Employing 2D Projections for Fast Visual Exploration of Large Fiber Tracking Data

Jorge Poco
Danilo Medeiros Eler
Fernando Vieira Paulovich
Rosane Minghim

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Data Source
Diffusion Tensor Imaging (DTI)

- Tensor data measuring the movement of water molecules.
- Water moves faster in the direction of fibers.
- Tracks neural fibers and, with that, the connections within the brain.
- Fiber tracts: fiber orientation followed by fiber connection
- Various methods: Streamline Fiber Tracking , Diffusion Tensor deflection, Monte-Carlo Probabilistic Tracking, Front Propagation e Diffusion Simulation-Based Fiber Tractography.

Visualization of DTI.

- 3 main categories of techniques
  - Glyphs
  - Classical scalar volume visualization techniques
    - Tensor can be converted to scalars
  - Streamlines
    - Tensor can be converted to vectors

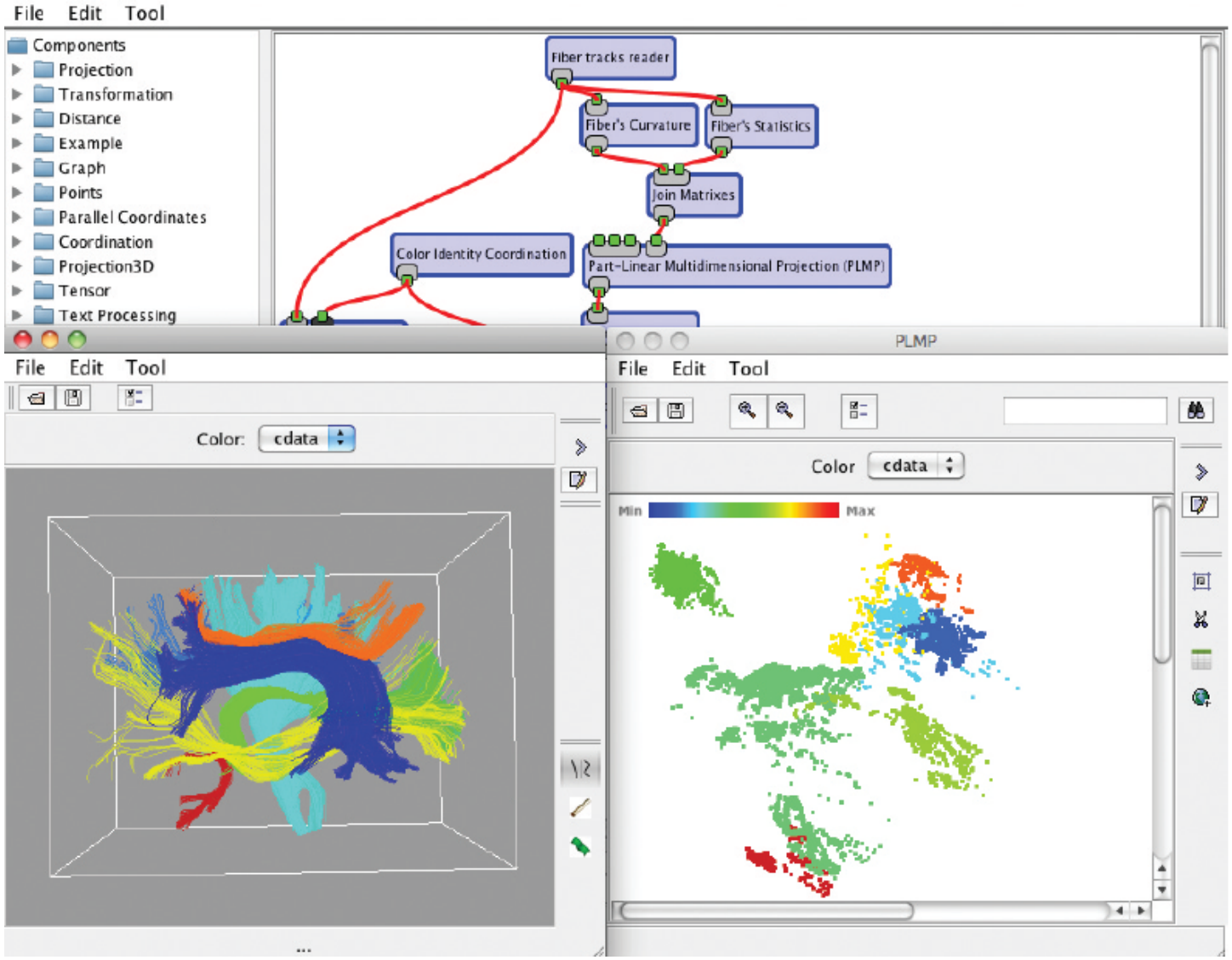
Problems

- Problems: large quantities of fibers with intricate topology.
- Unfavorable set up for direct manipulation.
- Plus: handling groups of neighboring fibers is required, and difficult.

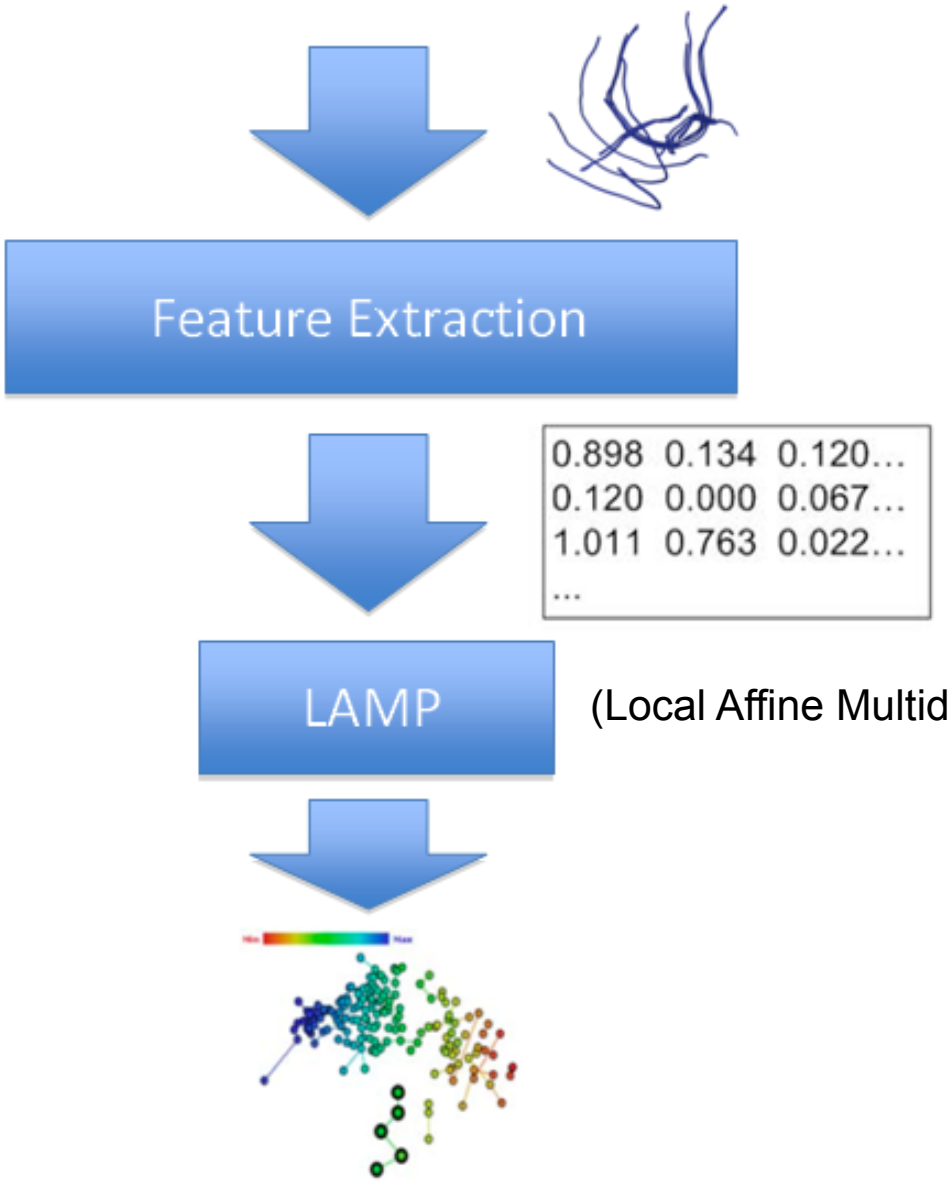
Goals

- A real-time visual exploration approach.
- Handling of neighboring fibers.
- A fast and accurate means to interact with brain fiber data.
  - two-way linked visual representations.
- Larger fiber tract data sets.

Tool - Vispipeline



Pipeline


Feature Extraction
0.898 0.134 0.120…
0.120 0.000 0.067…
1.011 0.763 0.022…
…
LAMP
(Local Affine Multidimensional Projection)

PBC dataset

- 2009 Pittsburgh Brain Competition (PBC)
  - Brain Connectivity Challenge
  - http://pbc.lrdc.pitt.edu/
- 250K fibers
  - 19k of which classified into 8 different classes

19,000 PBC dataset

CHEN et al.'s dataset[1]

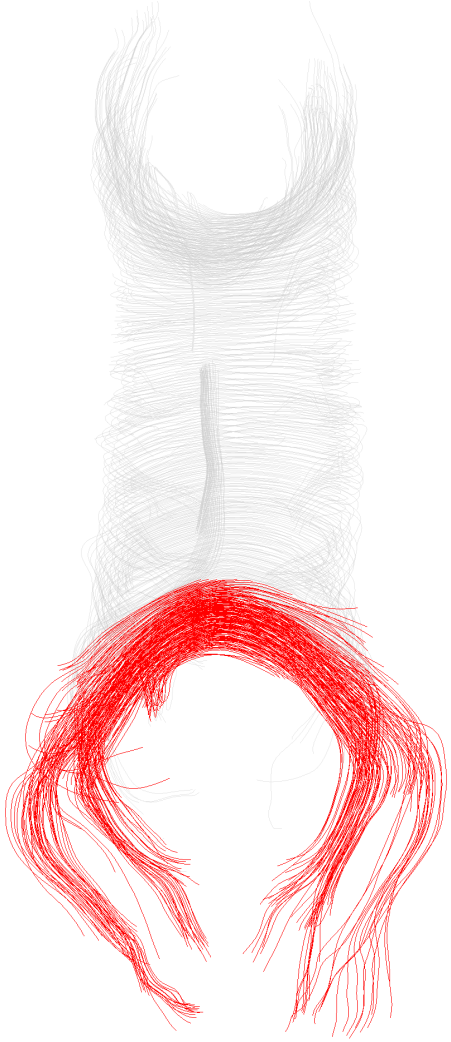
- A human brain dataset
  - 1,248 fibers
- Link:

  http://www.cad.zju.edu.cn/home/chenwei/interface/index.html

1. CHEN W., DING Z., ZHANG S., MACKAY-BRANDT A., CORREIA S., QU H., CROW J., TATE D., YAN Z., PENG Q.: A Novel Interface for Interactive Exploration of DTI Fibers. IEEE TVCG 15, 6 (2009), 1433–1440.

