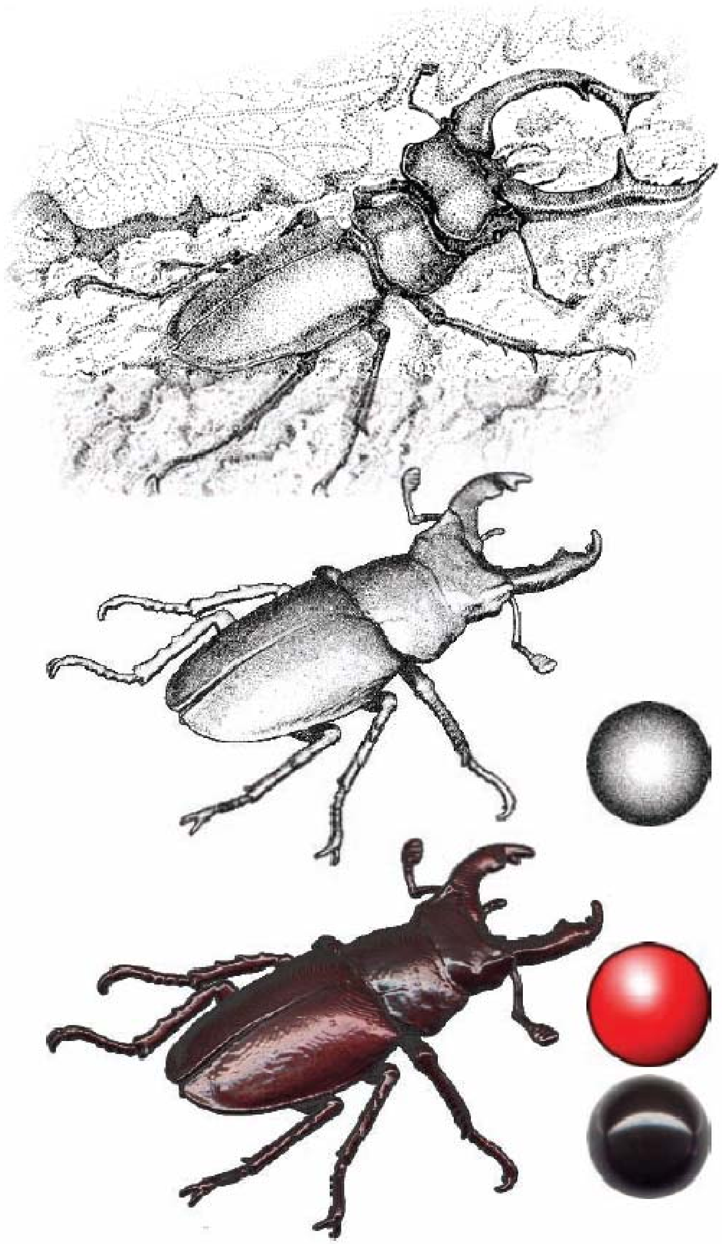


Knowledge-Assisted Visualization

Eduard Gröller

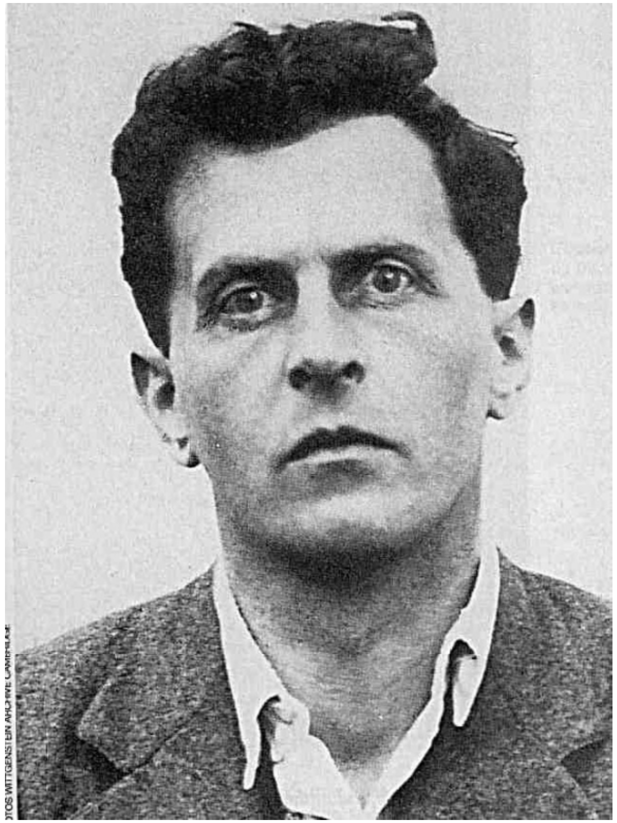
Institute of Computer Graphics and Algorithms

Vienna University of Technology

What is it all about?

The limits of my language
mean the limits of my world

[Ludwig Wittgenstein]



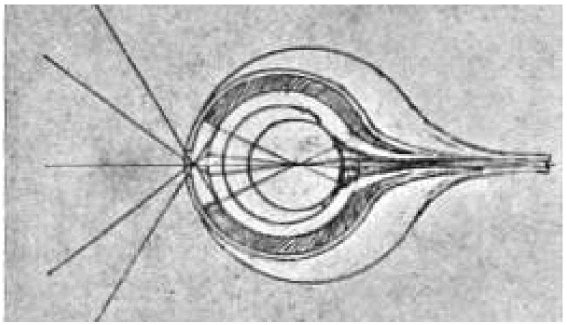
Is visualization using the right language?

Outline

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

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

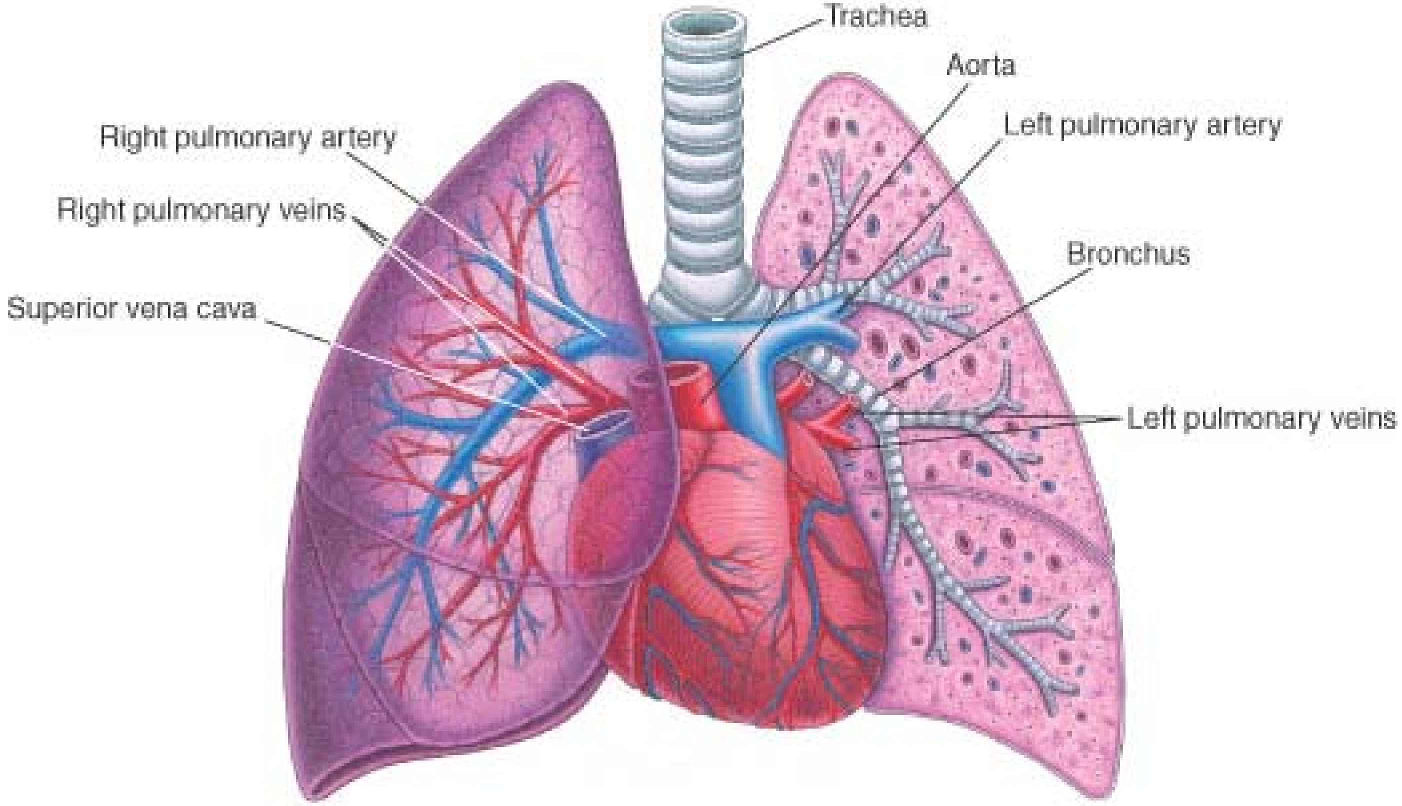


Abstraction (1)

- 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

Abstraction (2)

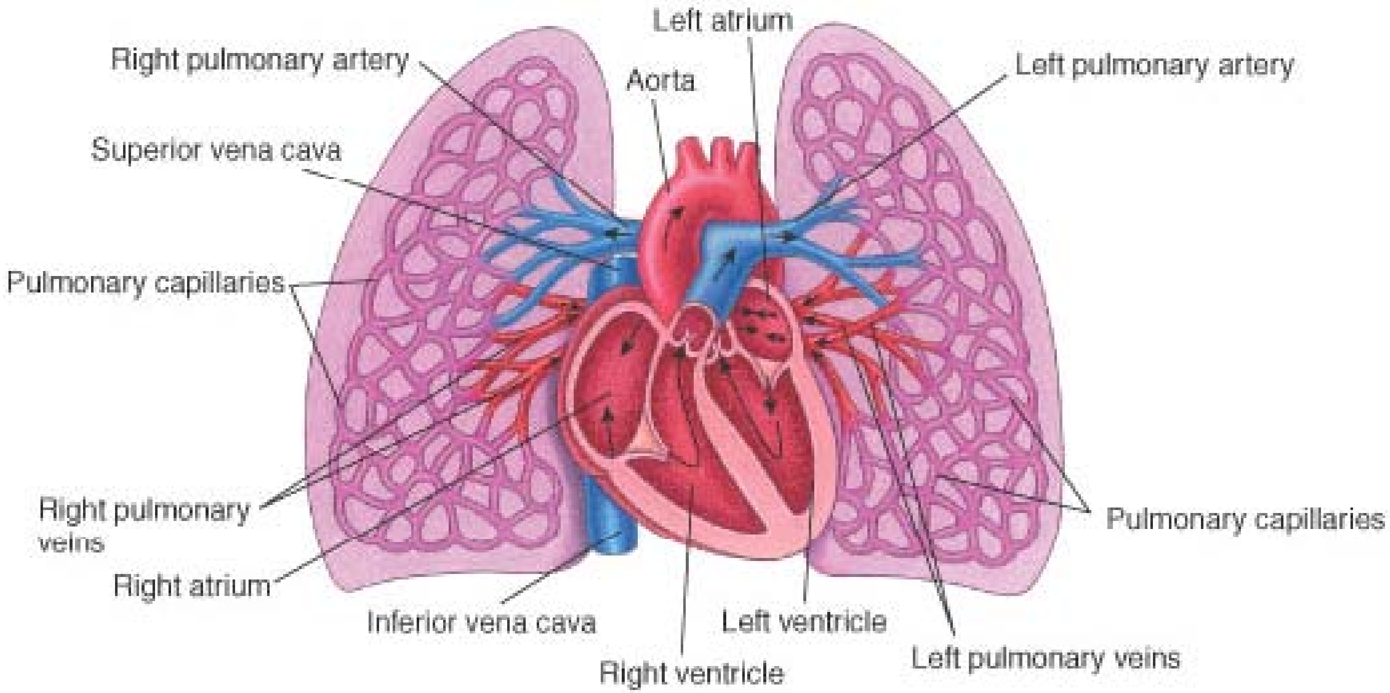
- Different degrees of abstraction for different intents



cut-away view of anatomy

Abstraction (2)

- Different degrees of abstraction for different intents



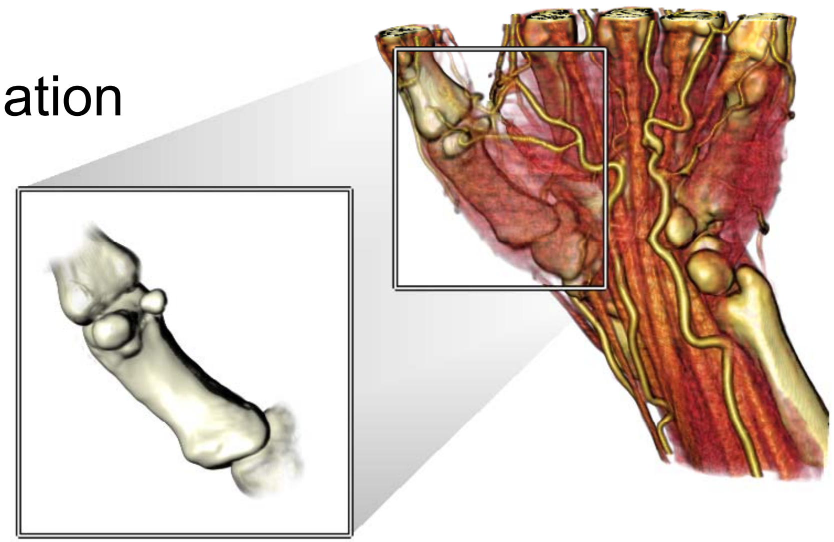
schematic view of blood flow

Illustrative Visualization

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

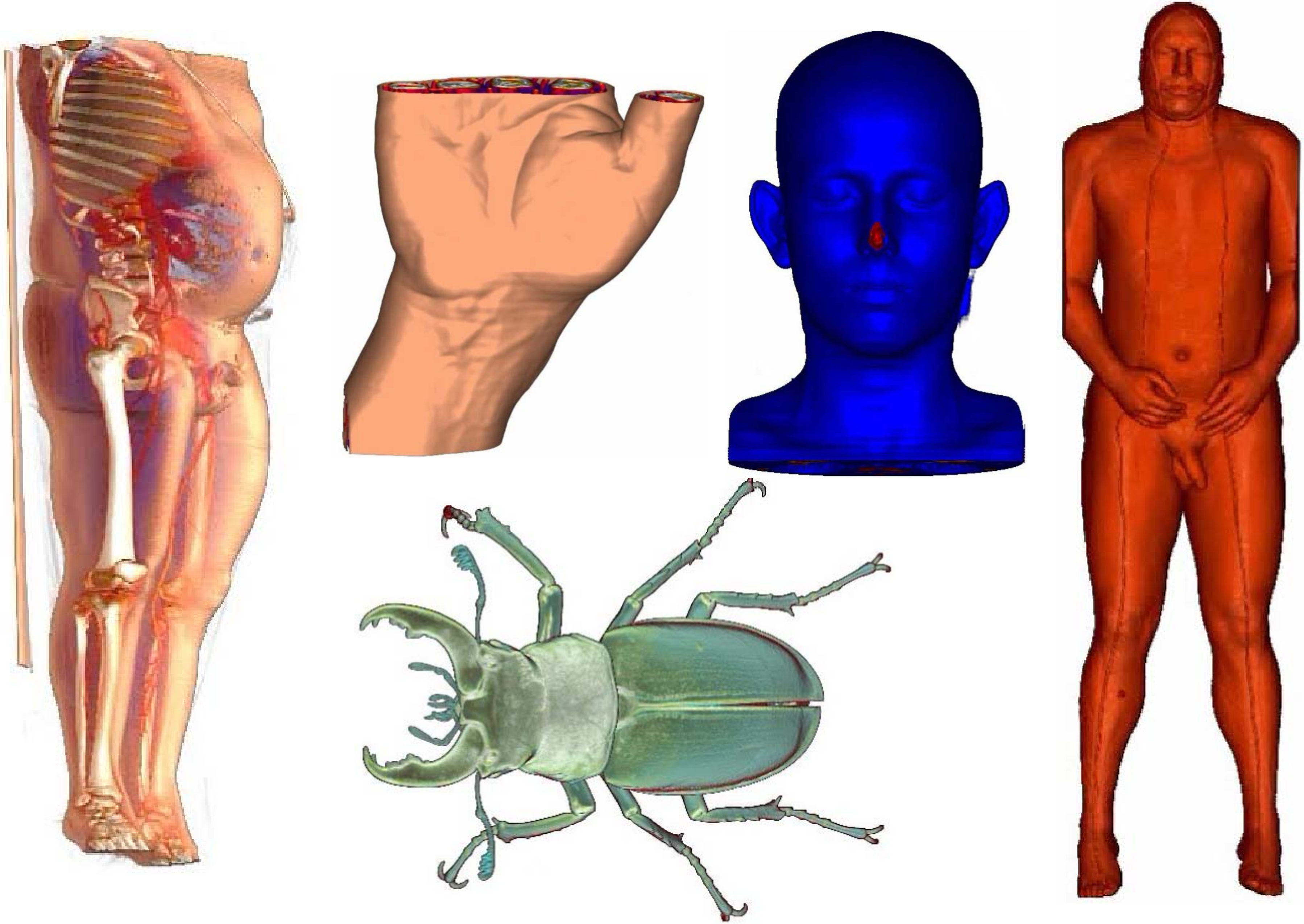
- Challenges
  - Smart visibility
  - Smart interaction
  - Smart transformation, deformation
  - Automatic transfer of styles
  - Novel application areas

