AFNI User Group Meeting

Anisotropic Smoothing

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Anisotropic Smoothing

- Image filtering operation that preferentially smoothes one part of an image versus another.
- This operation is in contrast to the more standard mean, median and Gaussian smoothing operations.
- Method based on Ding (Weickert, et al and Gerig, et al). Diffusion-based filtering.

Anisotropic Smoothing

Pseudo-code for DWI data (SmoothDWI) (2D only)

U_0 is original image data

For i=0 to 10

- Compute Image diffusion tensor (D)
  - Smooth U_i a little with Gaussian (sigma=0.5)
  - Compute gradients, matrix of products of gradients R=[$(du/dx)^2$ (du/dx)(du/dy); (du/dx)(du/dy) $(du/dy)^2$]
  - Smooth each component of R (sigma=1)
  - Compute eigenvalues (μ_1, μ_2) vectors for R
  - Compute $\phi_1 = 1/(\mu_1 * s)$, $\phi_2 = 1/(\mu_2 * s)$ where $s = 1/\mu_1 + 1/\mu_2$ (Ding method)
  - or $\phi_1 = 0.01 + 0.99 \exp[-0.01/(\mu_1 - \mu_2)^2]$, $\phi_2 = 0.01$ (exp method)

  Compute $D = V \Phi V^T$ where $\Phi = [\phi_1 \ 0; 0 \ \phi_2]$
- Smooth image dataset (DWI data) given D
  - Compute flux in image J_x, J_y
    - Jx = Exx du/dx + Exy du/dy
    - Jy = Exy du/dx + Eyy du/dy

    where E = [Dxx-Dm Dxy; Dxy Dyy-Dm] and Dm = mean diffusivity
  - $G_{pqn} = dJ_x/dx + dJ_y/dy$ = anisotropic part of the smoothing
  - $U_{p,q,n+1} = U_{p,q,n} + \Delta t \, (F_{pqn} + G_{pqn})$
  - where $F = Dm / \Delta x^2 * U_{smooth}$ = isotropic smoothing

    and Δt = Dmax/4

End loop

3danisosmooth

Usage: **3danisosmooth** [options] dataset

Smooth a DWI dataset using anisotropic smoothing.

The output dataset is preferentially smoothed in similar areas

may use a sub-brick selection list, as in program 3dcalc.

Options :

- **-prefix** pname = Use 'pname' for output dataset prefix name.
- **-iters** nnn = compute nnn iterations (default=10)
- **-2D** = smooth a slice at a time
- **-3D** = smooth through slices. Can not be combined with 2D option
- **-mask** dset = use dset as mask to include/exclude voxels
- **-automask** = automatically compute mask for dataset

  Can not be combined with -mask
- **-viewer** = show central axial slice image every iteration.

  Starts aiv program internally.

-nosmooth = do not do intermediate smoothing of gradients

-sigma1 n.nnn = assign Gaussian smoothing sigma before gradient computation for calculation of structure tensor. Default = 0.5

-sigma2 n.nnn = assign Gaussian smoothing sigma after gradient matrix computation for calculation of structure tensor. Default = 1.0

-deltat n.nnn = assign pseudotime step. Default = 0.25

-savetempdata = save temporary datasets each iteration. Dataset prefixes are Gradient, Eigens, phi and Dtensor. Each is overwritten each iteration.

-phiding = use Ding method for computing phi (default)

-phiexp = use exponential method for computing phi

-help = print this help screen

Gradient Filter Kernels

2D kernels

du/dx

-a	0	a
-b	0	b
-a	0	a

du/dy

-a	-b	-a
0	0	0
a	b	a

where a=3/16, b= 10/16

3D kernels at p-1, p+1

a	b	a
b	c	b
a	b	a

where

a = 0.02, b = 0.06, c = 0.18

Isotropic smoothing kernel

a	b	a
b	c	b
a	b	a

2D

a = 1/6, b=2/3, c = -10/3

a = 0.4, b = 2.0/15.0, c = 1.0/60.0,
d = (-6.0 * a) - (12.0 * b) - (8.0 * c) =-4.13

