Direct Volume Interaction for Visual Data Analysis

Alexander Wiebel, Tobias Isenberg,
Stefan Bruckner, Timo Ropinski

IEEE VIS Tutorial 2015

Direct Volume Interaction for Visual Data Analysis

Introduction

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Brief Overview

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

Presenters

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

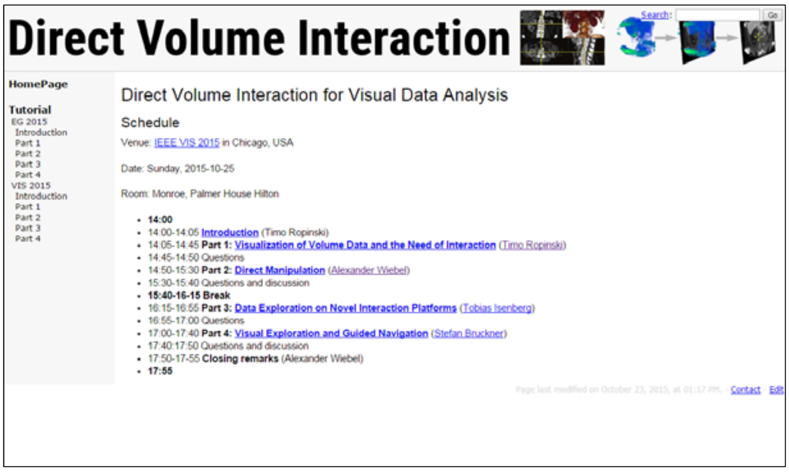
Prerequisites

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

Course Outline

14:00	Introduction (*Timo Ropinski*)
14:05	Visualization of Volume Data and the Need for Interaction (*Timo Ropinski*)
14:45	Questions
14:50	Direct Manipulation (*Alexander Wiebel*)
15:30	Questions and Discussion
15:40	Break
16:15	Data Exploration and Novel Interaction Platforms (*Tobias Isenberg*)
16:55	Questions
17:00	Visual Exploration and Guided Navigation (*Stefan Bruckner*)
17:40	Questions and Discussion
17:50	Closing Remarks (*Alexander Wiebel*)
17:55	The End

Updated Course Material



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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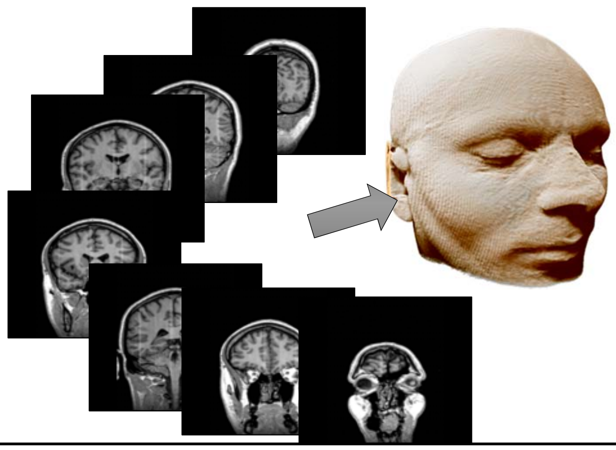
Outline of Part 1

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

Visualization of Volume Data

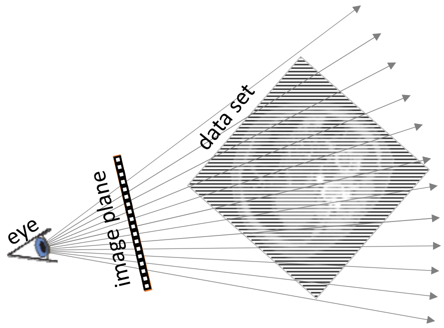
- Render 3D uniform grid to obtain a 2D image
- Interactively adapt rendering to modify 2D image
  - Camera parameters
  - Transfer function
  - Clipping parameters
  - Lighting parameters
  - …



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



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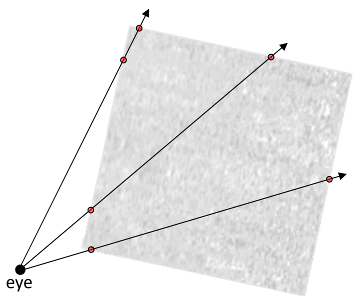
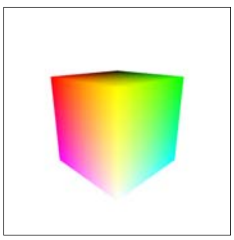
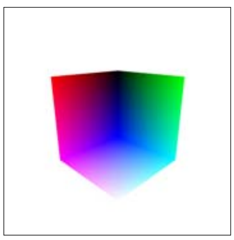
Entry- and Exit-Point Computation

