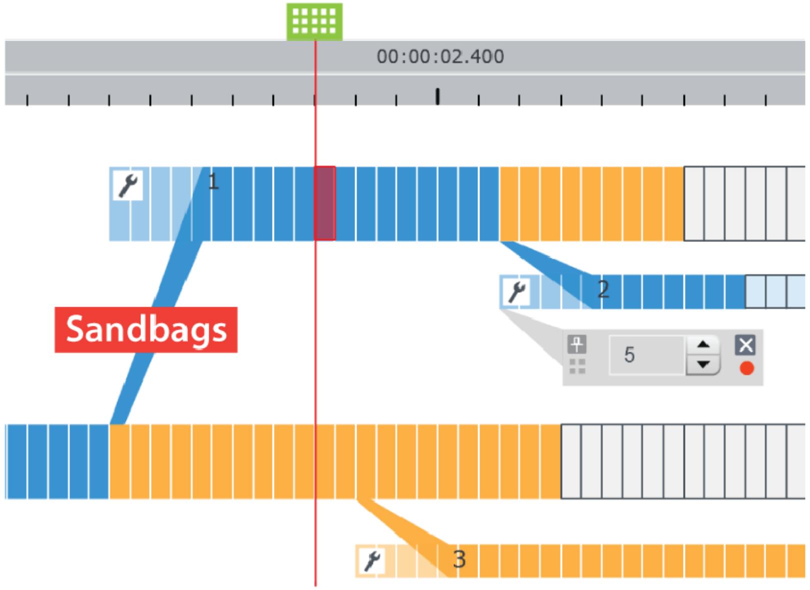
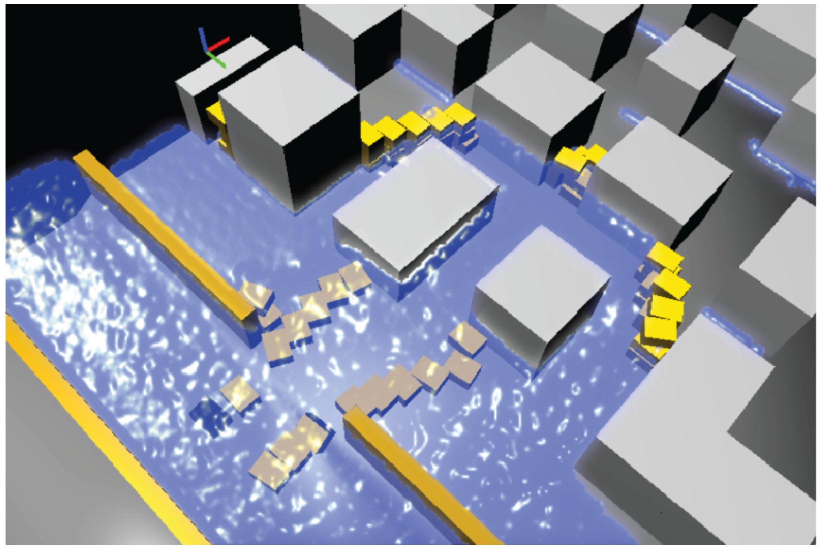




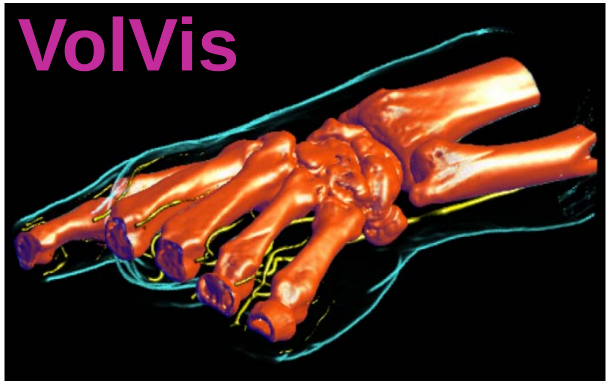
Trends in Visual Computing

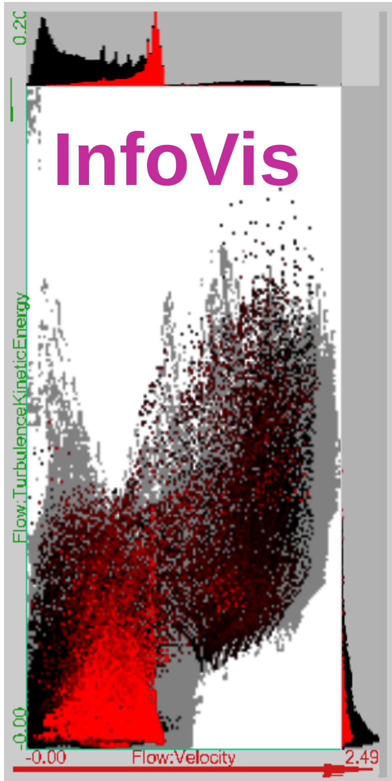
Eduard Gröller

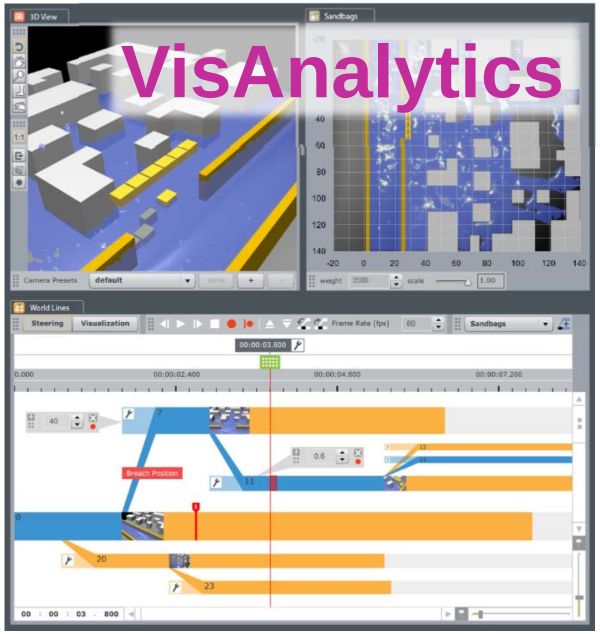
Institute of Computer Graphics and Algorithms
Vienna University of Technology

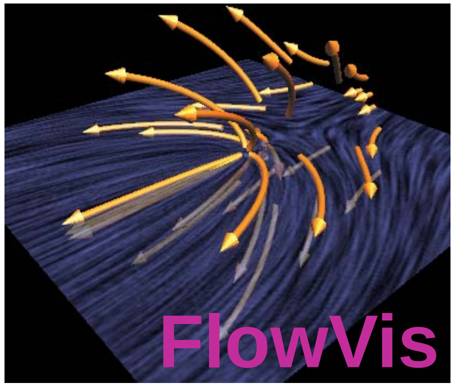
(Data) Visualization

"The use of computer-supported, interactive, visual representations of (abstract) data to amplify cognition"



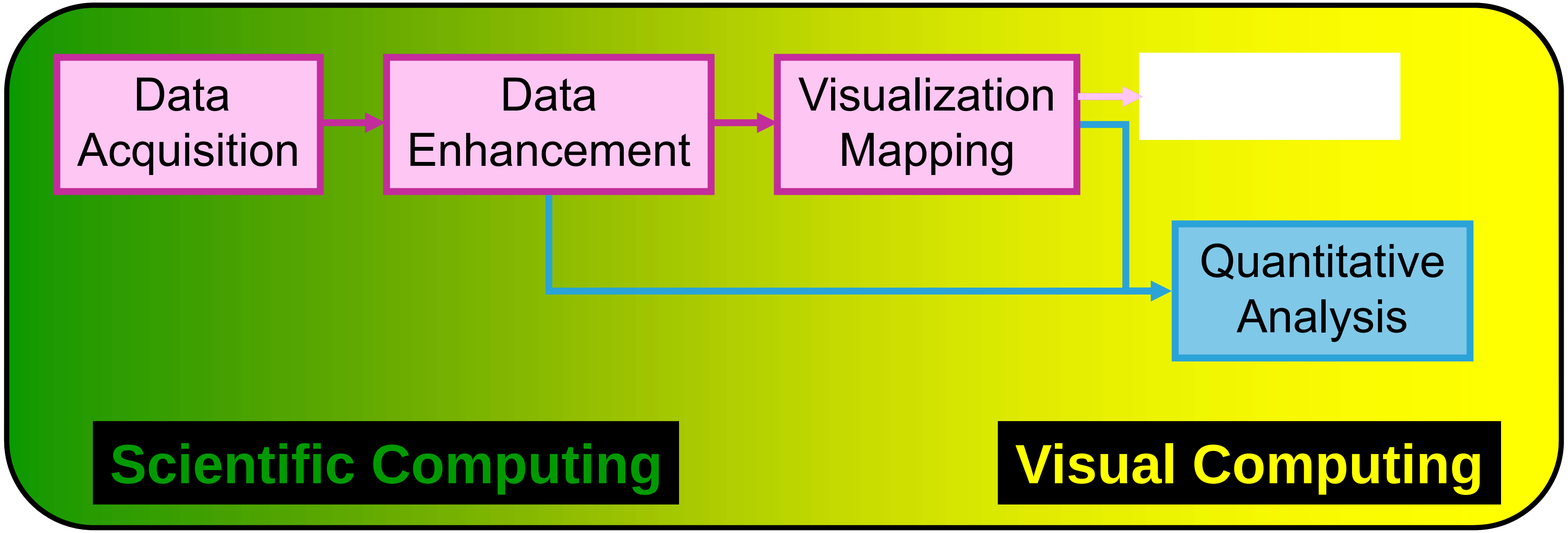






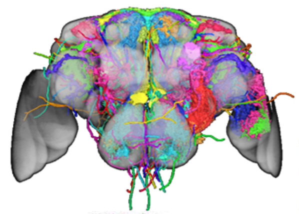
- Data is increasing in complexity and variability

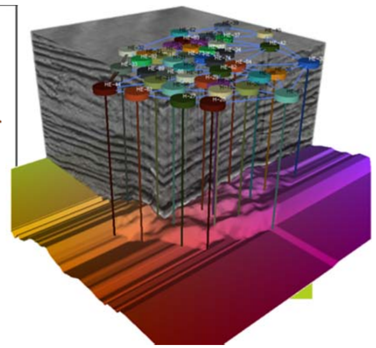
Visualization Pipeline



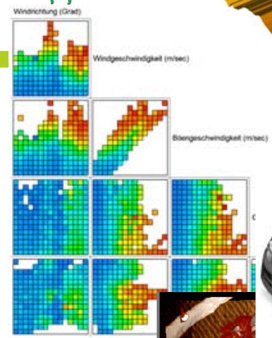
- Visualization is part of Visual Computing
- Visual Computing is acquistion, representation, processing, analysis, synthesis, and usage of visual information

Visual Computing is a Lot…

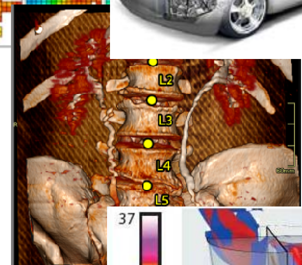




- **Computer Graphics**
  graphical user interfaces, animations ...
- **Computer Vision /Pattern Recognition**
  modeling human vision…

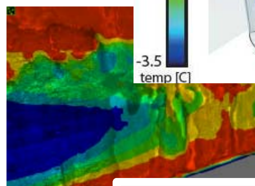


- **Visualization**
  displaying volume- and other high-dimensional data…

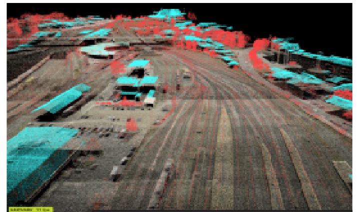


- **Interactive Visual Analysis**
  presenting multidimensional data for analysis…

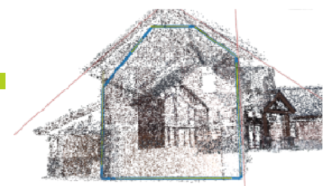
- **Visual Sensors**
  recording methods for obtaining visual information

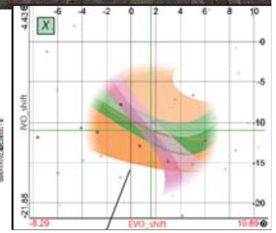


- **Modeling**
  digital models from data/images
- **Rendering**
  real-time visualization, illumination simulation, visibility…

