EZ-tracing: A New Ready-to-Use Algorithm for Magnetic Resonance Tractography

EZ-tracing is a new algorithm for tractography based on diffusion tensor analysis (DTA). This method adopts a new algorithm for analyzing DTA data, lambda chart analysis (LCA), and effectively overcomes the main shortcomings of previous methods for tractography. It is written in MATLAB scripting language (MathWorks, Natick, MA, USA) and can be implemented on common operating systems, such as Microsoft Windows, UNIX, and LINUX. At present, EZ-tracing is available on Microsoft Windows, Red Hat LINUX, and Sun Solaris.

***** Disclaimer *****
This Software is provided "AS IS" and without warranties of any kind.
Download and/or use of EZ-tracing are expressly at users own risk.

Update history:

2002/04/11 Released version 2.0.
2002/06/03 Updated version 2.0.
2003/07/10 Released version 3.0.
2003/09/10 Fixed minor bugs.
2003/09/10 Added ezt_export_tractography.m and tractography.lkup. The former function M-file saves multiple images of slice tractography as Analyze 7.5 format. See the file itself for details.
2003/09/16 Updated the routine of interpolating matrices of dwi and base images.2005/06/24 Fixed minor bugs and released version 3.02.
2007/08/27 Fixed minor bugs and released version 3.10, which is available in MATLAB R2007a or later.
Note: The DLL files (ezt_*.dll) in the package do not work with MATLAB version 5.3. The DLL files available with MATLAB version 5.3, ezt_DLLs_V5.zip, can be downloaded from our website (http://coe.bri.niigata-u.ac.jp/).

Installation:

Download ezt310.zip from our website (http://coe.bri.niigata-u.ac.jp/), and unzip files into a directory of your choice. Execute MATLAB (version 5.3 or

later) and add this directory to the MATLAB Path.

How to use:

1. Start EZ-tracing:
Execute MATLAB and type "ezt" in MATLAB command prompt window followed by "return" and EZ-tracing control panel will appear.

2. Specify directory of full tensor diffusion weighted imaging files (hereinafter abbreviated DWI files):
Push "Directory" button (available in MATLAB version 6.5 or later) or enter directory name in the text box.

3. Specify diffusion gradient b value and MPG vector set:
Sum of diffusion gradient b value in each axis is 1000 sec/mm^2 by default. If needed, enter different value in the text box.
Directional pattern of motion probing gradient (MPG) in diffusion weighted imaging sequence is defined by MPG vector set. The initial setting of MPG vector set is,

none
(1, 0, 1)
(-1, 0, 1)
(0, 1, 1)
(0, 1, -1)
(1, 1, 0)
(-1, 1, 0),

where (x, y, z) direction correspond to (read-out, phase, slice).

To customize the directional pattern for MPG, create comma separated values (csv) file describing MPG vector set as a following example, and push "MPG vector..." button to select and load this file. See two samples in the unzipped files, "ezt_tensor_dat.txt" and "ezt_tensor_dat2.txt".

(start of file)

-0.754267366, 0.173499508, -0.633228759
0.330321246, -0.372227441, 0.867372242
-0.533035489, -0.458931922, 0.710812675
-0.686807856, -0.708384154, -0.162747843
-0.321357402, 0.941504078, -0.101486408
0.617869469, 0.786068318, -0.018273425
0.019352413, 0.576222568, 0.817063667
0.311368579, -0.948900372, 0.05135847
-0.882505894, 0.313694805, 0.350398224
-0.038448968, -0.536051111, -0.843309482
0.184148321, 0.468947288, -0.863815858
0.936881687, 0.003852304, 0.349625321
0.813567705, -0.236010694, -0.531419365
(end of file)

Note: Each MPG vector in csv file does not have to be normalized.

4. Select and load DWI files into MATLAB workspace:

Supported file formats and how to arrange DWI files:
a) Analyze 7.5 format (http://www.mayo.edu/bir/PDF/ANALYZE75.pdf)
The files consist of image files (*.img) and corresponding header files (*.hdr). Each image file is 2D or 3D (multiple-slice) diffusion weighted image with one of MPG vectors defined in MPG vector set. The files must be sequentially numbered as follows,