[Bruckner et al. 2005]



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

Illustrative Visualization - Results



Outline

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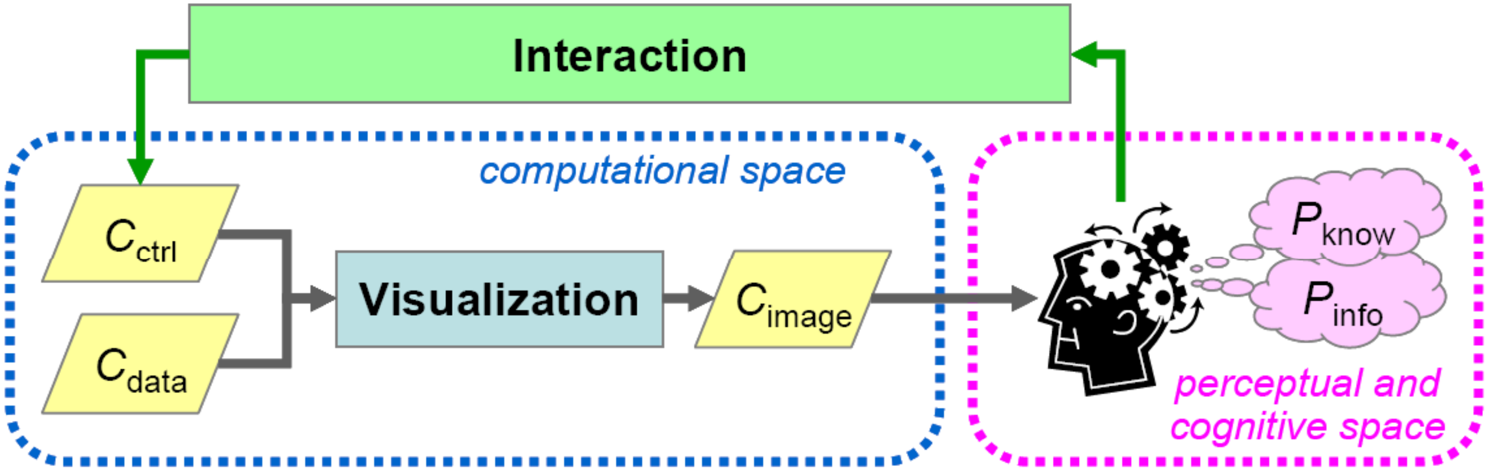
Knowledge Assisted Visualization (KAV)

"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

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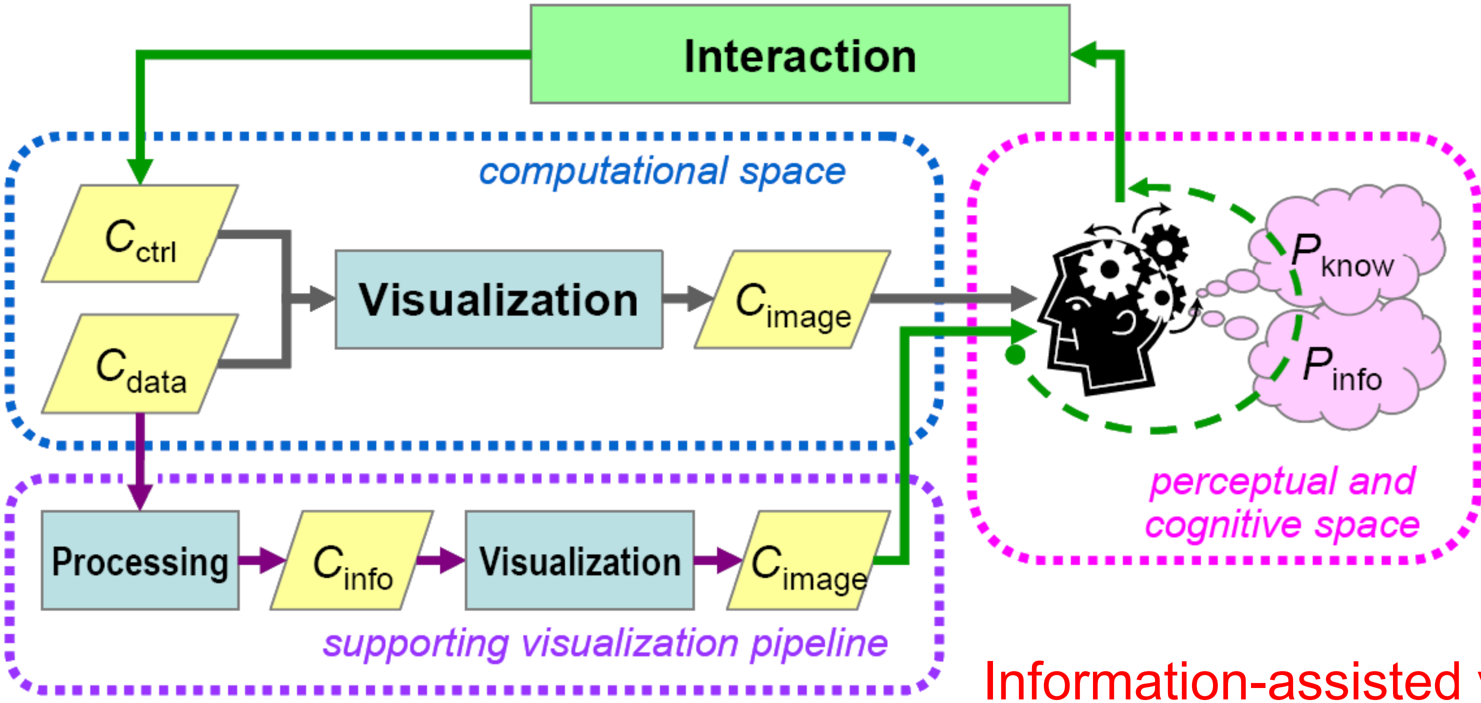

Information-assisted visualization

Knowledge Assisted Visualization (KAV)

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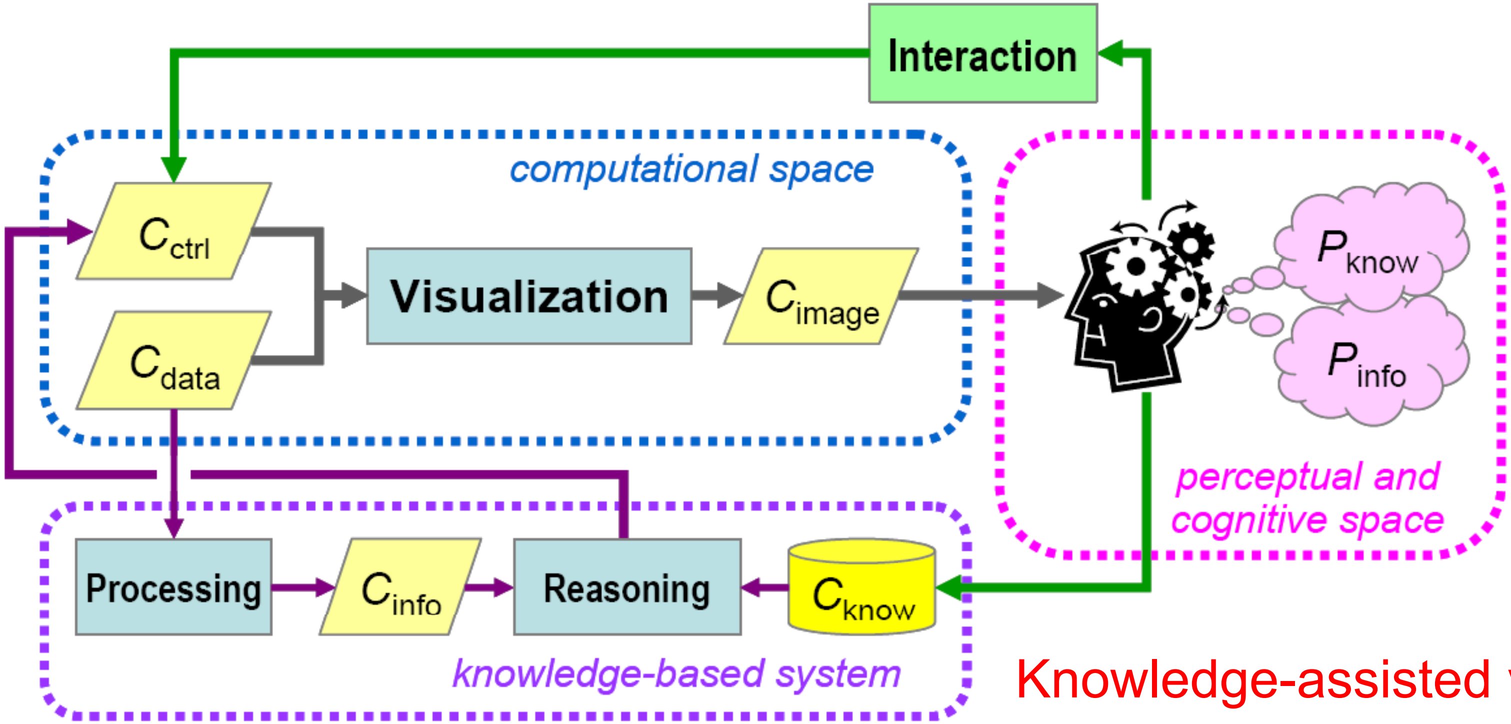

Knowledge-assisted visualization

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)

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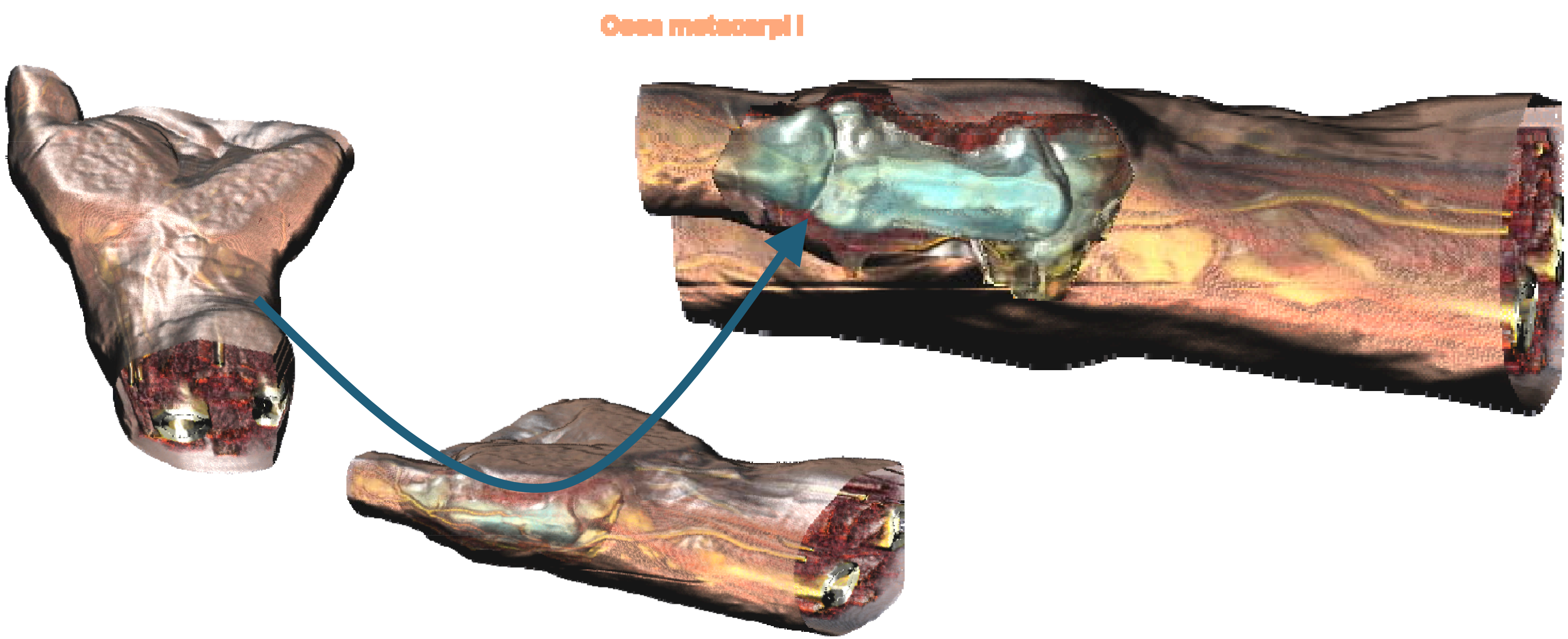
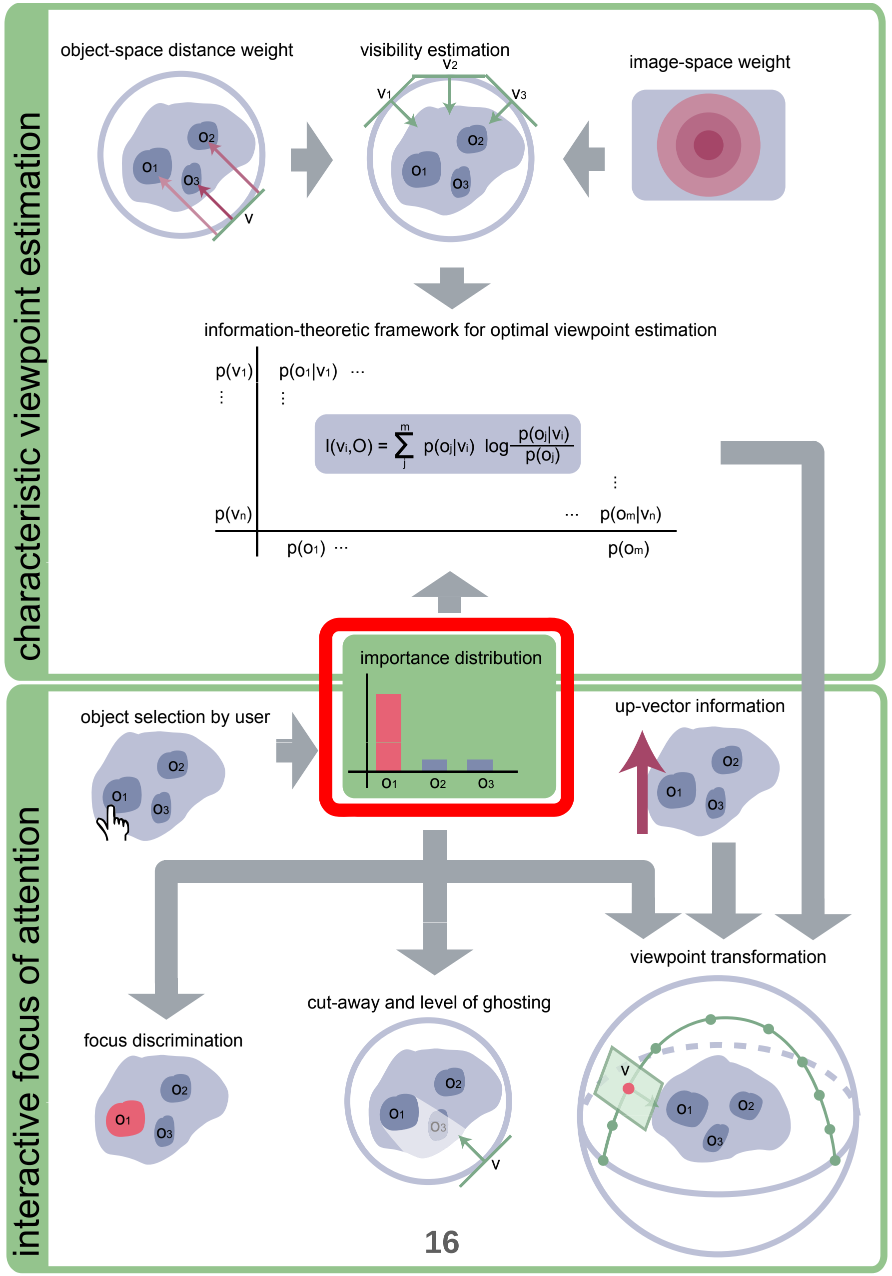
Importance-Driven Focus of Attention (1)

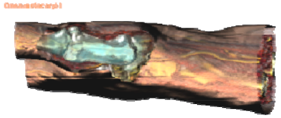
- Guided navigation between characteristic views

[Viola et al. 2006]

