Visualization of Diffusion Image Data and its Possible Models

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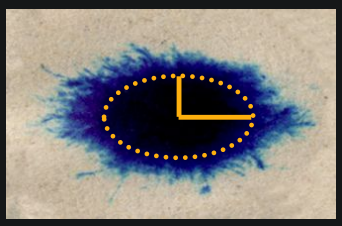
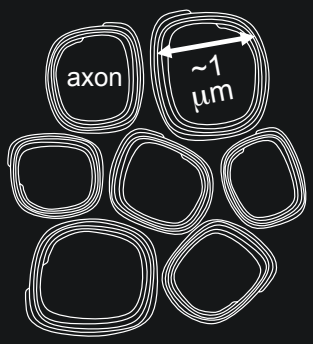
Diffusion MRI detects anisotropy

Kleenex



newspaper

White Matter fiber bundle Cross-section:



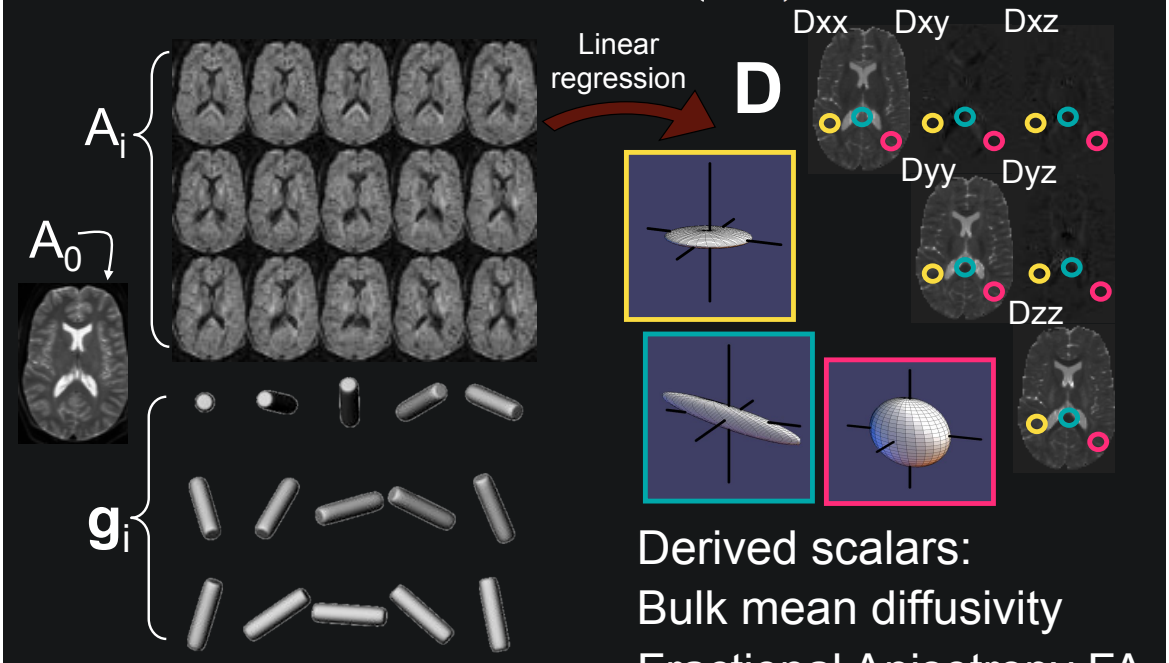
Anisotropy: directional variation in diffusivity

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)

Tensors from diffusion-weighted images (DWI)

