OHBM2021 Education course, June 2nd
Tractometry: Peering into the White Matter

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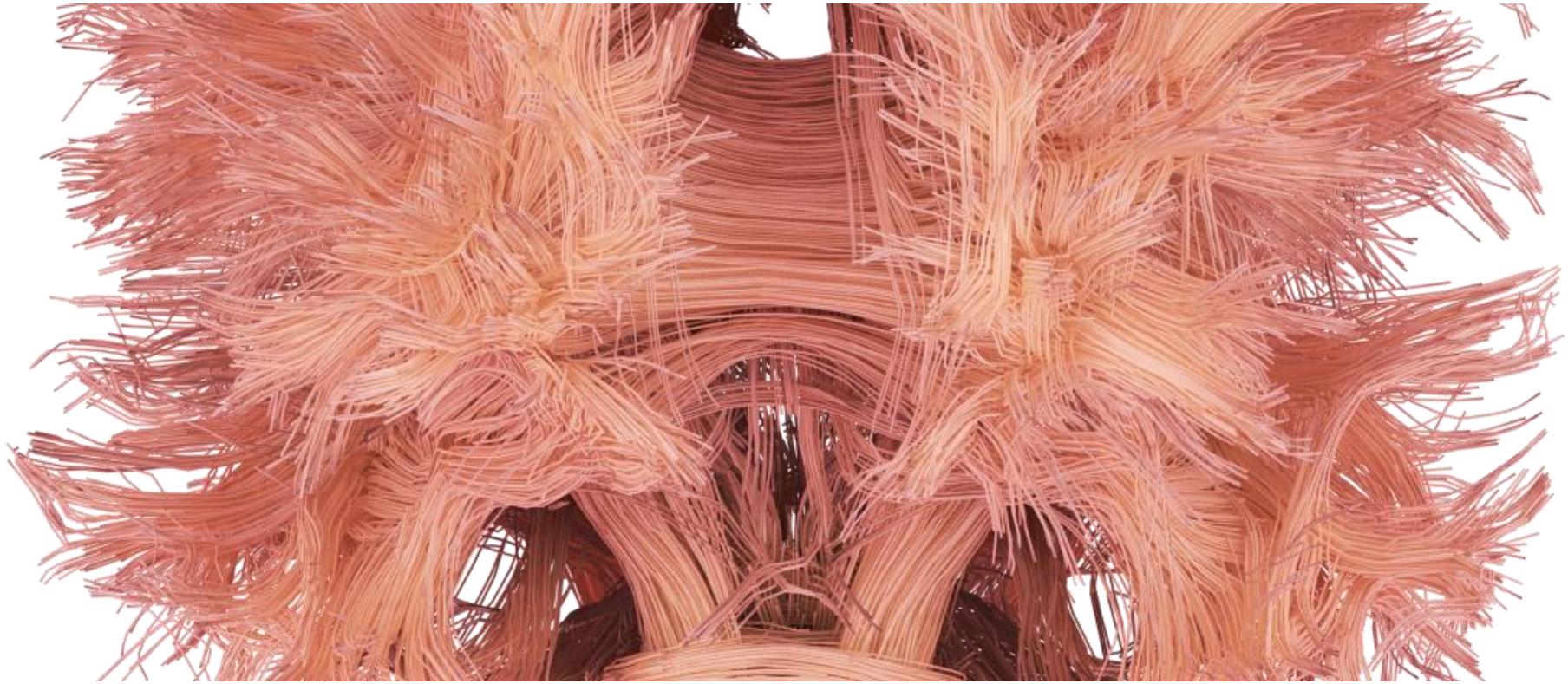
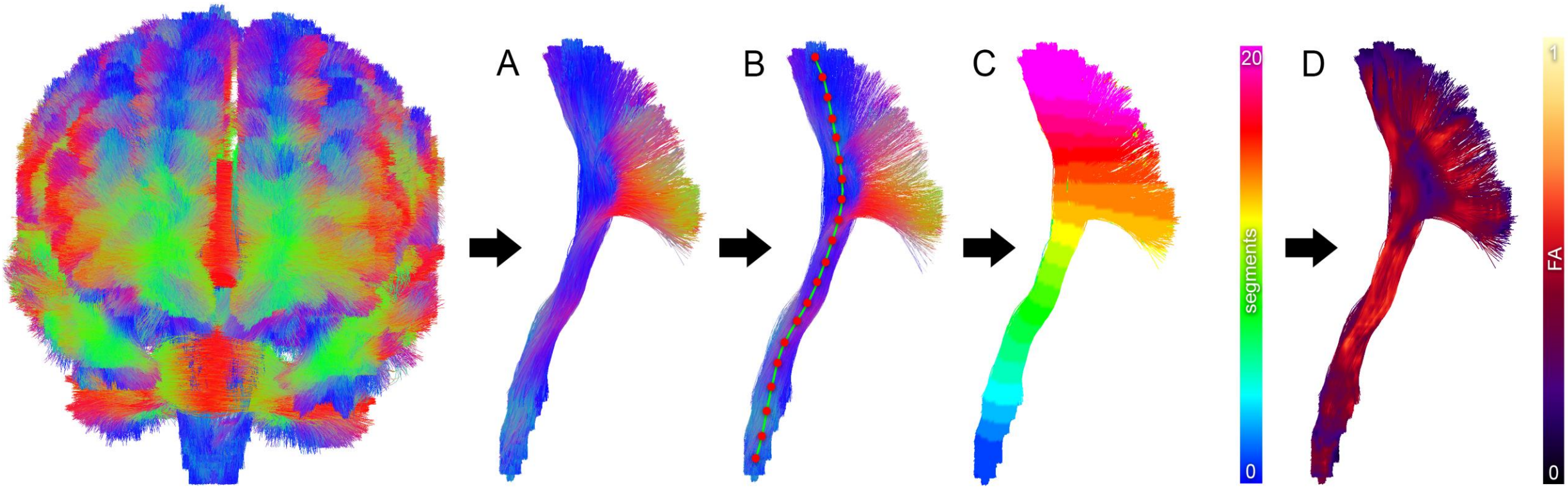


