

neurodata.io



m2g: an MRI Processing Reference Pipeline for Connectome Estimation

Greg Kiar
Oct 7th, 2015

Overview

- Mission
- Methods
- Results
- Future



Datasets

- an abundance of MR data
- data collected with widely varying scanner parameters
- few unified scanner protocols

Dataset	Number of Subjects
CoRR	1386
HCP	542
OASIS	416
MRN-1313	1313
MRN-114	111
KKI-42	21
CASL-36	12
NKI/RS	207
...	...
Total	4,044 +

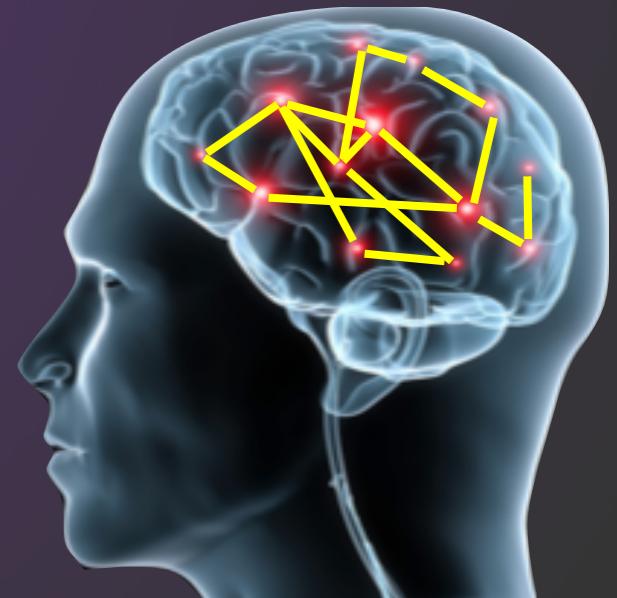
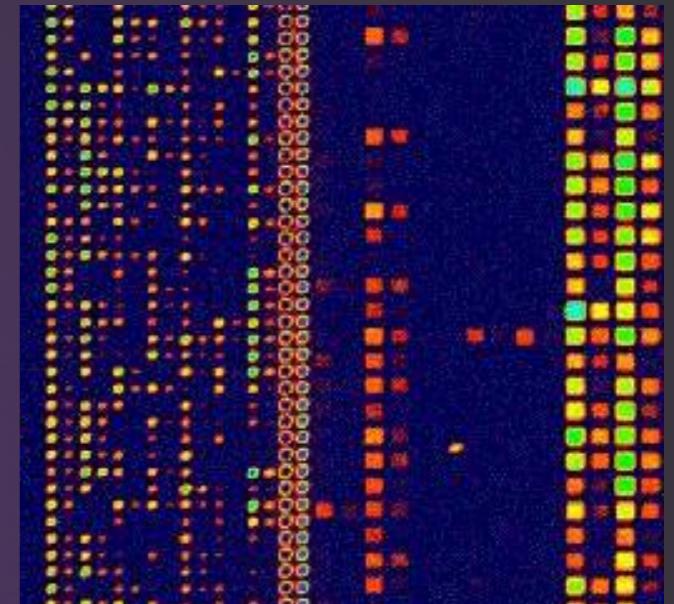
Processing tools

- a plethora of single-purpose tools exist
- a lack of end-to-end computational tools
- high computational barrier to entry



Mission

- Quantitative analysis of brain structure to predict or assess cognitive capabilities, medical diagnosis
- Lower the barrier for entry to large scale MR processing



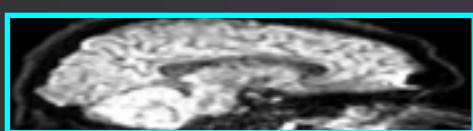
Connectomics is to the brain what Genomics is to DNA

What is m2g?

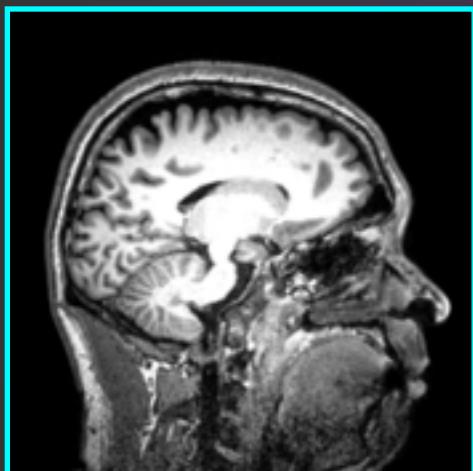
- Reference pipeline for diffusion and structural MRI processing
- Reliable connectome estimation at scale
- Platform for inference