(in case of 4 slice 2D files)
1st acquisition
image001.img(hdr) :MPG none :slice 1
image002.img(hdr) :MPG none :slice 2
image003.img(hdr) :MPG none :slice 3
image004.img(hdr) :MPG none :slice 4
image005.img(hdr) :MPG vector (1, 0, 1) :slice 1
image006.img(hdr) :MPG vector (1, 0, 1) :slice 2
image007.img(hdr) :MPG vector (1, 0, 1) :slice 3
image008.img(hdr) :MPG vector (1, 0, 1) :slice 4

image009.img(hdr)　:MPG vector (-1,　0,　1)　:slice 1
image010.img(hdr)　:MPG vector (-1,　0,　1)　:slice 2
image011.img(hdr)　:MPG vector (-1,　0,　1)　:slice 3
image012.img(hdr)　:MPG vector (-1,　0,　1)　:slice 4
image013.img(hdr)　:MPG vector (0,　1,　1)　:slice 1
image014.img(hdr)　:MPG vector (0,　1,　1)　:slice 2
image015.img(hdr)　:MPG vector (0,　1,　1)　:slice 3
image016.img(hdr)　:MPG vector (0,　1,　1)　:slice 4
image017.img(hdr)　:MPG vector (0,　1, -1)　:slice 1
image018.img(hdr)　:MPG vector (0,　1, -1)　:slice 2
image019.img(hdr)　:MPG vector (0,　1, -1)　:slice 3
image020.img(hdr)　:MPG vector (0,　1, -1)　:slice 4
image021.img(hdr)　:MPG vector (1,　1,　0)　:slice 1
image022.img(hdr)　:MPG vector (1,　1,　0)　:slice 2
image023.img(hdr)　:MPG vector (1,　1,　0)　:slice 3
image024.img(hdr)　:MPG vector (1,　1,　0)　:slice 4
image025.img(hdr)　:MPG vector (-1,　1,　0)　:slice 1
image026.img(hdr)　:MPG vector (-1,　1,　0)　:slice 2
image027.img(hdr)　:MPG vector (-1,　1,　0)　:slice 3
image028.img(hdr)　:MPG vector (-1,　1,　0)　:slice 4
2nd acquisition
..., and so forth.

(in case of 3D files)
1st acquisition
image01.img(hdr)　: MPG none
image02.img(hdr)　: MPG vector (1,　0,　1)
image03.img(hdr)　: MPG vector (-1,　0,　1)
image04.img(hdr)　: MPG vector (0,　1,　1)
image05.img(hdr)　: MPG vector (0,　1, -1)
image06.img(hdr)　: MPG vector (1,　1,　0)
image07.img(hdr)　: MPG vector (-1,　1,　0)
2nd acquisition
image08.img(hdr)　: MPG none
image09.img(hdr)　: MPG vector (1,　0,　1)
image10.img(hdr)　: MPG vector (-1,　0,　1)

image11.img(hdr)　: MPG vector (0, 1, 1)
image12.img(hdr)　: MPG vector (0, 1, -1)
image13.img(hdr)　: MPG vector (1, 1, 0)
image14.img(hdr)　: MPG vector (-1, 1, 0)
..., and so forth.

b) DICOM format (http://www.psychology.nottingham.ac.uk/staff/cr1/dicom.html)
The files (*.dcm) must be sequentially numbered as a following example of 4 slices,

1st acquisition
image001.dcm　:MPG none　:slice 1
image002.dcm　:MPG none　:slice 2
image003.dcm　:MPG none　:slice 3
image004.dcm　:MPG none　:slice 4
image005.dcm　:MPG vector (1, 0, 1)　:slice 1
image006.dcm　:MPG vector (1, 0, 1)　:slice 2
image007.dcm　:MPG vector (1, 0, 1)　:slice 3
image008.dcm　:MPG vector (1, 0, 1)　:slice 4
image009.dcm　:MPG vector (-1, 0, 1)　:slice 1
image010.dcm　:MPG vector (-1, 0, 1)　:slice 2
image011.dcm　:MPG vector (-1, 0, 1)　:slice 3
image012.dcm　:MPG vector (-1, 0, 1)　:slice 4
image013.dcm　:MPG vector (0, 1, 1)　:slice 1
image014.dcm　:MPG vector (0, 1, 1)　:slice 2
image015.dcm　:MPG vector (0, 1, 1)　:slice 3
image016.dcm　:MPG vector (0, 1, 1)　:slice 4
image017.dcm　:MPG vector (0, 1, -1)　:slice 1
image018.dcm　:MPG vector (0, 1, -1)　:slice 2
image019.dcm　:MPG vector (0, 1, -1)　:slice 3
image020.dcm　:MPG vector (0, 1, -1)　:slice 4
image021.dcm　:MPG vector (1, 1, 0)　:slice 1
image022.dcm　:MPG vector (1, 1, 0)　:slice 2
image023.dcm　:MPG vector (1, 1, 0)　:slice 3
image024.dcm　:MPG vector (1, 1, 0)　:slice 4

image025.dcm :MPG vector (-1, 1, 0) :slice 1
image026.dcm :MPG vector (-1, 1, 0) :slice 2
image027.dcm :MPG vector (-1, 1, 0) :slice 3
image028.dcm :MPG vector (-1, 1, 0) :slice 4
2nd acquisition
..., and so forth.