b	a	b
a	d	a
b	a	b

at slice p

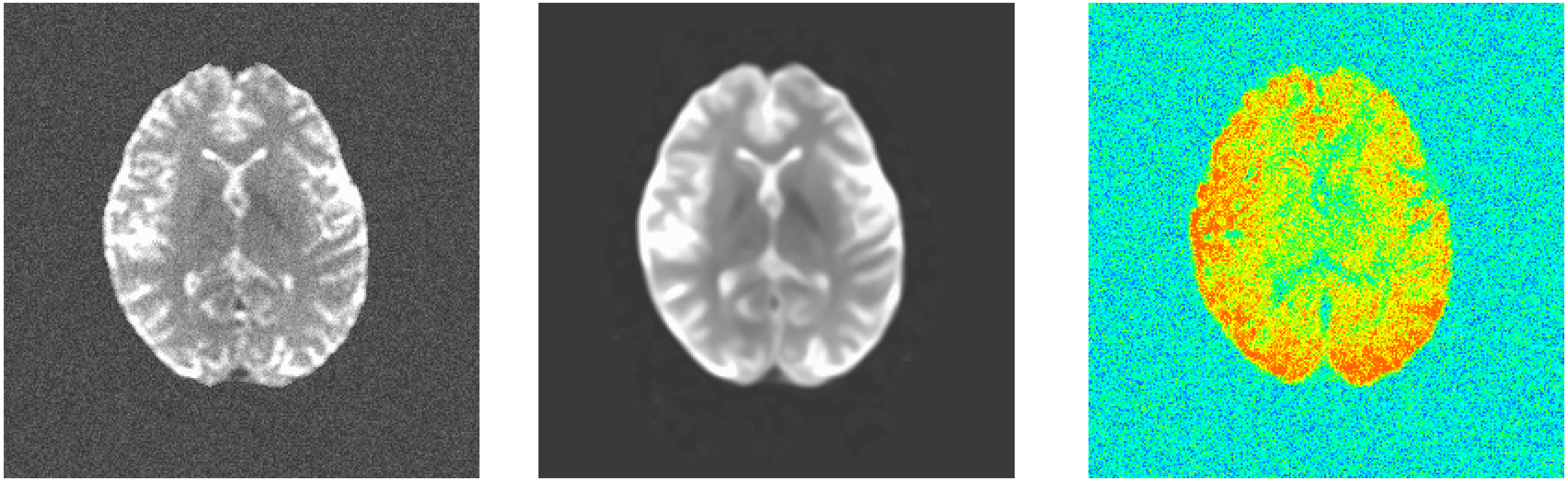
c	b	c
b	a	b
c	b	c

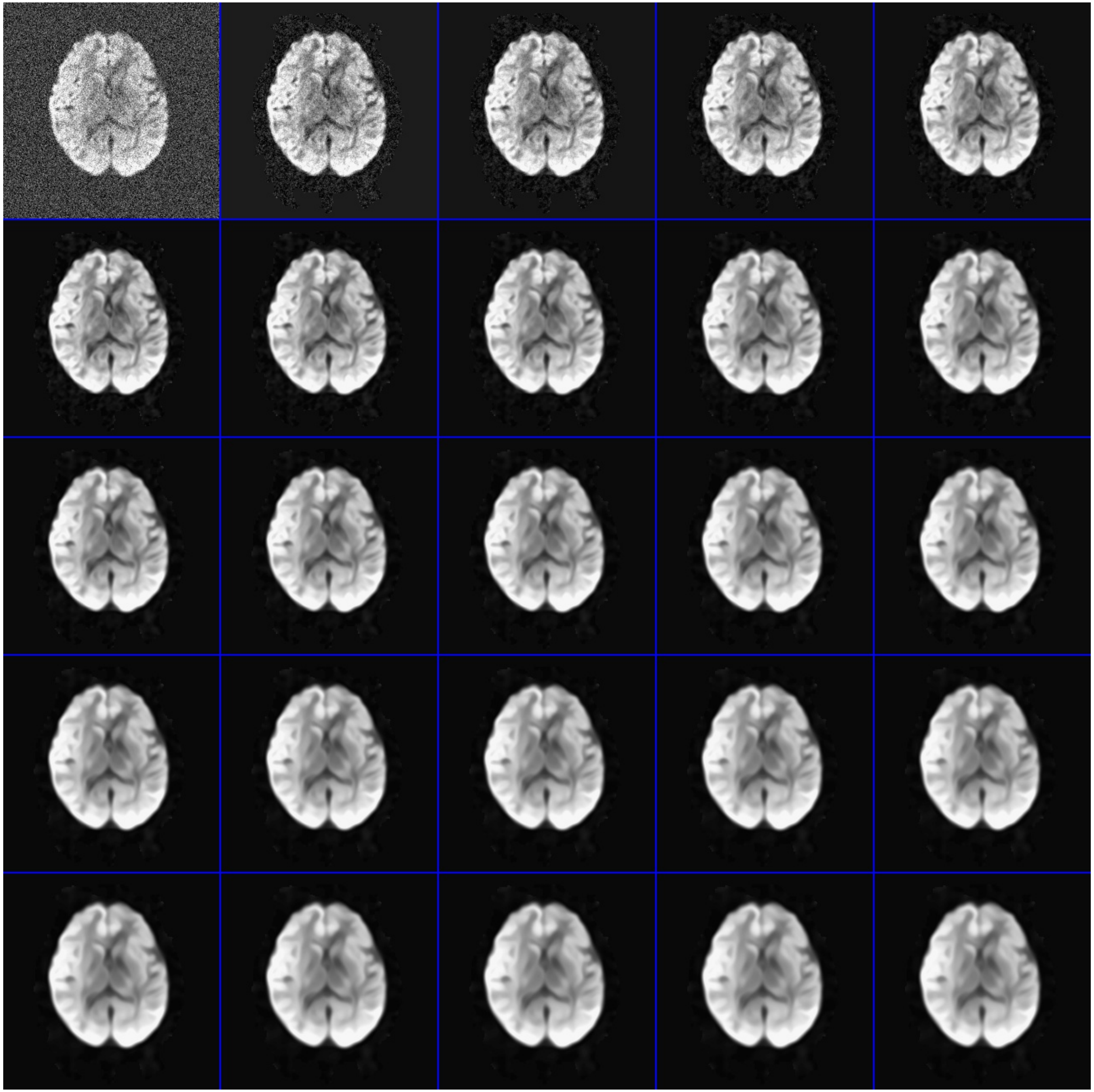
3D

at slice p-1,
p+1

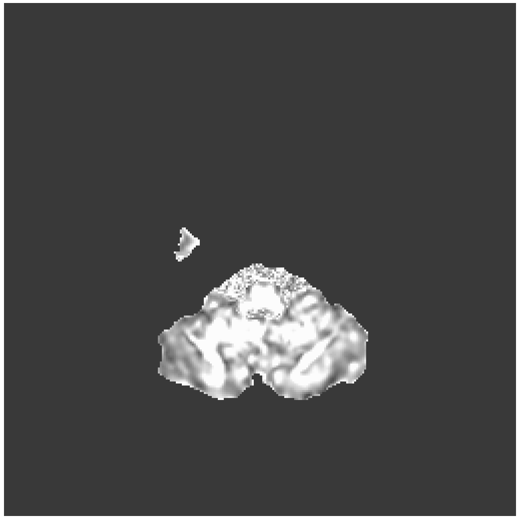
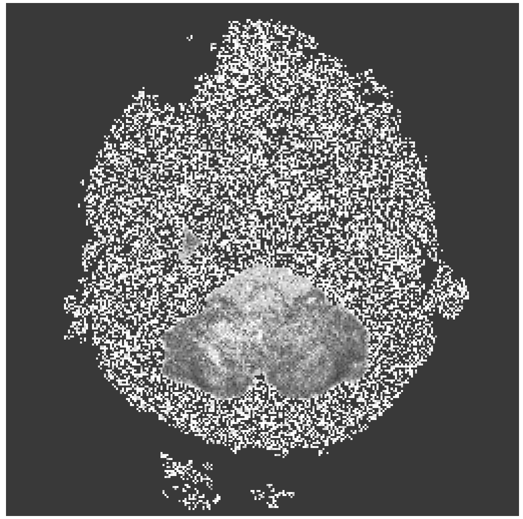
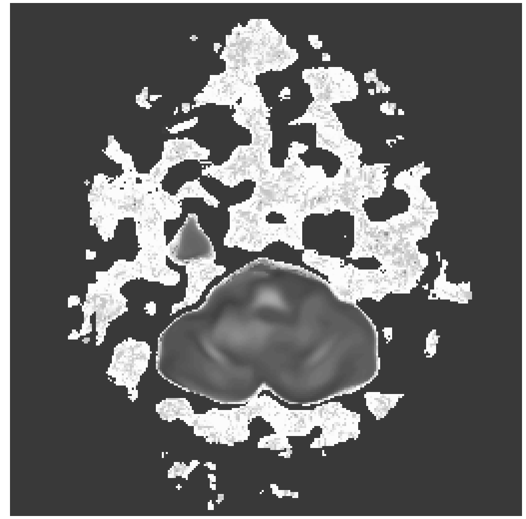
DWI Images

