

Tools & Techniques for Direct Volume Interaction

Alexander Wiebel, Tobias Isenberg,
Stefan Bruckner, Timo Ropinski

EG Tutorial 2015

Tools & Techniques for Direct Volume Interaction

Introduction

EG Tutorial 2015

Brief Overview

- GPU acceleration allows fast rendering
- Fast rendering enables interactive exploration
- Techniques for interactive exploration have been developed
 - Rendering parameter changes
 - Data manipulation

Presenters

- Alexander Wiebel
Coburg University of Applied Science, Germany
- Tobias Isenberg
INRIA-Saclay, France
- Stefan Bruckner
University of Bergen, Norway
- Timo Ropinski
Ulm University, Germany



Prerequisites

- Beginner to intermediate level course
- Assumptions about audience
 - Working knowledge in interactive computer graphics
 - Basic knowledge regarding volume data
 - Some basic graphics programming skills

Course Outline

- 13:20 Introduction (*Timo Ropinski*)
- 13:25 Visualization of Volume Data and the Need for Interaction (*Timo Ropinski*)
- 13:55 Questions
- 14:00 Direct Manipulation (*Alexander Wiebel*)
- 14:30 Questions and Discussion
- 14:35 Interaction with Non-Standard Input and Output Devices 1/2 (*Tobias Isenberg*)
- 14:50 Break
- 15:10 Interaction with Non-Standard Input and Output Devices 2/2 (*Tobias Isenberg*)
- 15:25 Questions
- 15:30 Guided Navigation and Exploration (*Stefan Bruckner*)
- 16:00 Questions and Discussion
- 16:05 Closing Remarks (*Alexander Wiebel*)
- 16:10 The End

Updated Course Material

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More information on the current Eurographics tutorial can be found [here](#).

Your tutorial team (Alexander, Stefan, Timo, Tobias)

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<http://tutorials.awmw.org/DirectVolumeInteraction>

Tools & Techniques for Direct Volume Interaction

Part 1: Visualization of Volume Data
and the Need for Interaction

Timo Ropinski, *Ulm University, Germany*

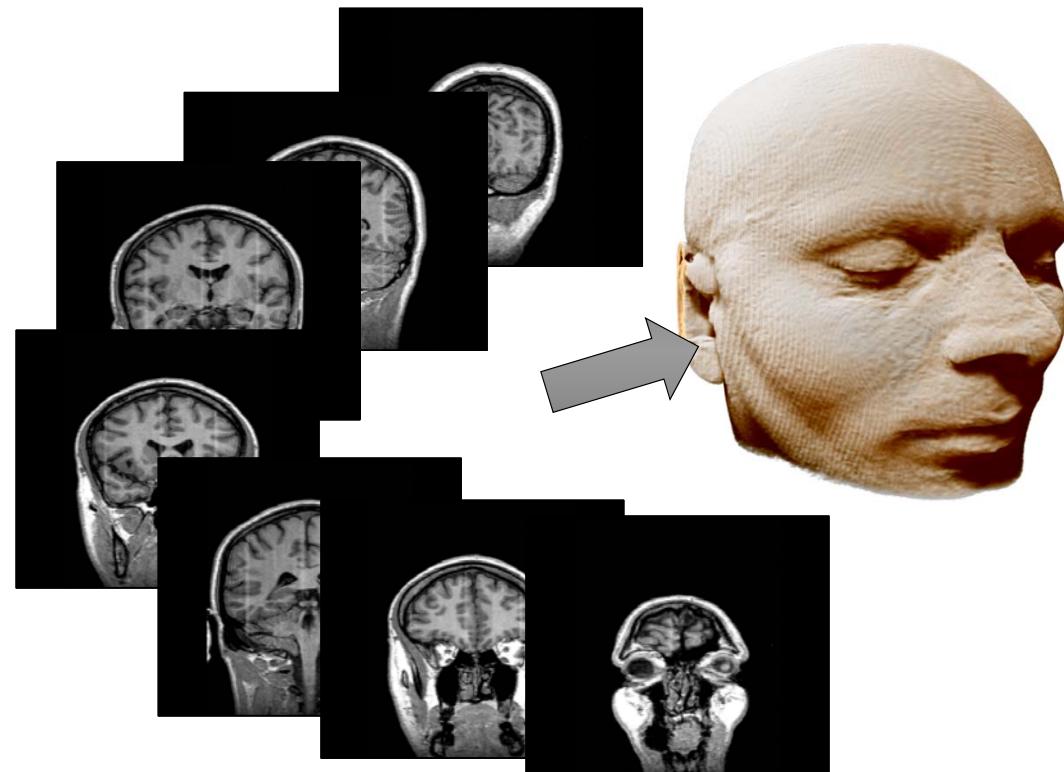
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Outline of Part 1

- Visualization of volume data
- Interaction as a parameter change method
- Direct vs. indirect interaction techniques
- Interaction tasks in volume visualization

Visualization of Volume Data

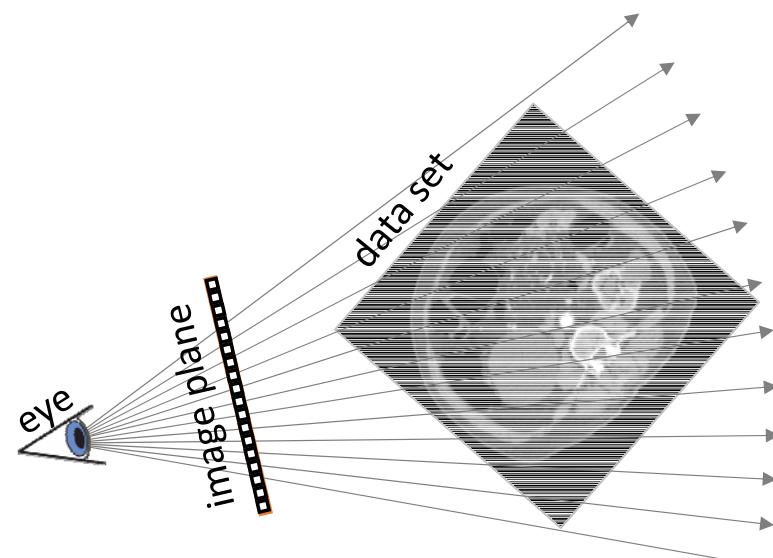
- Render 3D uniform grid to obtain a 2D image
- Interactively adapt rendering to modify 2D image
 - Camera parameters
 - Transfer function
 - Clipping parameters
 - Lighting parameters
 - ...



Volume Ray-Casting

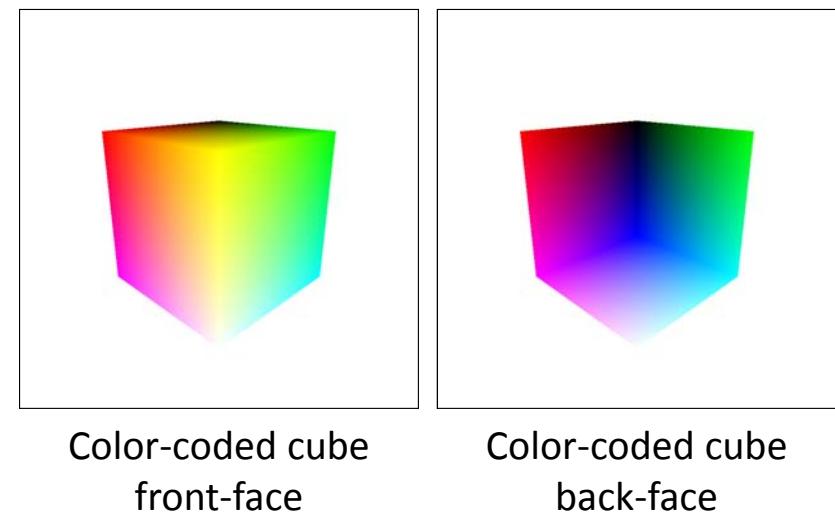
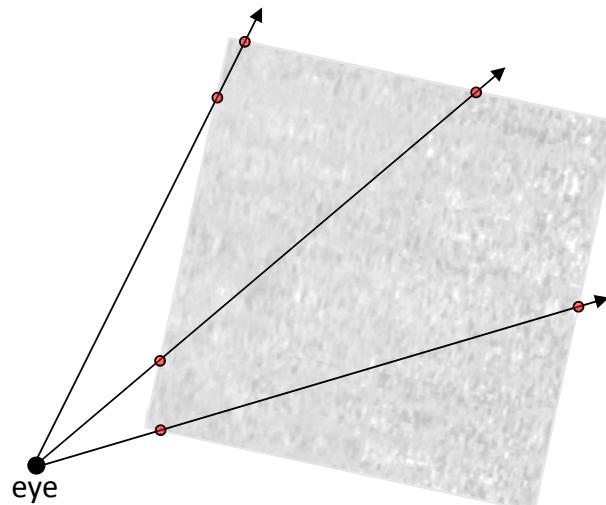
- Cast rays through each pixel and the volume

```
for each pixel on the image plane
    compute entry- and exit-points
    while current position inside volume
        read intensity
        apply transfer function
        (compute shading)
        apply compositing
        compute new position
    end while
    set pixel color
end if
```



Entry- and Exit-Point Computation

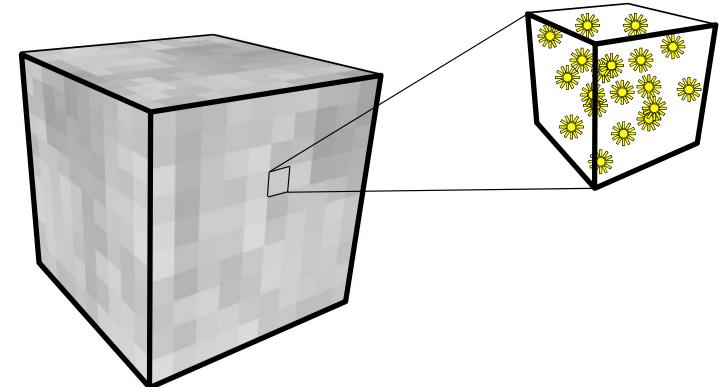
- GPU-based ray-casting exploits rasterization capabilities to achieve interactive frame rates



[Krüger & Westermann, IEEE VIS 2003]