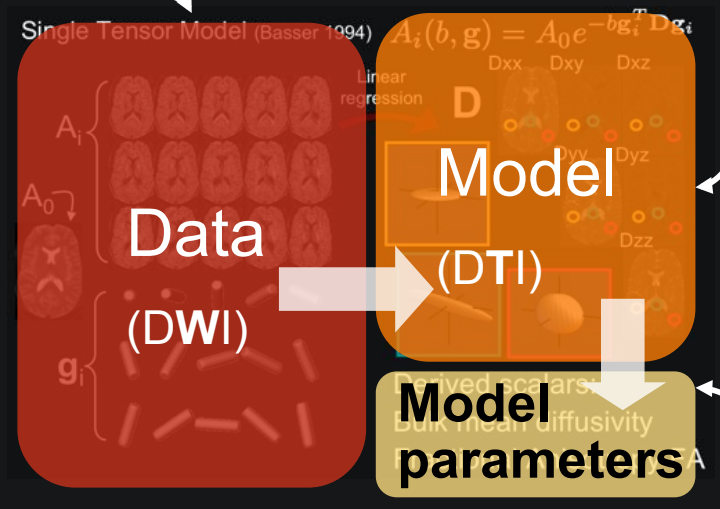
Single Tensor Model (Basser 1994) $A_i(b, \mathbf{g}) = A_0 e^{-b\mathbf{g}_i^T \mathbf{D} \mathbf{g}_i}$



Derived scalars:
Bulk mean diffusivity
Fractional Anisotropy FA

Data, model, parameters

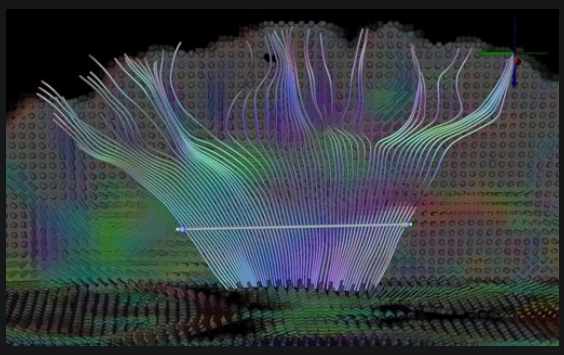
Difficult to visualize (and maybe pointless?)



What we (as Vis practitioners) typically visualize

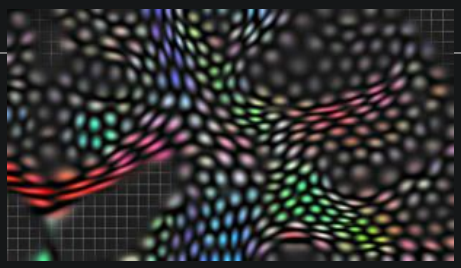
What others (mostly) do quantitative studies on

