


Knowledge-Assisted Visualization

Eduard Gröller

Institute of Computer Graphics and Algorithms
Vienna University of Technology


Illustration

- An illustration is a picture with a communicative intent
- Conveys complex structures or procedures in an easily understandable way
- Uses abstraction to prevent visual overload – allows to focus on the essential parts
- Abstraction is visualized through distinct stylistic choices



What is it all about?

The limits of my language mean the limits of my world
[Ludwig Wittgenstein]



Is visualization using the right language?

Abstraction (1)

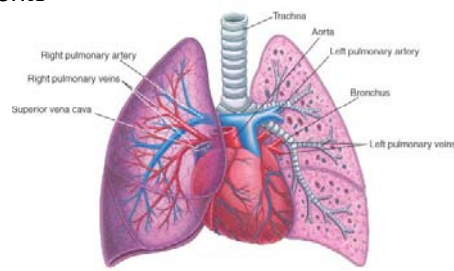
- Fundamental for creating an expressive illustration
- Introduces a distortion between visualization and underlying model
- Different degrees of abstraction introduced at different levels
- Task of an illustrator: find the necessary abstractions for the intent of the illustration

Outline

- Illustrative Visualization
- Knowledge-Assisted Visualization (KAV)
- KAV Examples
 - ◆ Importance-Driven Focus of Attention
 - ◆ Visualization with Style
 - ◆ LiveSync: Knowledge-Based Navigation

Abstraction (2)

- Different degrees of abstraction for different intents

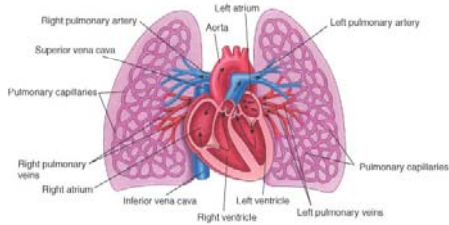


cut-away view of anatomy

Abstraction (2)



- Different degrees of abstraction for different intents



schematic view of blood flow

6

Outline



- Illustrative Visualization
- Knowledge-Assisted Visualization (KAV)
- KAV Examples
 - ◆ Importance-Driven Focus of Attention
 - ◆ Visualization with Style
 - ◆ LiveSync: Knowledge-Based Navigation

9

Illustrative Visualization

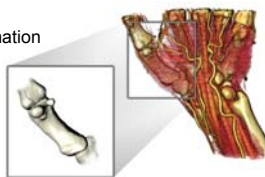


- **Illustrative Visualization:** computer supported interactive and expressive visualizations through abstractions as in traditional illustrations

Challenges

- ◆ Smart visibility
- ◆ Smart interaction
- ◆ Smart transformation, deformation
- ◆ Automatic transfer of styles
- ◆ Novel application areas

[Bruckner et al. 2005]



Examples

- ◆ Importance-driven rendering
- ◆ Exploded Views
- ◆ Style Transfer Functions
- ◆ Illustrative rendering of seismic data

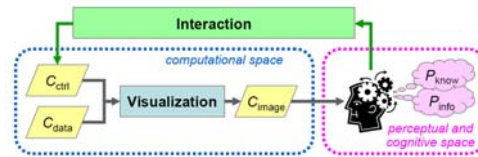
7

Knowledge Assisted Visualization (KAV)



“Utilize knowledge and information derived from the process of scientific visualization or from abstract data analysis”

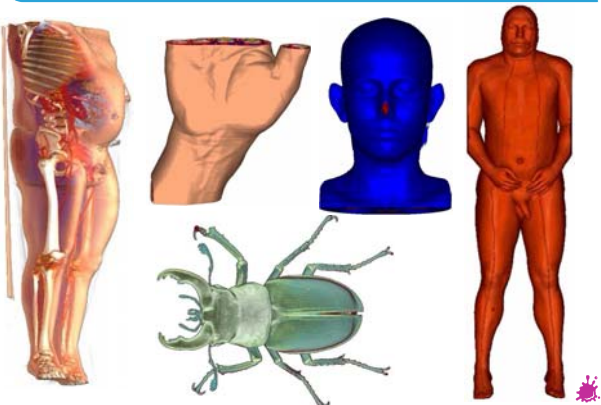
- KAV 2008: <http://kav.cs.wright.edu/>
- Position paper “Data, Information and Knowledge in Visualization” [Min Chen et al.]