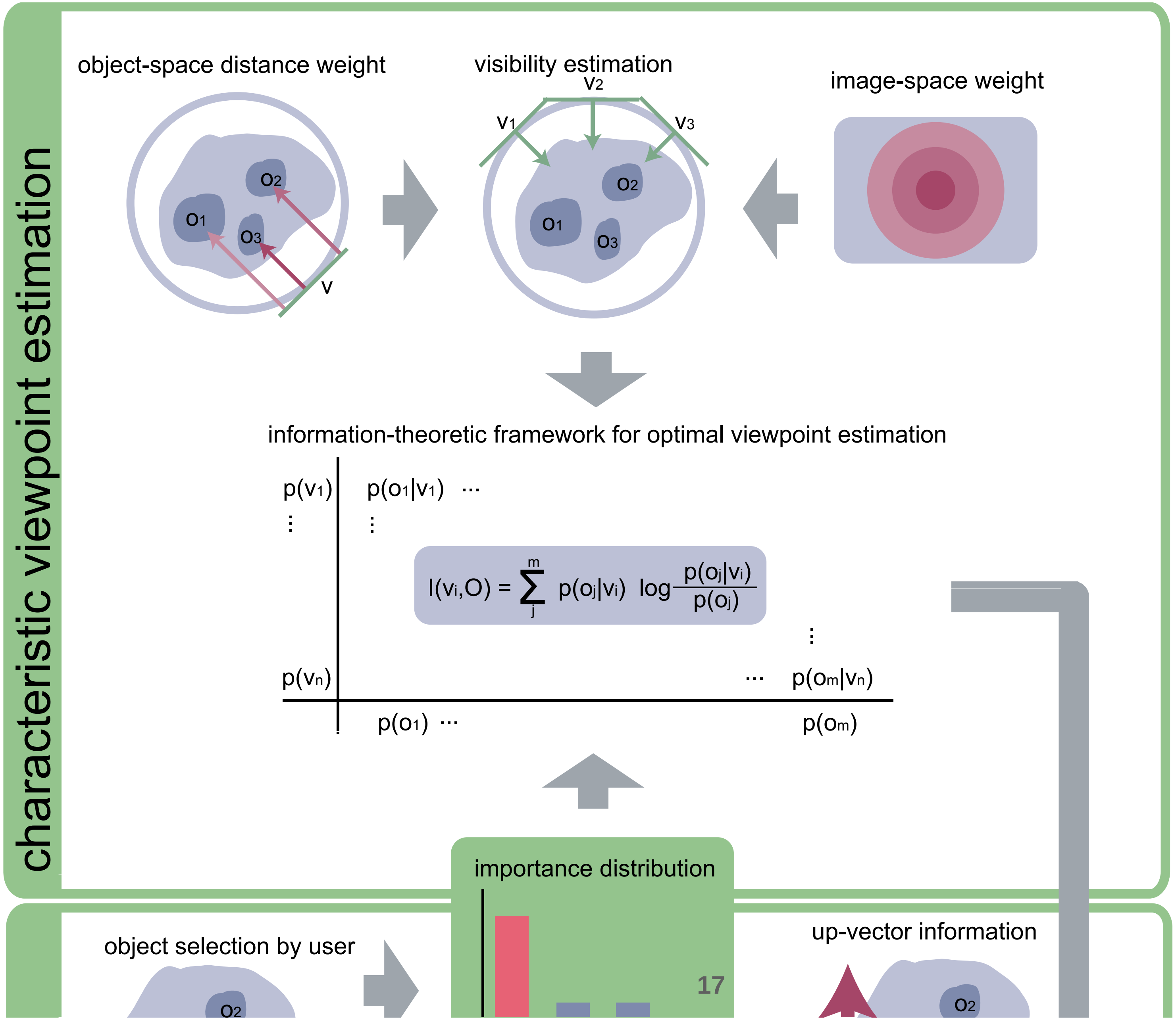


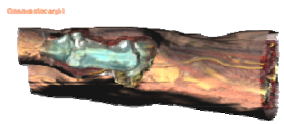
Importance-Driven Focus of Attention (2)



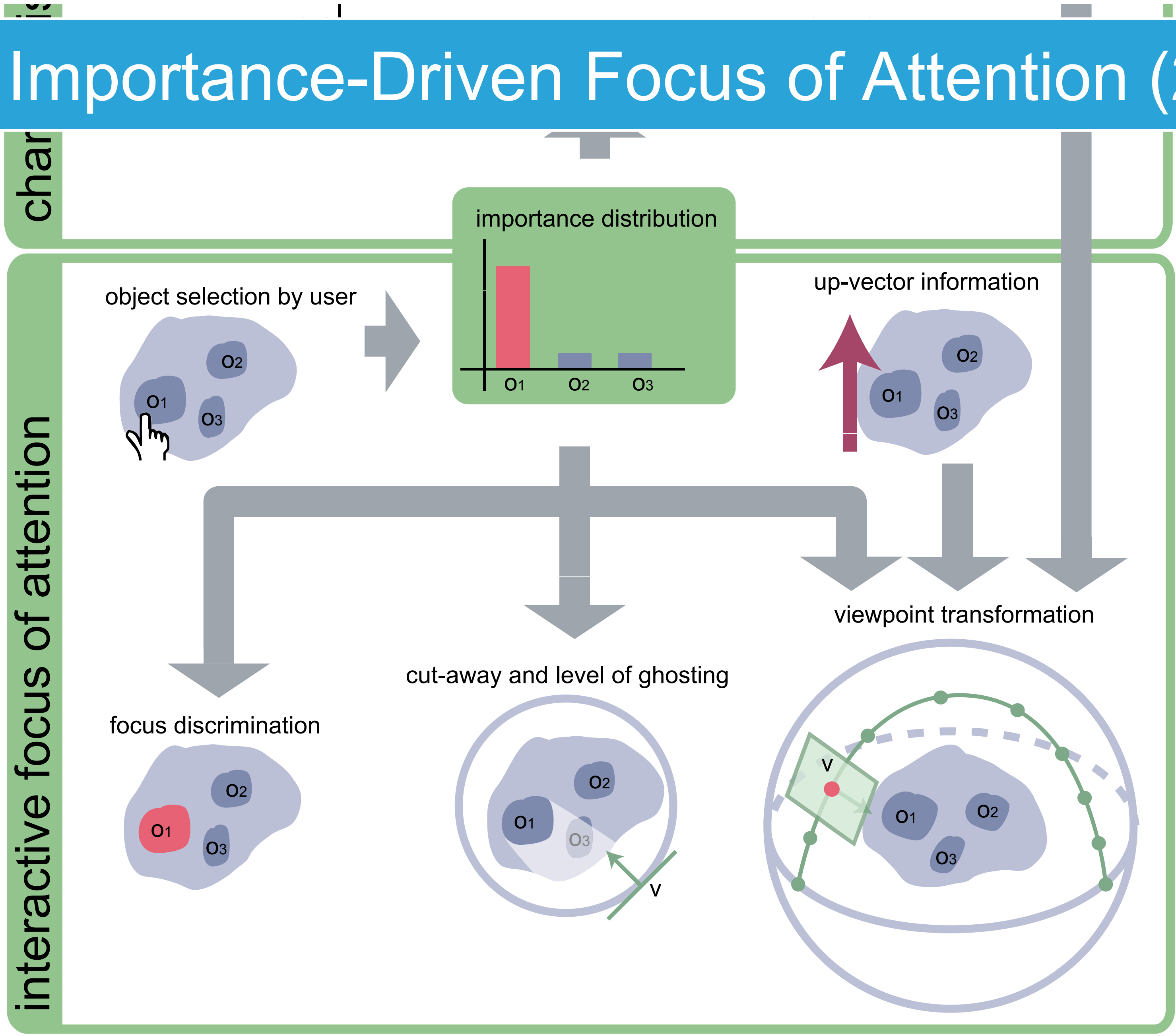


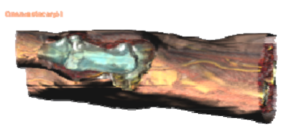
Importance-Driven Focus of Attention (2)





Importance-Driven Focus of Attention (2)





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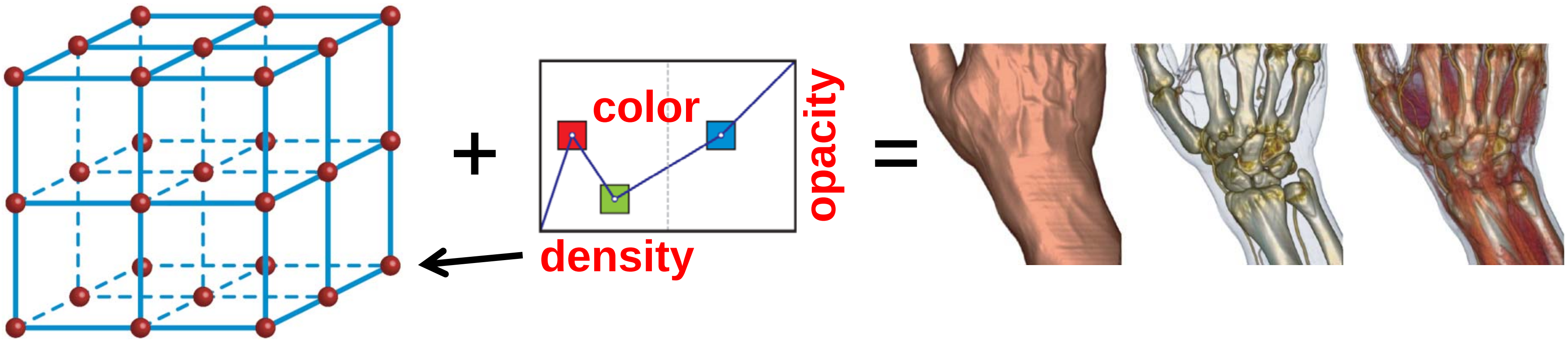
Visualization with Style

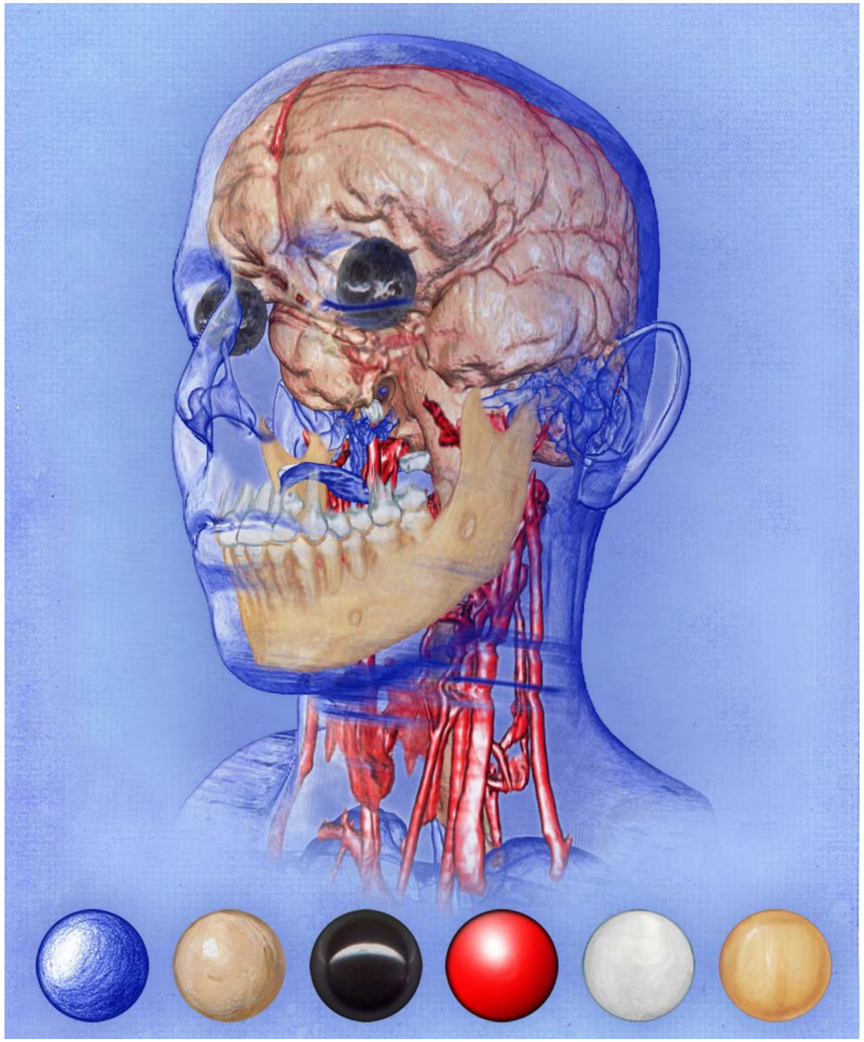
- Volume + transfer function = volume rendering



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

Visualization with Style =
Semantic Layers + Style Transfer Functions

Style Transfer Functions (STF) - Motivation

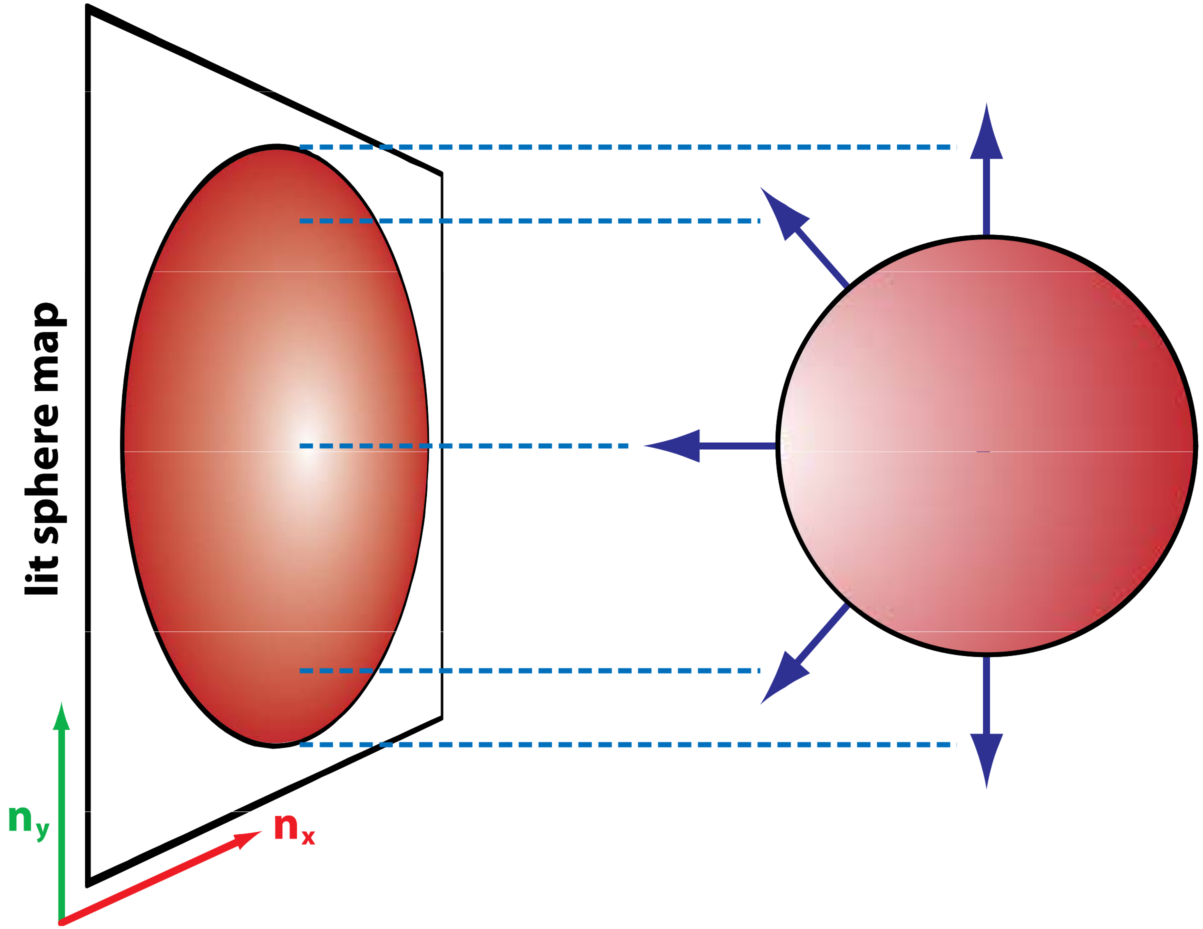


[Bruckner, Gröller; EG07]

- 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

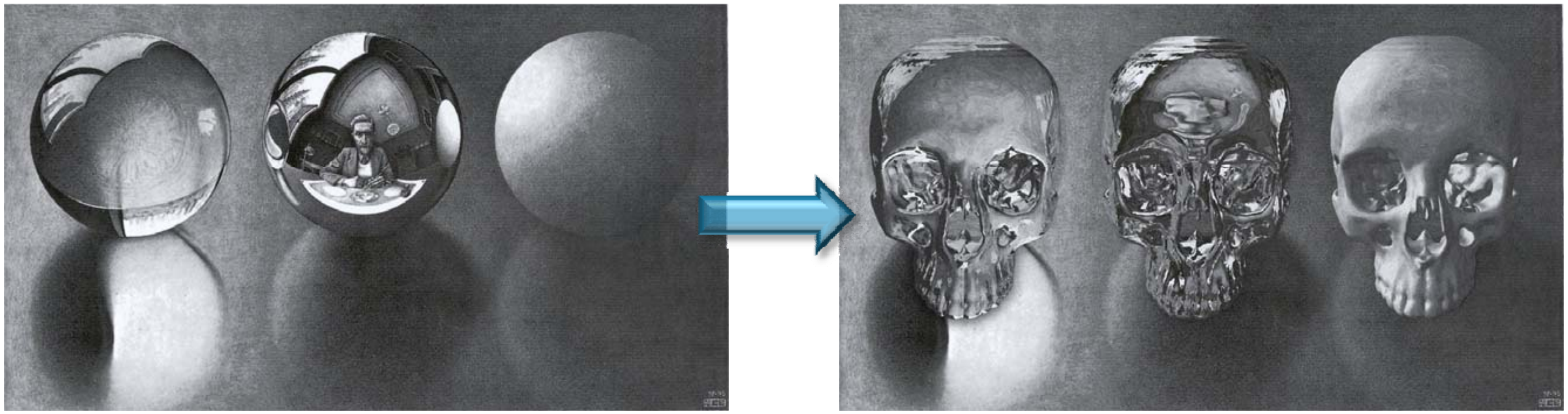
Lit Sphere Maps [Sloan et al. 1998] (1)

- Use a sphere map indexed by the eye-space normal to determine the color of a point



