July 16th - August 10th, 2007 - Istanbul, Turkey
eNTERFACE '07
The SIMILAR NoE Summer Workshop on Multimodal Interfaces

DTI Project

A DTI Analysis & Visualization Tool with Haptic Interaction

M. Aksoy, N. Avcu, S. Merino-Caviedes, D. Diktas, M.A. Martin-Fernandez, S. Girgin, I. Marras, E. Munoz-Moreno, E. Tekeli, B. Acar, R. Bammer, M.M. Fernandez, A.V. Sahiner, S. Uskudarli

www.vavlab.ee.boun.edu.tr

hosted by Boğaziçi University, Multimedia Group

Project Goal

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DTI Project aimed at developing a proof-of-concept DTI analysis and visualization tool with the following capabilities:

- Integration of SIMILAR Tensor Array Core (STAC) into VAVframe data structure
- DWI-to-DTI conversion (tensor field estimation)
- Basic fiber tractography
- Split & Merge Fiber Tractography
- Haptic Slicing
- Haptic ROI shaping and positioning

Diffusion Tensor - MRI Reminder

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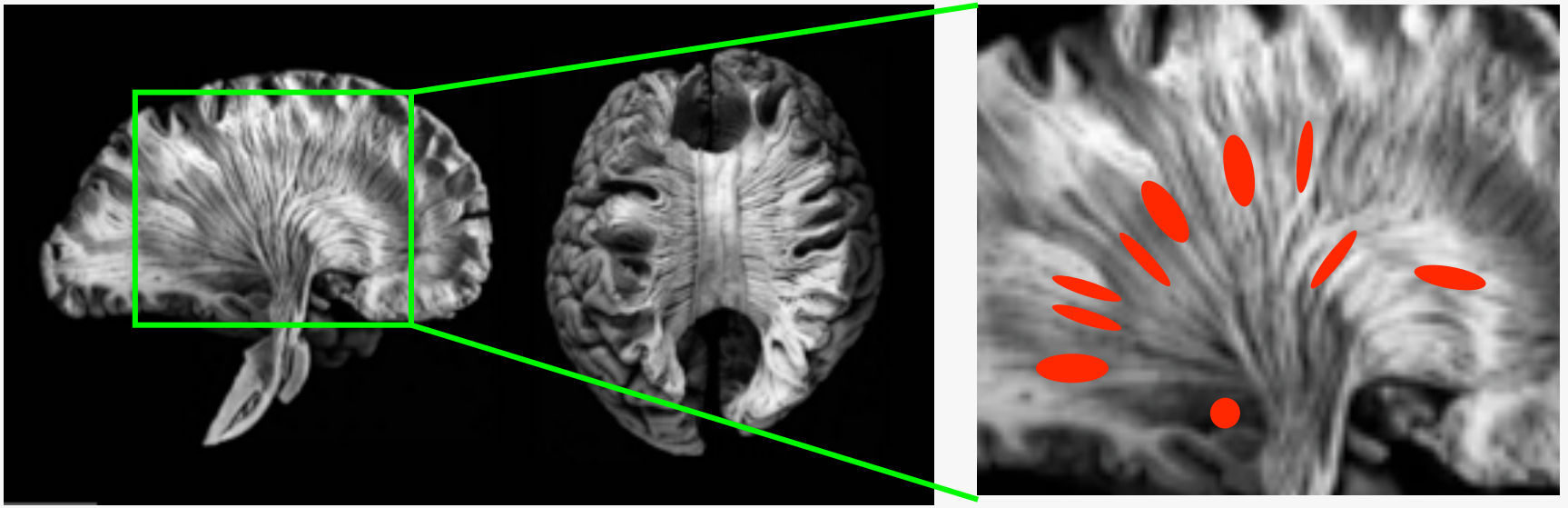
DT-MRI is a recent technique providing information about the geometry of fiberous structures by modeling the diffusion pattern of water molecules with a second order tensor.