Single-subject analysis via high-dimensional analysis

Maxime Chamberland, PhD

Radboud University Radboudumc

Along-tract profiling



A. Bundle segmentation B. Centreline extraction C. Segment definition D. Quantitative mapping

Jones et al. MRM (2005); **Corouge** et al. MedIA (2006); **Yeatman** et al. PLOS One (2012);
Colby et al. Nimg (2012); **Cousineau** et al. Nimg Clin. (2017); **Yeatman** et al. Nat. Comms. (2018)

The Tractometry *Philosophy*

‘The Tractometry framework was introduced to combine […] multi-parametric data… along multiple tracts’
Bells et al. ISMRM (2011); De Santis, S., et al. Neuroimage (2014).

Ph.D. Thesis ——— Sonya Bells ——— Cardiff University - Psychology ——— 2012

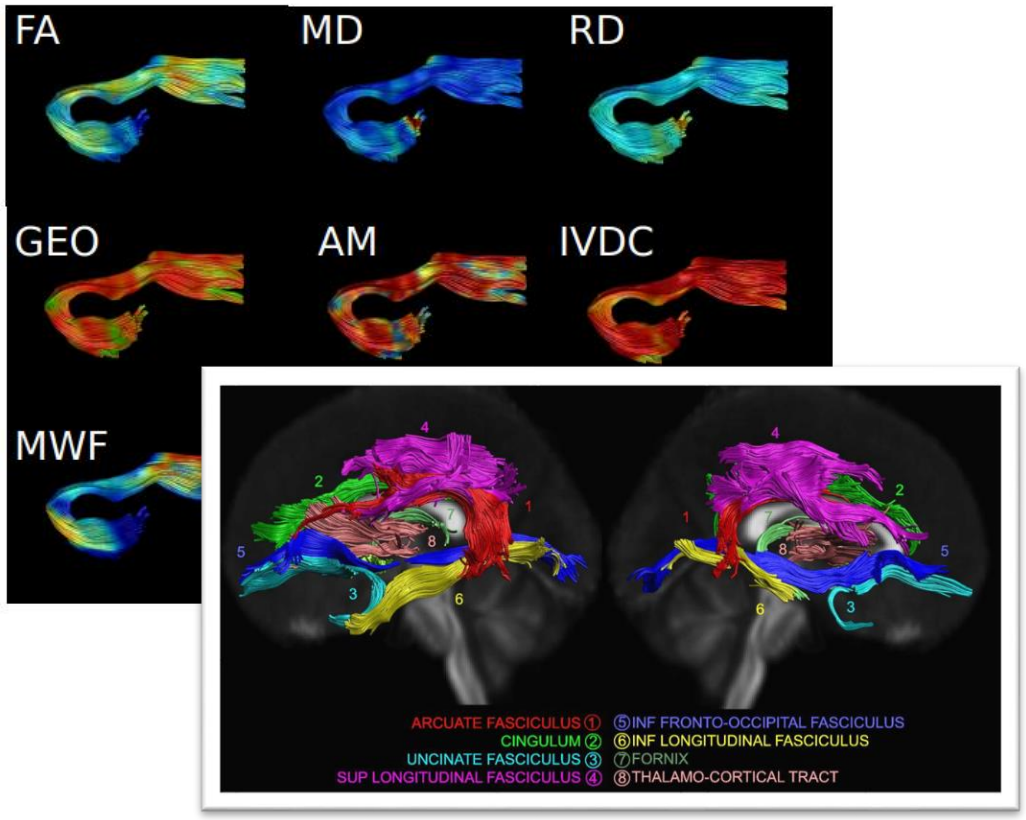
Abstract #0678

Tractometry Comprehensive Multi-modal Quantitative Assessment of White Matter Along Specific Tracts

Sonya Bells[1], Mara Cercignani[2], Sean Deoni[3,4], Yaniv Assaf[5], Ofer Pasternak[6], C John Evans[7], a Leemans[8], Derek K. Jones[7]