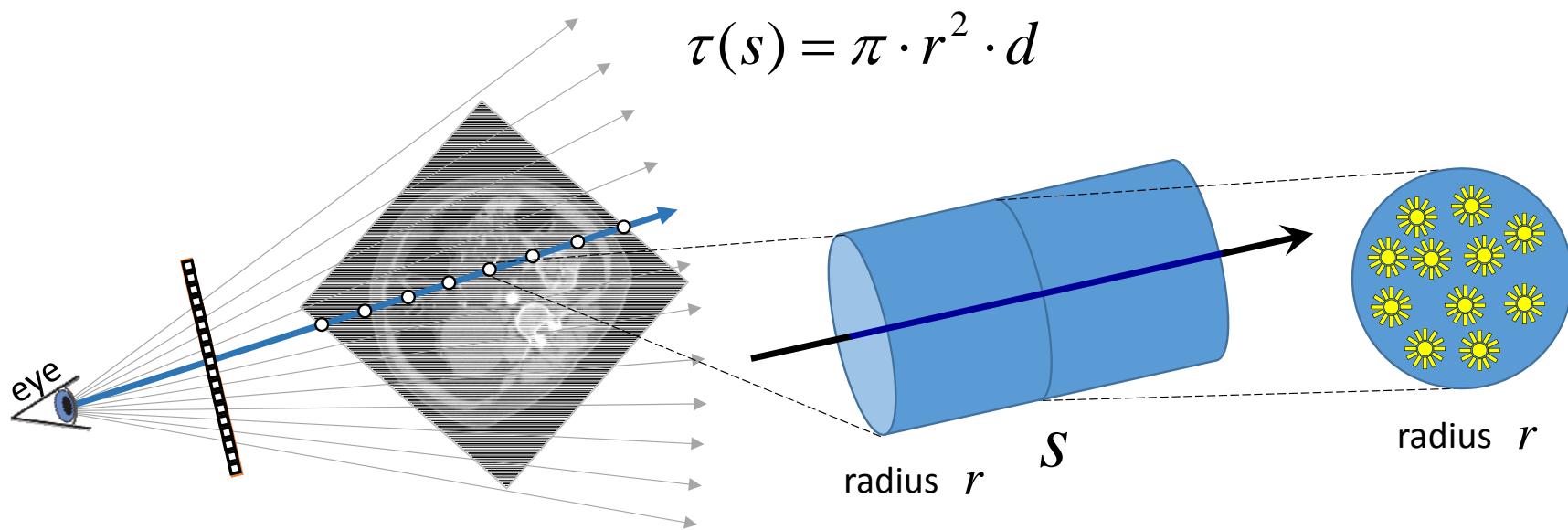
Volume Compositing

- Frequently realized through Emission Absorption Model
- Assumption: Volume consists of small particles which are
 - opaque
 - non-reflecting
 - light emitting
 - the only light sources in the scene



Absorption

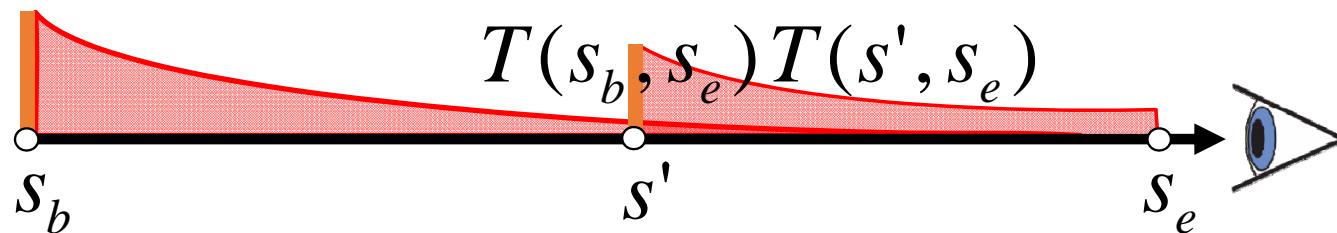
- Extinction coefficient τ
probability that a ray hits a particle
 - τ is proportional to d (=number density of particles)



From Absorption to Transparency

- Transparency $T(s_0, s_1)$
probability that a ray does not hit a particle between s_0 and s_1

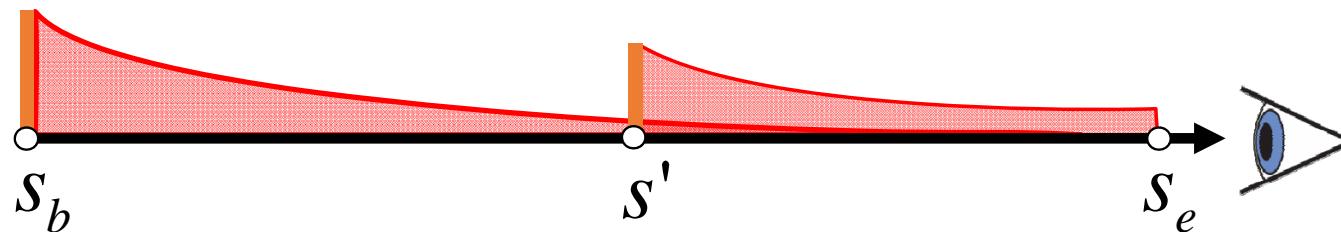
$$T(s_0, s_1) = \exp\left(-\int_{s_0}^{s_1} \tau(s) ds\right)$$



Emission

- Each sample potentially contributes emission

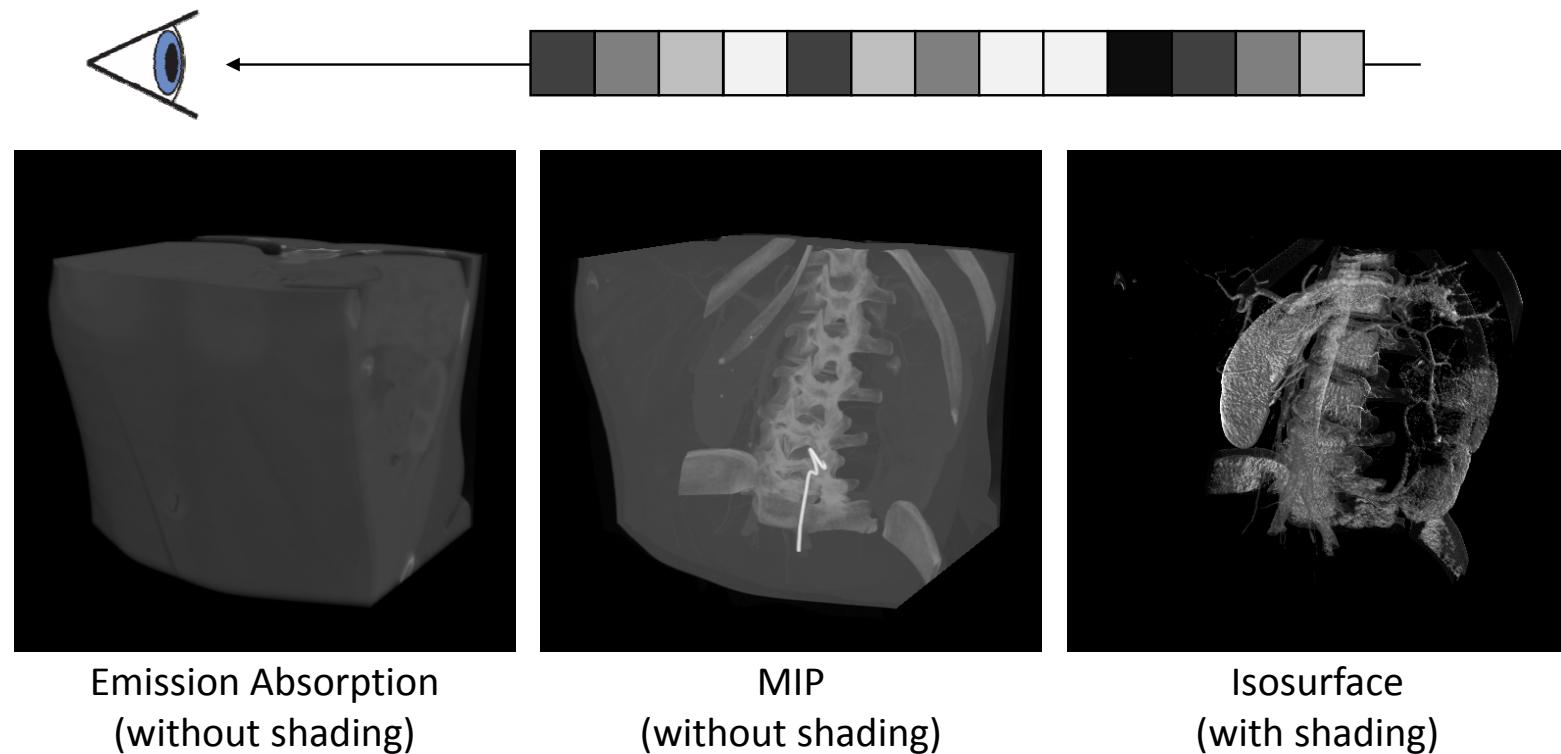
$$I(s_e) = T(s_b, s_e) \cdot I_B + \int_{s_b}^{s_e} T(s', s_e) \cdot \tau(s') \cdot c_e(s') ds'$$



- τ affects emission's impact
 - Small τ : particles are hit less likely => less emission
 - Large τ : particles are hit more likely => more emission