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





Color-coded cube front-face



Color-coded cube back-face

[Krüger & Westermann, IEEE VIS 2003]

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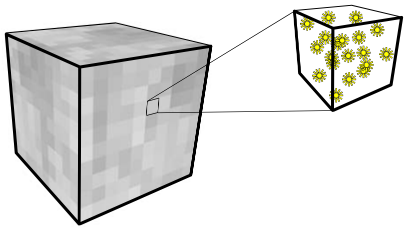
Volume Compositing

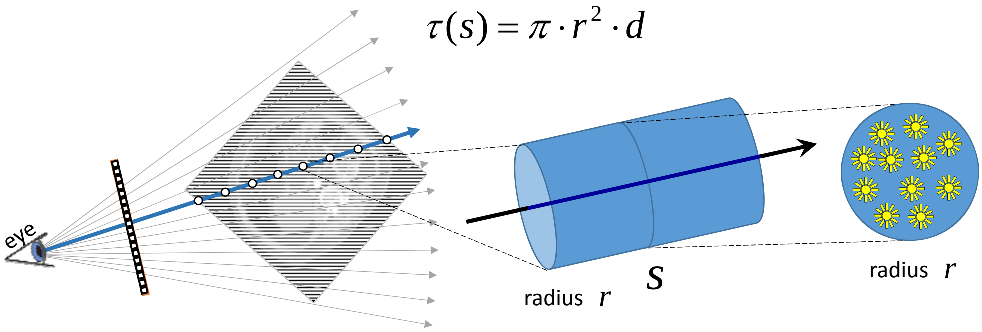
- Frequently realized through Emission Absorption Model
- Assumption: Volume consists of small particles which are
  - opaque
  - non-reflecting
  - light emitting
  - the only light sources in the scene



Absorption

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

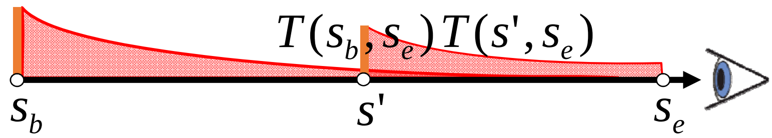
$$\tau(s) = \pi \cdot r^2 \cdot d$$



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

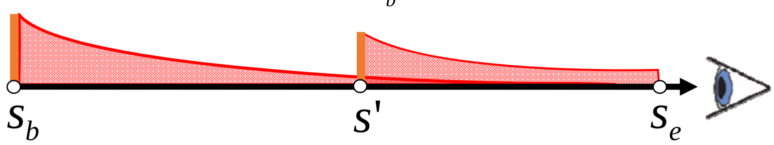
$$T(s_0, s_1) = \exp\left(-\int_{s_0}^{s_1} \tau(s)\,ds\right)$$



Emission

- Each sample potentially contributes **emission**

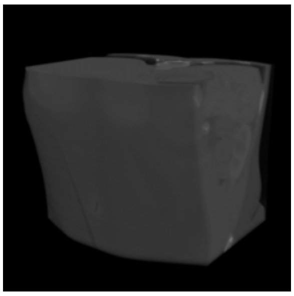
$$I(s_e) = T(s_b, s_e) \cdot I_B + \int_{s_b}^{s_e} T(s', s_e) \cdot \tau(s') \cdot c_e(s')\,ds'$$



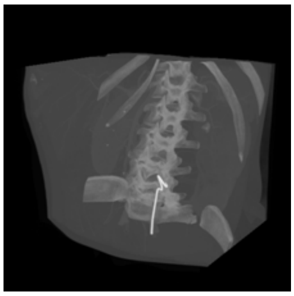
- τ affects emission's impact
  - Small τ: particles are hit less likely => less emission
  - Large τ: particles are hit more likely => more emission

Alternative Compositing Schemes

- Final pixel value depends on used compositing scheme



Emission Absorption
(without shading)

