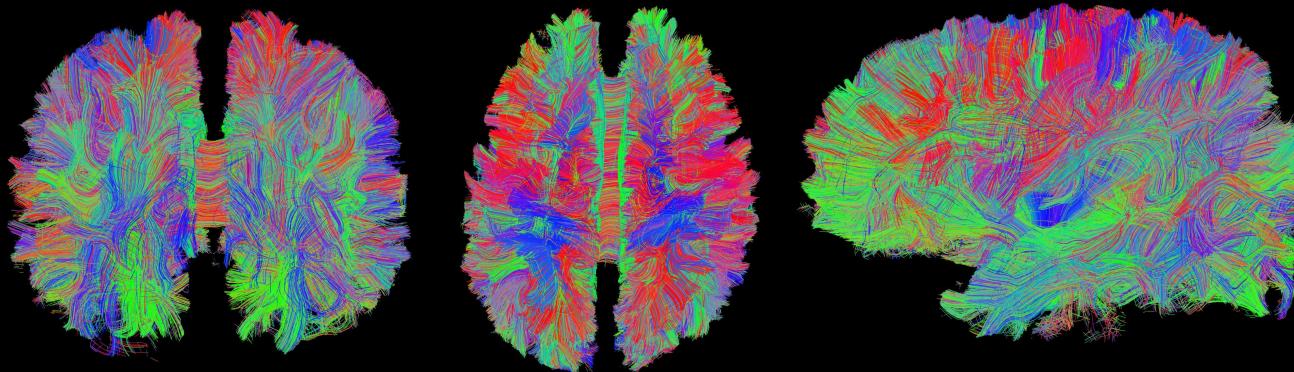


# Visualizing Diffusion Tensor Imaging with DiPy and Surf Ice

(Code walkthrough and visualizations)



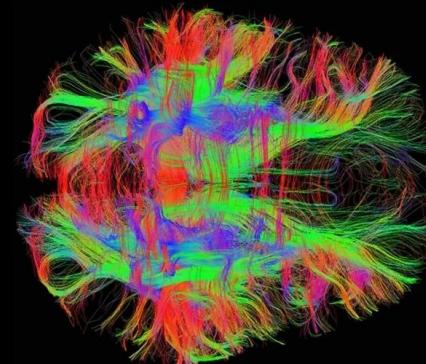
**COGS 510 Course Project Presentation**

Shashank Yadav, PhD Student, Biomedical Engineering



# Introduction

- **Diffusion Tensor Imaging(DTI)**: MRI technique used to measure the diffusion of water molecules in tissues, particularly in white matter of the brain.
- Estimate the structure and organization of white matter pathways in the brain.
- Information on the direction and magnitude of diffusion within each voxel of a 3D image.
- Used to generate tractography maps of white matter pathways.
- RGB (**red-green-blue**) encoding is used to represent directions.



# Introduction

- **Fiber tracking:**
  - Process of reconstructing white matter pathways in the brain using diffusion MRI data.
  - Model white matter fibers by creating streamlines from local directional information.
- **Tractography:**
  - Estimates the path of white matter tracts based on the direction of water diffusion.
  - Tractography provides 3D visualizations of white matter tracts in the brain, which can be used to study brain connectivity.



# Introduction

**Fiber tracking:** Usually Involves four steps:

- i. A method for getting directions from a diffusion MRI data set.
- ii. A method for identifying when the tracking must stop.
- iii. A set of seeds from which to begin tracking.
- iv. Selection of Tractography Algorithm

**Tractography Basics:** If the local directionality of a tract/pathway segment is known, one can integrate along those directions to build a complete representation of that structure. (<https://dipy.org>)



# Introduction

## Tractography Types:

### Deterministic:

- Deterministic fiber tracking can be viewed as a maximum likelihood estimation of the fiber trajectories.
- Finds the most probable track of the fiber pathways within the tracking constraint.

