

# Diffusion Tensor Visualization With Glyph Packing

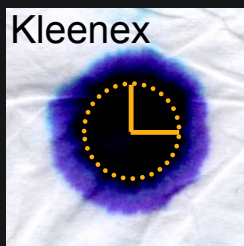
Gordon Kindlmann, Carl-Fredrik Westin



Laboratory of Mathematics in Imaging  
Department of Radiology  
Brigham & Women's Hospital  
Harvard Medical School

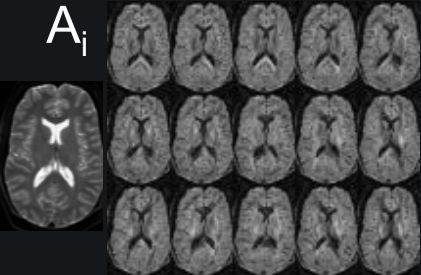
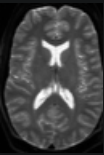
## Diffusion tensor imaging (DTI)

2/15 

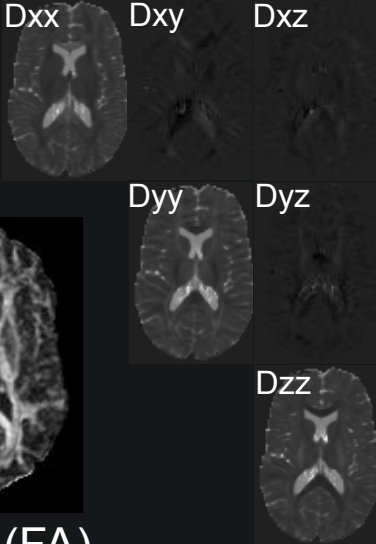



anisotropy

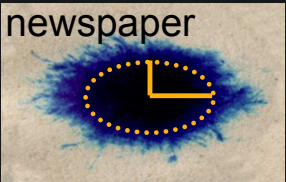
# Diffusion tensor imaging (DTI)

$A_i$    $A_0$  

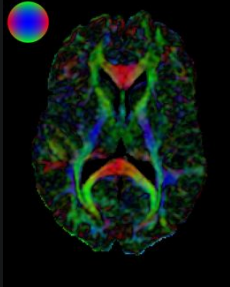
$A_i(b, \mathbf{g}) = A_0 e^{-b \mathbf{g}_i^T \mathbf{D} \mathbf{g}_i}$   
(Basser 1994)

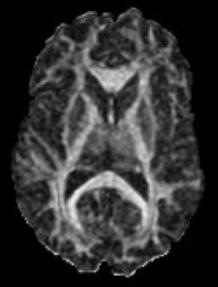
$\mathbf{D}$  

 Kleenex

 newspaper

anisotropy

  $\text{RGB}(\mathbf{e}_1)$

 fractional anisotropy (FA)

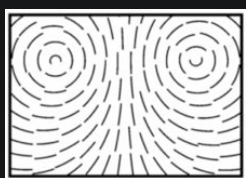
# Glyph packing compared to grid, fibers

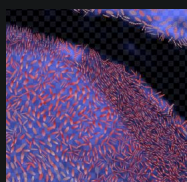
Formation of **discrete** glyphs into a **continuous** texture  
Need tensor interpolation

