Extraction of White Matter Connectivity in the Human Brain Using the Projected Diffusion Tensor Distance

Tetsuo Sato * and Kotaro Minato *

* Graduate School of Information Science,

Nara Institute of Science and Technology

Introduction

- MRI is important modality for imaging human brain function and structure
- With the development of devices, we can measure diffusion of water molecules (Bihan et al. 1986)
- Using diffusion tensor maps, we can obtain structural information of nerve bundles in white matter (Moseley et al. 1990)

Aim

- Obtain structural information of white matter trajectories
- Enhance and detect nerve bundles

⬇

Qualitative analysis of white matter trajectories

Apply the result to the statistical test of human brain function

Diffusion Coefficients

- Diffusion coefficients calculated from diffusion weighted images are reflecting the relative direction between diffusion gradient and fiber trajectories
  - Parallel measurements along a trajectory
    - High coefficient
  - Perpendicular measurements along a trajectory
    - Low coefficient

Diffusion Tensor

$$\begin{pmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{xy} & D_{yy} & D_{yz} \\ D_{xz} & D_{yz} & D_{zz} \end{pmatrix} \rightarrow \begin{pmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{pmatrix}$$

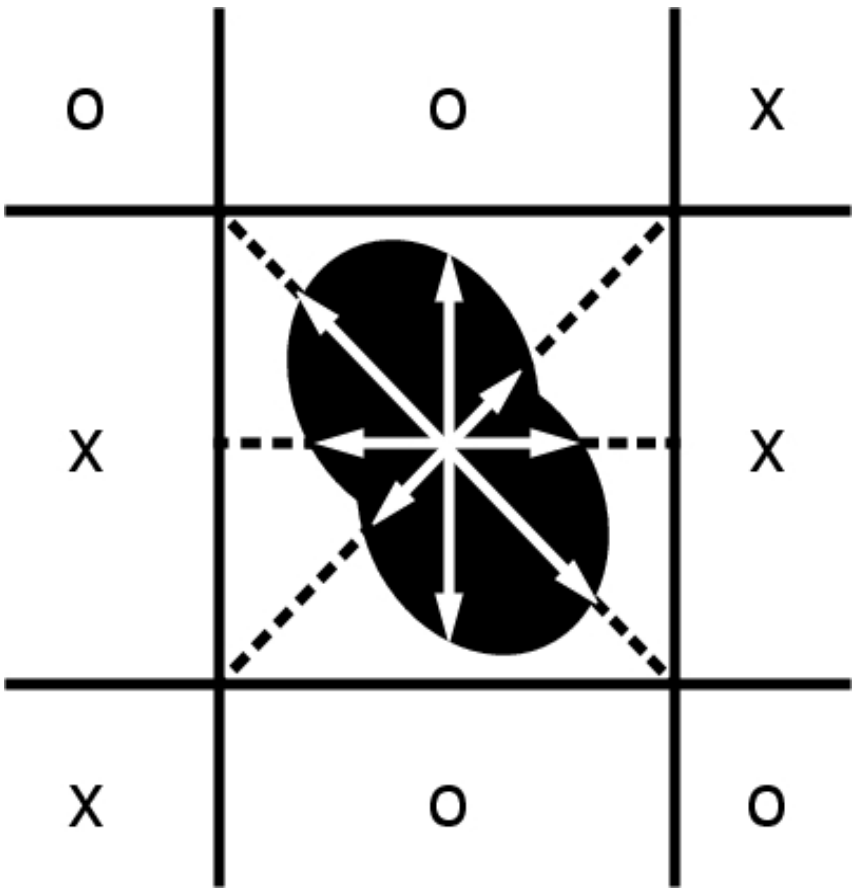
Diffusion tensor whose components are from diffusion coefficients

- Eigenvalues
  - Principal（e_1）, second（e_2）, third（e_3）
- Principal eigenvector
  - X, Y, Z components
- Fractional anisotropy（FA）

Diffusion Distance Analysis

- The connectivity is determined as a function of distance between the origin of the tensor and the surface for each voxel
- This approach is different from other methods that use the principal eigenvector or full tensor