### Probabilistic:

- Follows the trajectory of a possible pathway step by step starting at a seed, but the tracking direction at each point along the path is chosen at random from a distribution.
- Probabilistic fiber tracking aims to explore the empirical distribution of all possible trajectories of the fiber pathways.



# Methods

## What is DiPy?

- DiPy / DIPY :"Diffusion Imaging in Python".
- DiPy is built on top of the scientific python stack, including numpy, scipy, and matplotlib.
- DiPy includes a range of pre-processing tools, such as motion and eddy current correction, diffusion tensor estimation, and fiber orientation distribution function (fODF) reconstruction.
- Includes deterministic and probabilistic fiber tracking, as well as advanced techniques such as constrained spherical deconvolution (CSD) and diffusion spectrum imaging (DSI).
- Dipy provides various visualization tools, including interactive 3D tractography visualization, and support for various image formats such as png, svg, and pdf.



DIPY

# Methods

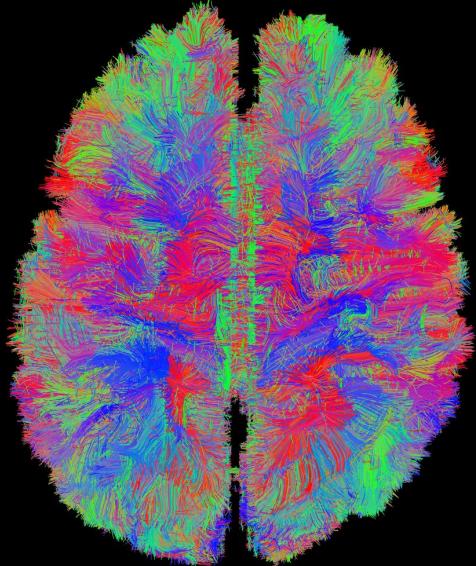
- **Code Walkthrough:**
  - DiPy Installation
  - Basic tracking and tractography with the following algorithms.
    - i. EuDx: Euler Delta Crossings
    - ii. Deterministic
    - iii. Probabilistic
  - Generating Connectivity Matrix
- **Visualization:**
  - Visualization of Tractography with DiPy
  - Visualization of Tractography with Surf Ice
  - Visualization of DTI Network Connectivity with Surf Ice



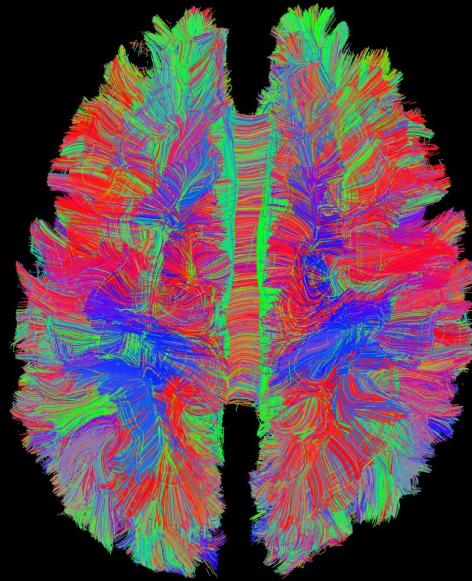
# Results

## Fiber Tracking Comparisons - Tractography Visualization

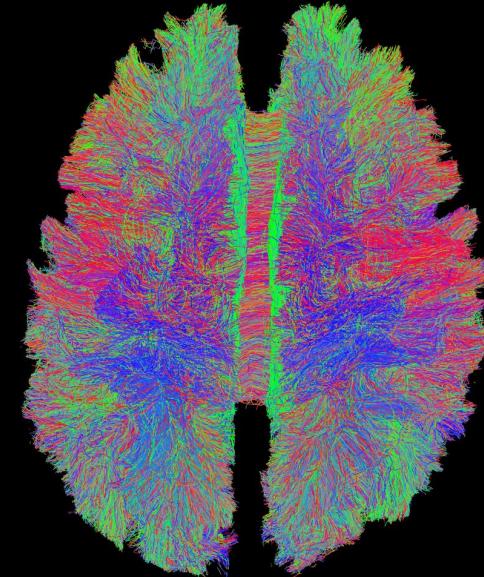
EuDx (Euler Delta Crossings)