m2g reference pipeline

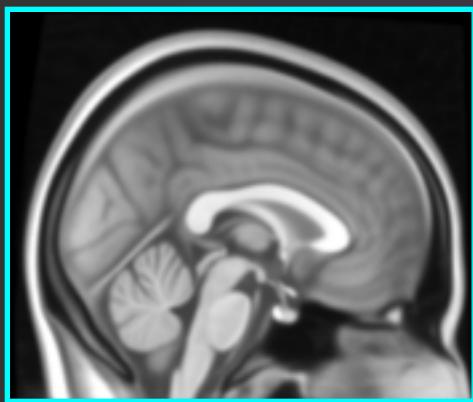
Data



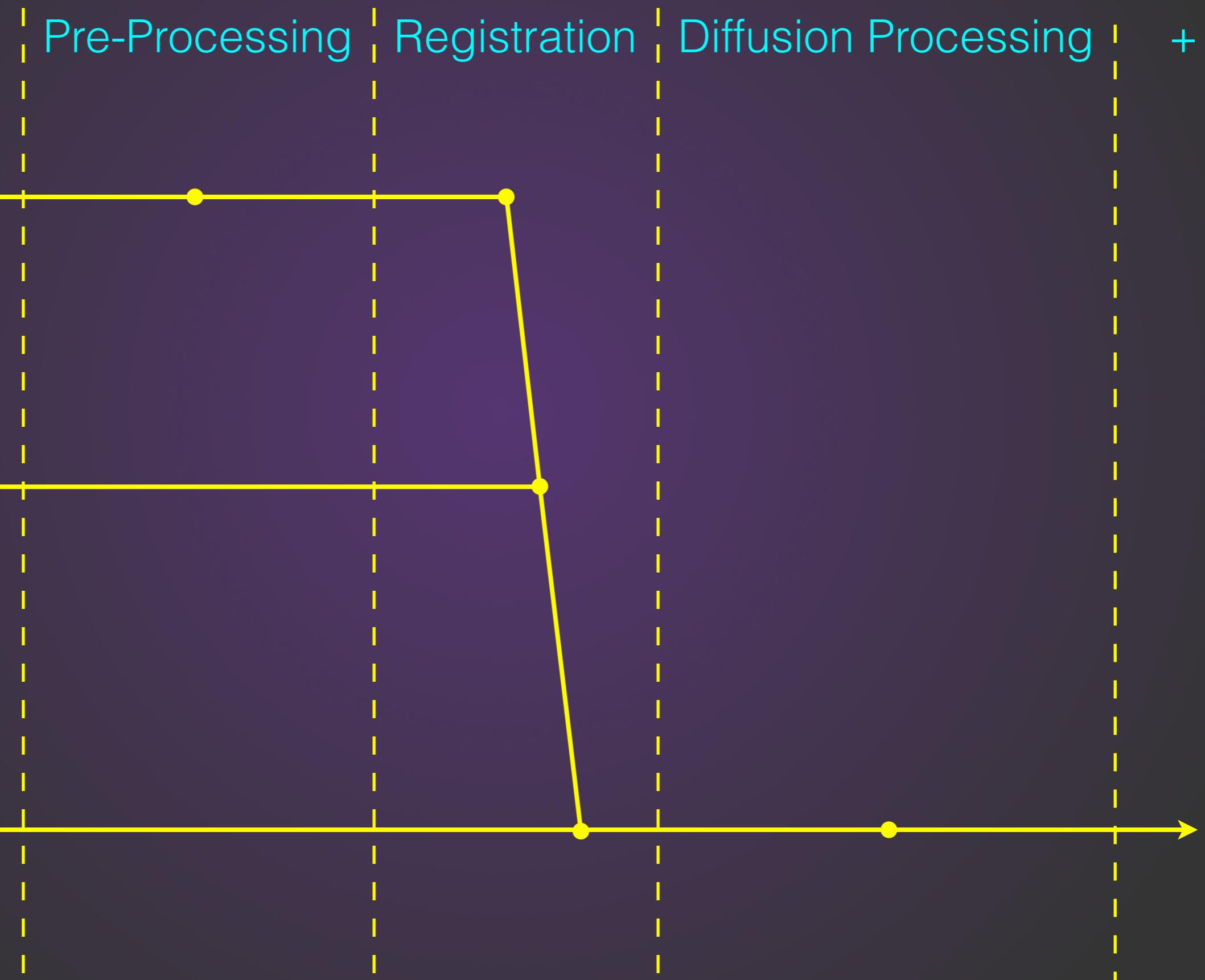
DTI volumes



MPRAGE volume



Atlas volume

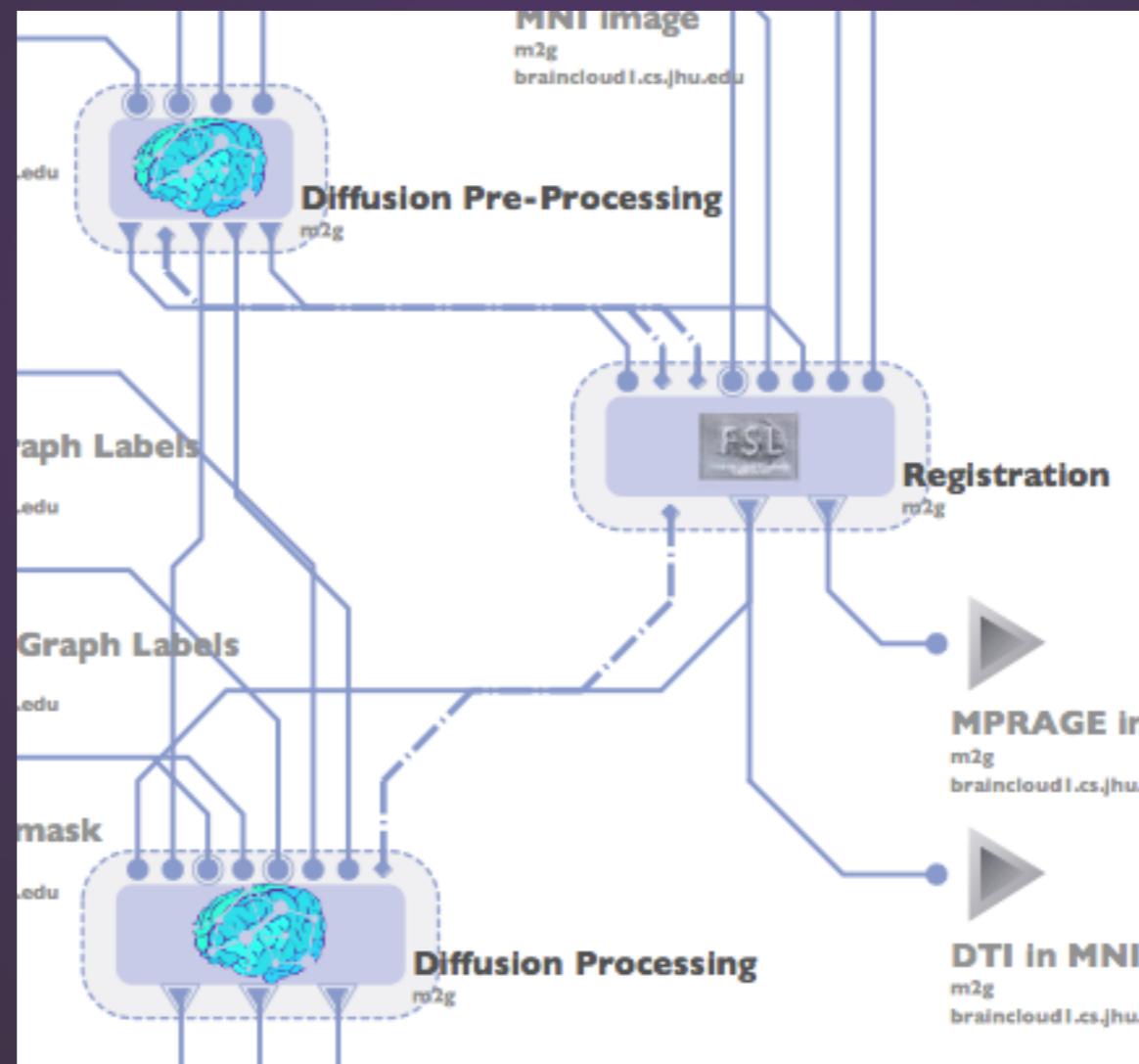


LONI Pipeline

- Framework for distributed computing
- Enables scalable implementation of processing workflows
- <http://pipeline.loni.usc.edu>