DTI Visualizations

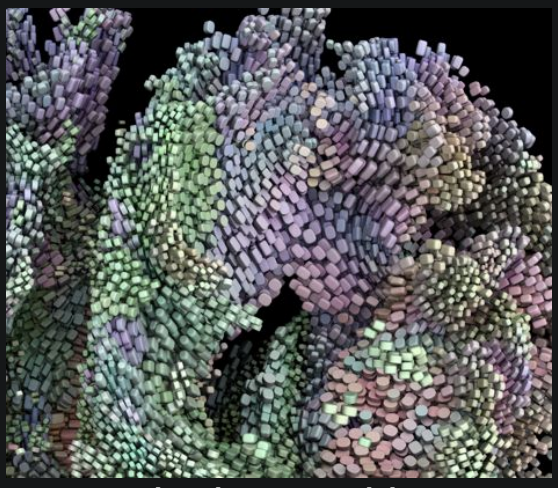


fiber tractography

volume rendering



textures

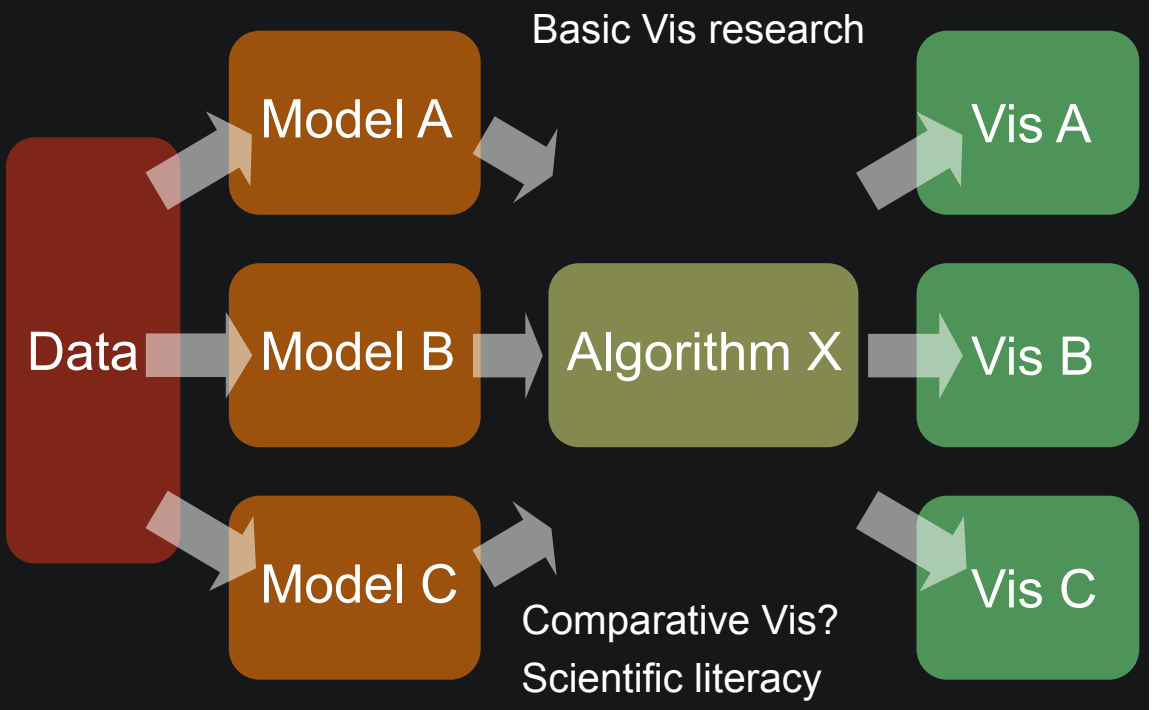


glyphs, packing

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 → connectivity (around tumors, to functional cortical areas, its symmetry)
- Model parameters are reliably measured, biologically meaningful, clinically significant

Data, Multiple Models/Explanations, Visualization

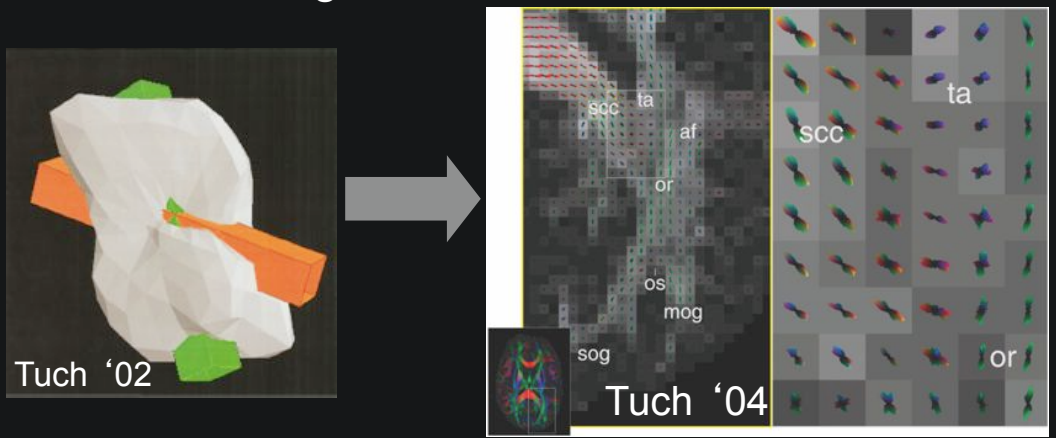


Beyond the Single Tensor Model

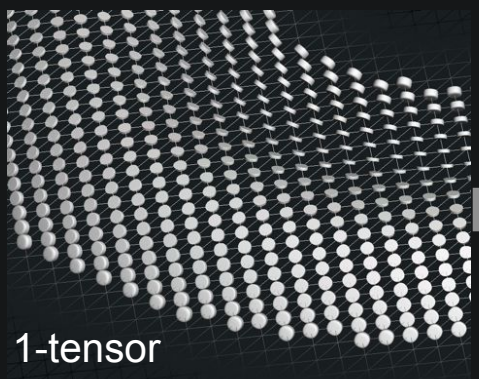
- Two (or more) Tensors ($\mathbf{D}_1$ and $\mathbf{D}_2$)

$$A_i = A_0(\alpha e^{-b\mathbf{g}_i^T \mathbf{D}_1 \mathbf{g}_i} + (1-\alpha)e^{-b\mathbf{g}_i^T \mathbf{D}_2 \mathbf{g}_i})$$