Brain dissection showing the structure of white matter (http://www.vh.org/Providers/Textbooks/BrainAnatomy/TOC.html)

STAC

- array_dimensionality
- array_size
- array_index_names
- array_tensor_metric

} Data Grid Description / Physical World

- tensor_order
- tensor_index_types
- tensor_index_names
- tensor_name

- description

} Tensor Description

DWI-to-DTI

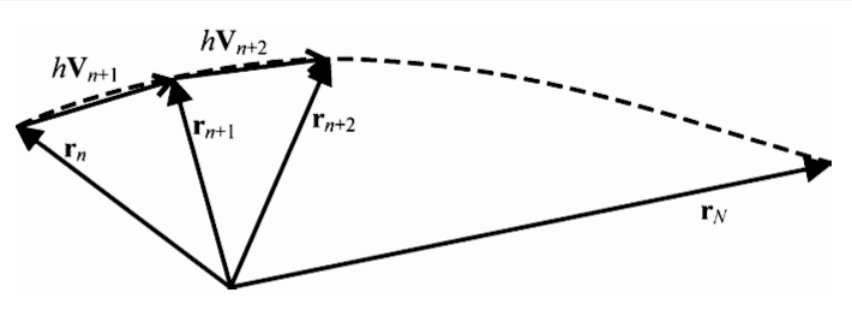
$$M_k = M_0 \exp\left(- \sum_{i \in x,y,z} \sum_{j \in x,y,z} b_k^{ij} D_{ij} \right)$$

$$\mathbf{b_k} = \begin{pmatrix} b_k^{xx} & b_k^{xy} & b_k^{xz} \\ b_k^{yx} & b_k^{yy} & b_k^{yz} \\ b_k^{zx} & b_k^{zy} & b_k^{zz} \end{pmatrix} = b_k \, \mathbf{r}_k \mathbf{r}_k^T$$

$$\mathbf{D} = \begin{pmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{pmatrix}$$

$$\Rightarrow \begin{cases} \begin{pmatrix} \ln(M_1) \\ \ln(M_2) \\ \\ \ln(M_N) \end{pmatrix} = \begin{pmatrix} 1 & -b_1^{xx} & \cdots & -b_1^{zz} \\ 1 & -b_2^{xx} & \cdots & -b_2^{zz} \\ \vdots & & \ddots & \vdots \\ 1 & -b_N^{xx} & \cdots & -b_N^{zz} \end{pmatrix} \begin{pmatrix} \ln(M_0) \\ D_{xx} \\ \vdots \\ D_{zz} \end{pmatrix} \\ \mathbf{S} = \mathbf{M}\,\mathbf{d} \\ \mathbf{d} = \left(\mathbf{M}^T\mathbf{M}\right)^{-1}\mathbf{M}^T\mathbf{S} \end{cases}$$

Basic Tractography



$$\mathbf{r}_{n+1} = \mathbf{r}_n + h\mathbf{V}_{n+1}$$

4th Order Runge-Kutta

$$\mathbf{V}_{n+1} = \frac{1}{6}(\mathbf{k}_1 + 2\mathbf{k}_2 + 2\mathbf{k}_3 + \mathbf{k}_4),$$

$$\mathbf{k}_1 = \frac{\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n)}{|\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n)|}\mathbf{E}(\mathbf{r}_n),$$

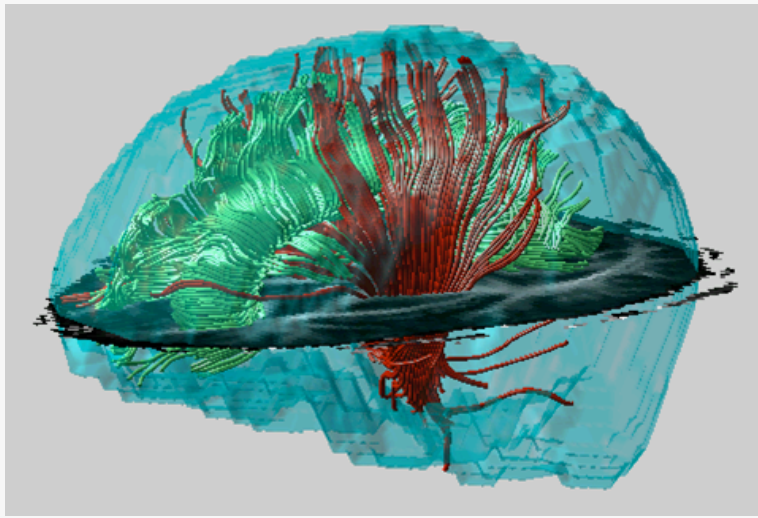
$$\mathbf{k}_2 = \frac{\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n + h/2\mathbf{k}_1)}{|\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n + h/2\mathbf{k}_1)|}\mathbf{E}(\mathbf{r}_n + h/2\mathbf{k}_1),$$

