

DoDTI

Automated analysis of diffusion tensor MRI toolbox

*Laboratory of Molecular Neuroimaging Technology
Yonsei University*

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Introduction

DoDTI has been designed to provide a tool for quantification of diffusion tensor imaging including visualization and analyzing techniques of DT-MRI. Diffusion tensor imaging techniques in physics and computer science is a rapidly growing field. The application to clinical research is active but has been hampered by the lack of good tools for analyzing DT-MRI data. For this reason, we introduce an easy to use diffusion tensor analysis tool designed to meet these needs in both clinical research and technical research. We will continue to incorporate new features into DoDTI. Currently this website is still being constructed. We will provide more detailed information on DoDTI as soon as possible.

Why DoDTI? : Major Features

DoDTI is a platform independent tool implemented in MATLAB (Mathworks Inc.), and is modular to facilitate maintenance and updates.

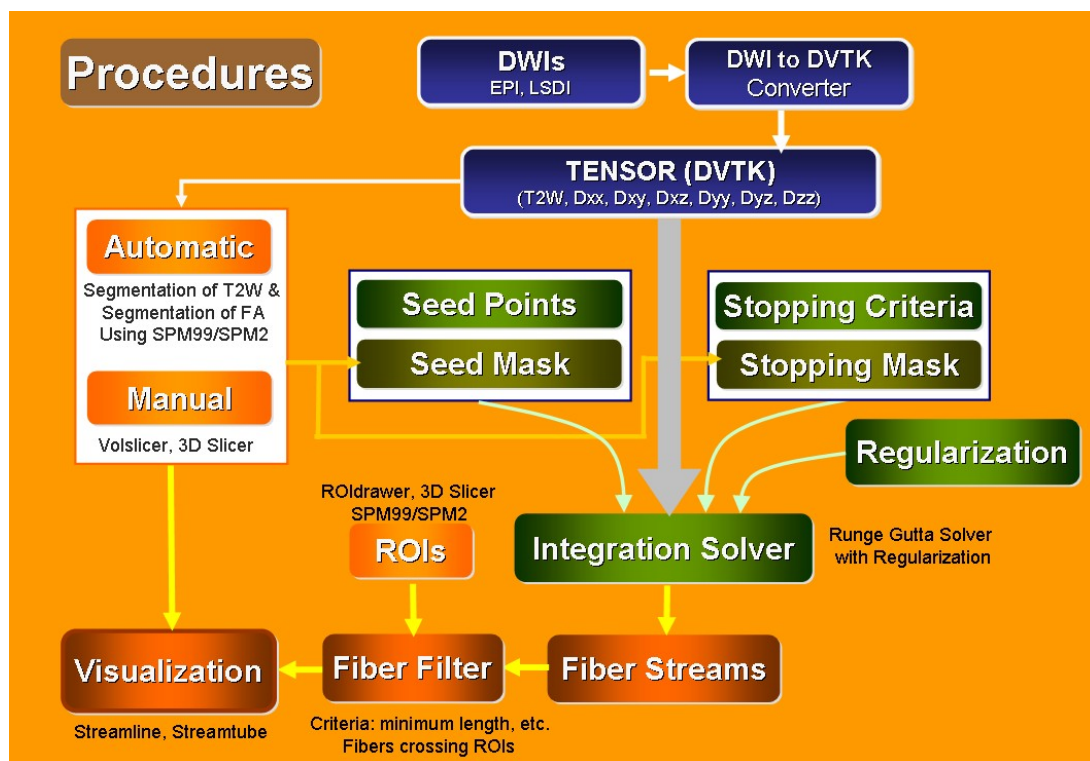
The basic features of the tool are:

- 1) 2D DT-MRI visualization where several types of glyphs are available to display with different coloring schemes with a background of the fractional anisotropy and the apparent diffusion coefficient.
- 2) A fully automated method for DT-MRI tractography where seed-points and stopping criteria can be assigned either from automated method or in an user-configurable manner. For the tractography, a 4th-order Runge-Kutta integration solver is used with a choice of several regularization schemes including TENS to better handle crossing fiber bundles.
- 3) Selection of fiber traces according to a user-defined criteria such as the length of a fiber, maximal angle difference, minimum distance between end points of a fiber. In addition, manually drawn regions of interest (ROIs) can be used for the selection of fibers of interest intersecting those ROIs.
- 4) Information about the properties of fibers of interest is available, such as the mean anisotropy along the fiber. Integration of functional MRI activation map in SPM99 (Wellcome Department of Cognitive Neurology, UK) format can be used as ROIs to enable the exploration of functional integration in relation with anatomical

connectivity. Measuring fractional anisotropy and cross-sectional area of fiber bundles along the pathway is also possible.

5) The 3D visualization techniques include both streamlines and streamtubes with or without background grayscale images and renderings of ROIs for better understanding of fiber connectivity and efficiency. In addition, individual fibers can be displayed with color-coded fractional anisotropy.

Analysis flow of DoDTI



Requirements

DoDTI is running on MATLAB v6.0 ([Mathworks](#)) and later. DoDTI can run independently of [SPM \(Wellcome Department, UK\)](#).

However, we recommend you to use either SPM99 or SPM2 if you want to utilize SPM's excellent modules such as segmentation and registration.

DoDTI: Automated analysis of diffusion tensor MRI toolbox

Also, if you are interested in combining diffusion tensor imaging with functional imaging such as PET or fMRI study, it would be necessary to use SPM.

Quick View

DoDTI is implemented in MATLAB environments, and available for the Windows, Linux, and Mac OS X operating systems. You need to run **doDTI** at MATLAB command window to start DoDTI.

After DoDTI starts, one main window appears.

DoDTI main window is constructed largely by following sections – File Open, 2D display, Tractography, Fiber Editing, Visualization, and ToolBox.

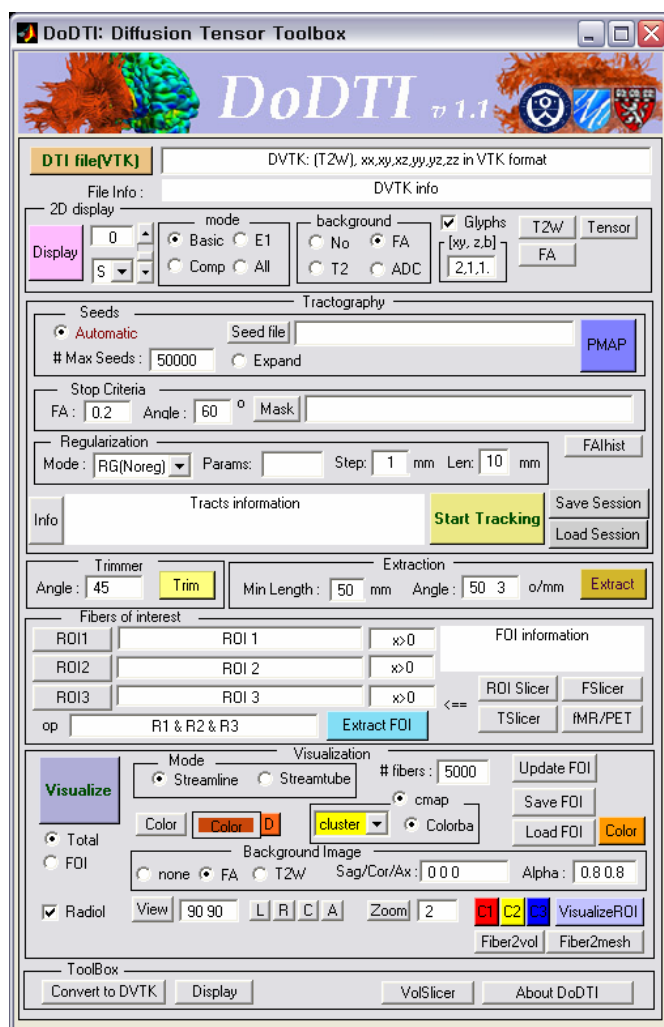
File Open: opens the basic DTI input file in VTK format – We call it DVTK format. You need to convert the conventional DWIs to DVTK format in **ToolBox**.