[1]CUBRIC , School of Psychology, Cardiff, United Kingdom; [2]Santa Lucia Foundation, Neuroimaging Laboratory, Rome, Italy; [3]School of Engineering, Brown University, Providence, RI, USA; [4]Centre of Neuroimaging Sciences-Institute of Psychiatry, King's College, London, United Kingdom; [5]Department of Neurobiology, Tel Aviv University, Tel Aviv, Israel; [6]Brigham & Women's Hospital, Harvard Medical School, Bostan, MA, USA; [7]CUBRIC, School of Psychology, Cardiff, United Kingdom; [8]Image Sciences Institute, University Medical Center Utrecht, Utrecht, Netherlands

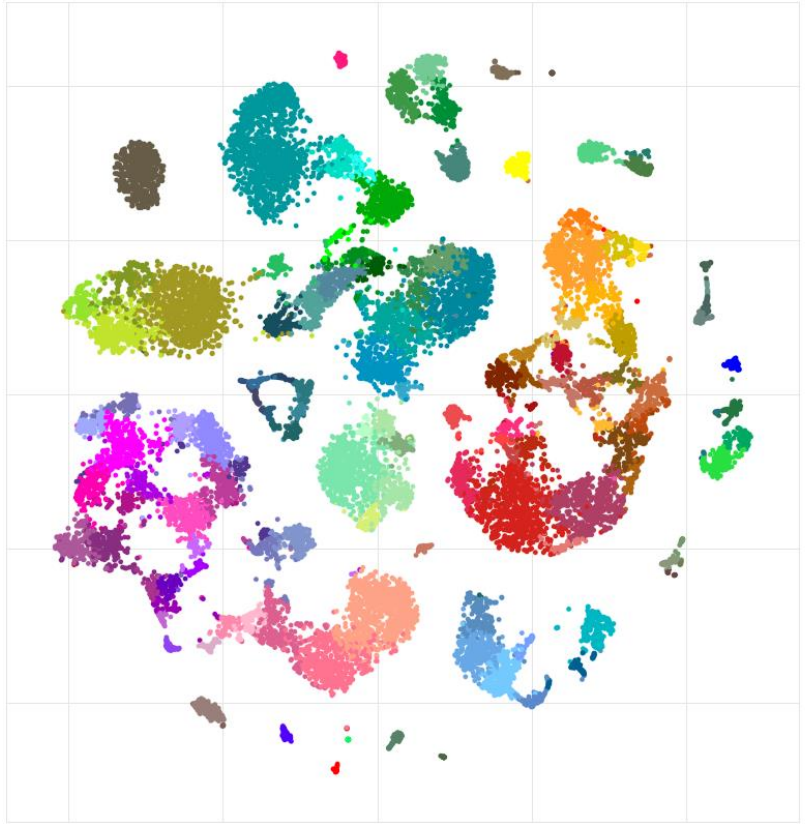
A new technique called tractometry is introduced. Tractometry is a comprehensive assessment of tract-specific microstructural measurements is introduced. This method combines macromolecular measurements from optimized



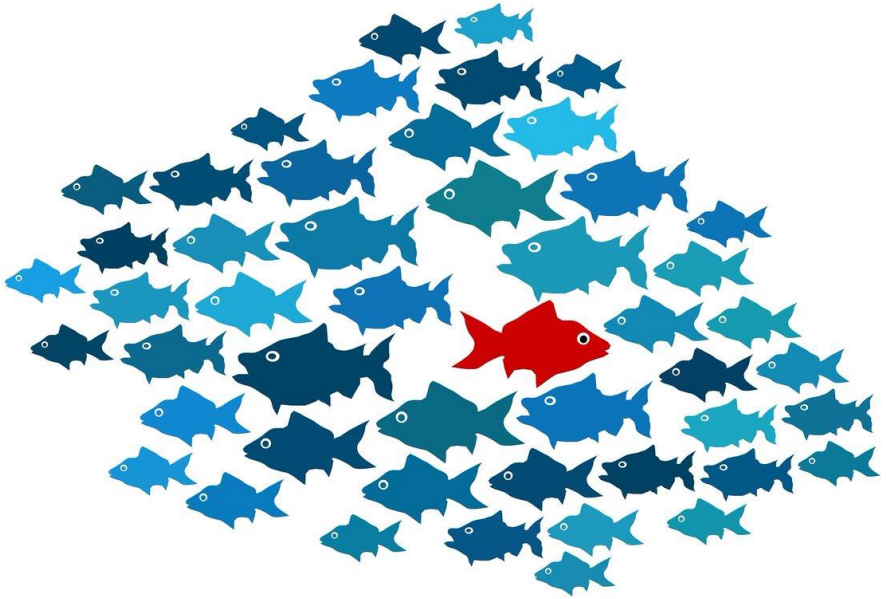
Bells et al. ISMRM (2011); **De Santis** et al. Nimg (2014);