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

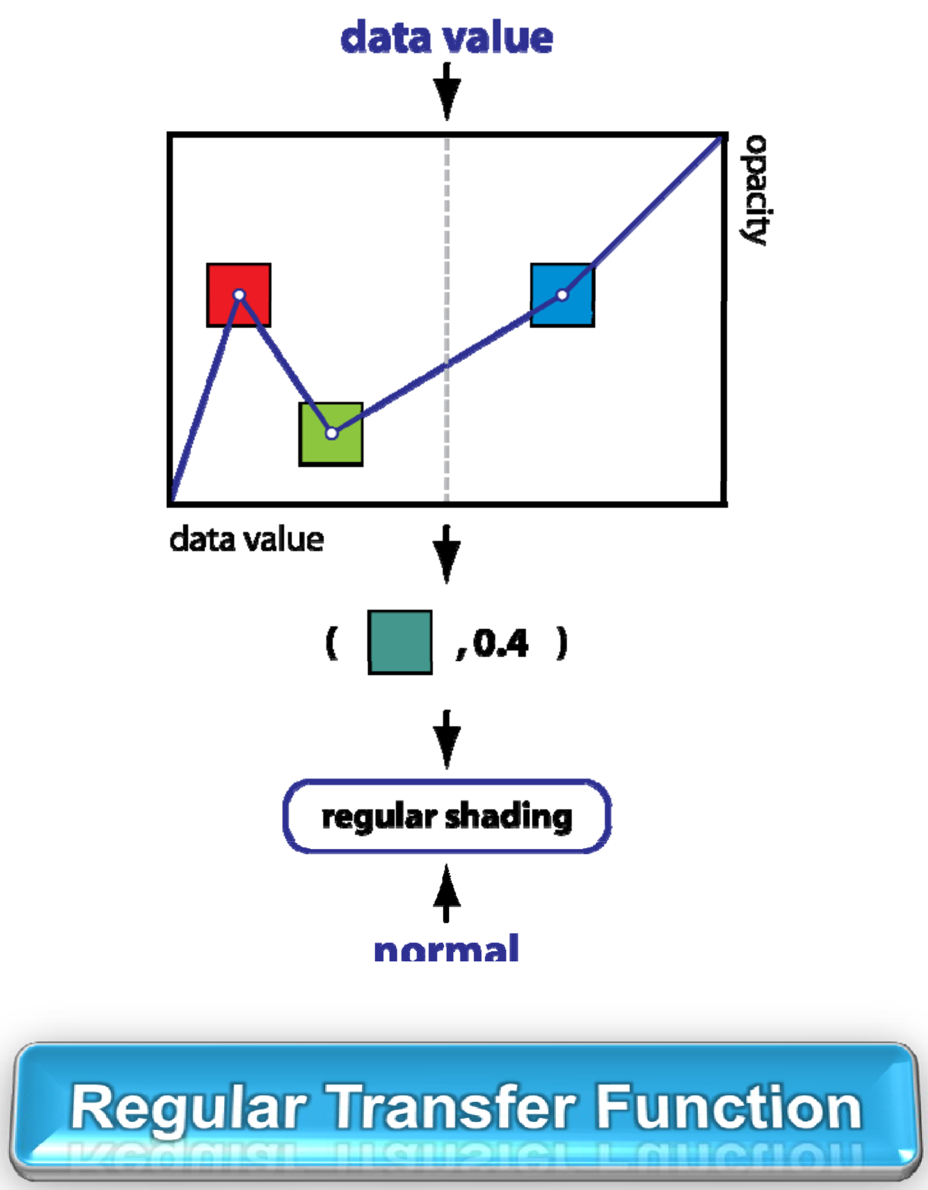
- Easy to obtain – lighting studies are frequently performed using spheres
- Sloan et al. describe simple extraction process from existing works of art
- Intuitive representation, can be directly displayed to the user as a preview

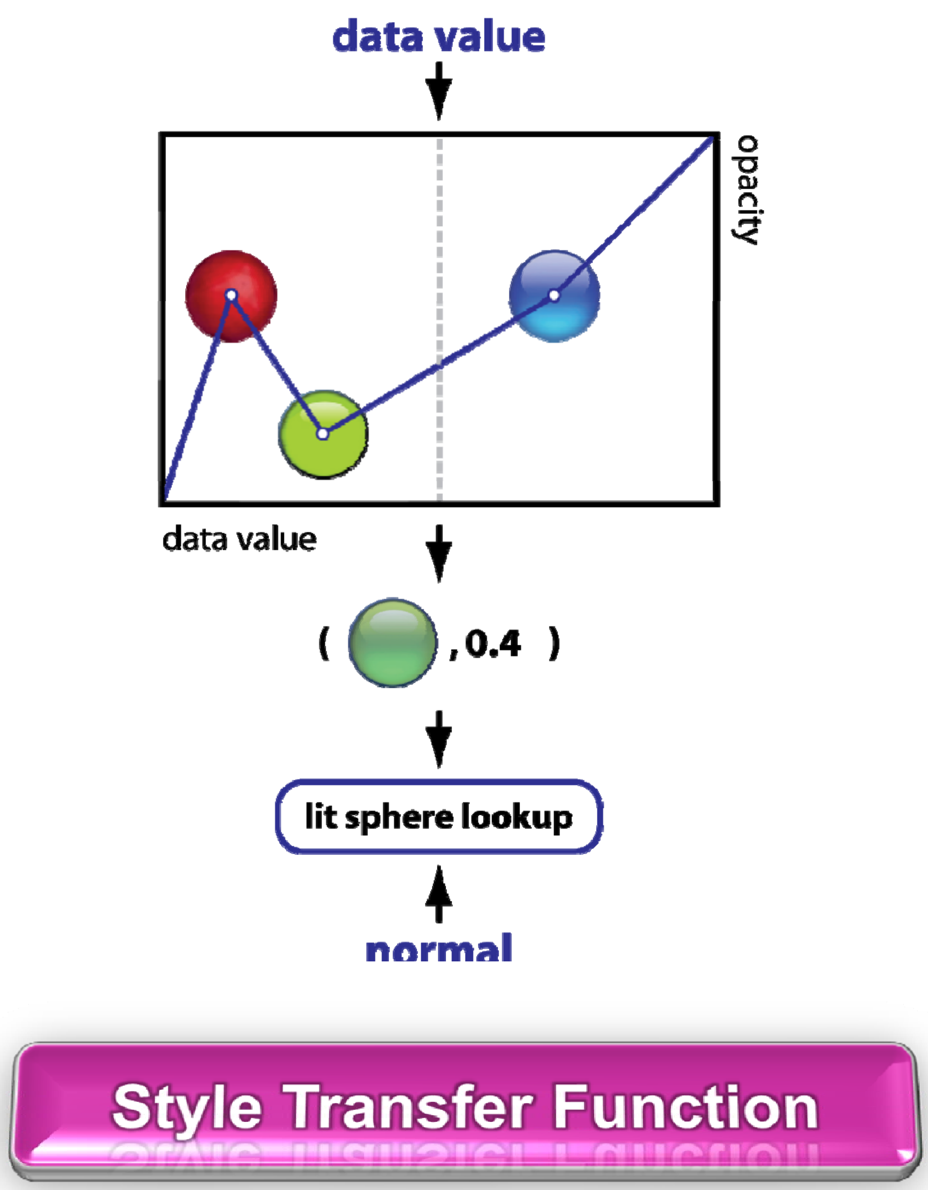


Style Transfer Functions (1)

- 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

Style Transfer Functions (2)

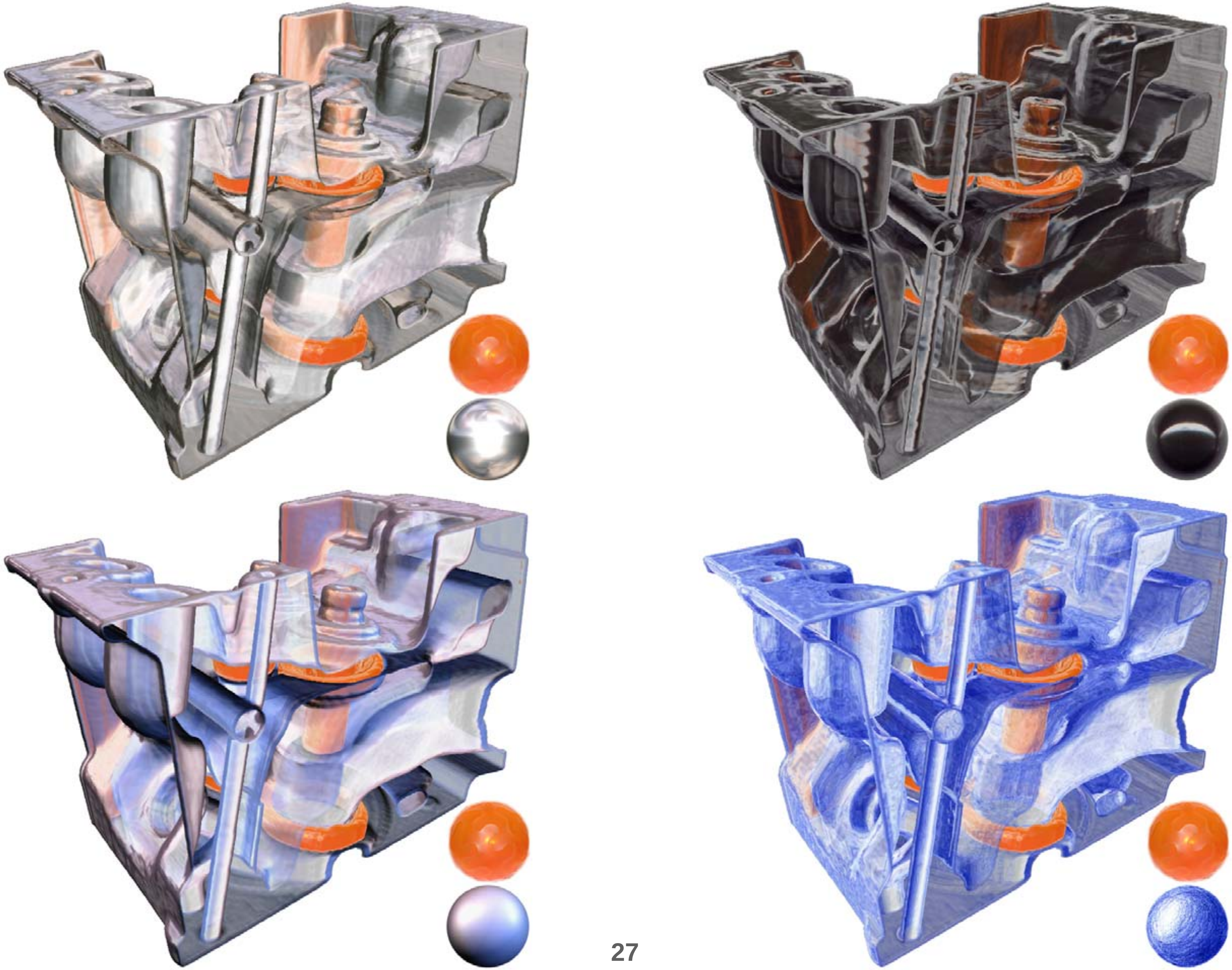




Style Transfer Functions (3)

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

Style Transfer Functions (4)

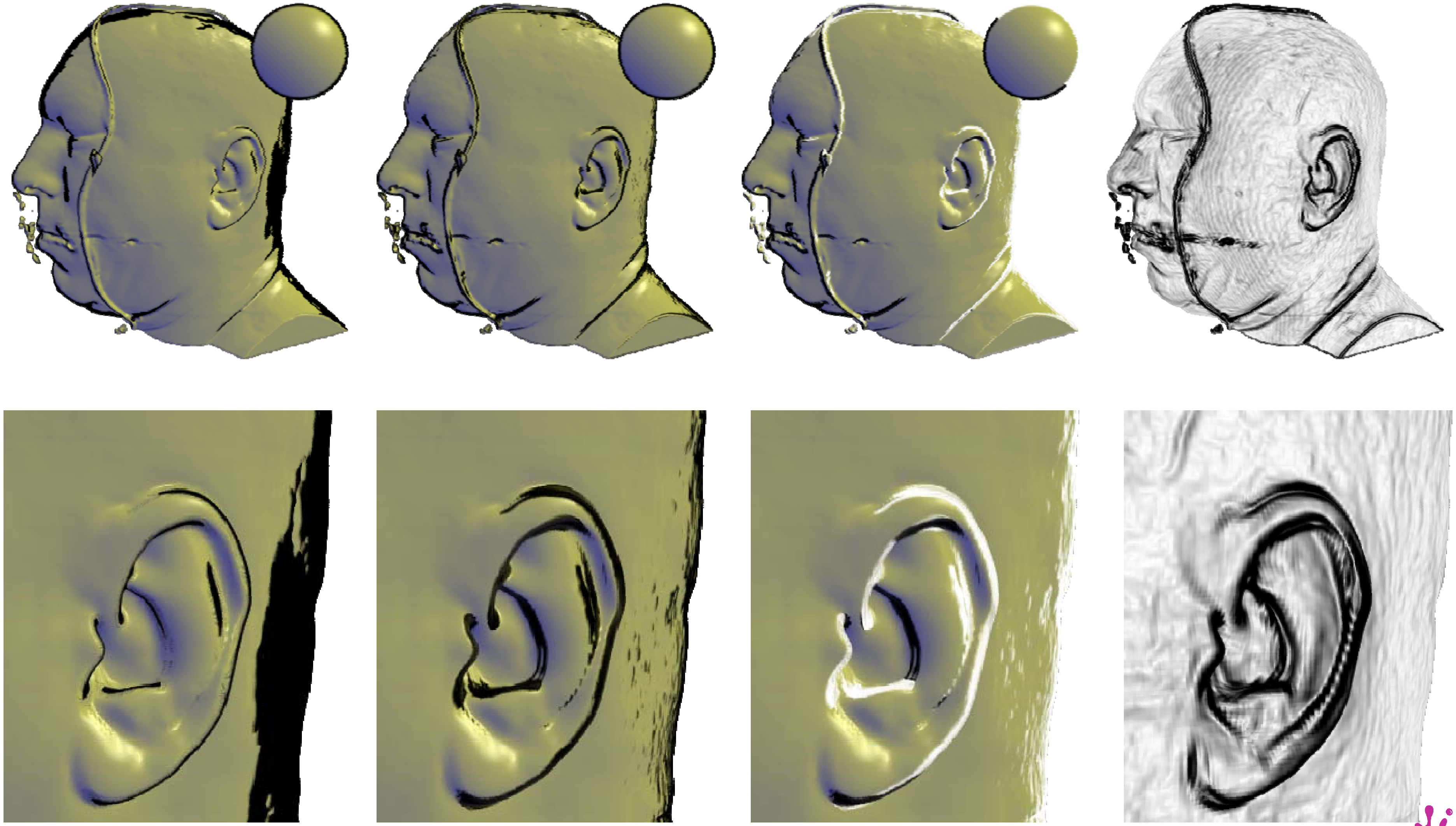


STF - Style Contours (1)

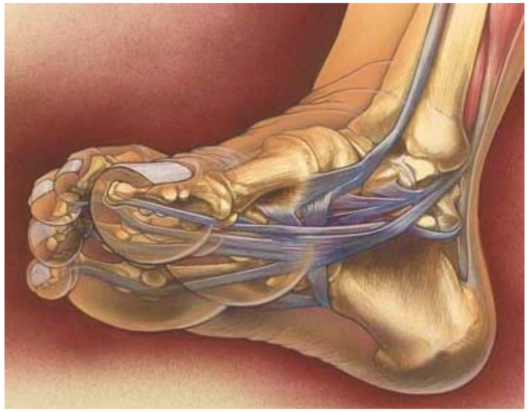
- Contours are a frequent stylistic element in illustrations
- Contour appearance should be derived from lit sphere map
- Apparent contour thickness varies based on curvature
- Solution by [Kindlmann et al. 2003]: use normal curvature along the view direction to modulate contour threshold

STF - Style Contours (2)

normal contours **thickness-controlled contours** **curvature image**



STF - Illustrative Transparency (1)

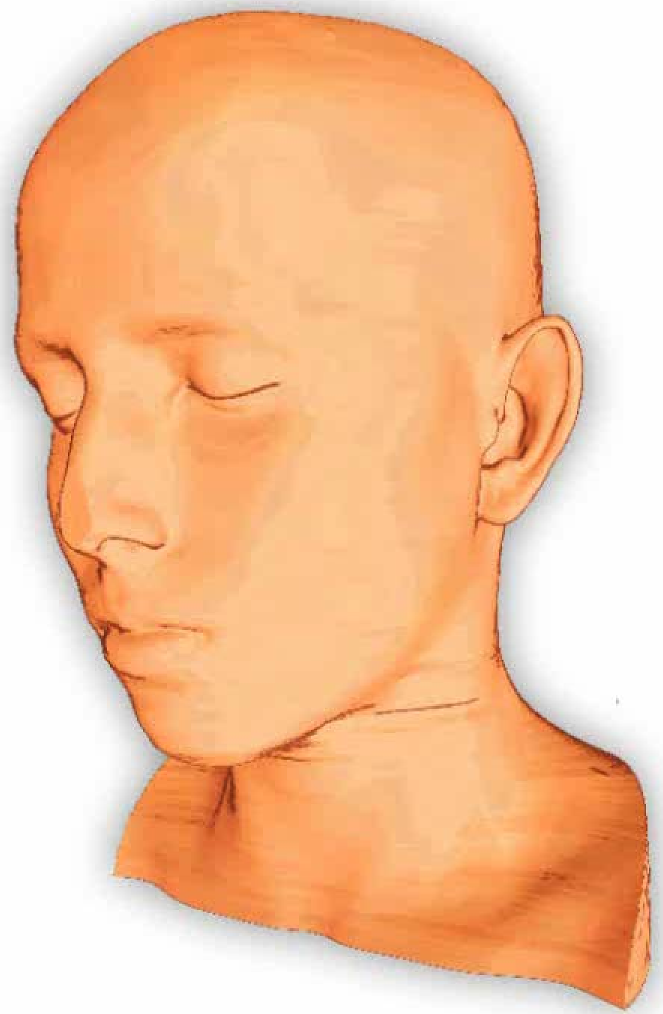


- Transparency in illustrations puts emphasis on edges
- Use of “contourness” to simulate this technique