Deterministic Tractography



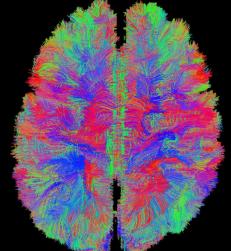
Probabilistic Tractography



# Results

## Fiber Tracking Comparisons - Tractography Visualization

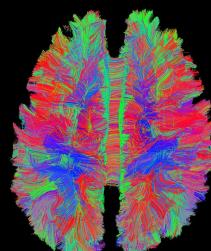
EuDx (Euler Delta Crossings)



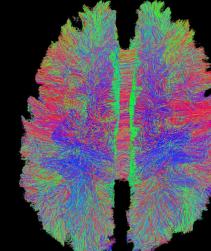
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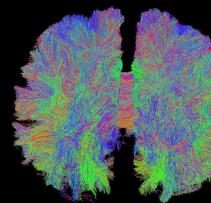
Deterministic Tractography



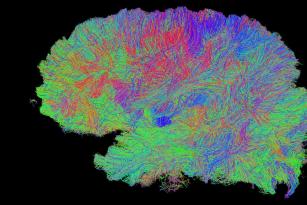
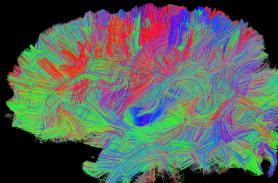
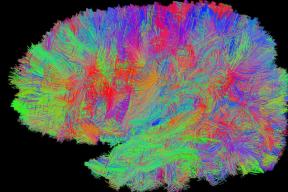
Probabilistic Tractography