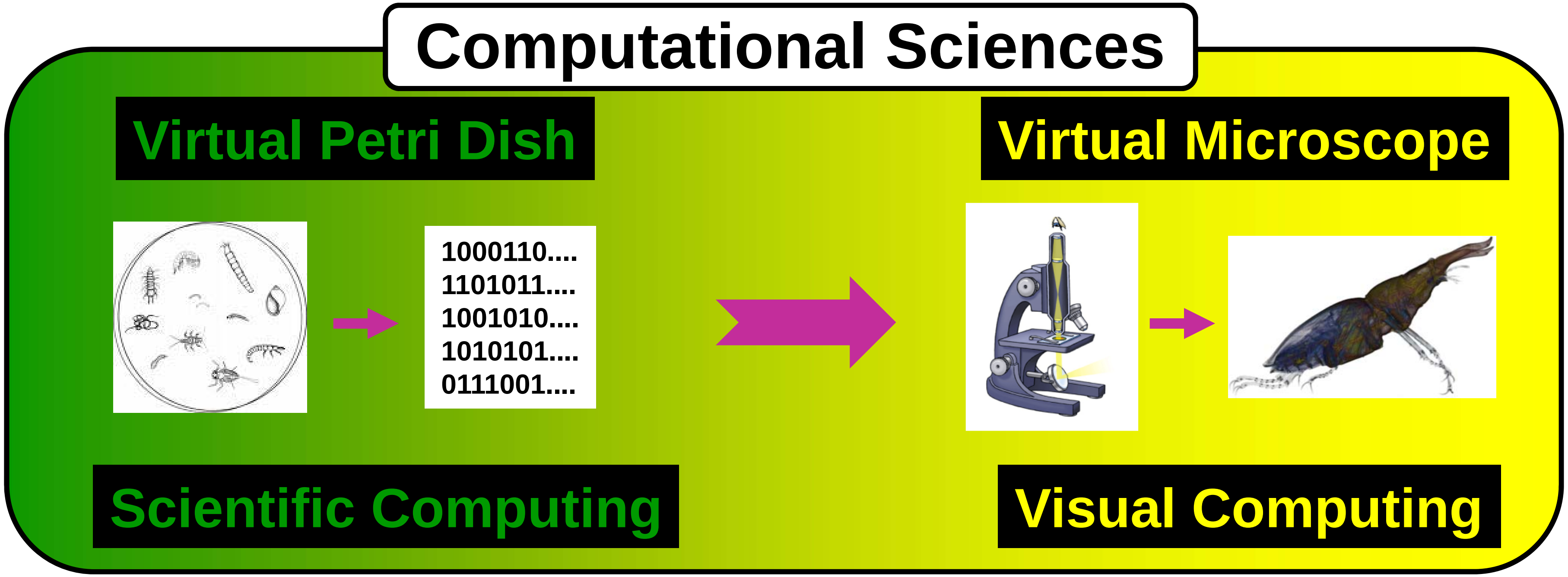


- **Virtual/Augmented Reality**
  combining real and virtual environments
- **Human-Computer-Interaction**
  the interface between users and computers

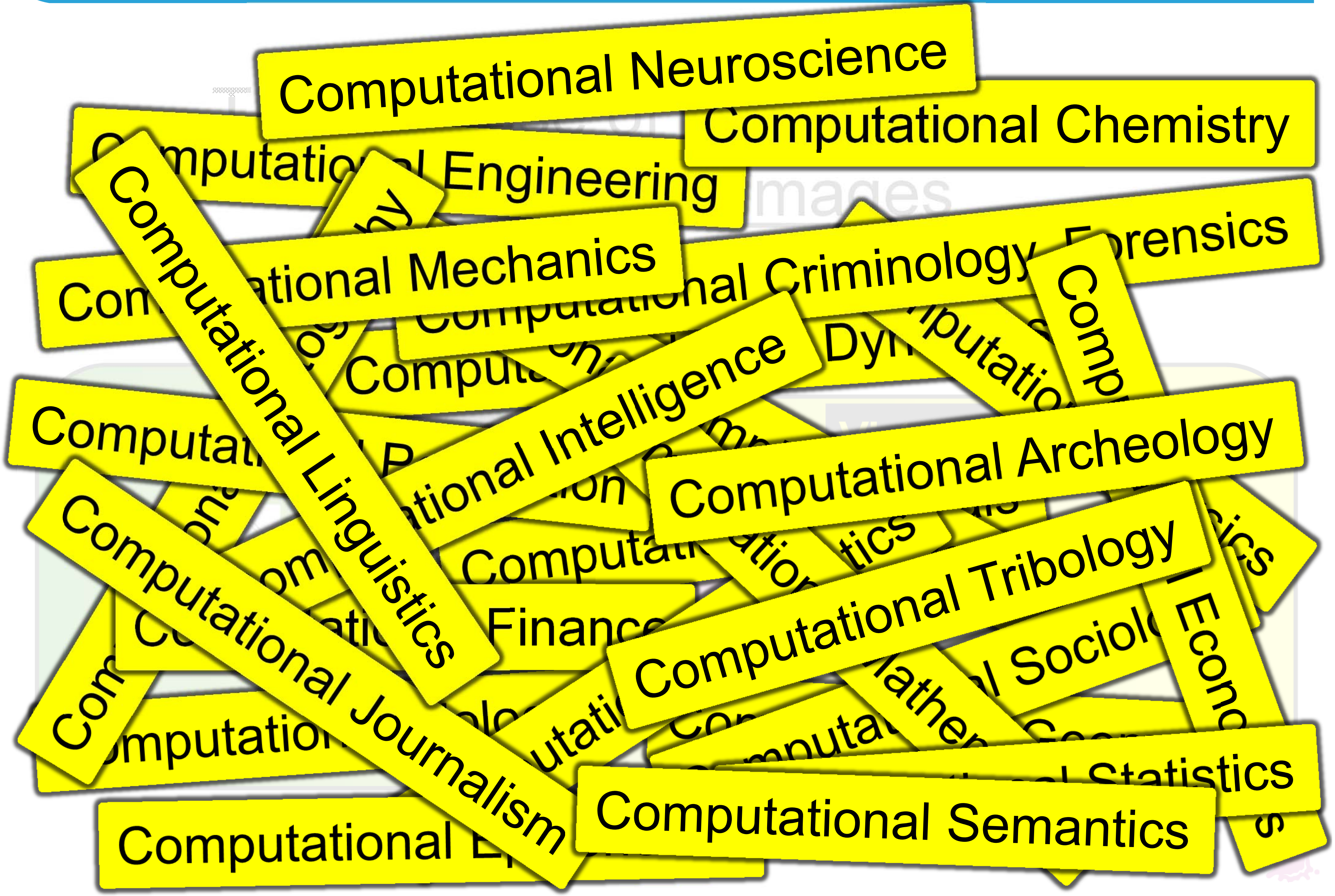




The purpose of visual computing is insight, not images



Visual Computing embedded in Science



- New Data Sources - Novel Imaging Modalities
-
-
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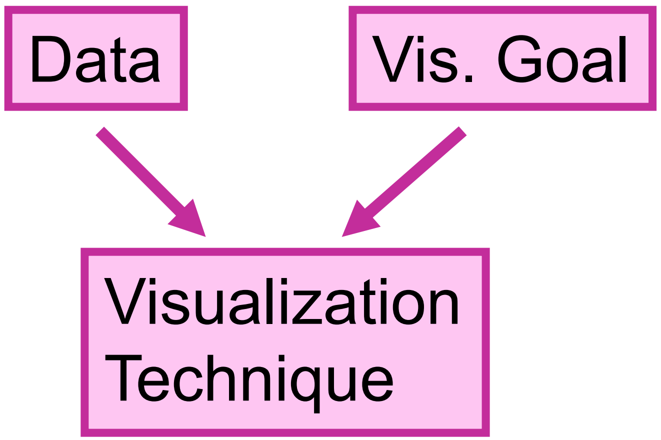
-

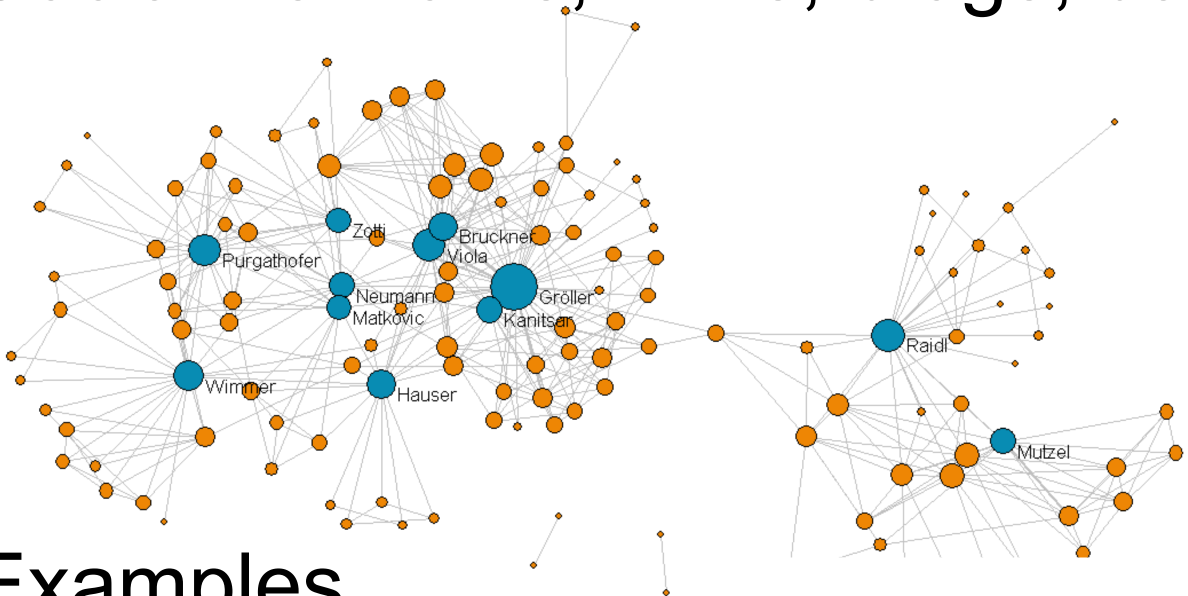
New Data Sources - Novel Imaging Modalities

- Challenges
  - Very large (abstract) data sets
  - High-dimensional, multi-valued, multi-modal, heterogeneous
  - Time varying
    - Spatially sparse/dense, temporally sparse/dense
    - Need for registration
    - Need for feature extraction
- Examples
  - Web 2.0
  - Sonar Explorer



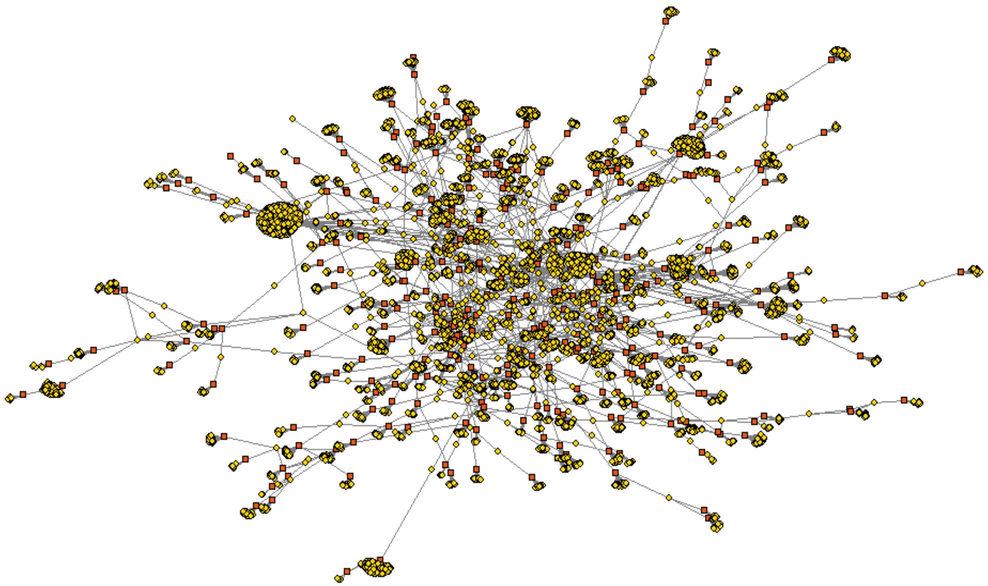
New Data Sources – Web 2.0

- Social networks, wikis, blogs, data warehouses



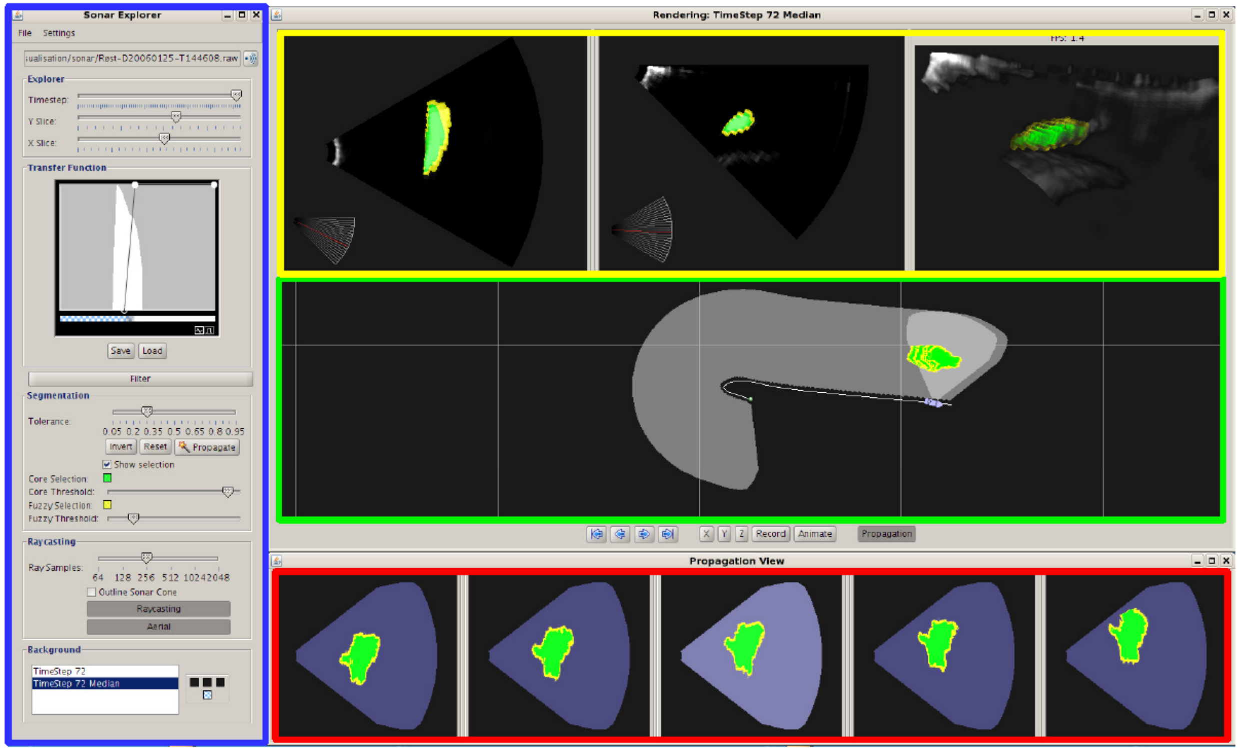
[Pfeffer]