- Trendy: No/minimal model (e.g. spherical harmonics)
  - Transforms go from ADCs to fiber orientations
  - Fiber crossing resolution

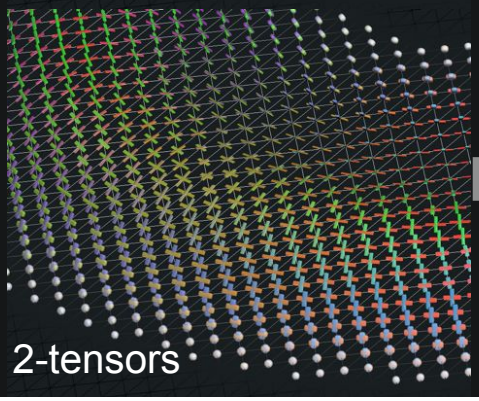


Tractography with 1,2 tensors, synthetic

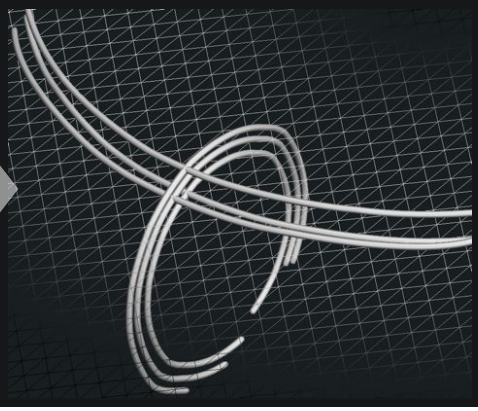


1-tensor

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



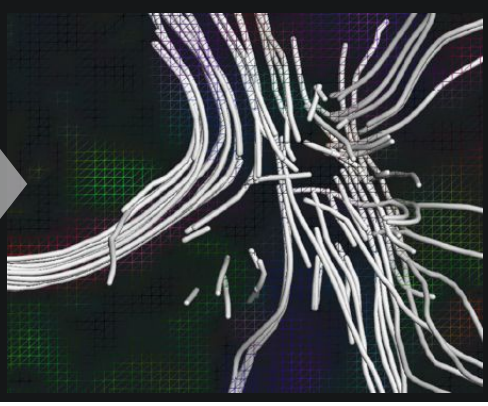
