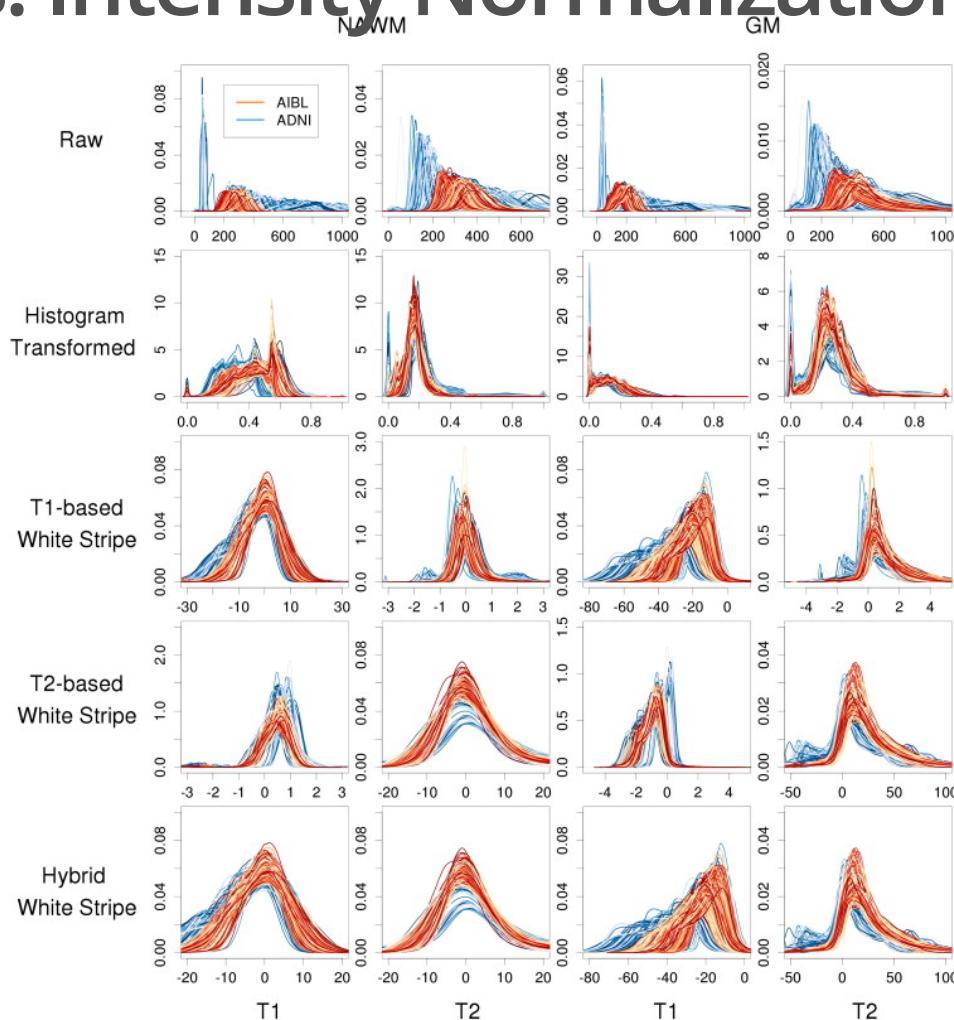
