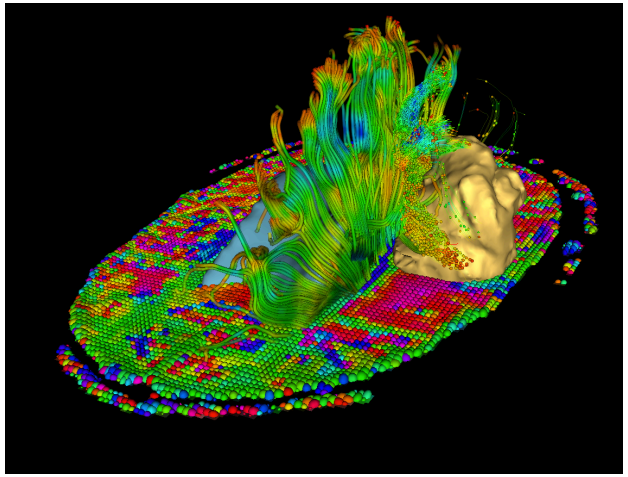
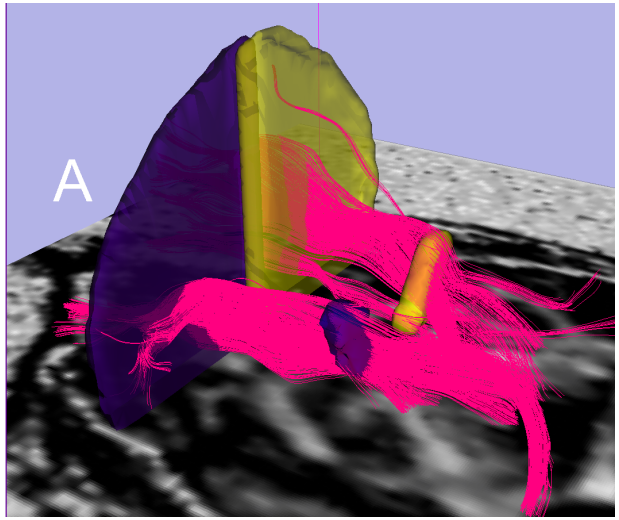


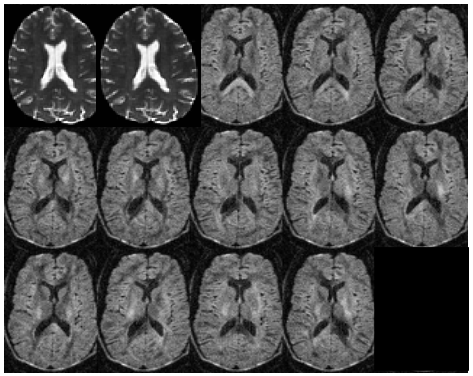
Challenges in clinical transfer of DT-MRI: Towards Validation of DTI Tractography

Sonia Pujol, Ph.D.

Surgical Planning Laboratory
Harvard University

White Matter architecture





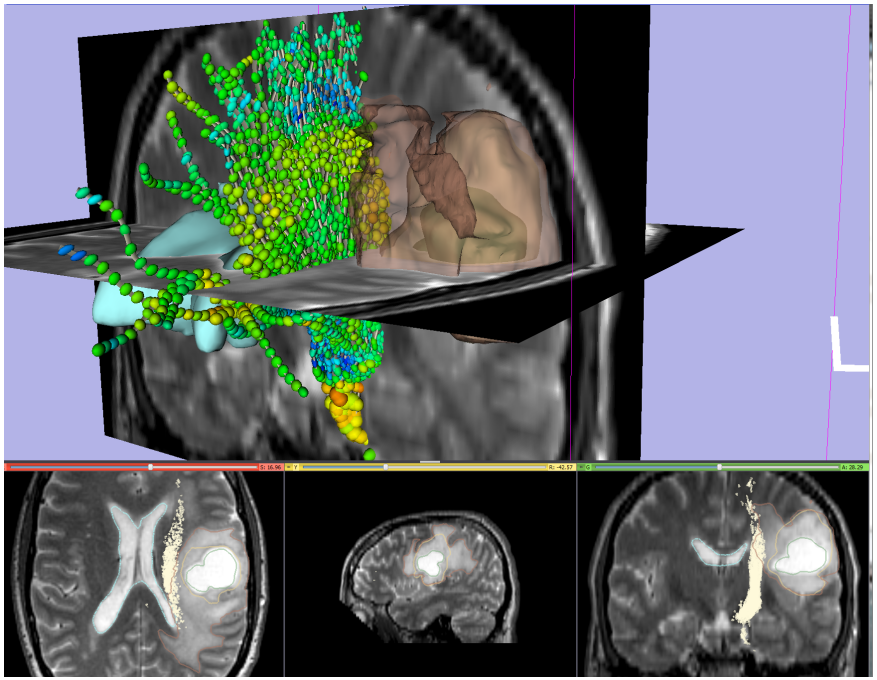
- 100 billions of neurons
- Complex neuronal networks
- Diffusion MRI is the first non-invasive window on the organization of the brain white matter pathways
- Tractography provides 3D visualization of the trajectory of major white matter bundles

DTI as a Neuroimaging marker

- Visualization of *in-vivo* normal and pathological anatomy

- Insights into white matter abnormalities which may include changes in direction, radial displacement or diameter of white matter fiber bundles