Similarly, in customized directional pattern for MPG, DWI files in both file formats must be sequentially numbered in the same order as those of corresponding MPG vectors described in csv file, as a following example of 3D Analyze format,

1st acquisition
image01.img(hdr) : MPG none
image02.img(hdr) : MPG vector in 1st line in the csv file
image03.img(hdr) : MPG vector in 2nd line in the csv file
image04.img(hdr) : MPG vector in 3rd line in the csv file
image05.img(hdr) : MPG vector in 4th line in the csv file
image06.img(hdr) : MPG vector in 5th line in the csv file
image07.img(hdr) : MPG vector in 6th line in the csv file
image08.img(hdr) : MPG vector in 7th line in the csv file
image09.img(hdr) : MPG vector in 8th line in the csv file
image10.img(hdr) : MPG vector in 9th line in the csv file
..., and so forth.

To select and load Analyze or DICOM files arranged as above, push "Analyze files...", or "DICOM files..." button. Change number of acquisitions in the text box in need. The figures of loaded images will appear. When another slice level of interest is selected using the pop list, the corresponding images will come up. The image parameters such as matrix size, FOV, and slice thickness (with spacing) are read from the header of the files and displayed in the control panel.

Note:
i) Please make sure of the specified directory before pushing "Analyze files..." or "DICOM files..." button. In addition, DWI files must be named with

extension, ".img" and ".hdr" in Analyze format, and ".dcm" in DICOM format, respectively. Pushing these buttons will only list files with these extensions in the directory.

ii) In EZ-tracing, the slice is supposed to be ordered from superior to inferior. If DWI files are numbered in the opposite order, click on "reverse slice" checkbox in the main control panel before pushing "Analyze files..." or "DICOM files..." button.

iii) In loading 2D Analyze or DICOM files, number of slices is decided from three parameters: number of directional patterns for MPG, number of selected files, and number of acquisitions. One must confirm these parameters correctly before pushing "Analyze files..." or "DICOM files..." button.

iv) In selecting Analyze or DICOM files in the list box, one cannot select the files in an arbitrary order. Selected files will be loaded in alphabetical order.

v) When one click on "interpolation" checkbox, matrices of loaded diffusion weighted images will be interpolated in slice plane (x-y plane) to those of double resolution. Although this is a time-consuming process, it often yields better results for tractography

5. Select and load files of base image for slice tractography into MATLAB workspace (optional):

One can specify structural base image (such as T1 weighed image) for slice tractography in much the same way as in the case of DWI files described above. Otherwise, tractography will be overlaid on the diffusion weighted image without MPG.

Note:

i) One must select and load DWI files first.

ii) Resolution of base image will be resized to that of diffusion weighted image.

6. Trimming images (optional):

Push "trimming" button and the diffusion weighted image without MPG in the selected slice level will appear in another figure for determining a trimming rectangle. To specify a trimming rectangle, drag mouse pointer from one of the corners of a rectangle and a green rectangle will appear when the pointer

rests. This rectangle can be moved by another mouse dragging or can be resized by dragging each corner of the rectangle. To determine trimming rectangle finally, push any key with keyboard. This trimming rectangle will apply to all of the loaded diffusion weighted and base images in all of the slice levels, and the figures will be updated with the trimmed images.

7. Create tractography:
Push "tracing" button, and the diffusion weighted image without MPG will appear in another figure. Specify slice level for selecting seed voxels in the pull down list, and push "select seed voxels" button. Choose one of the options for selecting seed voxels (yellow) on the image. When you push "confirm selected voxels", EZ-tracing will perform diffusion tensor analysis of all voxels and, in a while, will display a dialog box for input parameters of the condition for tracing. If needed, this condition can be edited. Subsequently, 3D and slice tractographies will be created.

Note: When the "specify seed points" checkbox is clicked, all voxels of the image matrix will be selected as seed points for tracing.

8. To reset current data in MATLAB workspace, push "reset" button.

9. To exit EZ-tracing, push "exit" button.

For details of this algorithm, see our article, K. Terajima and T. Nakada. EZ-tracing: a new ready-to-use algorithm for magnetic resonance tractography. J NeuroSci Methods 2002;116;147-155.

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