25 iterations

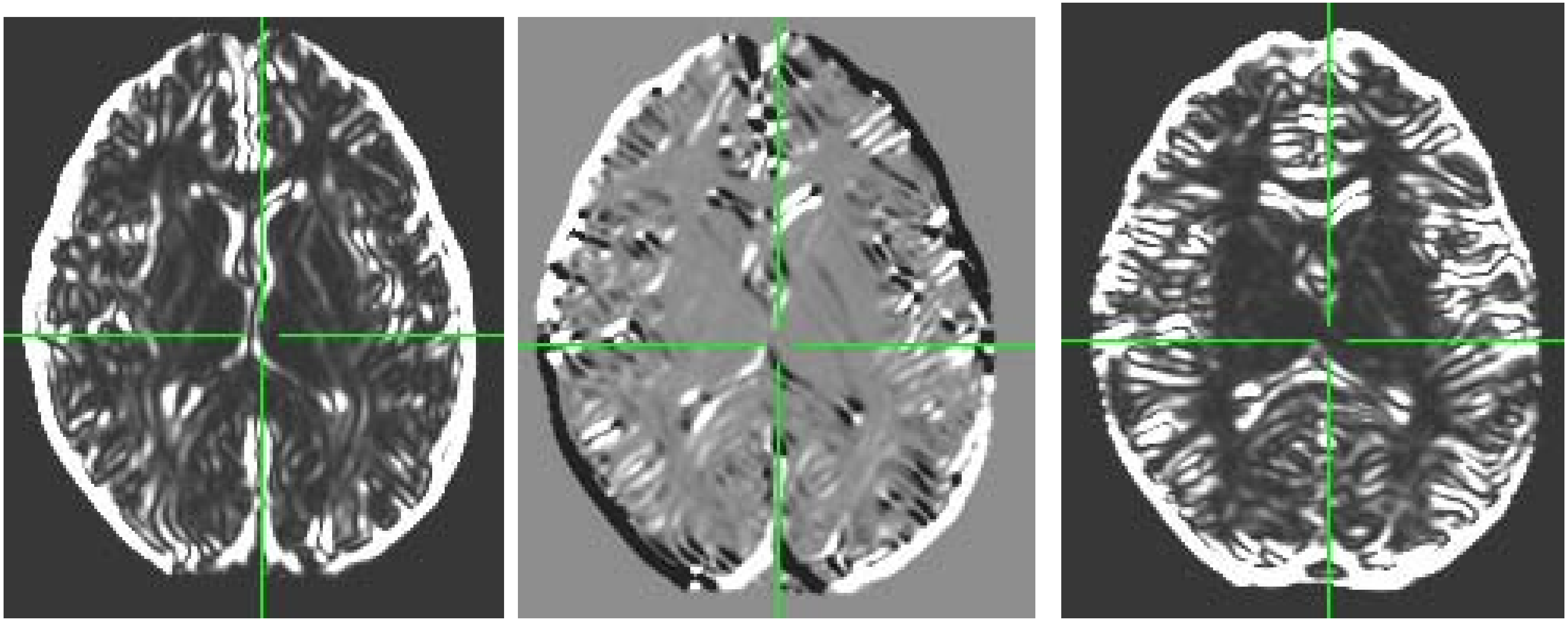




DWI/DT Images

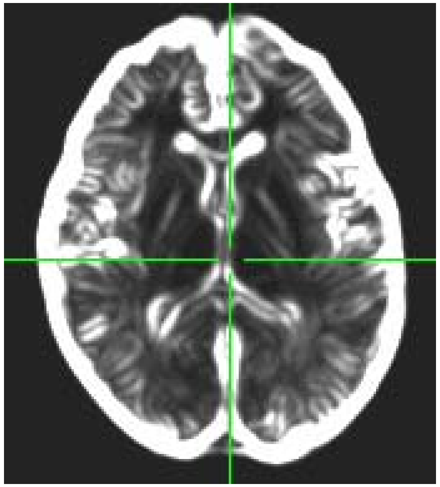
DWI Intermediate Images

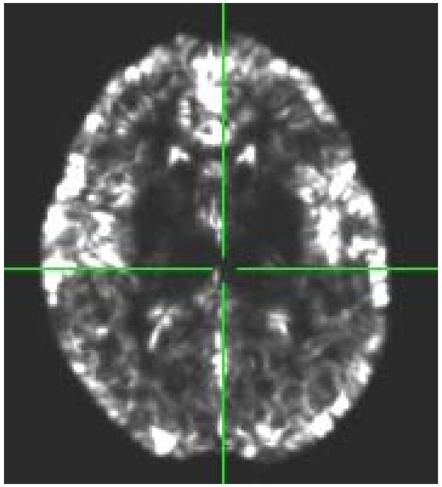


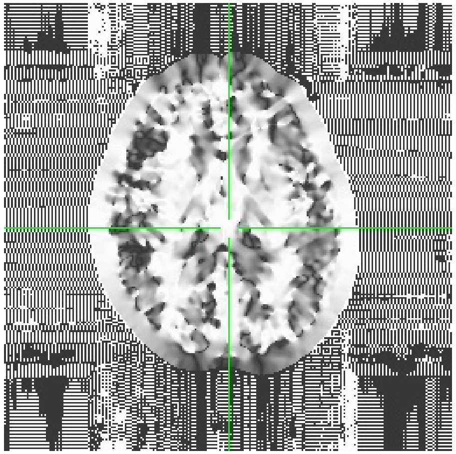
Gradient Dxx^2, Dxy, Dyy^2