Implementation + Results

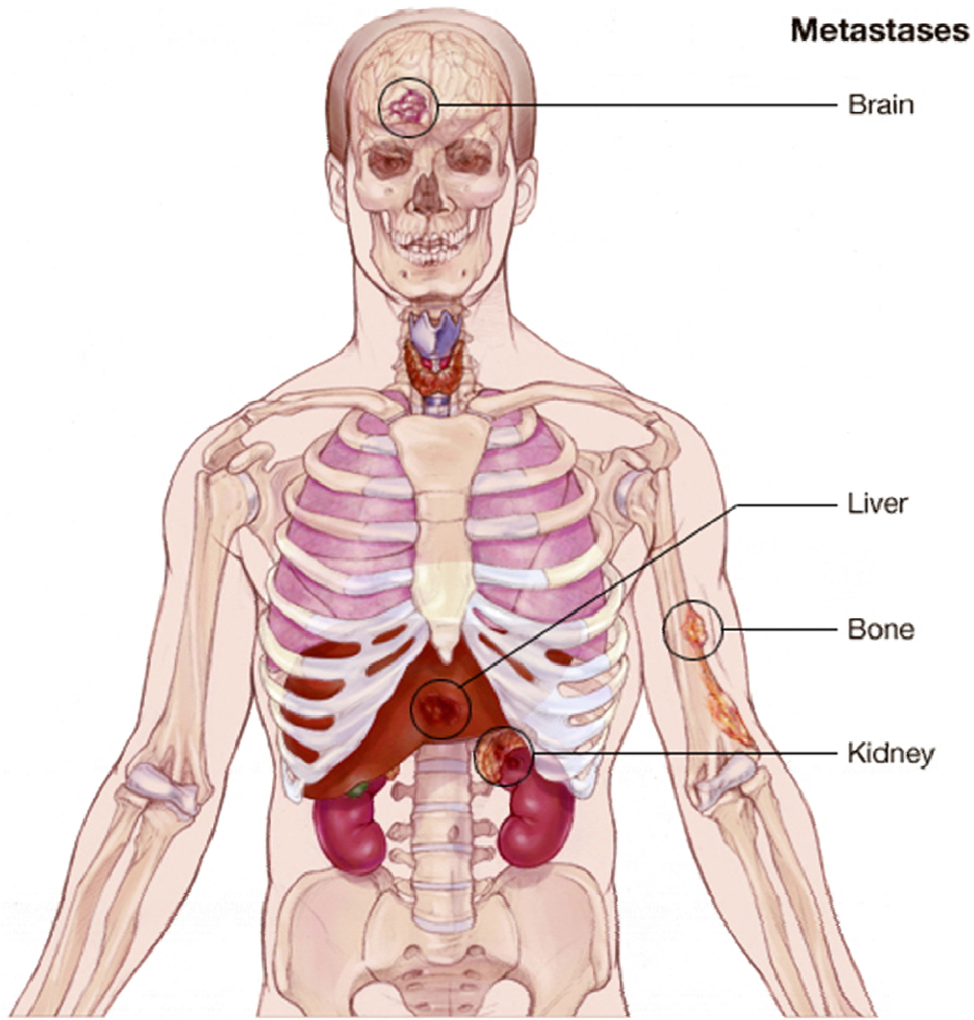
- Easy integration into existing GPU-based ray casting algorithms
- Performance between 80 and 100% of normal transfer function + Phong shading
- Style transfer function lookups require three textures, but additional memory requirement small
- Additional texture fetches incur an overhead, but shading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

Style Transfer Function - Example



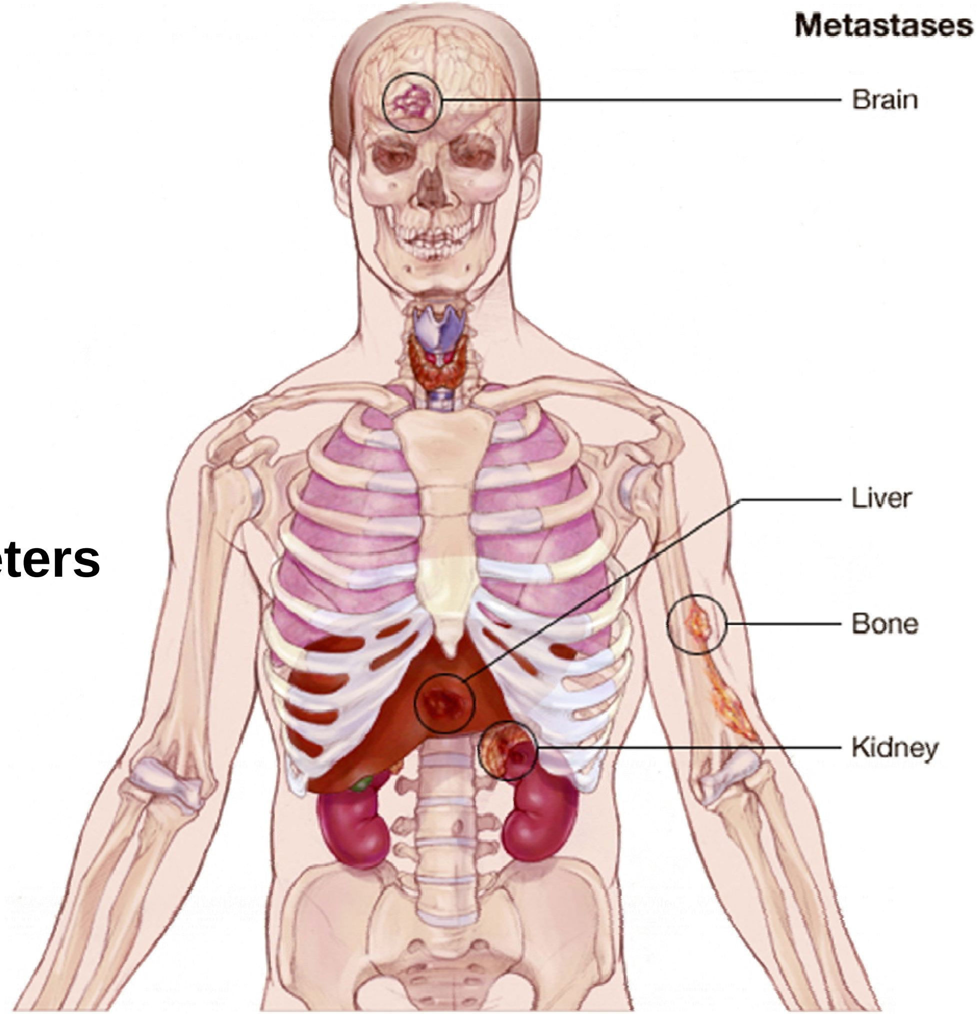
Style Transfer Functions + Semantic Layers

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



Style Transfer Functions + Semantic Layers

densities	transfer function →	colors, opacities
features, attributes w. values	semantic layers →	styles w. parameters

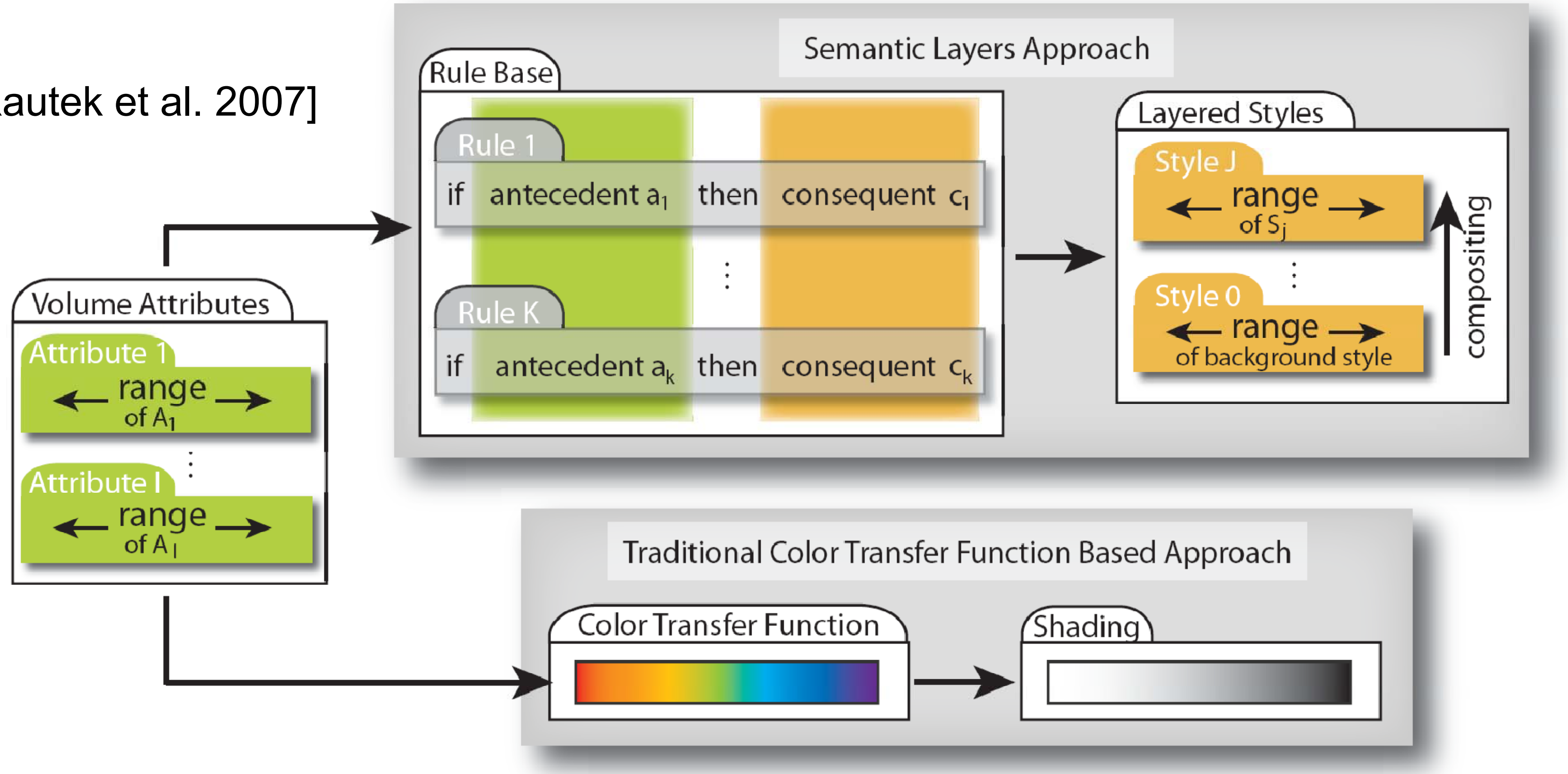


- Mapping from expert domain to visual appearance

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

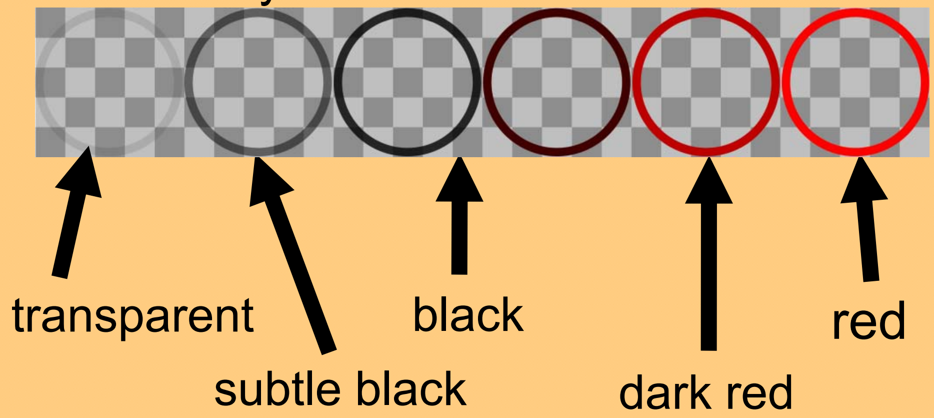
density:
low – … – high

curvature:
negative – zero – positive

etc.

illustrative styles

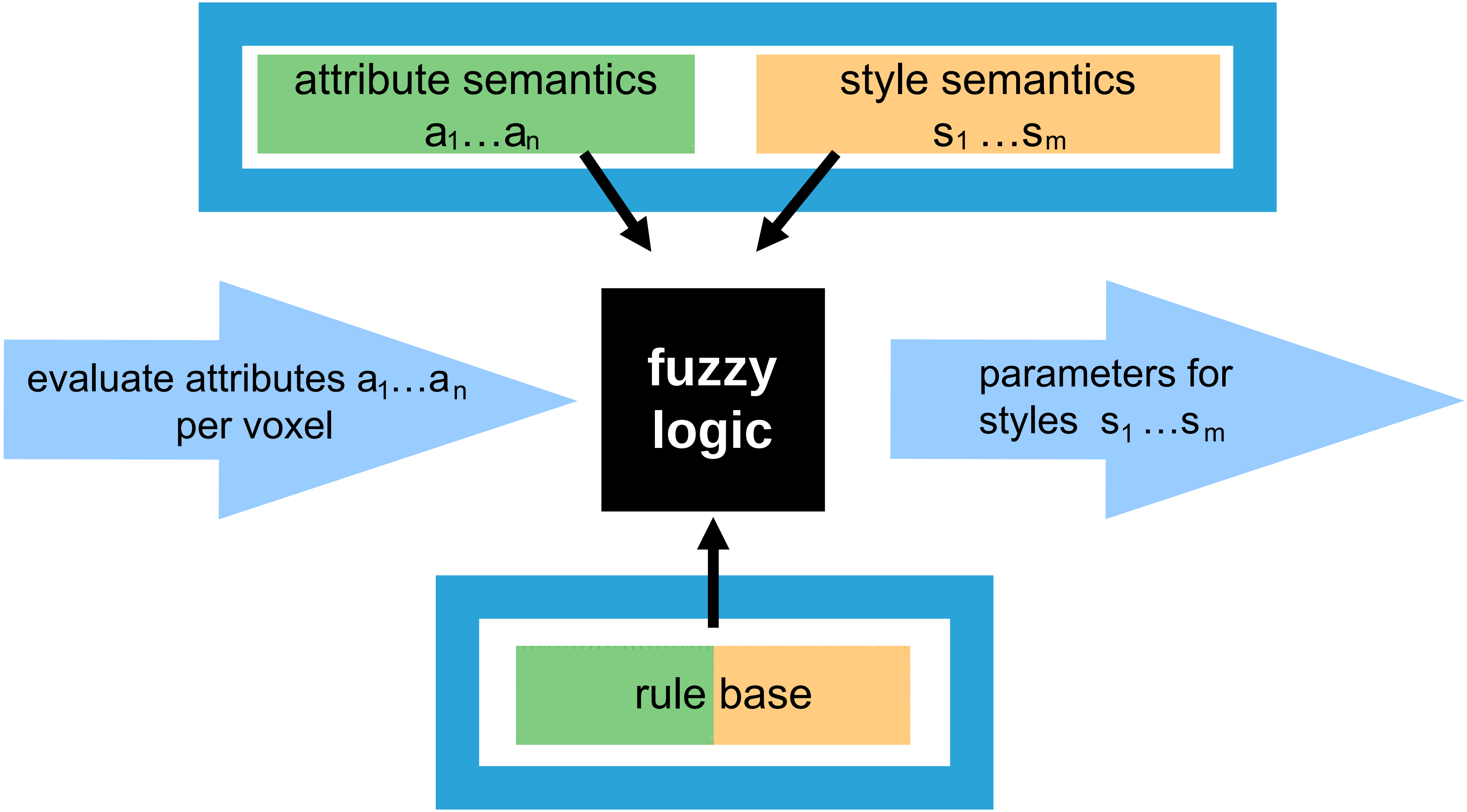
contour style



rules: if attribute a1 is v_{a1} … then style s1 is v_{s1}

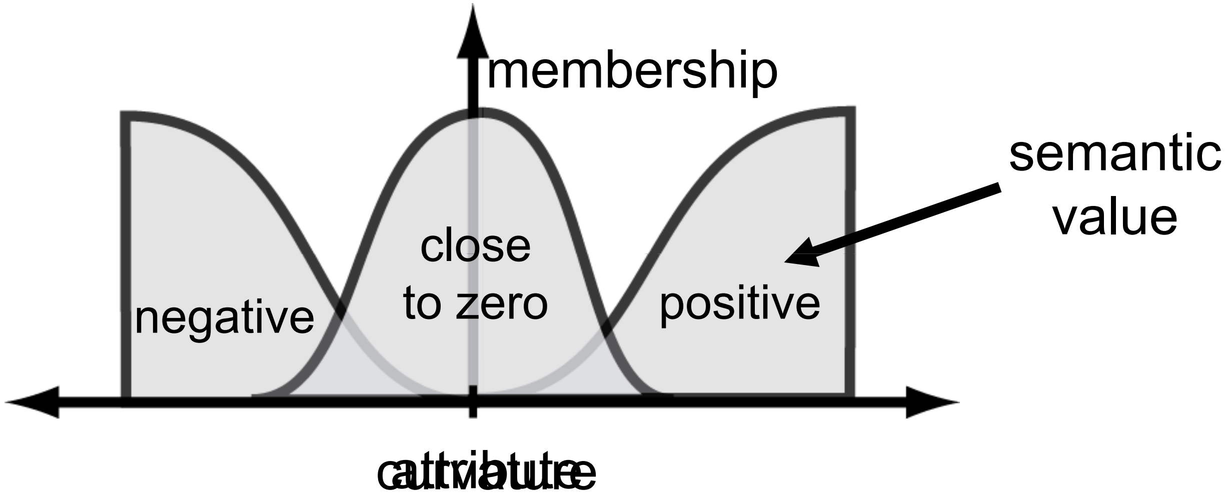
- Make use of semantics!