JIANU et al. 's dataset[2]

- A human brain dataset
  - 690 fibers
- Link: http://www.cs.brown.edu/~cad/projects/embedvis/



2. JIANU R., DEMIRALP C., LAIDLAW D. H.: Exploring 3D DTI fiber tracts with linked 2D representations. IEEE TVCG 15, 6 (2009), 1449–56.

Features

- Spatial features
  - start point
  - end point
  - center of mass
  - length
- Curvature features
  - Discrete Fourier Transform (DFT)
    - 1D DFT is applied on the coordinates x, y, z of each fiber
      - We only use the magnitude (real part) of the coefficients related to high-frequency values

Feature Space Analysis: 19,000 PBC dataset

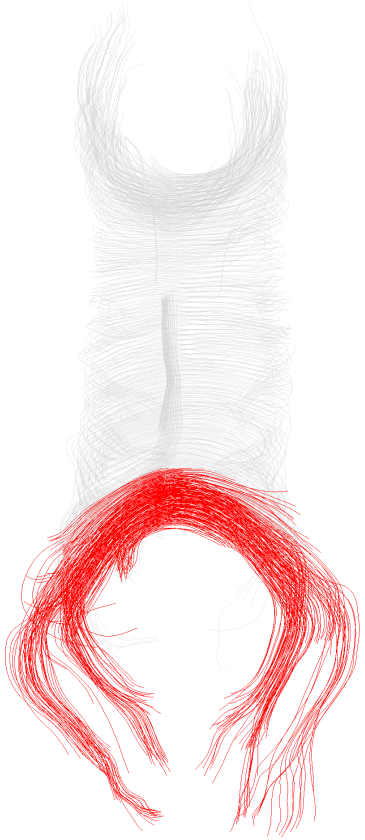
LAMP projection from **spatial** feature space
Silhouette 0,5054

LAMP projection from **curvature** feature space
Silhouette 0,5482

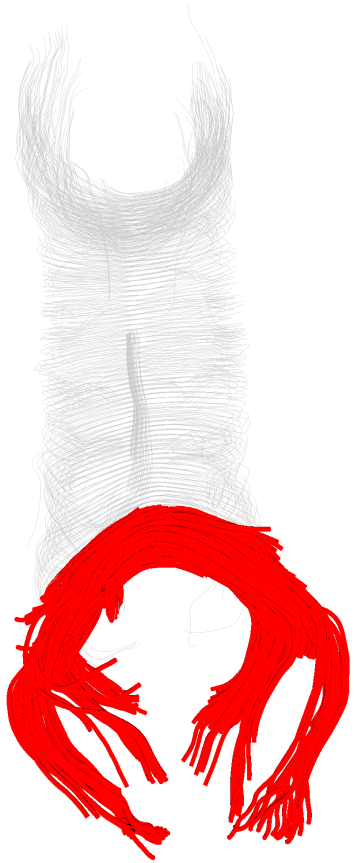
LAMP projection from **combined** feature space
Silhouette 0,5494

Fiber Representation

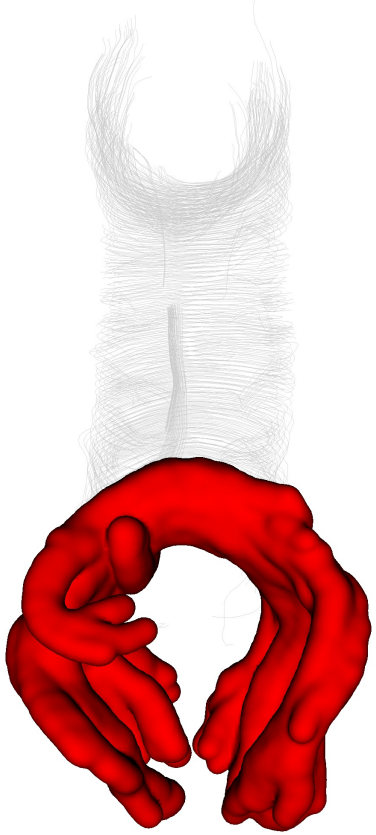
Lines



Tubes

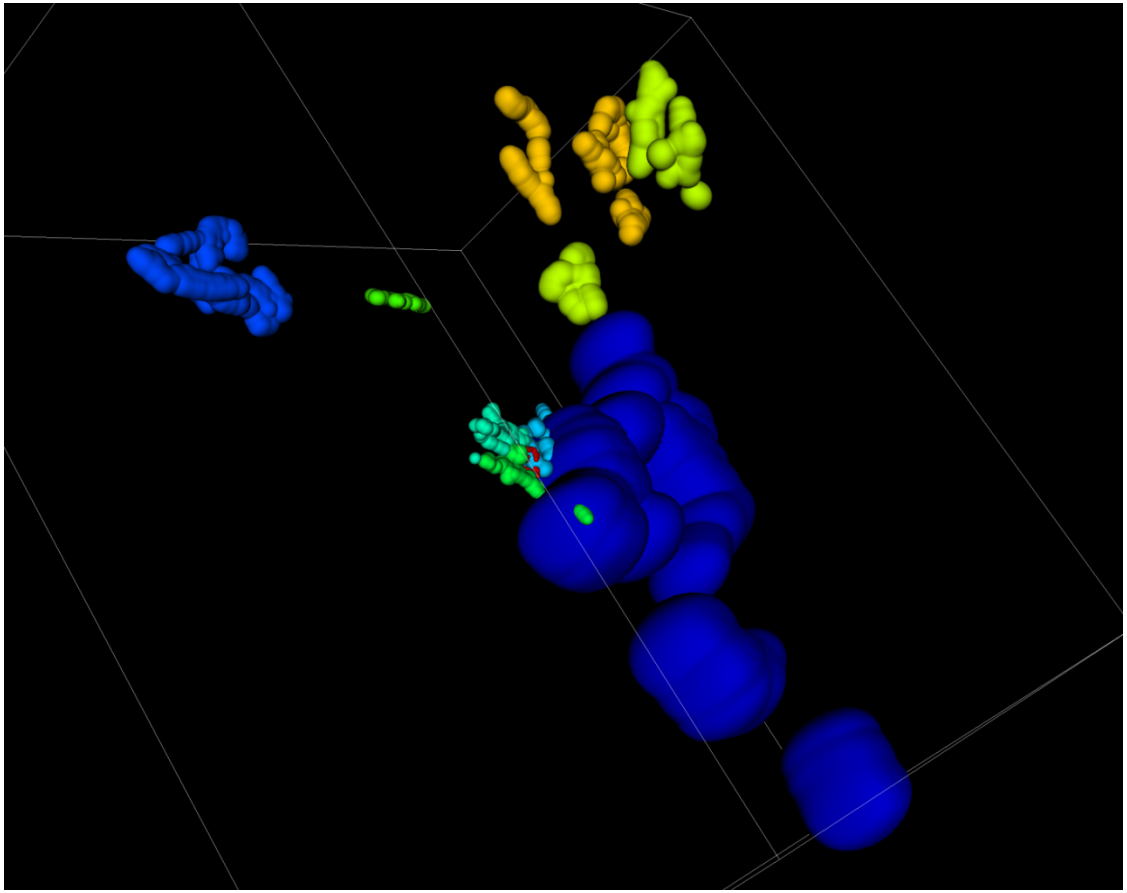


Surface



JIANU's dataset

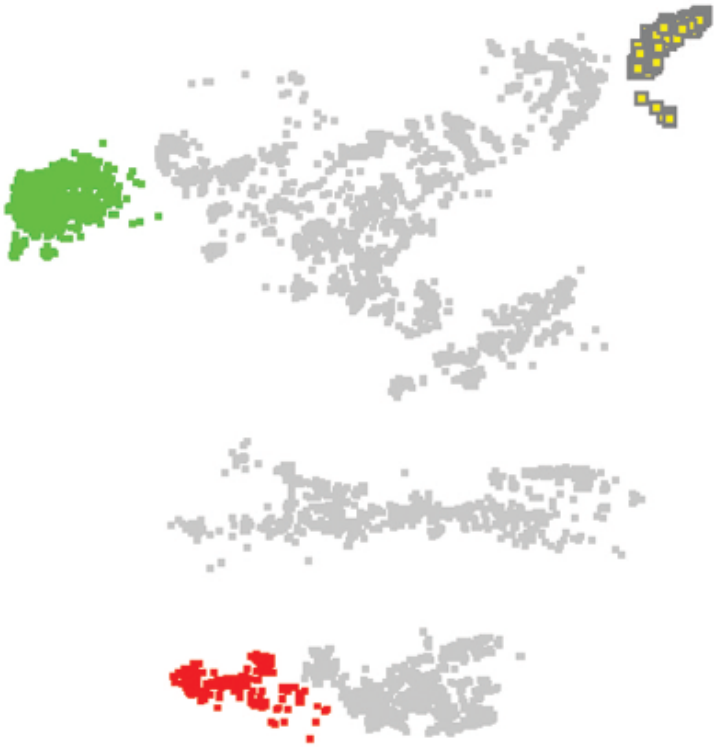
LSP 3D for segregation[3]