2D display: enables you to display the features of input DTI file in the 2D viewer windows.

Tractography: creates the fibers of input DTI file for DoDTI.

Fiber Editing: provides trimming and extracting tools to edit the calculated fibers, and we can use fibers of interest (FOI) in this section.

Visualization: enables you to display the extracted fibers in the 3D viewer windows.



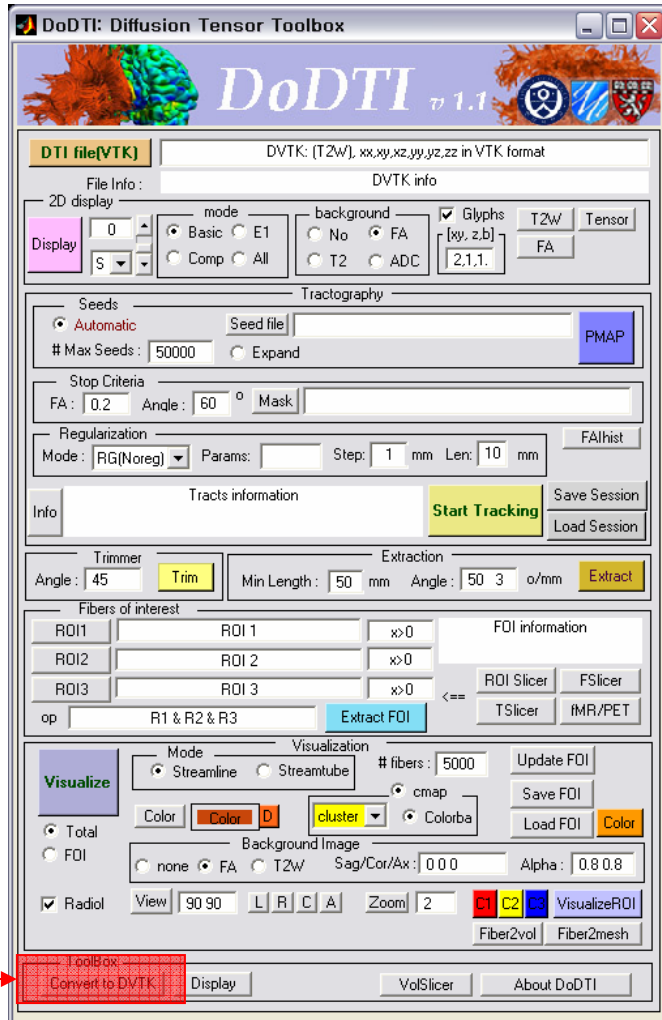
ToolBox: provides a conversion to DVTK format, SPM-based orthogonal display, and VoISlicer.

Data Conversion

MANUAL

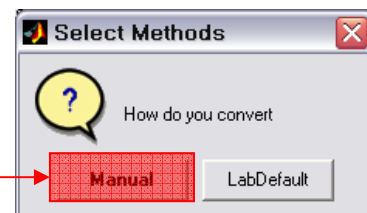
Step 1.

To create DVTK file format from ANALYZE img-files for DoDTI, click '**Convert to DVTK**'.



Step 2.

Click '**Manual**' for file conversion to DVTK format.



Step 3.

Click '**BO or All**' for your selection.

The choices may be

- 1) ANALYZE multi-volume file.
- 2) ANALYZE separated-volume files.
- 3) Philips PAR file.

If you use multiple ANALYZE files as DWI images, click '**DWIs**' in the order of gradient direction.

You should select your gradient matrix.

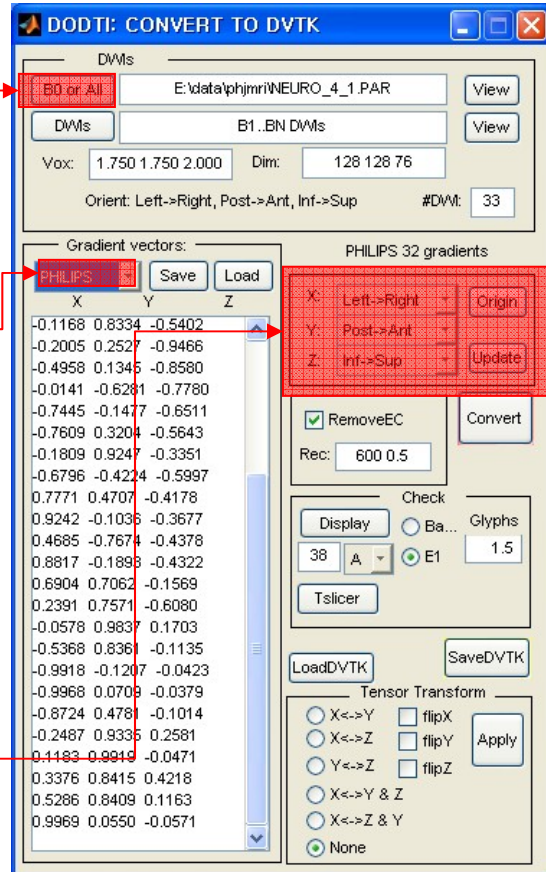
Your choices are

- 1) Philips
- 2) GE
- 3) Siemens
- 4) User defined gradients: You can manually input gradient vectors. It should begin by B0 i.e., 0 0 0.

Check for your gradients in the edit box.

You can select the coordinate of acquisition of the first column (X component), the second column (Y component) and the third column (Z component).

You may change or convert your gradients. Note to click the '**Update**' button for your changes.



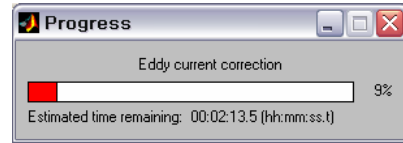
NOTICE !!!
The default gradient direction of DoDTI and the image storage is in RAS format (left to Right, posterior to Anterior, inferior to Superior).

Also you may save or load your changed gradients matrix.

Step 4.

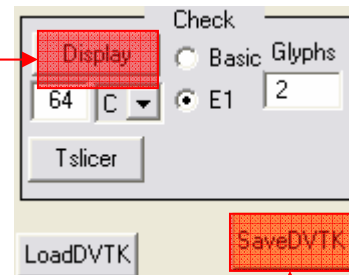
Click '**Convert**' to make DVTK file.

If you check '**RemoveEC**', eddy current removal is performed. Since it takes several minutes, use this option when you finally find the correct gradient without '**RemoveIEC**'.

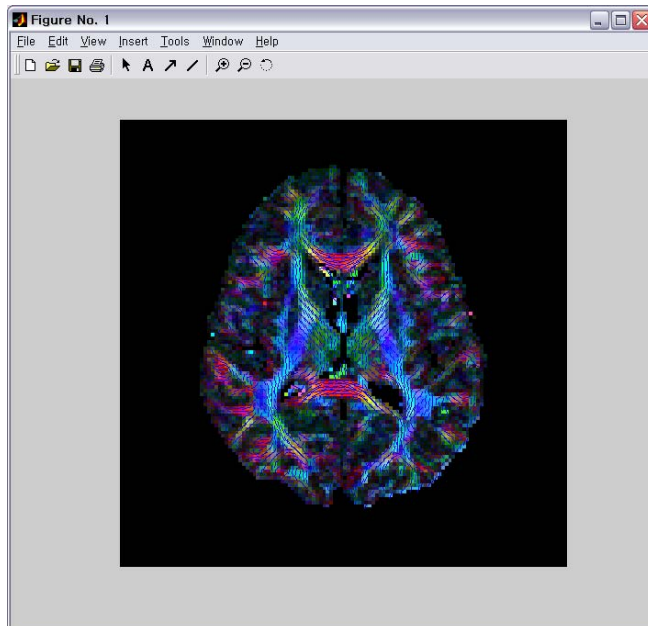


'Rec:' field: [B-value, threshold proportion for including tensor calculation]
Threshold = threshold proportion x mean global intensity of DWIs.