- Examples
  - Facebook
  - Twitter
  - LinkedIn
  - YouTube

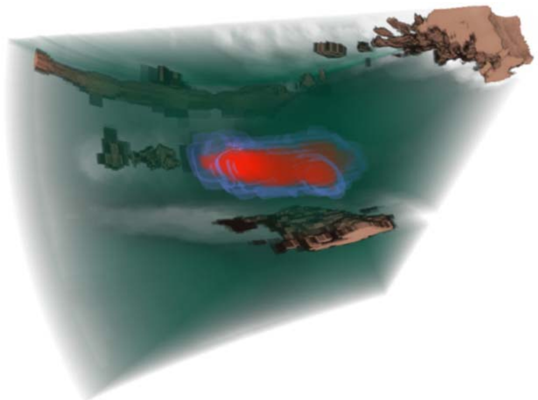


Novel Imaging Modalities – Sonar Explorer (1)

- 4D sonar data
- Cones with res: 25x20x1319
- Ping rate 1 Hz
- 2 GB/ping
- Time steps overlapping
- Highly anisotropic
- Noisy
- Signal strength reduced with spreading and absorption

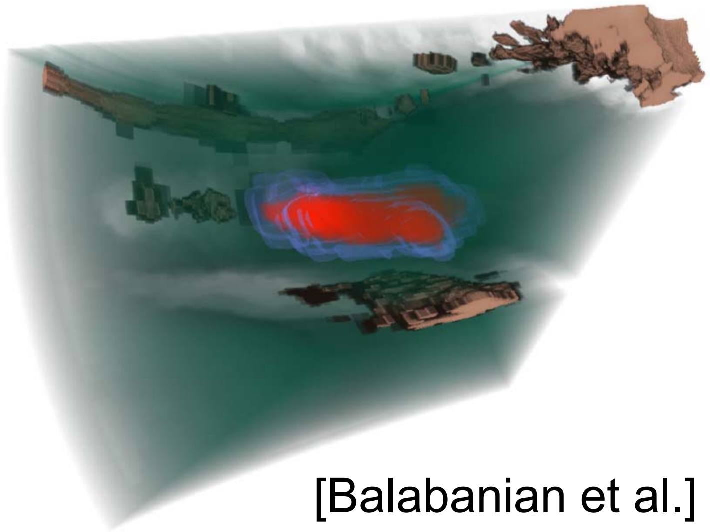


[Balabanian et al.]

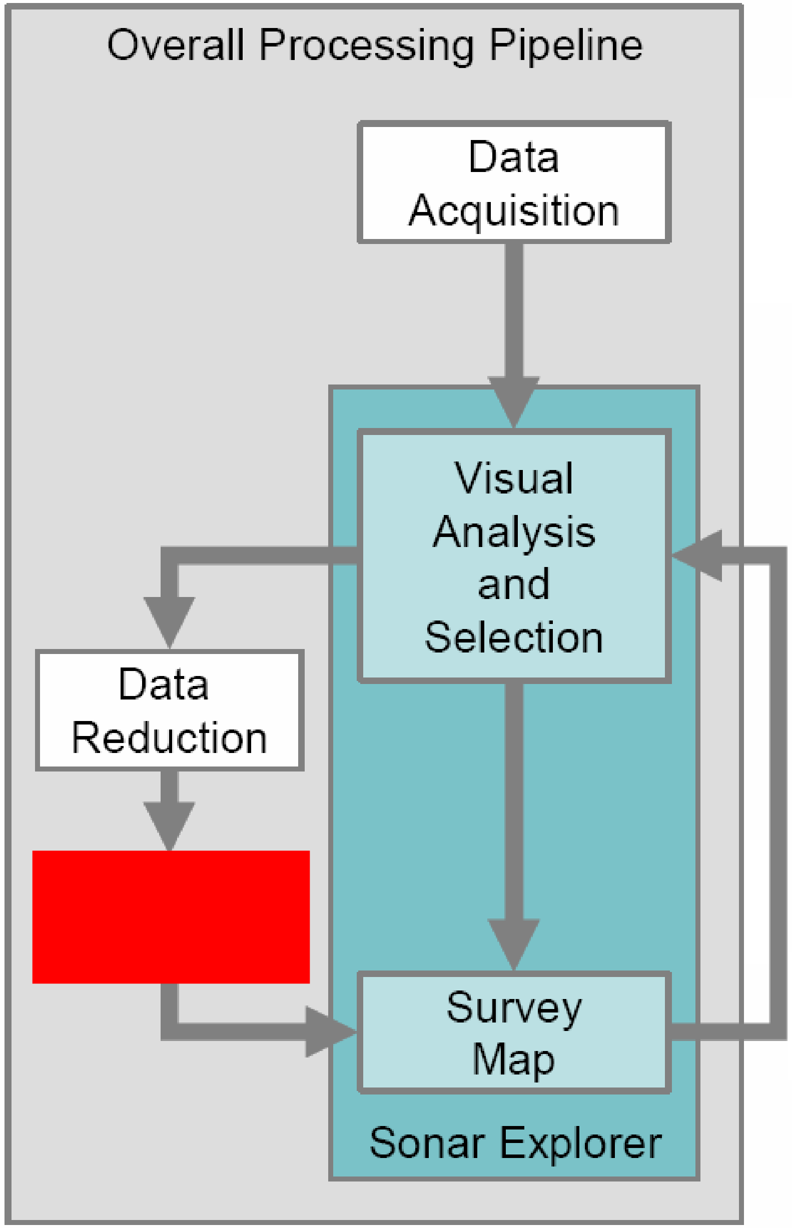


Novel Imaging Modalities – Sonar Explorer (2)

- Fish school monitoring
  - Size of school
  - Center of gravity
  - Shape parameters
  - Motion characteristics



[Balabanian et al.]



Challenges in Visual Computing

- New Data Sources - Novel Imaging Modalities
- Ensembles, Uncertainty, Parameter Spaces
-
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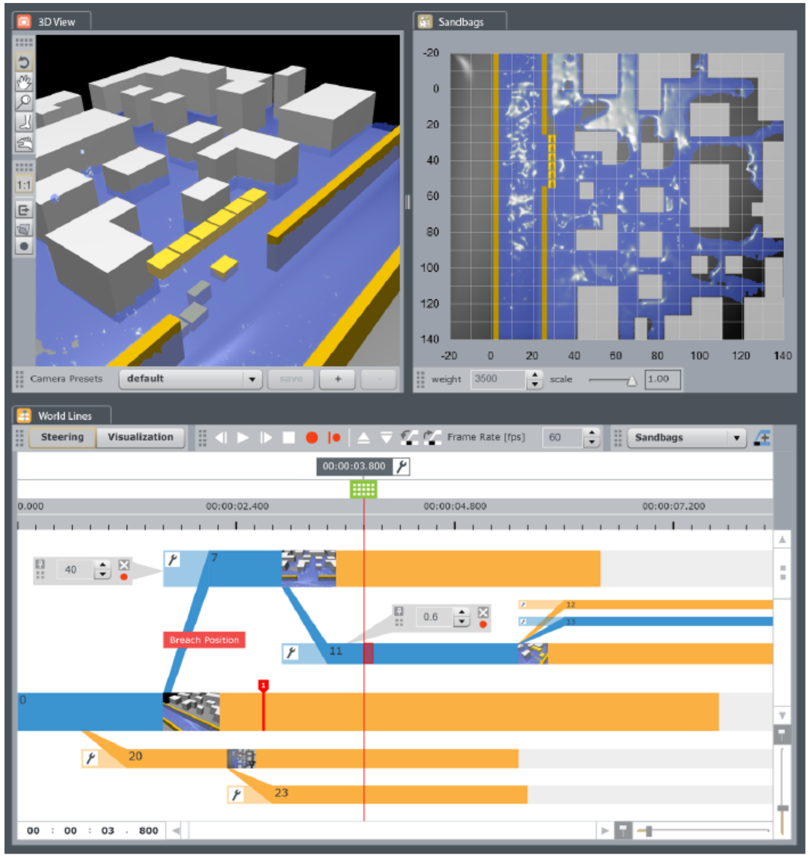


Visual Steering to Support Decision Making in Visdom

J. Waser, R. Fuchs, H. Ribičić, Ch. Hirsch,
B. Schindler, G. Blöschl, E. Gröller

Flood emergency assistance

- **New Orleans 2005: 17th canal levee breach**

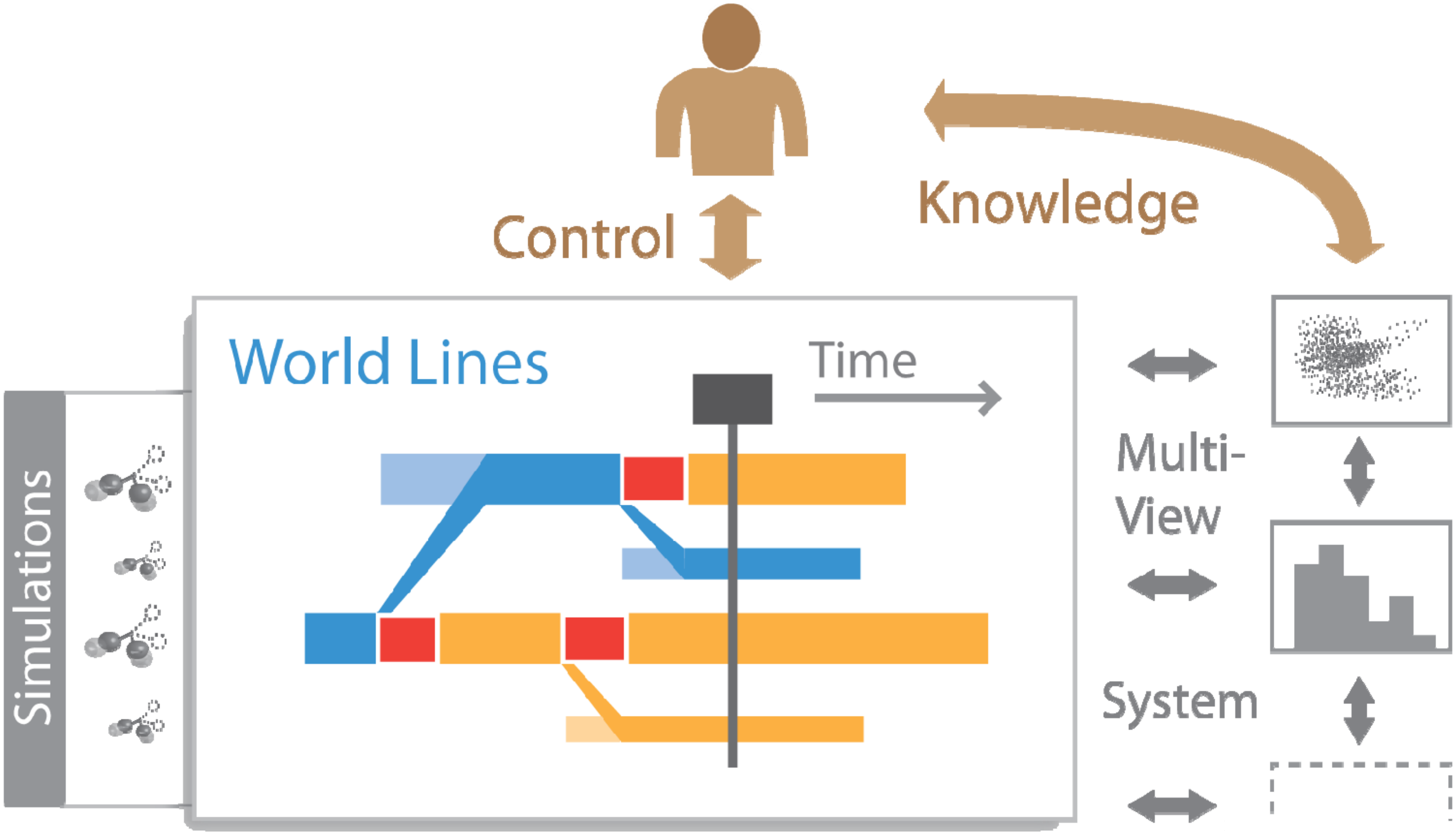
Image courtesy of USACE, US Army Corps of Engineers