m2g implementation

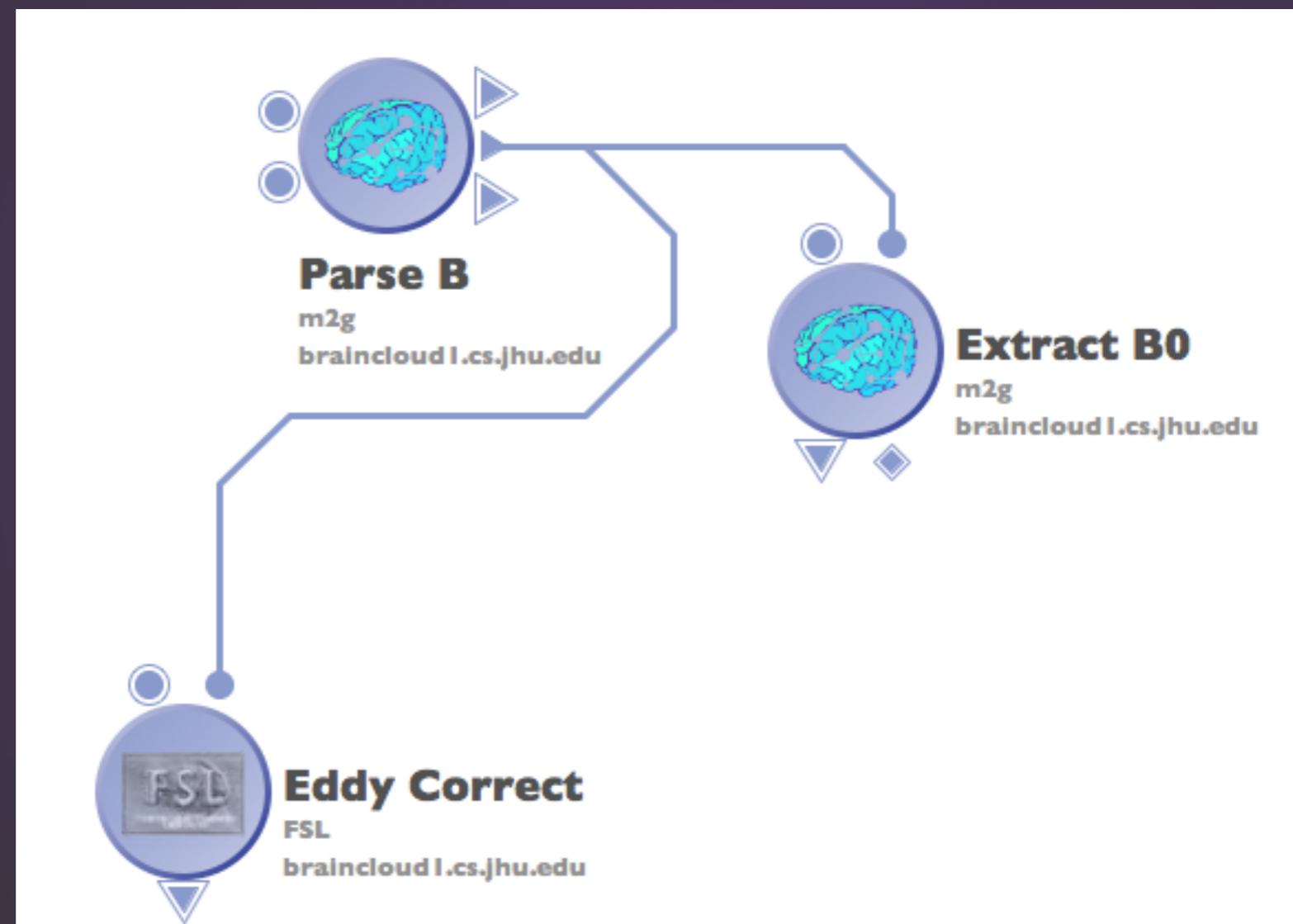
github.com/openconnectome/m2g



Sub-pipelines

- **Diffusion Pre-Processing** prepares the diffusion scan and parameters for advanced processing
- **Registration** maps the subject image data to the space defined by the template atlas
- **Diffusion Processing** exploits the diffusion data in order to estimate connectomes

diffusion pre-processing



Parse B

$$\begin{bmatrix} B_{x1} & B_{y1} & B_{z1} \\ B_{x2} & B_{y2} & B_{z2} \\ \vdots & \vdots & \vdots \\ B_{xd} & B_{yd} & B_{zd} \end{bmatrix}$$

B-vectors



$$[B_1 \ B_2 \ \dots \ B_d]$$

B-values

$$\begin{bmatrix} B_{x1} & B_{x2} & \dots & B_{xd} \\ B_{y1} & B_{y2} & \dots & B_{yd} \\ B_{z1} & B_{z2} & \dots & B_{zd} \end{bmatrix}$$