Please check your tensor results. ●
Coronal slice number 64 in this example.



If the color or direction of the tensor eigenvector is correct, then save to the DVTk result file by click '**SaveDVTk**'.
If not, verify the applied gradient matrix.

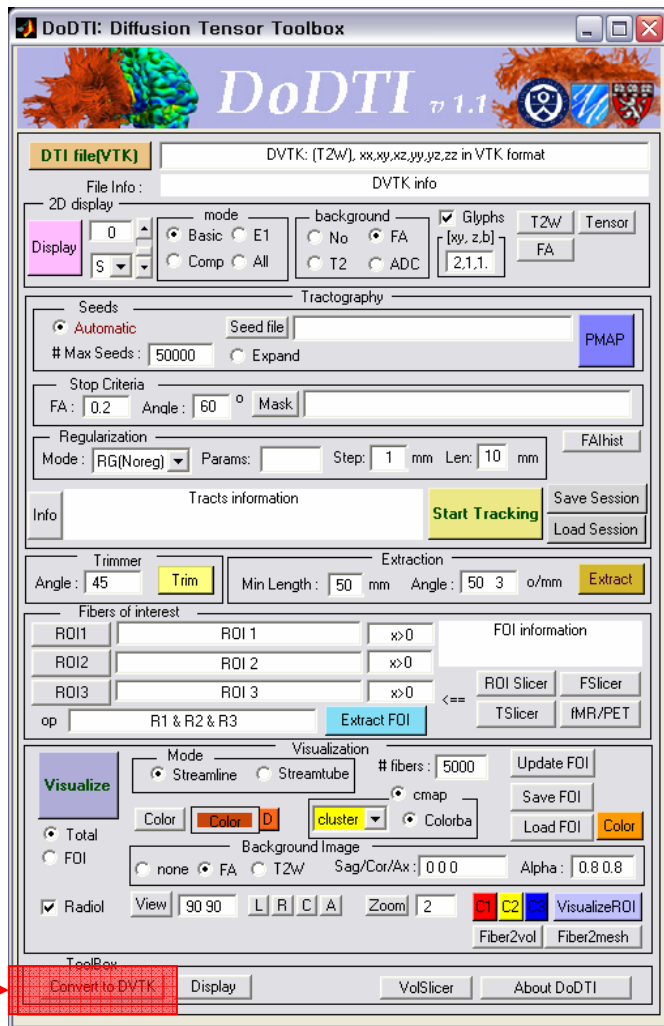


If you find a correct direction after several trial and error, you can save final gradient configuration to a file for later use. Use 'save' and 'load' button.

LabDefault

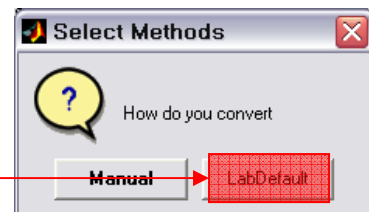
Step 1.

Click 'Convert to DVTK'.



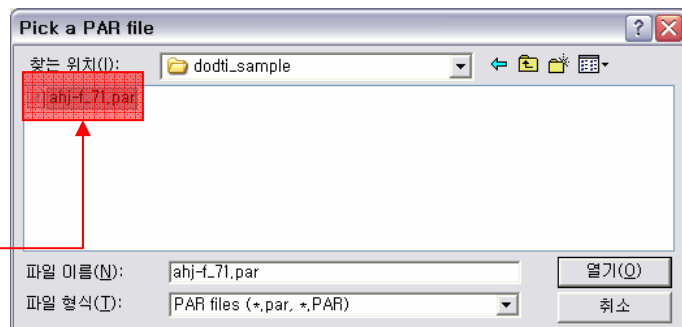
Step 2.

Click 'LabDefault'.

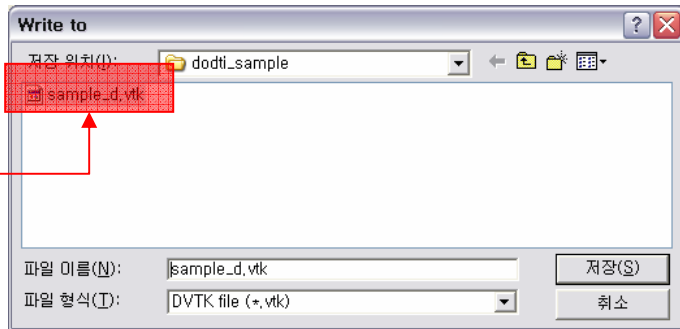


Step 3.

Select conventional DTI data. In here, we use REC file, and select PAR file linked to REC file.

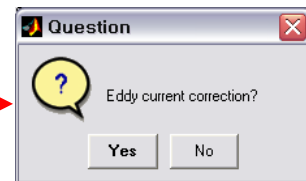


Write new file name for converted file of DVTK file format.



Step 4.

Check whether the eddy current is removed or not.



Hint !!!

You can modify your lab default by editing 'vtk_defaultconvert.m' file.

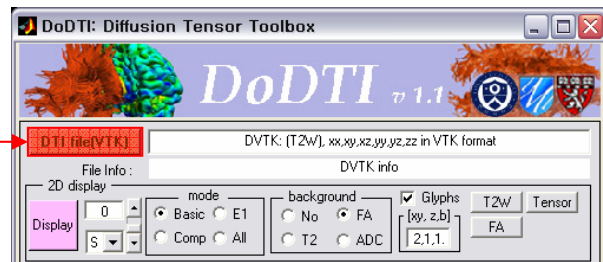
NOTICE !!!

When you have the source files in DICOM format, you should convert the files to ANALYZE format. We recommend to use the [MRICro](#) for this work.

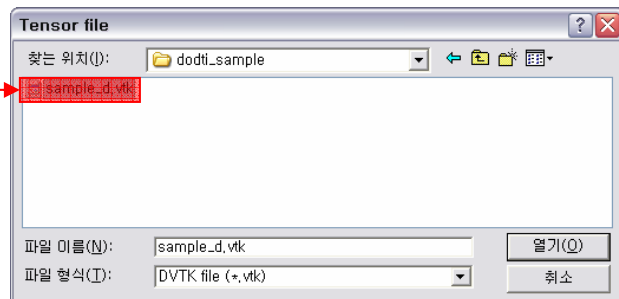
Voxel-Based Visualization

Step 1.

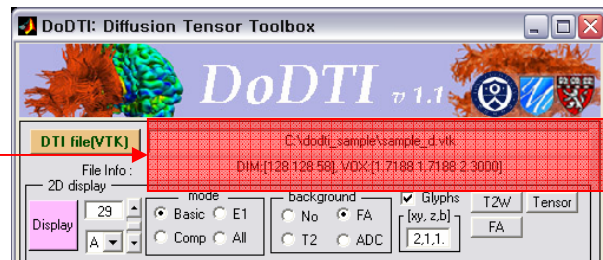
Click 'DTI file(VTK)':



Load VTK file.



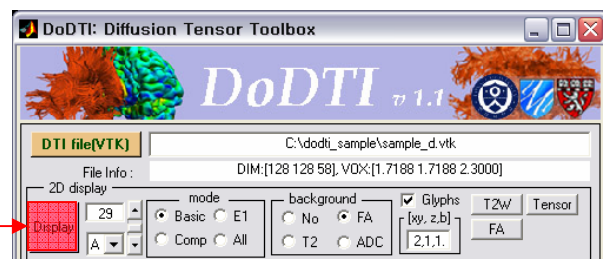
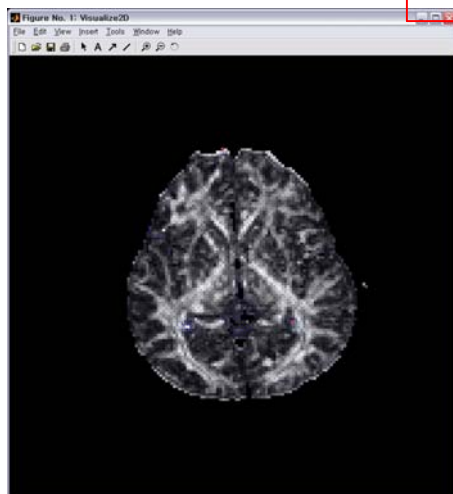
If you select correct VTK file, the basic file information will be represented.