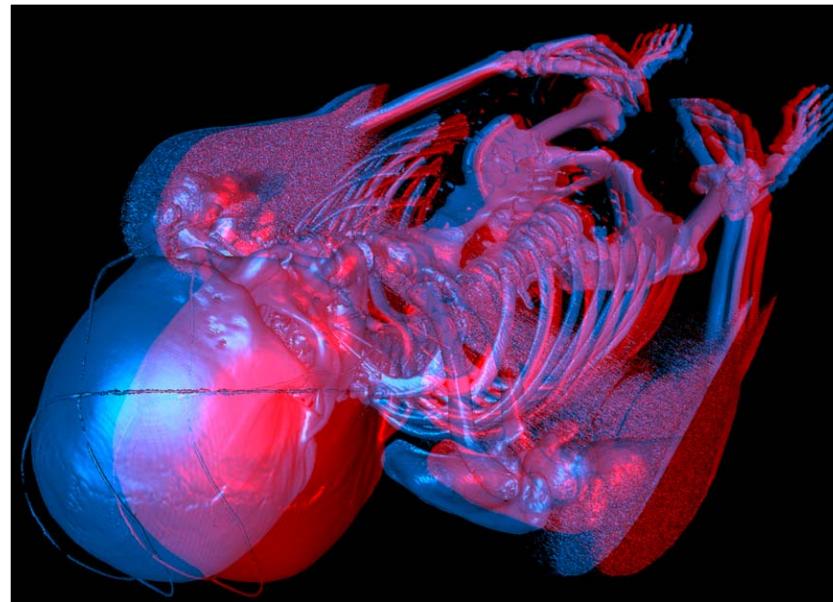
Alternative Compositing Schemes

- Final pixel value depends on used compositing scheme



Stereo Rendering

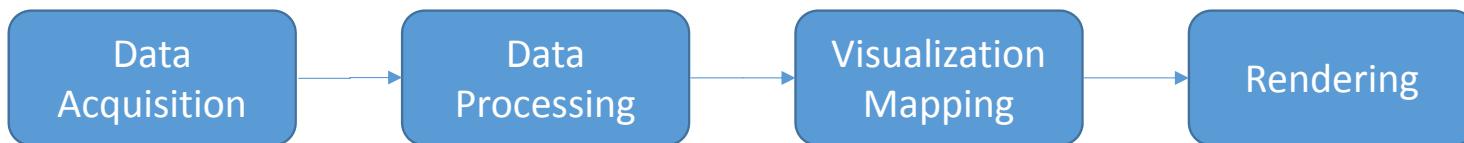
- Interactive frame rates of GPU-based volume rendering enable rendering of multiple views



Anaglyph Rendering
[ImageVis3D]

Volume Interaction

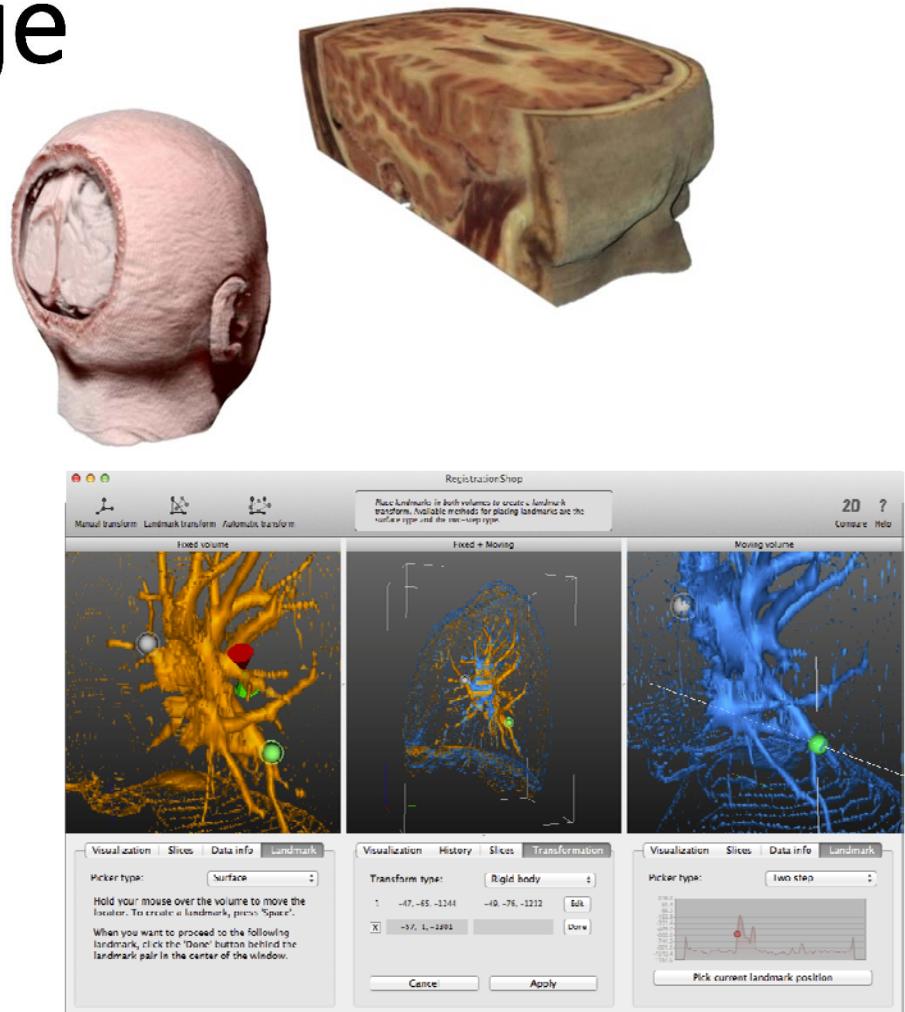
- Interactive frame rates of GPU-based volume rendering enable interaction with the visualization pipeline



- We focus mainly on three stages
 - Interaction with the data processing stage
 - Interaction with the visualization mapping stage
 - Interaction with the rendering stage

Data Processing Stage

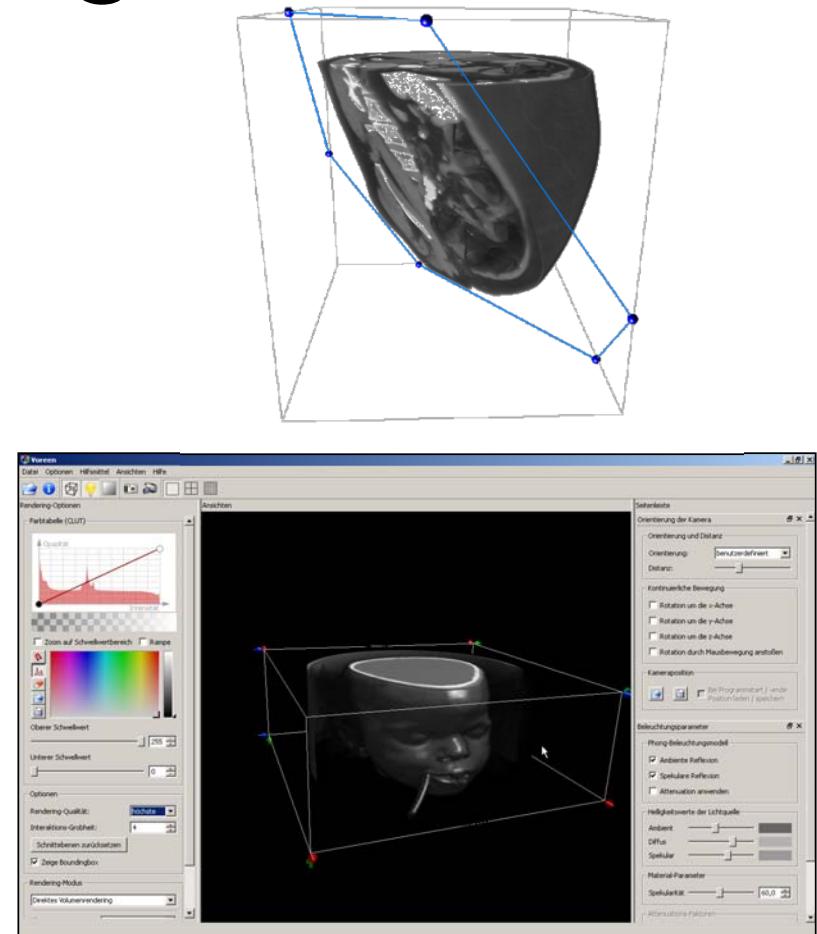
- Data cleaning
- Segmentation
- Registration
- Clipping
- Measuring
- Cutting & deformation



[Smit et al., EG VCBM 2014]

Rendering/Mapping Stage

- Transfer function mapping
 - Navigation
 - Lighting control
 - Annotation
-
- Registration
 - Clipping
 - Measuring
 - Cutting & deformation

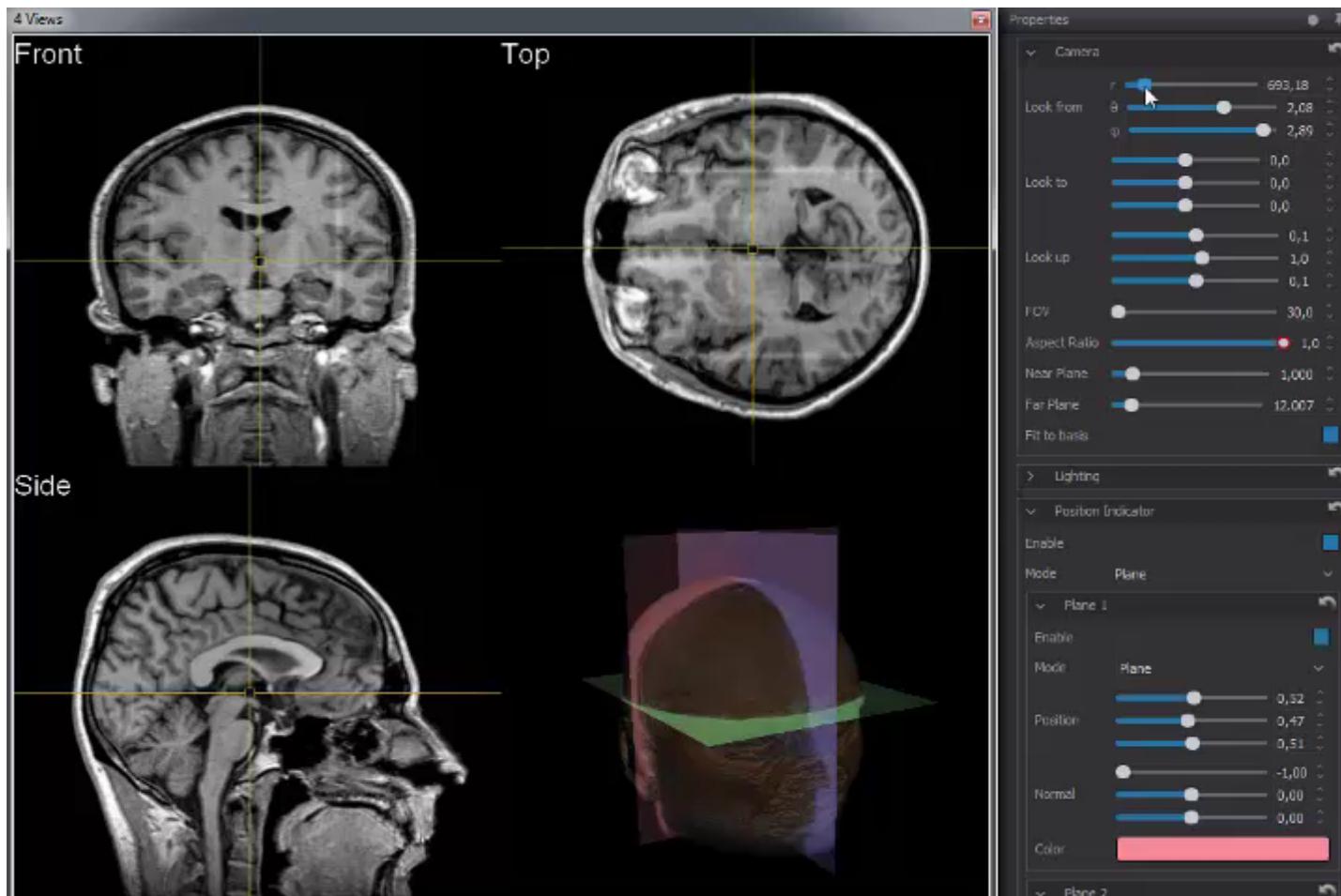


Direct vs. Indirect Interaction

- Often volumetric data is explored collaboratively
- Requests during collaborative data exploration
 - Visually emphasize certain features of interest
 - Add/remove features from the visualization
 - Navigate to a certain view
 - Cut/clip data at given position
 - Often pinpointing of features is relevant