Typical visualization process

10

Illustrative Visualization - Results

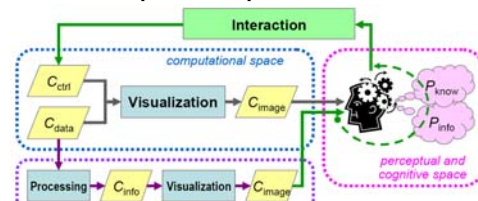


Knowledge Assisted Visualization (KAV)



“Utilize knowledge and information derived from the process of scientific visualization or from abstract data analysis”

- KAV 2008: <http://kav.cs.wright.edu/>
- Position paper “Data, Information and Knowledge in Visualization” [Min Chen et al.]



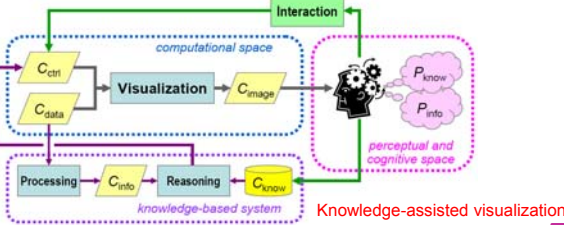
Information-assisted visualization

11

Knowledge Assisted Visualization (KAV)

“Utilize knowledge and information derived from the process of scientific visualization or from abstract data analysis”

- KAV 2008: <http://kav.cs.wright.edu/>
- Position paper “Data, Information and Knowledge in Visualization” [Min Chen et al.]

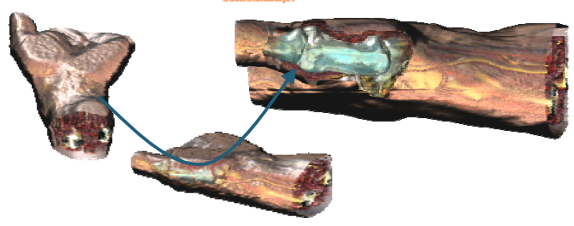


12

Importance-Driven Focus of Attention (1)

- Guided navigation between characteristic views

[Viola et al. 2006]



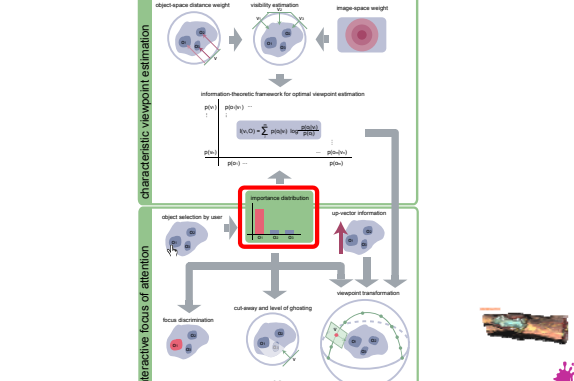
15

Knowledge Assisted Visualization (KAV)

- Challenges
 - ◆ Metadata visualization
 - ◆ Visualization enabled by
 - topological information of the data
 - statistical information of the data
 - geometric information of the data
 - semantic information of the data
 - ◆ Visualization via learning
 - ◆ Visualization via shared knowledge in a collaborative setting
 - ◆ Knowledge representation for visualization
- Examples
 - ◆ Viewpoint mutual information
 - ◆ Pre-determined ranking of visualization designs
 - ◆ Workflow management (VisTrails)

13

Importance-Driven Focus of Attention (2)