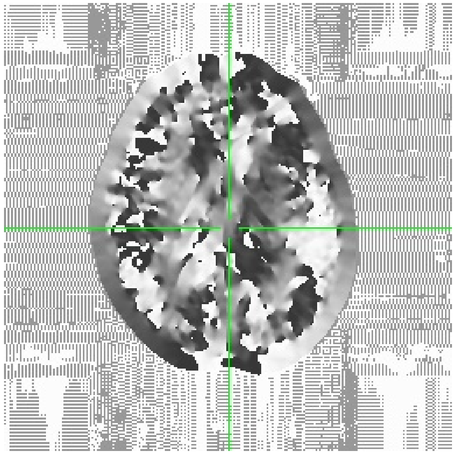
DWI Intermediate Images

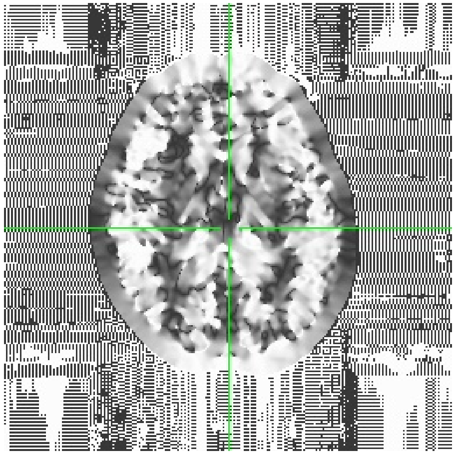
Eigenvalues, vectors

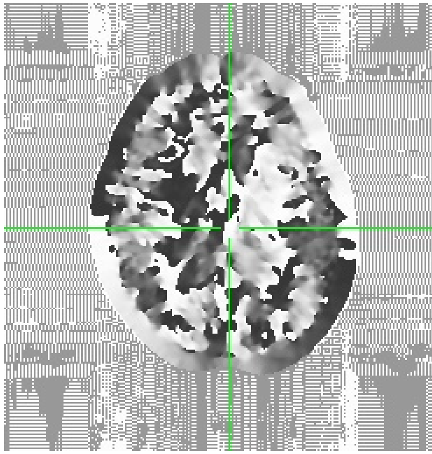




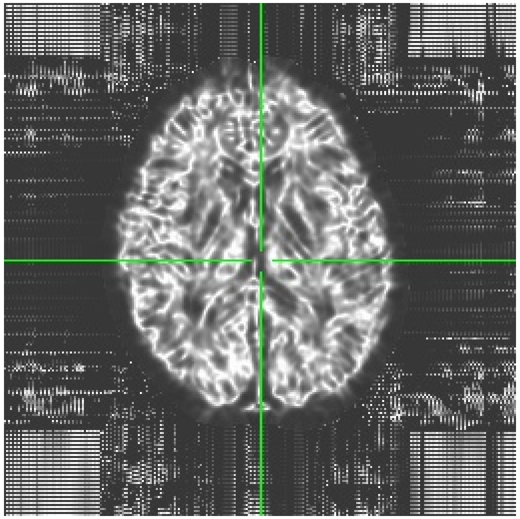
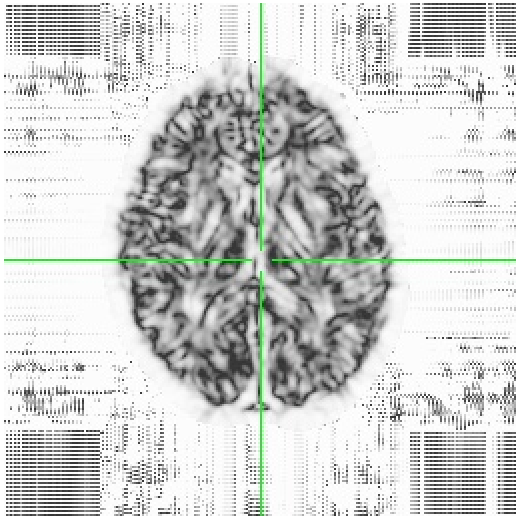