2-tensors



Tractography with 1,2 tensors, real

1-tensor

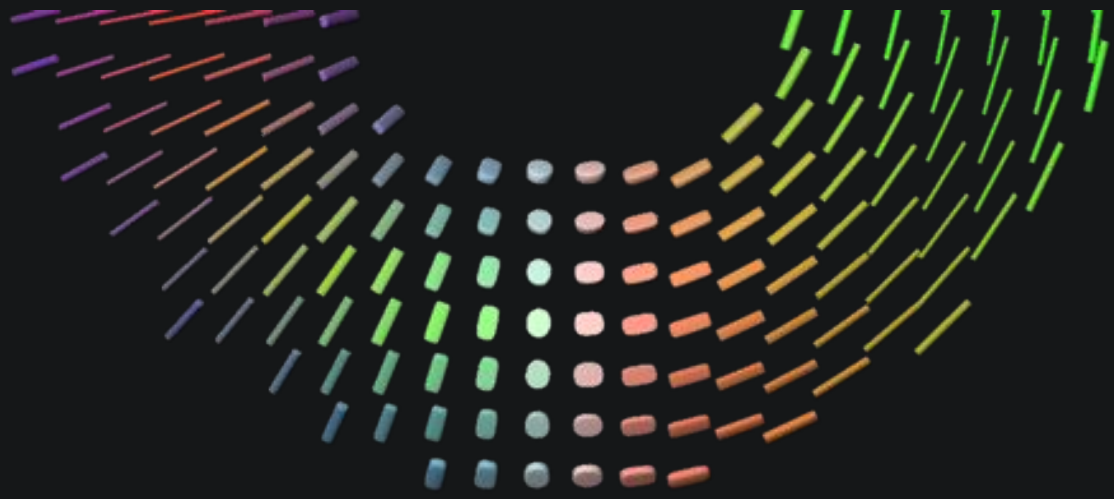
2-tensors



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

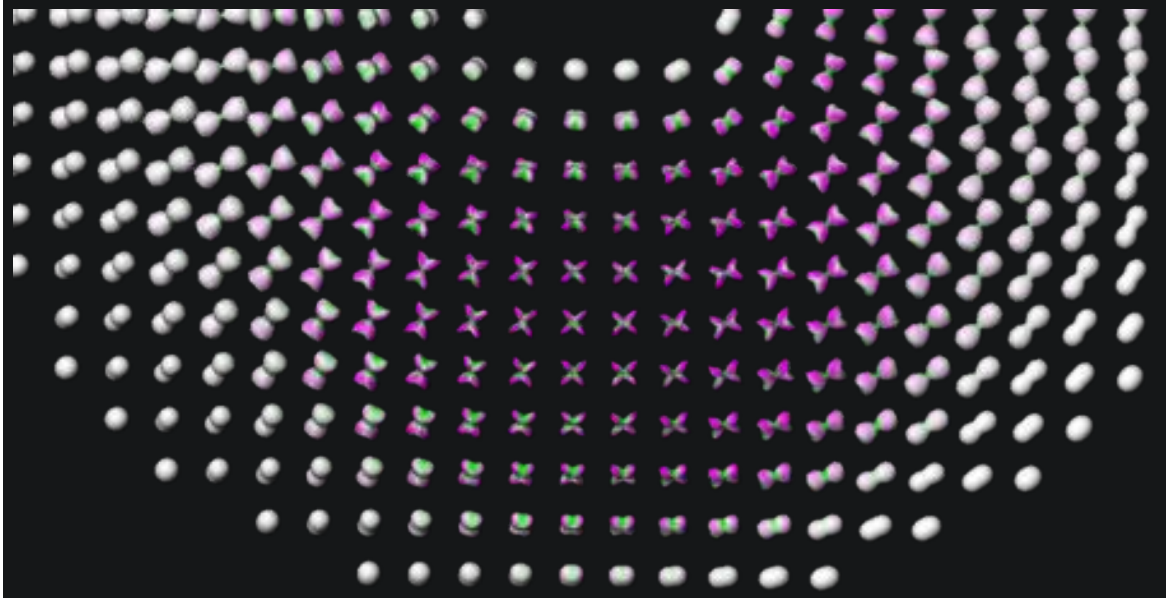


Visualizing single tensor fit (w/ RGB orientation coding)

No indication of how well the model fits the data

If it's a poor fit, why?