  $\text{RGB}(\mathbf{e}_1)$   FA

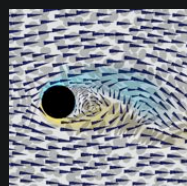
## Textures



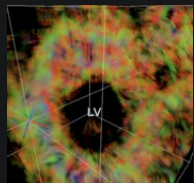
Turk & Banks '96



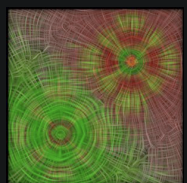
Laidlaw et al. '98



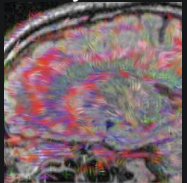
Kirby et al. '99



Sigfridsson et al. '02

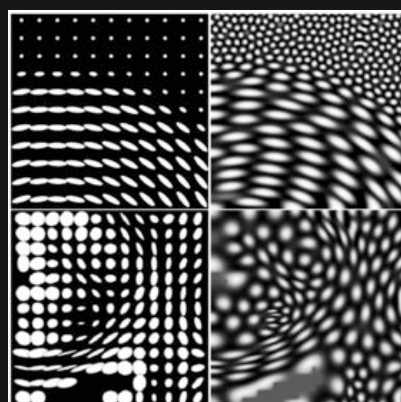


Hotz et al. '04



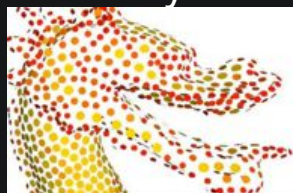
Benger et al. '06

## Reaction-Diffusion



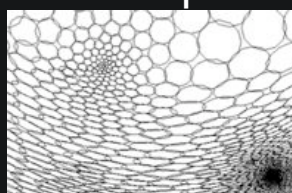
Kindlmann et al. '00

## Particle systems

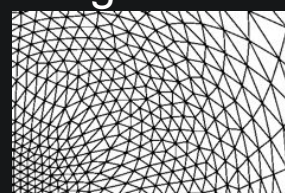


Meyer et al. '05

## Anisotropic Meshing



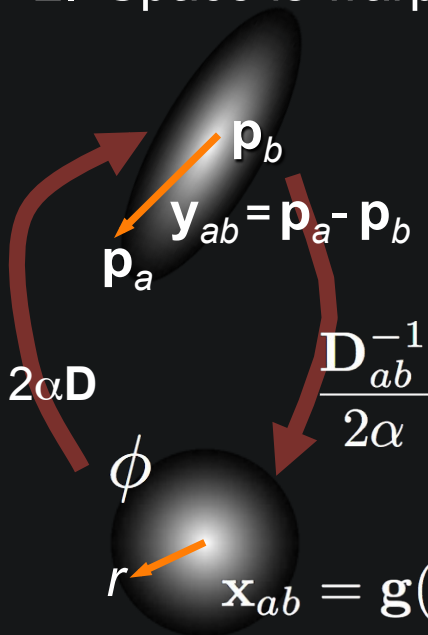
Shimada et al. '00



Bossen et al. '96

# Tensor-based potential energy

1. Particles push each other away
2. Space is warped by the local tensor



$$E_{ab} = \phi(r_{ab}) = \phi(|\mathbf{g}(\mathbf{y}_{ab})|)$$

$$\mathbf{D}_{ab} = \mathbf{D}\left(\frac{\mathbf{p}_a + \mathbf{p}_b}{2}\right)$$

$$\mathbf{x}_{ab} = \mathbf{g}(\mathbf{y}_{ab}) = \frac{\mathbf{D}_{ab}^{-1} \mathbf{y}_{ab}}{2\alpha}; r_{ab} = |\mathbf{x}_{ab}|$$

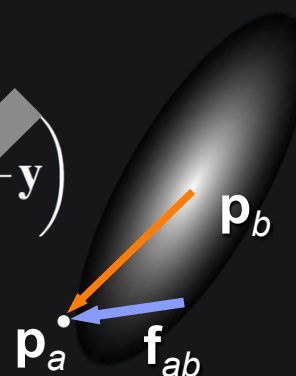
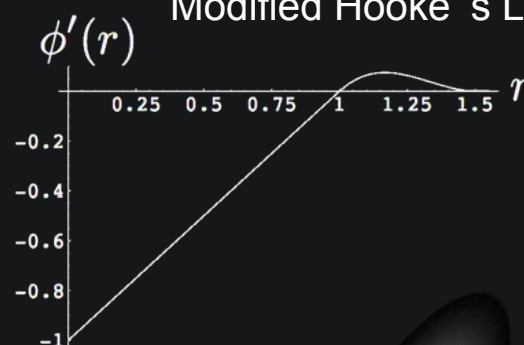
$$E = \phi(|\mathbf{g}(\mathbf{y})|)$$