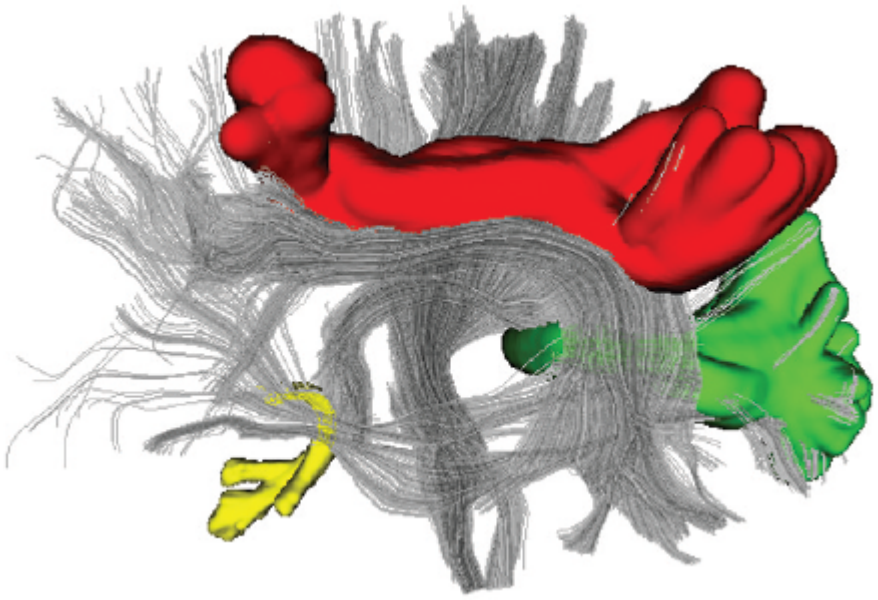


surface representation

3. POCO, J. ; PAULOVICH, F. V. ; ETEMADPOUR, R. ; LONG, V. T. ; ROSENTHAL, P. ; OLIVEIRA, M. C. F. ; LINSEN, L. ; MINGHIM, R. A Framework for Exploring Multidimensional Data with 3D Projections. CGF, 30, 1111-1120, 2011.