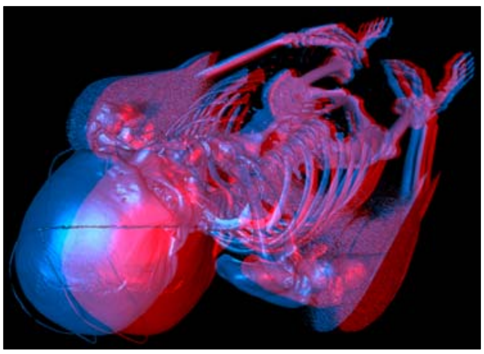


MIP
(without shading)

Isosurface
(with shading)

Stereo Rendering

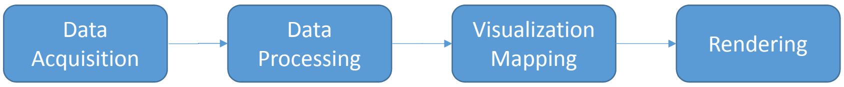
- Interactive frame rates of GPU-based volume rendering enable rendering of multiple views



Anaglyph Rendering
[ImageVis3D]

Volume Interaction

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

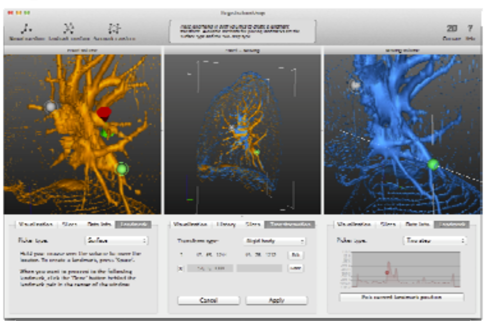


- We focus mainly on three stages
  - Interaction with the data processing stage
  - Interaction with the visualization mapping stage
  - Interaction with the rendering stage

Data Processing Stage

- Data cleaning
- Segmentation
- Registration

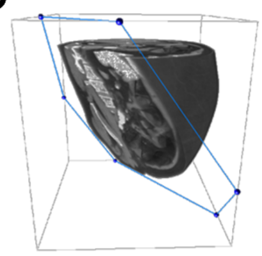
- Cutting & deformation
- Clipping
- Measuring

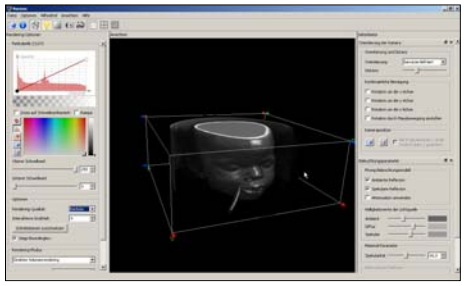


[Smit et al., EG VCBM 2014]

Mapping & Rendering Stage

- Annotation (M)
- Transfer function mapping (M&R)
- Cutting & deformation (M&R)
- Clipping (M&R)
- Measuring (R)
- Navigation (R)
- Lighting control (R)