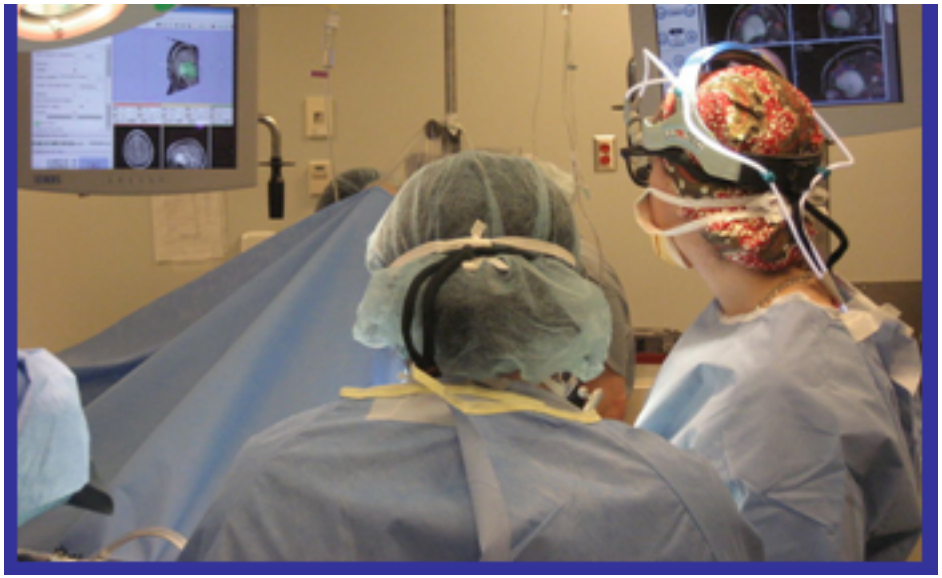
Tractography for neurosurgical planning



Courtesy of Ron Kikinis, MD

The location and integrity of eloquent white matter pathways is of major importance during neurosurgical planning

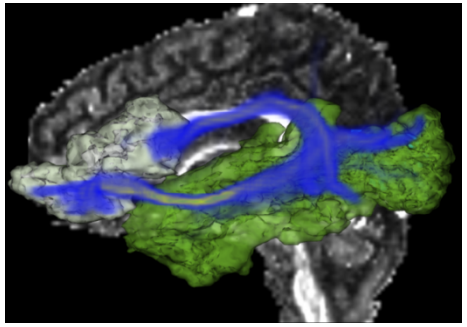
Tractography for neurosurgical planning



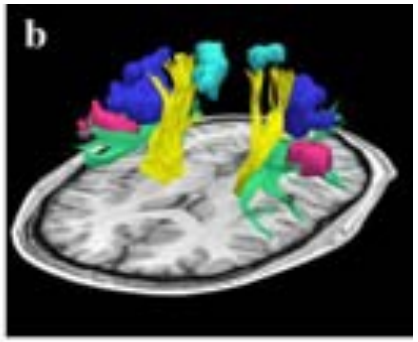
The location and integrity of eloquent white matter pathways is of major importance during neurosurgical planning

Tractography has the potentiel to bring valuable information to the neurosurgeon

Tractography

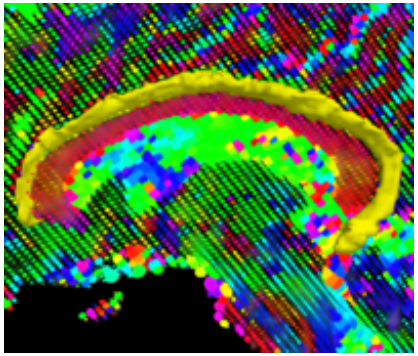


Courtesy of J De Siebenthal & CF Westin



Courtesy of A. Areza & CF Westin

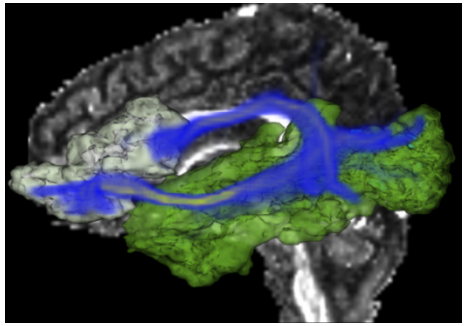
Courtesy of T.Fletcher & R. Whitaker



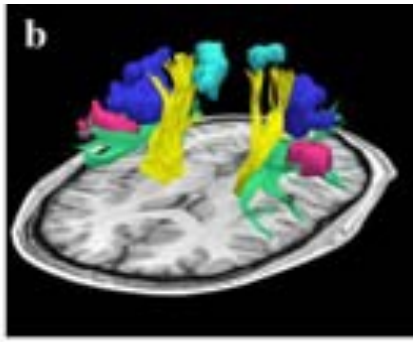
Courtesy of A. Tannenbaum

A wide variety of tractography techniques has been developed over the past decade (streamline, stochastic, volumetric, two-tensors…)