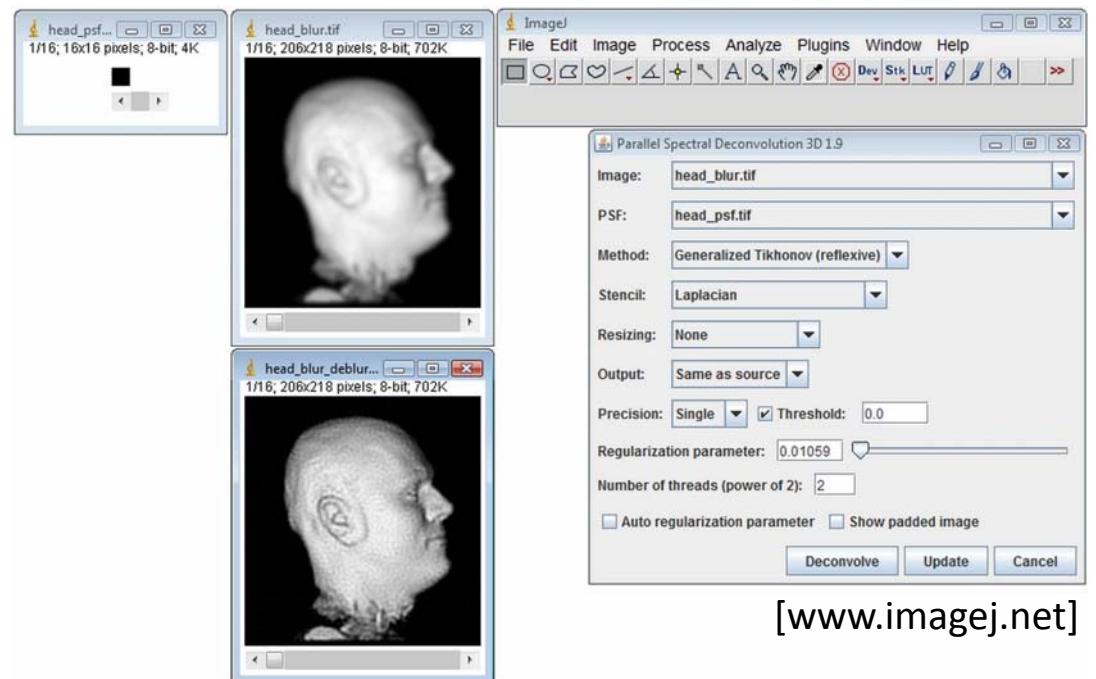


Direct vs. Indirect Interaction - Example



Data Cleaning

- Direct and indirect techniques facilitated
 - Apply global data filters
 - Refine data locally

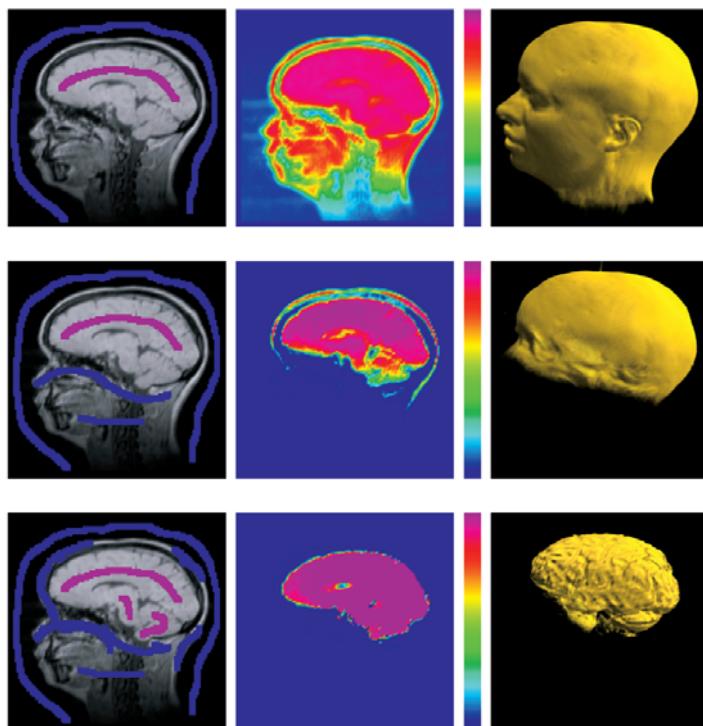


[www.imagej.net]

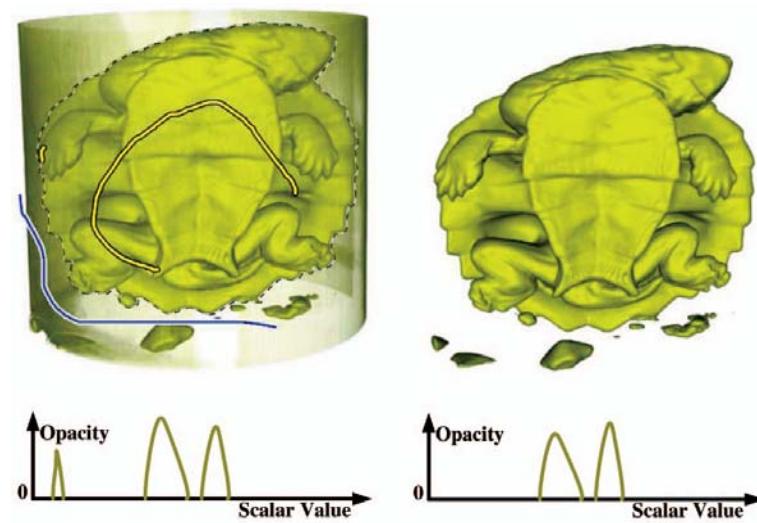
Segmentation

- Mostly direct techniques facilitated
 - Pre-defined primitives
 - Freehand segmentation

Segmentation – Direct



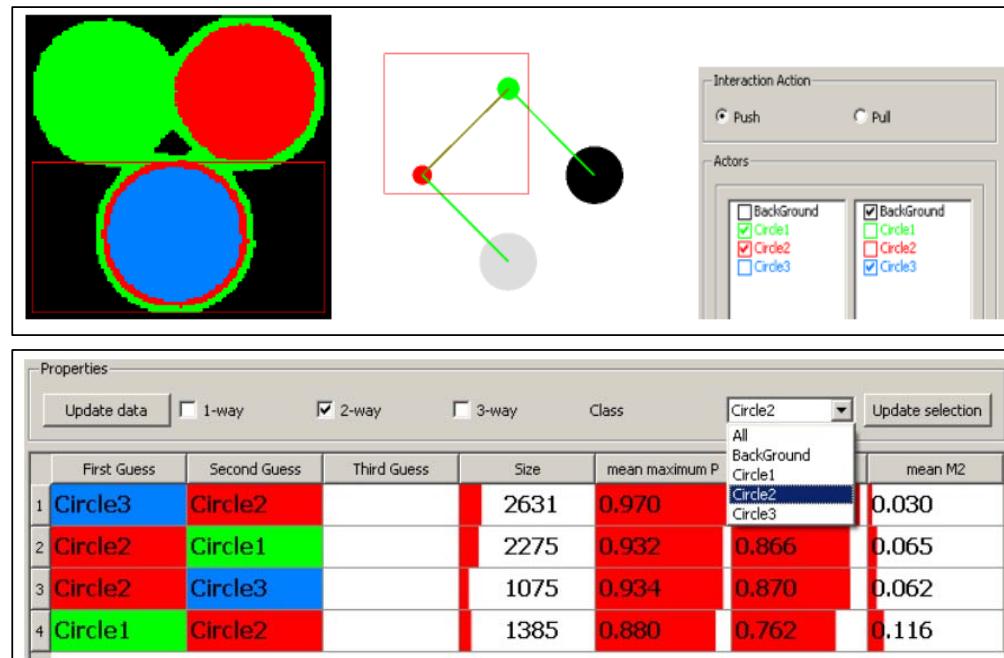
[Tzeng et al., Vis 2003]



[Wu and Qu, TVCG 2007]