Formatted B-vectors

$$[B_1 \ B_2 \ \dots \ B_d]^T$$

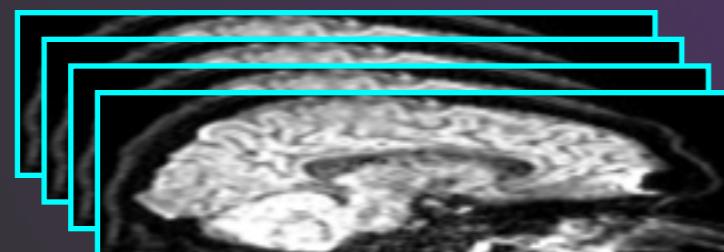
Formatted B-values

$ind(B_i == 0)$
Location of B0

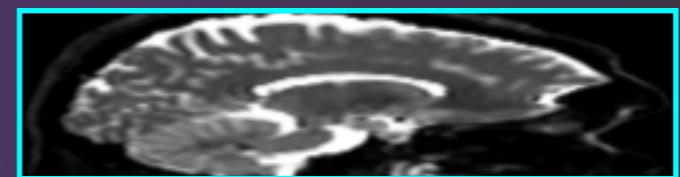
Extract B0

$ind(B_i == 0)$

Location of B0 volume



DTI volumes

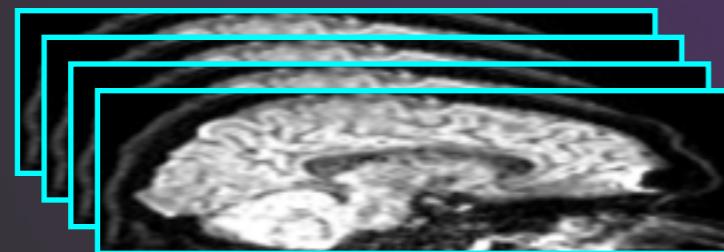


B0 volume

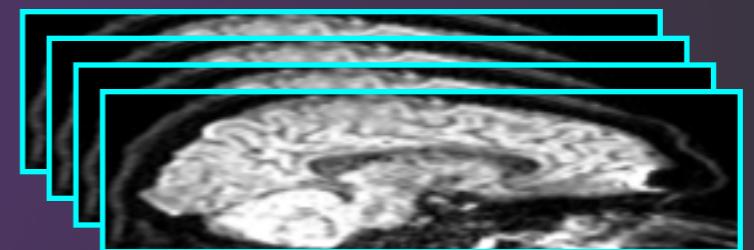
Eddy Correction

$ind(B_i == 0)$

Location of B0 volume

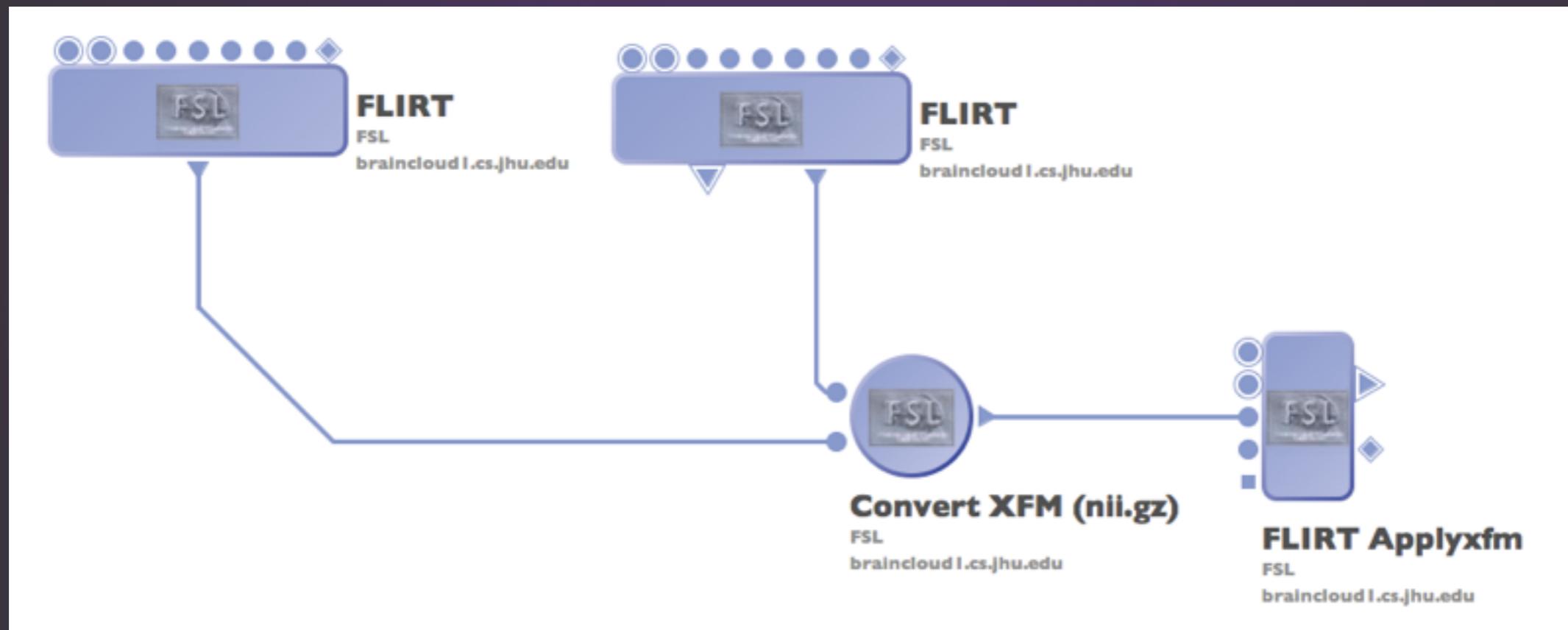


DTI volumes

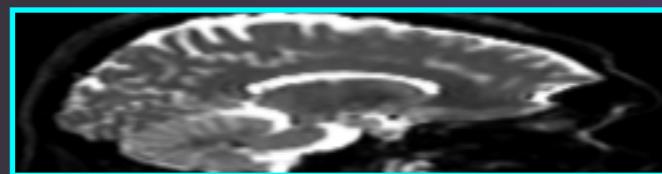


Eddy-corrected
DTI volumes

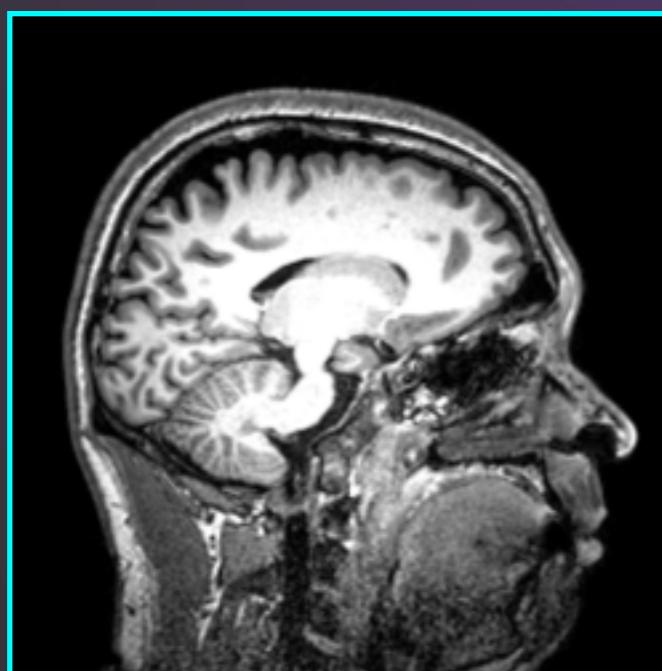
registration



FLIRT (1)



B0 volume



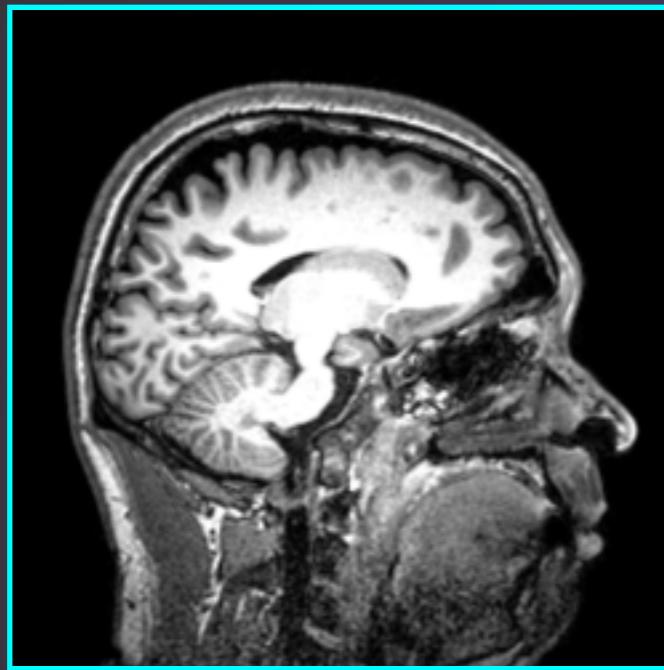
MPRAGE volume



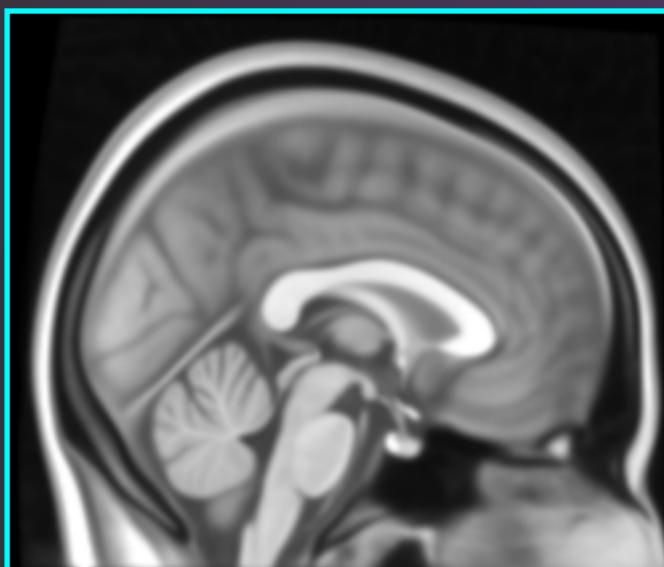
$$A = \begin{bmatrix} a_{1,1} & & & \\ & \ddots & & \\ & & & a_{4,4} \end{bmatrix}$$

Transform 1

FLIRT (2)



MPRAGE volume



Atlas volume



$$A = \begin{bmatrix} a_{1,1} & & & \\ & \ddots & & \\ & & a_{4,4} & \end{bmatrix}$$

Transform 2

Convert Transforms

$$A = \begin{bmatrix} a_{1,1} & & & \\ & \ddots & & \\ & & a_{4,4} & \end{bmatrix}$$

Transform 1

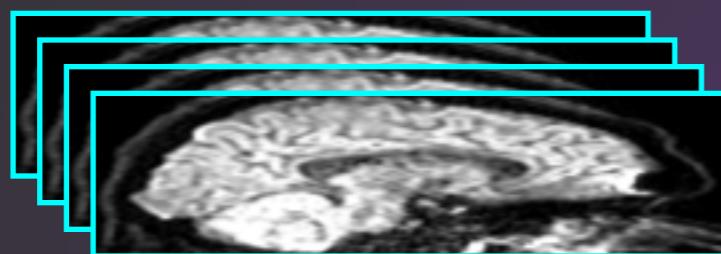
$$B = \begin{bmatrix} b_{1,1} & & & \\ & \ddots & & \\ & & b_{4,4} & \end{bmatrix}$$