Full path and file name of input file, file dimension [Width, Height, Depth], and voxel resolution (mm) is viewed.

Step 2.

Click 'Display':

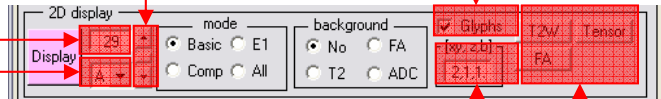


New window will be appeared according to the current setting.

Overlay line glyphs to the background.

Slice increase/decrease

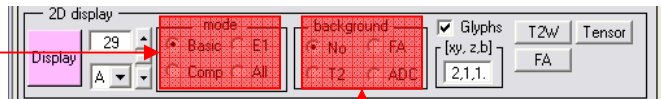
Slice number



View	SPM style orthogonal view	Scaling
S Sagittal	T2W B0 image	xy In-plane line glyphs
C Coronal	FA Fractional Anisotropy	Z Out-of-Plane color
A Axial	Tensor Color encoded map	B Color vector map

Mode

Background, weight, or types



Mode

- Basic FA, T2 or ADC display (See background.)
- E1 Color-encoded largest eigenvector (E1) of tensor (See weight.)
- Comp Color-encoded linear (Cl), planar (Cp) or spherical (Cs) component of tensor (See weight.)
- All Combination of some display (See types.)

Background

- No Do not display anything as background.
- FA Fractional anisotropy
- T2 Diffusion non-weighted image (B0)
- ADC Apparent diffusion coefficient

Weight

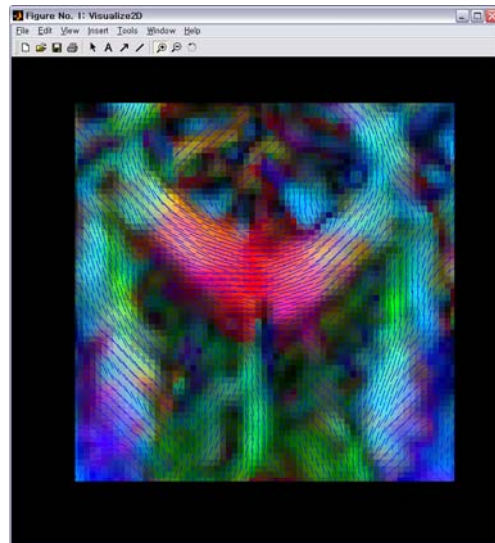
- No Do not weight.
- FA Weighted by fractional anisotropy
- CL Weighted by linear component (Cl) of tensor

Types

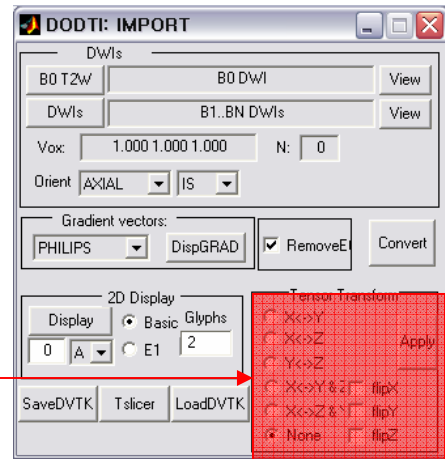
- Tensor component (Dxx, Dxy, Dxz, Dyy, Dyz, Dzz), T2, L1, L2, and L3
- T2, FA, ADC and the color-encoded E1 weighted by FA
- Linear (Cl), planar (Cp), spherical (Cs) component, and linear component weighted by FA

Caution!!!

You should confirm the direction of fiber bundles – e.g. in the display of 'E1' mode. If you concluded that the displayed fiber directions were flipped by different-formatted raw data or some mistakes.



You may adjust this erroneous direction when creating DVTK-file. See '**Data Conversion**'. Make sure the fiber direction is whether a real fault or just flipping mistake.

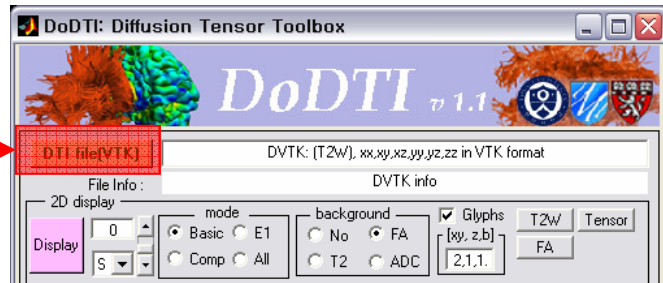


Tractography

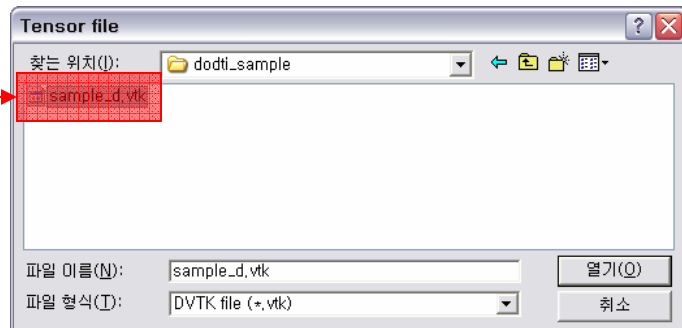
Fiber generation

Step 1.

Click 'DTI file(VTK)':



Load VTK file.



Step 2.

Set 'Seeds' to process tracking. Default is 'Automatic' and '50000' seed points.

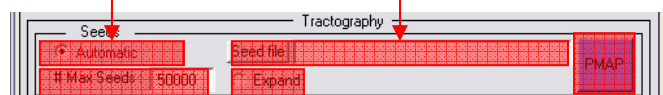
If you want to use ROI as seeds, use
MATLAB mat file or ANALYZE img-file.

Seeds by white matter from automated
SPM segmentation

You may select the maximum
number of seed points to
generate fiber bundles.

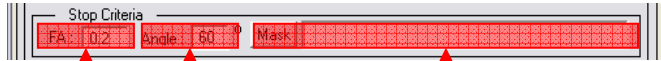
Expand

Probability fiber tracking at seed



Step 3.

Set 'Stop Criteria'.



Stop by FA. Default is 0.2

Stop by fiber curvature. Default is 60°

Mask file. (optional) Use ANALYZE img file.

Step 4.

Set 'Regularization'.



Mode	
RG(Noreg)	Param = 2
TEND	Tensor defletion method. CI = 0.9
PROJ	
BBKW	CI = 0.5

Parameters for regularization.

Step length for every iteration.

Length

FA histogram window to set a parameter will be appeared

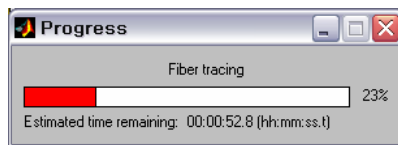
Step 5.

Click 'Start Tracking'.



When tracking is completed, reconstructed fiber information is represented.

Start fiber tracking.



You may save/load overall current setting as mat-file.

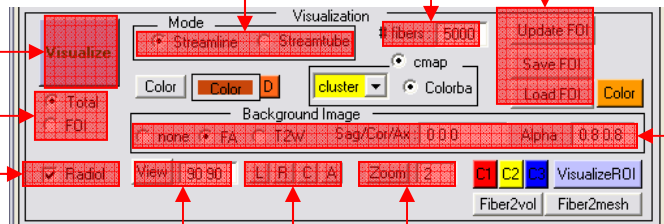
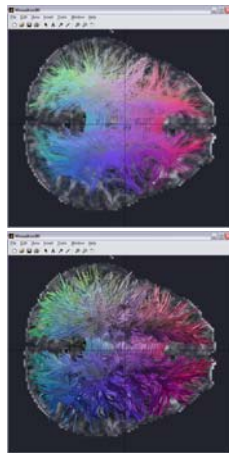
Visualization

Update/Save/Load overall setting of FOI

Number of visualized fibers. Default is 5000.