Concepts

1. Dimensionality reduction

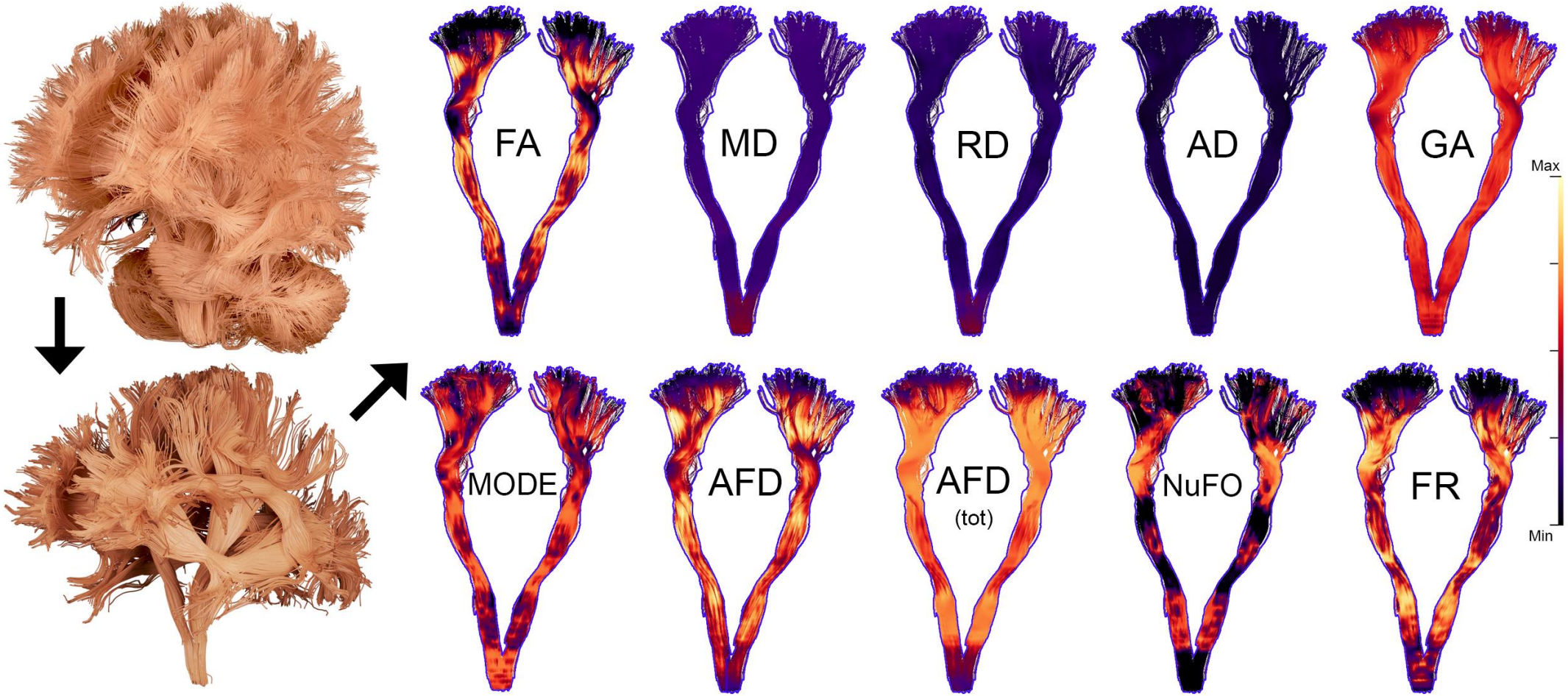


2. Anomaly detection



Dimensionality reduction

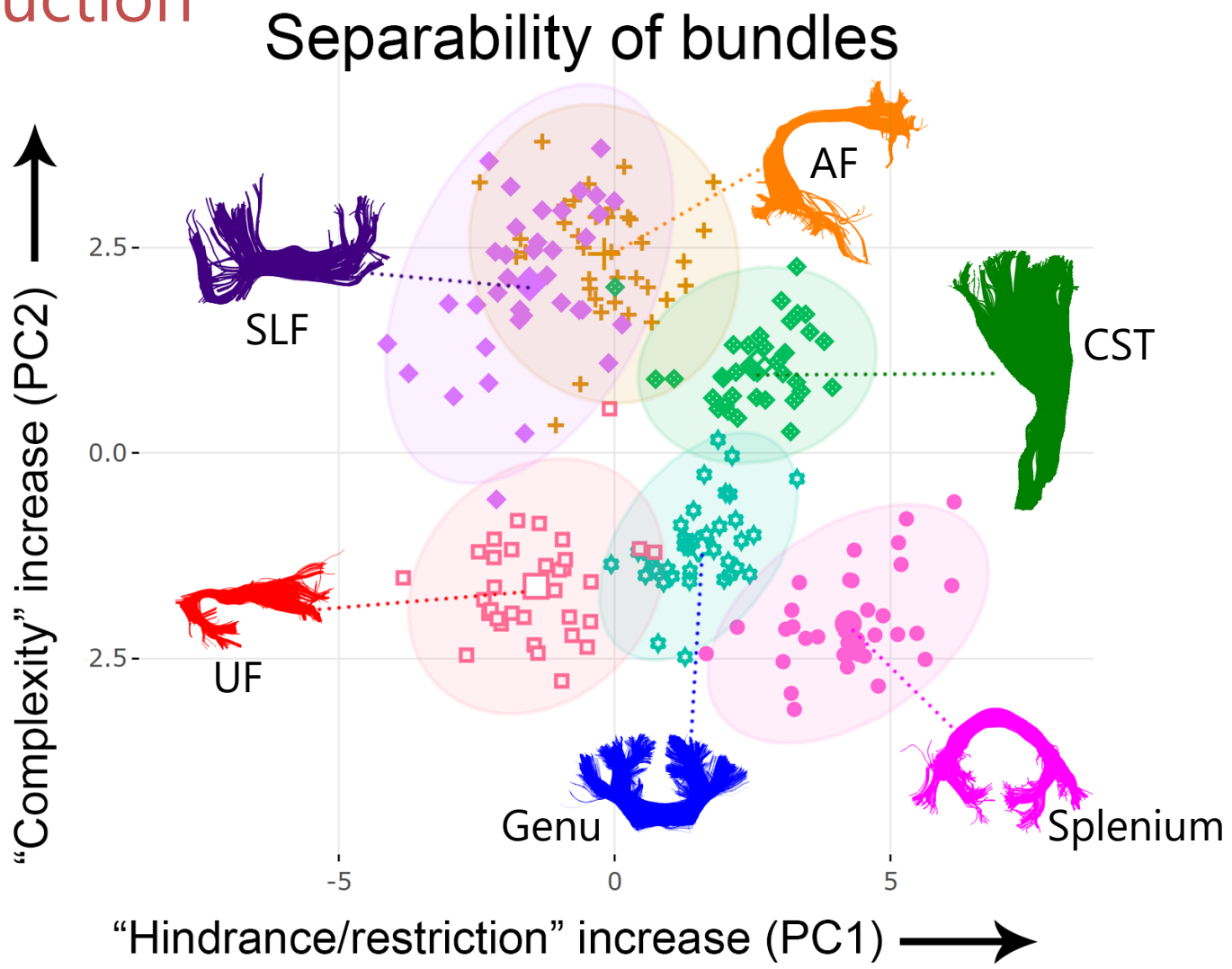
Working with multiple dMRI measures



Chamberland, M., Raven, E.P., Genc, S., Duffy, K., Descoteaux, M., Parker, G.D., Tax, C.M. and