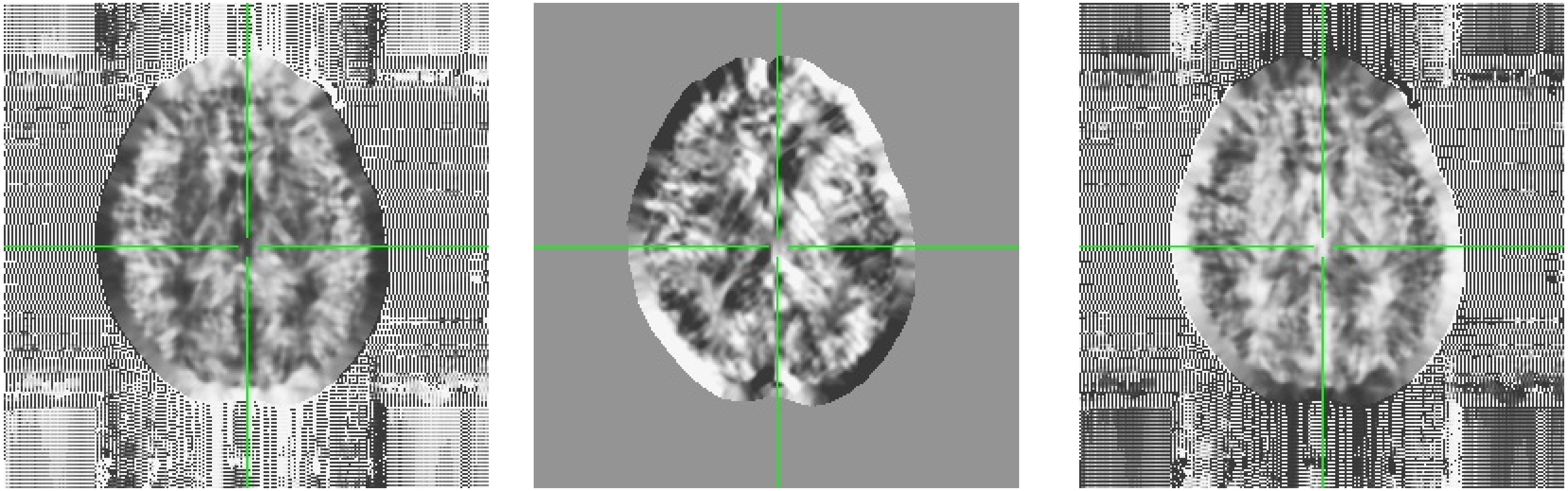


DWI Intermediate Images

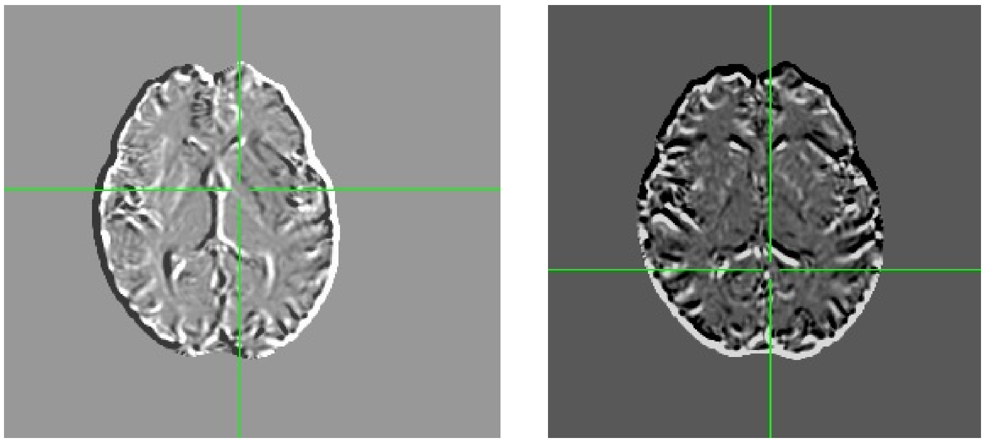
Phi Values

DWI Intermediate Images

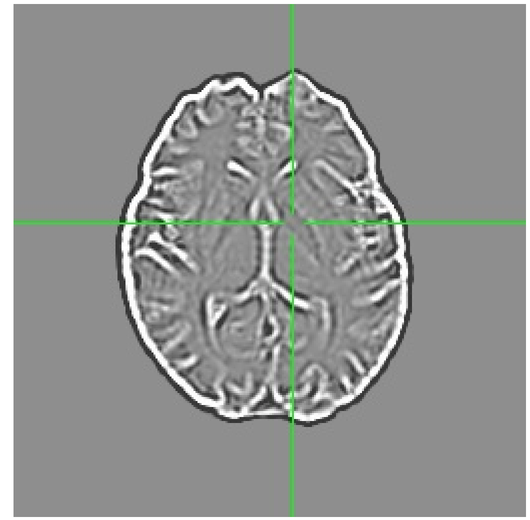


D Tensor: Dxx, Dxy, Dyy

DWI Intermediate Images

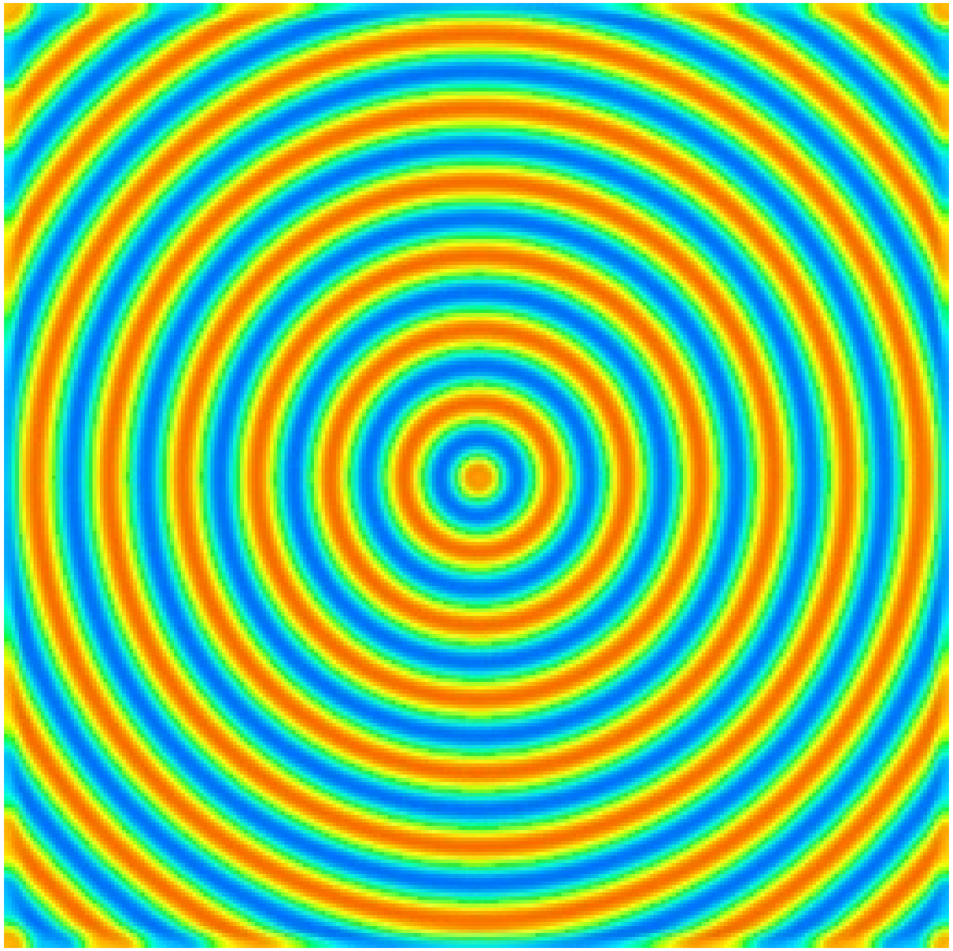


Flux in x
and y



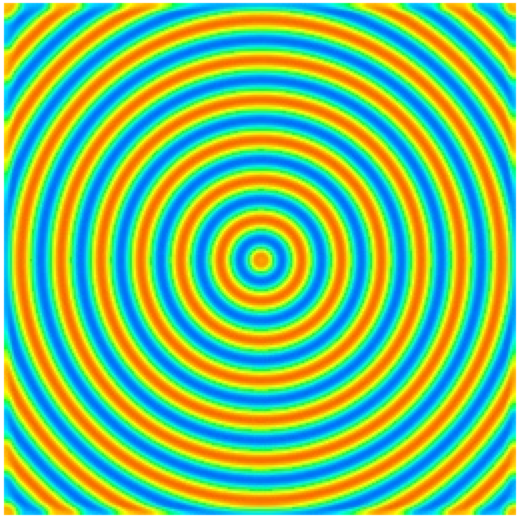
G matrix -
anisotropic part

Cosine Circles

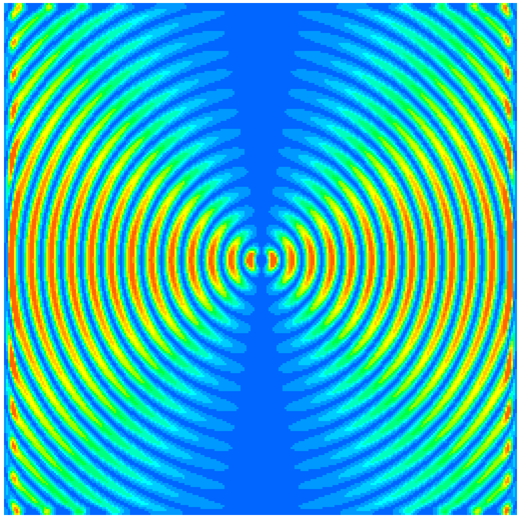


After 25 iterations

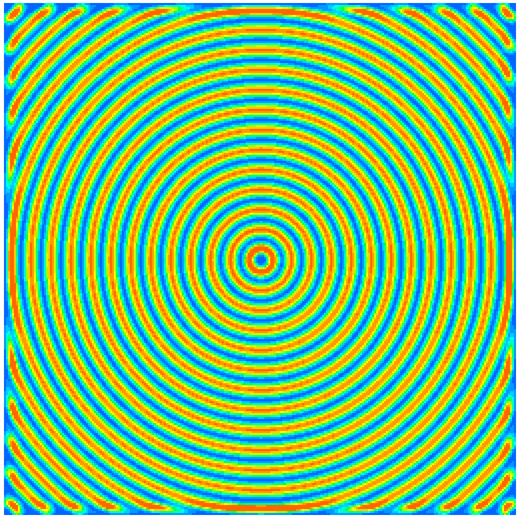
Cosine Circles



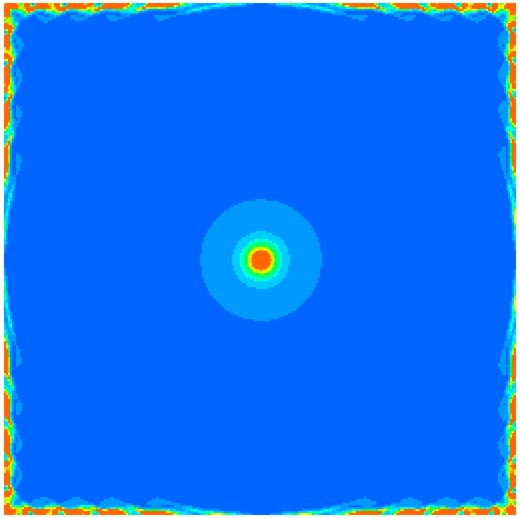
25 iterations



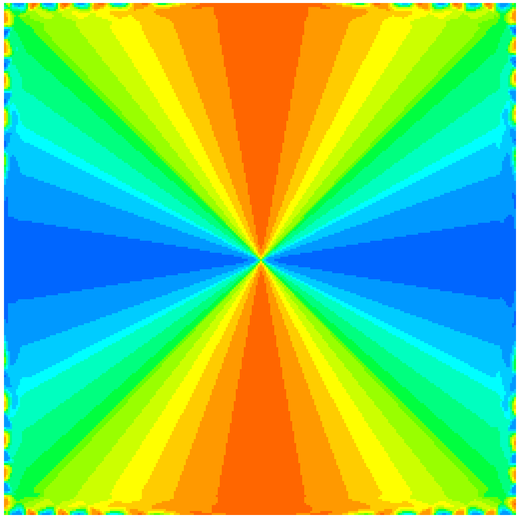
Gradient Dxx^2, Dxy, Dyy^2



Eigenvalues, vectors

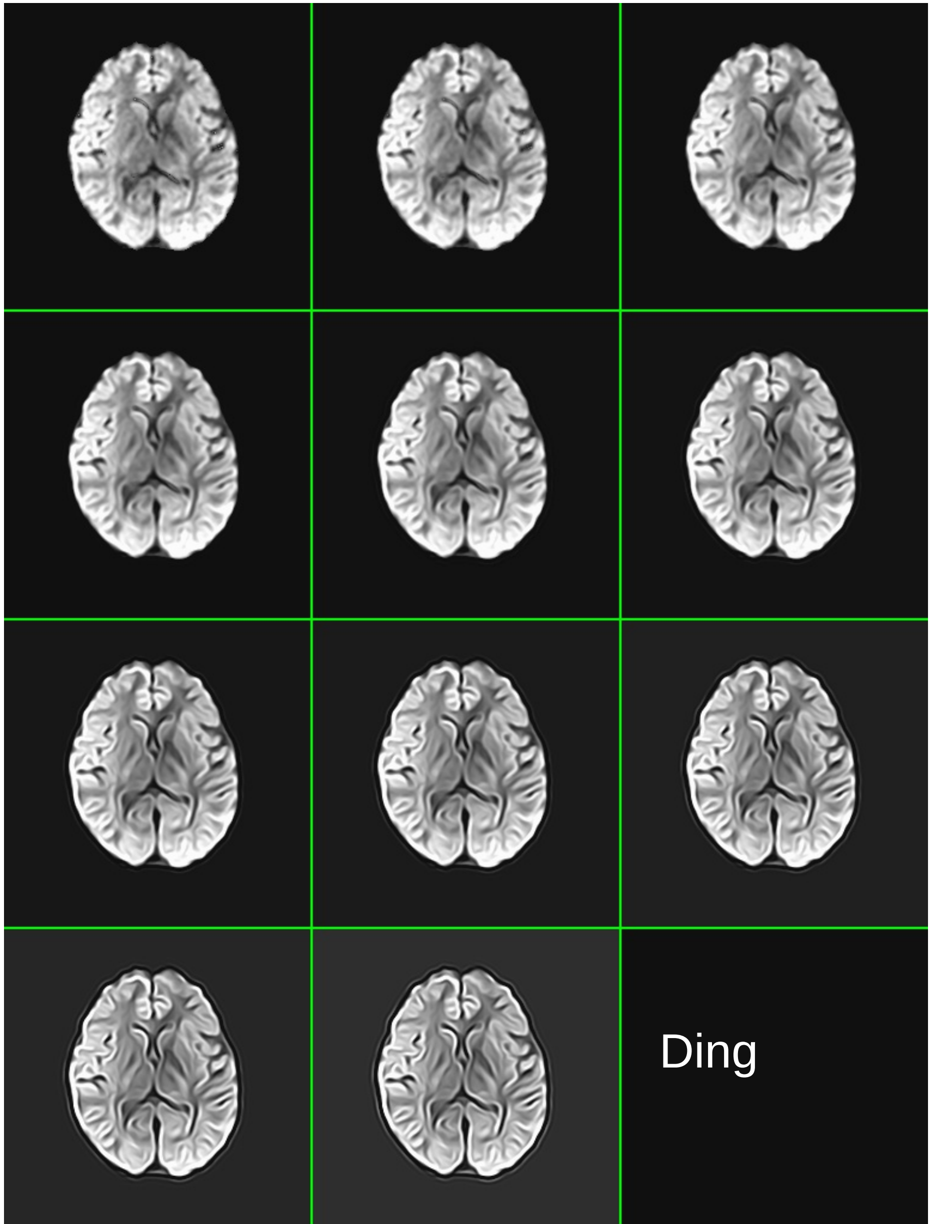