$$\frac{dE}{d\mathbf{y}} = \frac{dE}{dr} \frac{dr}{d\mathbf{x}} \frac{d\mathbf{x}}{d\mathbf{y}}$$

$$= \phi'(|\mathbf{x}|) \frac{\mathbf{x}^T}{|\mathbf{x}|} \frac{1}{2\alpha} \left( \mathbf{D}^{-1} + \frac{d\mathbf{D}^{-1}}{d\mathbf{y}} \mathbf{y} \right)$$

$$\mathbf{f}_{ab} = -\frac{\phi'(|\mathbf{x}_{ab}|)}{2\alpha} \mathbf{D}_{ab}^{-1} \frac{\mathbf{x}_{ab}}{|\mathbf{x}_{ab}|}$$

Modified Hooke's Law



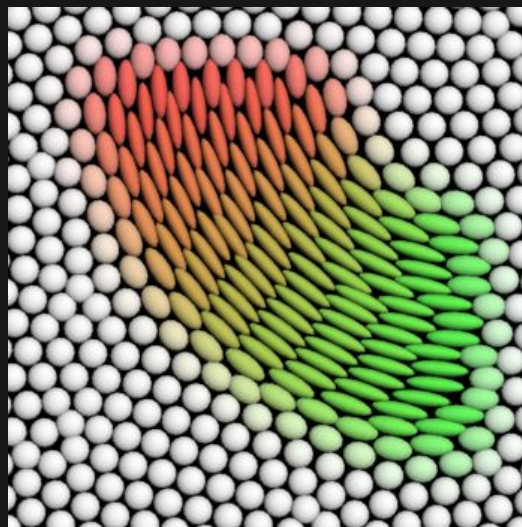
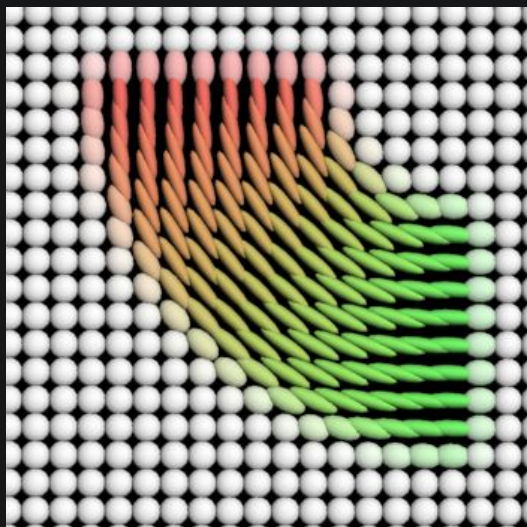
## Implementation

- Spatial Binning
- Inverse approximation :  $\mathbf{D}_{ab}^{-1} \approx \frac{\mathbf{D}^{-1}(\mathbf{p}_a) + \mathbf{D}^{-1}(\mathbf{p}_b)}{2}$
- Constraints on slices
- Solver:  $F=ma$  vs. Gradient descent
  - Order of faster convergence times than paper
- Probabilistically re-use probed tensors