Visualization mode: **streamline** or **streamtube**.

Default is streamline.



Start fiber visualization

View total fibers or FOI.

Default is Total.

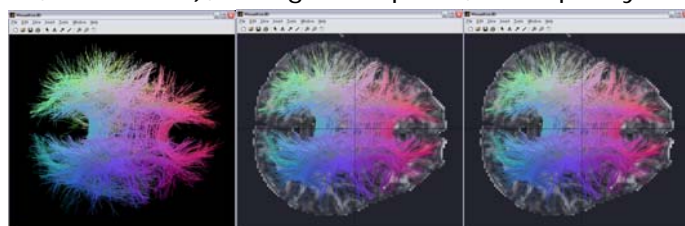
Convert radiological vs. neurological convention.

Viewing angle

View	
L	Left sagittal
R	Right sagittal
C	Coronal
A	Axial

Zoom

Background (None, FA or ADC), background panel, and opacity

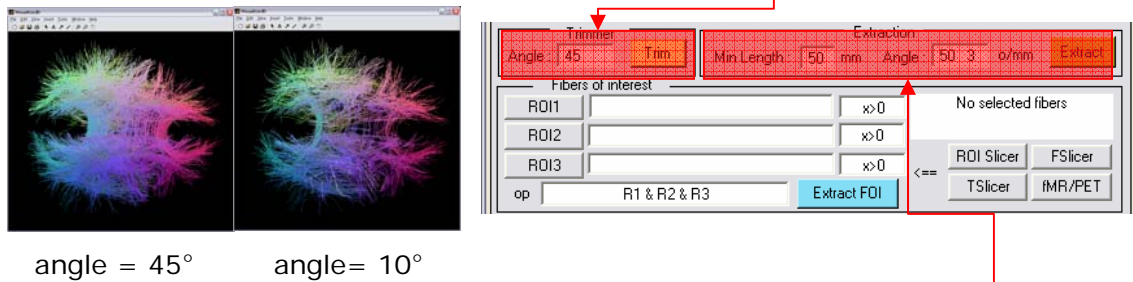


Fibers of interest

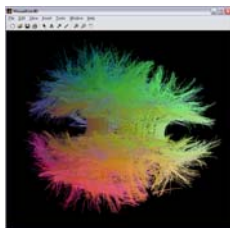
Step 1.

Set 'Trim' and 'Extract' parameters

Trim: splits fibers according to the defined angle.



Extract: extracts fibers according to the defined length and angle.



Step 2.

You may set ROIs through which fibers pass, by ROI file or user ROI generated using 'ROI Slicer', 'FSlicer', 'TSlicer', or 'fMR/PET' module.

These ROIs are handled using MATLAB operator in 'op' section

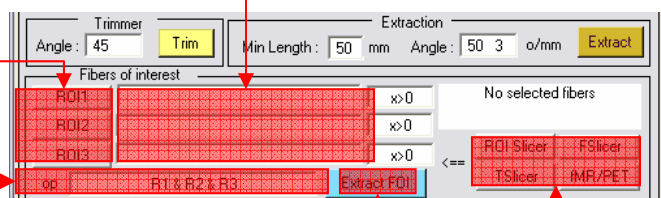
File name with full path or 'from memory' is represented according to the input.

Img or mat file is loaded.

ROI operation is possible using MATLAB operator.

Extract FOI from the operated ROIs.

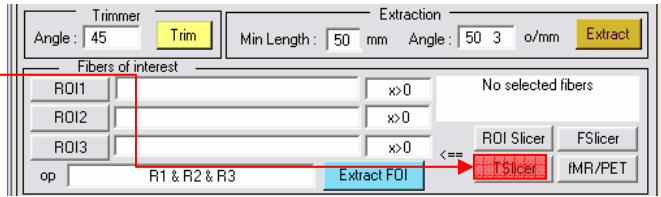
You may construct you own ROI from here. See next.



Creating fibers of interest (FOI) using TSlicer

Step 1.

Click 'TSlicer'.

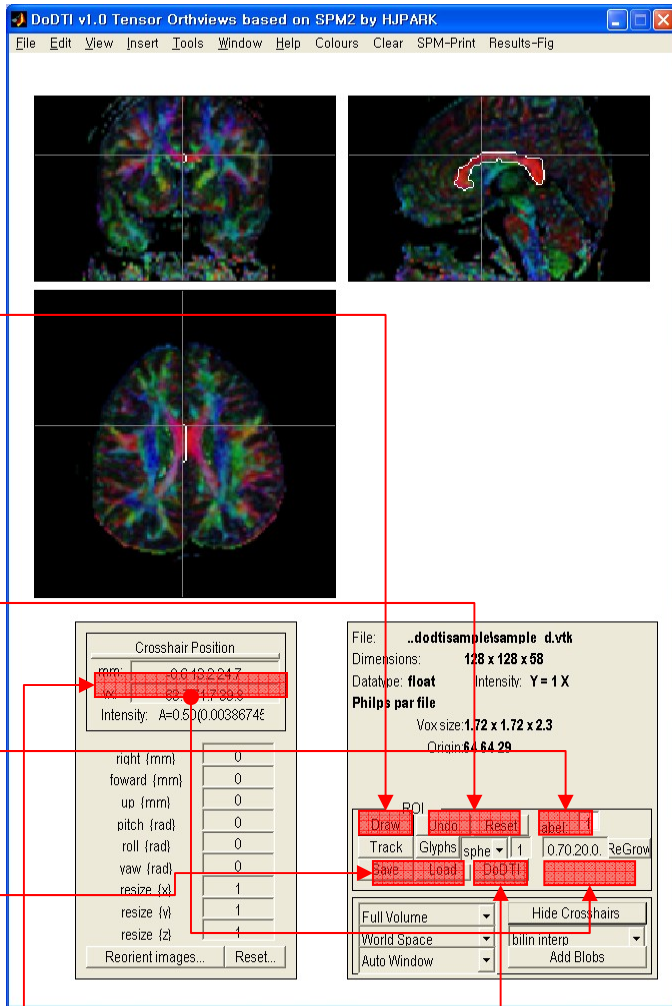


Step 2.

Select location to draw by clicking the brain image first. Guide line will be highlighted in the selected panel.

Click 'Draw'.

Draw ROI by left mouse button on the brain image. When drawing is completed, click right mouse button. Use 'Undo', and 'Reset'.



Multiple ROIs can be labeled by integer value.

Labeled ROIs can be saved or loaded with ANALYZE img-file.

Also when the seed point by vx is typed, click 'ReGrow', and automatic region growing ROI is drawn at the seed point.

ROIs can be sent to DoDTI directly by clicking 'DoDTI'.



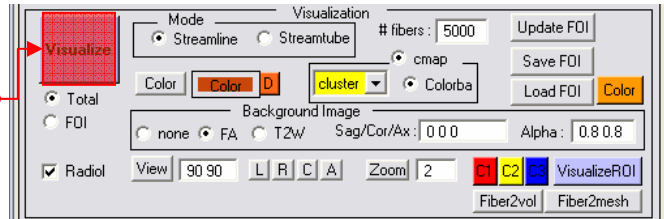
Step 3.

You can see **'from Memory'** in the selected ROI slot. Use your MATLAB based ROI operation and click **'Extract FOI'**.



Step 4.