POSTERIOR



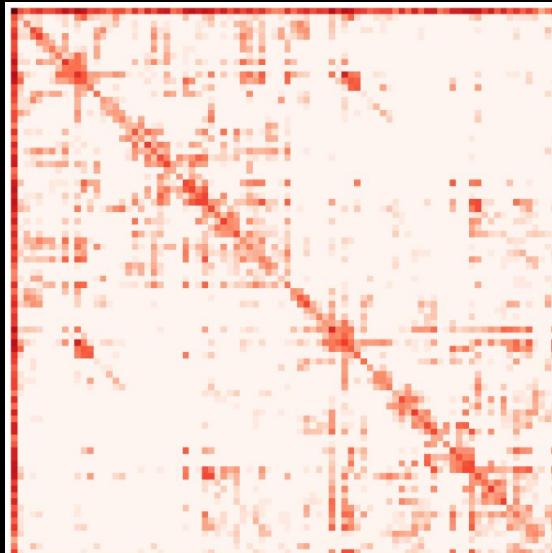
LEFT



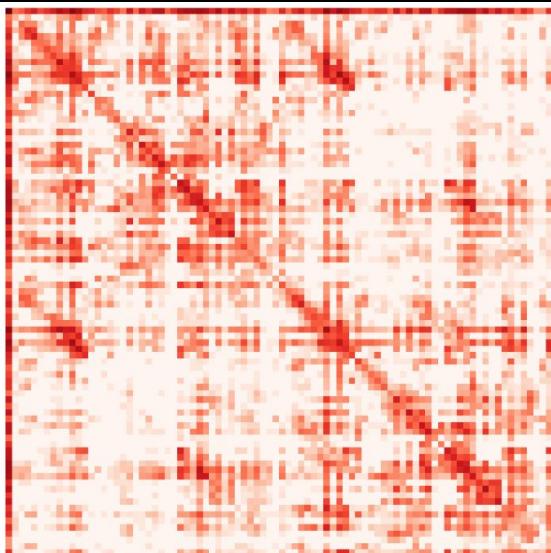
# Results

## Fiber Tracking Comparisons - Connectivity Matrix Visualization

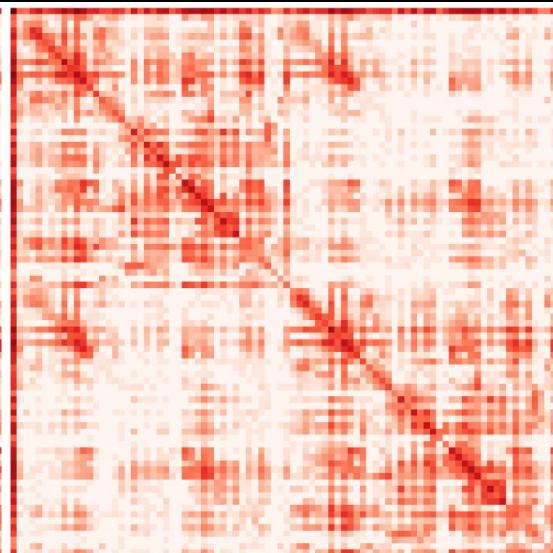
EuDx (Euler Delta Crossings)



Deterministic Tractography



Probabilistic Tractography



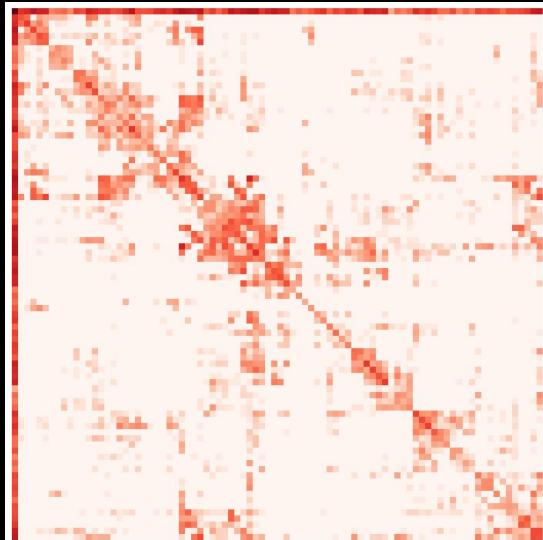
Brain Regions



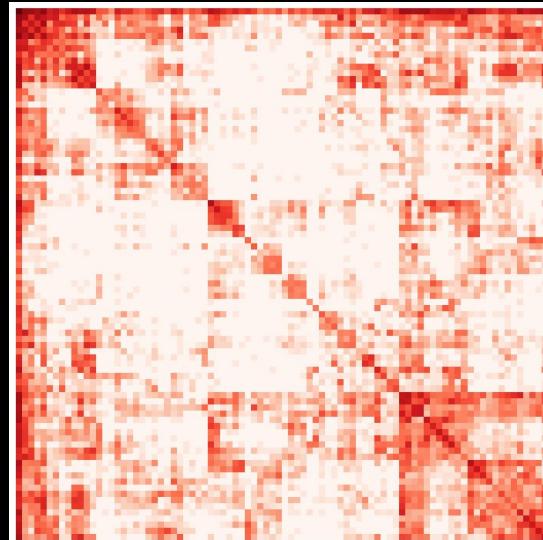
# Results

## Fiber Tracking Comparisons - Clustering Analysis - Densely Connected Regions

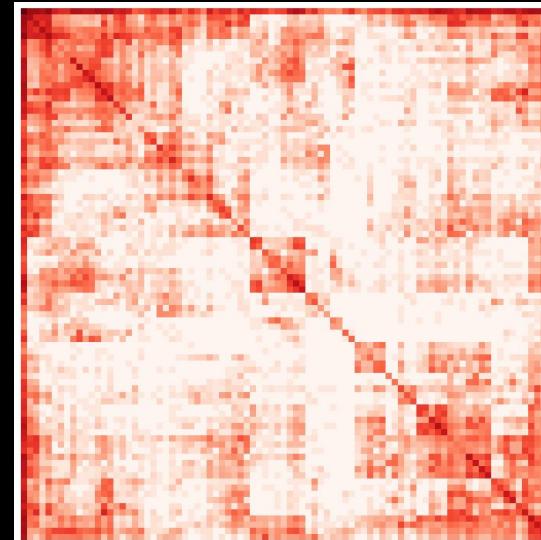
EuDx (Euler Delta Crossings)