$$\mathbf{k}_3 = \frac{\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n + h/2\mathbf{k}_2)}{|\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n + h/2\mathbf{k}_2)|}\mathbf{E}(\mathbf{r}_n + h/2\mathbf{k}_2)$$

$$\mathbf{k}_4 = \frac{\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n + h\mathbf{k}_3)}{|\mathbf{V}_n \cdot \mathbf{E}(\mathbf{r}_n + h\mathbf{k}_3)|}\mathbf{E}(\mathbf{r}_n + h\mathbf{k}_3).$$

Euler

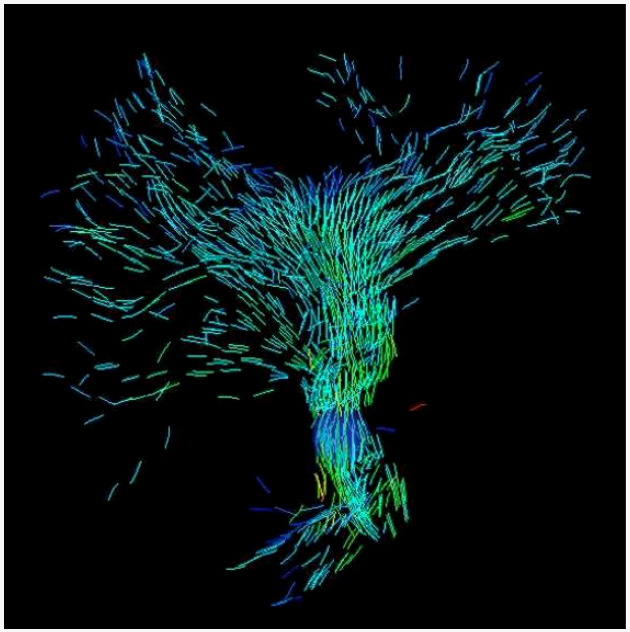
$$\mathbf{V}_{n+1} = \mathbf{E}(\mathbf{r}_{n+1})$$



SMT

SMT (Split & Merge Tractography) is a combination of basic tractography and probabilistic connectivity analysis in a Bayesian framework.

It aims at combining the advantages of both approaches.



See MICCAI 2007 (Brisbane, Australia) for further details or visit www.vavlab.ee.boun.edu.tr