Flood emergency assistance

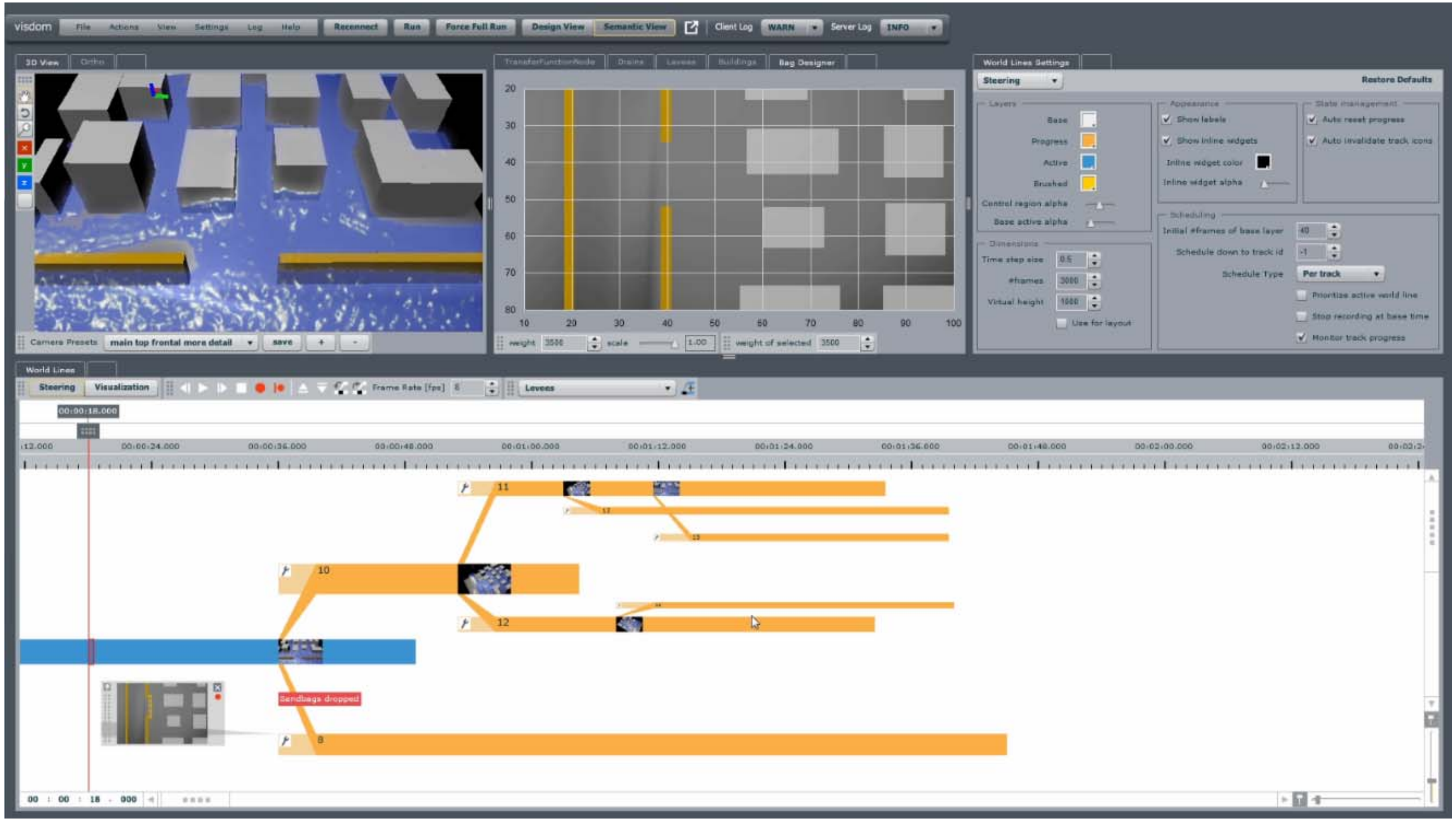
- **Evaluation of breach-closure techniques in a laboratory model**

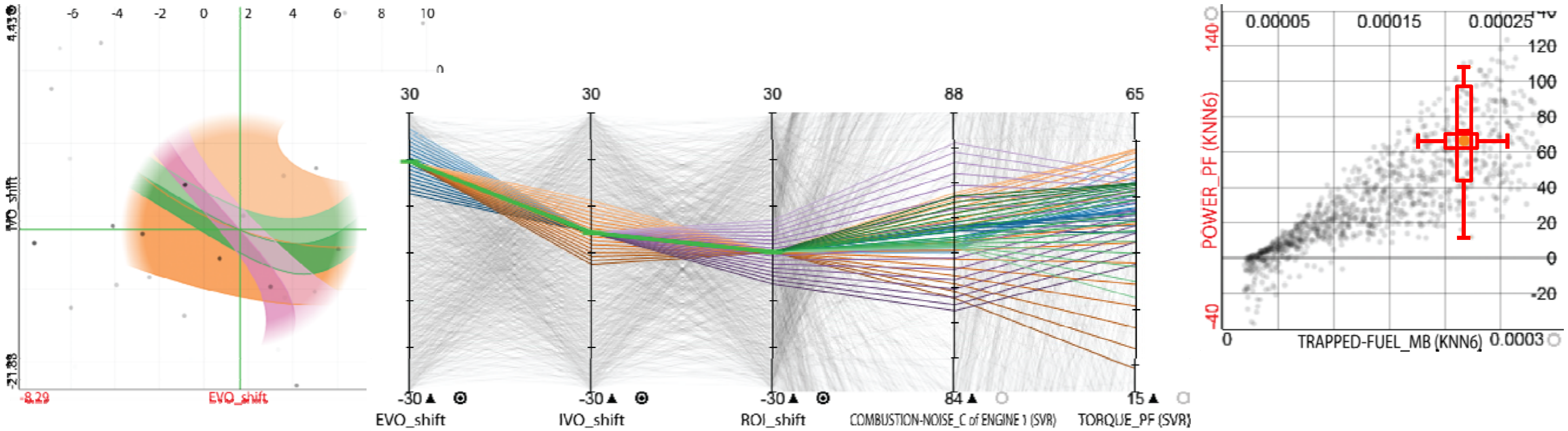
A. Sattar, A. Kassem, and M. Chaudhry. 17th street canal breach closure procedures. Journal of Hydraulic Engineering, 134(11):1547–1558, 2008.

Computational Steering: World Lines



Video: World Lines - Features





Uncertainty-Aware Exploration of Continuous Parameter Spaces Using Multivariate Prediction

W. Berger[1], H. Piringer[1], P. Filzmoser[2], E. Gröller[3]

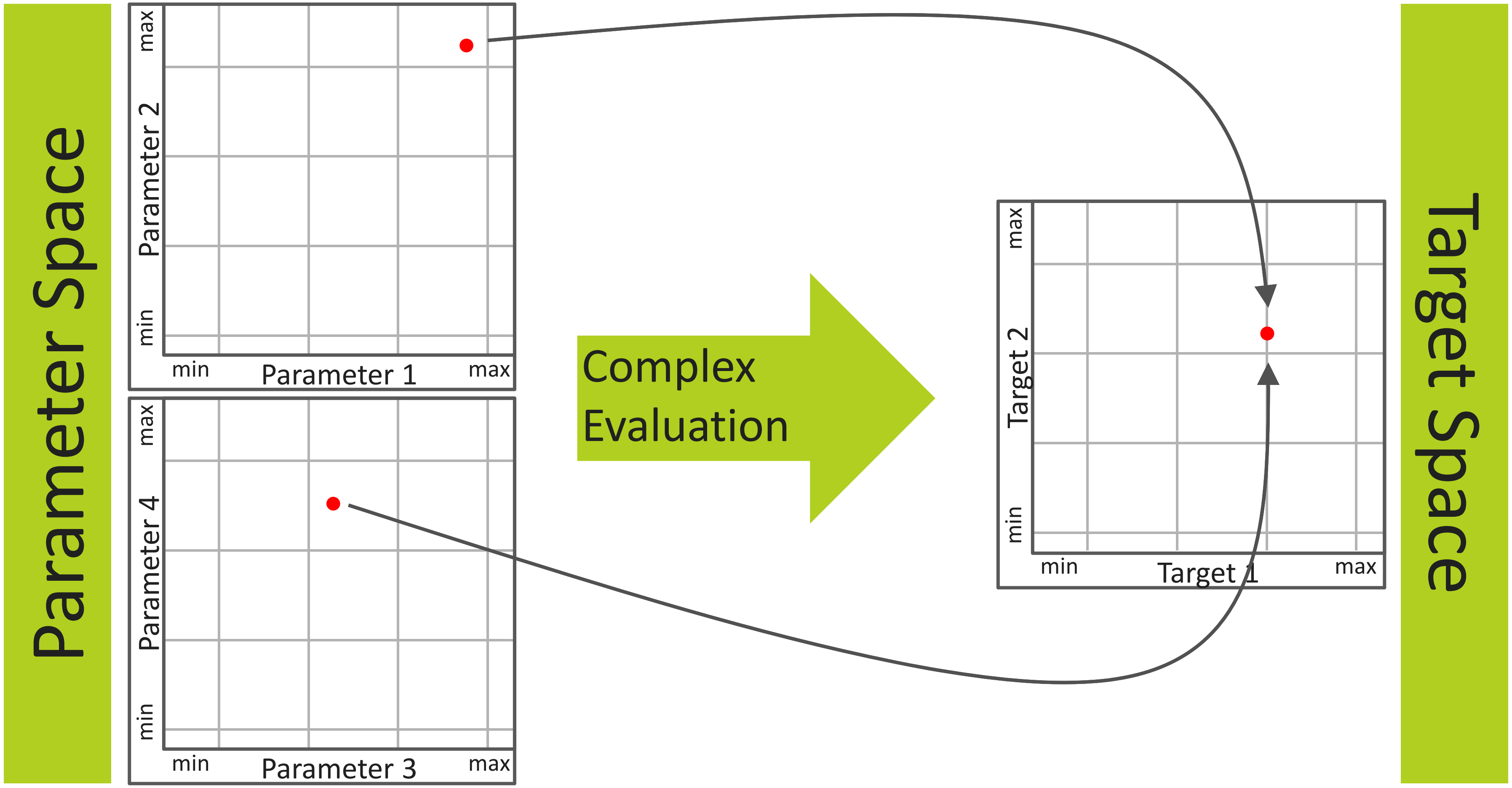
[1] VRVis Research Center, Vienna, Austria