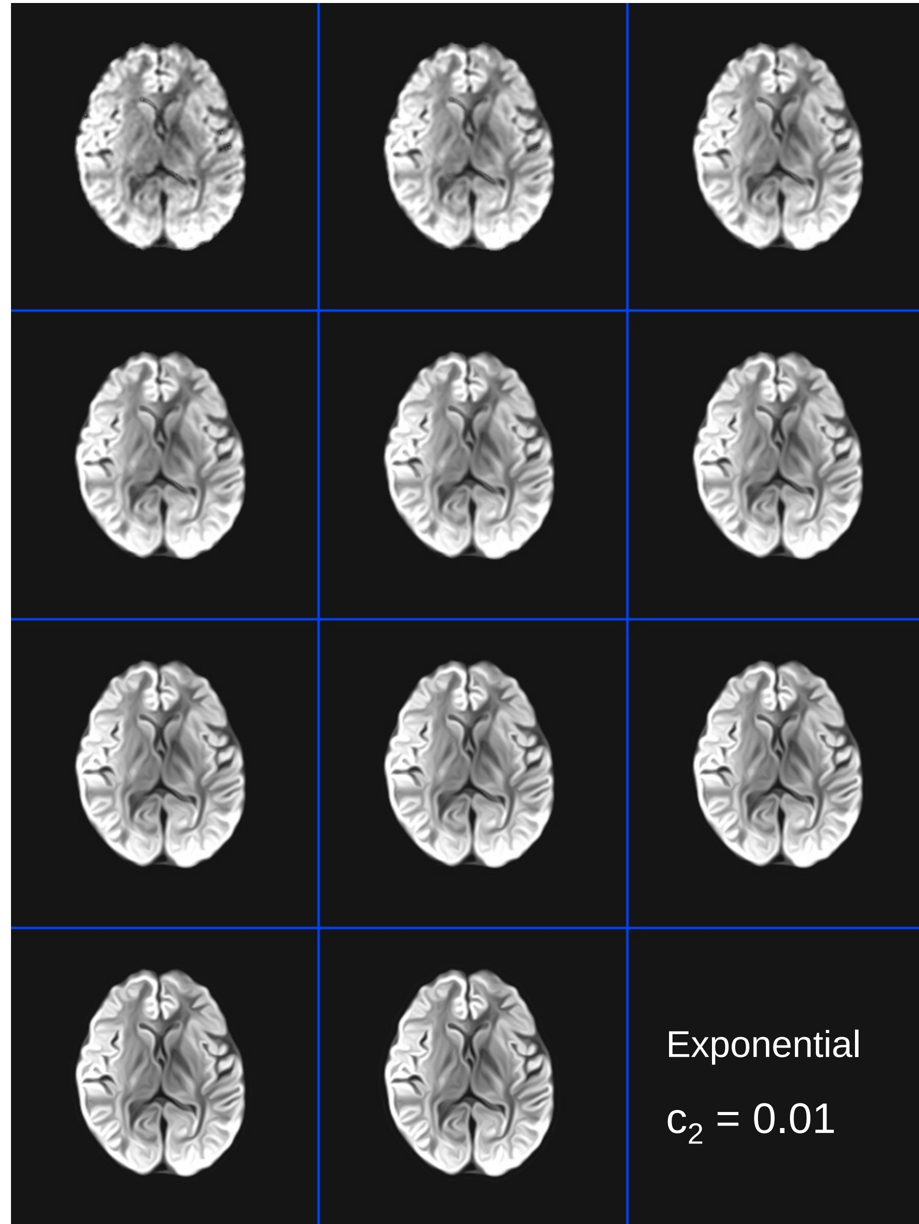
phi values



D tensor Dxx, Dxy, Dyy

Phi value calculation





Issues

- Performance and Memory
  - 3:30 for 10 iterations, 21 seconds per iteration with DWI 256x256x41 x 22 sub-bricks (2D)
  - ~ 1 sec/sub-brick/iteration ~ 0.025 sec/slice/iteration
  - 9:00 for 10 iterations, 54 seconds per iteration, 2.5 sec/sub-brick/iteration, 0.06 sec/slice/iteration (3D),
  - 5:54 for 10 iterations, 35 seconds per iteration with T2 512x512x112 single brick data (2D)
  - ~ 0.3 sec/slice/iteration
  - 16:22 for 10 iterations, 98 seconds per iteration, 0.88 sec/slice/iteration (3D)
  - 2n + 6 sub-briks for 2D, 2n+12(3D), n=number of sub-bricks (almost 1GB)
  - Improvements made in
