Visualization of Diffusion Image Data and its Possible Models

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Diffusion MRI detects anisotropy

Kleenex newspaper

Anisotropy: directional variation in diffusivity

Diffusion-weighted MRI measures “apparent diffusion coefficient” (ADC) along many directions

Microstructure of bundles directionally constrains water diffusion along fiber direction (LeBihan et al. 1985)
Single Tensor Model (Basser 1994)

\[ A_i(b, g) = A_0 e^{-bg_i^T D g_i} \]

Linear regression

**Tensors from diffusion-weighted images (DWI)**

**Data, model, parameters**

Difficult to visualize (and maybe pointless?)

What we (as Vis practitioners) typically visualize

What others (mostly) do quantitative studies on

Derived scalars:
- Bulk mean diffusivity
- Fractional Anisotropy FA
Clinical DTI Applications: Model Parameters

- Changes in FA due to pathology
  - Really the mainstay of DTI applications
- Change in FA/diffusivity relationship
  - E.g. Tumor Infiltration Index (Lu et al. ‘04)
- Eigenvectors \(\rightarrow\) connectivity (around tumors, to functional cortical areas, its symmetry)
- Model parameters are reliably measured, biologically meaningful, clinically significant
Beyond the Single Tensor Model

- Two (or more) Tensors ($D_1$ and $D_2$)
  \[ A_i = A_0(e^{-bg_i^TD_1g_i} + (1 - \alpha)e^{-bg_i^TD_2g_i}) \]
- Trendy: No/minimal model (e.g. spherical harmonics)
  - Transforms go from ADCs to fiber orientations
  - Fiber crossing resolution
Tractography with 1,2 tensors, synthetic

(planar anisotropy; no main diffusion direction; not possible)

Tractography with 1,2 tensors, real
Visualization as **data↔model** inspection

- Visualize underlying DWI data
  - How noisy?
  - How complicate a model can it support?
- Inspect **relationship** of DWI data ↔ 1-tensor model
  - Systematic errors highlight fiber crossings
- General ideas:
  - Use intuition of old (single tensor model) as guide
  - Use visualization to “illuminate” path forward to more complicated models

**Synthetic Data**

Visualizing single tensor fit (w/ RGB orientation coding)

No indication of how well the model fits the data

If it’s a poor fit, why?
Synthetic Data

ADC profile colored by single-tensor error
Color highlights single-tensor model fails
• Models enable science on complex data

• Complex data supports multiple models

• Choice between models, and the consequences of the models, can be informed by visualization
  • Also quantitatively: Akaike Information Criterion

• What are other examples of this?
  • Medical: fMRI
  • Non-medical? Do tell!!
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