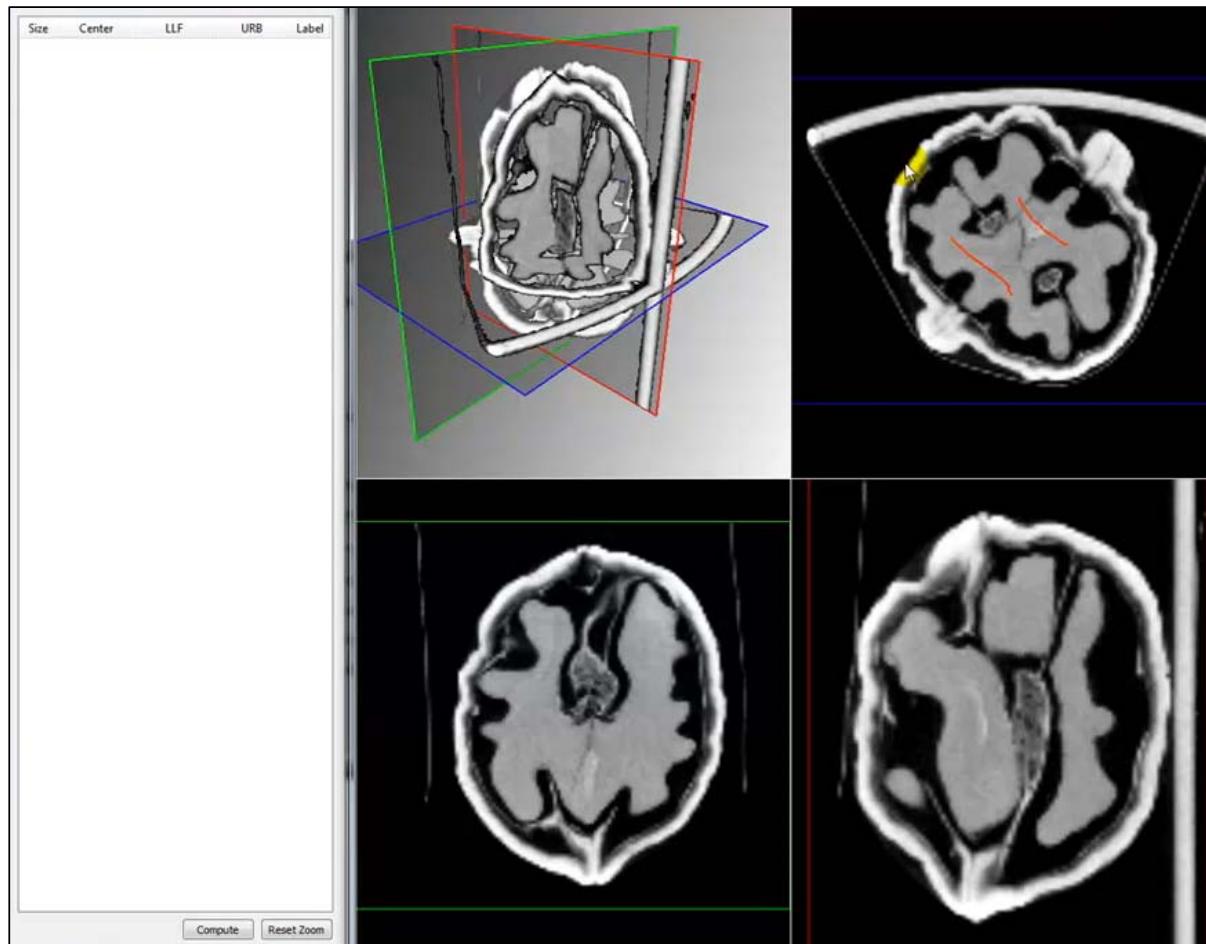
Segmentation - Systems

- Exploit interactive dialog between human and computer



[Saad et al., EuroVis 2010]

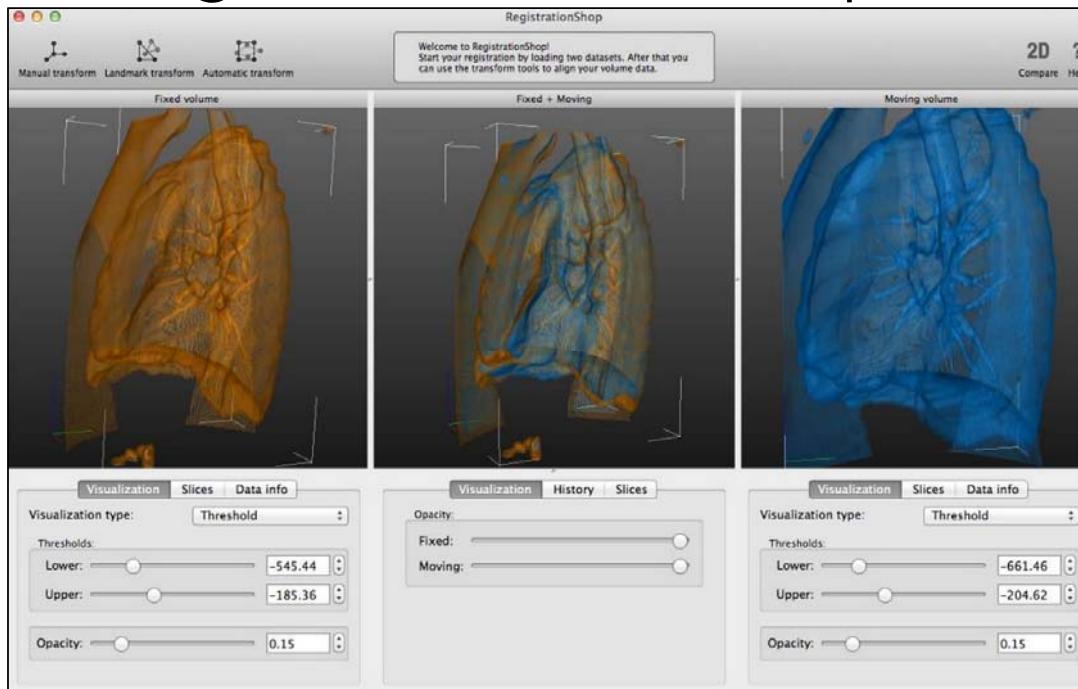
Segmentation – Direct Systems



[Prassni et al., IEEE Vis 2010]

Registration

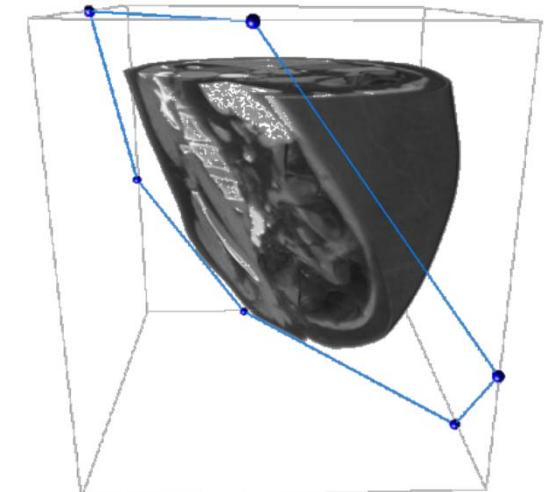
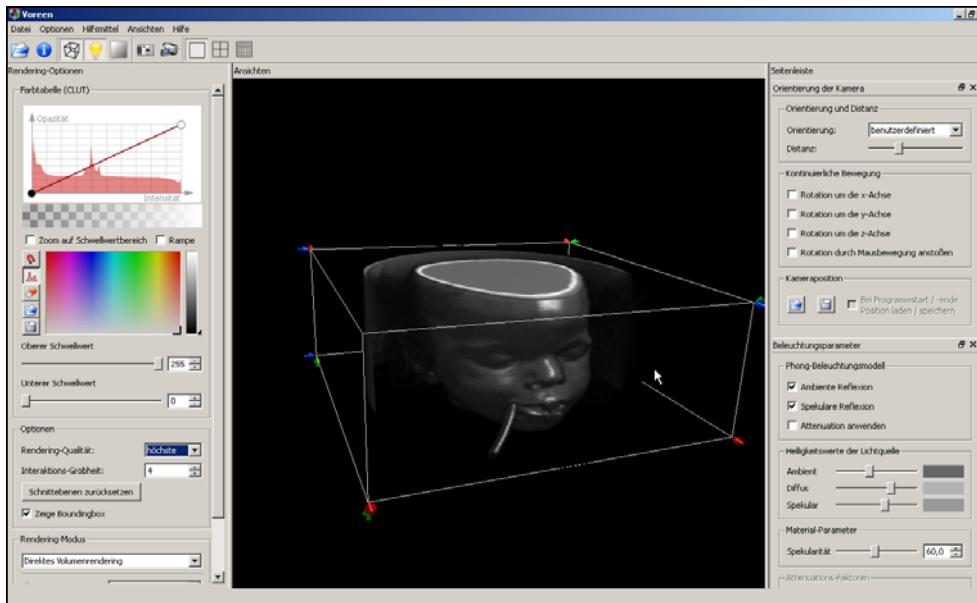
- Often performed directly through landmark matching
(rigid and non-rigid transformations possible)



[Smit et al., EG VCBM 2014]

Clipping

- Direct and indirect techniques used
 - Both adequate for axis-aligned planes
 - Direct techniques preferred for arbitrary planes

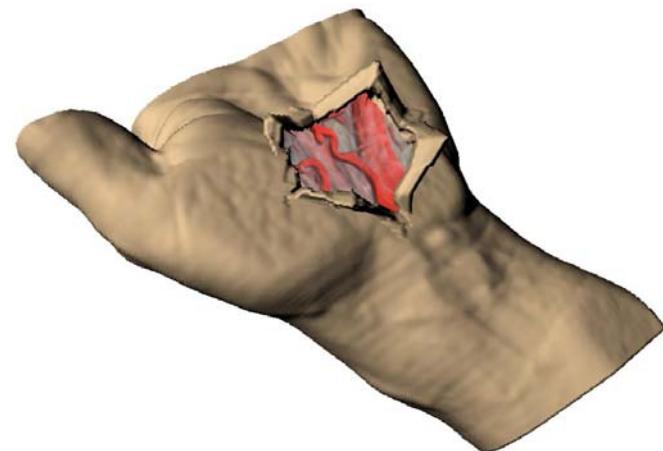


Measuring

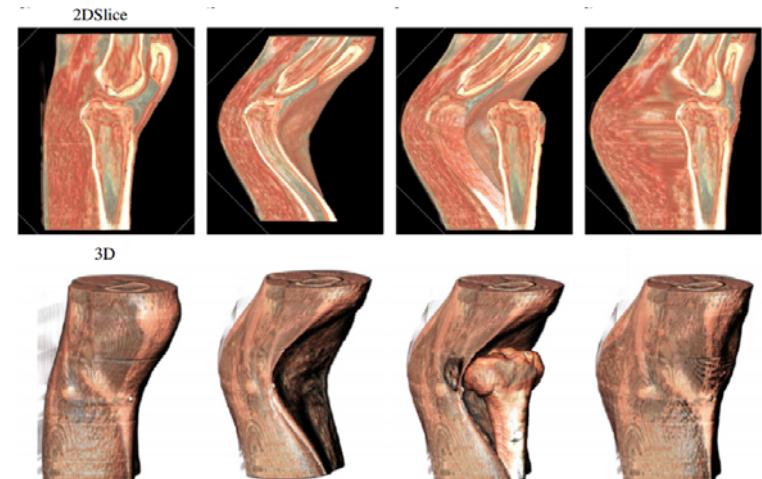
- Mostly direct techniques used
 - 2D tools: circle, distance, angle, ROI, pixel lens, text, freehand distance
 - 3D tools: distance, pixel lens, text