Tractography

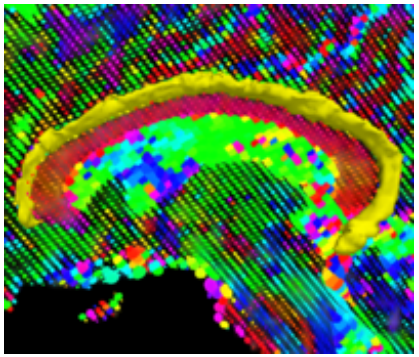


Courtesy of J De Siebenthal & CF Westin



Courtesy of A. Areza & CF Westin

Courtesy of T.Fletcher & R. Whitaker

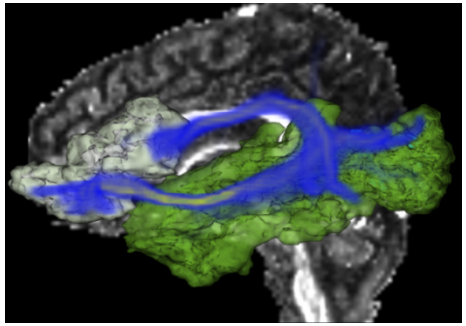


Courtesy of A. Tannenbaum

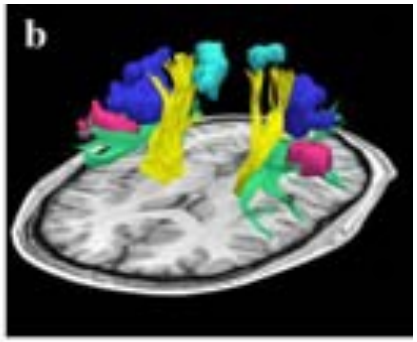
Current achievements include:

- 3D visualization of healthy & pathological anatomy
- Assessment of group differences (e.g Schizophrenia, Alzheimer's disease)

Tractography

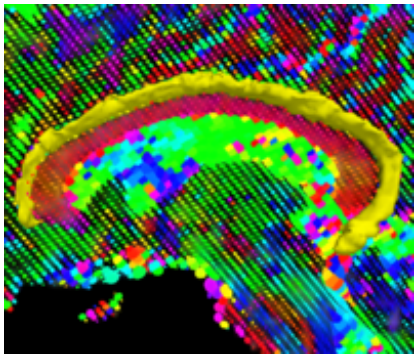


Courtesy of J De Siebenthal, CF Westin



Courtesy of A. Areza CF Westin

Courtesy of T.Fletcher & Ross Whitaker

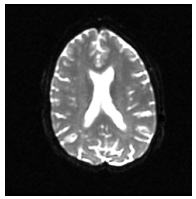


Courtesy of A. Tannenbaum

Current Challenge:

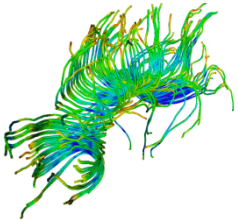
Characterization of different tractography approaches

Sources of variability



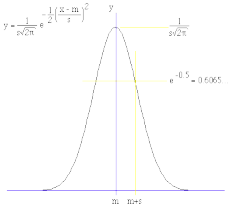
patient

acquisition



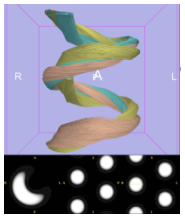
fascicle

algorithm/models

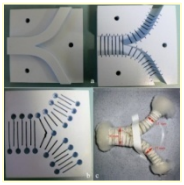


$$\ln p(X \mid \pi, \mu, \Sigma) = \sum_{n=1}^{N} In \{ \sum_{k=1}^{K} \pi_k N(x_n \mid \mu_k, \Sigma_k) \}$$