[2] Department of Statistics and Probability Theory, Vienna UT, Austria

[3] Institute of Computer Graphics and Algorithms, Vienna UT, Austria

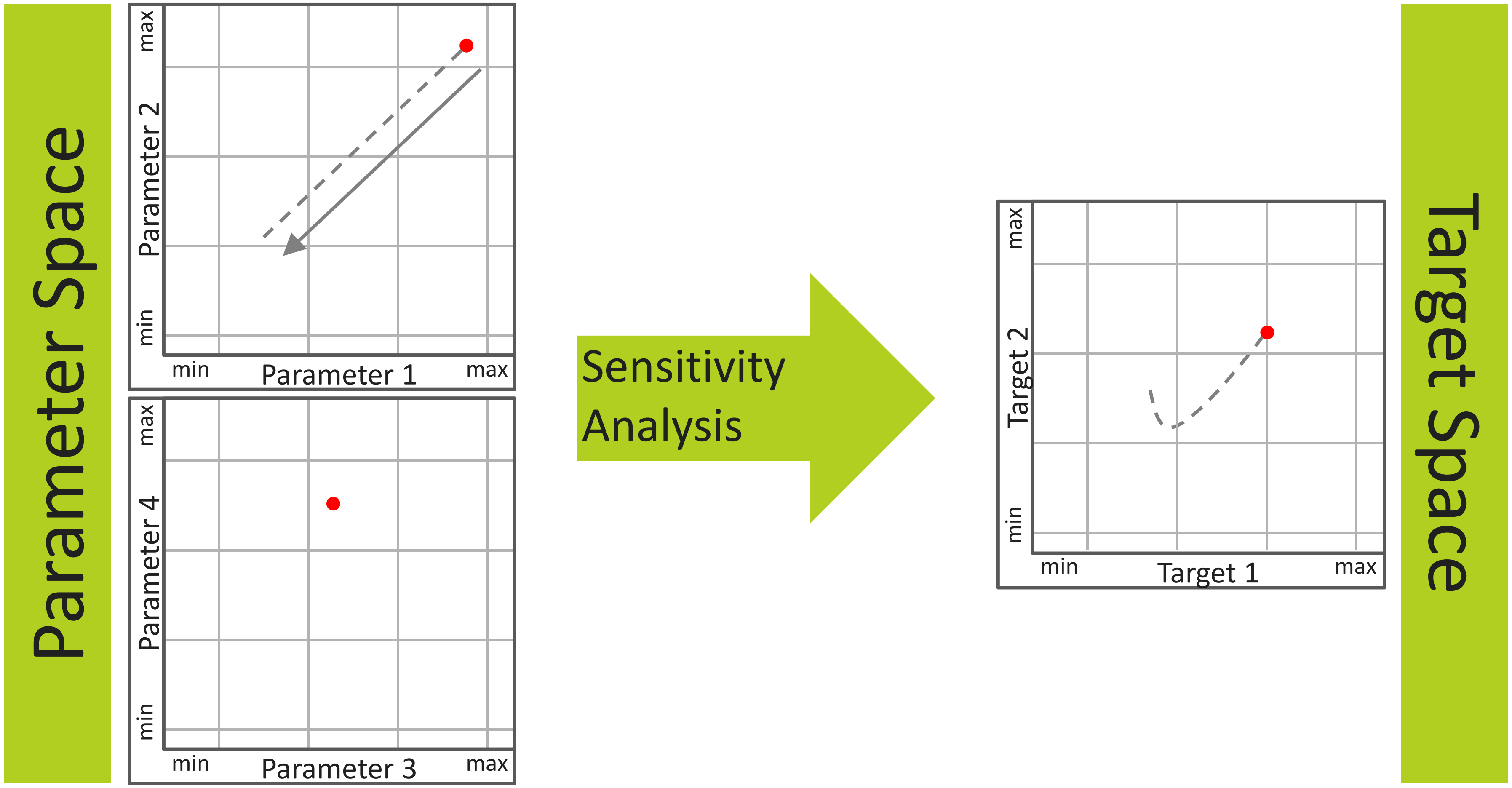
vrvis

Motivation



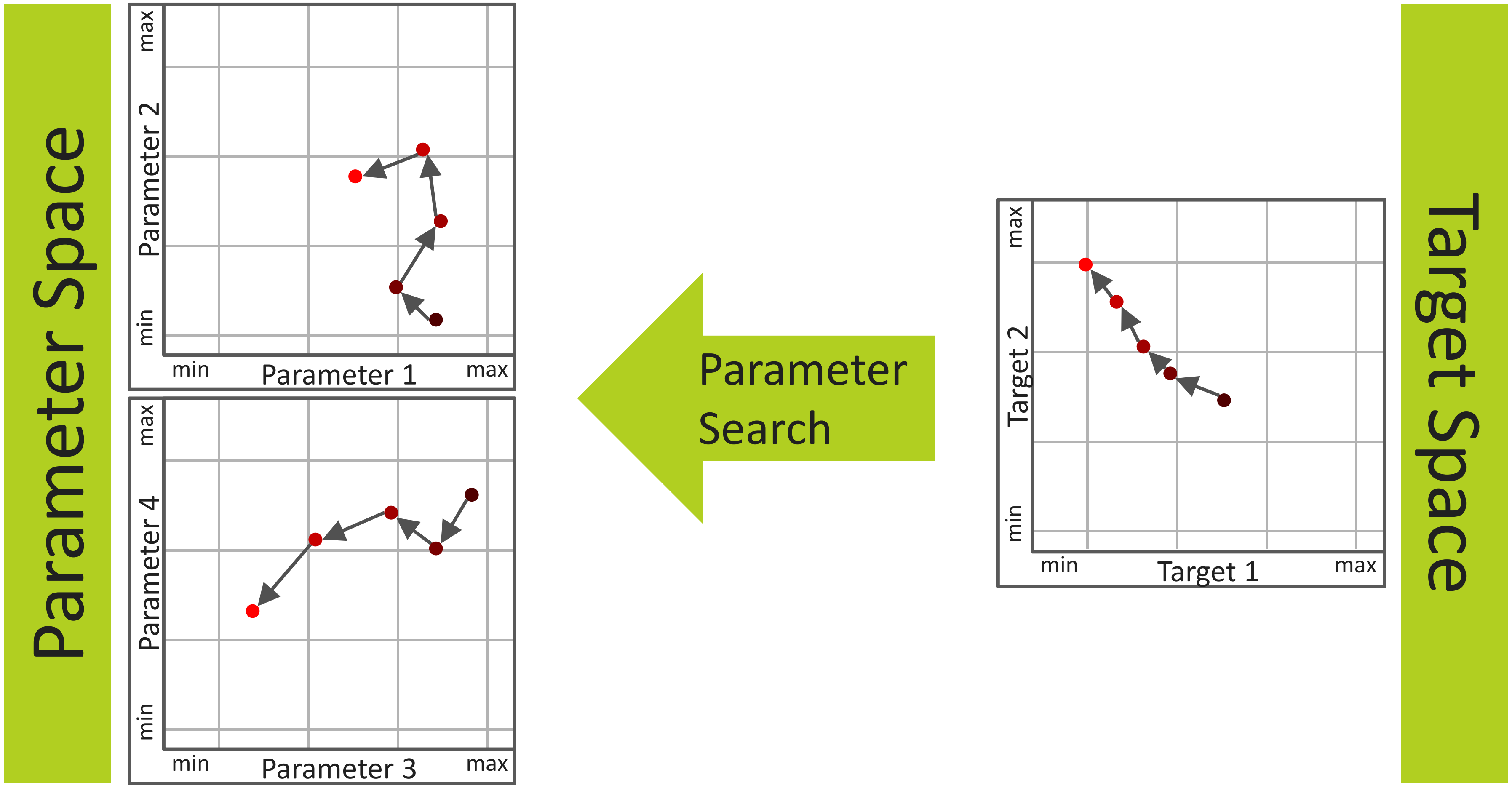
Parameter Space
max
Parameter 2
min
min
Parameter 1
max
max
Parameter 4
min
min
Parameter 3
max
Complex
Evaluation
max
Target 2
min
min
Target 1
max
Target Space

Motivation

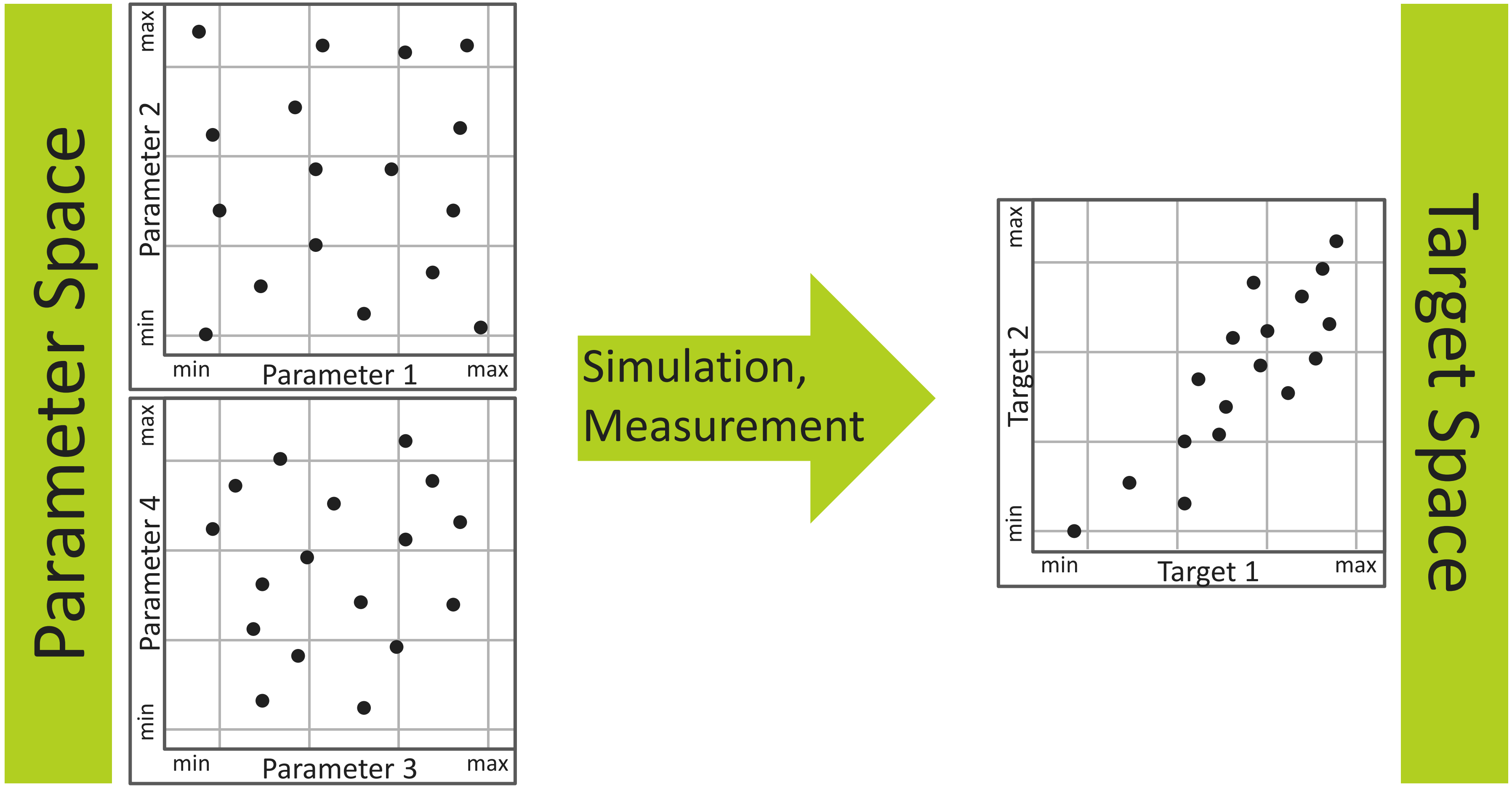


Parameter Space
max
Parameter 2
min
min
Parameter 1
max
max
Parameter 4
min
min
Parameter 3
max
Sensitivity Analysis
max
Target 2
min
min
Target 1
max
Target Space

Motivation

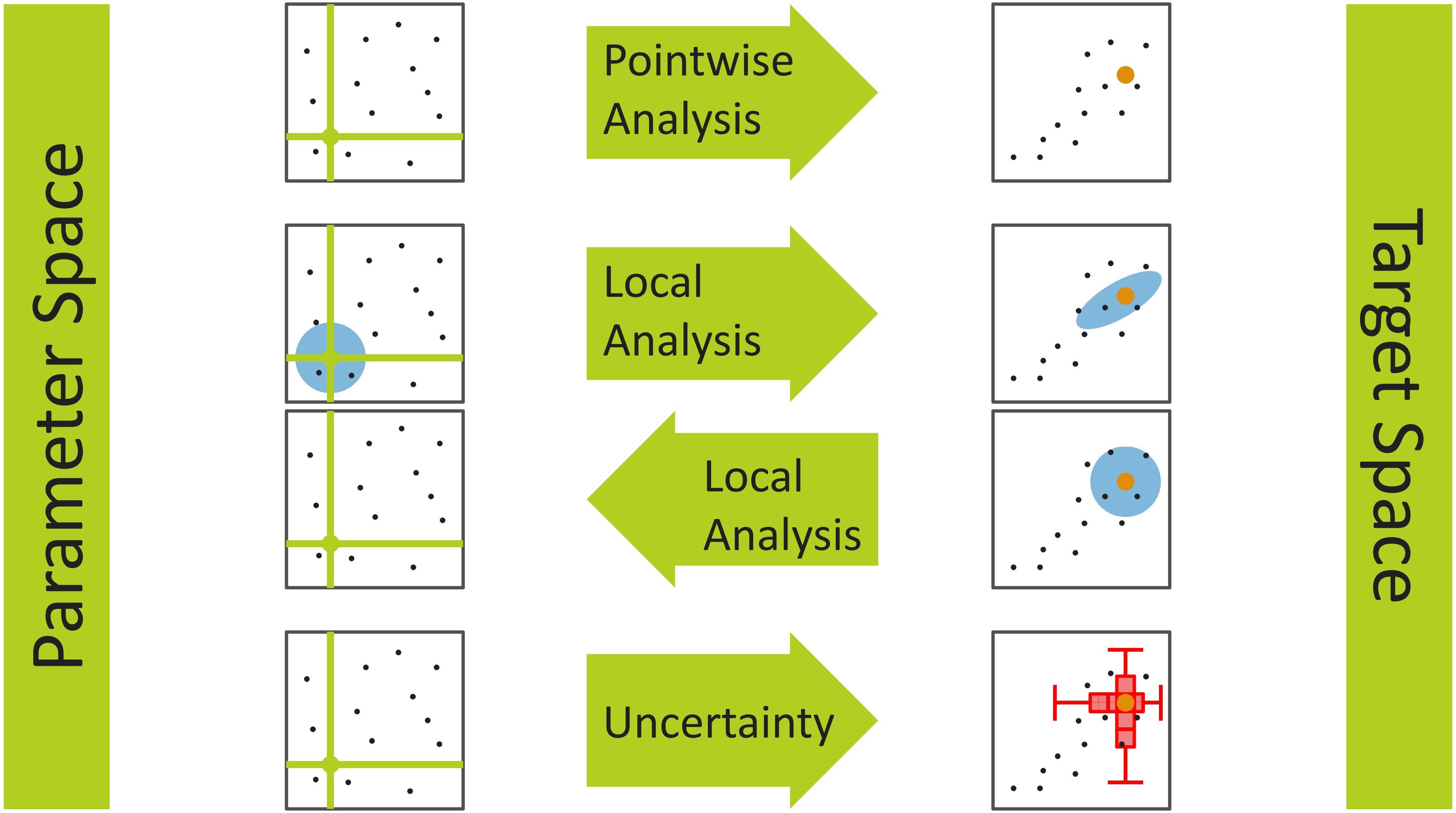

Parameter Space
max
Parameter 2
min
min
Parameter 1
max
max
Parameter 4
min
min
Parameter 3
max
Parameter Search
max
Target 2
min
min
Target 1
max
Target Space