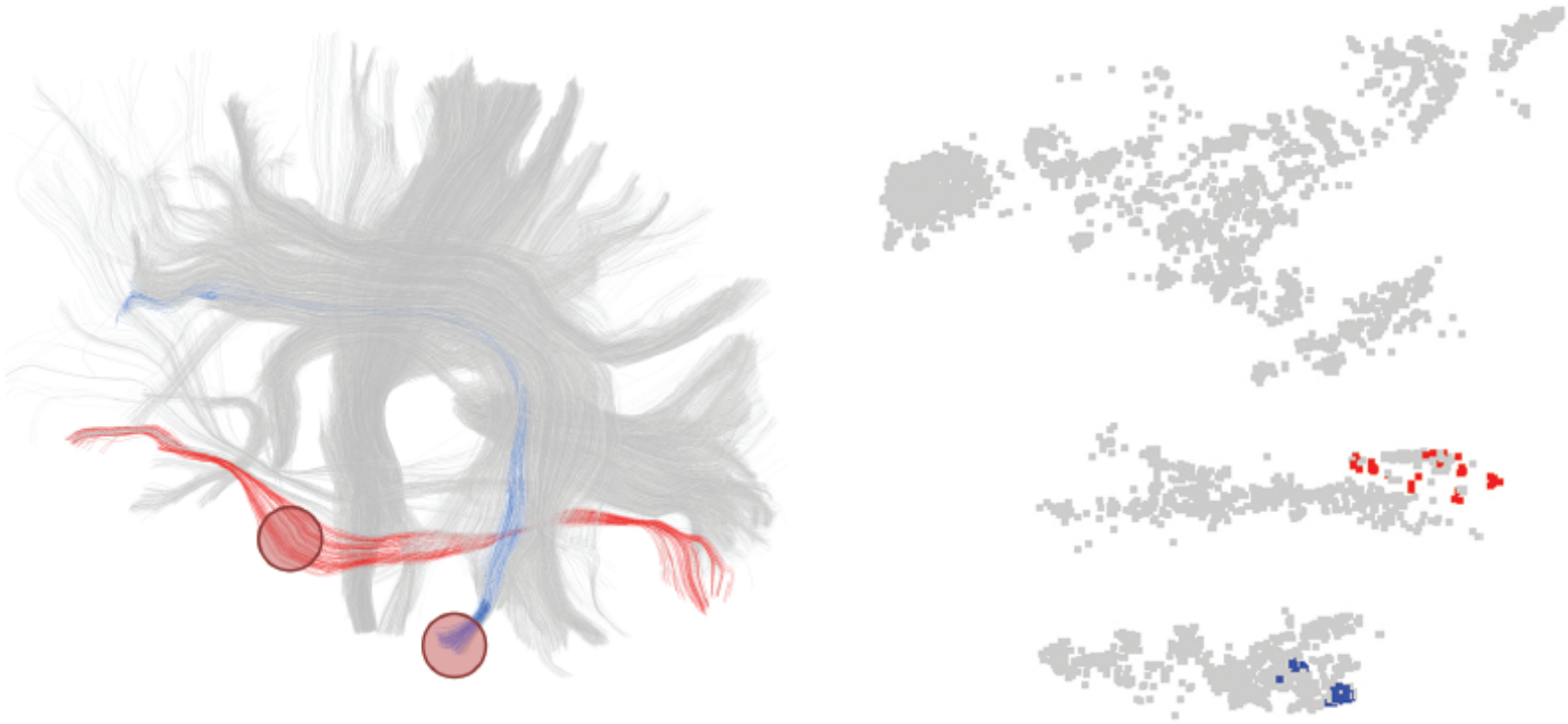
Linked Views





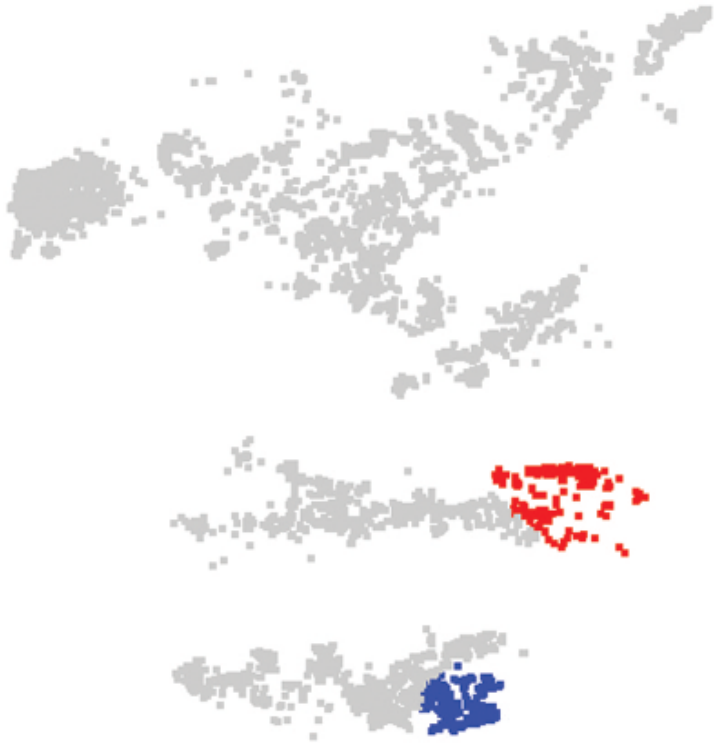
19,000 PBC dataset

Linked Views



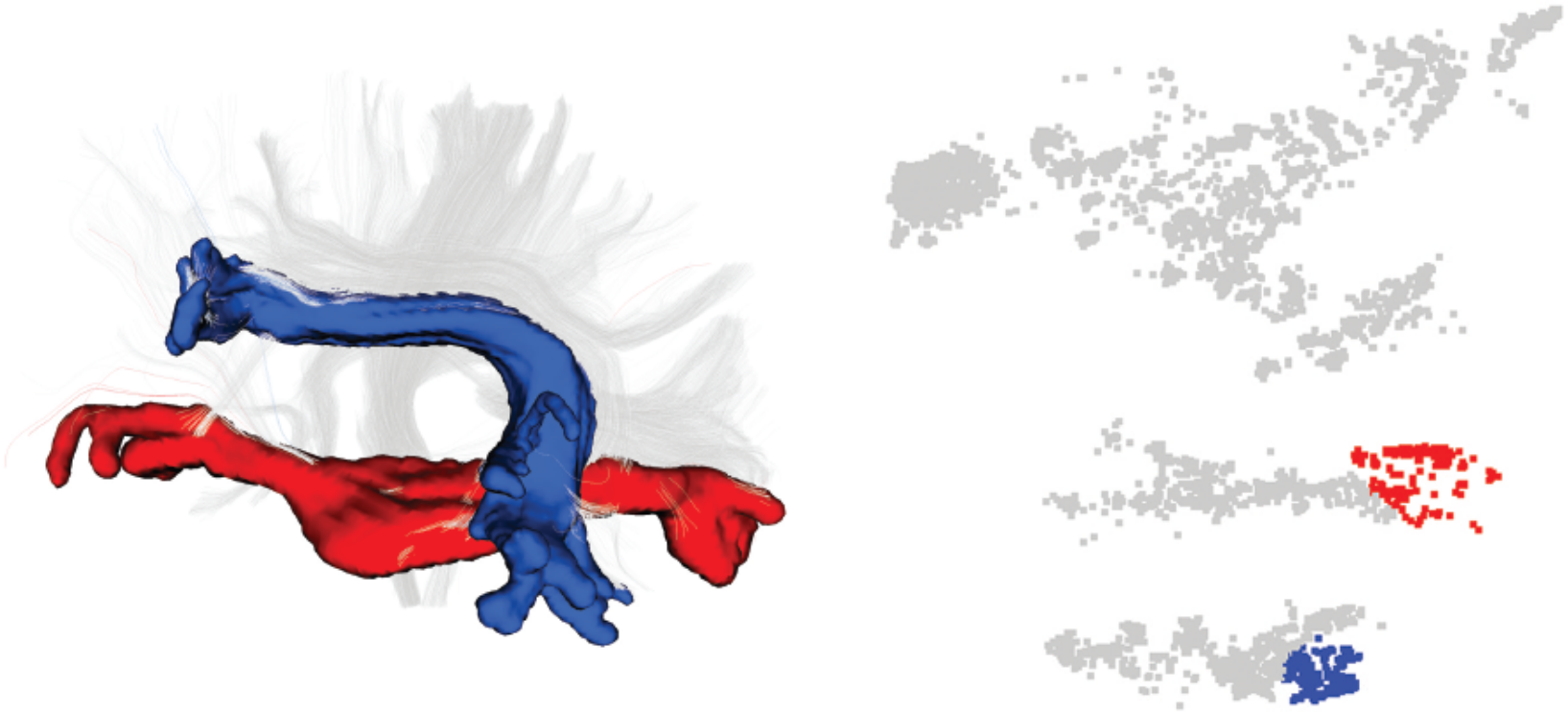
19,000 PBC dataset

Linked Views



19,000 PBC dataset

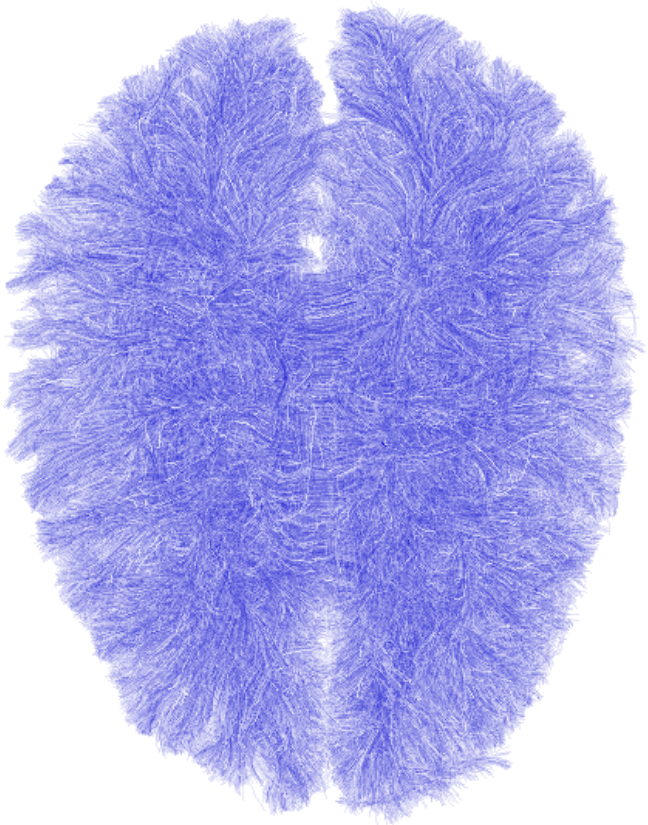
Linked Views