Jones, D.K., 2019. Dimensionality reduction of diffusion MRI measures for improved tractometry of the human brain. NeuroImage

Dimensionality reduction

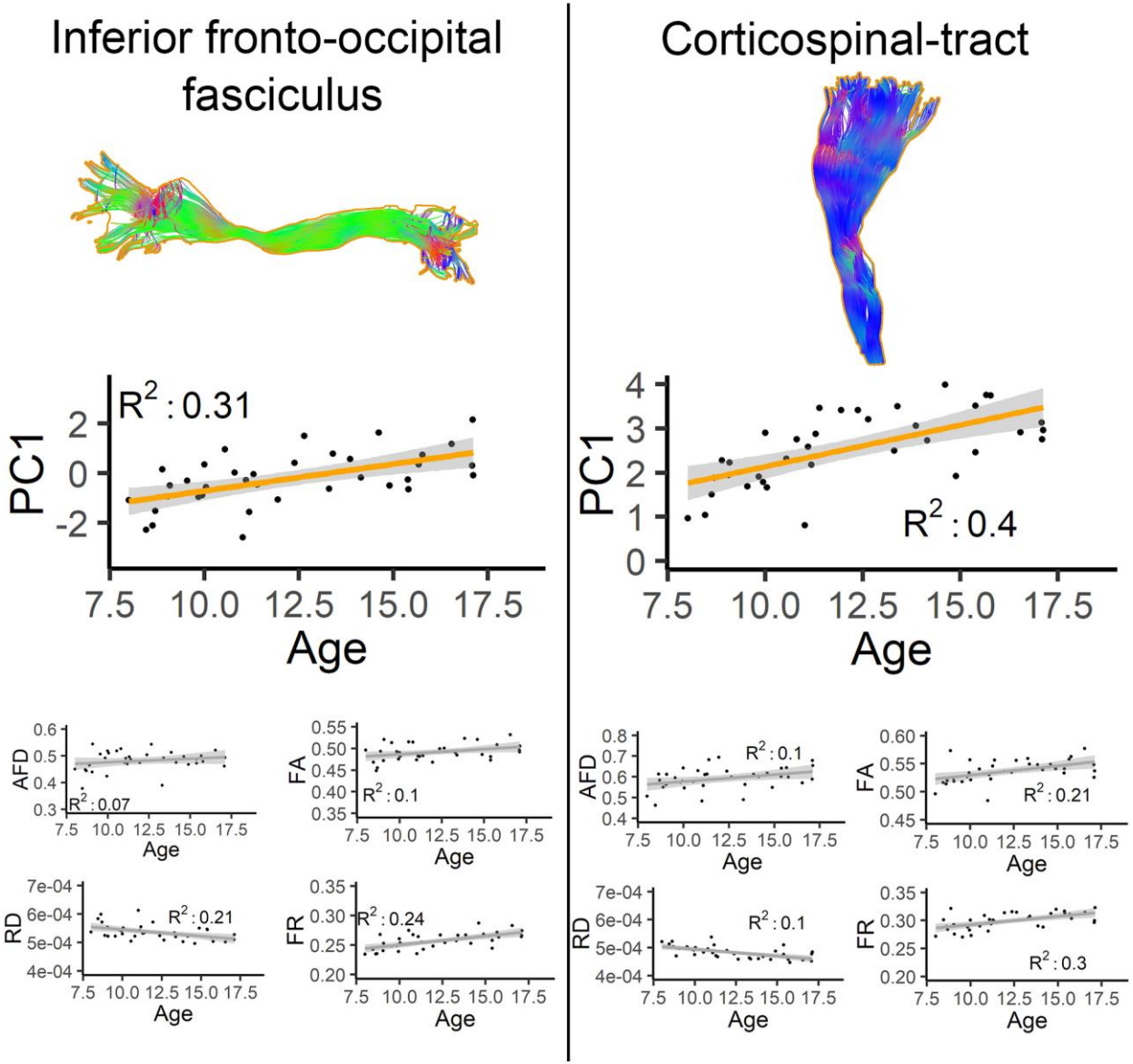
Goal: represent **m**-dimensional data in **n**-dimensional space, where **m** > **n**