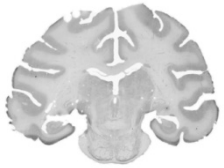
Validation Approaches



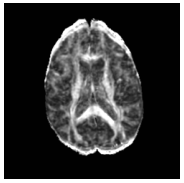
Mathematical Phantoms



Physical Phantoms

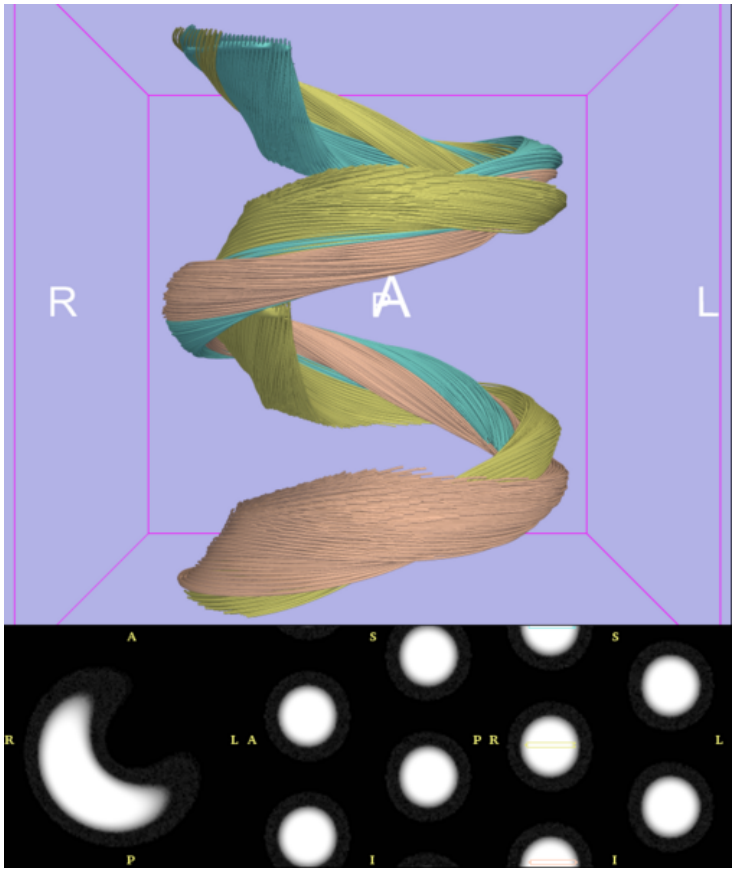


Histological Studies



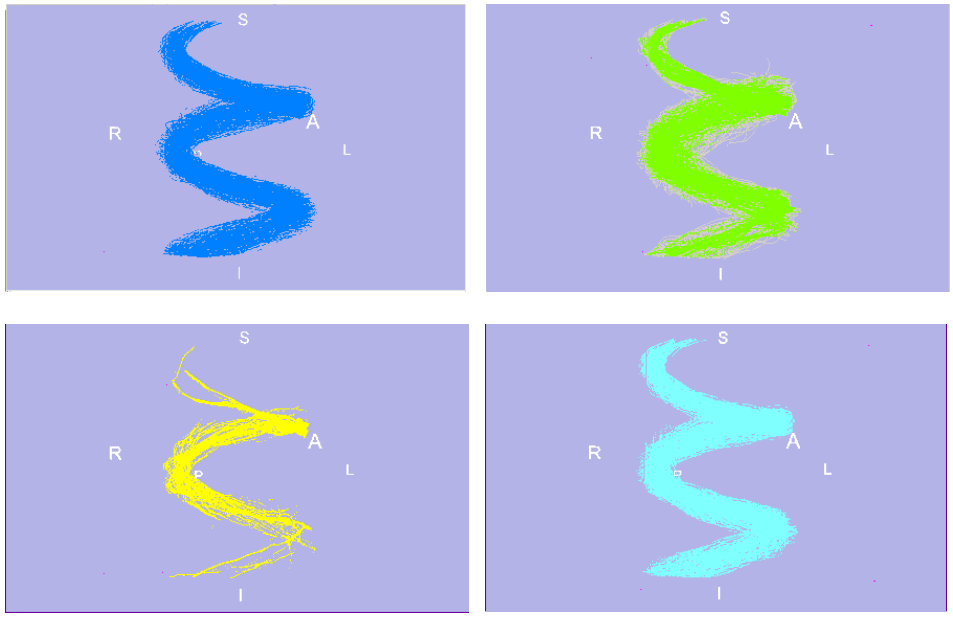
Real Subject Data

Mathematical Phantoms



- Known absolute ground truth
- Freedom of shape design

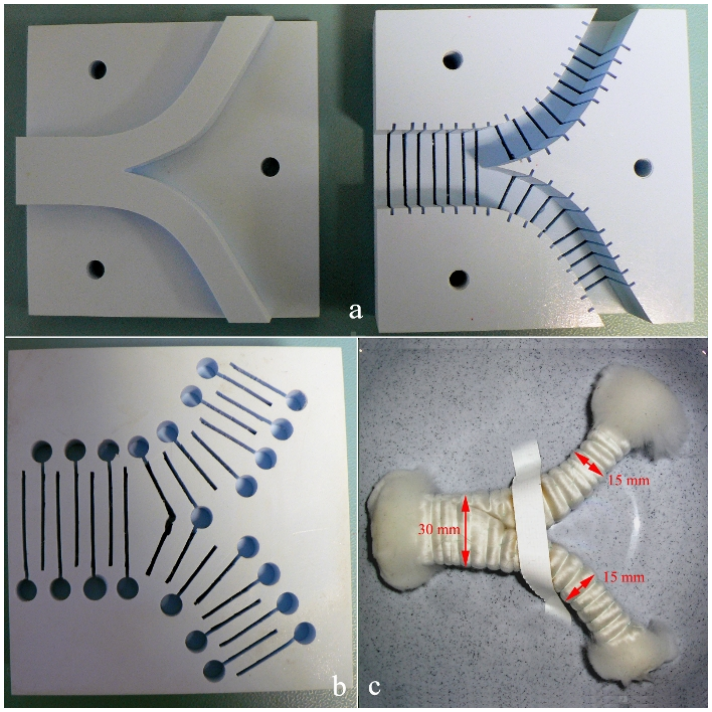
Mathematical Phantoms



- Known absolute ground truth
- Freedom of shape design
- Freedom of parameter selection

Performance evaluation

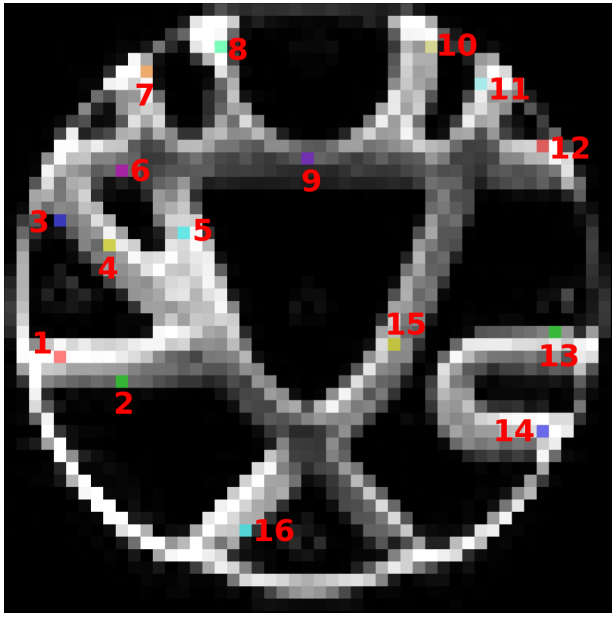
Physical Phantom



- Simple/complex tract configurations

Poupon et al. Magn Reson Med. 2008 Dec;60(6):1276-83.