Deterministic Tractography



Probabilistic Tractography



Brain Regions

**The story is not over yet...**

- **What we are missing here:**
  - Linking brain regions with connectivity matrix
  - Surface based visualizations
  - Thresholding of brain connectivity edge weights.

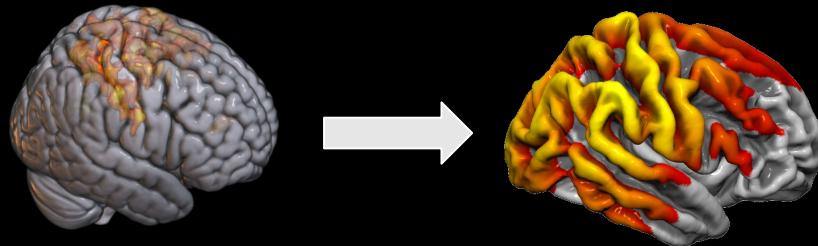
**What can we do here?**



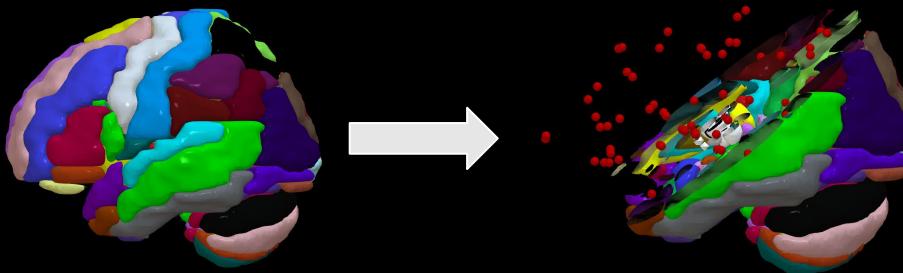
THE UNIVERSITY  
OF ARIZONA

# Methods

- Convert volume-based Atlas (nii) to surface-based Atlas (mz3) using SPM



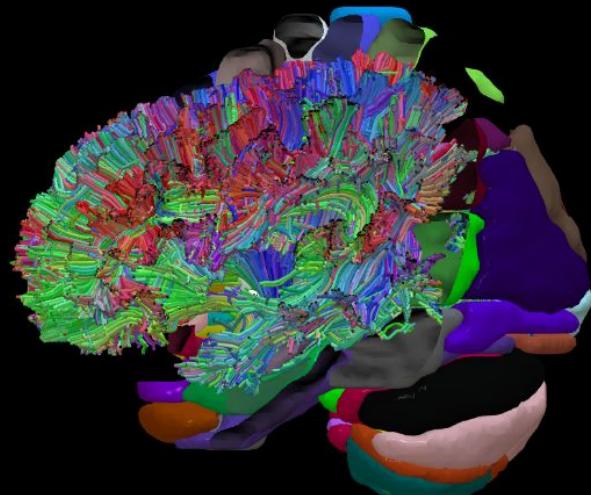
- Use surface based atlas to extract network nodes using SPM