Cutting & Deformation

- Direct techniques mostly applied

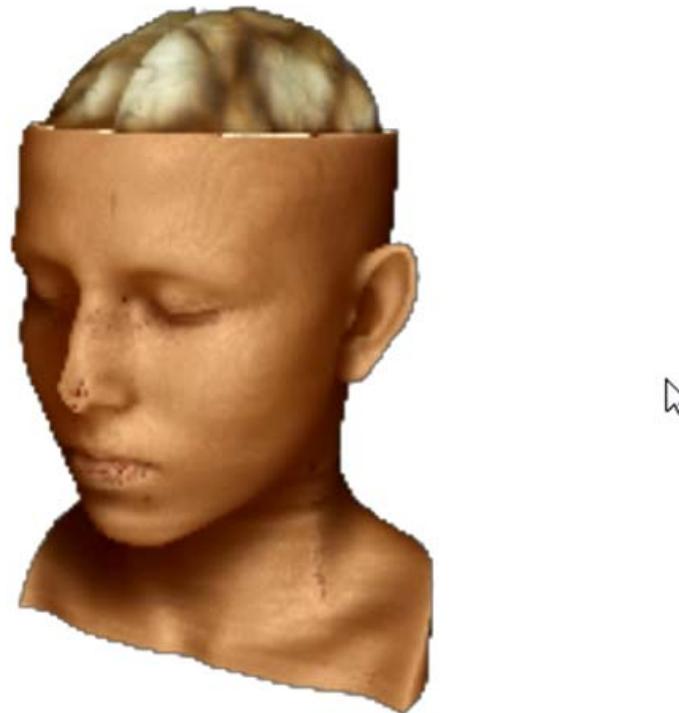


[Mensmann et al., WSCG 2008]



[Correa et al., C&G 2010]

Cutting & Deformation cont.

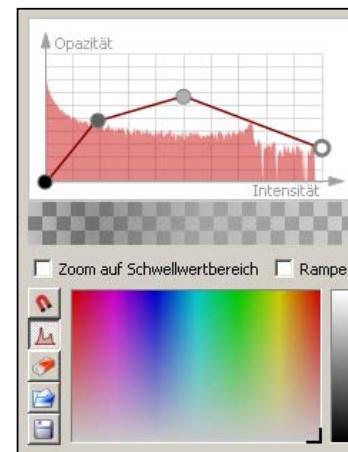


[Ropinski et al., IEEE TVCG 2012]

Transfer Function Mapping

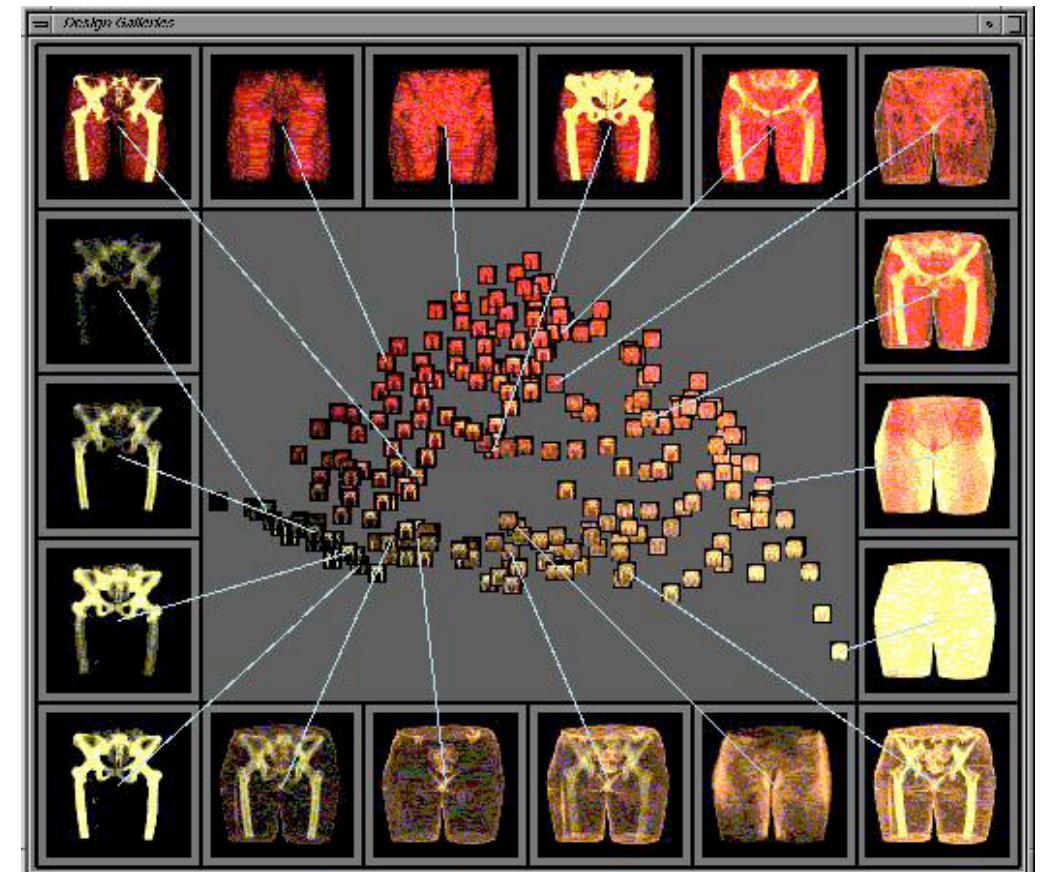
- Manual setup of transfer functions is
 - Time-consuming
 - Error-prone
 - Hard to reproduce

[Rezk-Salama et al., IEEE Vis 2006]



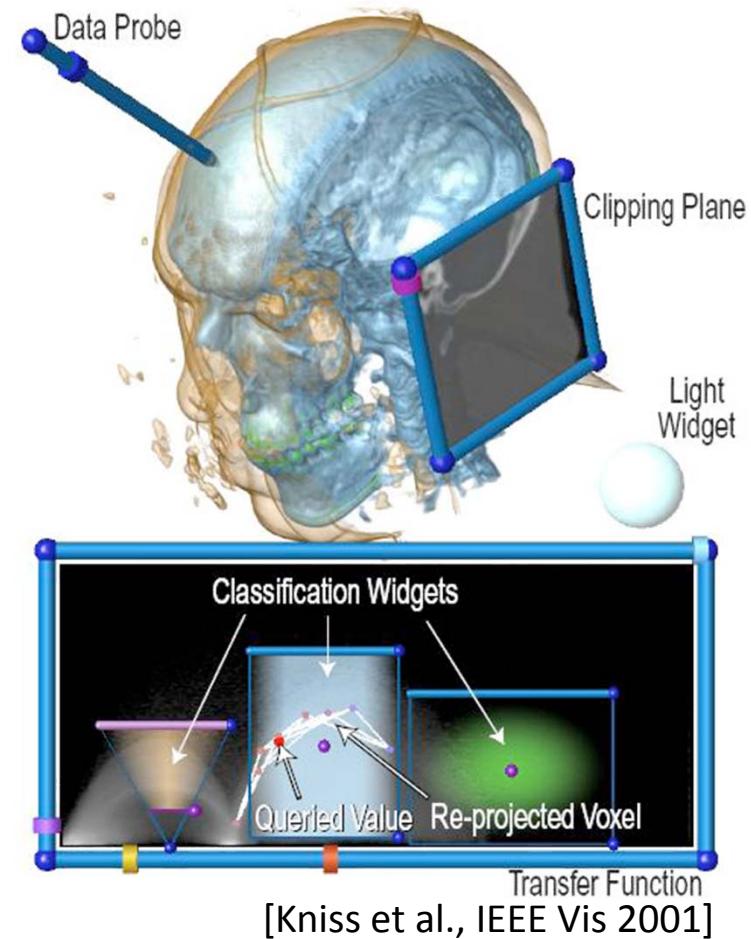
Indirect Transfer Function Mapping

- Two main alternatives
 - Interact with data histogram
 - Selection of parameter presets

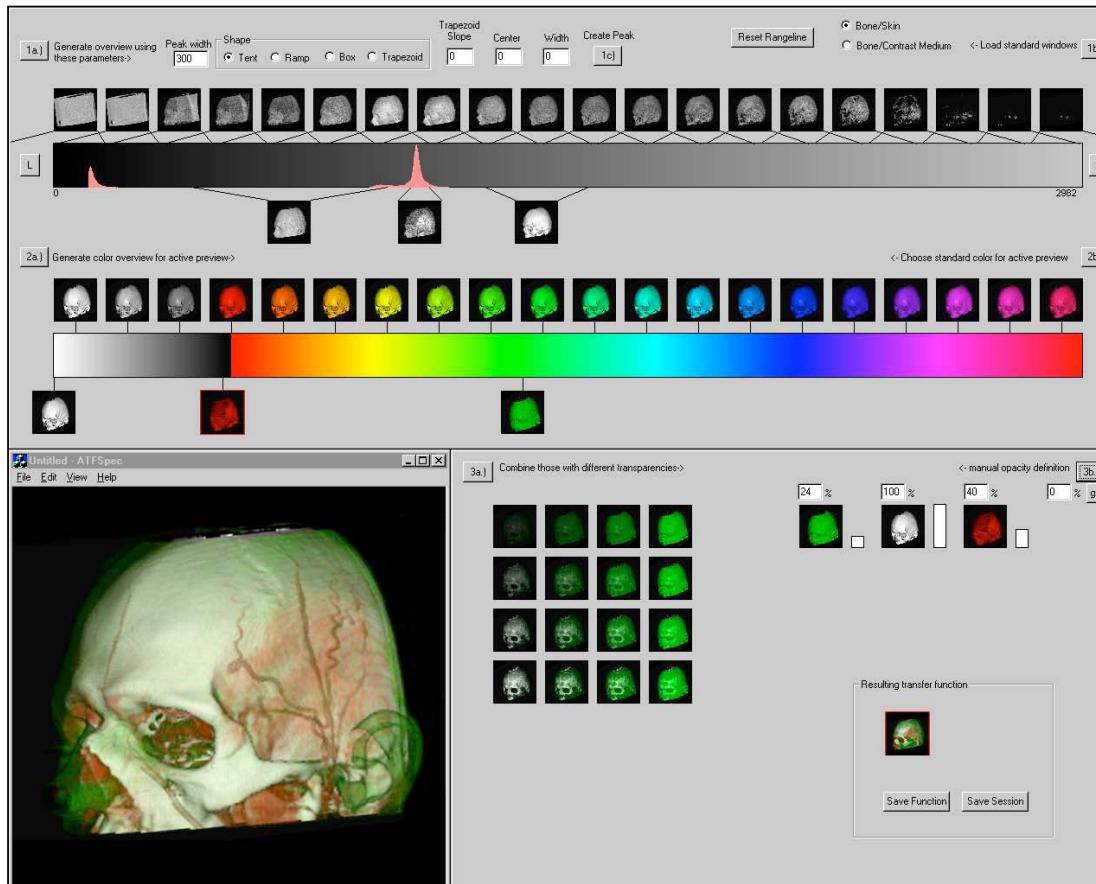


[Marks et al., ACM Siggraph 1997]