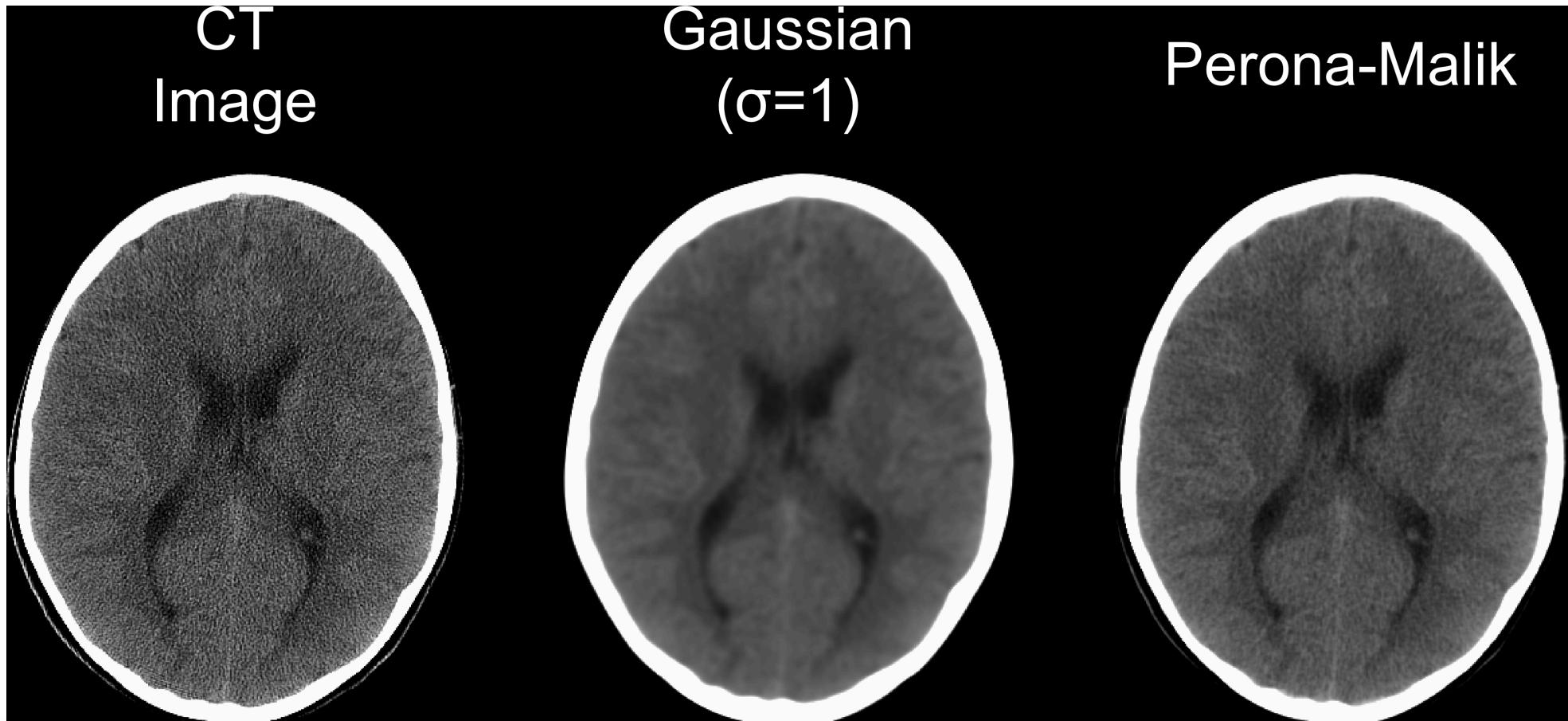