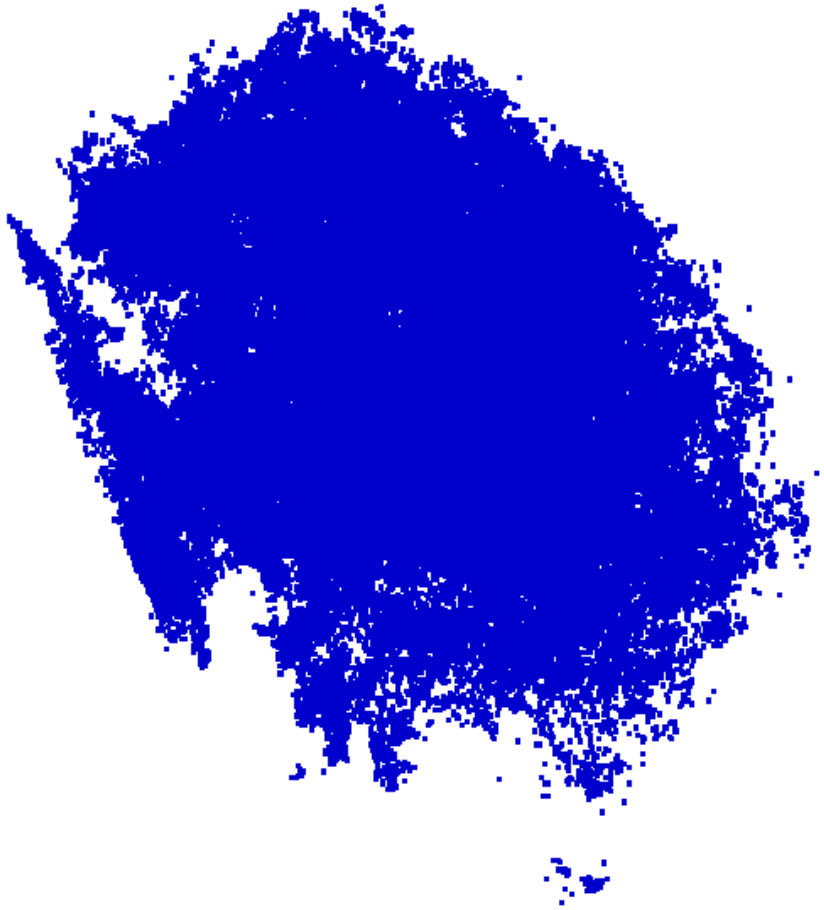


19,000 PBC dataset

Larger Dataset: 250,000 PBC dataset

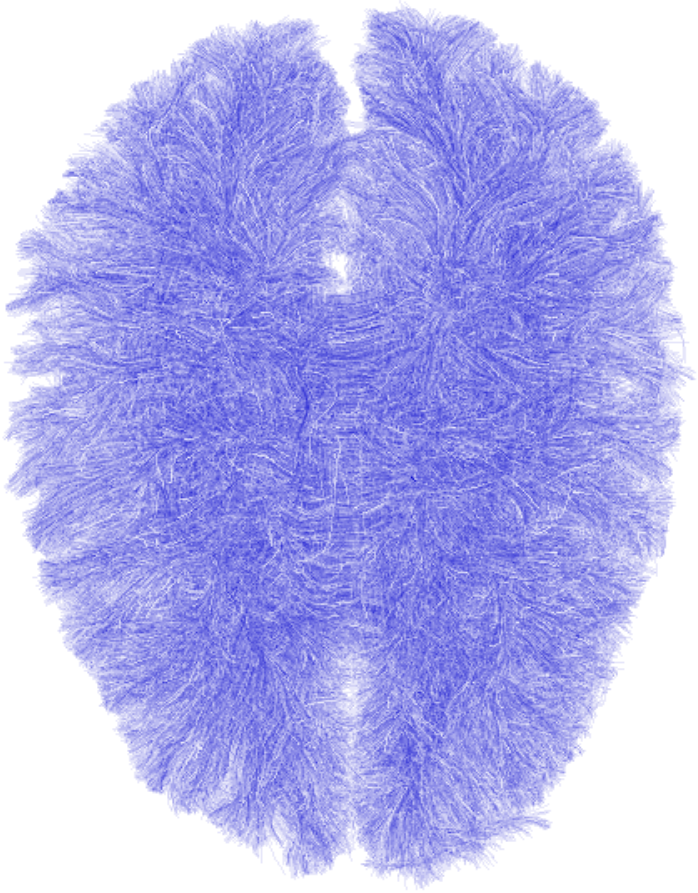
Full View

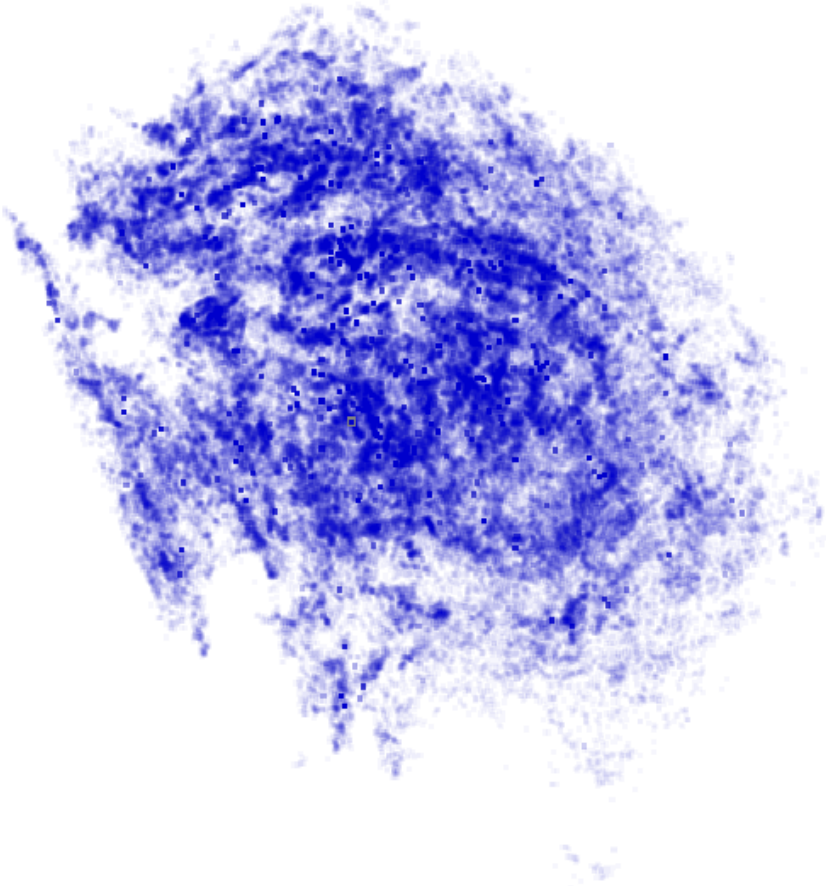




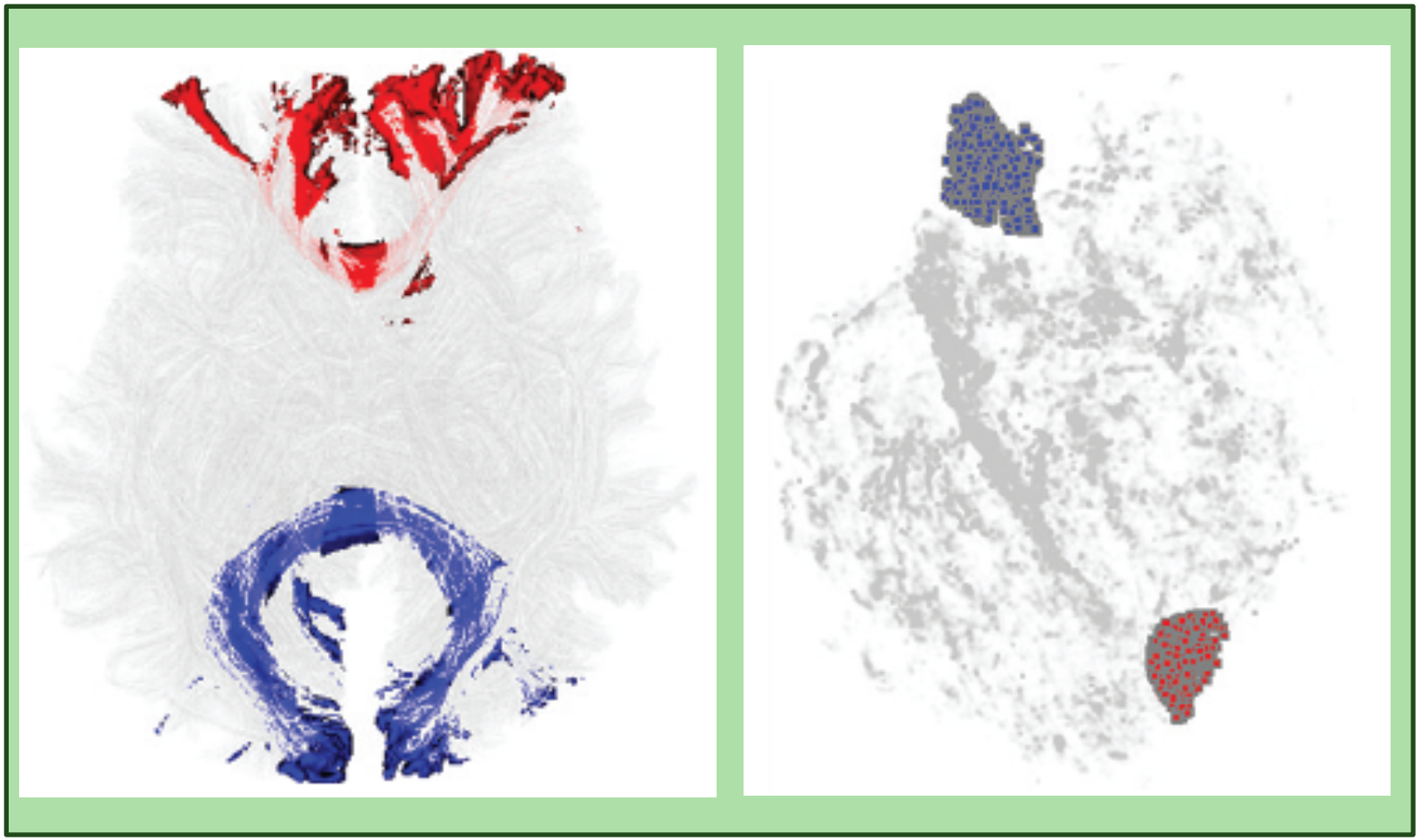
Larger Dataset: 250,000 PBC dataset

Full View - transparency