Direct Transfer Function Mapping

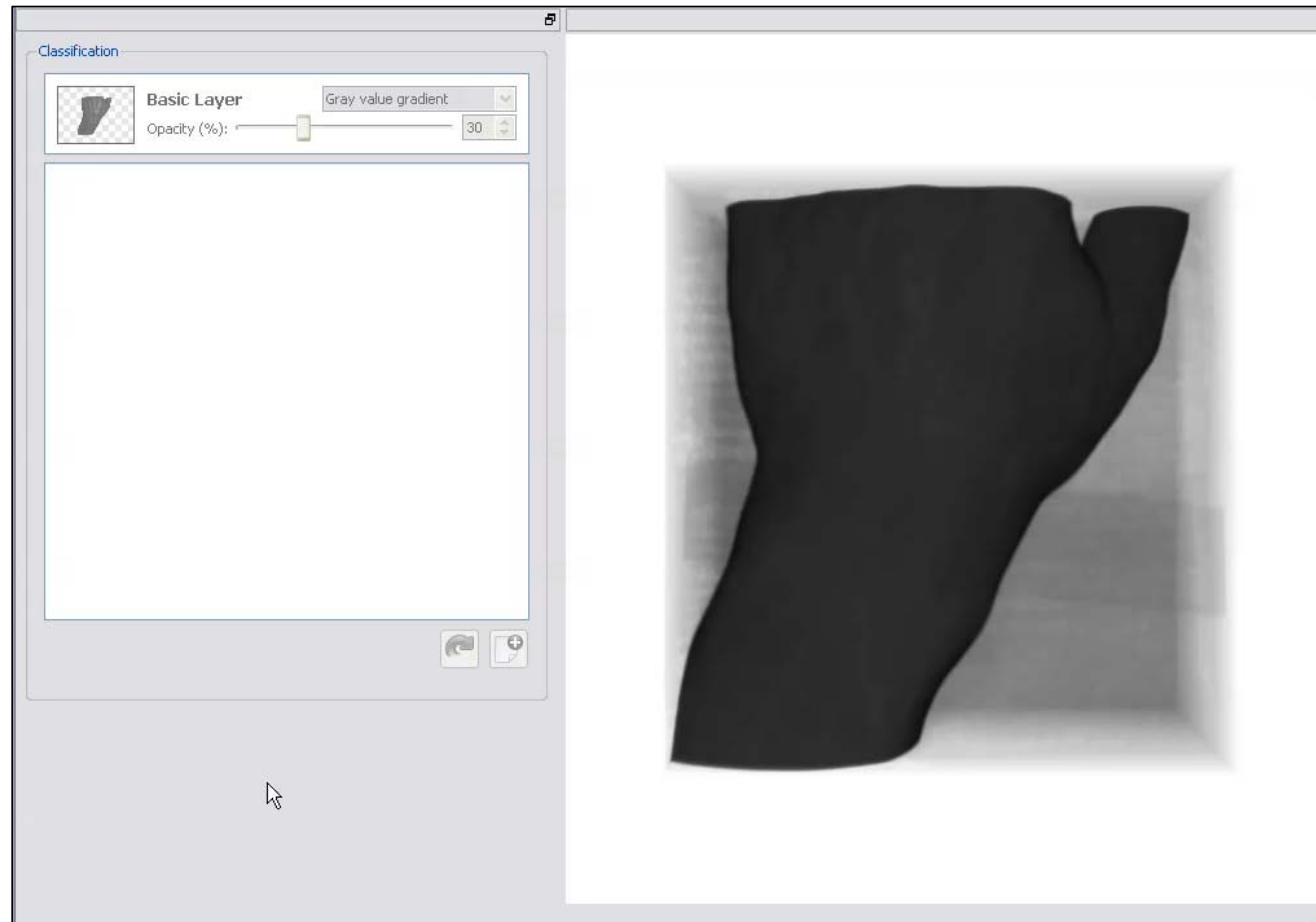


Transfer Function Mapping - Mixed



[König and Gröller, SCCG 2001]

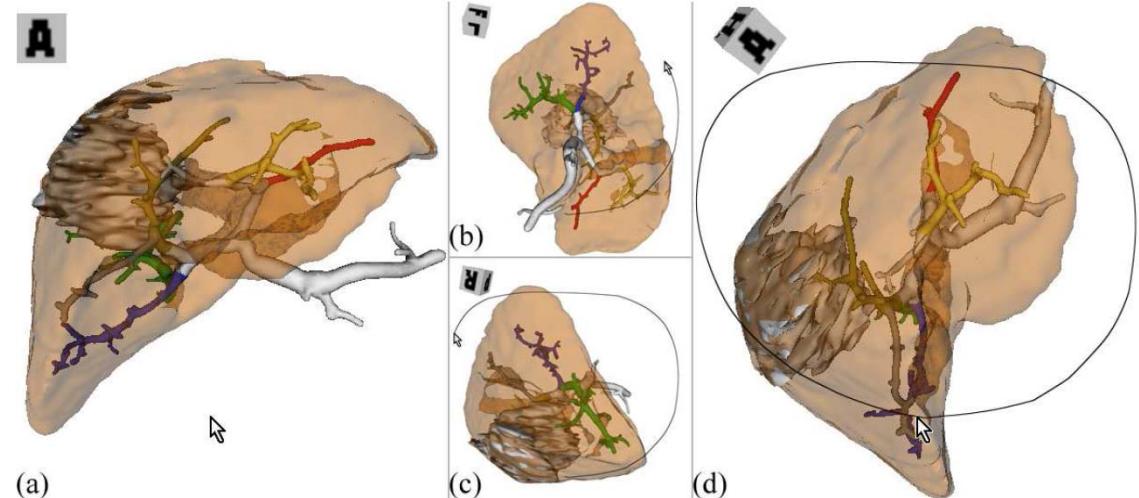
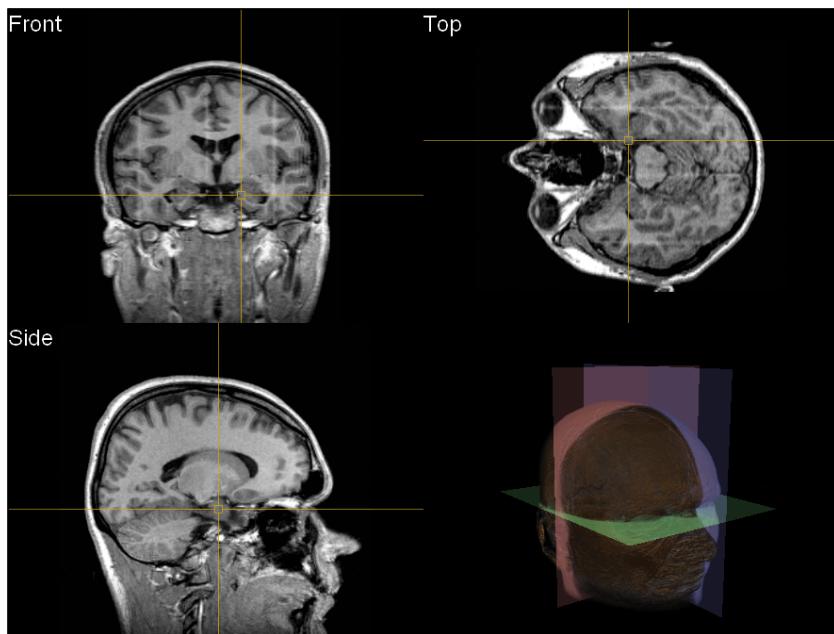
Transfer Function Mapping - Mixed



[Ropinski et al., IEEE Volume Graphics 2008]

Navigation

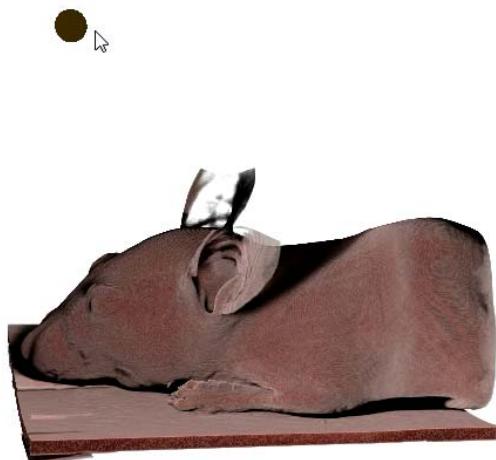
- Preferrable approach depends on dimensionality
 - 2D: Can be done directly or indirectly
 - 3D: Most efficiently performed directly



[Bade et al., Smart Graphics 2005]