Figure from Shinohara, Russell T., et al. "Statistical normalization techniques for magnetic resonance imaging." *NeuroImage: Clinical* 6 (2014): 9-19.

Package Features: Smoothing

- fslr, ANTsR, AnalyzeFMRI

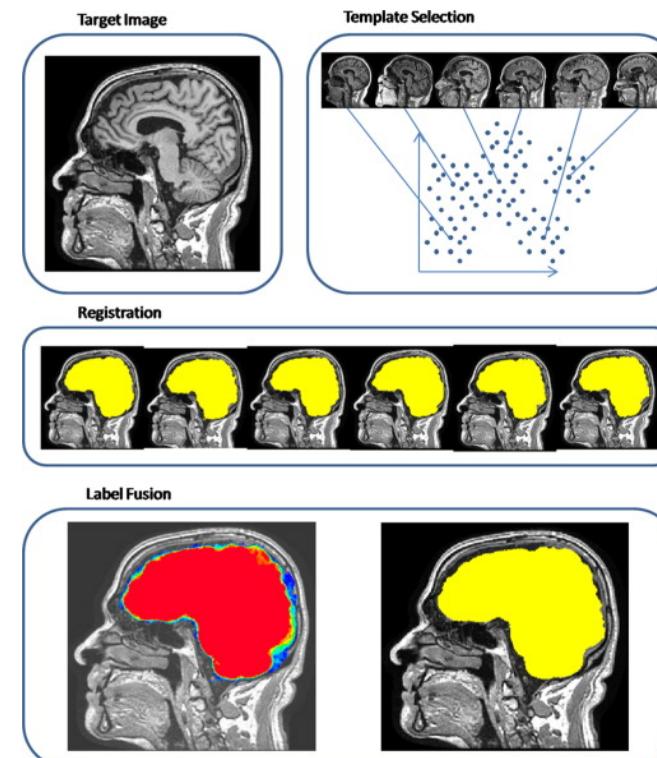


Package Features: Data

- neurohcp - [Human Connectome Project](#)
- kirby21.t1, kirby21.fmri - <https://www.nitrc.org/projects/multimodal>
- nitrcbot - <https://www.nitrc.org/>
- Rxnat - XNAT databases

Multi-Atlas Label Fusion (MALF)

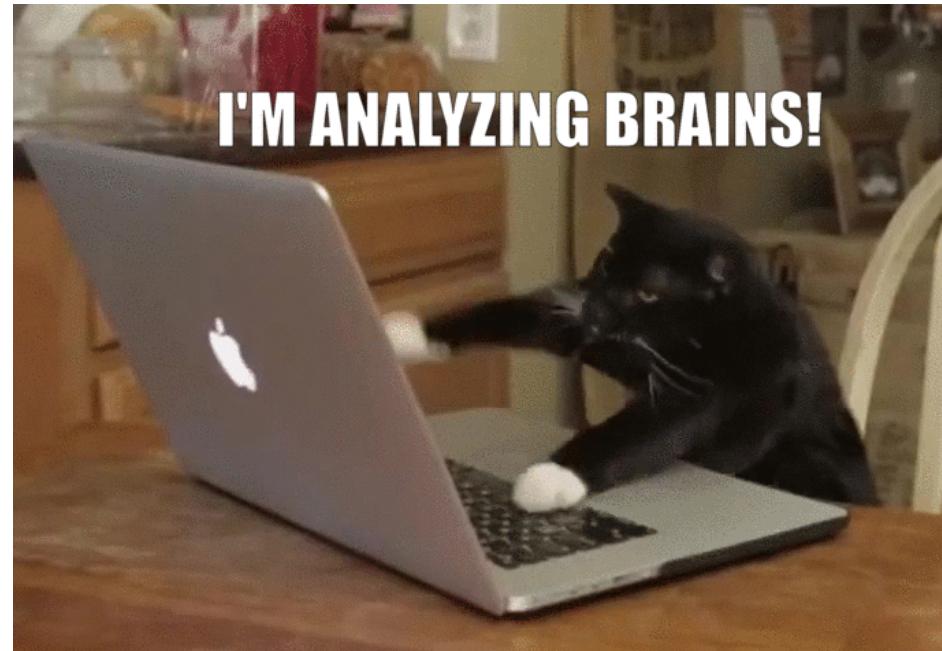
- malf.templates - <https://github.com/muschellij2/malf.templates>



Neuroconductor

Goal:

Detailed **tutorials**
on how to actually
perform an
analysis



From <http://i.imgur.com/0Y1xISa.gifv>.

<http://johnmuschelli.com/neuroc>

Some (Unpopular?) Opinions for Statisticians

1. No code = no method...yet.
 - “Available upon request” - not usually upheld
2. We are not the leaders in imaging
3. Not everyone cares about our methods
4. Many engineers are better in imaging at a)
distributing code and b) selling their method
5. Most grants (& depts) don’t really support
software well.