Fuzzy Logic as a Black Box

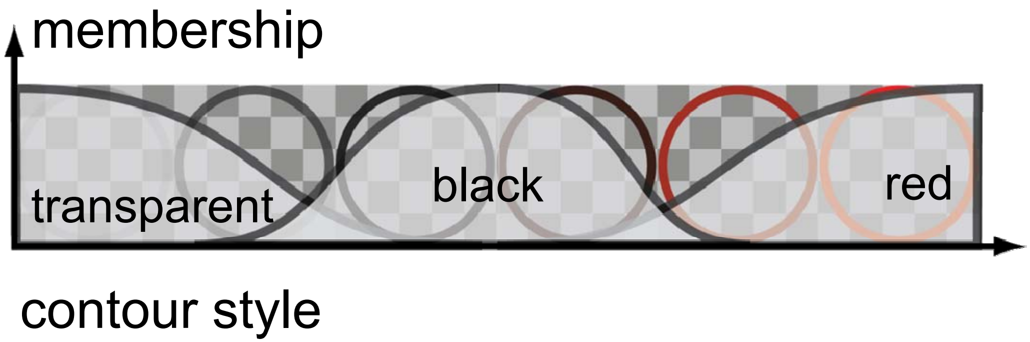


Membership Functions

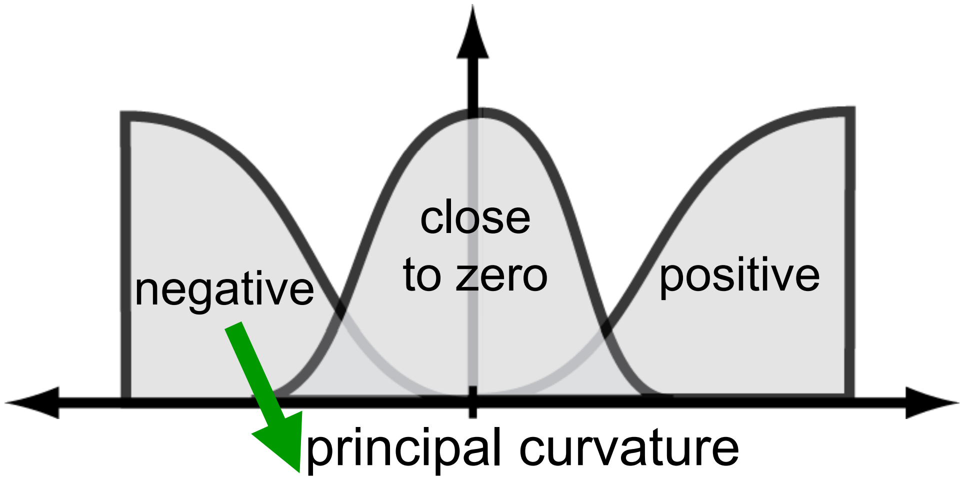
- if-part: semantics for volume attributes



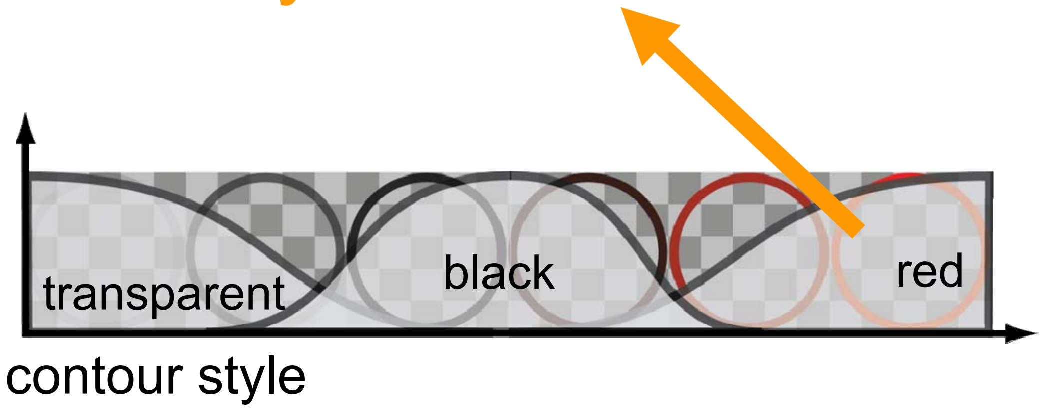
- then-part: semantics for visual appearance



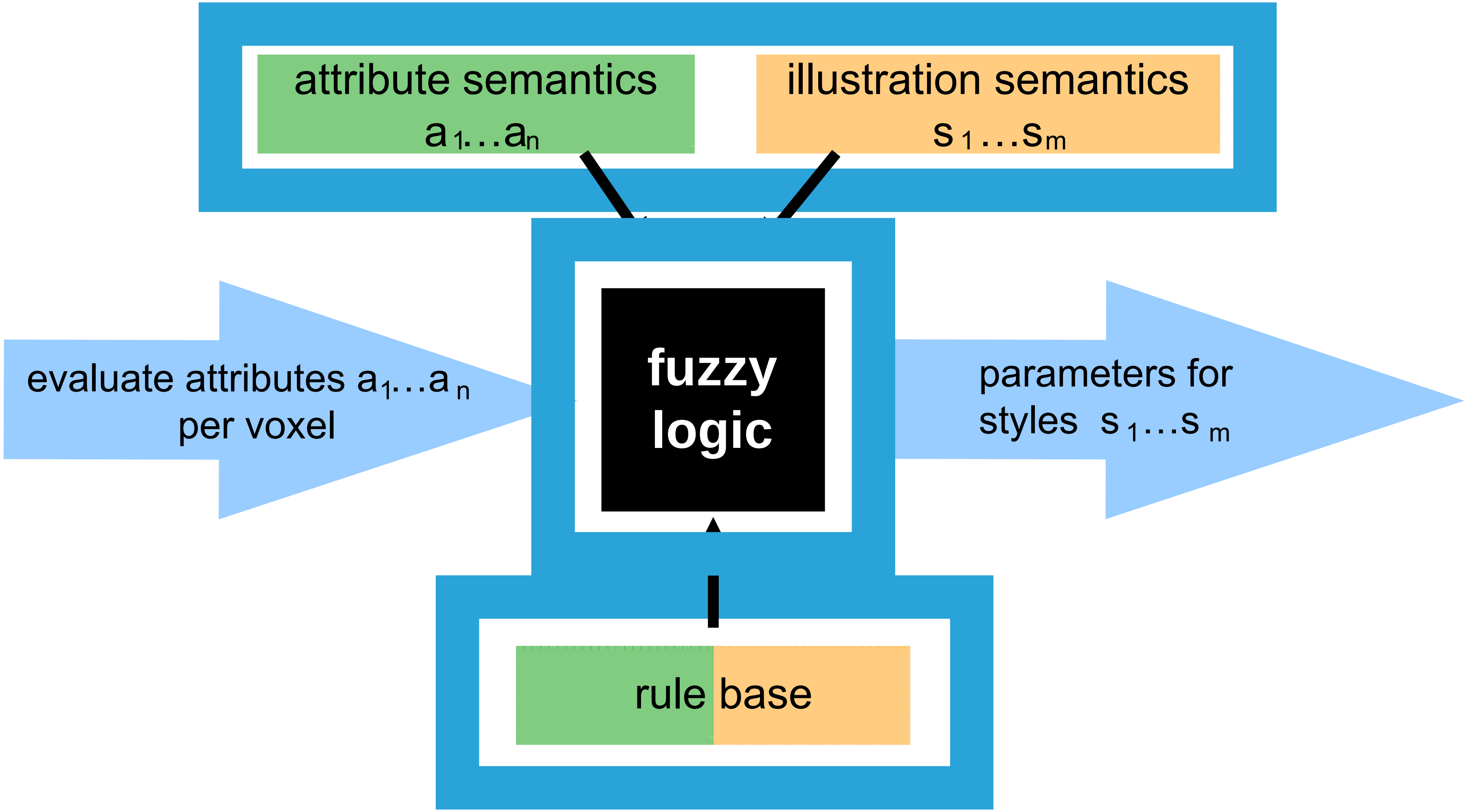
Rule Base



- 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

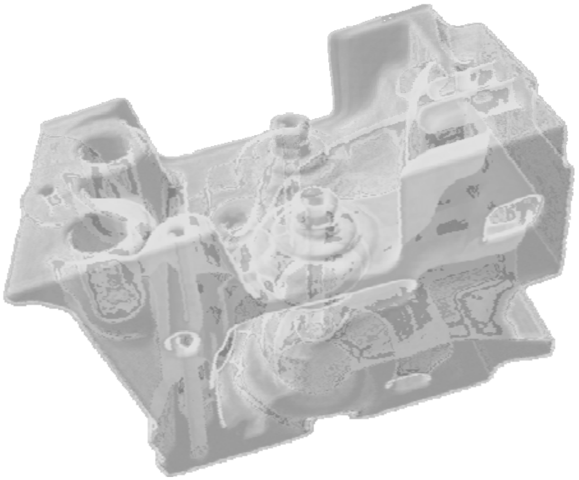


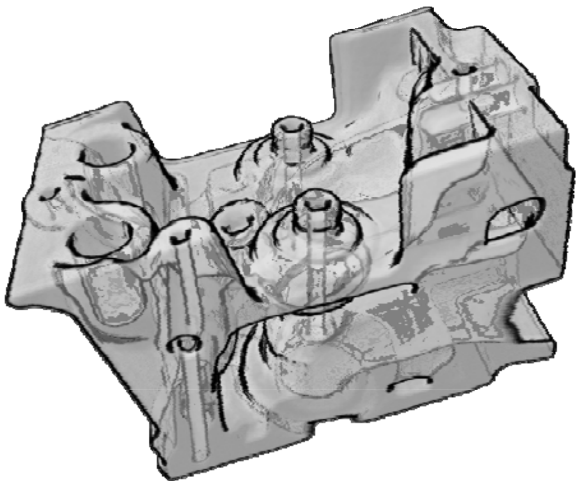
Fuzzy Logic Inside the Black Box

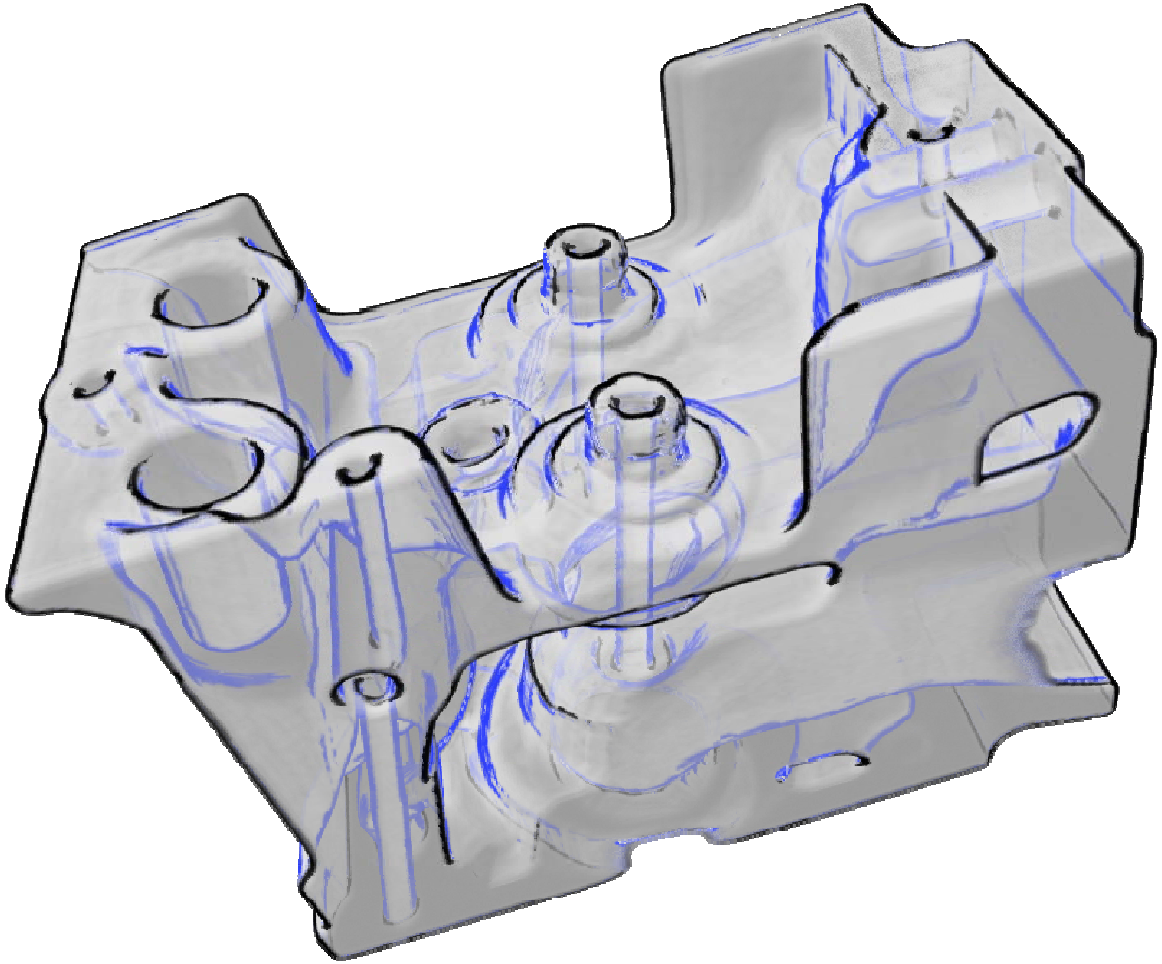


Curvature Based Selective Application

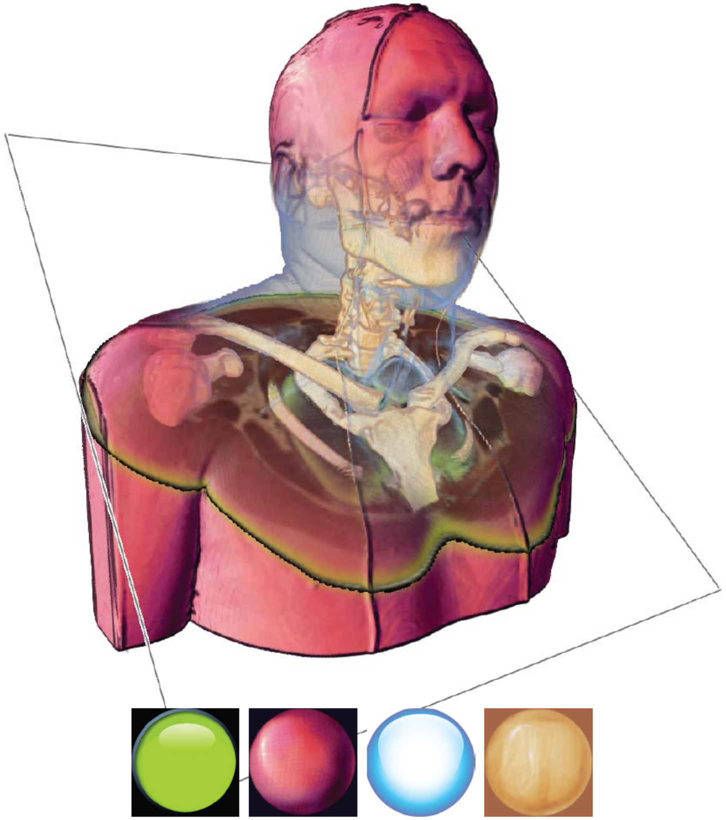
if *principal curvature is not positive then contours are blueish*