Base Application

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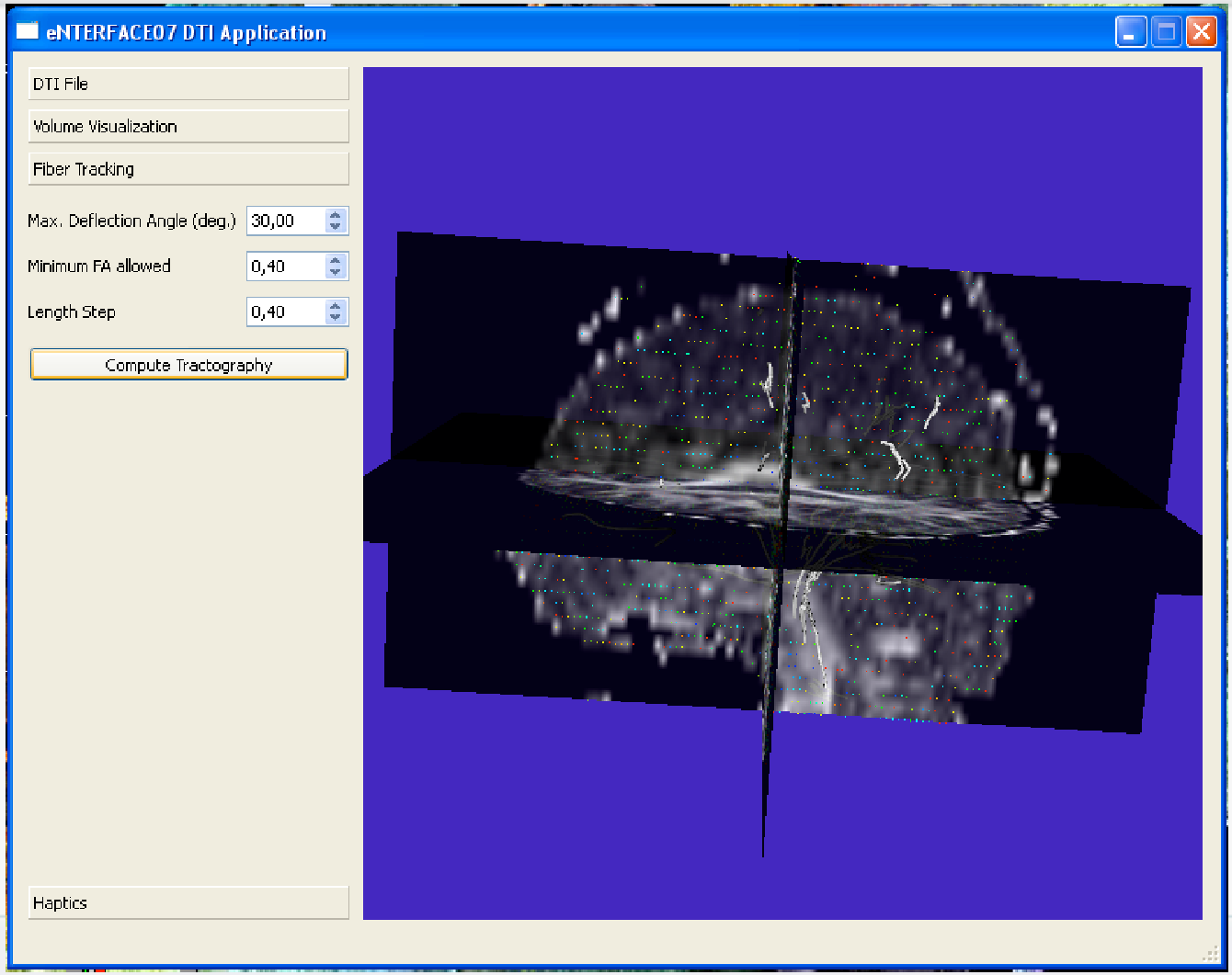
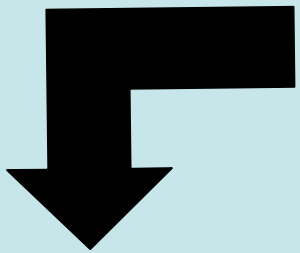


