Web-based TRACTOGRAM.OBSERVER for comparing diffusion imaging results with tract-tracing experiments in Macaques

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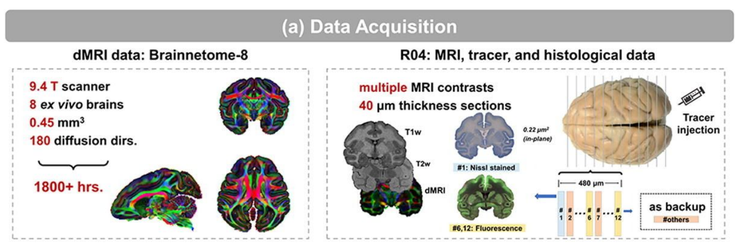
Motivation

Diffusion-weighted Imaging (DWI) is a non-invasive technique that informs us about human brain connectivity. DWI-processing algorithms are calibrated with Macaque data for which we have both DWI and gold standard invasive data.

Non-invasive and invasive tractography data sources

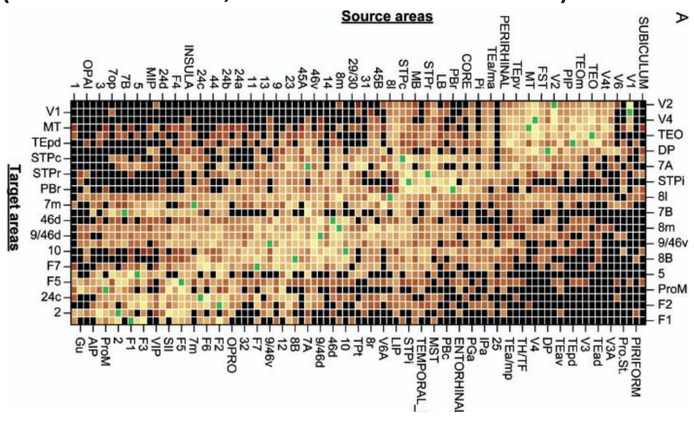
1. Diffusion MRI ex-vivo Macaque ⇒ whole brain tractography

Public resource: 8 subject DWI volumes of the Brainnetome Macaque project (Lu et al, Science Bulletin 2024)



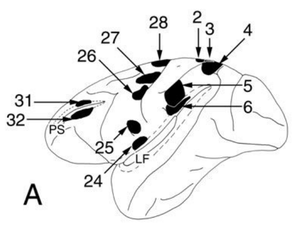
2. Retrograde tract-tracer studies ⇒ target-source connectome

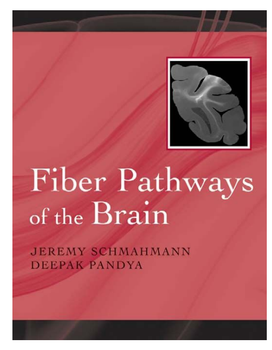
Kennedy lab 29-tracer injections database (Markov et al, Cereb Cortex 2012)



3. Anterograde autoradiographic tract-tracing ⇒ fiber pathways

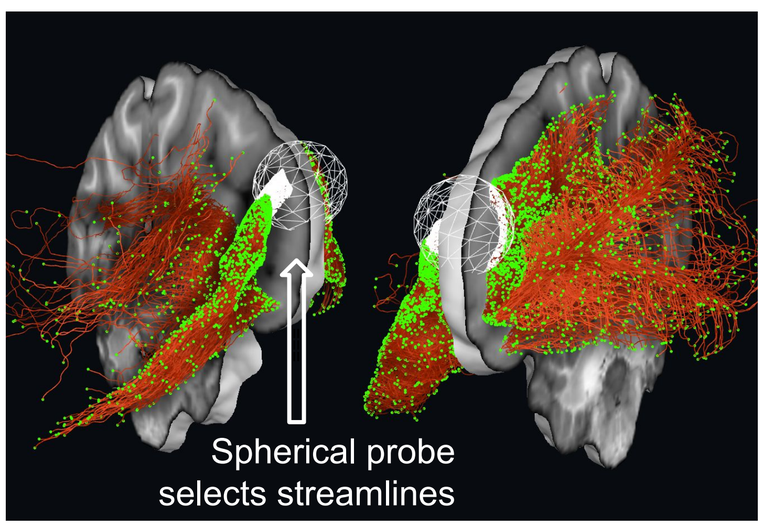
Schmahmann and Pandya's (2006) seminal work