Transform 2

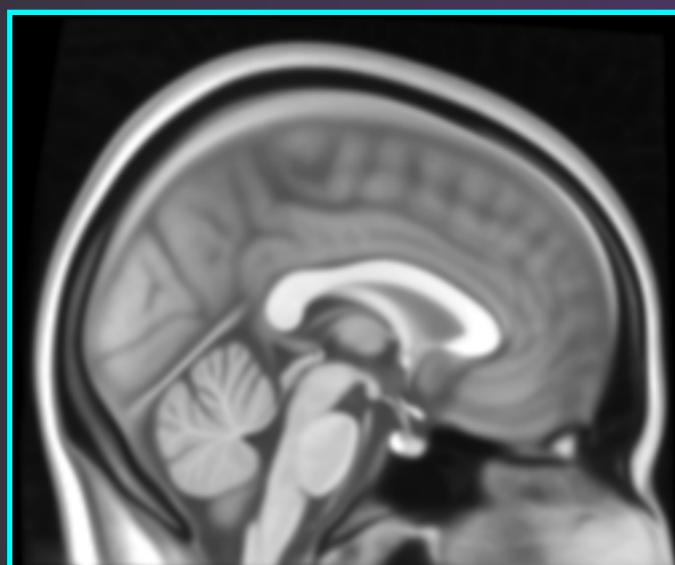
$$\longrightarrow C = A \circ B = \begin{bmatrix} c_{1,1} & & & \\ & \ddots & & \\ & & c_{4,4} & \end{bmatrix}$$

Combined Transform

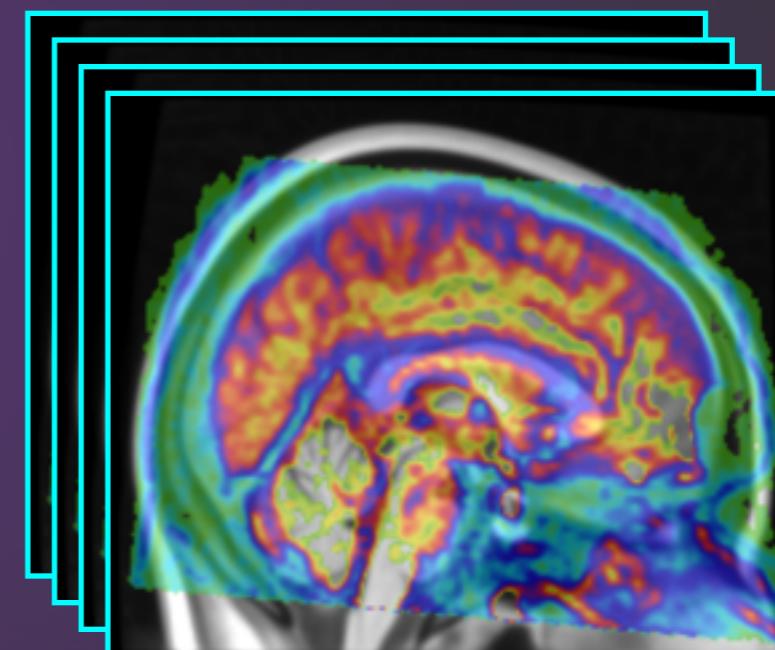
Apply Transforms



Eddy-corrected
DTI volumes



Atlas volume

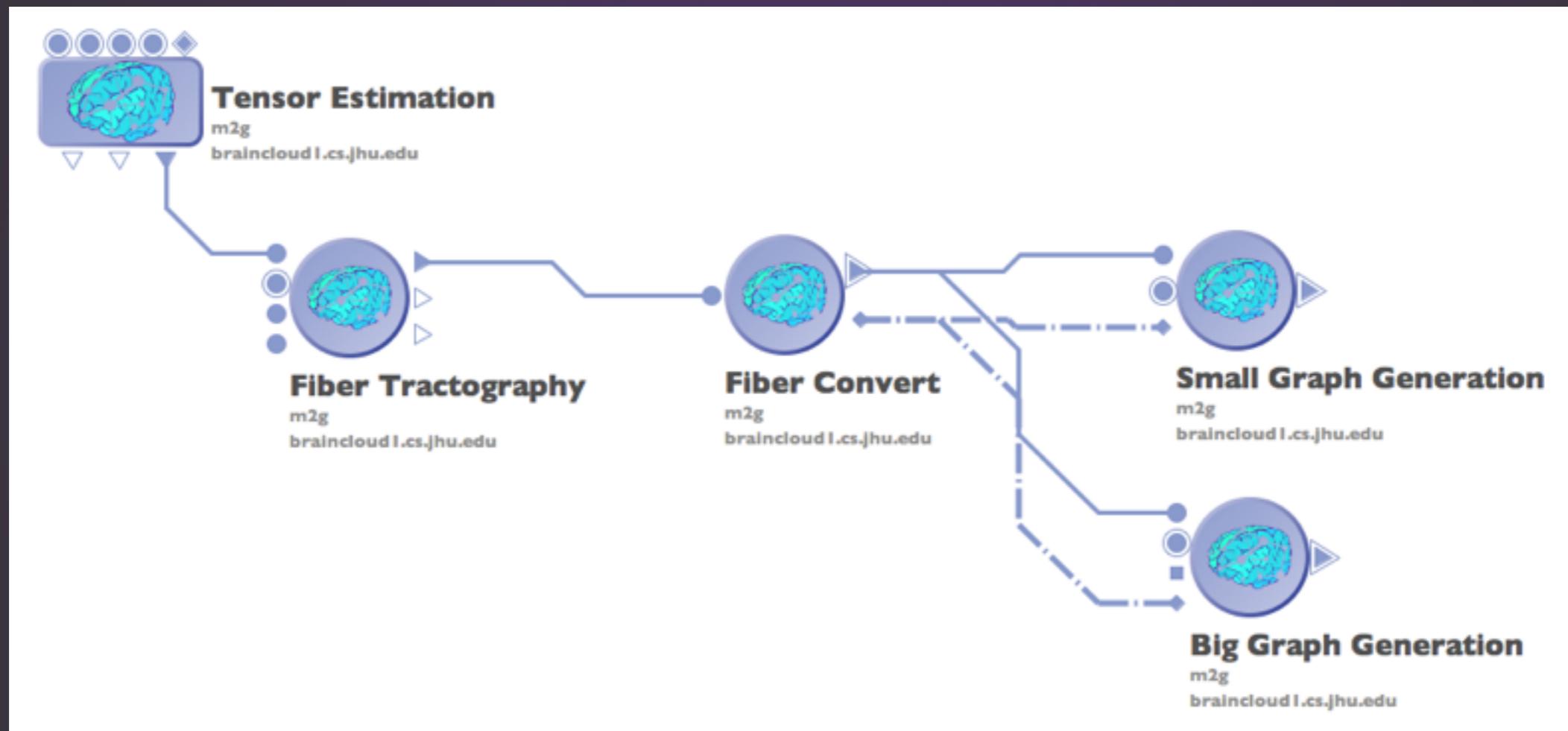


Aligned DTI volumes

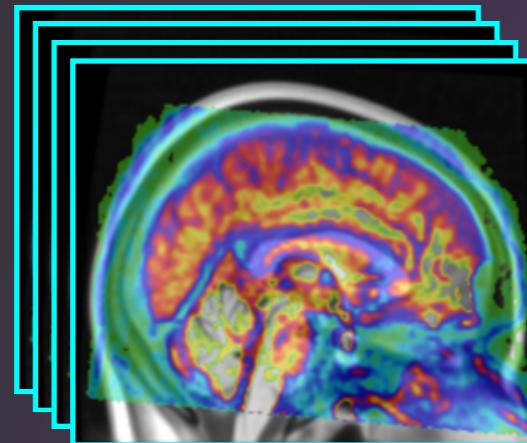
$$C = A \circ B = \begin{bmatrix} c_{1,1} & & & \\ & \ddots & & \\ & & c_{4,4} & \end{bmatrix}$$