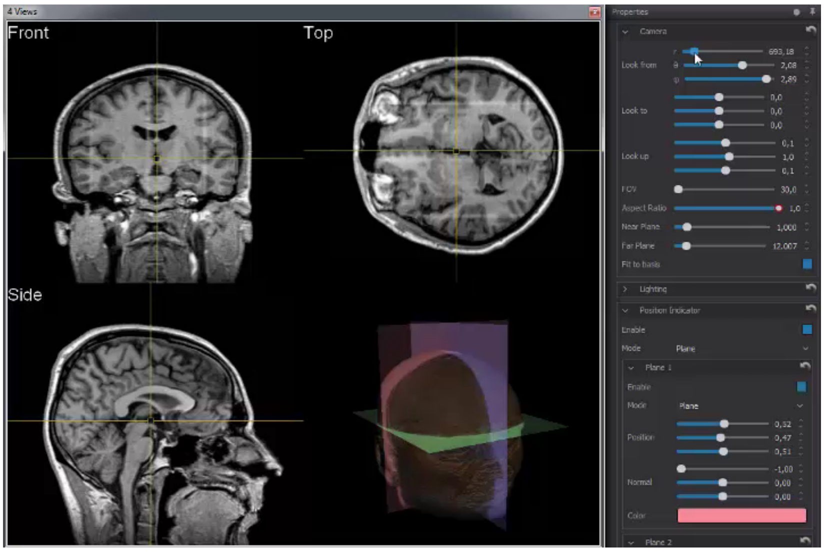




Direct vs. Indirect Interaction

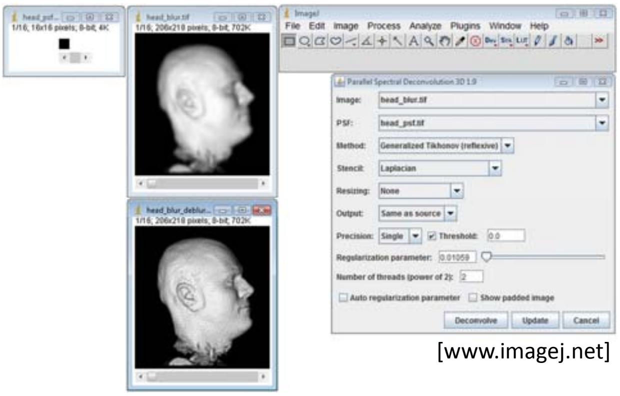
- Often volumetric data is explored collaboratively
- Requests during collaborative data exploration
  - Visually emphasize certain features of interest
  - Add/remove features from the visualization
  - Navigate to a certain view
  - Cut/clip data at given position
  - ► Often pinpointing of features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

Direct vs. Indirect Interaction - Example



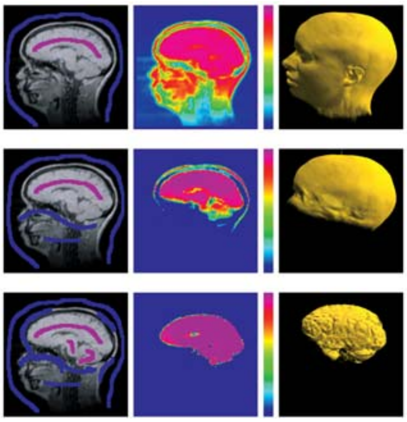
Data Cleaning

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

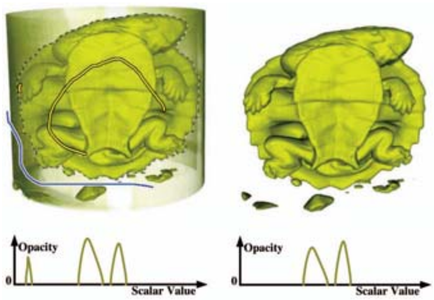


[www.imagej.net]

Segmentation – Direct



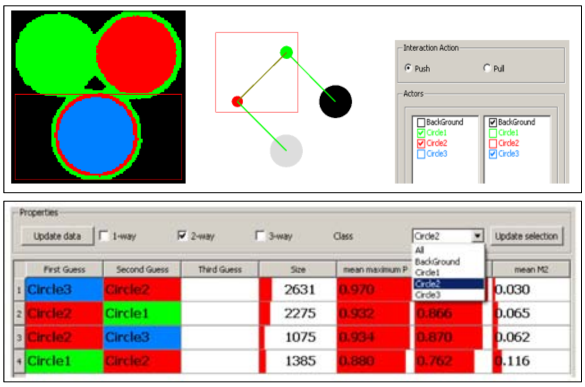
[Tzeng et al., IEEE VIS 2003]



[Wu and Qu, IEEE TVCG 2007]

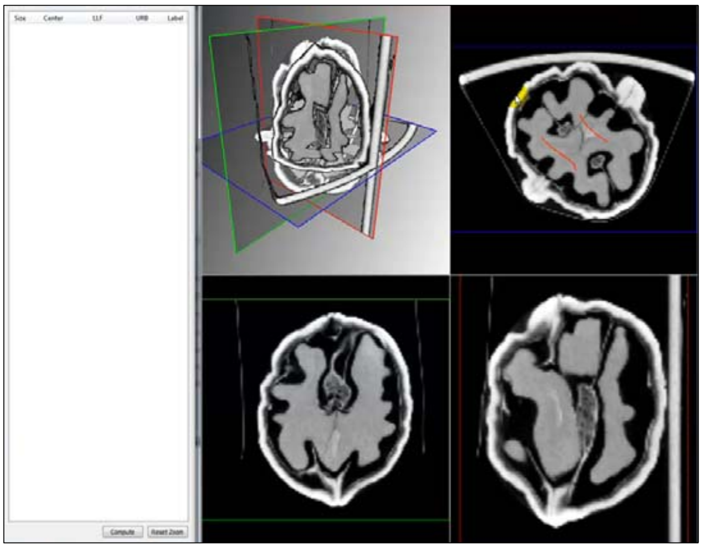
Segmentation - Systems

- Exploit interactive dialog between human and computer



[Saad et al., IEEE VIS 2010]