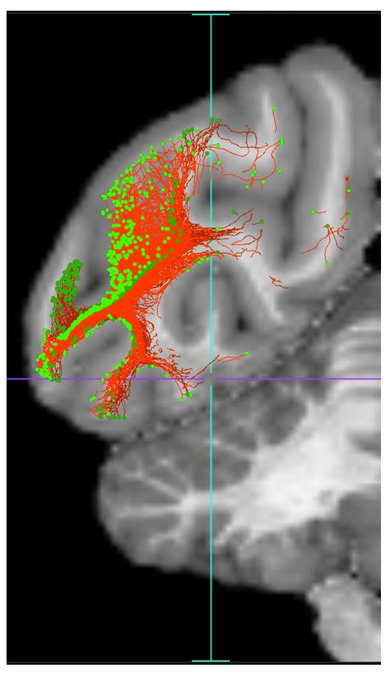


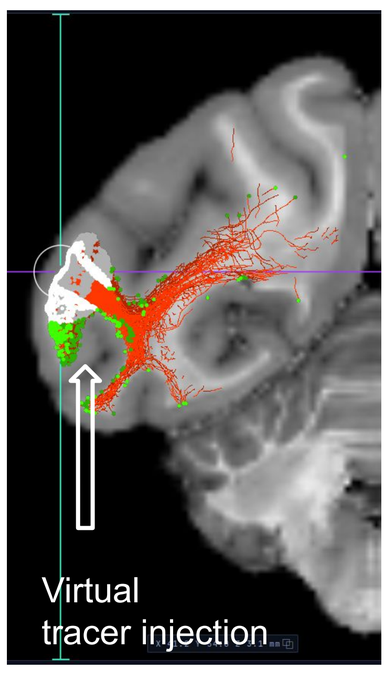


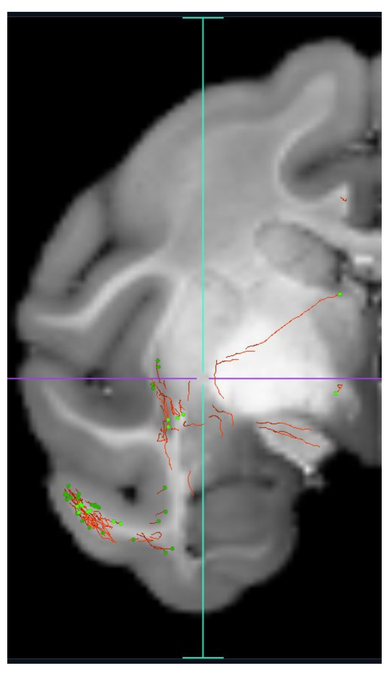
https://tractogram.observer: platform for virtual tractography

Brainnetome monkey M03, 1M streamlines, ∅ 8mm probe at (41.2, 54.0, 3.1)

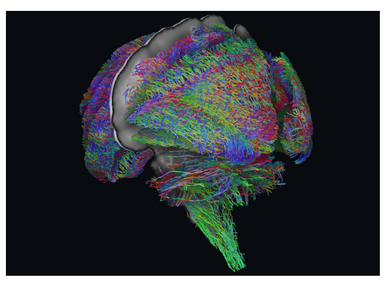








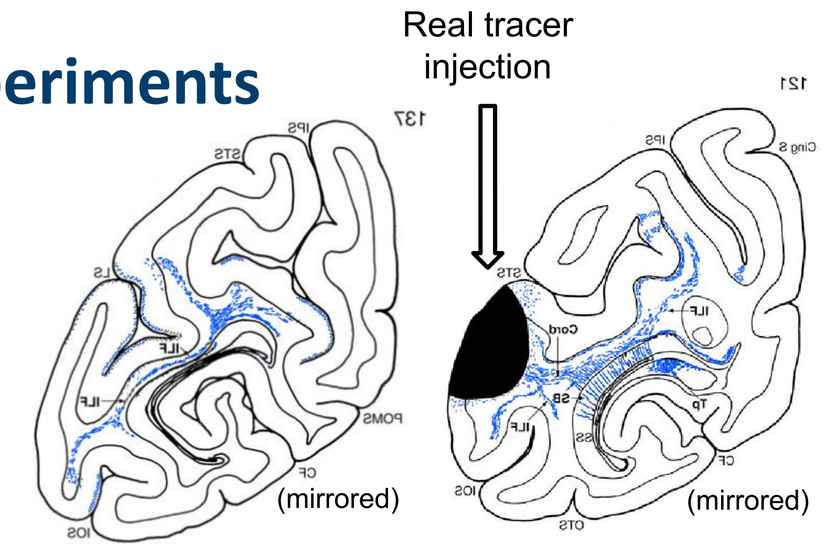
visual cortex render showing crossing fibers.