Helping Developers

- GitHub allows the Neuroconductor team to help fix issues
- Pull Requests to developers
- Standardized checking of Packages (Travis configuration)
- Remove unnecessary hurdles for developers



Image from: <https://giphy.com/gifs/medblr-medschool-dr-dres-anatomy-uRb2p09vY8lEs>

Training we are providing

Coursera Course:
Introduction to
Neurohacking In R

[https://www.coursera.org/
learn/neurohacking/](https://www.coursera.org/learn/neurohacking/)



http://johnmuschelli.com/imaging_in_r/

Neuroimaging Analysis in Stroke

The MISTIE Stroke Trial

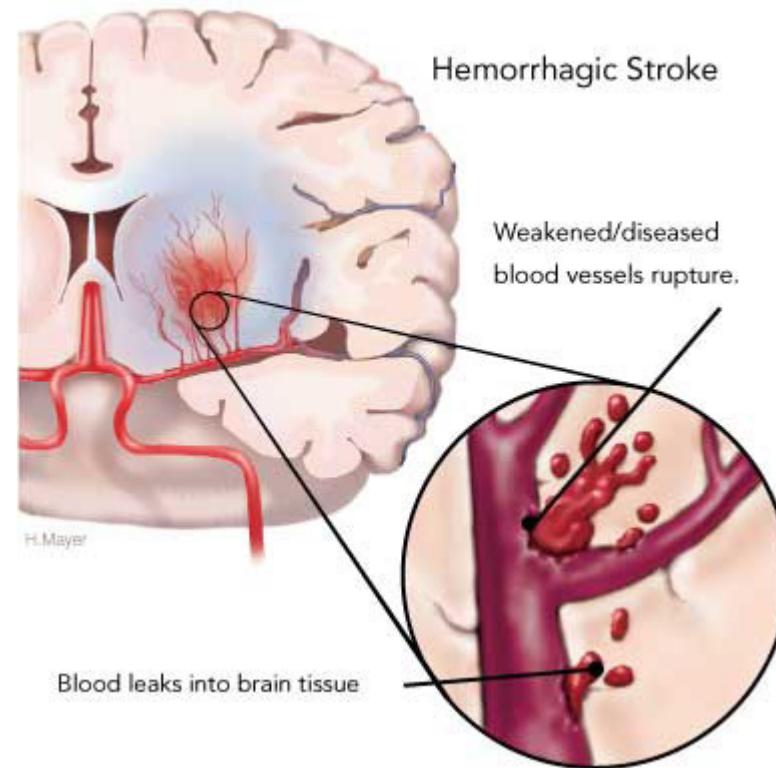
- Minimally Invasive Surgery plus r-tPA for Intracerebral Hemorrhage Evacuation (**MISTIE**)
 - Multi-center, multi-national Phase II RCT
- Patients with intracerebral hemorrhages (≥ 20 milliliters)



- <http://braininjuryoutcomes.com/mistie-about>

What is Intracranial/Intracerebral hemorrhage?

- When a blood vessel ruptures into:

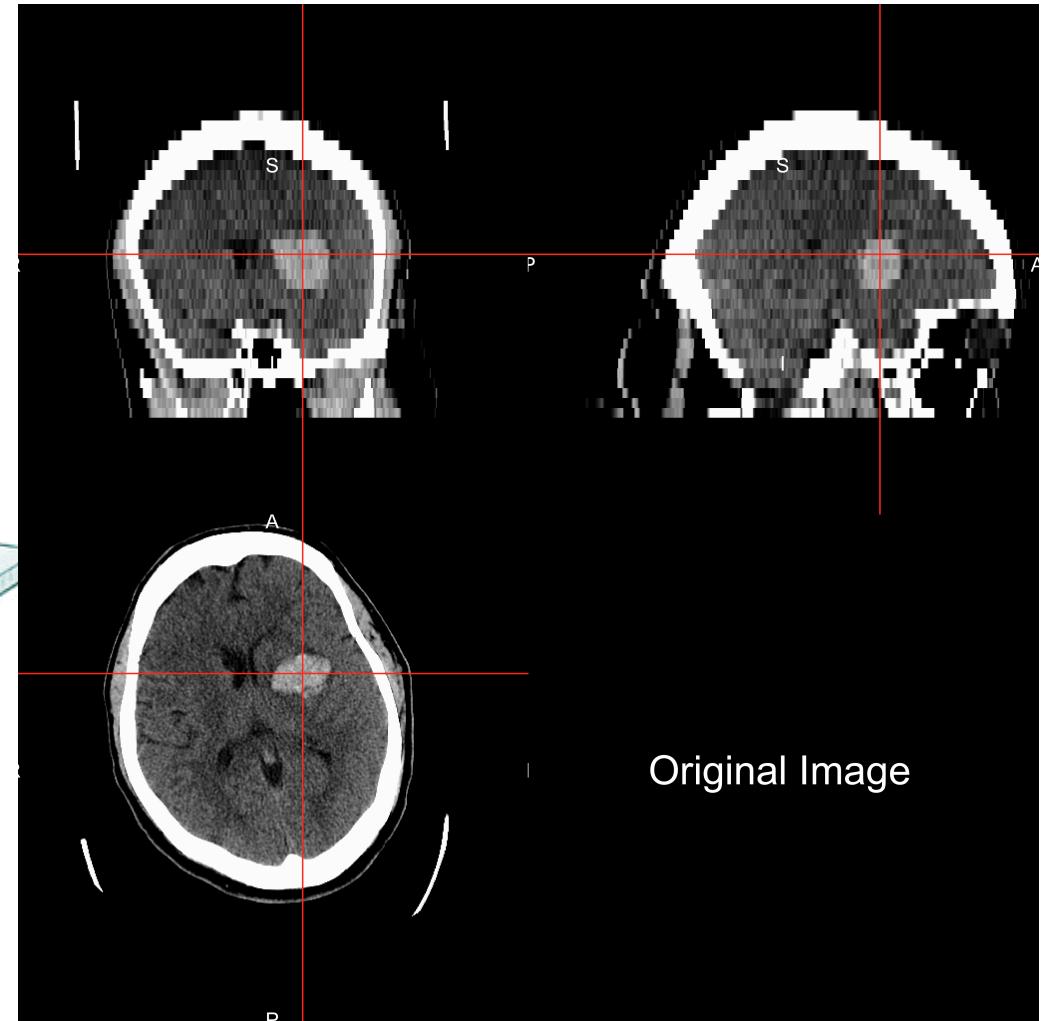
