# Perceptual Coloring and 2D Sketching for Segmentation of Neural Pathways

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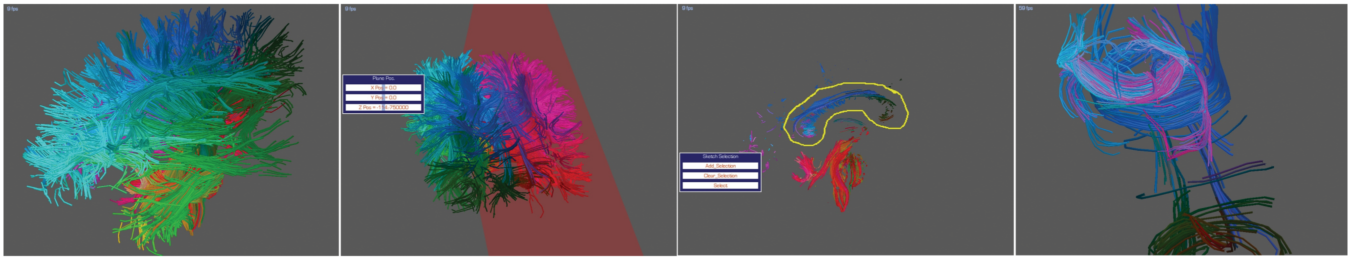


Figure 1: Our application displaying data from the brain of a normal subject (a) color differences indicate differences between pathways show with $4K$ tubes. (b-d) Sketching selection and interaction.

We present a system which visualizes the geometric disparity between white matter tracts obtained from DT-MRI by coloring in perceptually uniform color space and allows expert users of the application to select regions interactively with a 2D based sketching mechanism. This approach, in contrast to automatically clustering tracts, better reflects the uncertainity in forming scientific model from geometric information and the 2D sketching interface exploits neuroscientists' expertise with sectional anatomy.

## Introduction

Understanding white matter structure within human brain is crucial for studying diseases such as HIV. Current visualizations and analysis of diffusion tensor magnetic resonance images (DT-MRI) have focused on rendering tracts and segmentation of white matter tracts into bundles. Automatic segmentation methods impose a rigid, possibly inaccurate, model of which white matter tracts belong to which bundles. Instead, we visualize geometric disparity between white matter tracts and let the expert user of our application select regions. Our system couples 3D visualization of geometric differences between tracts with a 2D sketch-based selection mechanism. Contemporaneous to this work, Akers [2006] presents a 3D sketching and gesture interface for pathway selection. Our coloring work is similar to Brun et al. [2003]. That work applies smooth coloring to DT-MRI data using a simpler distance metric.

## Methods and Results

We visualize distances between white matter tracts using the metric in [Zhang et al. 2003]. Our system consists of an interactive component and pre-processing. The pre-processing is as follows: first, streamtubes that represent white matter paths are computed from DT-MRI data. Second, we compute an adjacency matrix of distances between every pair of streamtubes in the brain. Third, using a spectral embedding method, we assign colors to every streamtube such that differences in colors correspond to the distances in the matrix. Finally these colors are converted from a perceptually uniform color space to RGB for display(Fig. 1 a.) On a 2K streamtube dataset, the relative error of the embedding measured with Frobenius norm of tube embedded distance matrix and original distance matrix is 13%. We suspect using a more sophisticated method would yield embeddings with less error.

After we've assigned a coloring of streamtubes we view them in BrainApp [Lee et al. 2006] an interactive tool for visualizing DT-MRI data. We extended this software with a new selection interaction. The user selects axis-aligned planes in 3D (Fig. 1 b) then views, as a 2D view (Fig. 1 c), the colors of streamtubes intersecting that slice. Next the user makes a free-form closed curve. The streamtubes that pass through the this region are selected (see Fig. 1 d). This axis-aligned view and selection method exploits the training neuro-scientists have received viewing aligned 2D images (sectional anatomy) of the brain.