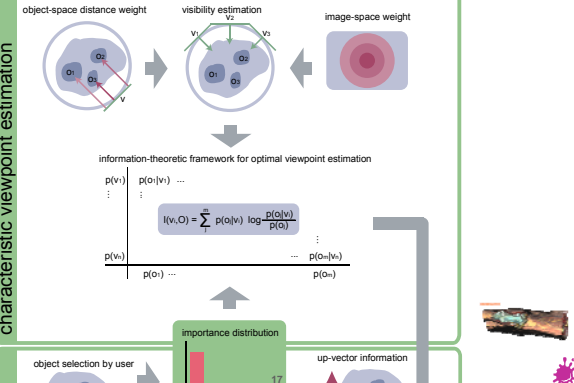
16

Outline

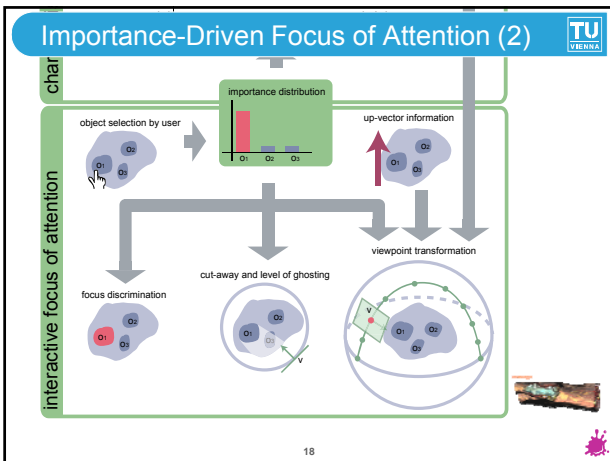
- Illustrative Visualization
- Knowledge-Assisted Visualization (KAV)
- KAV Examples
 - ◆ Importance-Driven Focus of Attention
 - ◆ Visualization with Style
 - ◆ LiveSync: Knowledge-Assisted Navigation

14

Importance-Driven Focus of Attention (2)



17



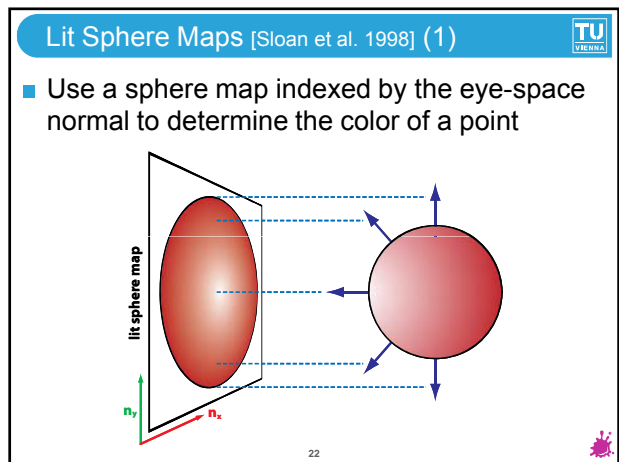
Style Transfer Functions (STF) - Motivation

- Generate scientific illustrations directly from volume data
- Provide illustrator with the possibility to quickly modify rendering styles
- Ability to extract styles from existing works of art

[Bruckner, Gröller; EG07]

21

- ### Outline
- Illustrative Visualization
 - Knowledge-Assisted Visualization (KAV)
 - ◆ KAV Examples
 - ◆ Importance-Driven Focus of Attention
 - ◆ Visualization with Style
 - ◆ LiveSync: Knowledge-Based Navigation
- 19



Visualization with Style

■ Volume + transfer function = volume rendering

- Language of the domain expert, illustrator??
 - ◆ ~~density~~, feature, attribute
 - ◆ ~~color, opacity~~, style

Visualization with Style =
Semantic Layers + Style Transfer Functions

20

Lit Sphere Maps [Sloan et al. 1998] (2)