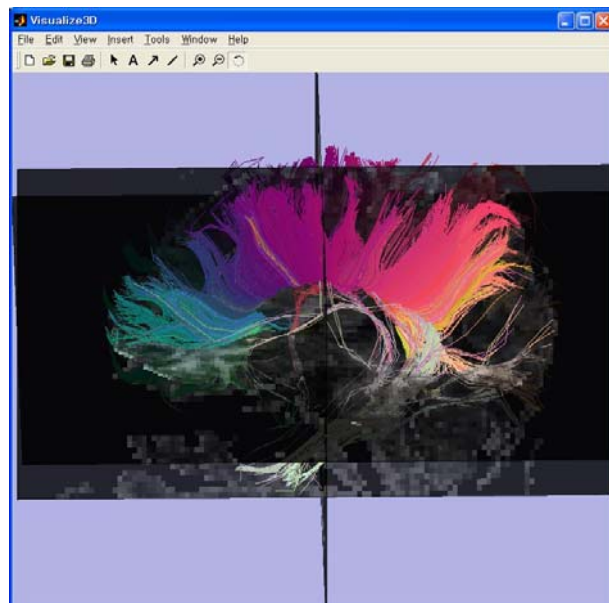
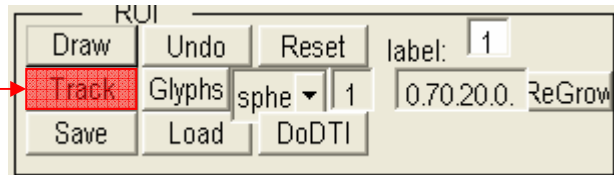
Select **'FOI'**, and click **'Visualize'** to display FOI fibers.



TIPS!

You can directly create fibers from ROI. In the Tslicer, draw ROI first and then select **'Track'**, then you will get fiber tracks originating from the ROI you draw.

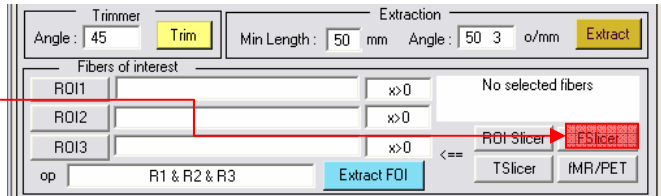
By changing the visualization configuration, you can get different configurations of fiber visualization.



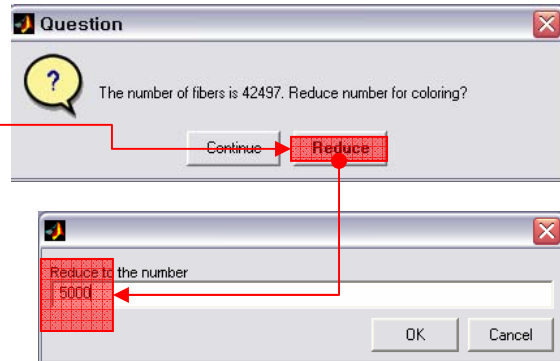
Creating fibers of interest (FOI) using FSlicer

Step 1.

Click 'FSlicer'. A question dialog box is appeared.

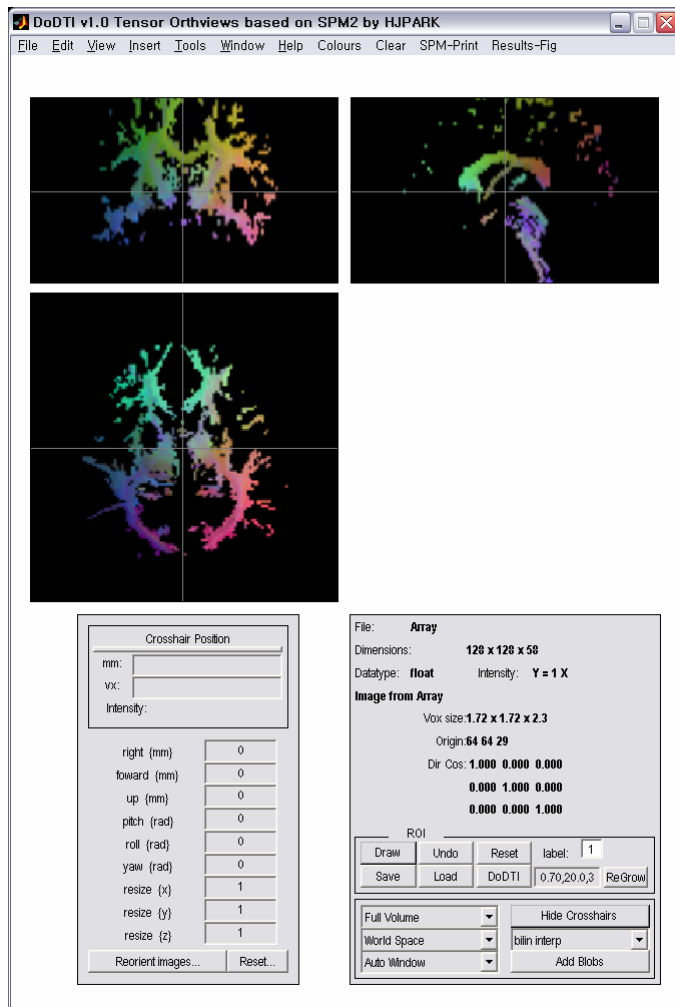


If you want to reduce the processing fibers, click 'Reduce' and type your appropriate value in the edit box.



Step 2.

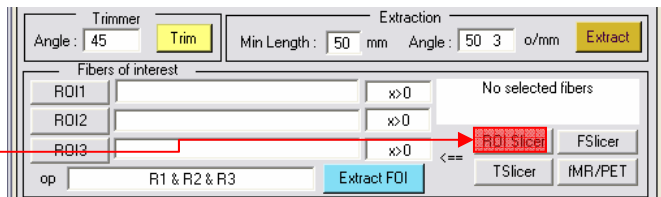
Draw ROIs in the same manner of using TSlicer, send to DoDTI, and visualize it.



Creating fibers of interest (FOI) using ROI Slicer

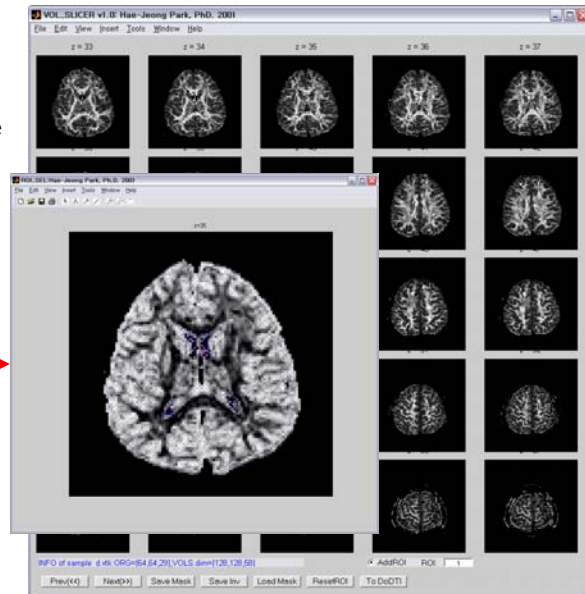
Step 1.

Click 'ROI Slicer'. A figure dialog box is appeared.



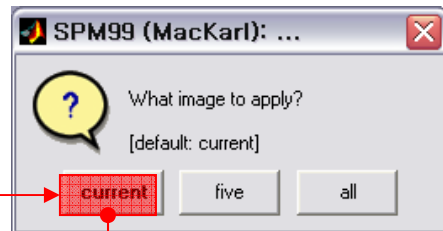
Step 2.

In the dialog box, you may click one figure, and then a expanded figure is appeared.

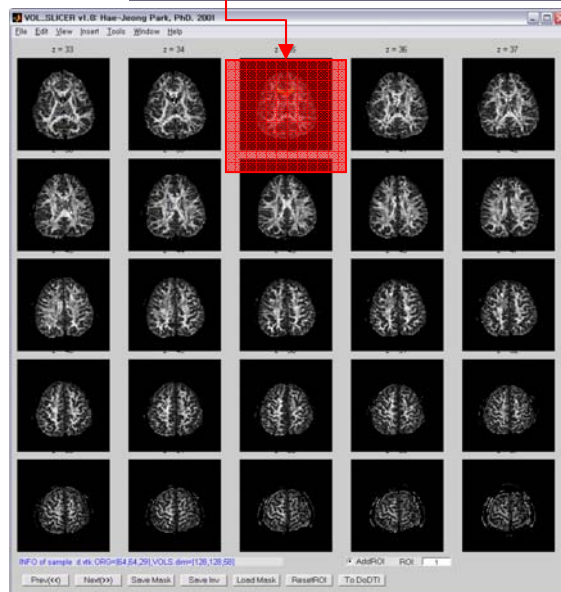


Step 3.