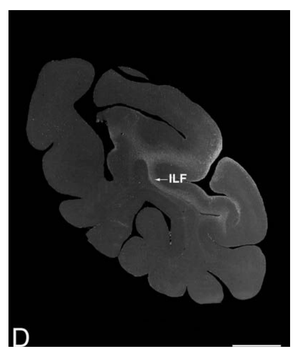
Matching tract-tracer experiments

Anterograde data

Case 20 from Schmahmann & Pandya.
Blue dots are fibers or axon terminals that the injection site projects to.

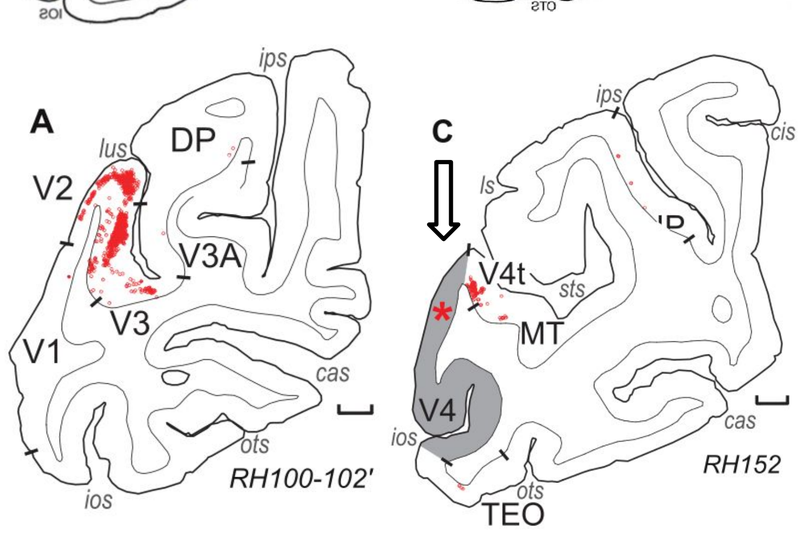


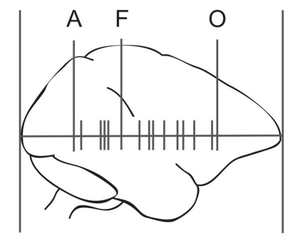
autoradiography slice example



Retrograde data

Case 9 from Markov et al.
Red dots = cell bodies projecting towards injection site.





Case 9: M121RH

coronal slice positions, match figure labels.

Tractography

Anatomically-Constrained Tractography with gray/white matter border seeding, not allowed to go into gray matter, powered by MRTrix (Tournier et al. (2019). This needs a 5-tissue-type segmentation, typically derived from a T1w image. Here we register a T2w image to the NMT_v2 template (Jung et al, 2021), and use its segmentation as an initial seed to a multi-modal segmentation tool (Avants et al, 2011).

Markov et al. (2012) Cerebral Cortex 24(1). doi: 10.1093/cercor/bhs270.
Lu et al. (2024) *Science Bulletin* 69(14). doi: 10.1016/j.scib.2024.03.031.
Schmahmann & Pandya (2006) Fiber pathways of the brain. doi: 10.1093/acprof:oso/ 9780195104233.001.0001
Tournier et al. (2019) *NeuroImage* 202. doi 10.1016/j.neuroimage.2019.116137.
Avants et al, (2011) *Neuroinformatics* 9(4), doi: 10.1007/s12021-011-9109-y
Jung et al, (2011) NeuroImage 235, doi: 10.1016/j.neuroimage.2021.117997

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Result

This single case study shows quite a good match between DWI and tract-tracer results, with some fundamental limitations:

- DWI streamlines are symmetric, real connections are not. The caudate nucleus connection is only present in the anterograde study and the TEav/PERI connection only in the retrograde study.
- Patterns look quite different since fiber tracking does not enter cortex, real fibers do and terminate in distinct layers.
- No target specificity: tractography can manage crossing fibers, but it sees them as highways whose exits form all-to-all connections.

Our next step is to register all tracer injections into the space of the tractogram.

Open source tool

Tractogram.observer is an open source tool, created in coworking mode with claude.ai. This poster's tractogram is available from the homepage. Or drag /drop your own tractogram (.tck/.trk) and image volume (.nii.gz). It uses 2d sections for probe positioning and 3d visualization (reflection, shadowing) for fiber bundles. Cutting angles are adjustable (pitch, yaw, roll) and it supports segmentations (.nii.gz with lookup table) to overlay atlas regions or tissue classes.