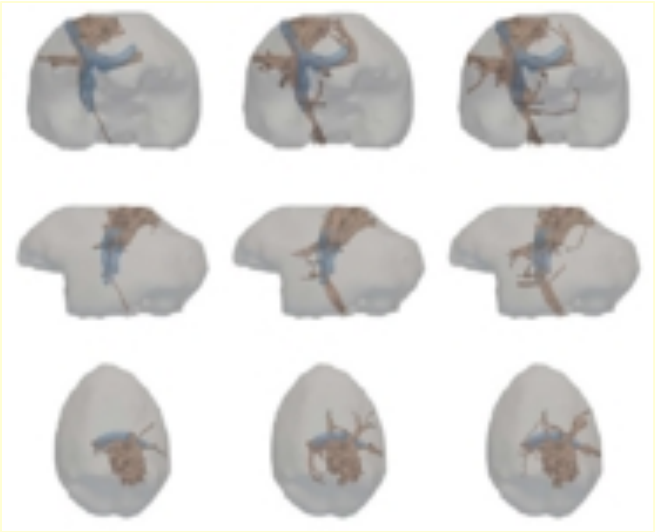
Physical Phantom



- Simple/complex tract configurations
- Real MR images
- Variations in voxel size, B-value and SNR

Courtesy of C.Poupon and P.Fillard, LNAO

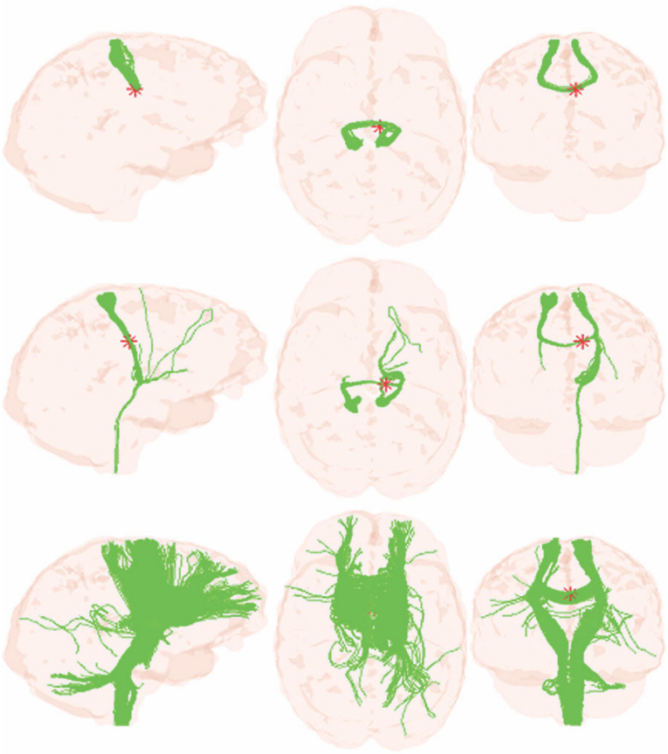
Histological studies



- Real anatomical structures
- Correlation with ground truth white matter anatomy

Dauguet et al, Neuroimage 2007

Boostrapping

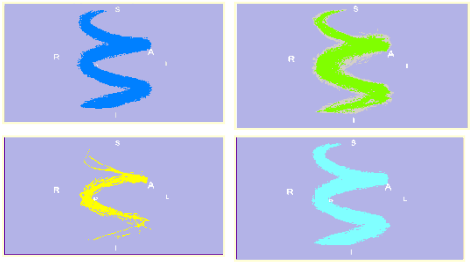


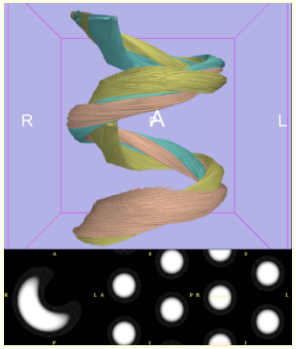
Jones and Pierpaoli, MRM 2007

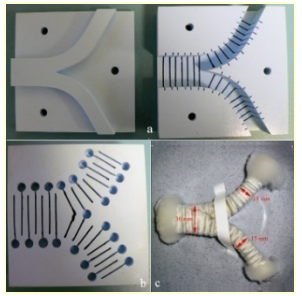
- Non parametric statistical approach
- Assessment of