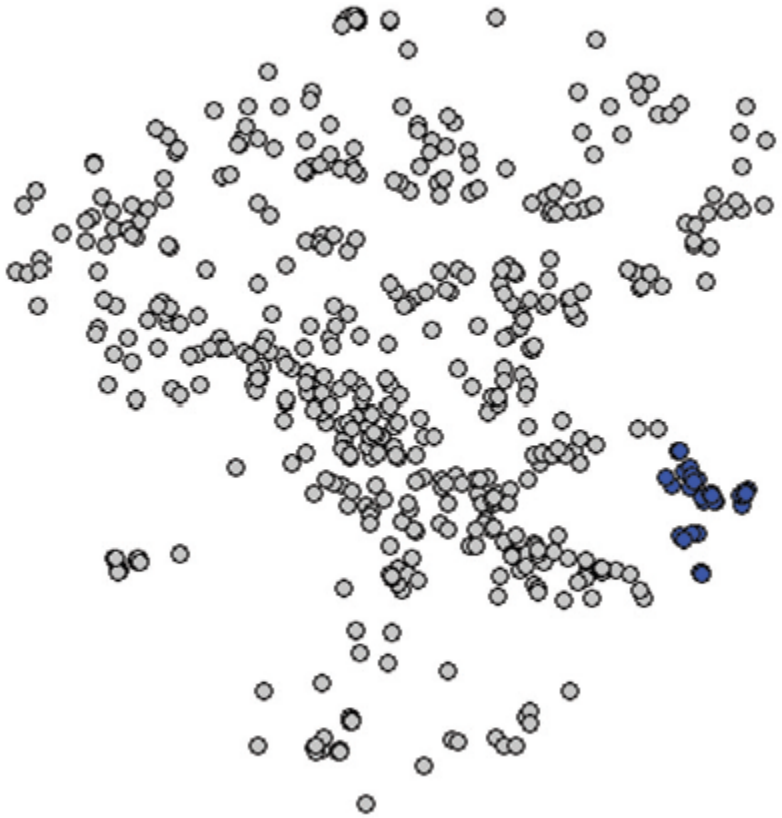


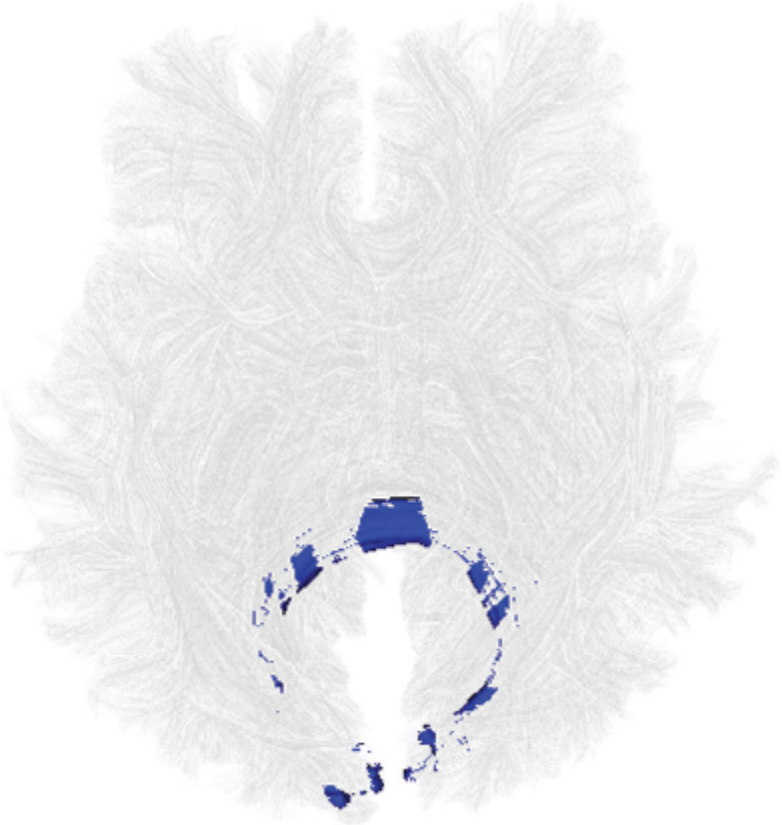
Larger Dataset: 250,000 PBC dataset



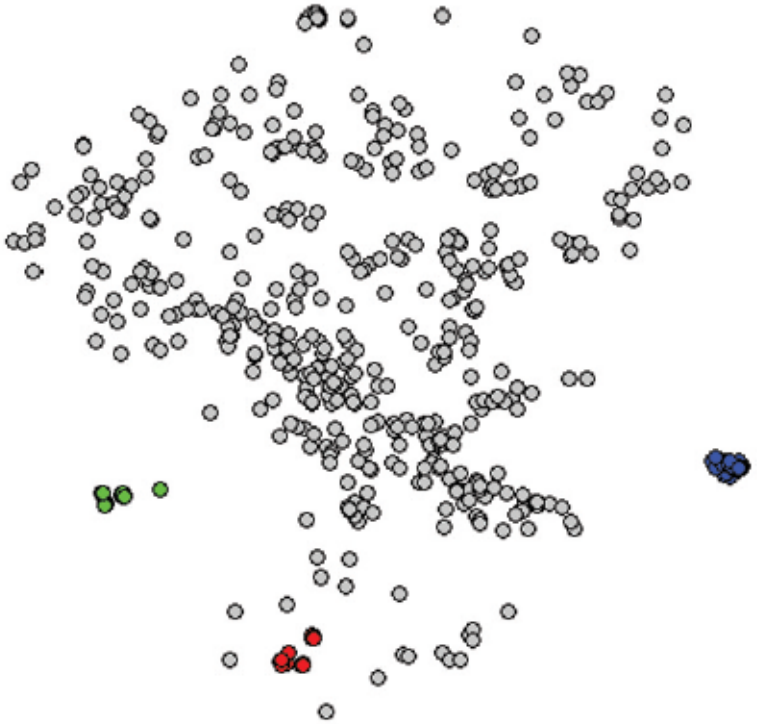
Exploration Based on Samples

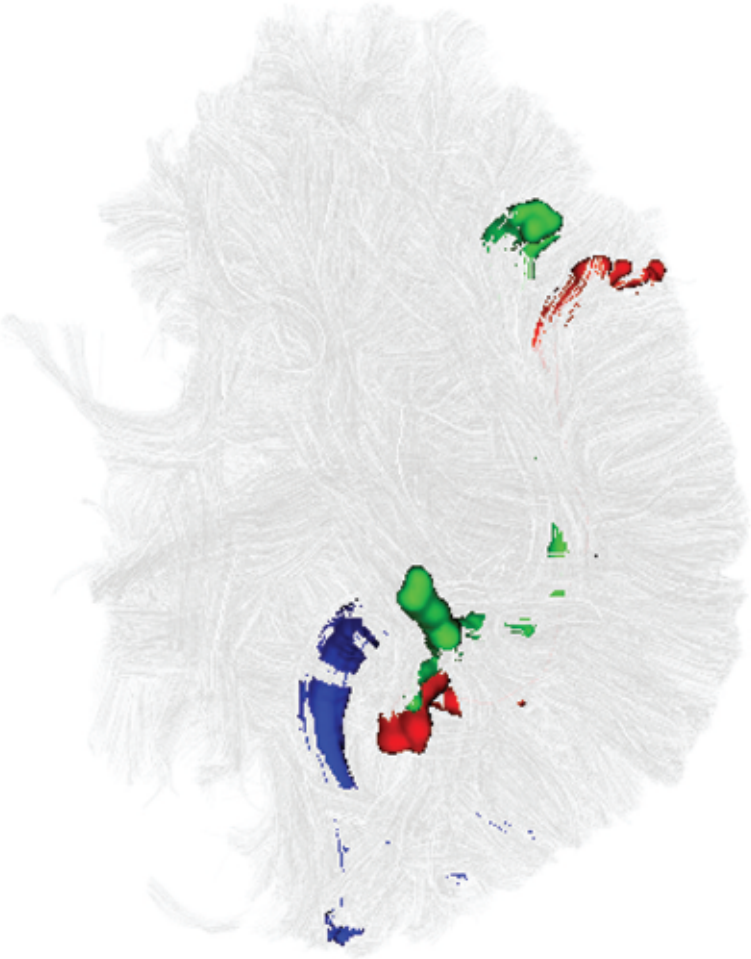
LAMP (Local Affine Multidimensional Projection): Sample Projection from PBC 250k fibers