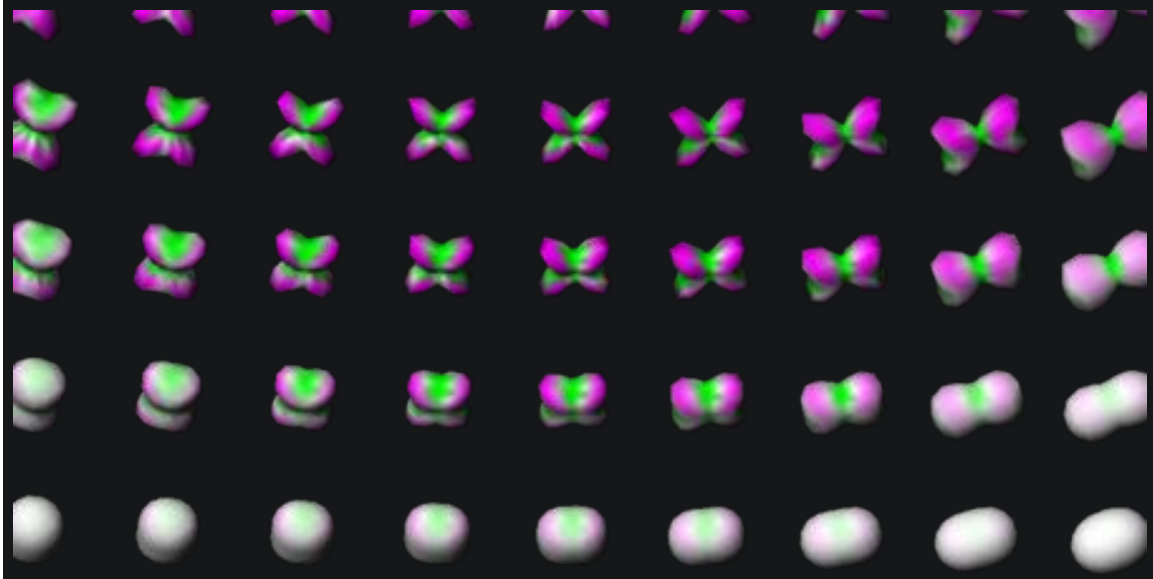
Synthetic Data



ADC profile colored by single-tensor error

Color highlights single-tensor model fails

Synthetic Data



ADC profile colored by single-tensor error

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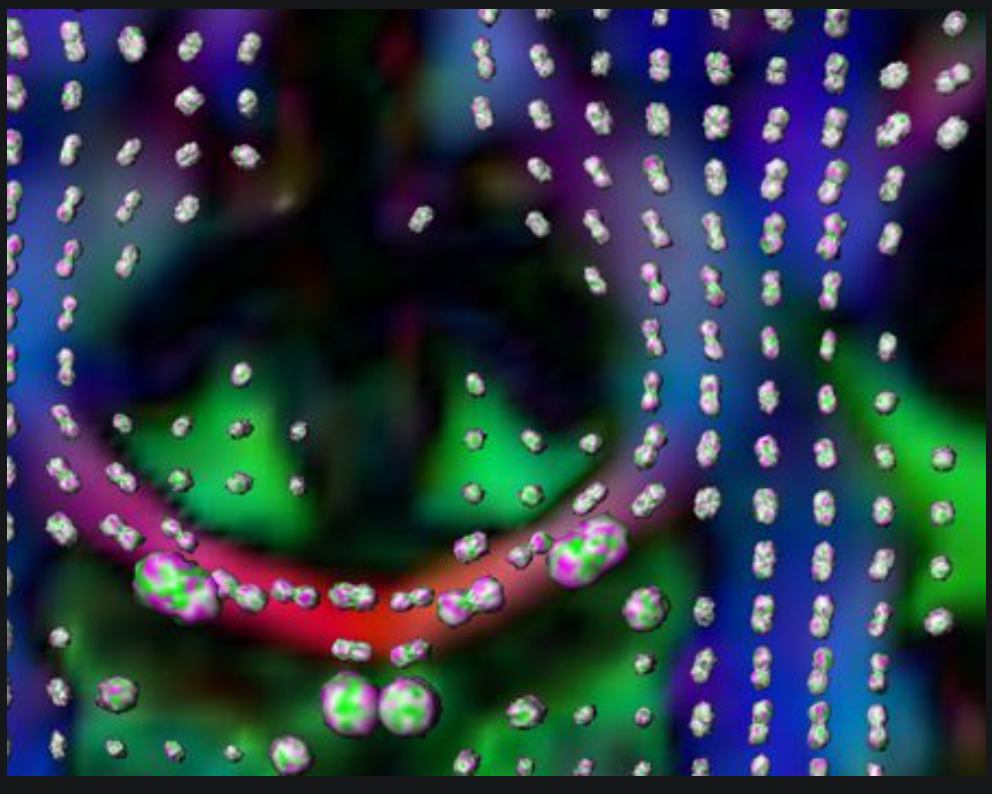
Real Data



Discussion

- 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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thank you