Motivation

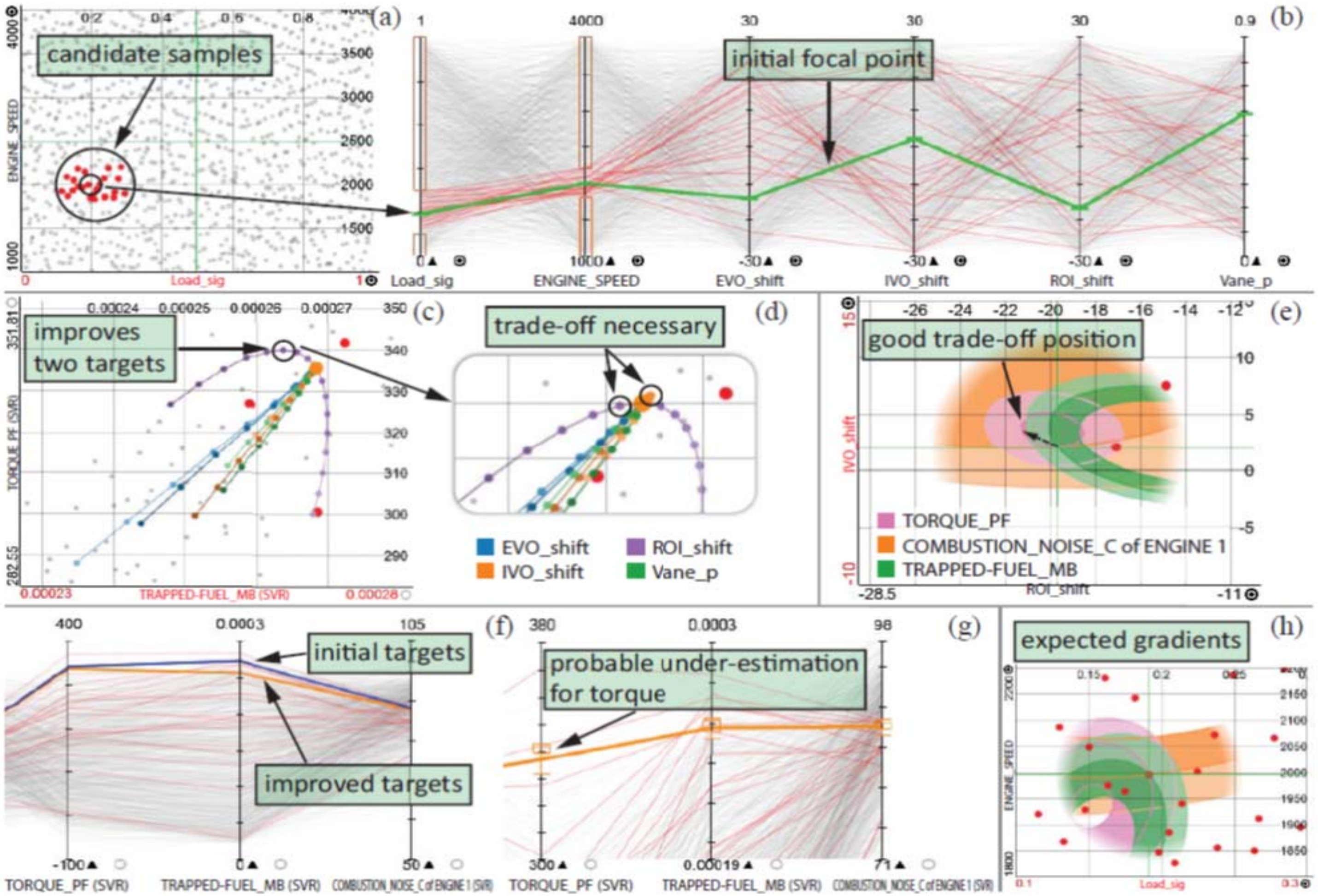


Wolfgang Berger

Contribution



Application Example: Car Engine Design

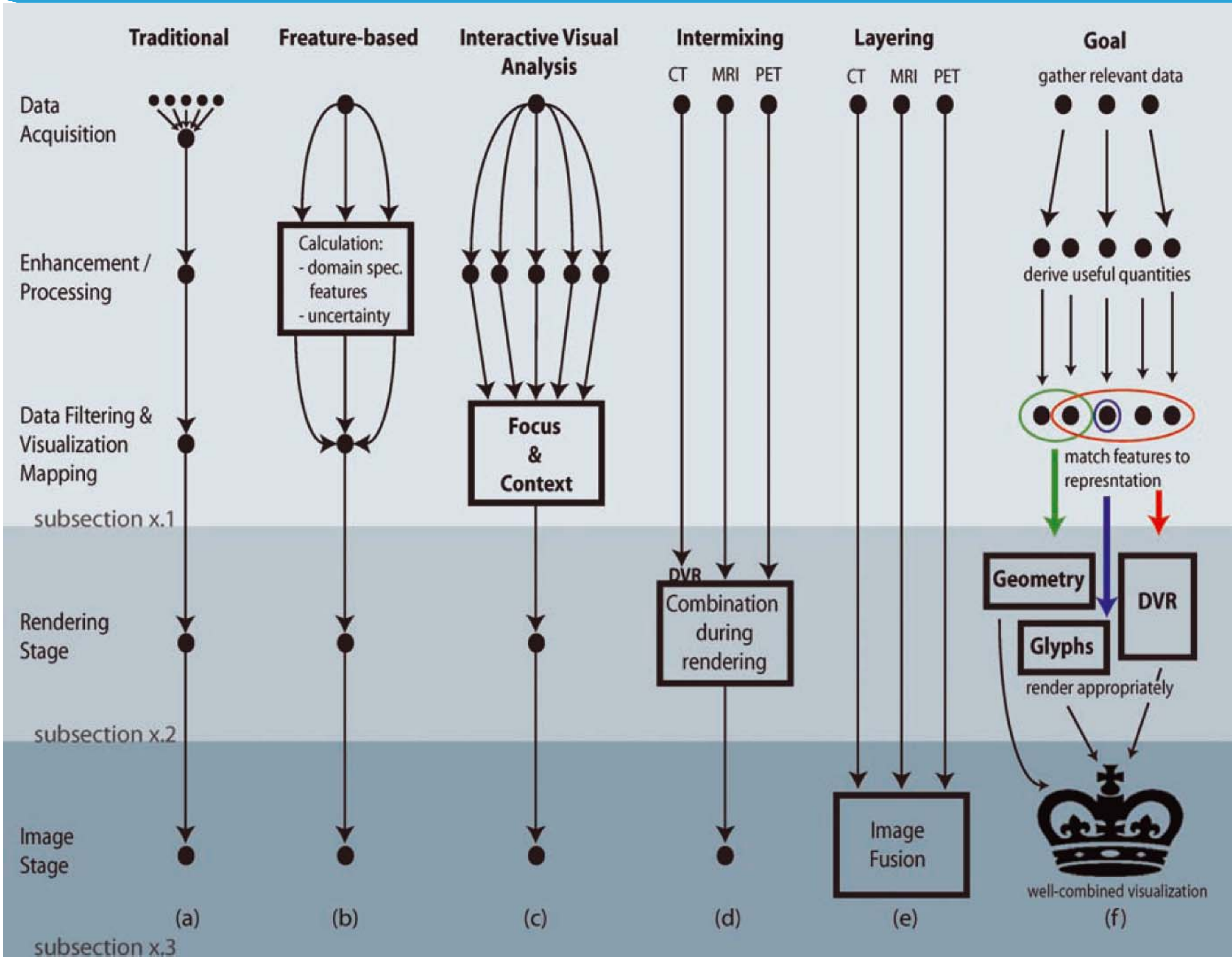


Eduard Gröller

Challenges in Visual Computing

- New Data Sources - Novel Imaging Modalities
- Ensembles, Uncertainty, Parameter Spaces
- Multivariate, Heterogeneous Data

Visualization of Multi-Variate Scientific Data



[Fuchs& Hauser]

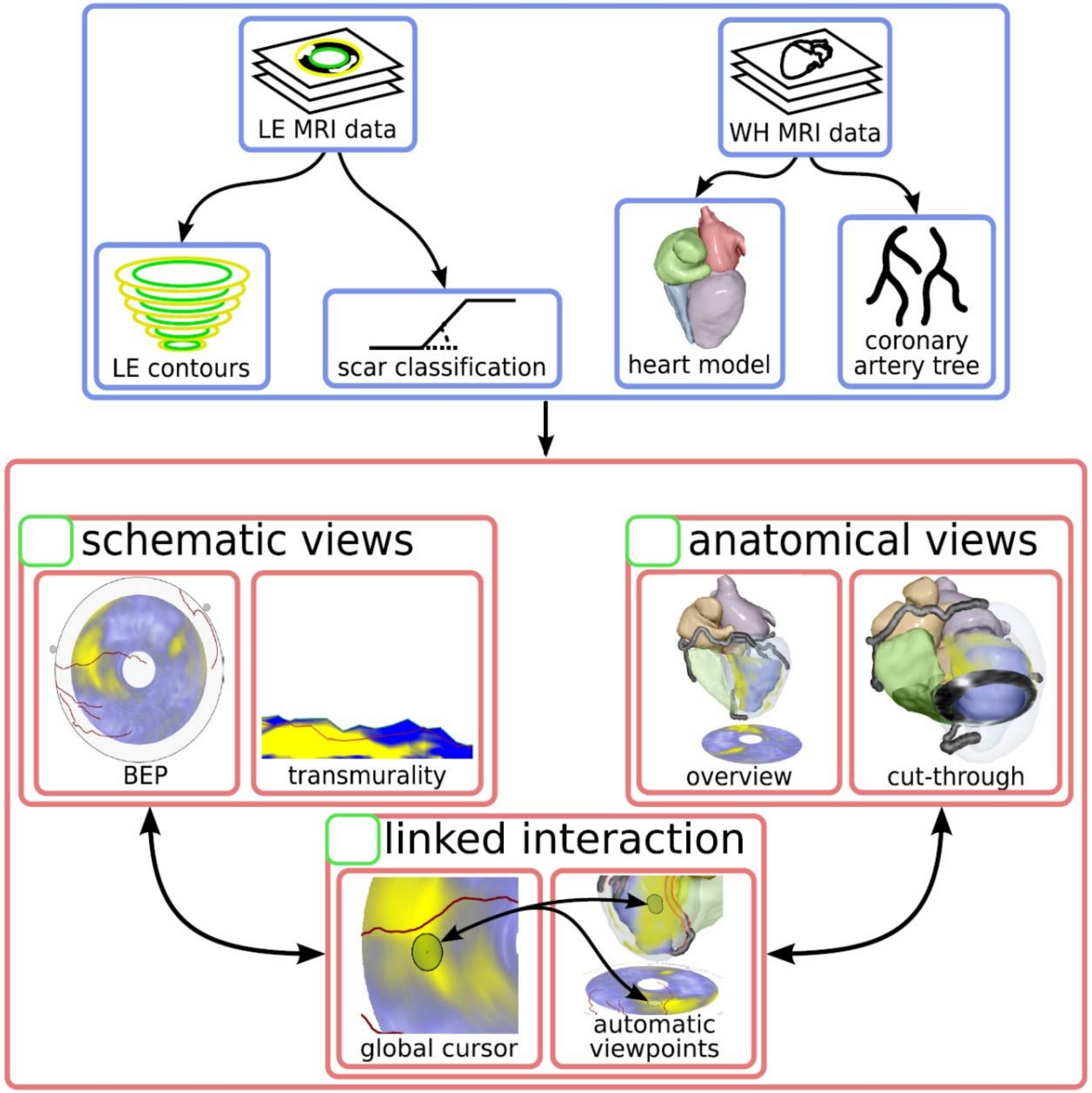
Coping with Complexity and Variability

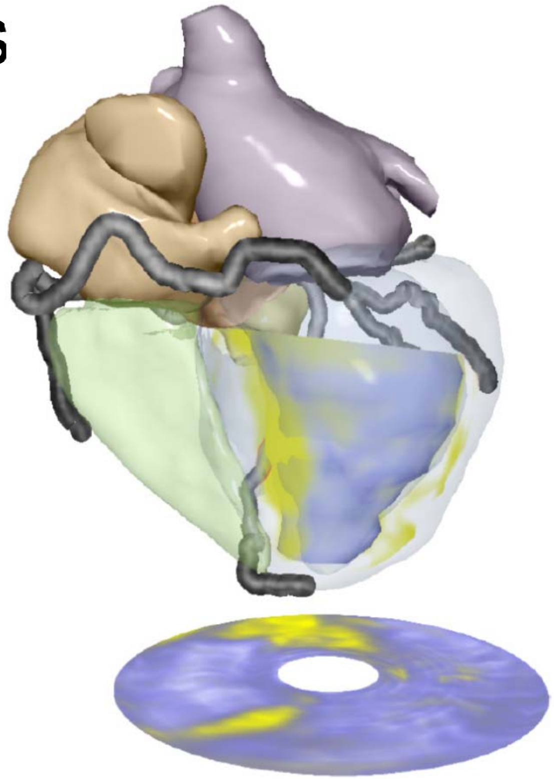
- Reducing data complexity well established
  - Sub-setting
  - Slicing
  - Projection
  - Dimension reduction
  - Clustering