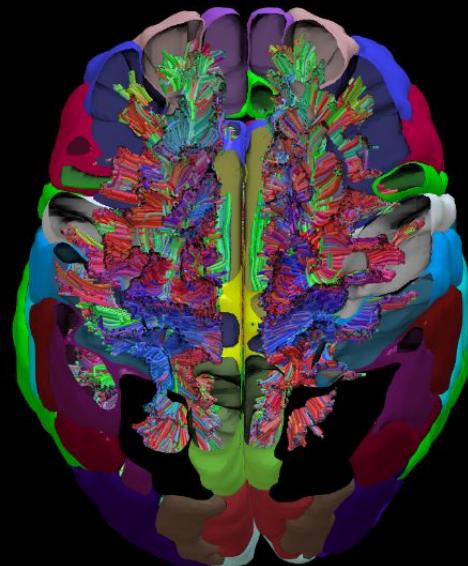
# Results

Visualization of white matter tracks in Surf Ice - Deterministic Tractography

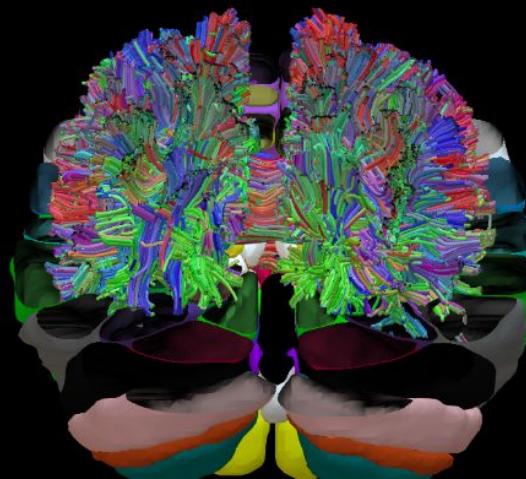
LEFT



SUPERIOR



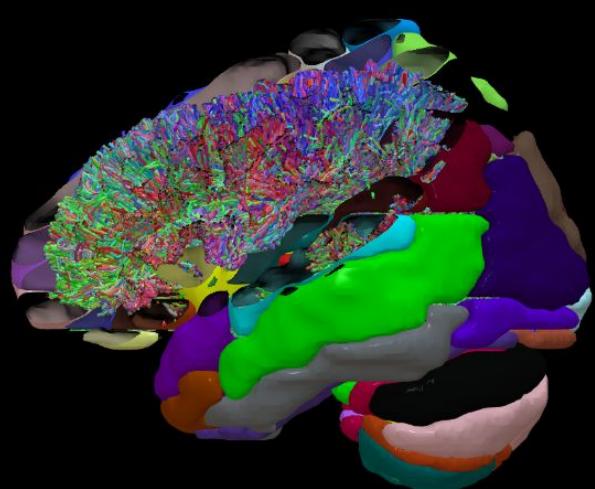
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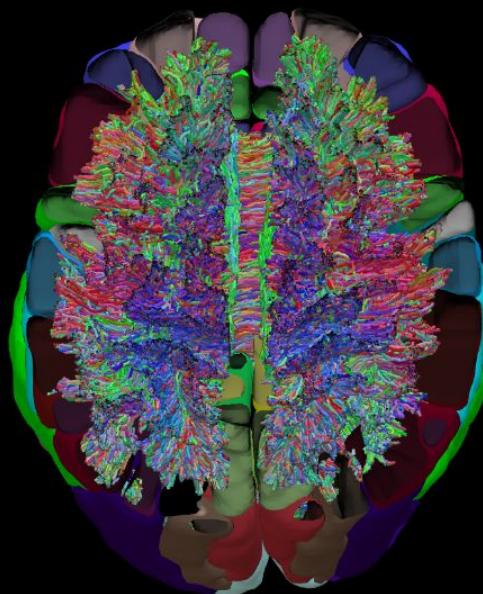
# Results