Chamberland, M., Raven, E.P., Genc, S., Duffy, K., Descoteaux, M., Parker, G.D., Tax, C.M. and Jones, D.K., 2019. Dimensionality reduction of diffusion MRI measures for improved tractometry of the human brain. NeuroImage

Extracting components

The components showed age-related effects across developmentally sensitive pathways.



Chamberland, M., Raven, E.P., Genc, S., Duffy, K., Descoteaux, M., Parker, G.D., Tax, C.M. and Jones, D.K., 2019. Dimensionality reduction of diffusion MRI measures for improved tractometry of the human brain. NeuroImage

DEMO

Anomaly detection

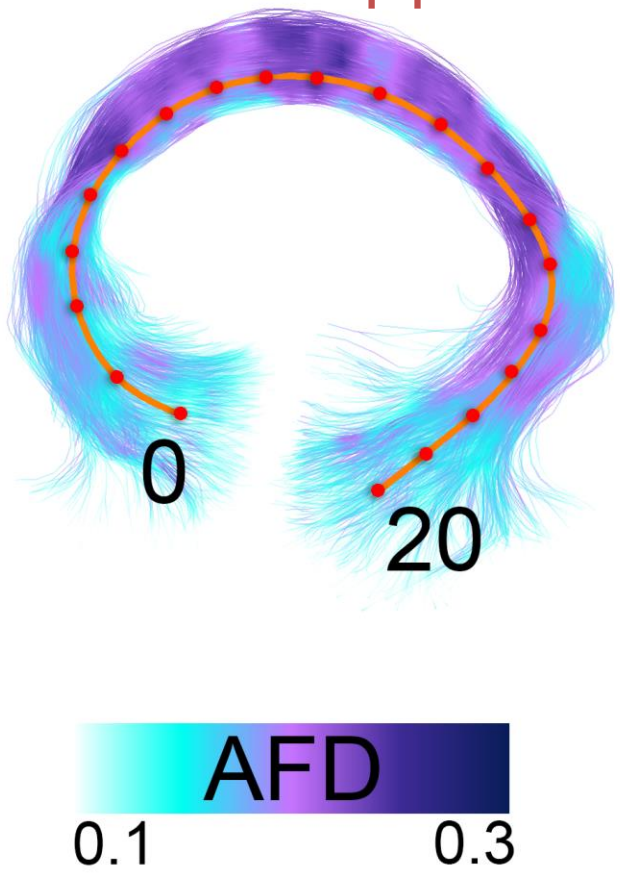
Normative modeling[1]