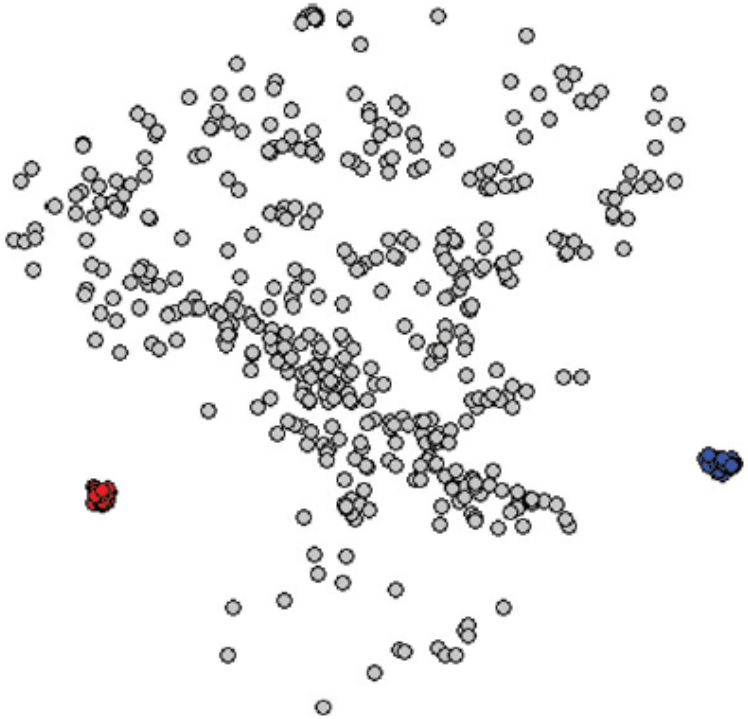


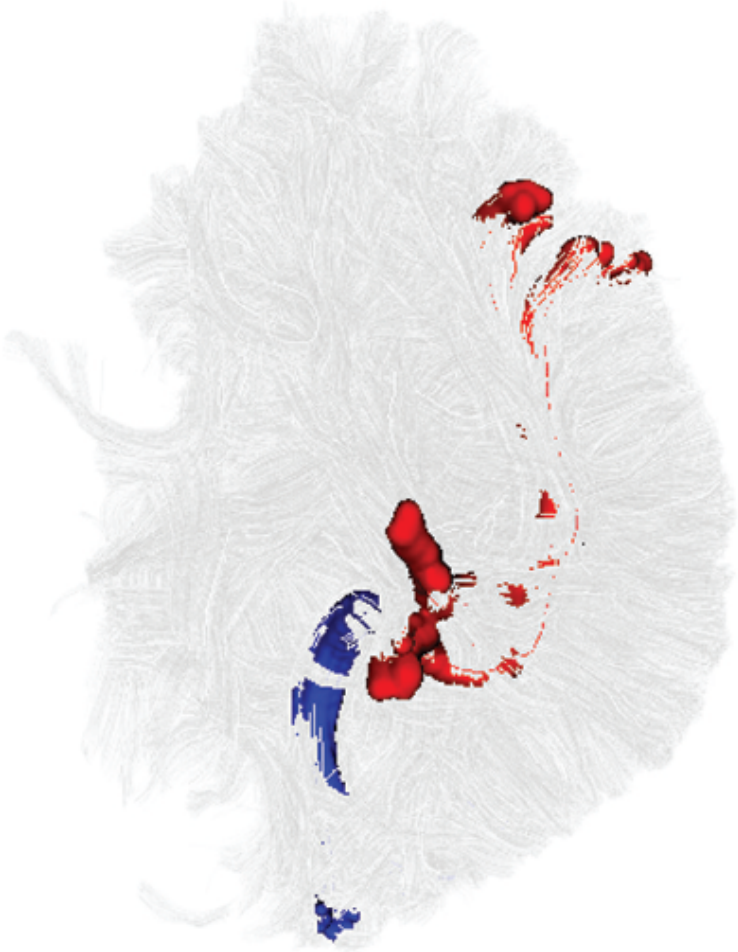
Sample Projection from PBC 250k



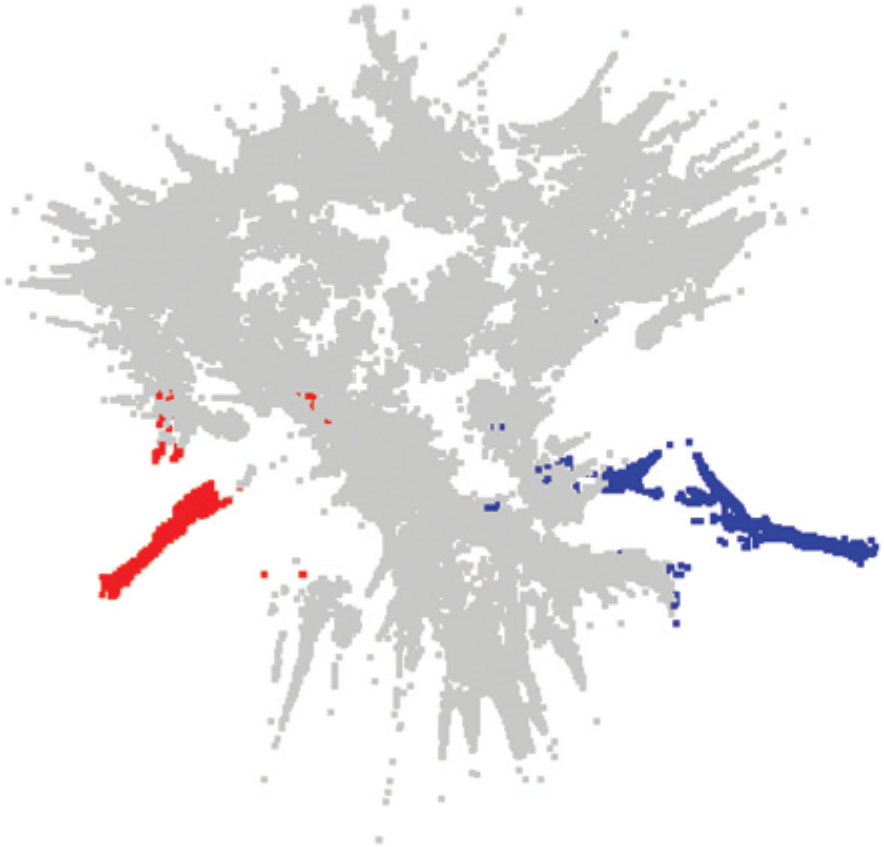


Sample Projection from PBC dataset

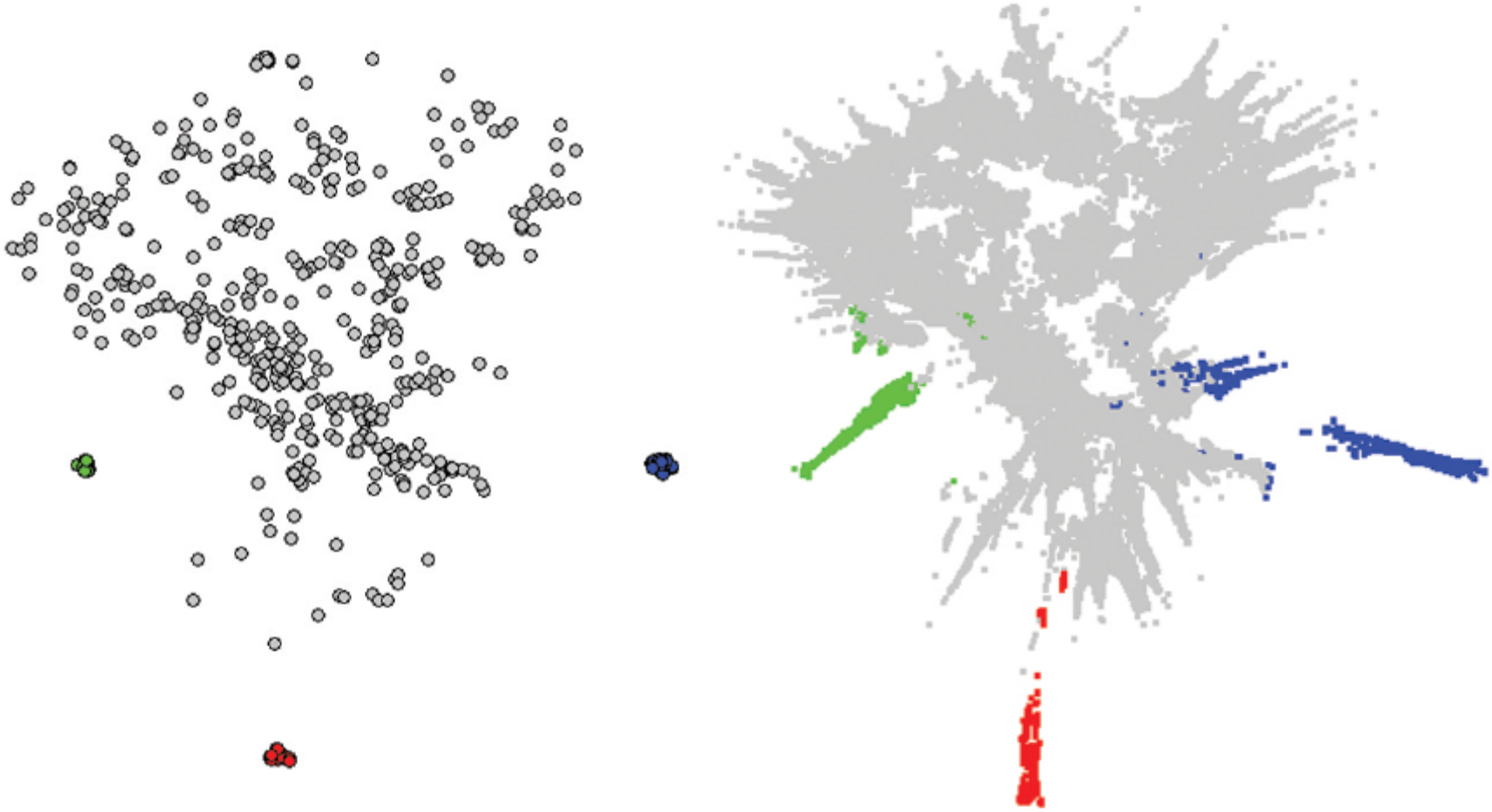




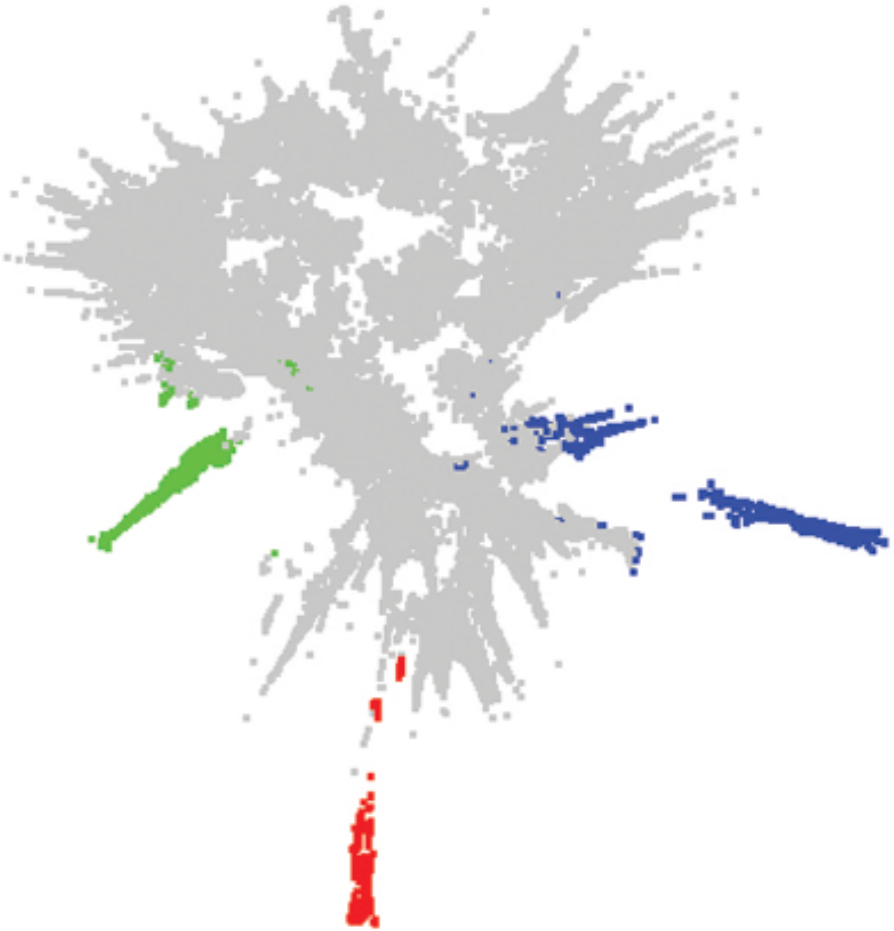
Final Projection from 250,000 PBC dataset



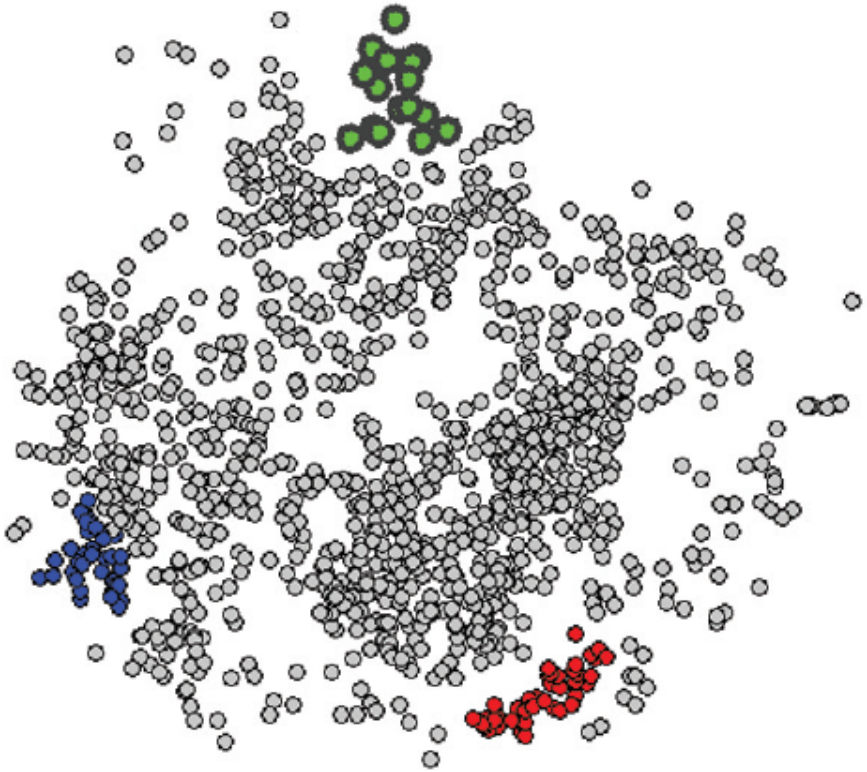
Sample Projection from 250,000 PBC dataset – Alternative exploration



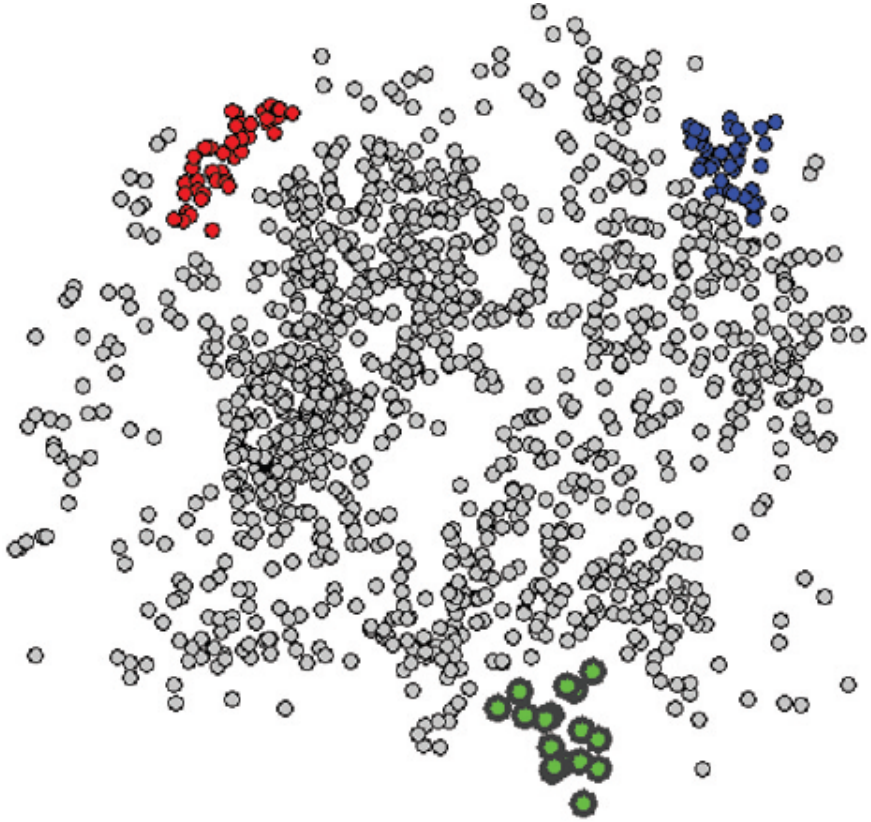
Final Projection from 250,000 PBC dataset – Alternative exploration