Visualization of white matter tracks in Surf Ice - Probabilistic Tractography

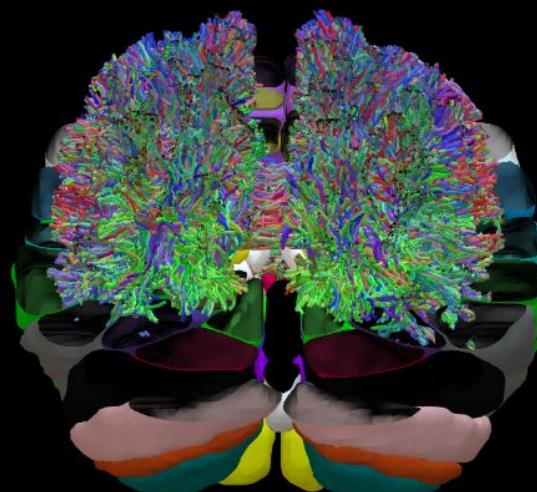
LEFT



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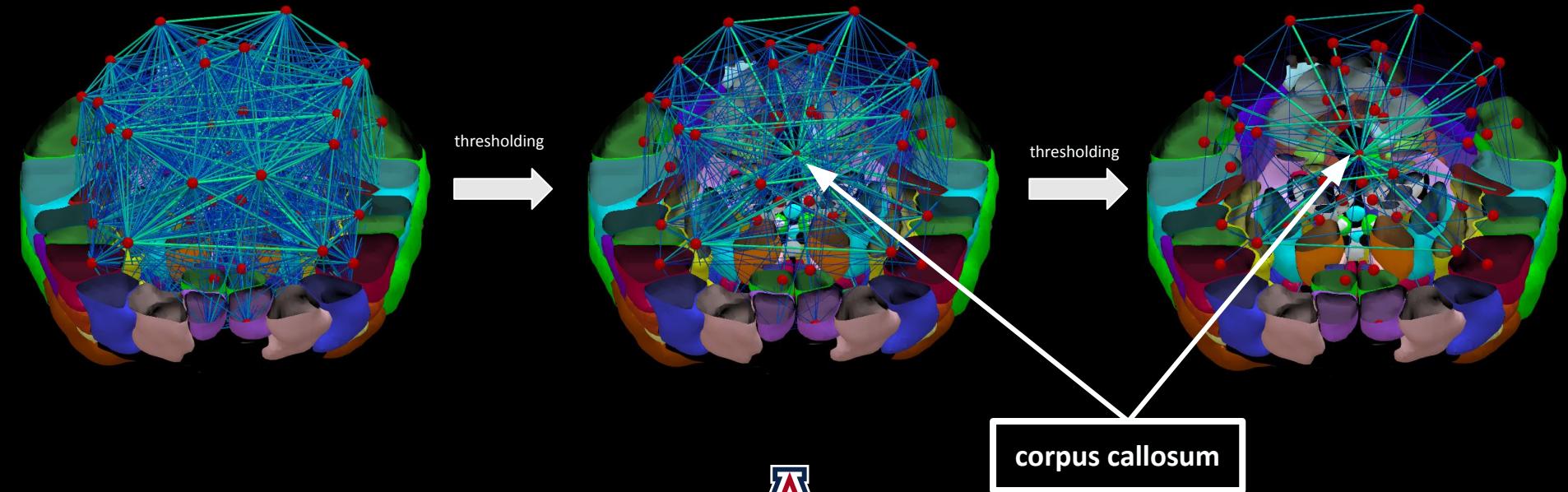
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# Results