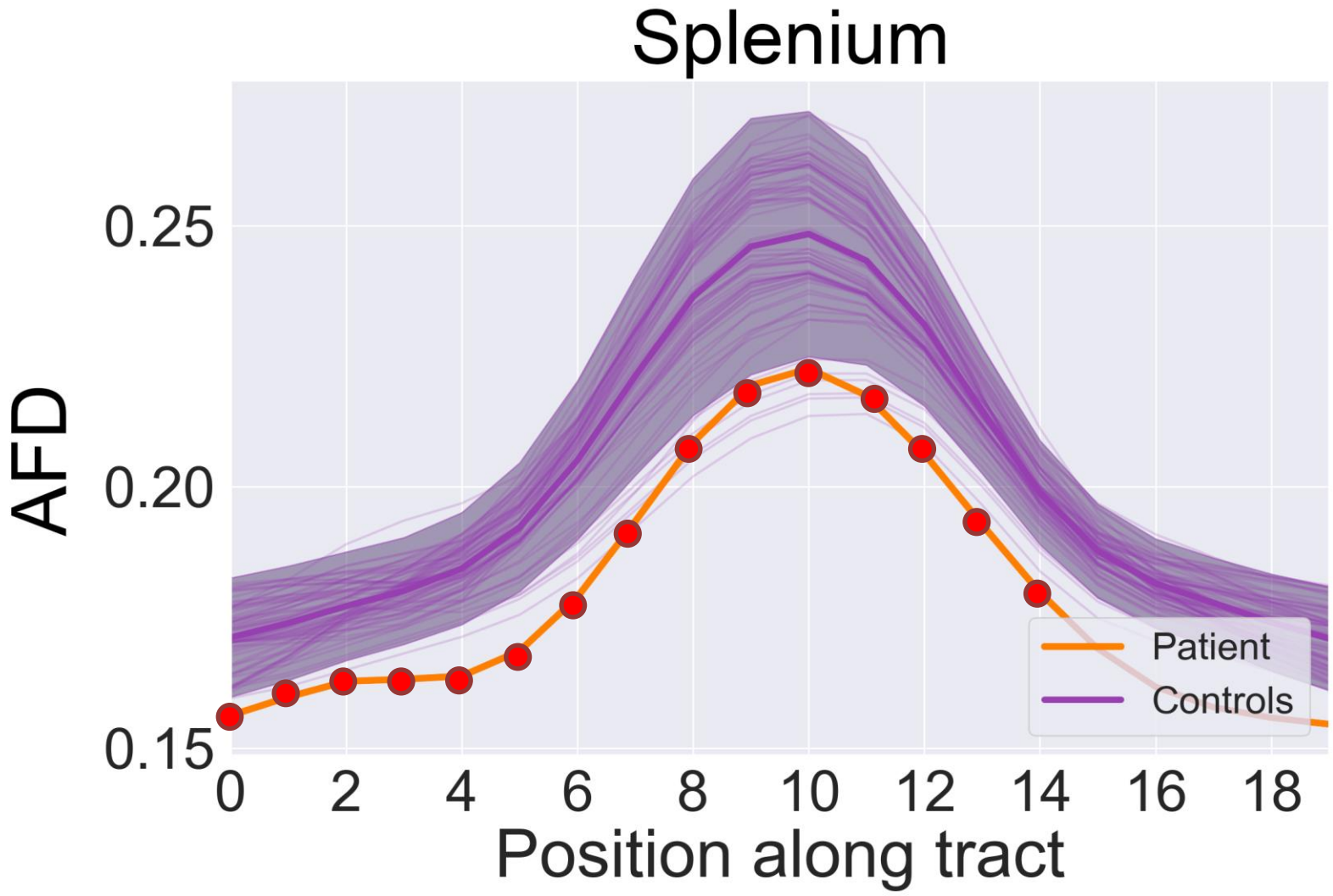
1 subject

M controls

1. **Marquand**, AF., et al. "Understanding heterogeneity in clinical cohorts using normative models: beyond case-control studies." Biological psychiatry 80.7 (2016): 552-561.

Z-score approach

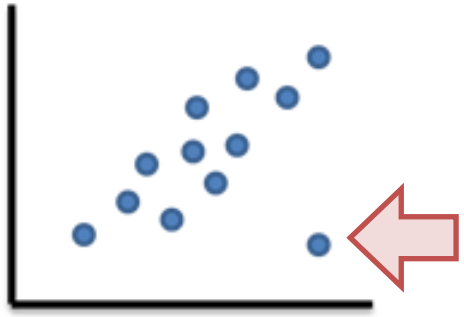


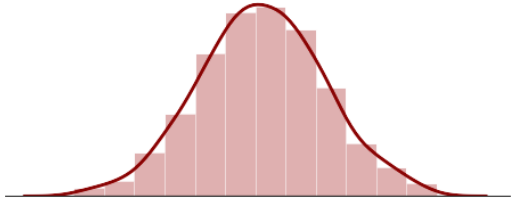


As done in: **Yeatman** et al. PLOS One (2012), **Yeh** et al. HBM (2017)

Anomaly detection principle

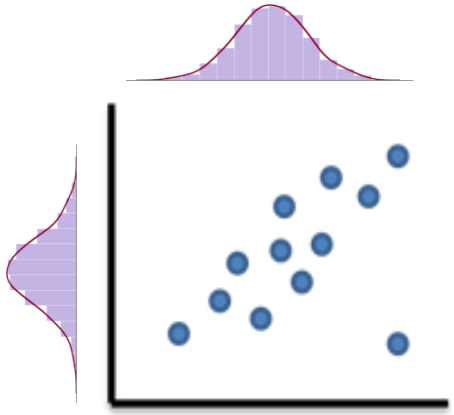
"An outlier is an observation, which deviates so much from other observations as to arouse suspicions that it was generated by a different mechanism." -Hawkins, 1980