- Reducing visual complexity ??
  - Integrated views
  - Comparative visualization
  - Fuzzy visualization
  - …

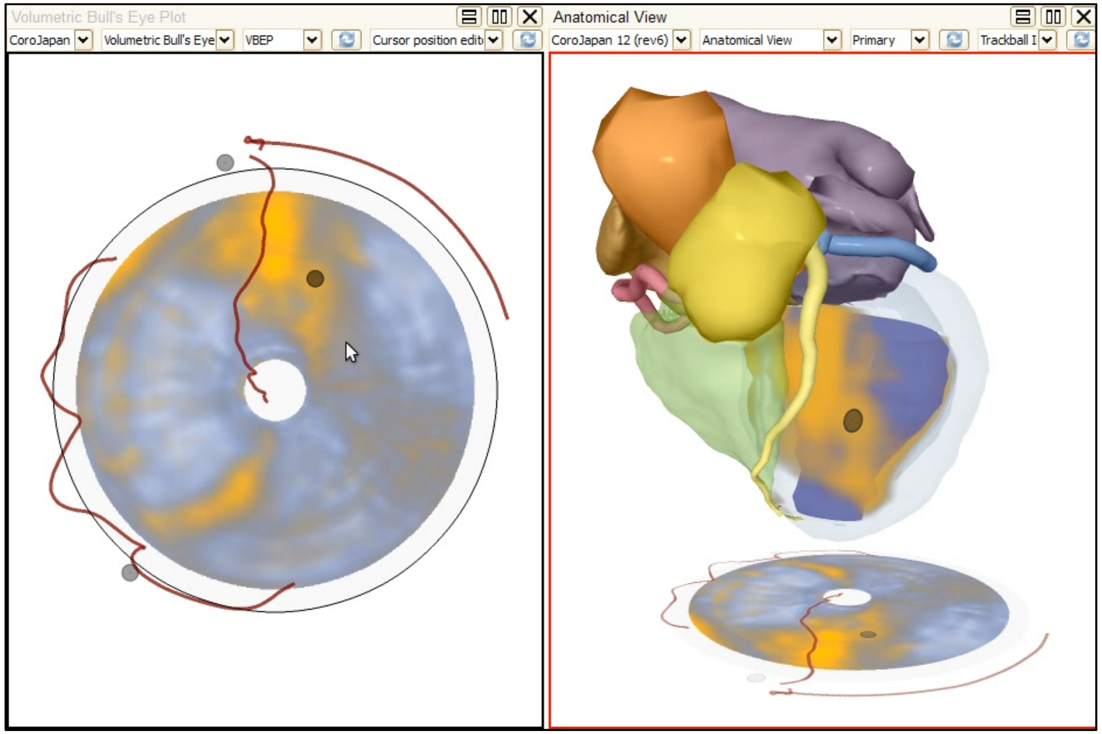
Cardiac Data Visualization [Termeer et al.]

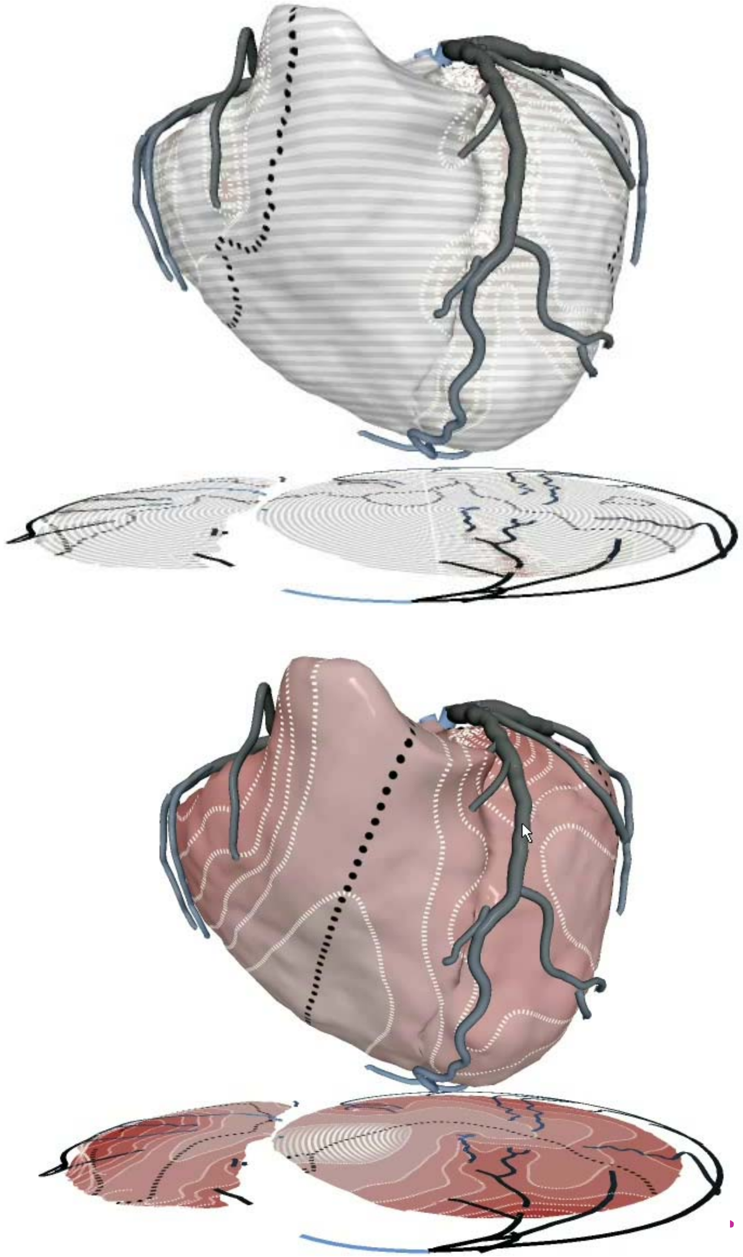
- Fusion of 4 diverse data types





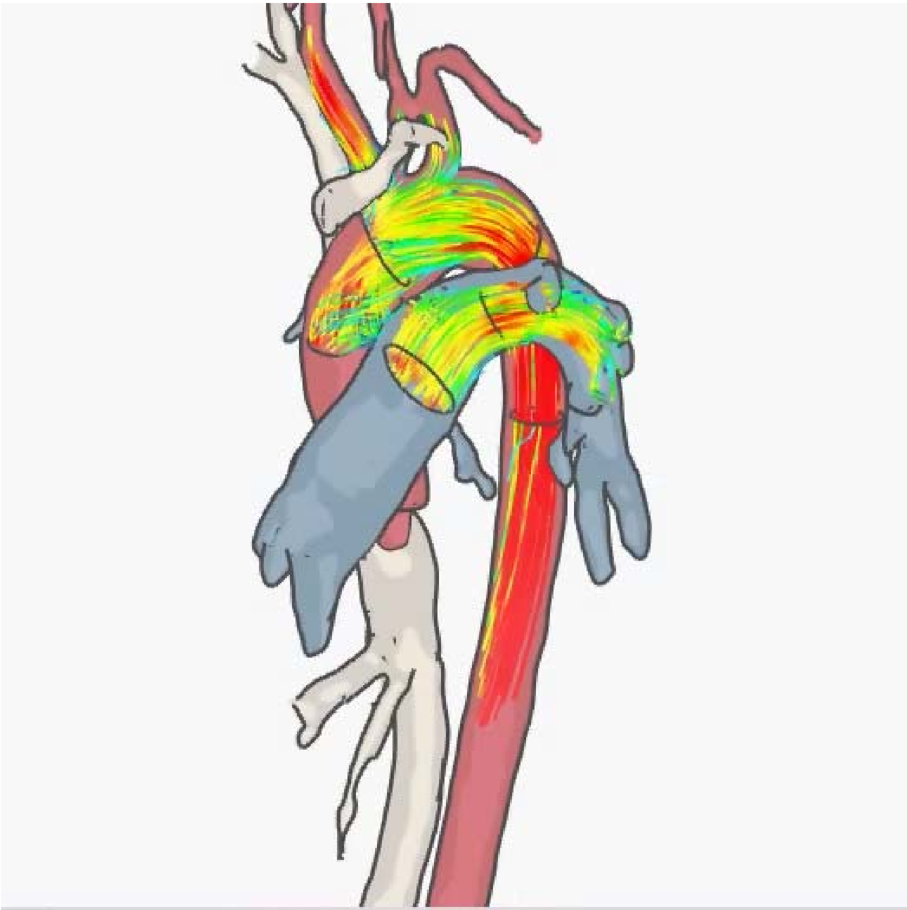
Cardiac Data Visualization - Examples

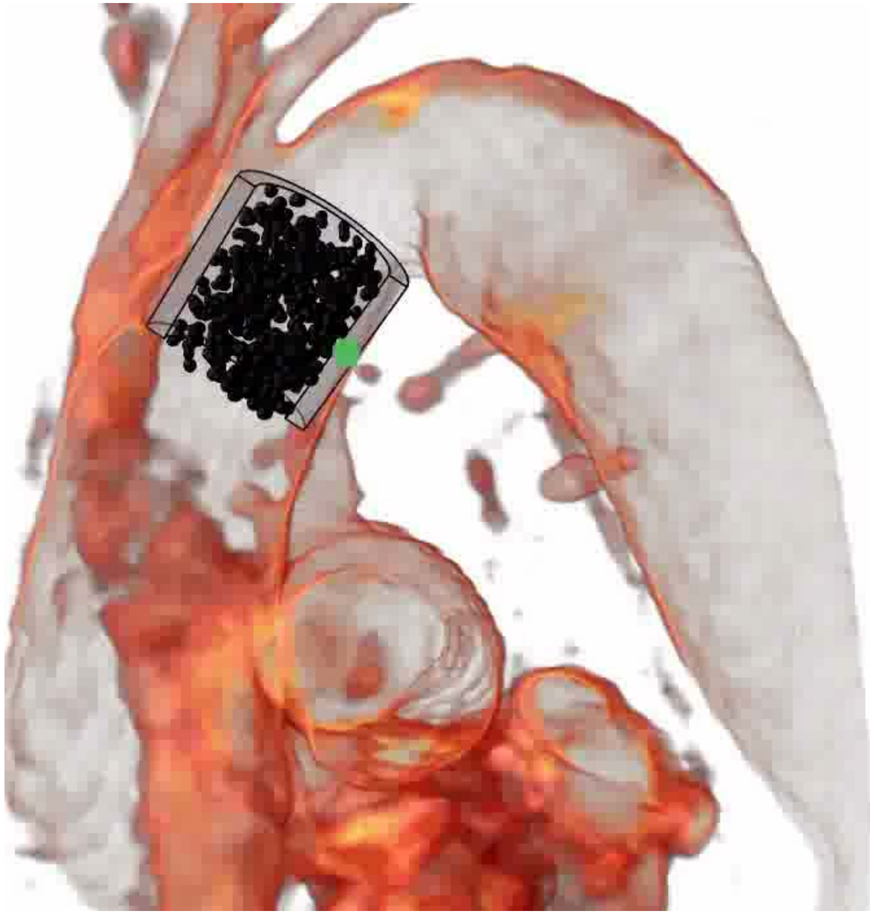




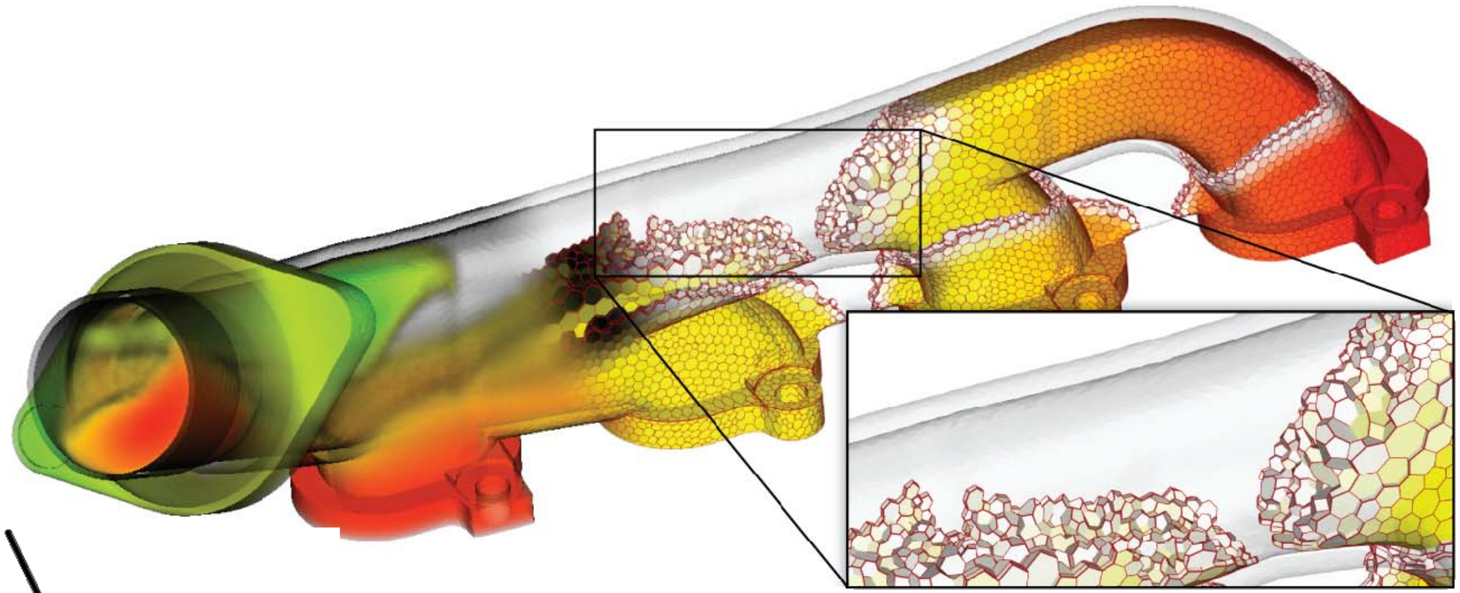
- Interactive navigation
- Perfusion simulation
- Stenosis simulation