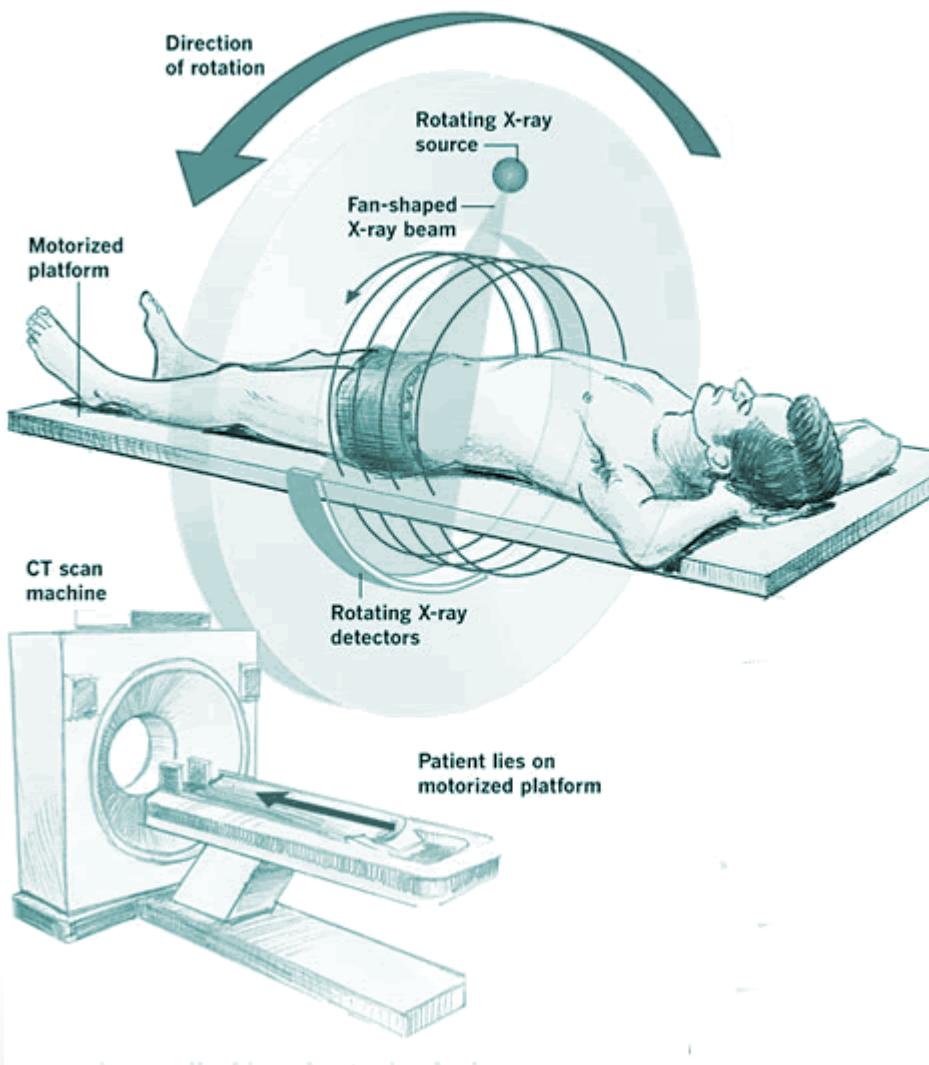