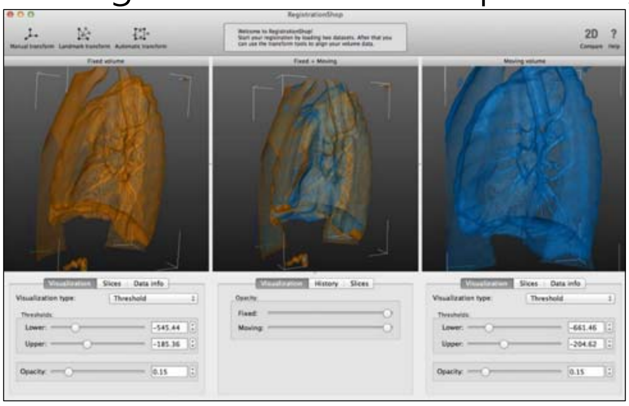
Segmentation – Direct Systems



[Prassni et al., IEEE VIS 2010]

Registration

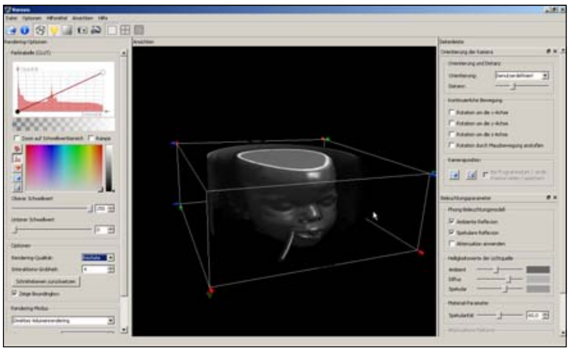
- Often performed directly through landmark selection (rigid and non-rigid transformations possible)

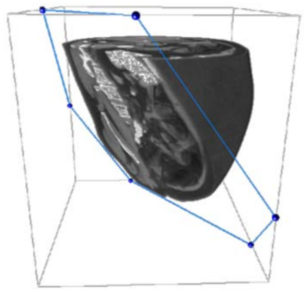


[Smit et al., EG VCBM 2014]

Clipping

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



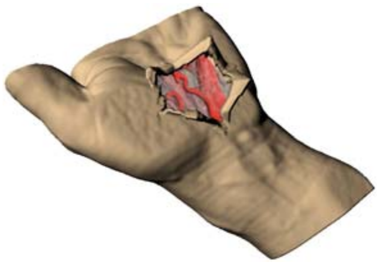


Measuring

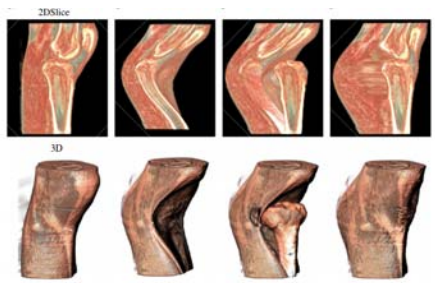
- Mostly direct techniques used
  - 2D tools: circle, distance, angle, ROI, pixel lens, text, freehand distance
  - 3D tools: distance, pixel lens, text

Cutting & Deformation

- Direct techniques mostly applied



[Mensmann et al., WSCG 2008]



[Correa et al., C&G 2010]

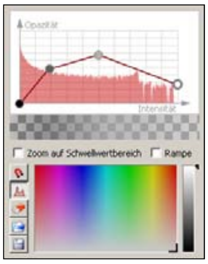
Cutting & Deformation cont.