- Easy to obtain – lighting studies are frequently performed using spheres
- Sloan et al. describe simple extraction process from existing works of art
- Intuitive representation, can be directly displayed to the user as a preview

23

Style Transfer Functions (1)

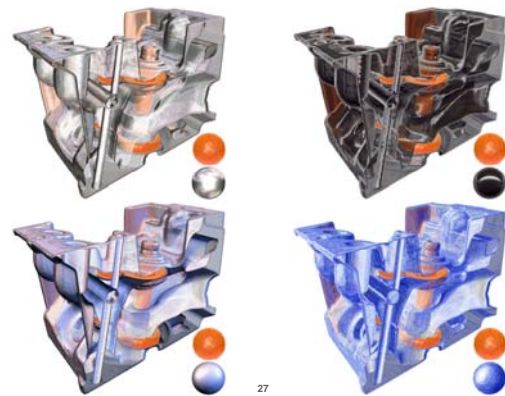


- Use lit sphere maps to allow data-dependent illustrative shading for volume rendering
- One lit sphere map represents one specific rendering style
- Transfer function is defined over styles instead of colors
- Combines the power of data-dependent lighting with the flexibility of lit sphere maps

24



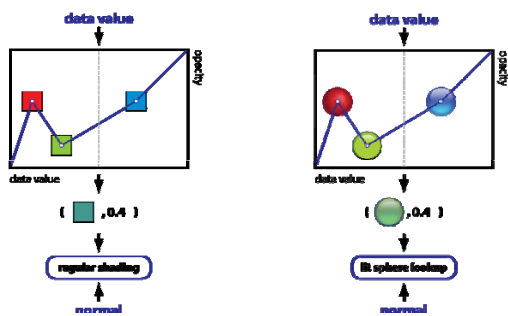
Style Transfer Functions (4)



27



Style Transfer Functions (2)



Regular Transfer Function

Style Transfer Function

STF - Style Contours (1)



- Contours are a frequent stylistic element in illustrations
- Contour appearance should be derived from lit sphere map
- Apparent contour thickness varies based on curvature
- Solution by [Kindlmann et al. 2003]: use normal curvature along the view direction to modulate contour threshold

28



Style Transfer Functions (3)

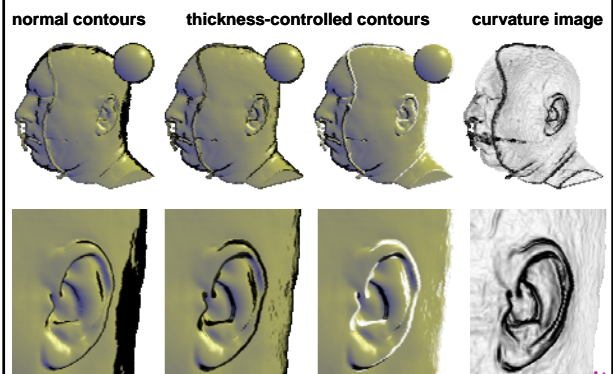


- Replace color nodes in transfer function by 2D lit sphere maps
- Essentially a 3D transfer function of data value and eye-space normal: $\mathbf{stf}(s, n_x, n_y)$
- Prohibitive storage requirements – split up into two functions: $\mathbf{sf}(\mathbf{tf}(s))(n_x, n_y)$
- Linear blending between styles – complex transitions possible through intermediate styles

26



STF - Style Contours (2)



29



STF - Illustrative Transparency (1)

- Transparency in illustrations puts emphasis on edges
- Use of “contourness” to simulate this technique

Style Transfer Functions + Semantic Layers

- Different styles
 - Tissue texture
 - Specular highlights
 - Contours
- Complex rules for illustrations
- Mapping from expert domain to visual appearance

Implementation + Results

- Easy integration into existing GPU-based ray casting algorithms
- Performance between 80 and 100% of normal transfer function + Phong shading
- Style transfer function lookups require three textures, but additional memory requirement small
- Additional texture fetches incur an overhead, but shading computations are simplified
- Can completely replace conventional lighting computations