Combined Transform

diffusion processing



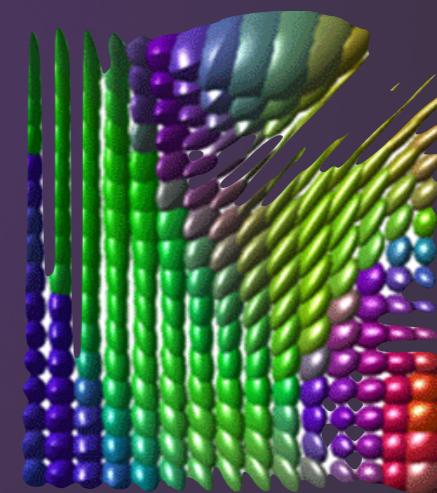
ODF Estimation



Aligned DTI volumes



Brain mask

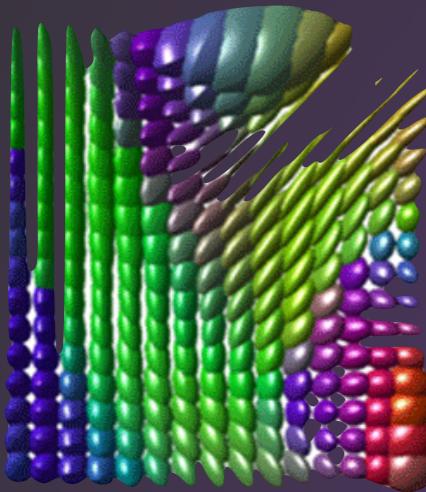


Diffusion tensors/ODFs

$$\begin{bmatrix} B_{x1} & B_{x2} & \dots & B_{xd} \\ B_{y1} & B_{y2} & \dots & B_{yd} \\ B_{z1} & B_{z2} & \dots & B_{zd} \end{bmatrix}$$