## Results: synthetic data

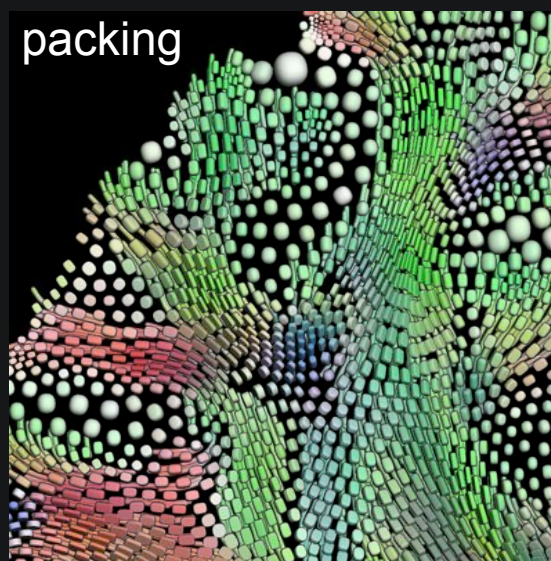
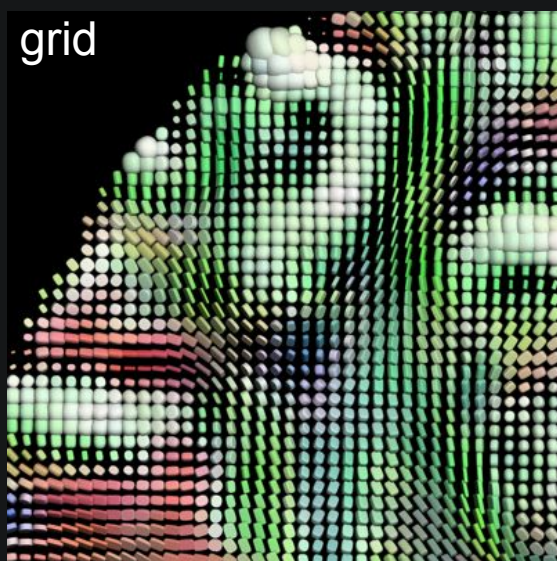
9/15



Glyph overlap reduced  
Smoother orientation change  
Problem (?): new hexagonal grid  
Packing results can seed other glyph geometry