Projections from Chen et al.'s dataset

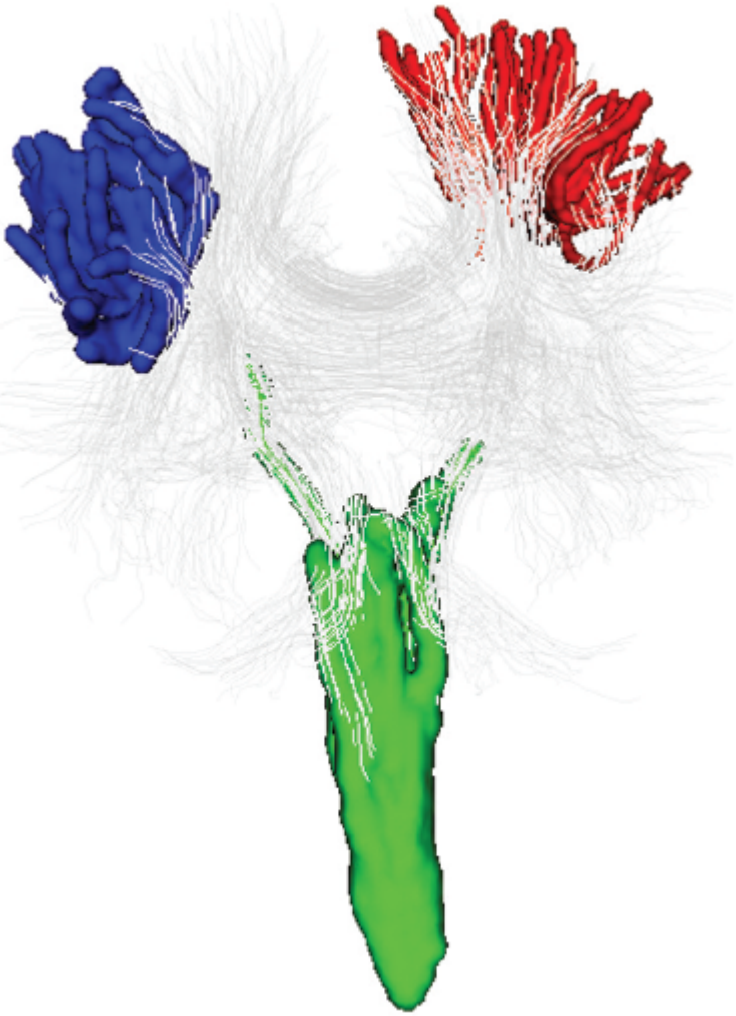


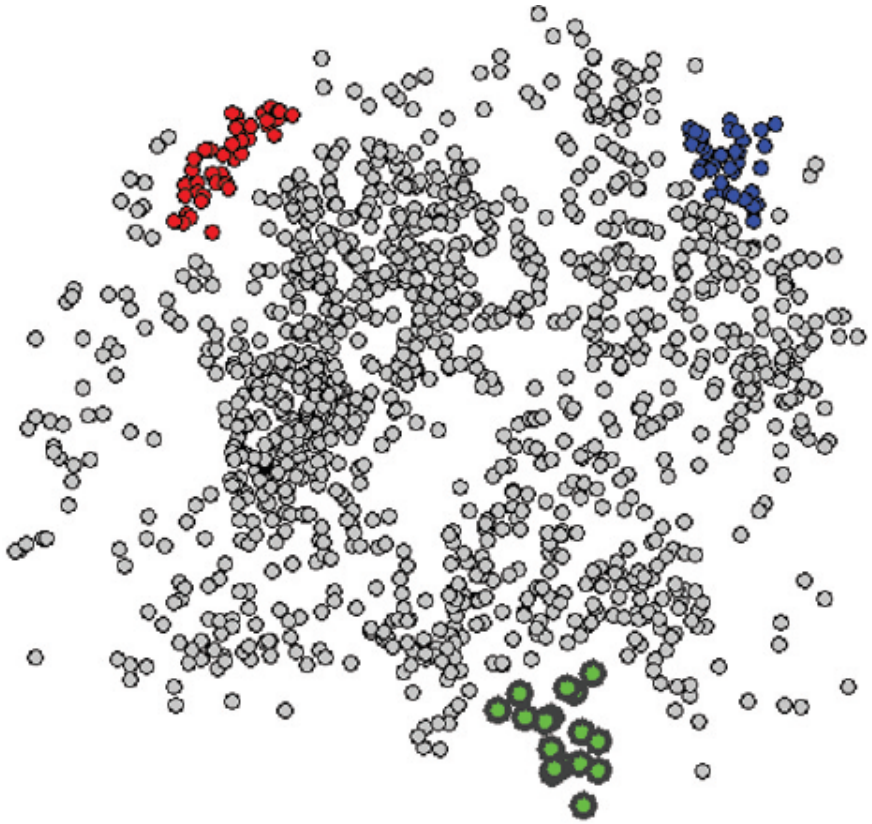
2D projection from MDS technique



LAMP projection

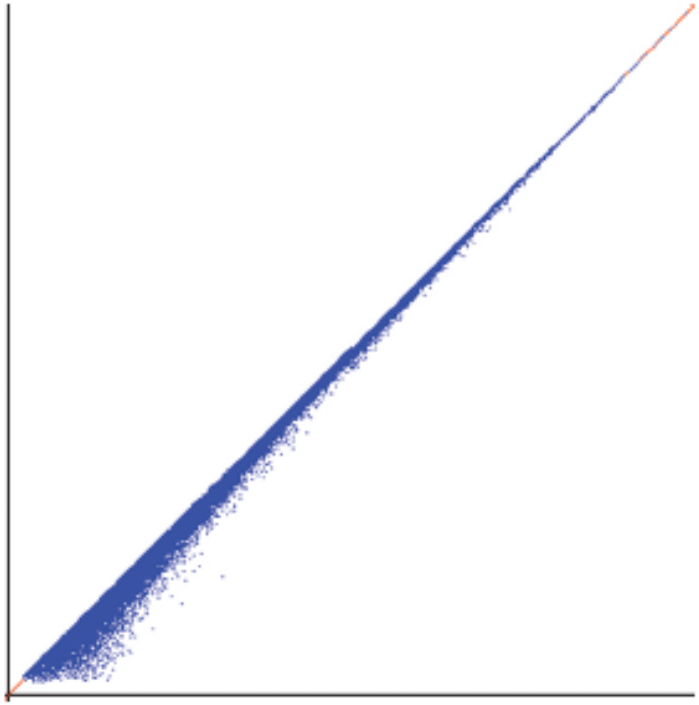
Projections from Chen et al.'s dataset



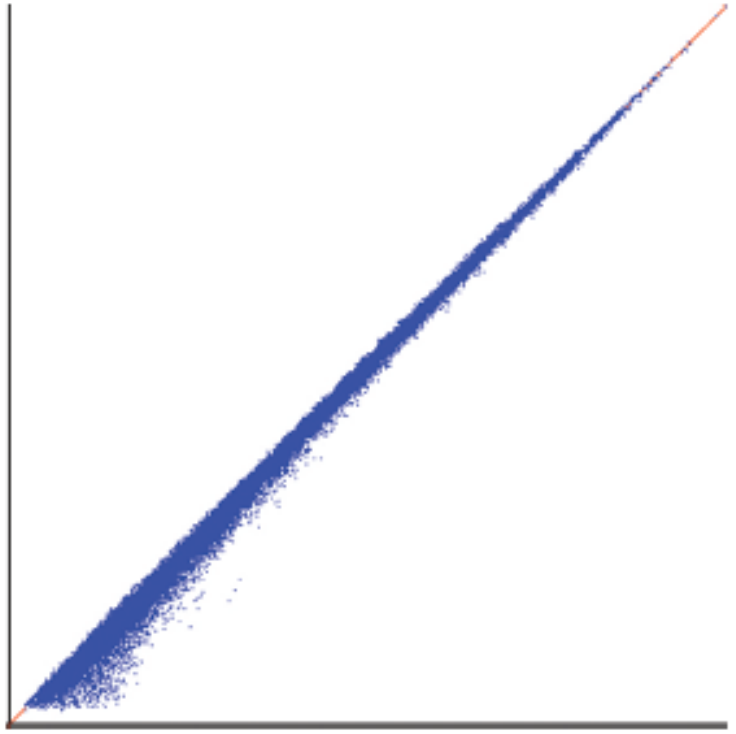


LAMP projection

Distance Plot: R^n x R^2



Distance plot for MDS technique



Distance plot for LAMP projection

Running Times

- Running times (in seconds) comparing LAMP and other approaches

Dataset	PLP	PLMP	LAMP	MDS
PBC (250K)	273.07s	1.01s	7.26s	—
PBC (19K)	1.01s	0.06s	0.24s	105.33s
JIANU	0.11s	0.02s	0.02s	0.13s
CHEN	0.04s	0.02s	0.01s	0.32s

- 250,000 fibers were not supported by MDS technique

Running Times

- Comparison of the group quality using silhouette coefficient and distinct feature spaces

Features	PLP	PLMP	LAMP	MDS
Curvature	0.6050	0.4826	0.5482	0.5354
Spatial	0.5496	0.5025	0.5054	0.5251
Both Combined	0.6040	0.6269	0.5494	0.5359

Conclusions

- A process to explore large collections of fiber tracts via projections.
- An exploration strategy whereby the user is in control of the projections.
- An extensible system based on components to support the analysis of fiber tracts.

Finally

- Software available at:

  http://infoserver.lcad.icmc.usp.br/infovis2/Tools

  http://infoserver.lcad.icmc.usp.br/infovis2/FiberTractsExploration

- Thanks to:

  CNPq, CAPES, FAPESP

  (Brazilian Financial Agencies)