Formatted B-vectors

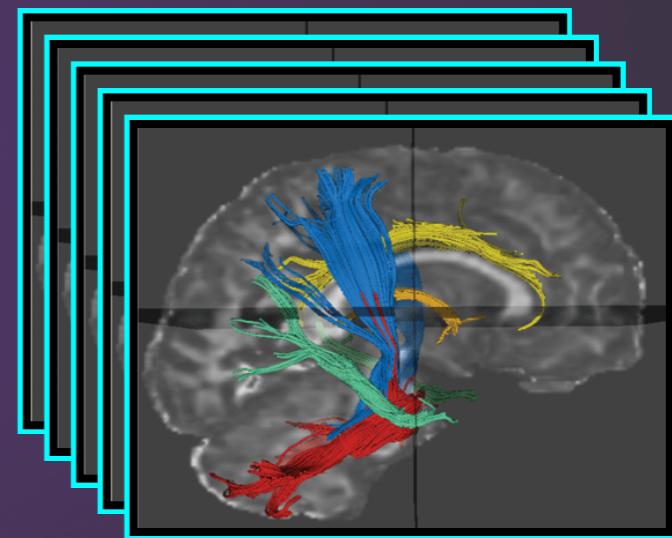
Fiber Tractography



Diffusion tensors/ODFs



Brain mask

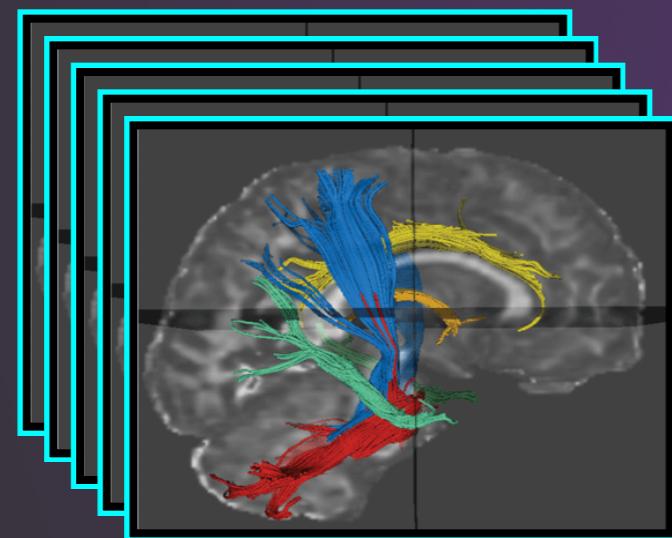


Fiber streamlines

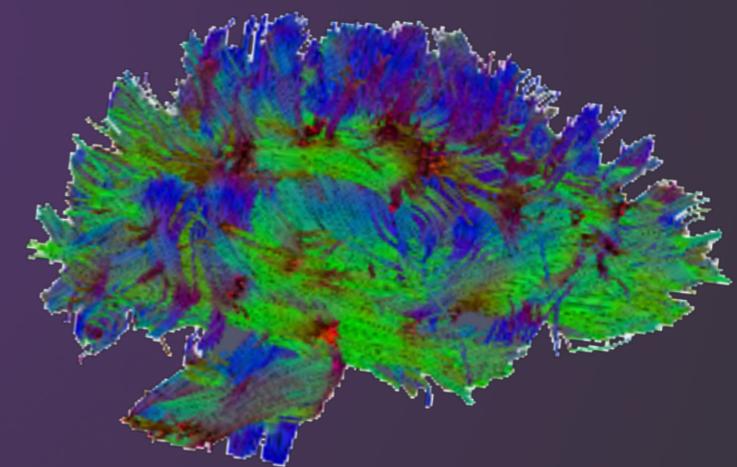
$$b_{fa}$$

Fractional anisotropy
threshold

Fiber Conversion

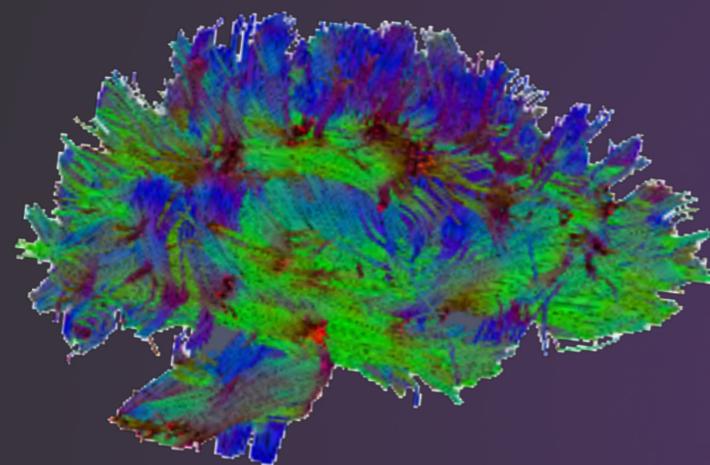


Fiber streamlines

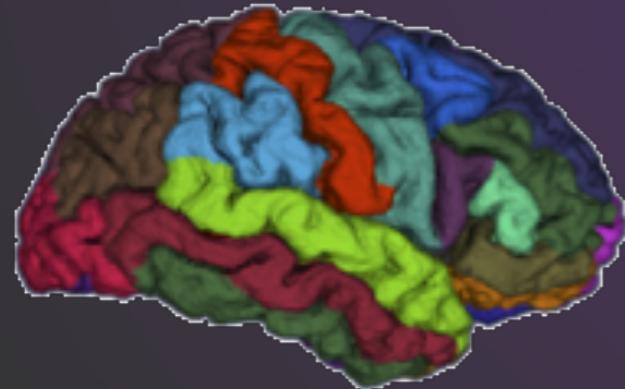


Fiber streamlines

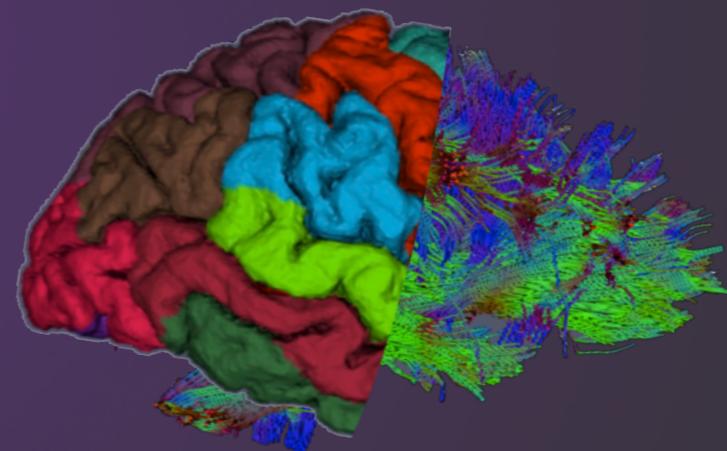
Graph Generation (p1)



Fiber streamlines

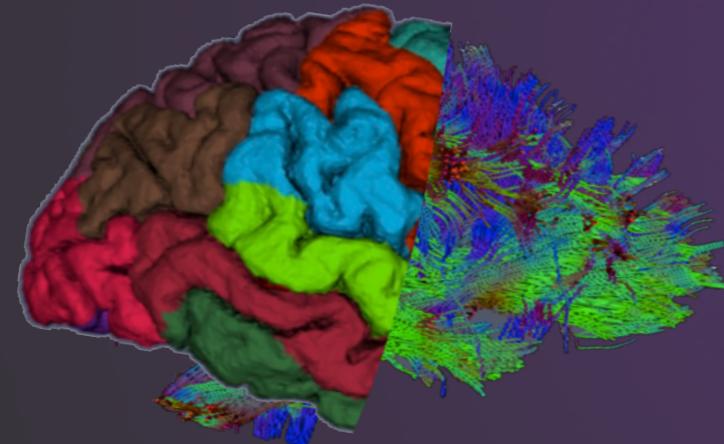


Region labels

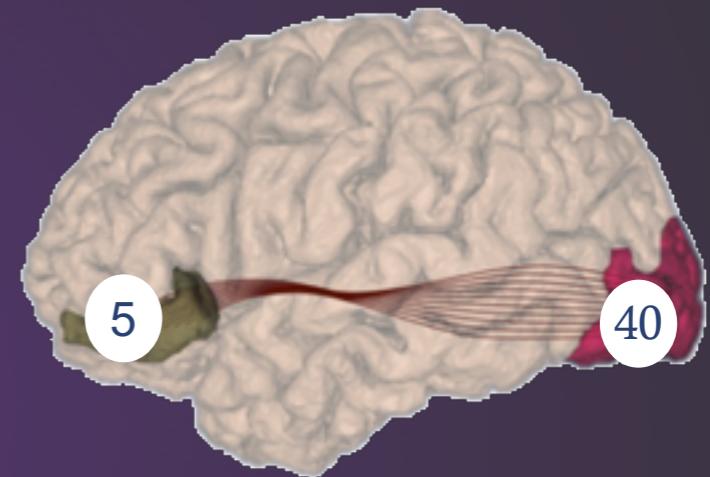


Labeled fibers

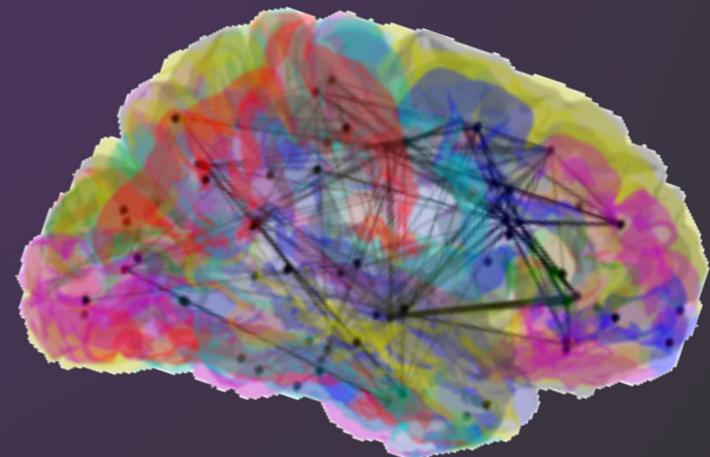
Graph Generation (p2)