the precision of DTI tractography

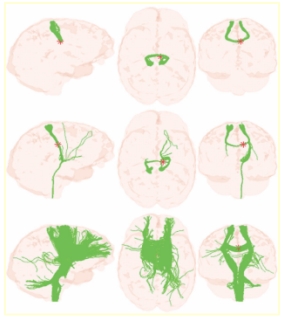
Complementary approaches

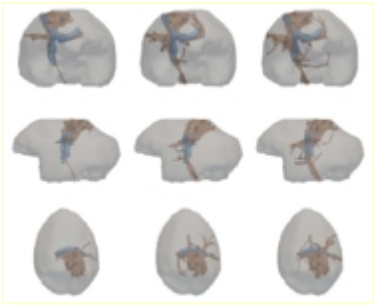






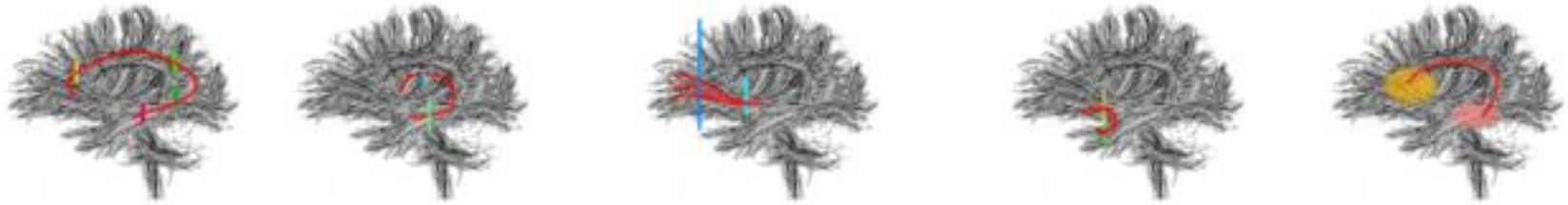
Ground truth





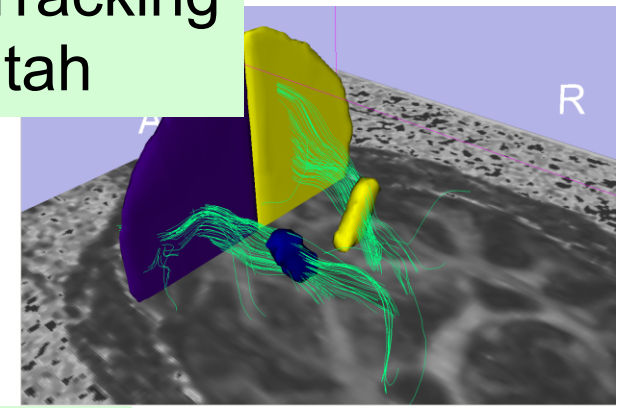
NA-MIC pilot initiative

- Exploratory work initiated by the National Alliance for Medical Image Computing
- 7 major research centers across the US
- Cross-comparison of tractography algorithms on major white matter fascicles

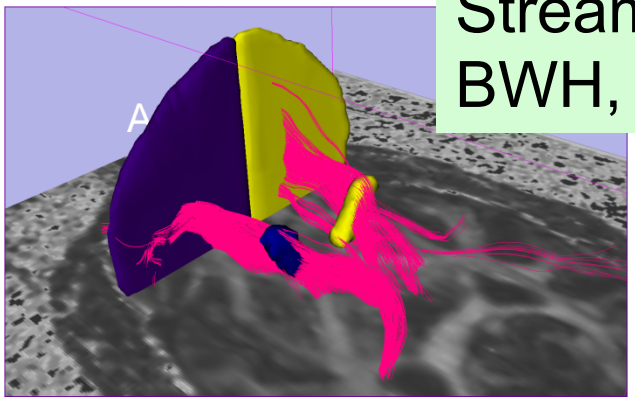


Early Implementation

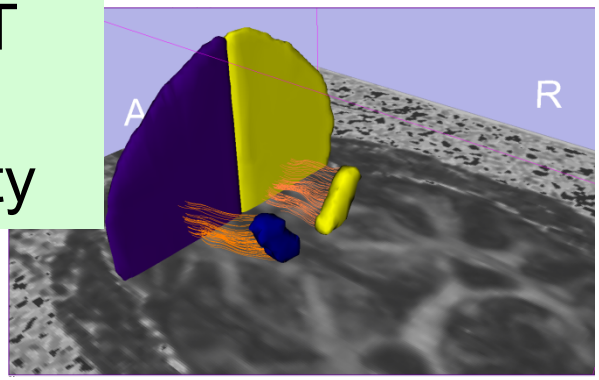
Fiber Tracking
SCI, Utah



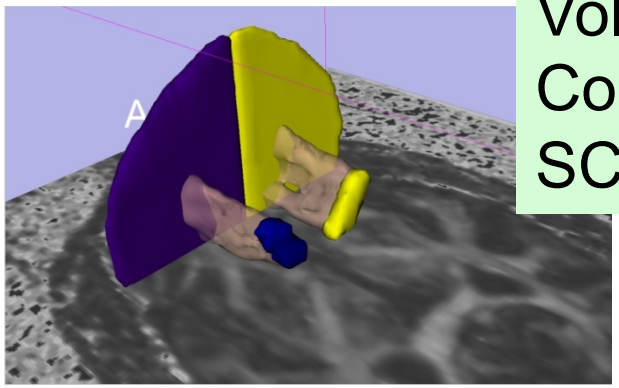
Streamline
BWH, Harvard



GTRACT
Iowa
University



Volumetric
Connectivity
SCI, Utah



Pujol et al. ISMRM 2009

Our approach

- Comparison of segmentation of structural images in the absence of ground truth: STAPLE

Warfield SK, Zou KH, Wells WM. STAPLE. Simultaneous Truth and Performance Level Estimation (STAPLE): An algorithm for the Validation of Image Segmentation. IEEE Trans Med Imaging. 23(7):903-21.