You may draw ROI using the previous manner – left and right mouse click. And select image to which this ROI is applied.



ROI	
Current	Only to current figure.
Five	Apply to the next 5 figures.
all	Apply to overall figures.

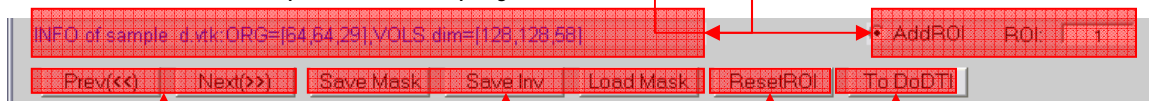


Step 4.

You may **'Save'**, **'Load'**, **'Reset'**, or send **'To DoDTI'** the ROIs.

Several ROIs can be labeled.

Information of the input file is displayed.



Display previous/next slices.

Save/Load mask.

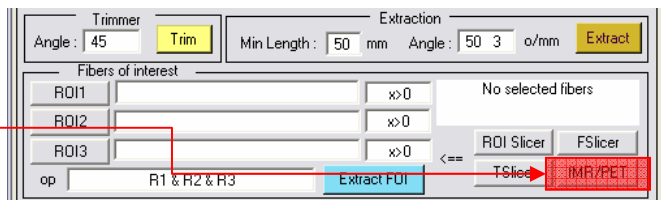
Clear ROIs.

Send ROIs to DoDTI.

Creating fibers of interest (FOI) using fMR/PET

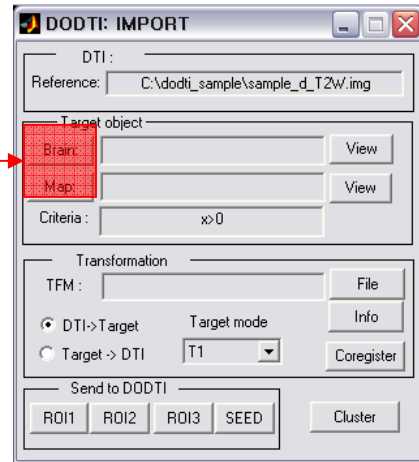
Step 1.

Click 'fMR/PET'. A figure dialog box is appeared.

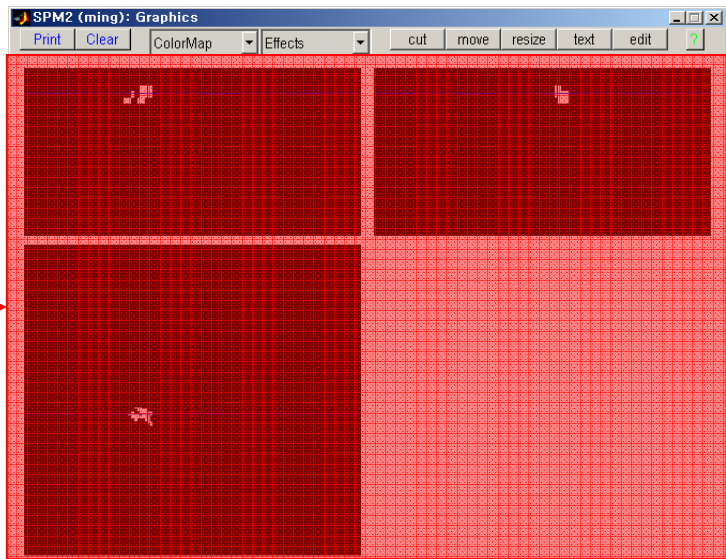


Step 2.

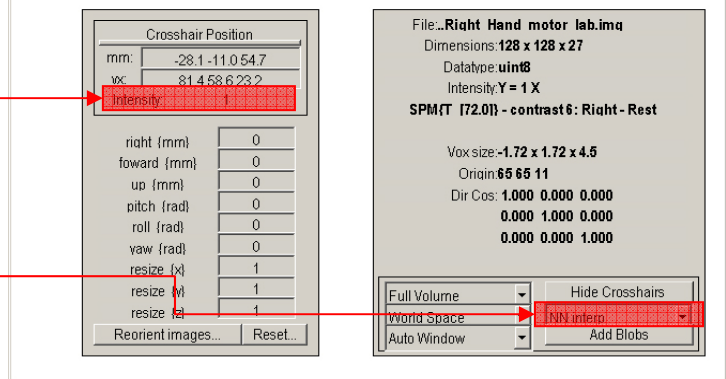
Click 'Brain' and select T1 image (img file).
Click 'Map', and select fMRI result (mat file).



Find ROI by clicking images.



Check intensity of ROI that you want. There is one ROI in these data.



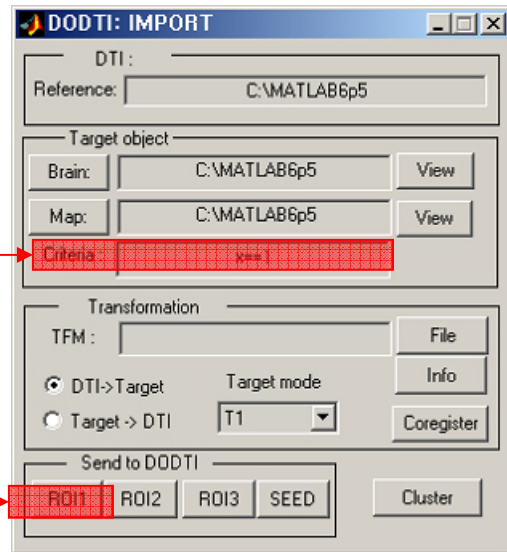
Select 'NN interp' as good as possible.

DoDTI: Automated analysis of diffusion tensor MRI toolbox

Step 3.

Set criteria as $x==1$.
(ROI of intensity 1)

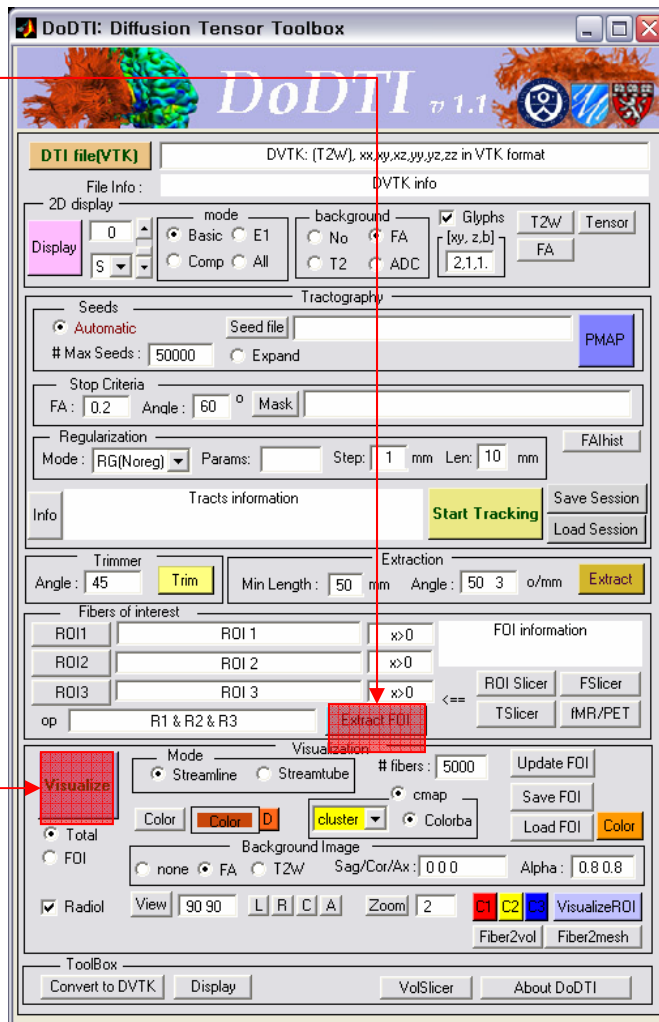
Click 'ROI1'.