We performed two informal evaluations with an expert visualizing a normal and an HIV-positive brain data-set. Our expert reported high anatomic specificity, and he reported being able to easily pick out meaningful fiber bundles even though colors varied smoothly. He noted that the hemispheric color differences easily gave context when navigating in 3D views. He felt the subtle color variations were visually easier to process. The user felt that he was the one making the model (instead of a predefined cluster of tracts). We asked the expert how our approach fared against displaying hard segmentation where whole bundles are colored with one color versus the smooth color variation. The user felt the smooth coloring was more compatible with the uncertainty of tractography. Based on user feedback, fractional anisotropy (FA) variation integrated into the streamtube-distance metric might make the tool more useful for comparing brains across subjects.

## Conclusion

Our evaluation suggests this is a promising approach. Our visualization method shows relevant anatomic structures without imposing a segmentation. The tool provided a simpler 2D drawing tracts-of-interest selection method which is an important brain diagnosis interaction for experts familiar with sectional anatomy.

AKERS, D. 2006. Wizard of oz for participatory design: Inventing an interface for 3d selection of neural pathway estimates. In *CHI*. Work In Progress.

BRUN, A., PARK, H.-J., KNUTSSON, H., AND WESTIN, C.-F. 2003. Coloring of dt-mri fiber traces using laplcian eigenmaps. In *EUROCAST'03*, 564–572.

LEE, S., CORREIA, S., TATE, D., PAUL, R., ZHANG, S., SALLOWAY, S., MALLOY, P., AND LAIDLAW, D. H. 2006. Quantitative tract-of-interest metrics for white matter integrity based on diffusion tensor mri data. In *ISMRM*.

ZHANG, S., DEMIRALP, C., AND LAIDLAW, D. H. 2003. Visualizing diffusion tensor MR images using streamtubes and streamsurfaces. *IEEE TVCG 9*, 4 (October), 454–462.