http://www.heartandstroke.com/site/c.iklQLcMWjtE/b.3484153/k.7675/Stroke_Hemorrhagic_stroke.htm

- ≈ 13% of strokes

X-ray Computed Tomography (CT) Scans

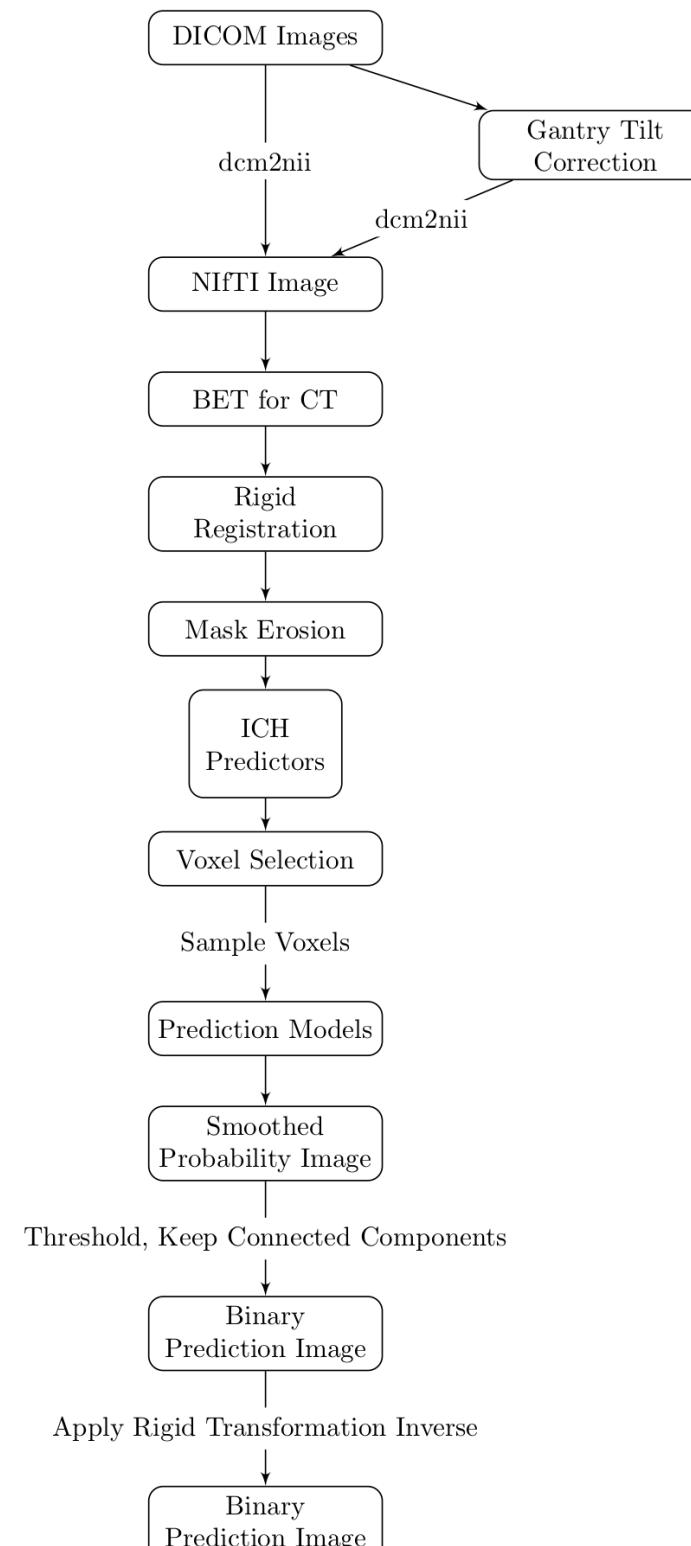
Image from <http://www.cyberphysics.co.uk/topics/medical/CTScanner.htm>