Style Transfer Functions + Semantic Layers

densities $\xrightarrow{\text{transfer function}}$ colors, opacities

features, attributes w. values $\xrightarrow{\text{semantic layers}}$ styles w. parameters

- Mapping from expert domain to visual appearance

Style Transfer Function - Example

Semantic Layers for Illustrative Volume Rendering (1)

- Mapping volumetric attributes to visual styles
- Use natural language of domain expert (rules)
- Rules evaluated with fuzzy logic arithmetics

[Rautek et al. 2007]

Semantic Layers System

- Semantics exist
 - volumetric attributes
 - density: low - ... - high
 - curvature: negative - zero - positive
 - etc.

illustrative styles

rules: if attribute a_1 is v_{a1} ... then style s_1 is v_{s1}

- Make use of semantics!

Rule Base

- if (principal curvature is negative and density is high and gradient magnitude is high) or distance to user focus is low then contour style is red

Fuzzy Logic as a Black Box

Fuzzy Logic Inside the Black Box

Membership Functions

- if-part: semantics for volume attributes
- then-part: semantics for visual appearance

Curvature Based Selective Application

if principal curvature is not positive then contours are blueish

Semantics Driven Illustrative Rendering

if penetration depth is low and distance to focus is low then skin-style is transparent white

if penetration depth is high or distance to focus is high then skin-style is pink

if distance to plane is low then skin-style is transparent blueish and glossy green is low

if distance to plane is high then skin-style is opaque pink and glossy green is transparent

video1
video2
video3

42

Traditional Workflow – Medical Workstation

45

Outline

- Illustrative Visualization
- Knowledge-Assisted Visualization (KAV)
- KAV Examples
 - ◆ Importance-Driven Focus of Attention
 - ◆ Visualization with Style
 - ◆ LiveSync: Knowledge-Based Navigation

43

Viewing Sphere

- Concept
 - ◆ Surrounds object
 - ◆ Viewpoints on surface of viewing sphere
 - ◆ Viewing direction to sphere's center
- Encoding of viewpoint quality
 - ◆ Deformation of viewing sphere
 - ◆ High radial distance indicates good viewpoint

46

LiveSync: Knowledge-Based Navigation

- Slice View → 3D View
- Underconstrained problem
 - ◆ Viewpoint
 - ◆ Clipping plane
 - ◆ Zoom

44

Viewing Sphere

- Concept
 - ◆ Surrounds object
 - ◆ Viewpoints on surface of viewing sphere
 - ◆ Viewing direction to sphere's center
- Encoding of viewpoint quality
 - ◆ Deformation of viewing sphere
 - ◆ High radial distance indicates good viewpoint

47

LiveSync: Knowledge-Based Navigation

- Interaction with 2D slices
- Automatic generation of expressive 3D views

The diagram illustrates the LiveSync workflow. It starts with 'Initial Views' showing a 3D model and a 2D slice. A 'Picking' action is shown on the 2D slice. This leads to 'View Input Parameters' which include Orientation, Last Viewpoint, Local Object Opac, and Visibility. These parameters are used for 'Viewing Sphere Manipulations' to create a 'Derived Viewing Parameters' block. This block then uses 'Viewing Sphere Operators' (including 'produceur Dimensional Viewing Sphere' and 'View-Aligned Clipping Plane') to generate a 'Live-Synchronized Volumetric View'.

[Kohlmann et al. 2007] 48 Video

LiveSync++: Transfer Function Tuning

This slide compares three visualization methods: 'Picked point', 'LiveSync', and 'LiveSync++'. It shows two rows of images. The top row shows a 'Picked point' (a small orange dot on a 2D slice), 'LiveSync' (a 3D volume with a yellow arrow), and 'LiveSync++' (a 3D volume with a yellow arrow and a more detailed texture). The bottom row shows similar comparisons from different angles. A 'Video' icon is present in the bottom right corner.