STAPLE

(Simultaneous Truth and Performance Level Evaluation)

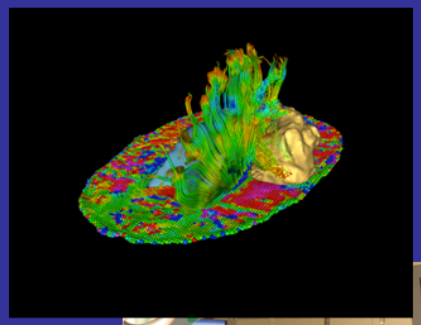
- Expectation-Maximization algorithm (EM) to maximize the incomplete data log likelihood function

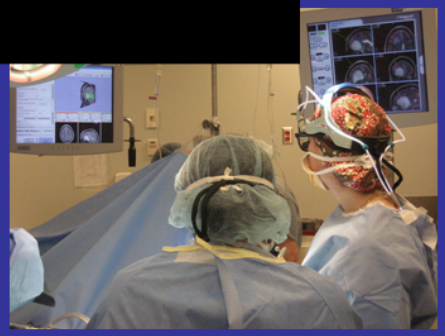
$$In\ f(D \mid p,q)$$

*Warfield SK, Zou KH, **Wells WM.** STAPLE. Simultaneous Truth and Performance Level Estimation (STAPLE): An algorithm for the Validation of Image Segmentation.*
IEEE Trans Med Imaging. 23(7):903-21.

MICCAI 2011 DTI Challenge

14th International Conference on Medical Image Computing and Computer Assisted Intervention





DTI Tractography for Neurosurgical Planning: A Grand Challenge

Sunday September 18, 2011
Westin Harbor Hotel
Toronto, Canada

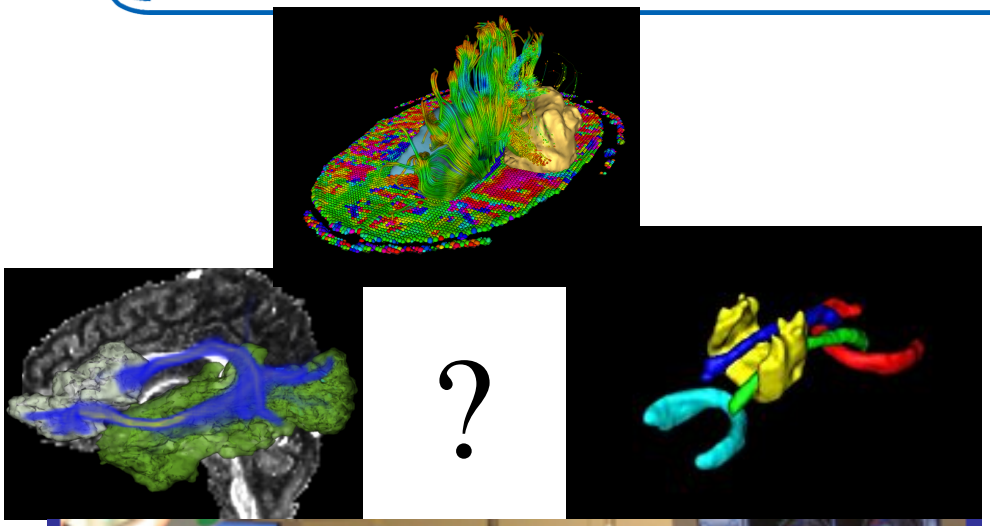
Workshop Faculty

Sonia Pujol, PhD, Brigham and Women's Hospital, Harvard Medical School
Ron Kikinis, MD, Brigham and Women's Hospital, Harvard Medical School
Alexandra Golby, MD, Brigham and Women's Hospital, Harvard Medical School
Guido Gerig, PhD, The Scientific Computing and Imaging Institute, University of Utah
Martin Styner, PhD, Neuroimage Research and Analysis Laboratory, University of North Carolina
William Wells, PhD, Brigham and Women's Hospital, Harvard Medical School
Carl-Fredrik Westin, PhD, Brigham and Women's Hospital, Harvard Medical School
Sylvain Gouttard, MSc, The Scientific Computing and Imaging Institute, University of Utah

MICCAI 2011 workshop
National Alliance for Medical Image Computing

http://www.na-mic.org/Wiki/index.php/Events:_DTI_Tractography_Challenge_MICCAI_2011