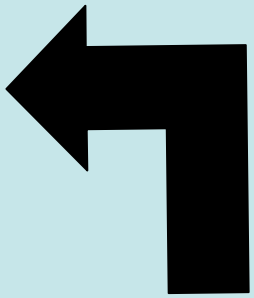
Haptic Interface Architecture

Qt



Haptic Messenger

- Q Object



Visualization Operations

- QVTK-Widget environment
- VTK (www.kitware.com)
- 50 Hz update rate

Haptic Device Operations

- QGL-Widget environment
- CHAI-3D (www.chai3d.org)
- 1000 Hz update rate

Haptic Slicing & ROI

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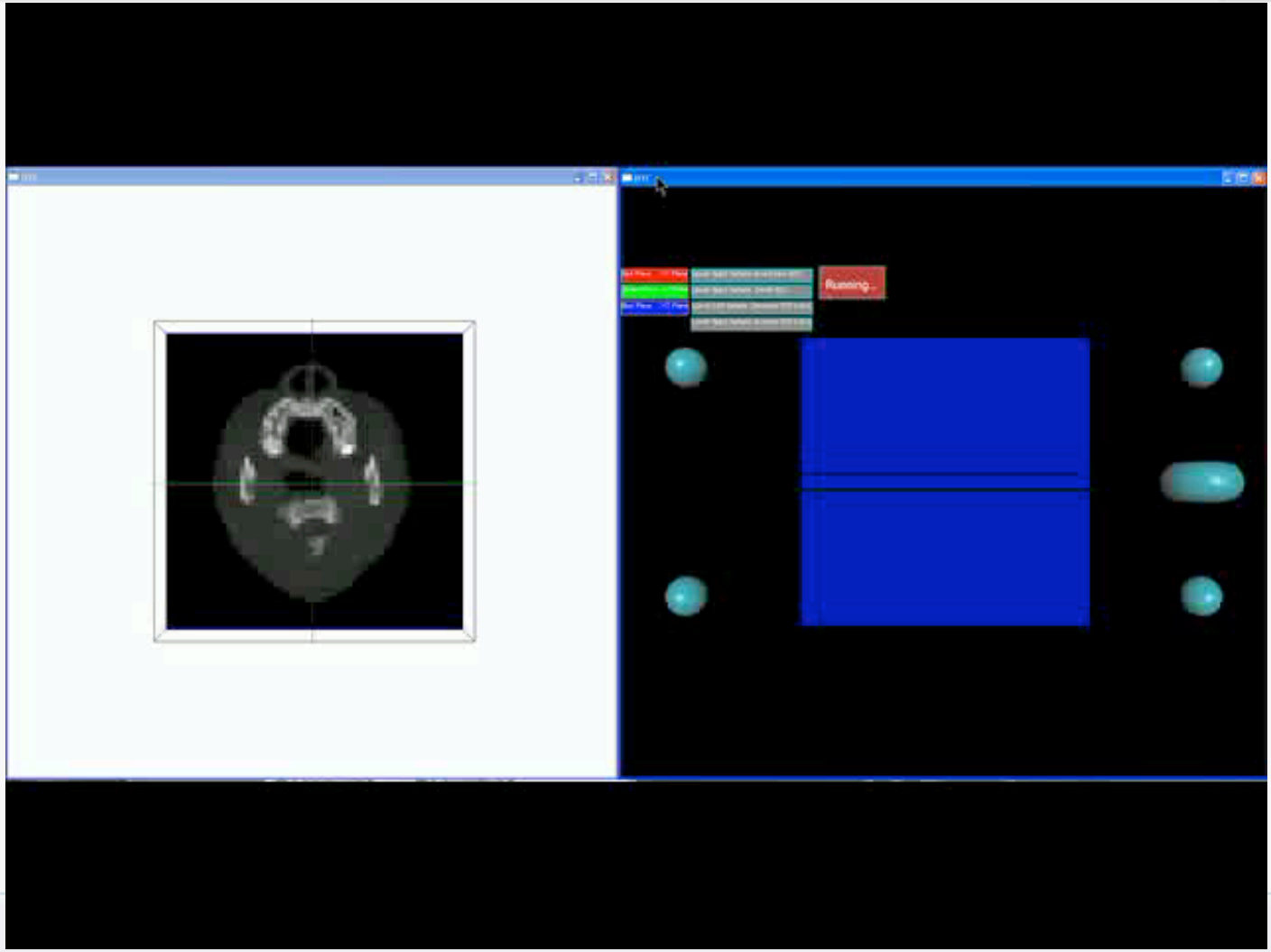
Demo Video



Missing Parts

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- Fine tuning of the haptic interface for clinic usability
- Integration of tractography output with the haptic interface
- Integration of SMT algorithm

Future Direction: 3D stereo vision