## Visualization of Connectivity in Surf Ice - Deterministic Tractography

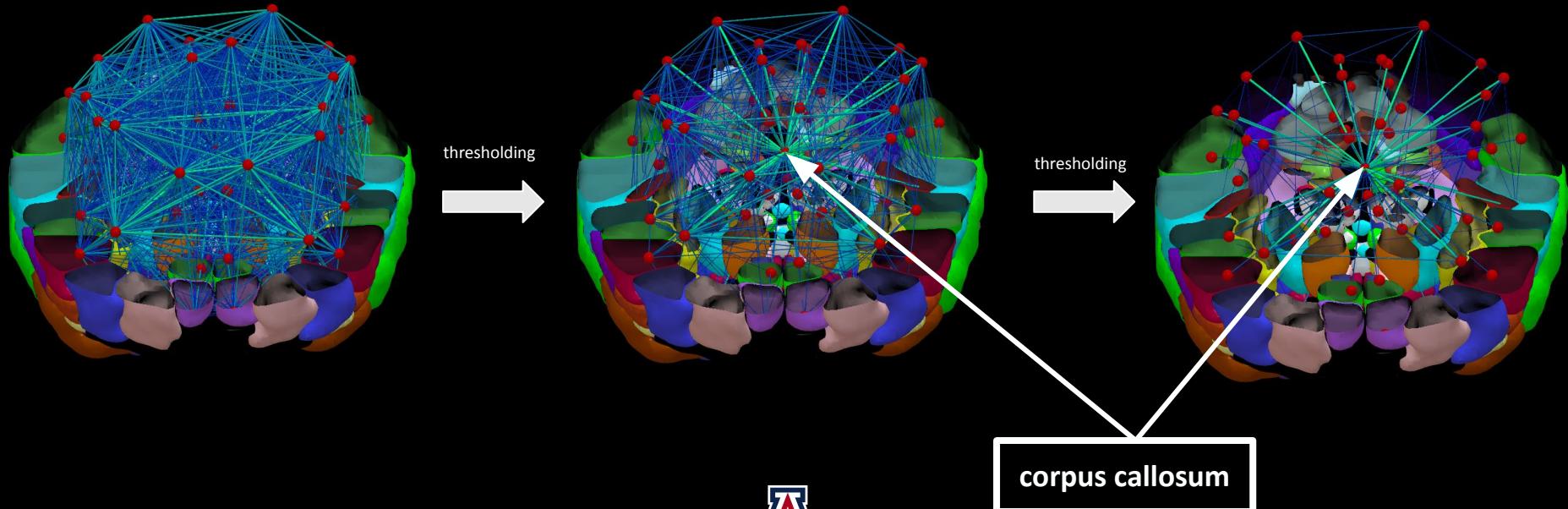
Combining “Nodes” obtained from SPM and “Edges” from the connectivity matrix



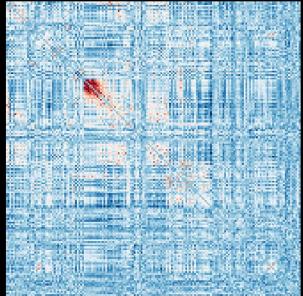
# Results

## Visualization of Connectivity in Surf Ice - Probabilistic Tractography

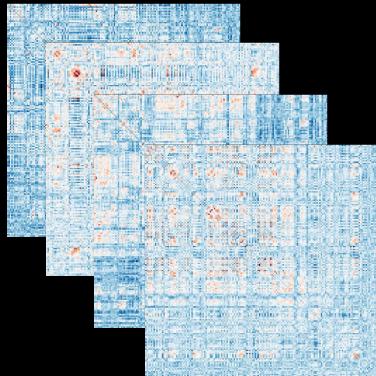
Combining “Nodes” obtained from SPM and “Edges” from the connectivity matrix



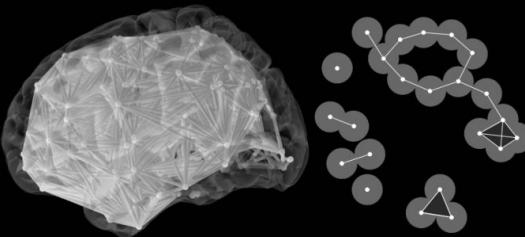
# Future Work



Healthy



VS



Disease



Topological Data Analysis

How does cognitive impairment  
affects brain connectivity?

# References

- i. Garyfallidis, Eleftherios, et al. "Dipy, a library for the analysis of diffusion MRI data." *Frontiers in neuroinformatics* 8 (2014): 8.
- ii. <https://dipy.org/tutorials/>

# Code Availability

- i. <https://github.com/xinformatics/cogs510>



# Thank You!