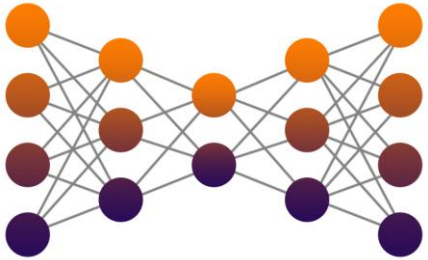
Z

Univariate
Z-score



M

PCA +
Mahalanobis Distance



E

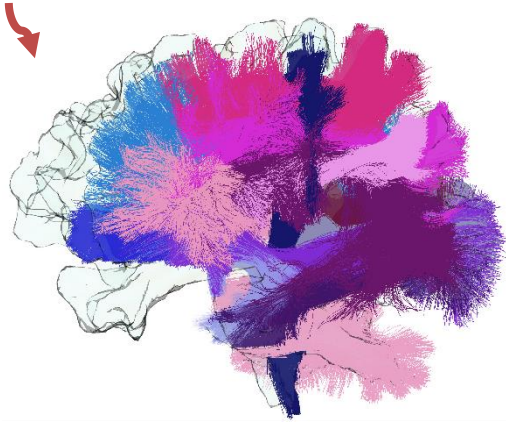
Autoencoder +
Reconstruction error

Taylor et al. Neurology (2020), **Chamberland** et al. MIDL (2020)

Deep learning of normative features

Original
dMRI features

Healthy adults only



x

Reconstructed
dMRI features

$\hat{x}$

Chamberland, M., Genc, S., Tax, CMW., Shastin, D., Koller, K., Raven, EP., Parker, GD., Hamandi, K., Gray, WP., and Jones, DK. "Detecting microstructural deviations in individuals with deep diffusion MRI tractometry." medRxiv (2021).

Relevant frameworks

Detect

A browser-based anomaly detection framework for diffusion MRI using Tractometry.

https://github.com/chamberm/detect

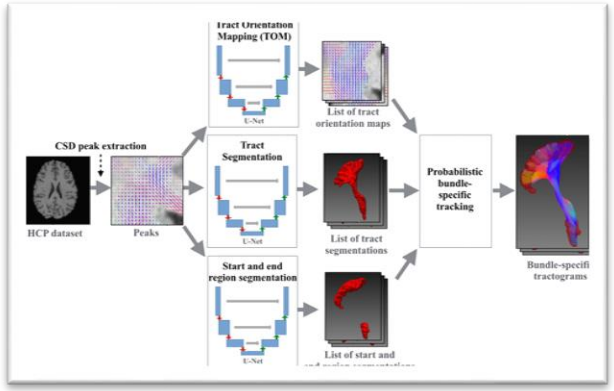
https://dipy.org/

A browser-based tool for visualization and analysis of diffusion MRI data

Jason D. Yeatman, Adam Richie-Halford, Josh K. Smith, Anisha Keshavan & Ariel Rokem

Nature Communications **9**, Article number: 940 (2018) | Cite this article

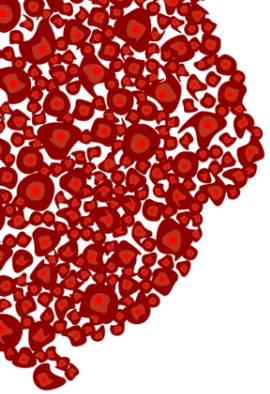
https://yeatmanlab.github.io/AFQBrowser-demo/



https://github.com/MIC-DKFZ/TractSeg

***AFQ-Insight* Python based statistical learning for tractometry**

https://github.com/richford/AFQ-Insight



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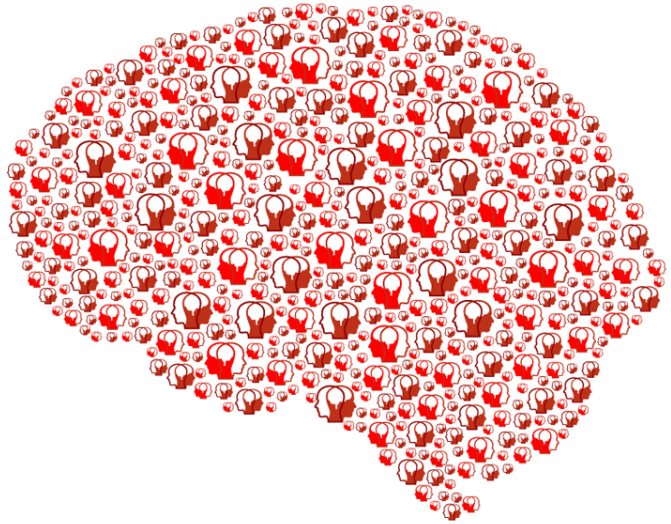
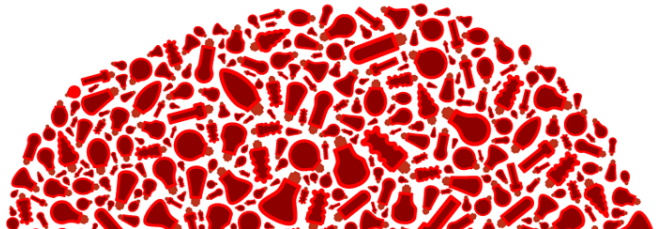


@MaxChamb

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