Step 4.

Click 'Extract FOI'

Select 'FOI' and
Click 'Visualize'



Displaying 3D Glyphs

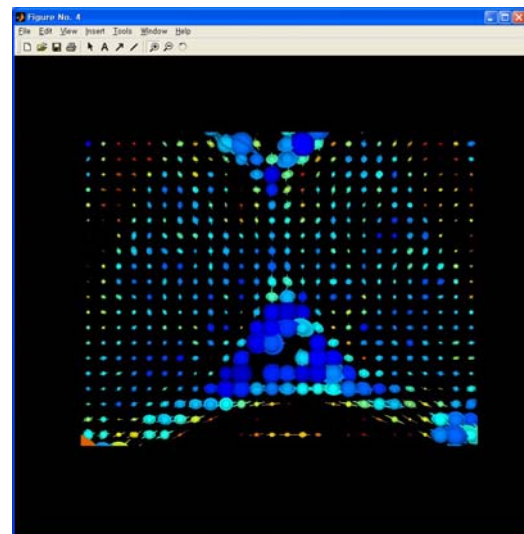
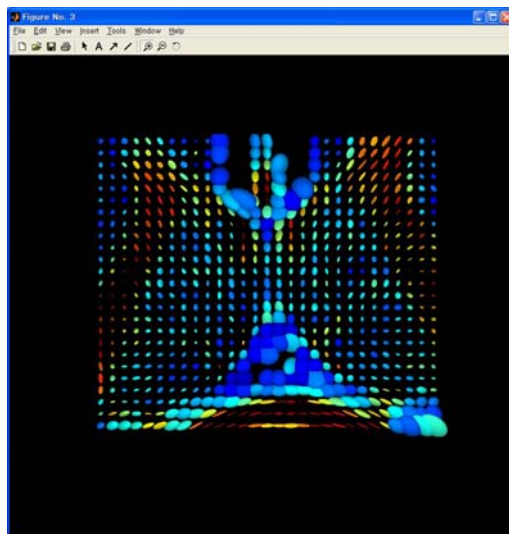
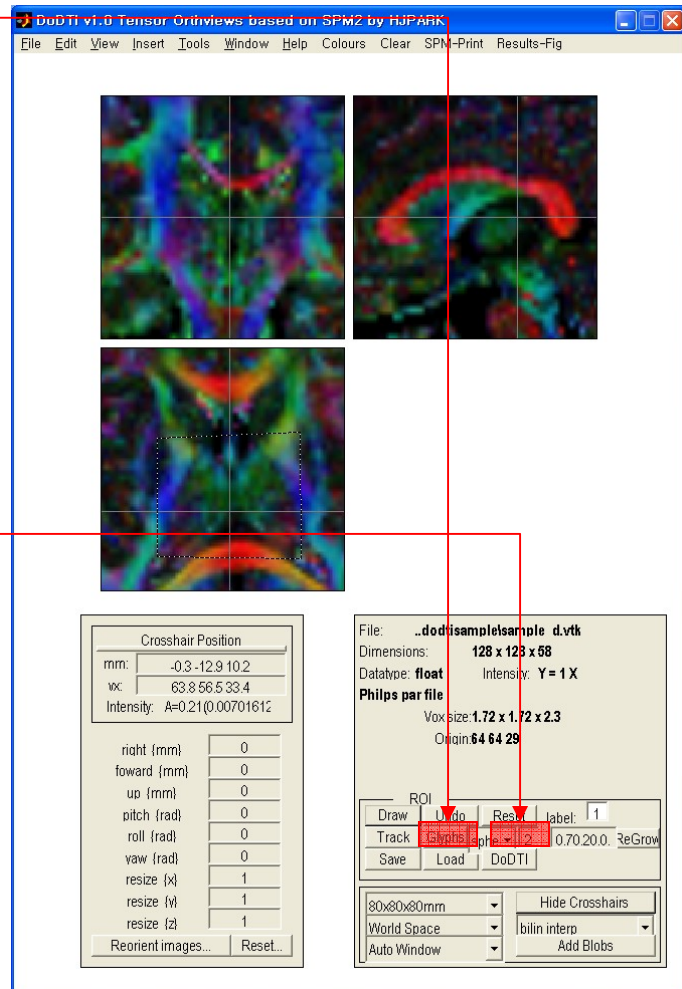
First, select Glyphs,

And draw ROI on the active plane,
For example, roi on the axial plane.

Then you will get glyphs display
of the rectangle box covering
your roi.

You can select glyphs type and
the scale of the glyphs.

The below are examples of the
3D glyphs around the thalamus.



Miscellaneous

Acknowledgements

DoDTI utilizes several excellent online sources contributed by anonymous developers. We have tried to give credit where appropriate.

Current Version

Current version of DoDTI is v. 1.2.

Contact Us

Hae-Jeong Park, Ph.D. (parkhj@yumc.yonsei.ac.kr)

[Laboratory of Molecular Neuroimaging Technology](#)

Dept. Diagnostic Radiology, Yonsei University, College of Medicine, KOREA

Appendix A: File Formats

Currently the basic tensor file format of DoDTI in most processing is VTK ([Kitware co.](http://www.kitware.com)) [DATASET STRUCTURED POINTS format](#). We call it DVTK format in this documentation.

1. DVTK file format

```
-----  
  
# vtk DataFile Version 3.0  
AX: [DTI:t2w xx xy xz yy yz zz]  
BINARY  
DATASET STRUCTURED_POINTS  
DIMENSIONS 256 256 43  
SPACING 0.859375 0.859375 3.000000  
ORIGIN -109.570312 -109.570312 -63.000000  
POINT_DATA 2818048  
SCALARS scalars float 7  
LOOKUP_TABLE default  
=>from here BINARY DATA Image Blocks  
  
[Block T2W][Block Dxx][Block Dxy][Block Dxz]  
  
[Block Dyy][Block Dyz][Block Dzz]  
  
-----
```

The second line of the file describes the image orientation stored in the file and channels of the gradient directions.

The first channel is the T2W image for anatomical reference, the second to seventh channels are Dxx, Dxy, Dxz, Dyy, Dyz, Dzz in sequence, which are components of a tensor image. They are stored from the image volume block of the first channel to the image volume block of the last channel.

2. The coordinate system of Tensor Image

DVTK is stored as RAS coordinate system, i.e. left to right (x), posterior to anterior(y) and inferior to superior(z).

DoDTI assumes the stored tensor image in neurological convention, i.e., Left figure is left hemisphere and right is right hemisphere.

3. How to convert conventional MRI Diffusion weighted data to DVTK format

Currently, DoDTI supports conversion tool for LSDI files of GE MRI and REC file of EPI sequence at Philips MRI.

We are planning to add more conversion tools for other machines. We would greatly appreciate for any contributions for this.

If you have other MRI machines than above two MRIs, you can also generate DVTK file from analyze files.

It is rather simple to create DVTK if you can manage MATLAB. DoDTI also provides some codes for writing Tensor array to DVTK.

We would greatly appreciate if users can contribute the conversion code to DoDTI communities.

4. The file format of Gradient directions

In order to compose tensors from diffusion weighted images, DoDTI requires several types of information, such as direction vectors of Gradients and index of non-diffusion weighted image. It could be easily modified with a text editor.

grad/xxx.grad

Department of Diagnostic Radiology

134 Shinchon-Dong, Seodaemoon-Ku, Seoul, KOREA 120-749

Yonsei University College of Medicine

Tel : 82-2-361-5759 Fax: +82-2-393-3035

<http://neuroimage.yonsei.ac.kr/>