[Ropinski et al., IEEE TVCG 2012]

Transfer Function Mapping

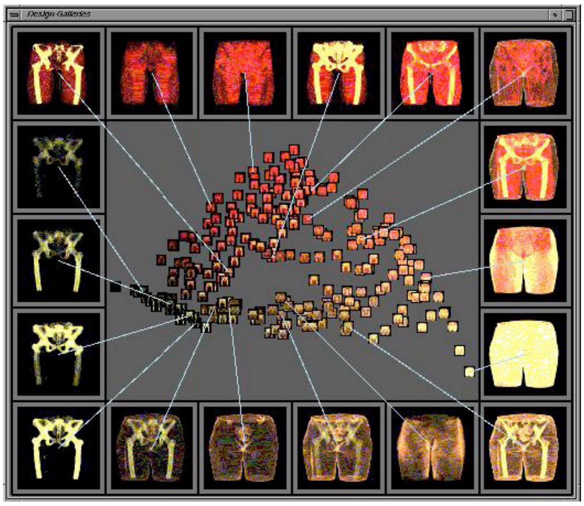
- Manual setup of transfer functions is
  - Time-consuming
  - Error-prone
  - Hard to reproduce

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



Indirect Transfer Function Mapping

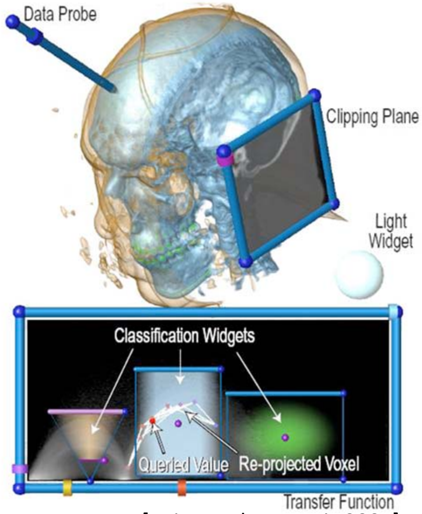
- Two main alternatives
  - Interact with data histogram
  - Selection of parameter presets



[Marks et al., ACM Siggraph 1997]

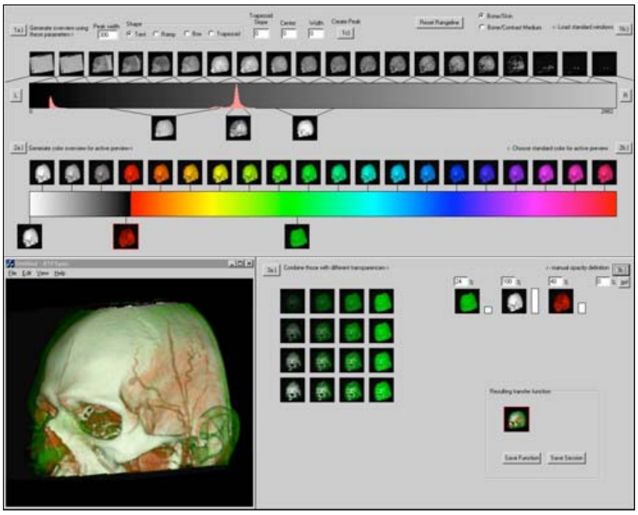
Direct Transfer Function Mapping

[Botha and Post, SPIE 2002]



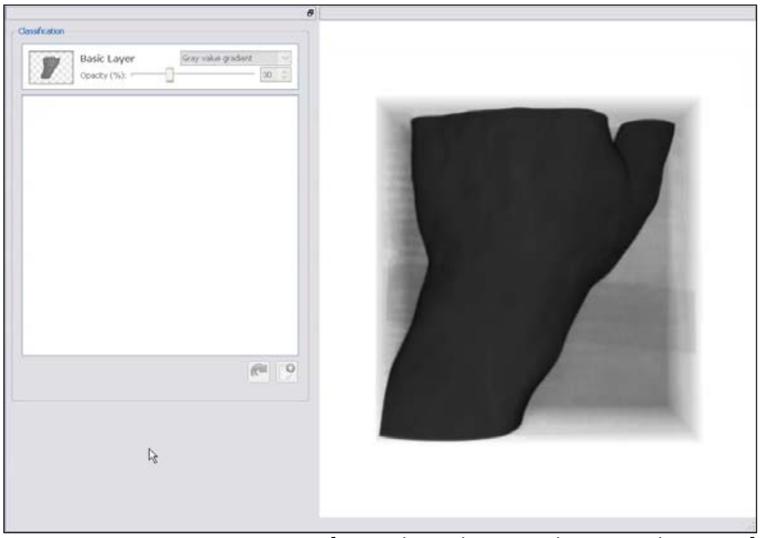
[Kniss et al., IEEE Vis 2001]