51 Video

LiveSync Workflow

The image shows a sequence of four frames illustrating the LiveSync workflow. The first frame shows a 3D volume of a brain. The second frame shows two 2D axial slices. The third frame shows two 2D sagittal slices. The fourth frame shows two 2D coronal slices. The text 'LiveSync workflow' is overlaid on the bottom of the sequence.

49

Outline

- Illustrative Visualization
- Knowledge-Assisted Visualization (KAV)
 - KAV Examples
 - Importance-Driven Focus of Attention
 - Visualization with Style
 - LiveSync: Knowledge-Based Navigation

52

Results

- Aneurism

Two side-by-side images of an aneurism. The left image is labeled 'Manually adjusted (~ 1:50 min)'. The right image is labeled 'LiveSync generated & manual clipping (< 20 sec)'. The LiveSync generated image shows a more refined and focused visualization of the aneurism.

50

What is it all about?

The limits of my language mean the limits of my world
[Ludwig Wittgenstein]

Is visualization using the right language?


- Data and parameters are like characters but not words or sentences
- Add features, knowledge, semantics to the visualization process
- Knowledge-assisted visualization a step in the right direction

53

The End

Knowledge is in the end based on acknowledgement [Ludwig Wittgenstein]

- Thanks to
 - Stefan Bruckner
 - Miquel Feixas
 - Armin Kanitsar
 - Peter Rautek
 - Mateu Sbert
 - Ivan Viola
 -



Questions ?
Comments?

54

Knowledge-Assisted Visualization

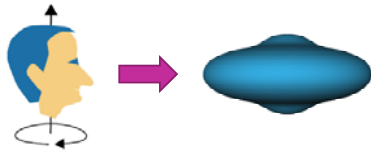
- Utilizing knowledge and information derived from the visualization process or from data analysis helps in generating more effective visualizations. The inclusion of knowledge and employing abstractions on various levels, generates expressive visualizations and allows user-centric interaction metaphors. The talk will discuss several examples of knowledge-assisted visualizations of volumetric data:
- Importance-driven focus of attention is a concept for automatically focusing on interesting features within a volumetric data set. The user selects a focus, i.e., object of interest, from a set of pre-defined features. The system automatically determines the most expressive view on this feature. A characteristic viewpoint is estimated by an information-theoretic framework which is based on the mutual information measure. Viewpoints change smoothly by switching the focus from one feature to another one. This mechanism is controlled by changes in the importance distribution among features in the volume.
- We will explain style transfer functions which allow to combine a multitude of different shading styles in a single rendering. In the case of multiple volumetric attributes and multiple visual styles the specification of a multi-dimensional transfer function becomes challenging and non-intuitive. We describe semantic layers as a methodology for the specification of a mapping from several volumetric attributes to multiple illustrative visual styles. Semantic layers enable an expert user to specify the mapping in the natural language of her/his domain.
- LiveSync utilizes deformed viewing spheres for knowledge-based navigation in the medical domain. It is a new concept to synchronize 2D slice views and volumetric views of medical data sets. Through simple and intuitive picking actions on a 2D slice, the users define the anatomical structures they are interested in. The 3D volumetric view is updated automatically with the goal that the users are provided with expressive result images. To achieve this live synchronization we use a minimal set of derived information, i.e., picked point, slice view zoom, patient orientation, viewpoint history, local object shape and visibility, without the need for segmented data sets or data-specific pre-computations.
- Further information on the research projects discussed in the talk is available at <http://www.cg.tuwien.ac.at/research/vis/>
- 50 Minutes + 10 Minutes discussion??