Lighting Control

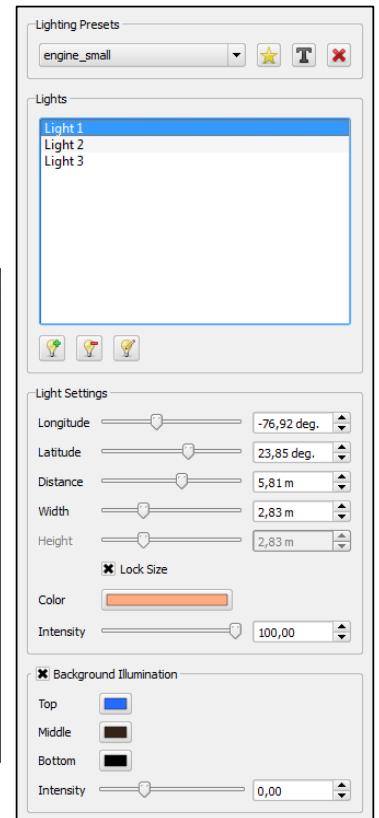
- Most efficiently performed directly
- But some parameters not directly available



[Ropinski et al., IEEE PaVis 2010]



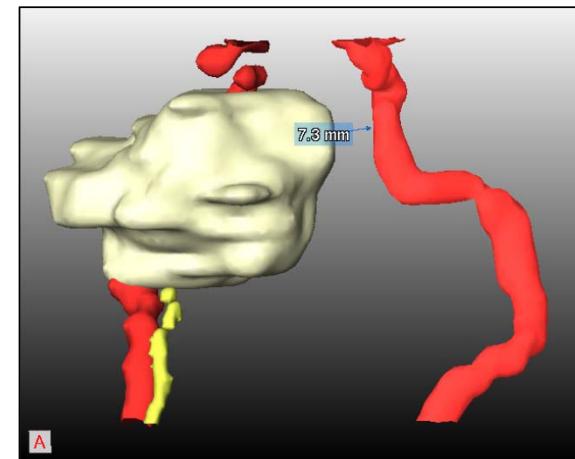
Inviwo
[www.inviwo.org]



Exposure Renderer
[Kroes et al., PLoS ONE 2012]

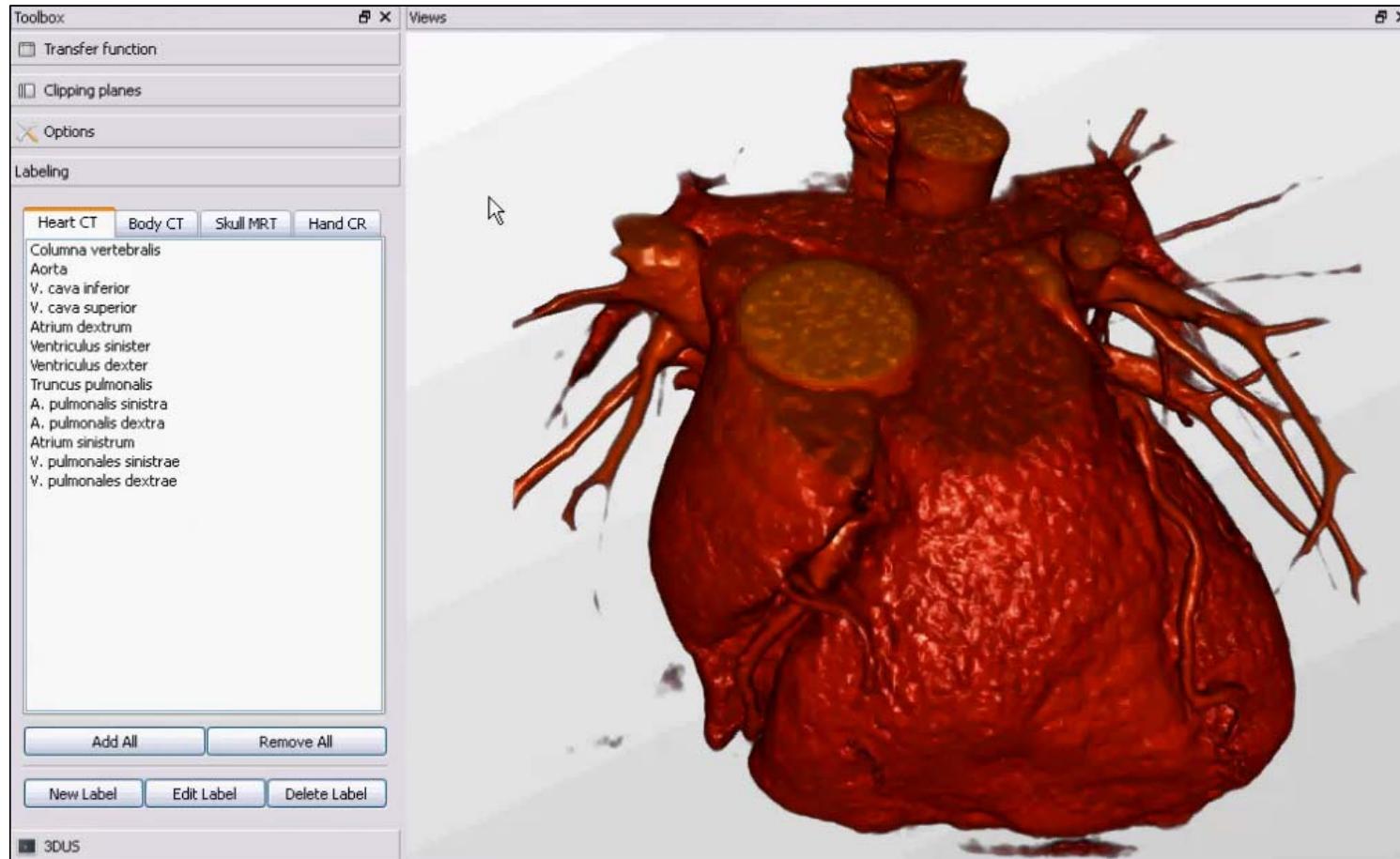
Annotation

- Different label types exist
 - Internal labels (direct)
 - External labels (less direct)
 - Hybrid techniques
- Interaction most often direct



[Krueger et al., EuroVis 2005]

Annotation - Mixed



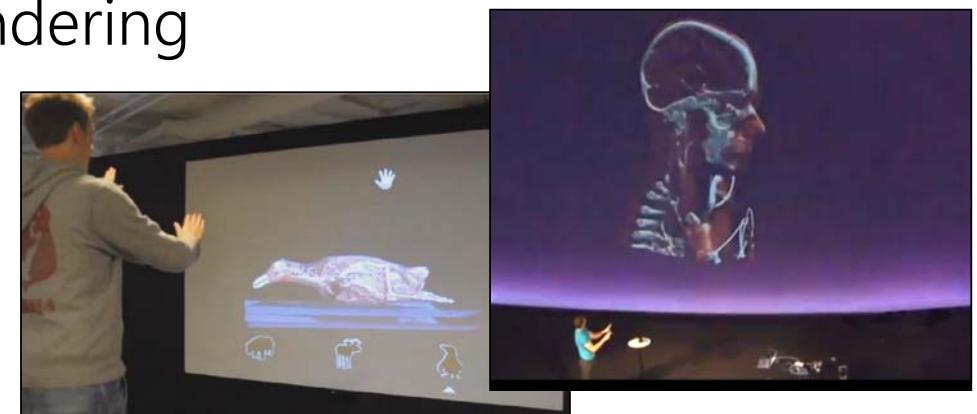
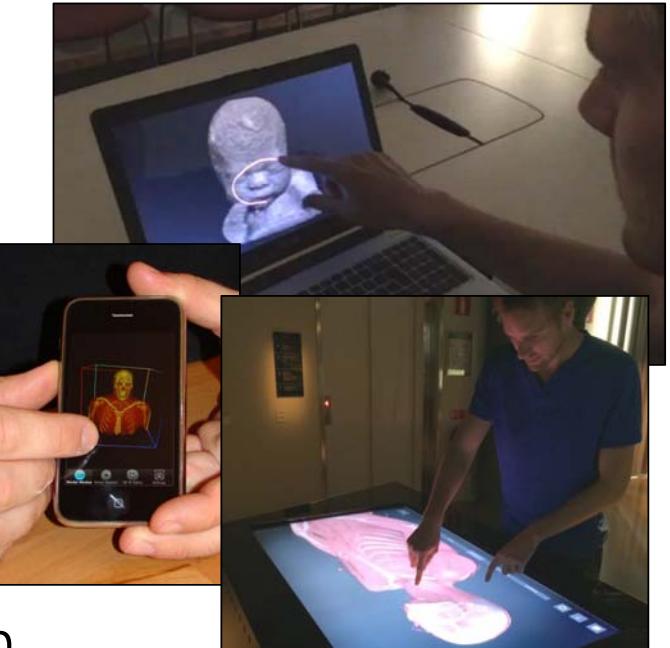
[Ropinski et al., VMV 2007]

Interaction Semantics vs. Techniques

- Semantics
 - Data cleaning
 - Segmentation
 - Registration
 - Clipping
 - Measuring
 - Cutting & deformation
 - Transfer function mapping
 - Navigation
 - Lighting control
 - Annotation
- Direct Techniques
 - Sketching lines
 - Marking regions
 - Selecting
 - Points: Picking
 - Lines: Outlining/Sketching
 - Volumes: Drawing/Sketching
 - Trackball
- Required 3D Actions
 - Selecting points, lines and surfaces
 - Segmenting and 3D painting
 - Manipulating transfer functions and other global parameters

Interaction Hardware

- Modern hardware focusses on direct interaction with the content
- Touch interaction
 - Direct connection with the data
 - Occlude the visualization during interaction
 - Results in issues with stereo rendering
- Touchless interaction
 - Registered gestures
 - Unregistered gestures
 - Good communication



End of Part 1

Thank You and all Collaborators!

The screenshot shows the official website for Inviwo. At the top is a dark header with the Inviwo logo and a navigation bar with links for Home, Download, Documentation, and Team. Below the header is a sub-navigation bar with Overview, Features, and Download. The main content area features a large title "Inviwo" above a description of the software as a framework for rapid visualization prototyping written in C++, exploiting modern graphics hardware, and available under the BSD License. A blue "Download Inviwo" button is prominently displayed. To the right of the text is a screenshot of the Inviwo application interface, which includes a 3D volume rendering of a biological structure (like a blood vessel) and various control panels for parameters like color mapping and transformation. Below the main content are three sidebar boxes: "For Users" (describing how users can download and design their own visualizations), "For Developers" (describing how developers can extend the framework), and "News" (listing recent releases and availability dates).

www.inviwo.org

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