Transfer Function Mapping - Mixed



[König and Gröller, SCCG 2001]

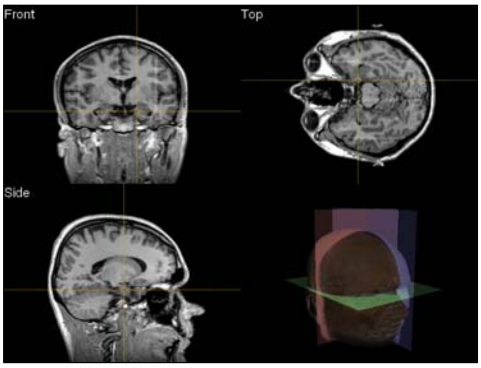
Transfer Function Mapping - Mixed

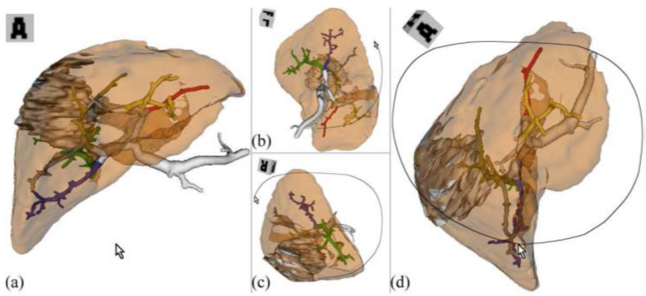


[Ropinski et al., IEEE Volume Graphics 2008]

Navigation

- Preferable 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

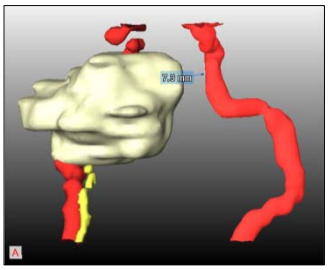
[Ropinski et al., IEEE PaVis 2010]

Inviwo
[www.inviwo.org]

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

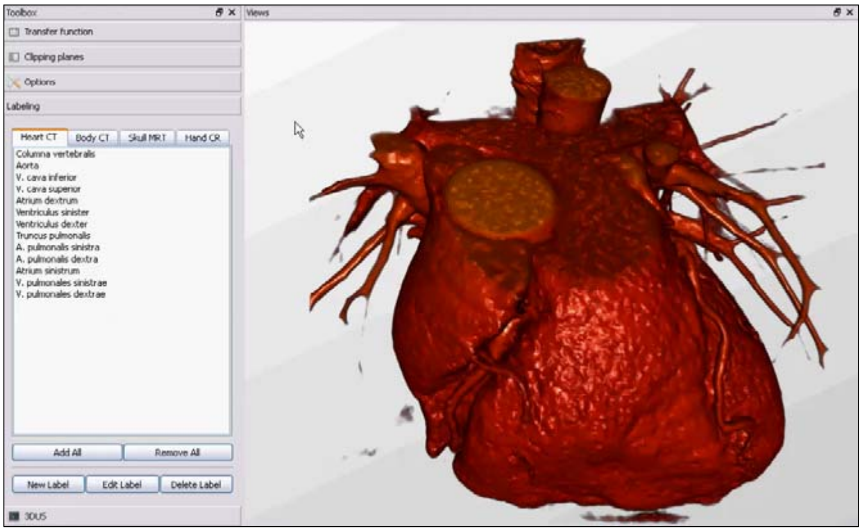
Annotation

- 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

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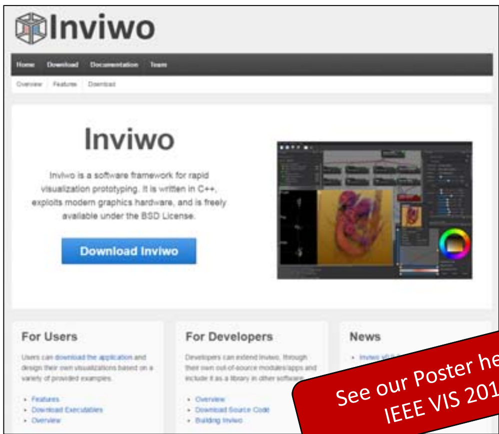
End of Part 1

Thank You
and all Collaborators!



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