A note the MRI folks (about CT)

- CT is the modality for clinical ICU imaging
- CT has standard units (Hounsfield Units)
- Takes seconds vs. minutes (MRI)
- Muschelli, J., 2019. Recommendations for Processing Head CT Data. *Frontiers in neuroinformatics*, 13, p.61.
- https://johnmuschelli.com/process_head_ct/example/

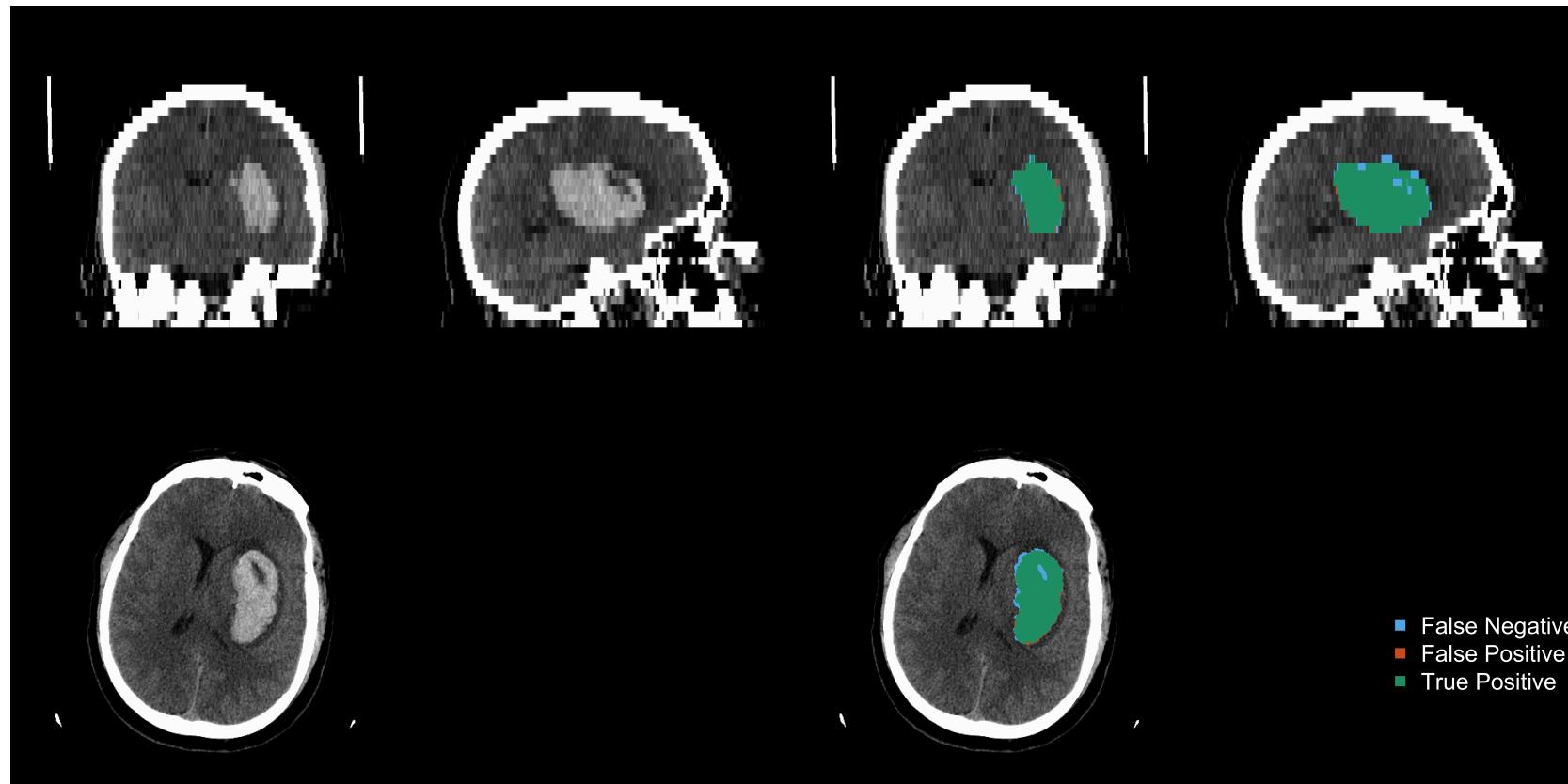
Muschelli, J., Sweeney, E.
M., Ullman, N. L., Vespa,
P., Hanley, D. F., &
Crainiceanu, C. M.
(2017). PIItcHPERFeCT:
Primary intracranial
hemorrhage probability
estimation using random
forests on CT.
NeuroImage: Clinical, 14,
379-390.



ichseg: ICH Segmentation on CT



```
ichseg::ich_segment(img = "/path/to/ct/scan")
```



Things in the Works/Other work

- <https://github.com/ANTSXNet> - Wide array of deep learning applications for R
- <https://github.com/msharrock/deepbleed> - CNN for ICH Segmentation
- EEG -
<https://github.com/craddm/eegUtils>

1

github.com/ANTsXNet

BrainSegmentationPatchBased

Three tissue (CSF, GM, WM) patch-based brain segmentation

● R ⚡ 2 ★ 0 ⓘ 2 🔍 0 Updated on Oct 8, 2019

BrainSegmentation

Brain segmentation (6-tissue) ANTsRNet app

● R ⚡ 3 ★ 2 ⓘ 2 🔍 1 Updated on Oct 4, 2019

ProtonMRI_LungSegmentation

Proton MRI lung segmentation ANTsRNet app

● R ⚡ 0 ★ 1 ⓘ 0 🔍 0 Updated on Sep 12, 2019

FunctionalLungSegmentation

Functional hyper polarized gas MRI lung segmentation ANTsRNet app

● R ⚡ 0 ★ 1 ⓘ 0 🔍 0 Updated on Sep 8, 2019

PigLungSegmentation

● R ⚡ 0 ★ 0 ⓘ 0 🔍 0 Updated on Aug 28, 2019

BrainAgeGender

Predict age and gender from gray matter probability images

● R ⚡ 0 ★ 1 ⓘ 0 🔍 0 Updated on Feb 11, 2019

Questions?



Email:

Submit Packages at:
<https://neuroconductor.org/submit-package>

Funding: NIH 2R01NS060910 and U24HG010263