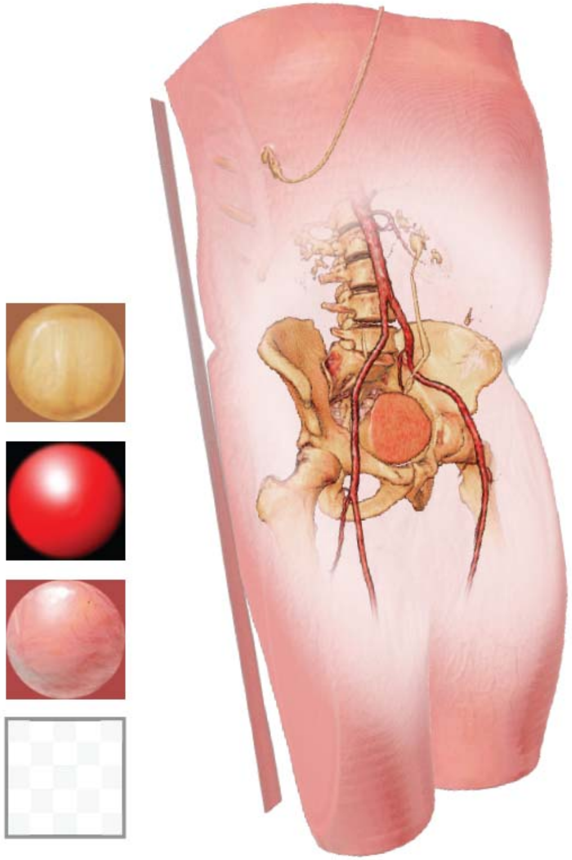


Semantics Driven Illustrative Rendering



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

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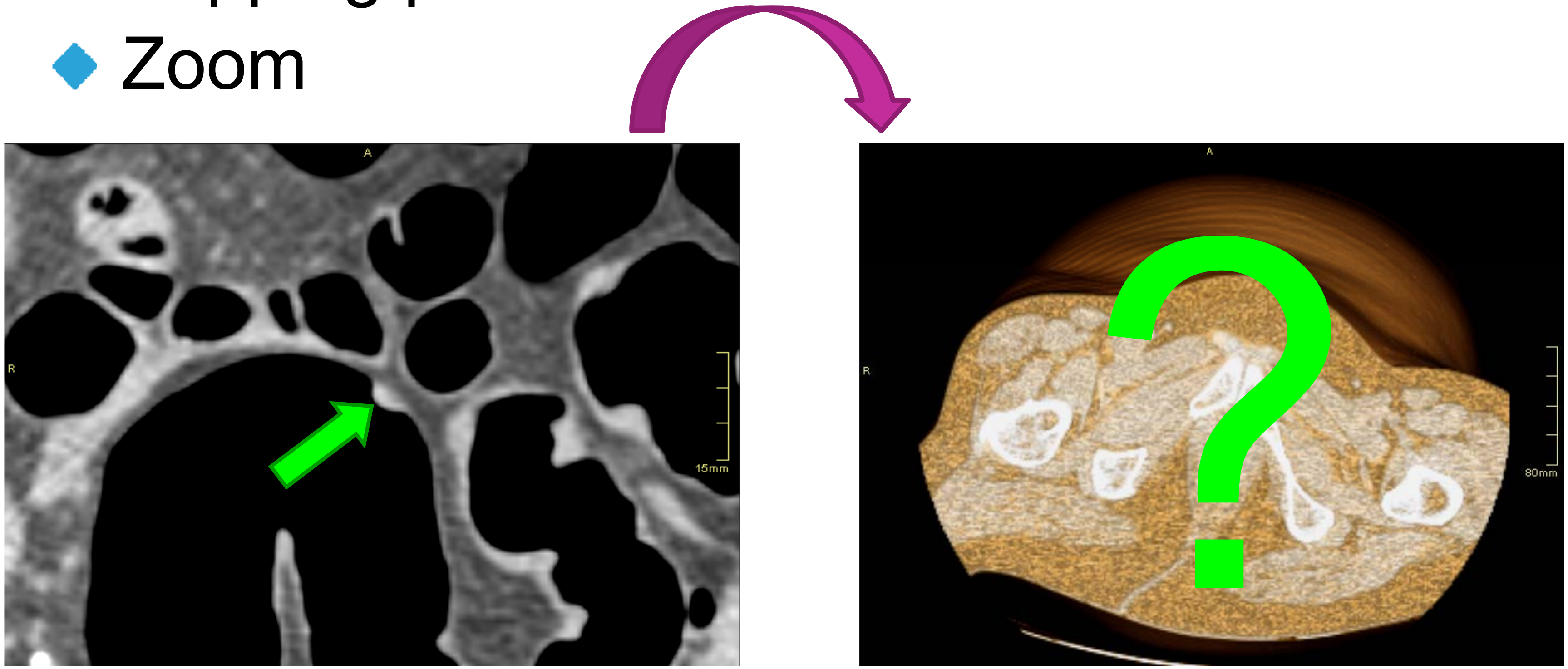
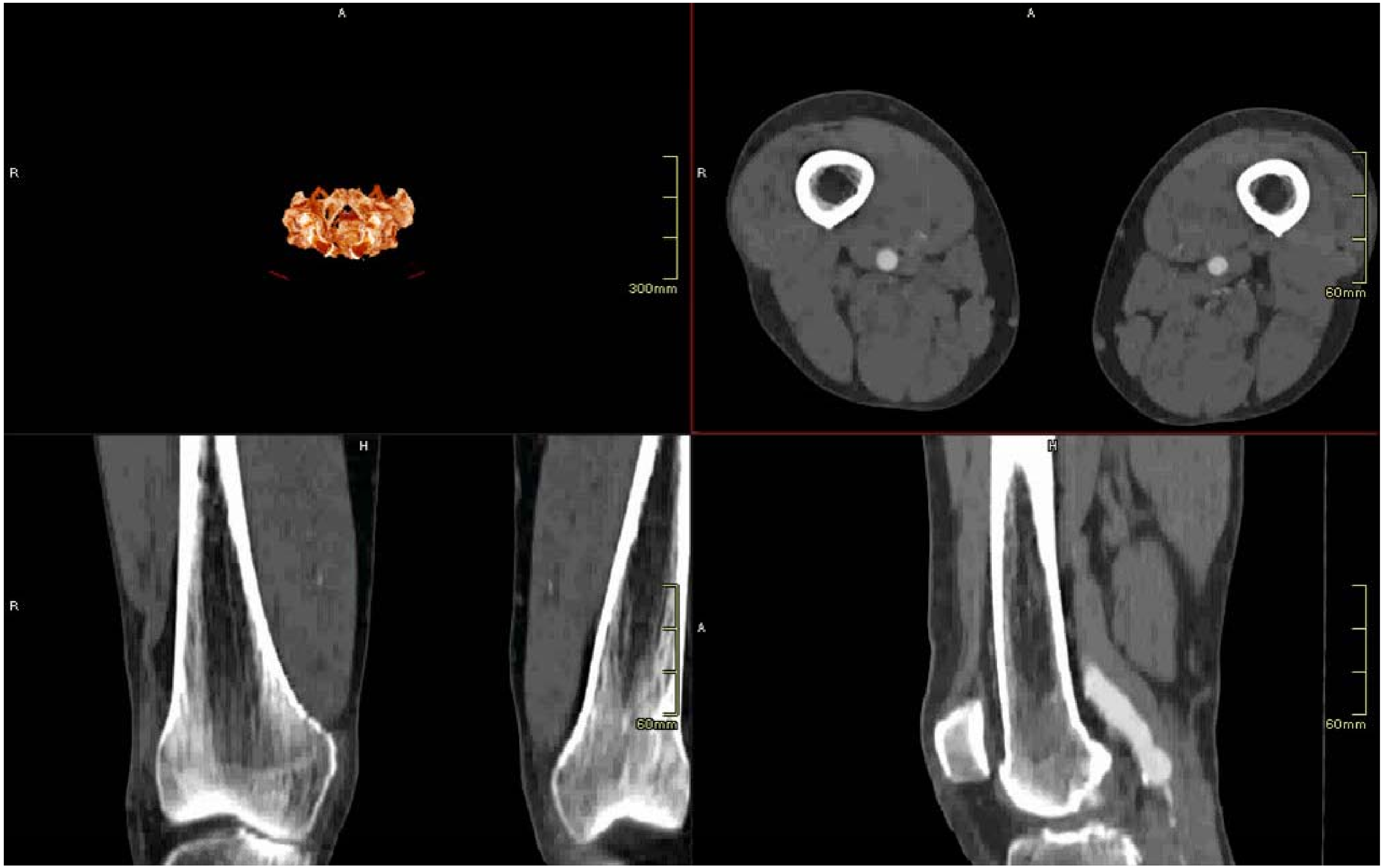
LiveSync: Knowledge-Based Navigation

- Slice View ➞ 3D View
- Underconstrained problem
  - Viewpoint
  - Clipping plane
  - Zoom

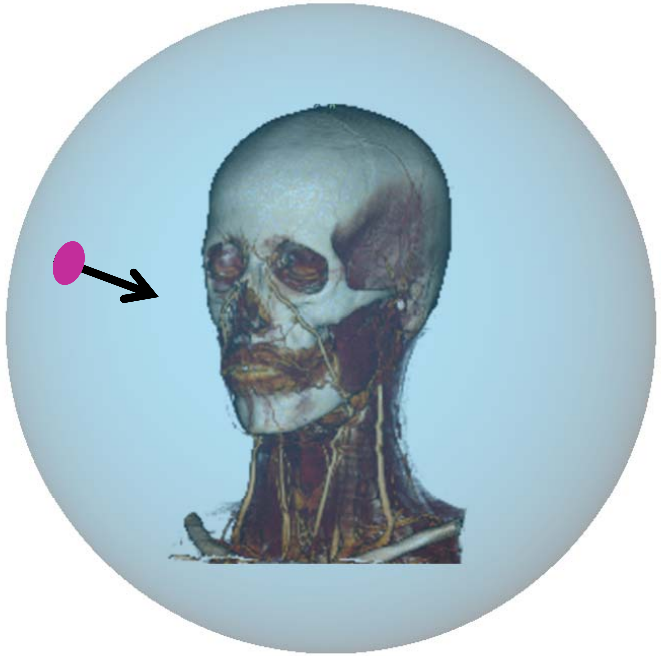


Traditional Workflow – Medical Workstation



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

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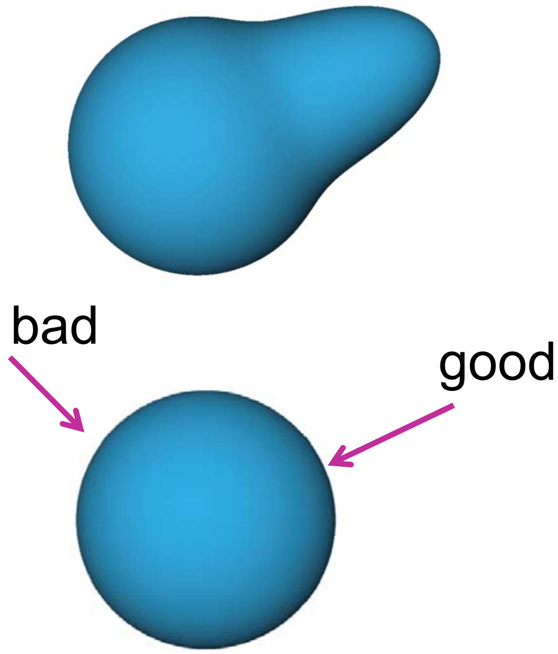
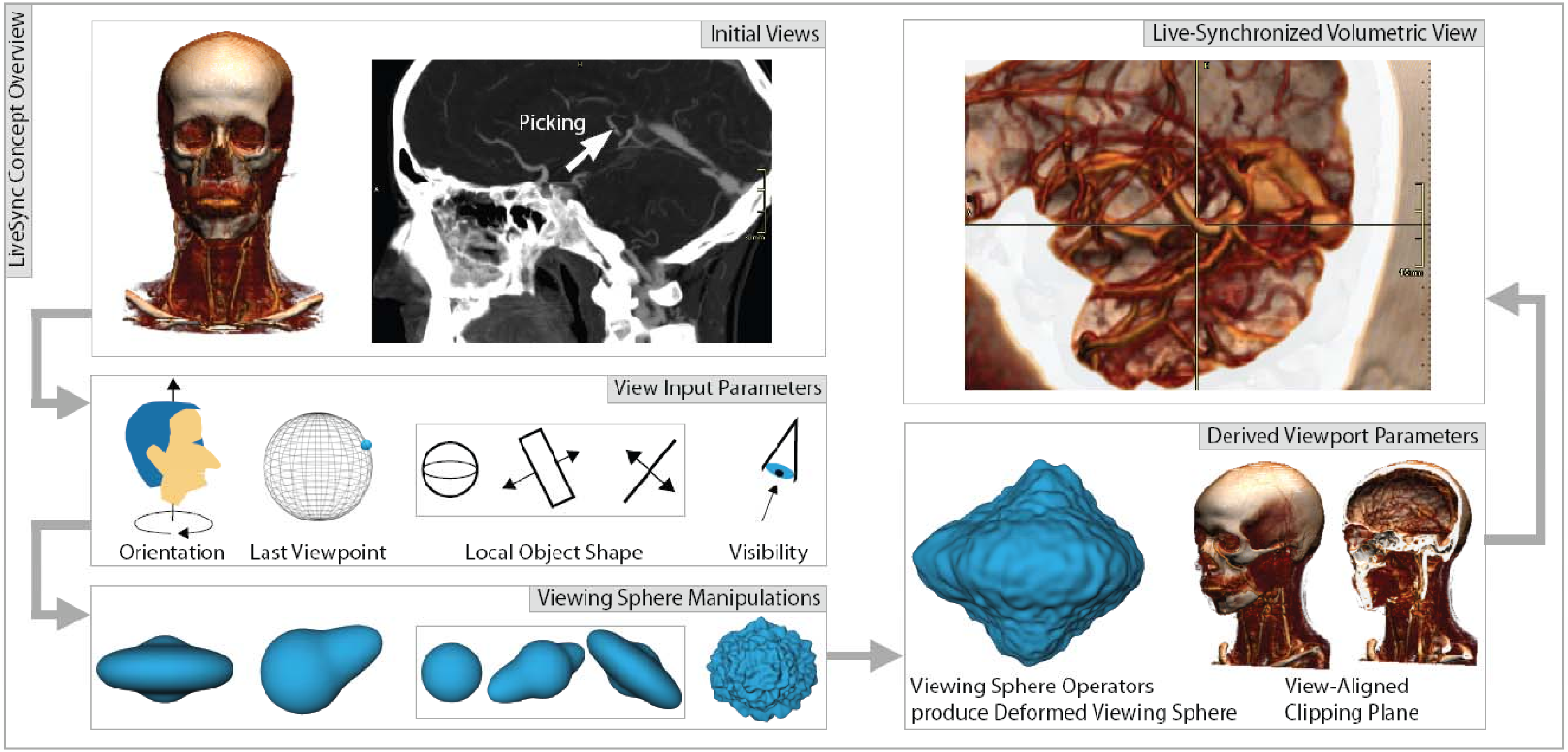


- Encoding of viewpoint quality
  - Deformation of viewing sphere
  - High radial distance indicates good viewpoint

LiveSync: Knowledge-Based Navigation

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



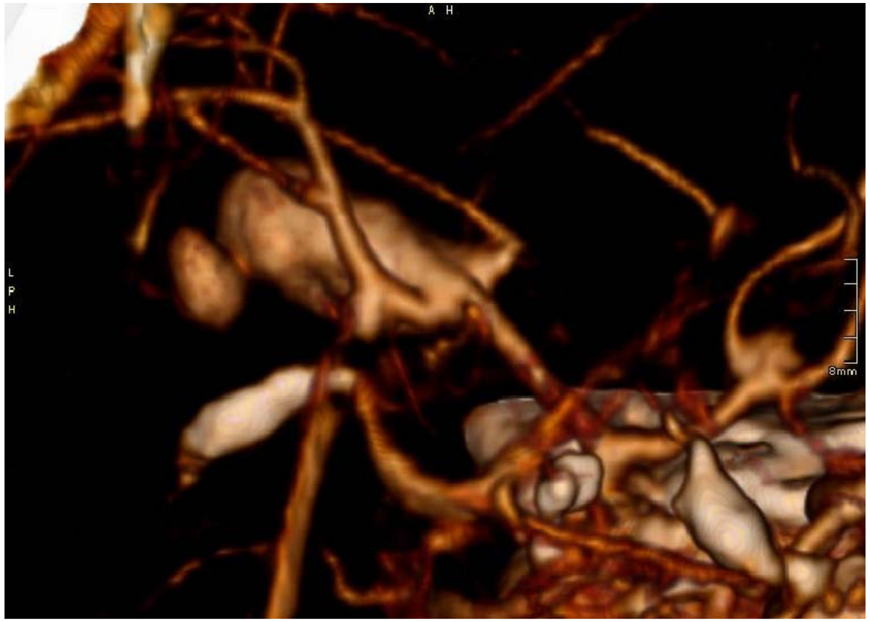
[Kohlmann et al. 2007]