Iterative Algorithm



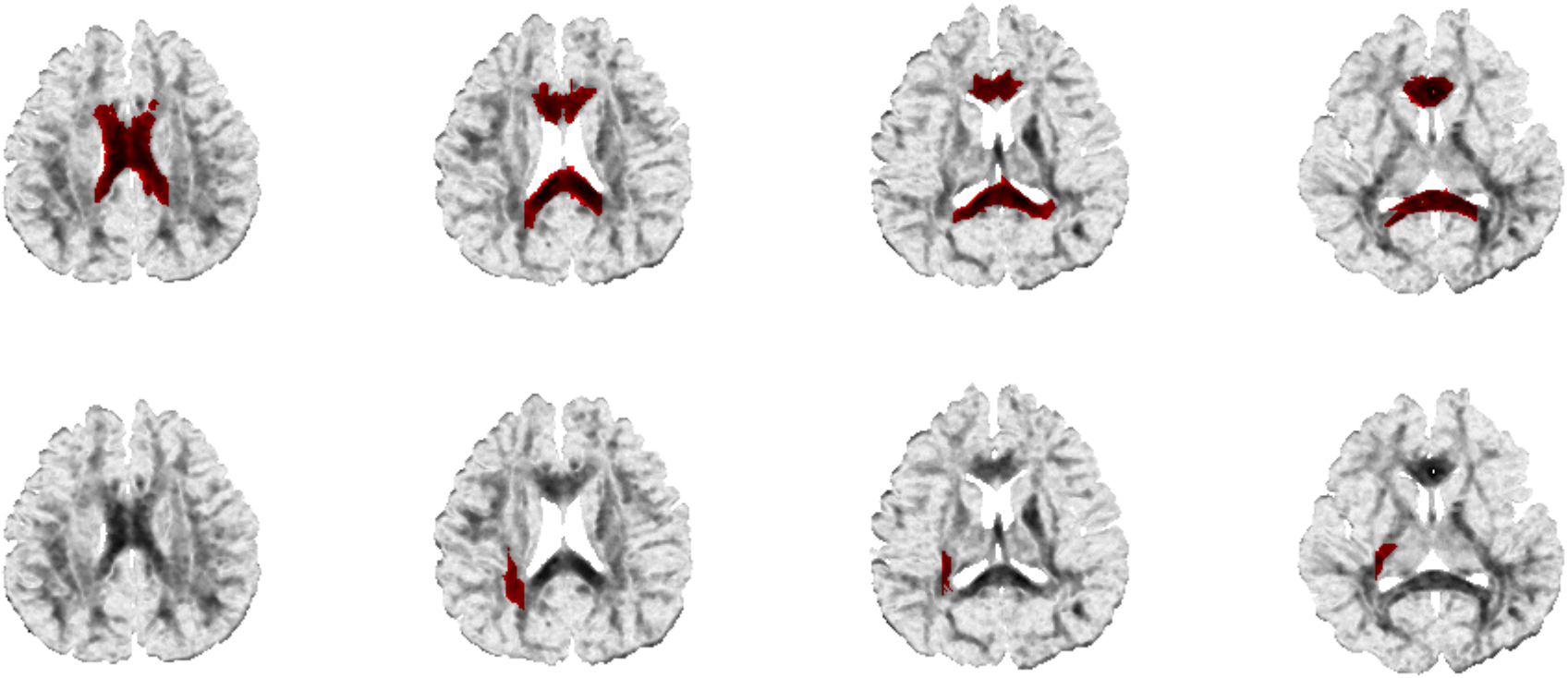
- Start from the center in the left, next check right-up, up, left-up, right-down, down, left-down iteratively
- Continue searching until visiting the already tracked voxel again

Distance Potential

$$\varphi_i = \{\vec{x}_i{}^t D\vec{x}_i / Trace(D_i)\}\{\vec{x}_j{}^t D\vec{x}_j / Trace(D_j)\}$$

- Consider the normalized distance potential combining by the in-coming distance and the out-going distance divided by its trace (D)
- Where i indicates the reference, j indicates the neighborhood

Result



Result of an iterative algorithm superimposed on cor-responding FA images

(8 contiguous slices: dark regions are seeding from Corpus Callosum and Internal Capsule)

Discussion

- The result of the algorithm depends on the threshold value
- To determine the value statistically and automatically is important
- To verify the feasibility of our methods by way of adding noise simulation will be important before using the method in clinical studies

Conclusion

- In this study, we propose a method to assess the white matter connectivity using projected diffusion tensor distance
- Proposed algorithm is different from other tracking methods and has potential to be used in combination with conventional tracking algorithm

References

1. Le Bihan D, Breton E, Lallemand D, Grenier P, Cabanis E, Laval-Jeantet M. MR imaging of intravoxel incoherent motions: application to diffusion and perfusion in neurologic disorders. Radiology. 1986 Nov;161(2):401-7.
2. Moseley ME, Cohen Y, Kucharczyk J, Mintorovitch J, Asgari HS, Wendland MF, Tsuruda J, Norman D. Diffusion-weighted MR imaging of anisotropic water diffusion in cat central nervous system. Radiology. 1990 Aug;176(2):439-45.

Acknowledgments

This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Young Scientists (B), 16700360.

Address for correspondence

Tetsuo Sato
Graduate School of Information Science,
Nara Institute of Science and Technology,
8916-5 Takayama-cho, Ikoma, Nara, Japan 630-0192
E-mail: tsato@is.naist.jp