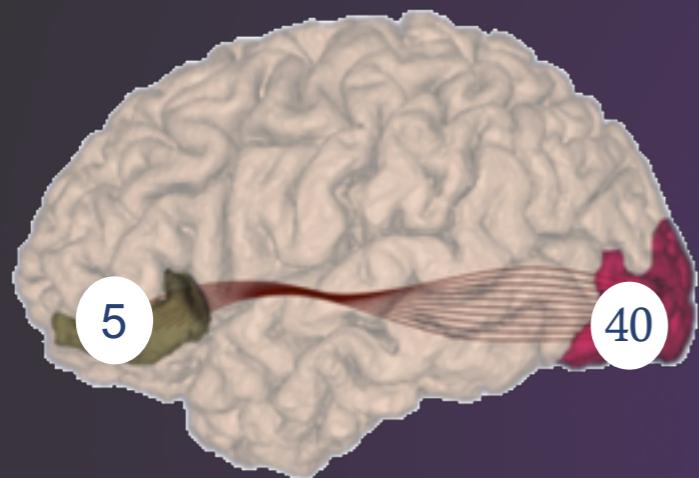
Labeled fibers



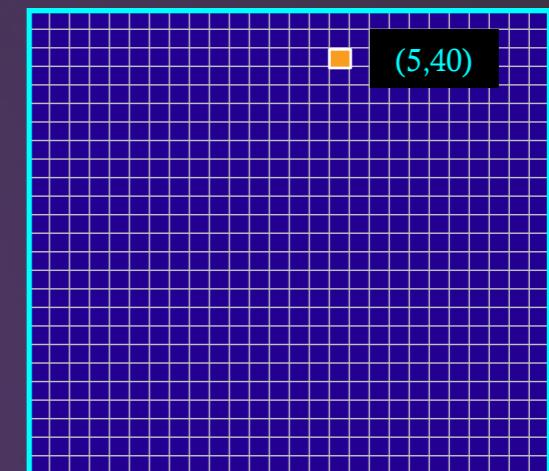
Region Connectivity



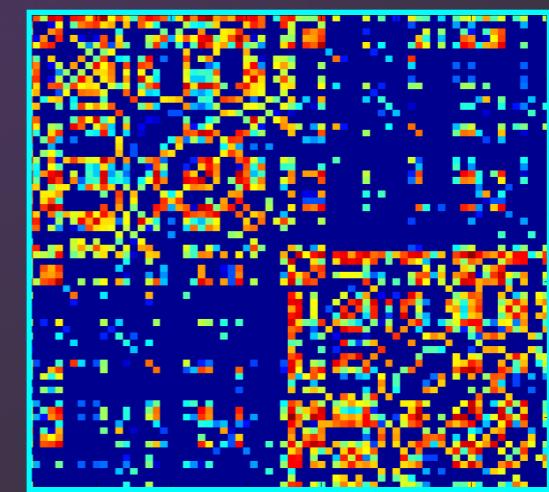
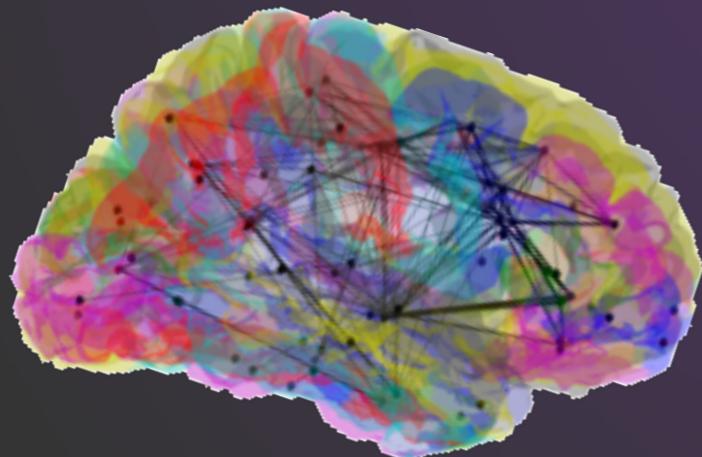
Graph Generation (p3)



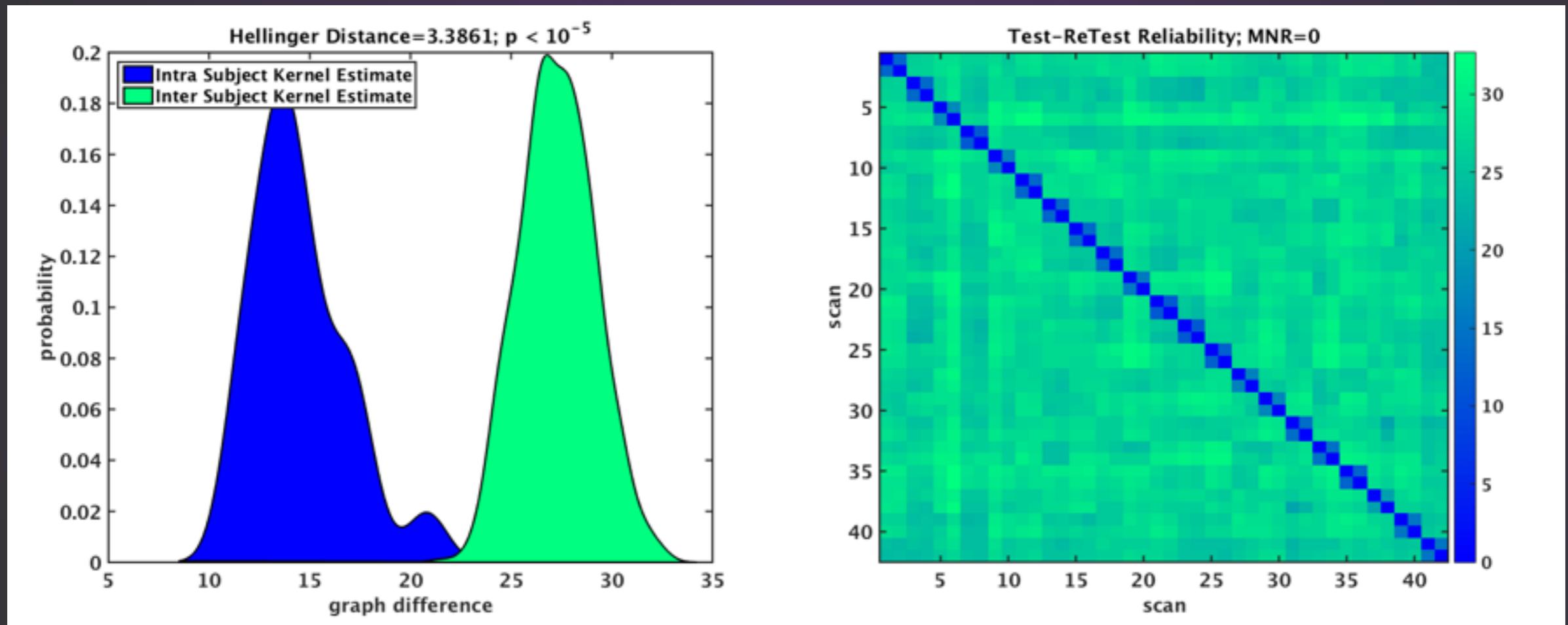
Region Connectivity



Connectivity map



Reliability



$$R = p(\|a_{ij} - a_{ij'}\| \leq \|a_{ij} - a_{i'j'}\|)$$

Code

github.com/openconnectome/m2g

Accessible Service

The screenshot displays the MRI | OCP website interface. At the top left is the logo 'MRI | OCP'. The main content area features several brain connectivity visualizations:

- MAKE MY CONNECTOME**: A large, colorful brain surface map showing white matter tracts.
- SOFTWARE**: A section with a blue background and a grid pattern, containing the text "Learn about and download the m2g software".
- GRAPHS**: A visualization of a complex network graph with many nodes and connecting edges.
- RAW DATA**: A visualization of raw connectivity data with a grid and colored points.
- SUPPORT**: A visualization of brain tracts in a dark space.

At the bottom left, there is copyright information: "© 2015 OCP" and "Image credits from top left going clockwise: <http://humanconnectome.org/>, <http://m2g.io/>, <http://m2g.io/>, <http://discovermagazine.com/>, Daniel Margulies and Joachim Börger". Social media icons for Facebook and Twitter are also present. At the bottom right, there is citation information: "If you use m2g or its data derivatives, please cite: G Kiar, W R Gray Roncal, D Mhember, R Burns, JT Vogelstein (2015). m2g v1.1.1. Zenodo. 10.5281/zenodo.18066 zenodo bibtex".

Roadmap

- process all available DTI+T1/MPRAGE datasets
- test and evaluate pipelines to determine optimal operating points
- development of models for inference

the peeps

Joshua T. Vogelstein
Carey Priebe Randal Burns
Mark Chevillet
Eric Bridgeford Kunal Lillianey
Cencheng Shen Alex Baden Anish Simhal
Youngser Park Michael Miller
Tyler Tomita Avanti Athreya Ivan Kuznetsov
Alex Eusman Guillermo Sapiro Greg Hager
Dean Kleissas Konrad Kording Kwame Kutten
Da Zhang Eva Dyer Will Gray Roncal
Disa Mhembere Ron Boger
Shangsi Wang Greg Kiar
Jordan Matelsky
Minh Tang

the groups

Johns Hopkins University (CS, BME, AMS, EE), JHU Applied Physics Laboratory,
Duke University (EE), Child Mind Institute, Mind Research Network

the funding

NIBIB 1R01EB016411-01 (CRCNS), DARPA N66001-14-1-4028 (GRAPHS), NSF ACI-1261715, NSF
OCI-1040114, NIDA 1R01DA036400-01, JHU Applied Research Laboratory IRAD, and JHU Whiting School of
Engineering, Dean's Award.