Eduard Gröller 57



Patient-Orientation Viewing-Sphere

- Consider preferred viewing directions according to type of examination
- Technique:** Head-feet axis serves as rough estimation to derive preferred viewpoints



Peter Kohlmann et al. 58

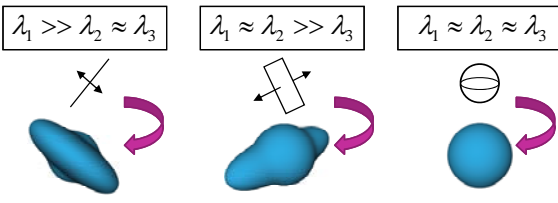
Content

- Smart Visibility (two types of smartness), illustration + abstraction
- Style transfer functions + Semantic Layers (T85-Utah shorten, EuroVis2008)
- LiveSync (Vis2007+GI2008)
- Automatic view point detection: (importance driven rendering + Focus of attention)
- Additional Material
 - Take a look at David Ebert talk at KAV
 - <http://kav.swansea.ac.uk/>
 - Take a look at position paper Chen et al.
 - <http://cs.swan.ac.uk/~csbob/research/kav/KAVabstracts08/index.htm>

Eduard Gröller 56

Local Shape-Estimation Viewing-Sphere

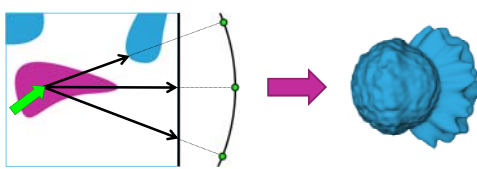
- Consider local shape of structure of interest
- Technique:**
 - Local region growing (picked point as seed)
 - Principal component analysis on result



Peter Kohlmann et al. 59

Visibility Viewing-Sphere

- Include information about occlusion
- **Technique:** Cast & analyze visibility rays
 - ◆ Exit of tissue of interest
 - ◆ Distance to occluding objects



Peter Kohlmann et al. 60


Derived Viewport Parameters

Viewpoint:
Indicated by highest radial distance on deformed viewing sphere

Clipping Plane:
Information obtained by visibility calculation

- unobstructed view of picked object
- preservation of context information

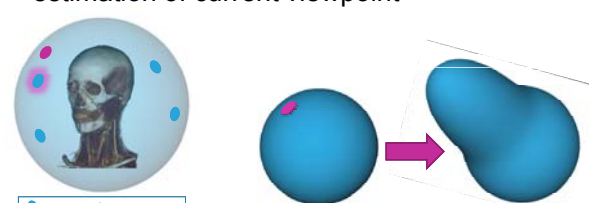
Zoom Factor:
Slice view zoom as rough estimation about size of interesting structure



Peter Kohlmann et al. 63

Viewpoint-History Viewing-Sphere

- Avoid big shifts for successive pickings
- **Technique:** Consider previous viewpoint for estimation of current viewpoint

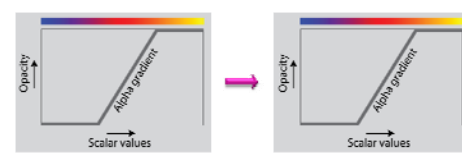


● Candidate
 ● Previous viewpoint
 ● Preferred viewpoint

Peter Kohlmann et al. 61

Transfer Function Tuning

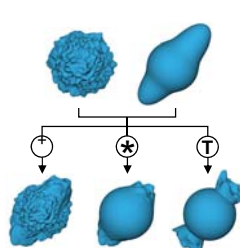
- Method
 - ◆ Based on intensity mean value and standard deviation of segmented voxels
 - ◆ Adjustment of ramp
 - Center of slope set to mean value
 - Slope width set to 3 x standard deviation



Peter Kohlmann et al. 64

Viewing-Spheres Combination

- Unified representation of parameters
- Each deformed sphere contains incomplete information → Combination



Summation:
 intuitive approach
 ■ good results
Multiplication:
 ■ emphasize characteristics
 ■ high impact of low values
Thresholding:
 ■ preferred sphere
 ■ definition of knock-out criteria

Peter Kohlmann et al. 62