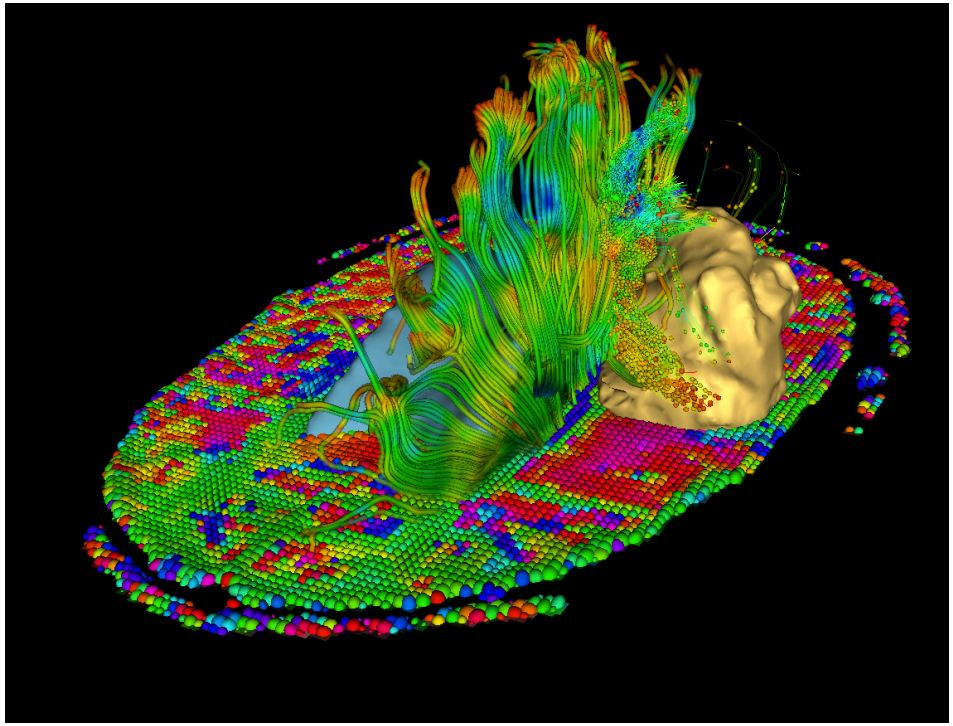
How to choose ?



Neurosurgeons face the challenge of selecting the appropriate tractography method and tract selection strategy

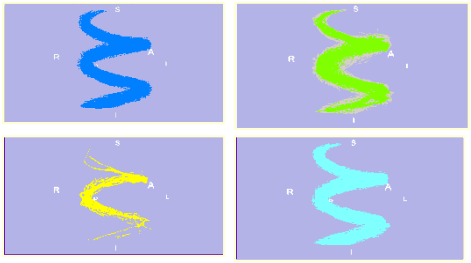
Need for validation to accelerate clinical use of DT-MRI findings

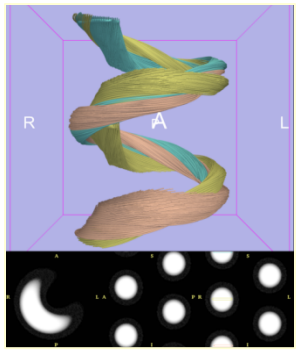
MICCAI 2011 DTI Tractography Challenge

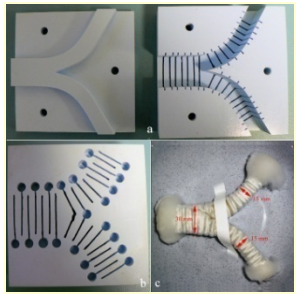


- Four clinical cases with
  - T1, T2 anatomical scans
  - DWI acquisitions
  - Segmentation of tumor and edema
- Two healthy subject scans with repeated acquisitions of T1,T2, and DWI images
- Qualitative evaluation and quantitative assessment

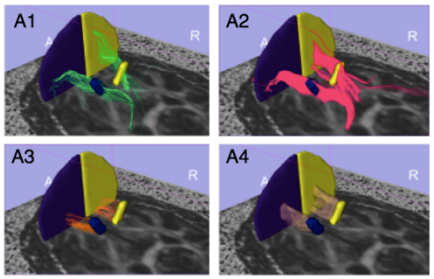
Complementary approaches

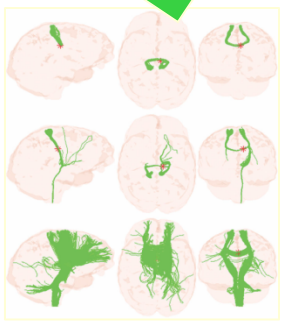


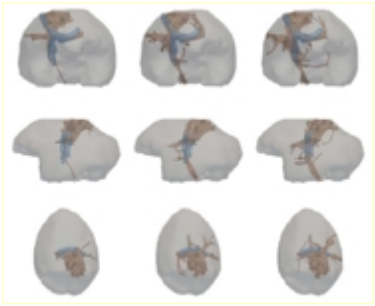




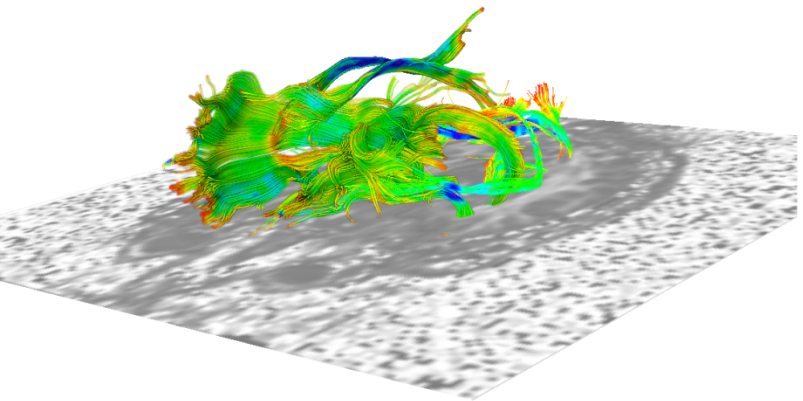
Ground truth







Conclusion



- Evaluation of various tractography approaches in the absence of ground truth
- Validation is key to the transfer from bench to bedside
- DTI tractography as an *in-vivo* neuroimaging marker

Acknowledgements

National Alliance for Medical Image Computing (NA-MIC)
(NIH Grant U54EB005149)

Neuroimage Analysis Center (NAC)
(NIH Grant P41 RR013218)