    - Gaussian smoothing (spatial kernels instead)
    - more efficient spatial kernels for gradient and other smoothing kernel in algorithm
    - eigenvalue solver specific for symmetric 2x2 and 3x3
    - mask operations – edge of mask gets special treatment
  - Larger Delta T step (instability possible)
  - Cheaper D tensor and alternative phis - eigenvalue alternative (Ding, Matlab)
- Edges, Masks, Anisotropy
  - Edges show problems after many iterations
  - Masks treated equivalently to edges in program
  - Voxels treated “isotropically” (dx=dy=dz)
- Overfiltering and end points
  - Truth
  - Shock filter (stop determination)

References

Z Ding, JC Gore, AW Anderson, Reduction of Noise in Diffusion Tensor Images Using Anisotropic Smoothing, Mag. Res. Med., 53:485-490, 2005

J Weickert, H Scharr, A Scheme for Coherence-Enhancing Diffusion Filtering with Optimized Rotation Invariance, CVGPR Group Technical Report at the Department of Mathematics\n" " and Computer Science,University of Mannheim,Germany,TR 4/2000.

J.Weickert,H.Scharr. A scheme for coherence-enhancing diffusion filtering with optimized rotation invariance. J Visual Communication and Image Representation, Special Issue On Partial Differential Equations In Image Processing,Comp Vision Computer Graphics, pages 103-118, 2002.

Gerig, G., Kubler, O., Kikinis, R., Jolesz, F., Nonlinear anisotropic filtering of MRI data, IEEE Trans. Med. Imaging 11 (2), 221-232, 1992.