## Results: healthy slice

10/15

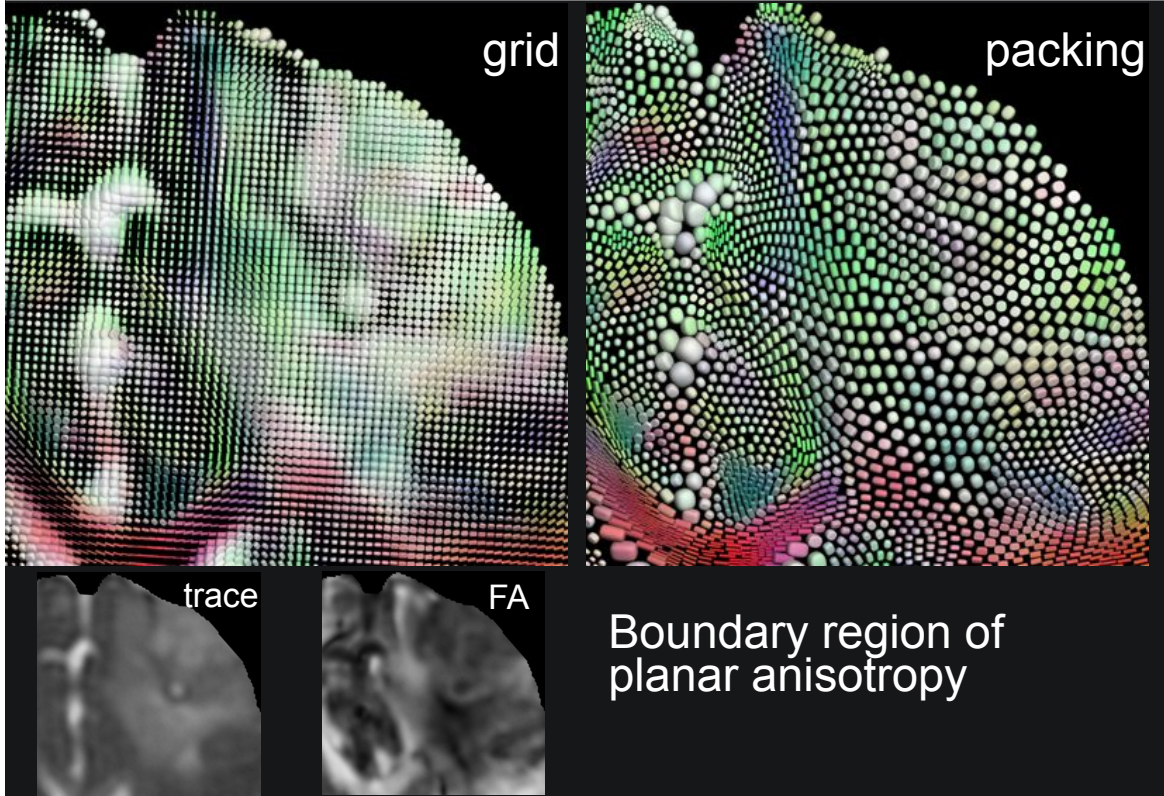


Tracts only in linear anisotropy; glyphs everywhere  
Glyph packing complements tractography



# Results: oligodendrogloma slice

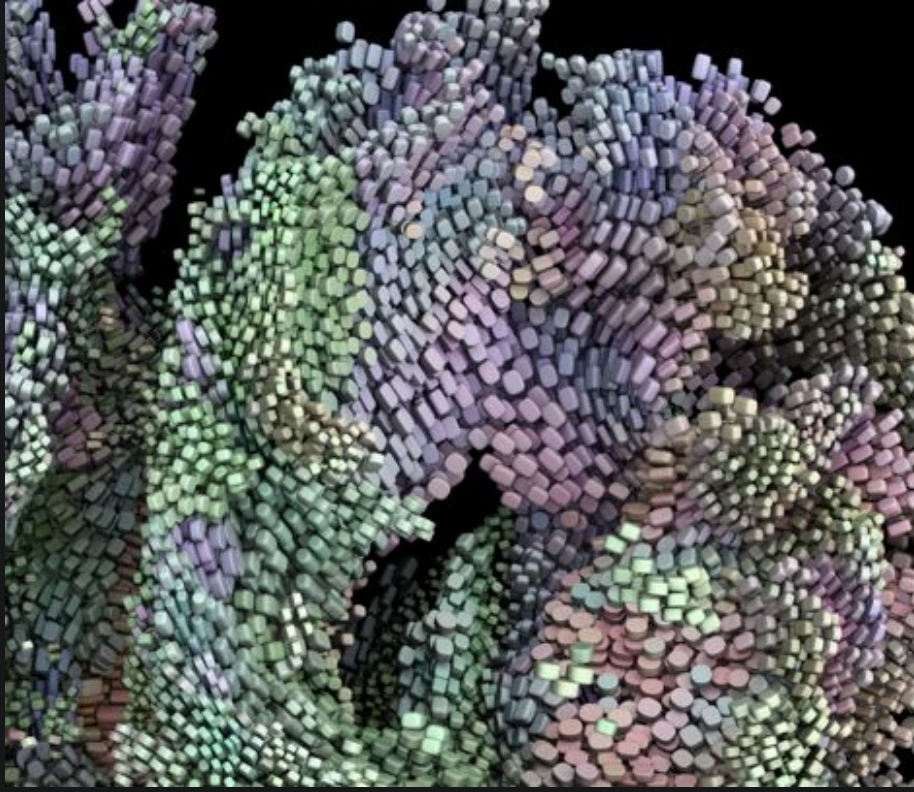
11/15



# Results: volume of glyphs

12/15





## Conclusions & Future Work



- 3D glyphs can compose a dense, texture-like tensor field visualization in 2D or 3D.
- Particle systems have a role in tensor vis.
- Glyph-based tensor field visualizations can work in three dimensions.
- Implicit surfaces, tensor field derivative
- Rendering effects, painterly techniques
- User study? (Acevedo et al. Vis '06)



## Acknowledgements

15/15



- NIH funding: NIBIB T32-EB002177, NCRR P41-RR13218 (NAC), R01-MH050740
- Alexandra Golby, MD; U41-RR019703-01A2, Brain Science Foundation.
- URL for paper + software info:  
<http://lmi.bwh.harvard.edu/~gk/vis06/>

thank you