Video

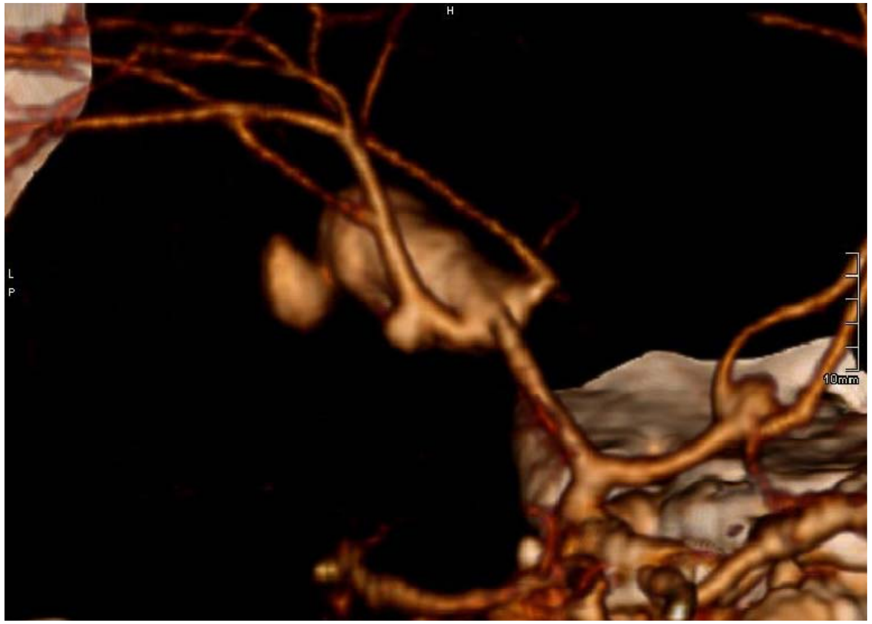
LiveSync Workflow

Results

- Aneurism



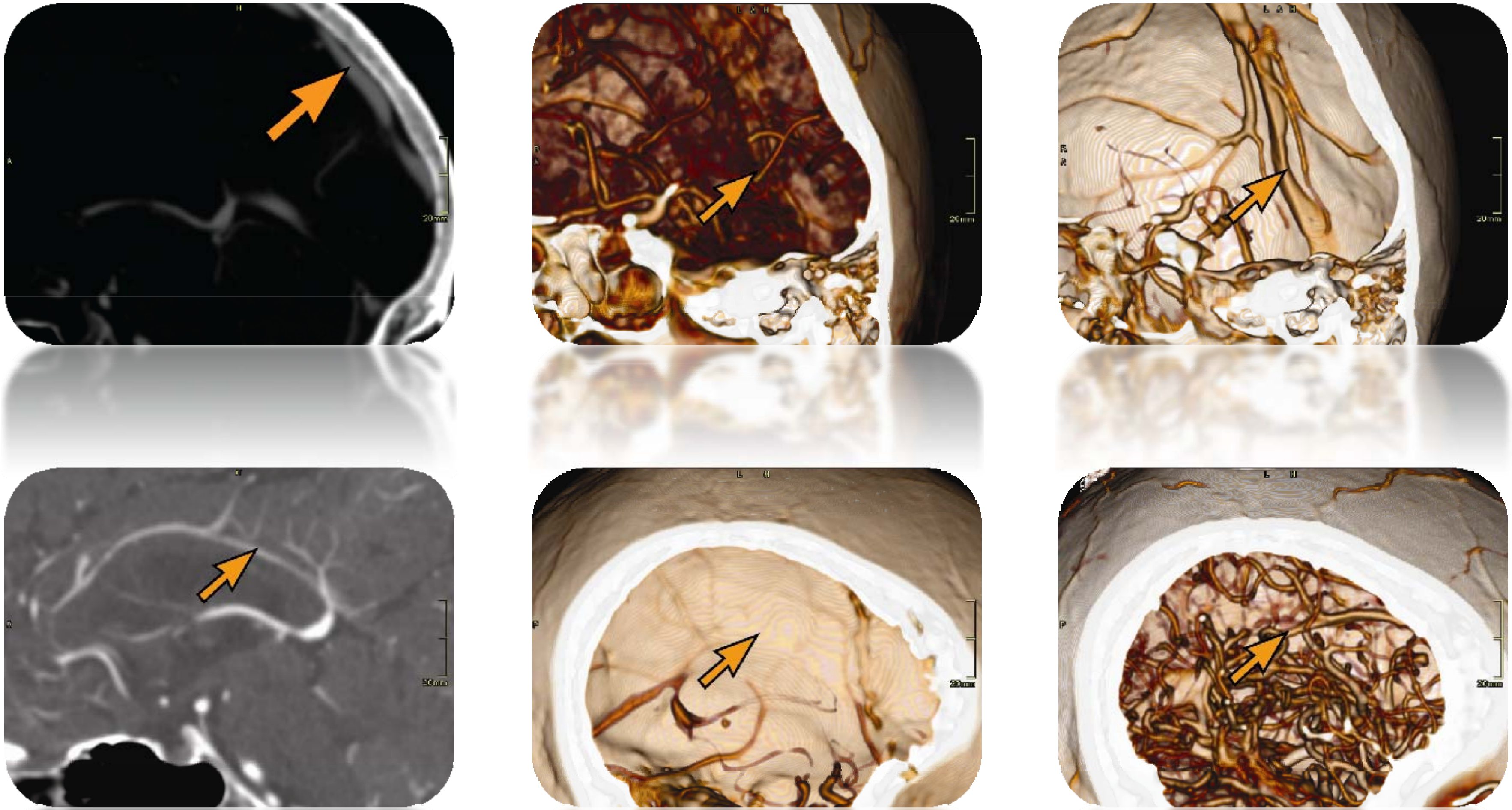
Manually adjusted
(~ 1:50 min)

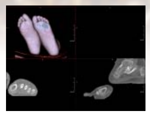


LiveSync generated
& manual clipping
(< 20 sec)

LiveSync++: Transfer Function Tuning

Picked point	LiveSync	LiveSync++





Video

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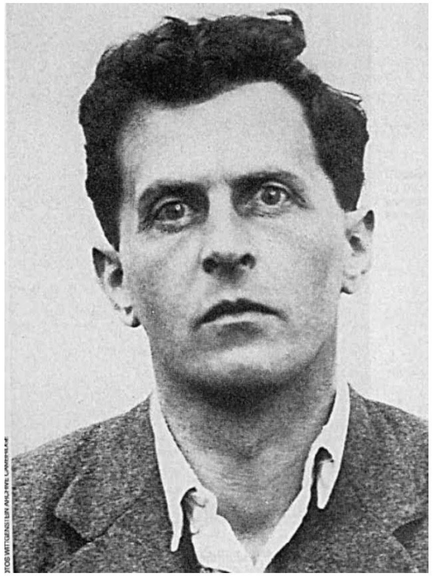
What is it all about?

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

The End

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

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

Questions ?
Comments?

Content

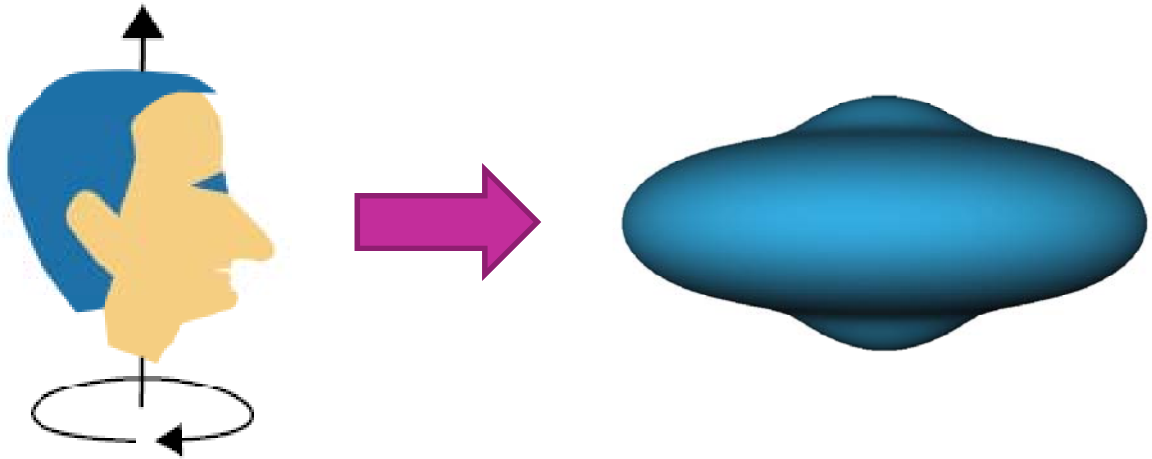
- Smart Visibility (two types of smartness), illustration + abstraction
- Style transfer functions + Semantic Layers (T85-Utah shorten, EuroVis2008)
- LiveSync (Vis2007+GI2008)
- Automatic view point detection: (importance driven rendering + Focus of attention)
- Additional Material
  - Take a look at 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

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??

Patient-Orientation Viewing-Sphere

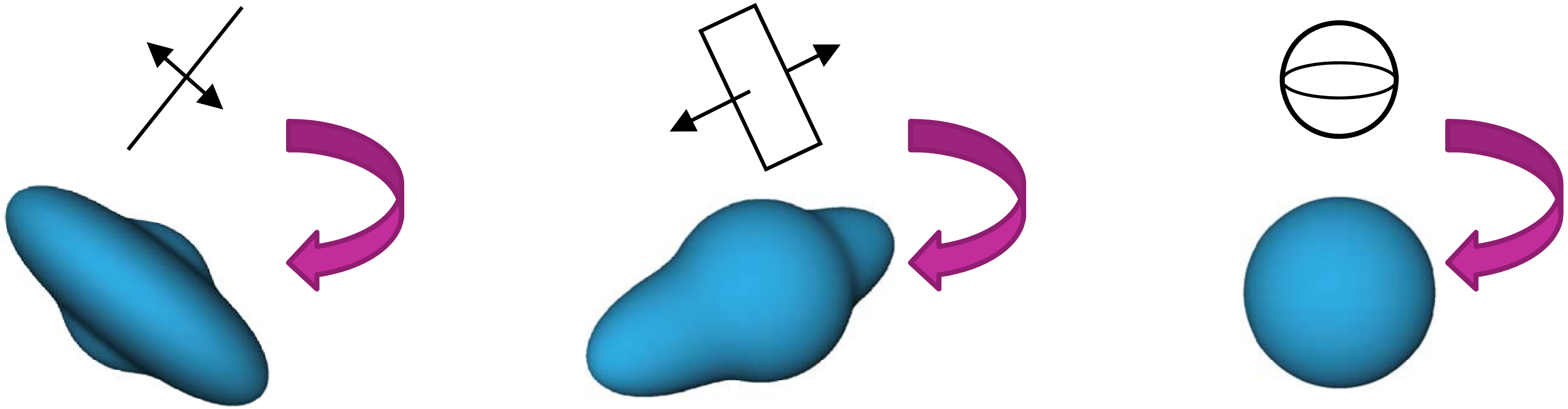
- Consider preferred viewing directions according to type of examination
- **Technique:** Head-feet axis serves as rough estimation to derive preferred viewpoints



Local Shape-Estimation Viewing-Sphere

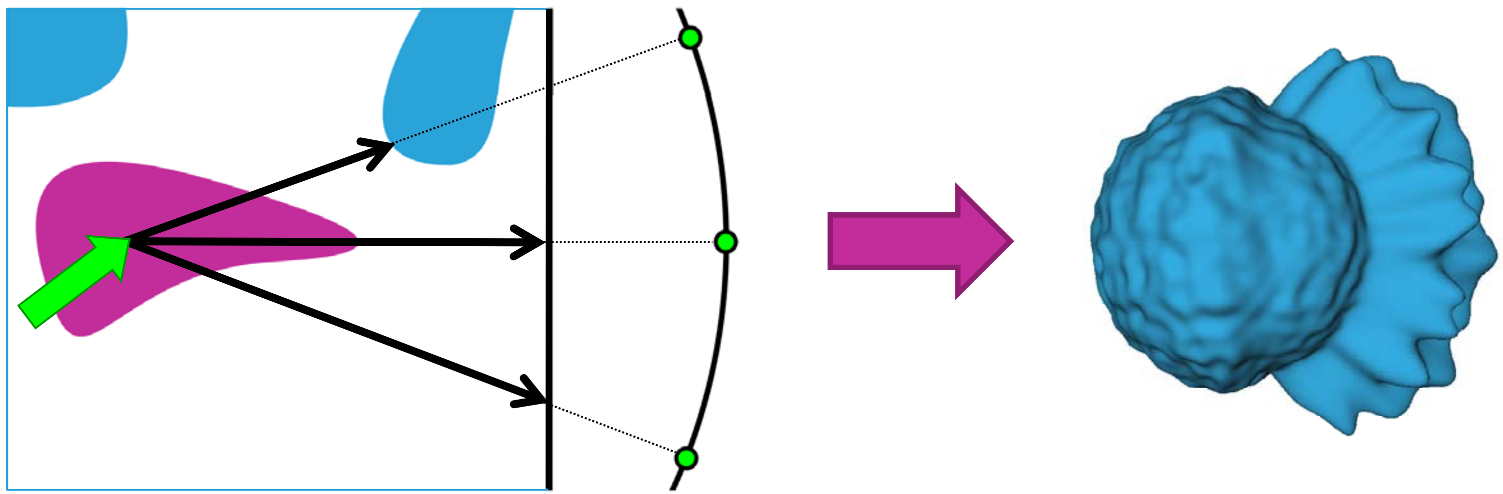
- Consider local shape of structure of interest
- **Technique:**
  - Local region growing (picked point as seed)
  - Principal component analysis on result

$\lambda_1 >> \lambda_2 \approx \lambda_3$ $\lambda_1 \approx \lambda_2 >> \lambda_3$ $\lambda_1 \approx \lambda_2 \approx \lambda_3$



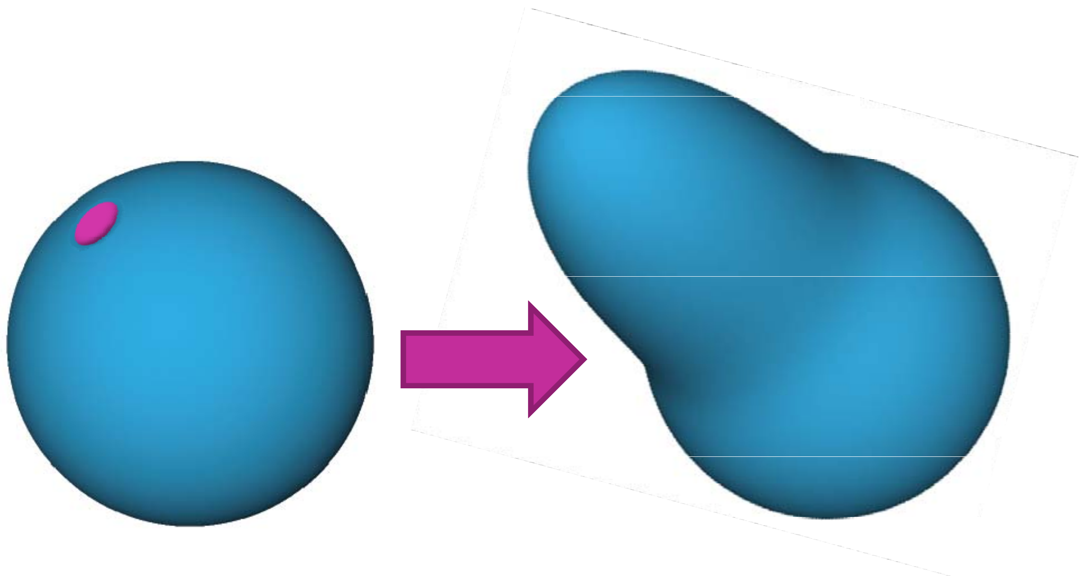
Visibility Viewing-Sphere

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



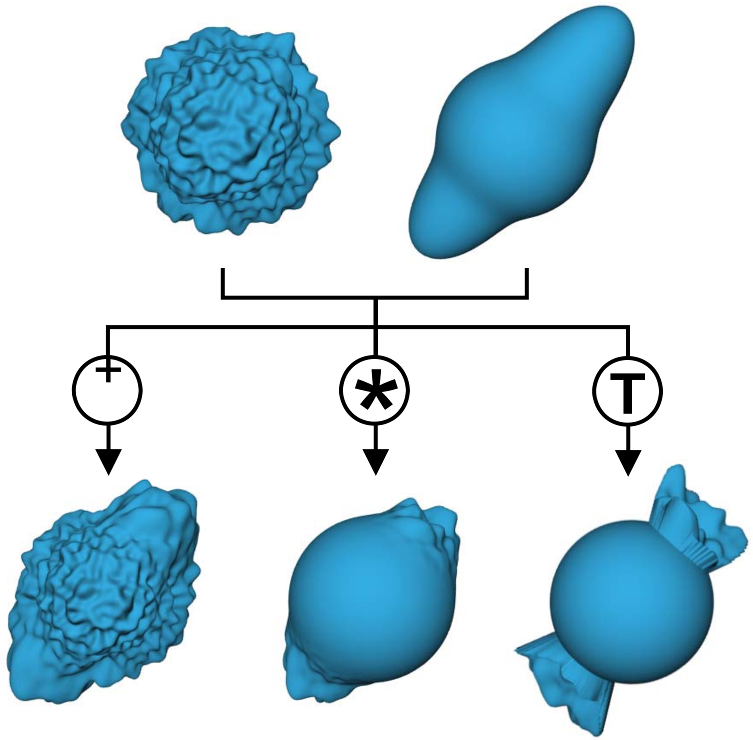
Viewpoint-History Viewing-Sphere

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



Viewing-Spheres Combination

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

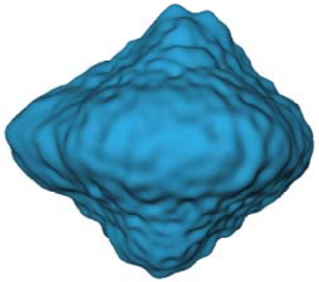


Summation:
- intuitive approach
- good results

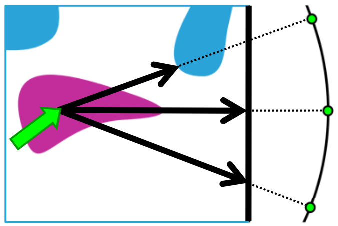
Multiplication:
- emphasize characteristics
- high impact of low values

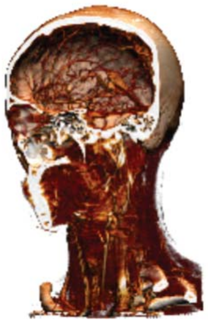
Thresholding:
- preferred sphere
- definition of knock-out criteria

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

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