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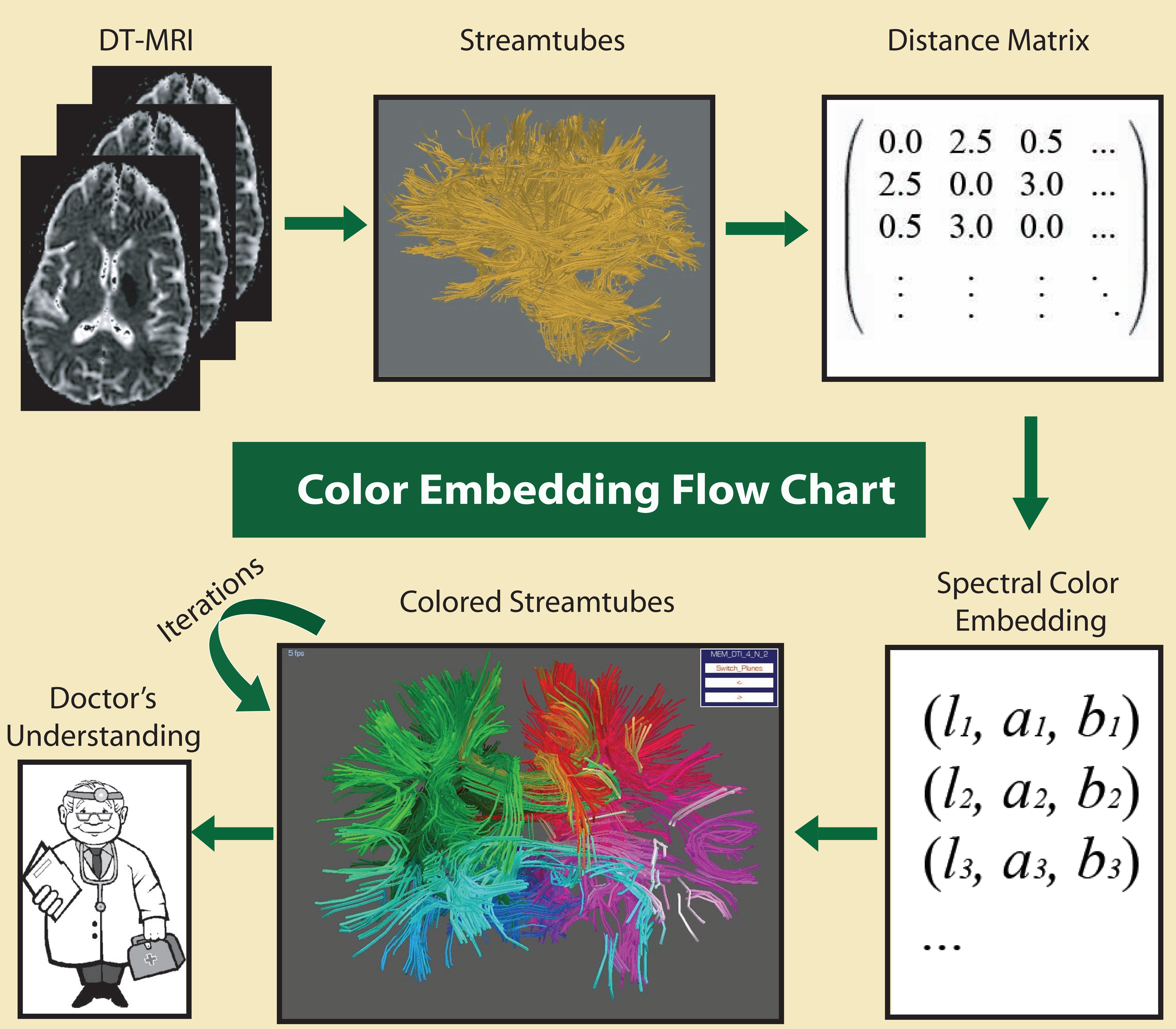
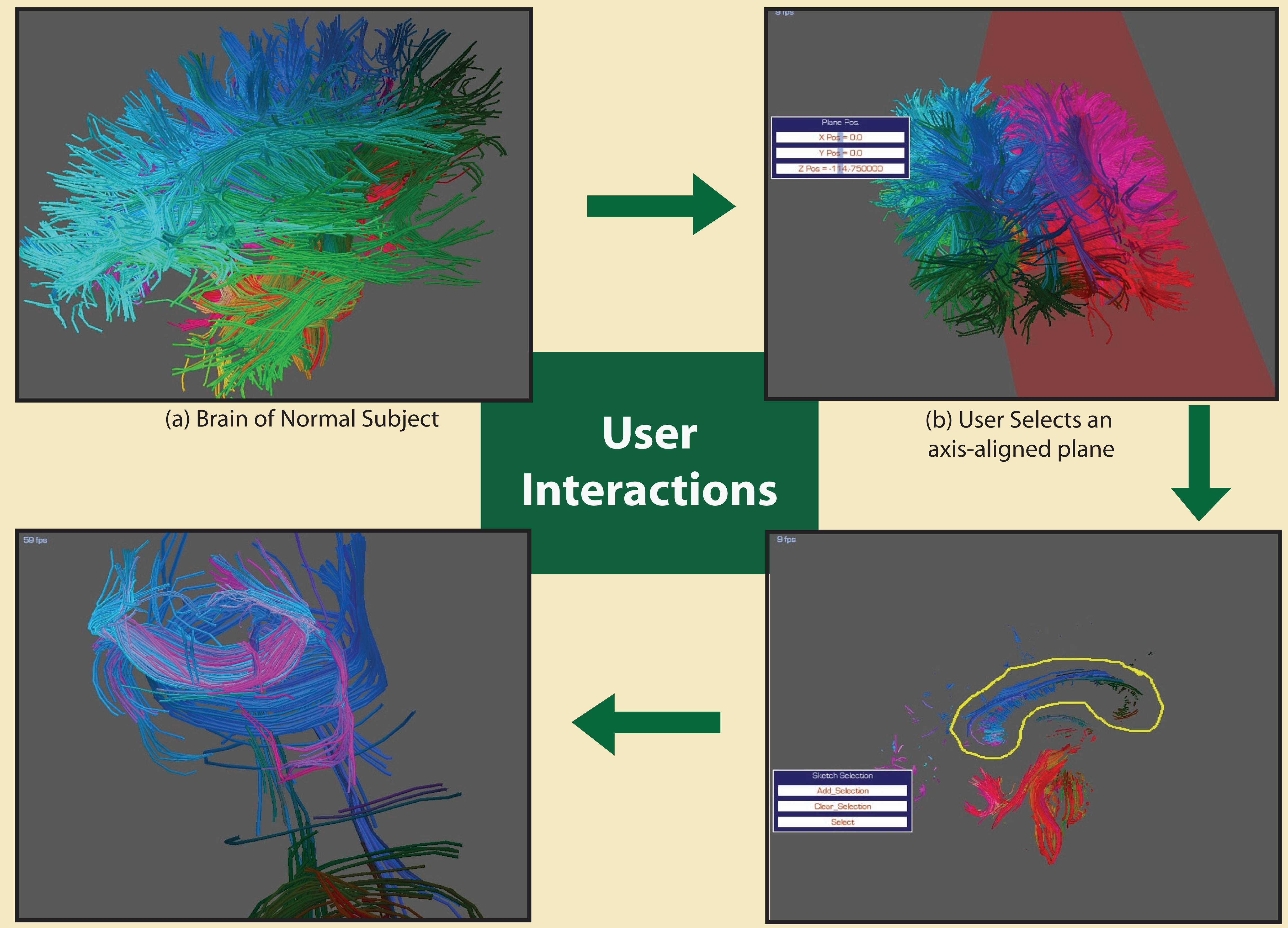
## Motivations

This project is motivated by the desire to help doctors in understanding white matter structure within human brain for studying diseases such as HIV.

- Visualize the geometric disparity between white matter tracts obtained from DT-MRI (Diffusion Tensor Magnetic Resonance Images)
- Allow expert users to select regions interactively with a 2D based sketching mechanism
- Better Reflects the uncertainty in forming scientific model from geometric information
- Avoid rigid, possibly inaccurate, segmentation from automatic clustering of tracts
- 2D sketching interface exploits neuroscientists' expertise with sectional anatomy




[1] AKERS, D. 2006. Wizard of oz for participatory design: Inventing an interface for 3d selection of neural pathway estimates. In CHI. Work In Progress.
[2] BRUN, A., PARK, H.-J., KNUTSSON, H., AND WESTIN, C.-F. 2003. Coloring of dt-mri fiber traces using laplcian eigenmaps. In EUROCAST'03, 564–572.
[3] LEE, S., CORREIA, S., TATE, D., PAUL, R., ZHANG, S., SALLOWAY, S., MALLOY, P., AND LAIDLAW, D. H. 2006. Quantitative tract-of-interest metrics for white matter integrity based on diffusion tensor mri data. In ISMRM.
[4] ZHANG, S., DEMIRALP, C., AND LAIDLAW, D. H. 2003. Visualizing diffusion tensor MR images using streamtubes and streamsurfaces. IEEE TVCG 9, 4 (October), 454–462.




(a) Brain of Normal Subject

(b) User Selects an axis-aligned plane

(c) Selected plane shown in 2D, user selects a free-form region

(d) All tracts passing through the region are displayed

## Methods

### Color Embedding

- Compute streamtubes that represent white matter paths from DT-MRI data
- Compute adjacency matrix of distances between every pair of streamtubes in the brain
- Using spectral embedding method, assign colors to every streamtube such that differences in colors correspond to the distances in the matrix
- Convert these colors from perceptually uniform color space to RGB for display

### Expert User Interactions

- View the generated streamtubes in BrainApp, an interactive tool for visualizing DT-MRI data
- Select axis-aligned planes in 3D, then view as a 2D view, the colors of streamtubes intersecting that slice
- Makes a free-form closed curve, the streamtubes that pass through this region are selected
- Selected streamtubes will be displayed and allows interactions

## Expert Feedback

We performed two informal evaluations with an expert visualizing a normal and an HIV-possitive brain dataset. Our expert reported:

- High anatomic specificity
- Hemispheric color differences easily gave context when navigating in 3D views
- Smooth coloring was more compatible with uncertainty of tractography

## Conclusions

- Our evaluation suggests that visualizing the geometric disparity between white matter tracts using perceptual color embedding is a promising approach
- Our visualization methods shows relavant anatomic structure without imposing a rigid segmentation
- The axis-aligned view and selection method exploits the training neuroscientists have received viewing aligned 2D images of the brain

Comparison of Generated Streamtubes