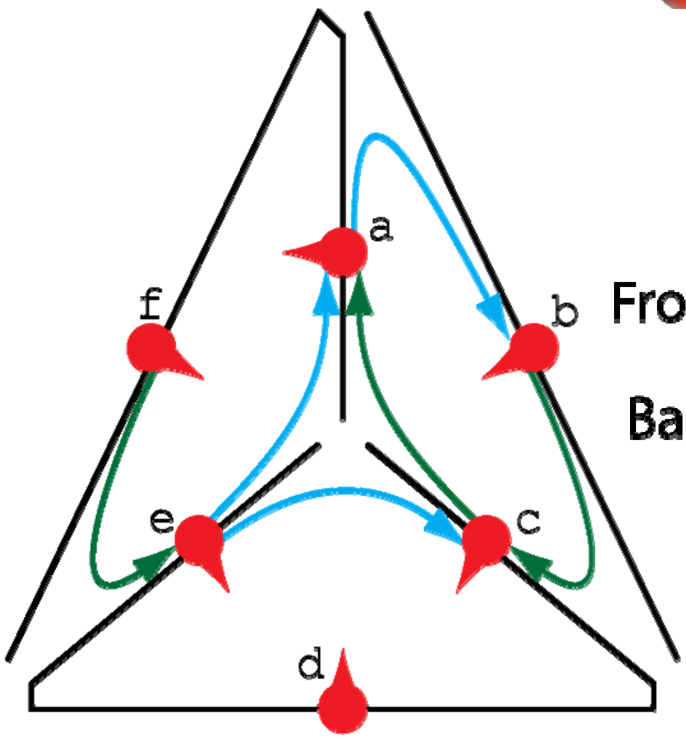
4D MRI Blood Flow [van Pelt et al.]





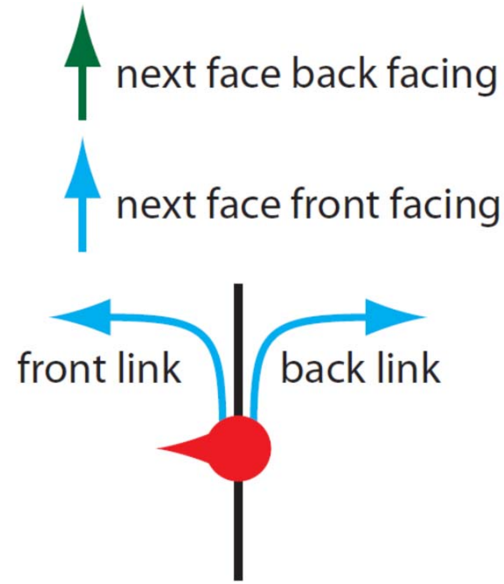
Generalized Polyhedral Grids [Muigg, Doleisch et al.]





Face Sequences

Front	[c]	[e]	[c]
	[c d e]	[a f]	[b]
Back	[a - a]	[b -]	[-]



Challenges in Visual Computing

- New Data Sources - Novel Imaging Modalities
- Ensembles, Uncertainty, Parameter Spaces
- Multivariate, Heterogeneous Data
- Visual Analytics (↔ SciVis ↔ InfoVis)
-
-
-

Visual Analytics (↔ SciVis ↔ InfoVis)

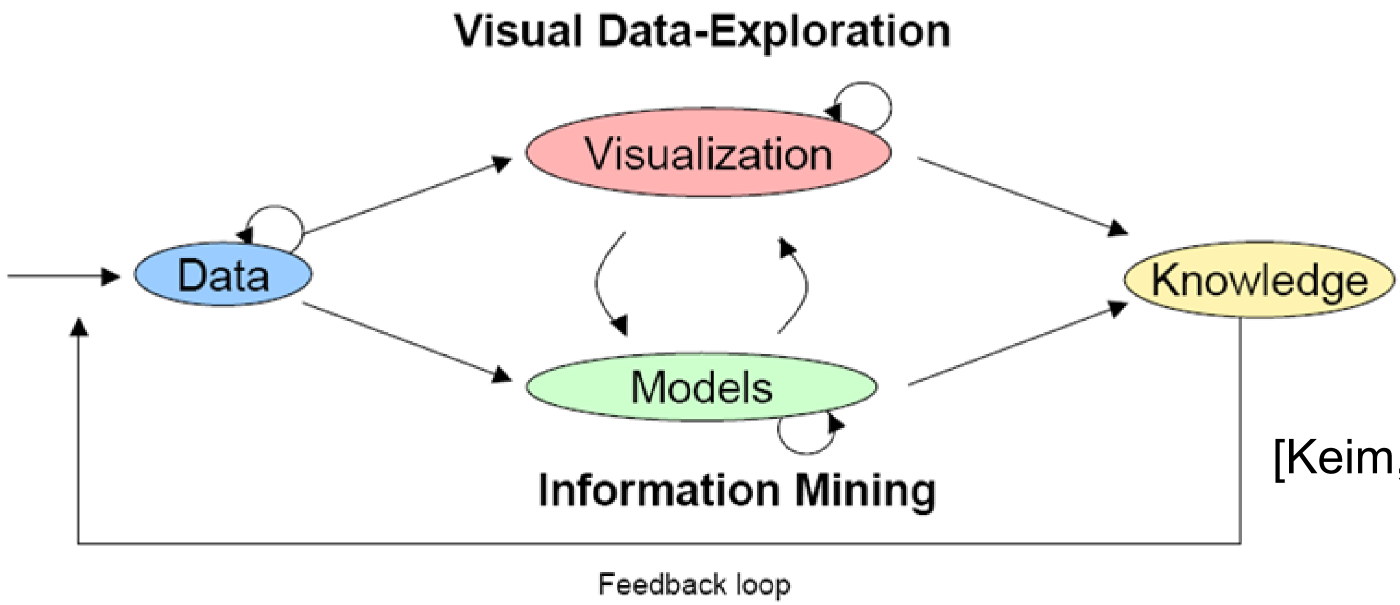
"Visual Analytics is the science of analytical reasoning facilitated by interactive visual interfaces"

What do we have?

- Automatic Knowledge Discovery & Information Mining
- Interactive Visual Data-Exploration

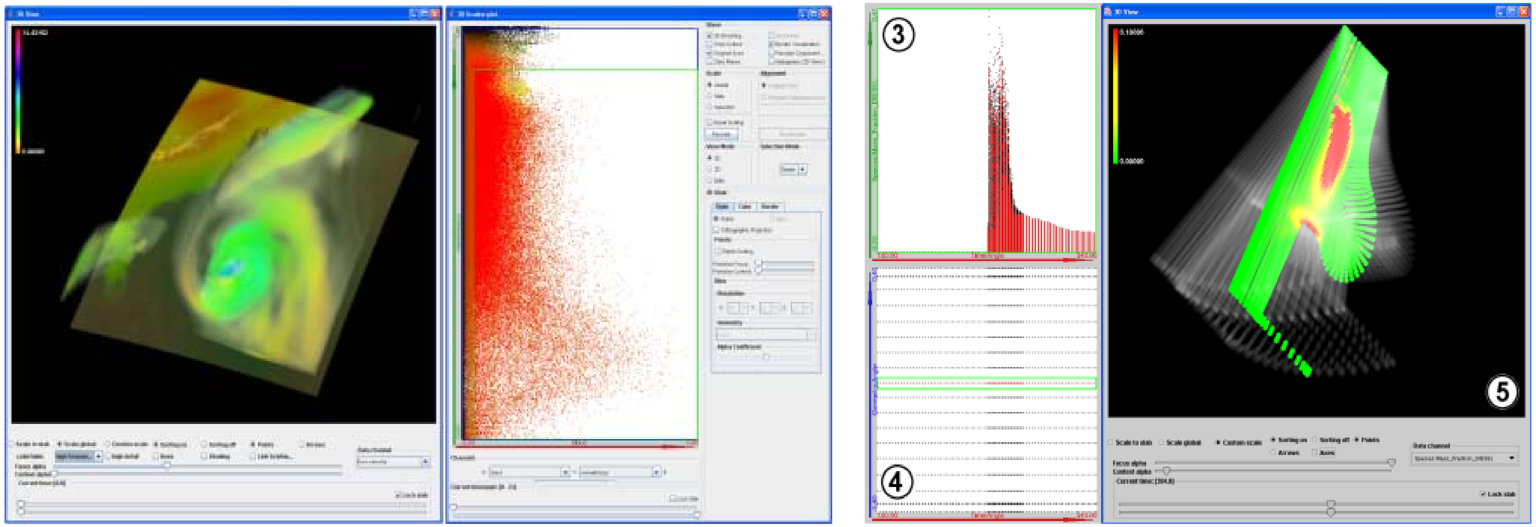
What do we need?

Tight Integration of Visual and Automatic Data Analysis Methods with Database Technology for a Scalable Interactive Decision Support



[Keim, Thomas]

SimVis: Interactive Visual Analysis of Large & Complex Simulation Data



Helmut Doleisch et al.

Challenges in Visual Computing

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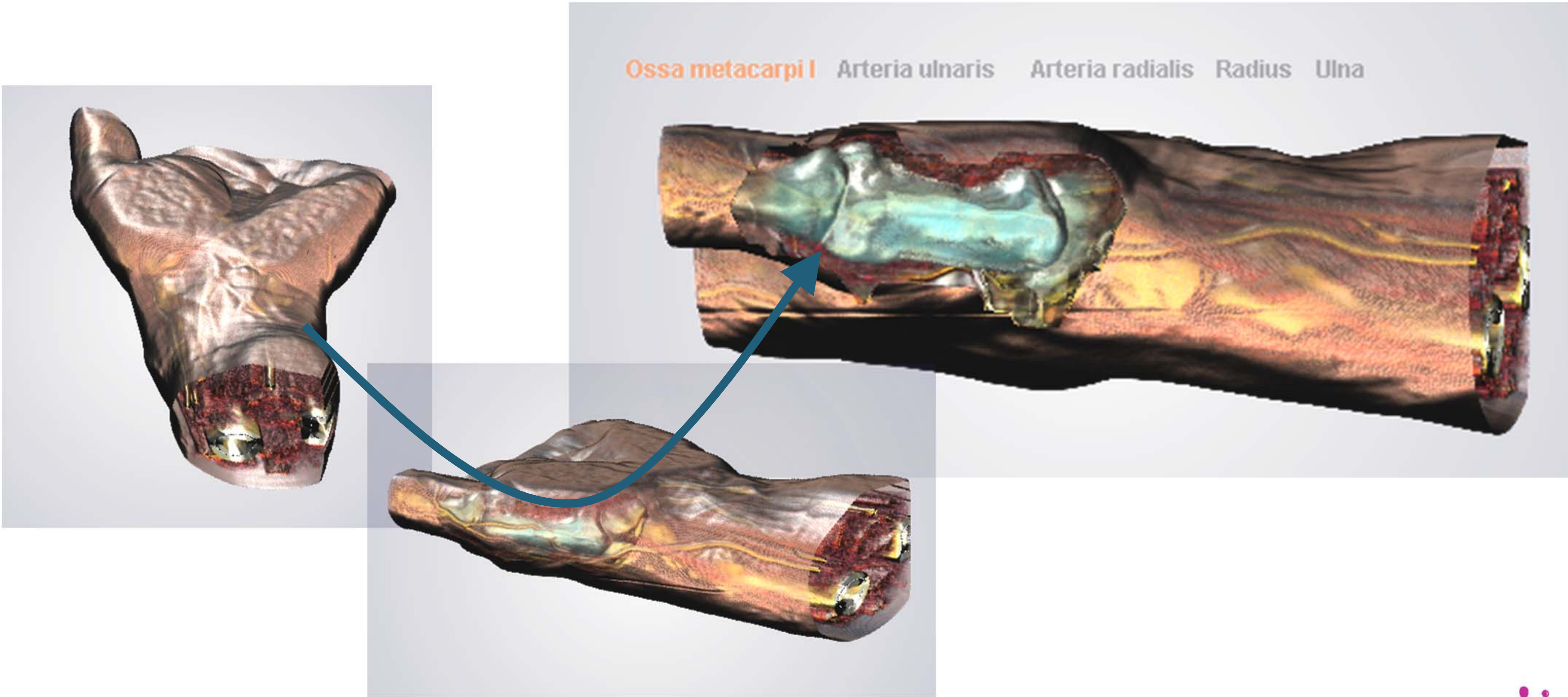
- Visual Analytics (↔ SciVis ↔ InfoVis)
- Interaction (Knowledge-assisted, User-centric)

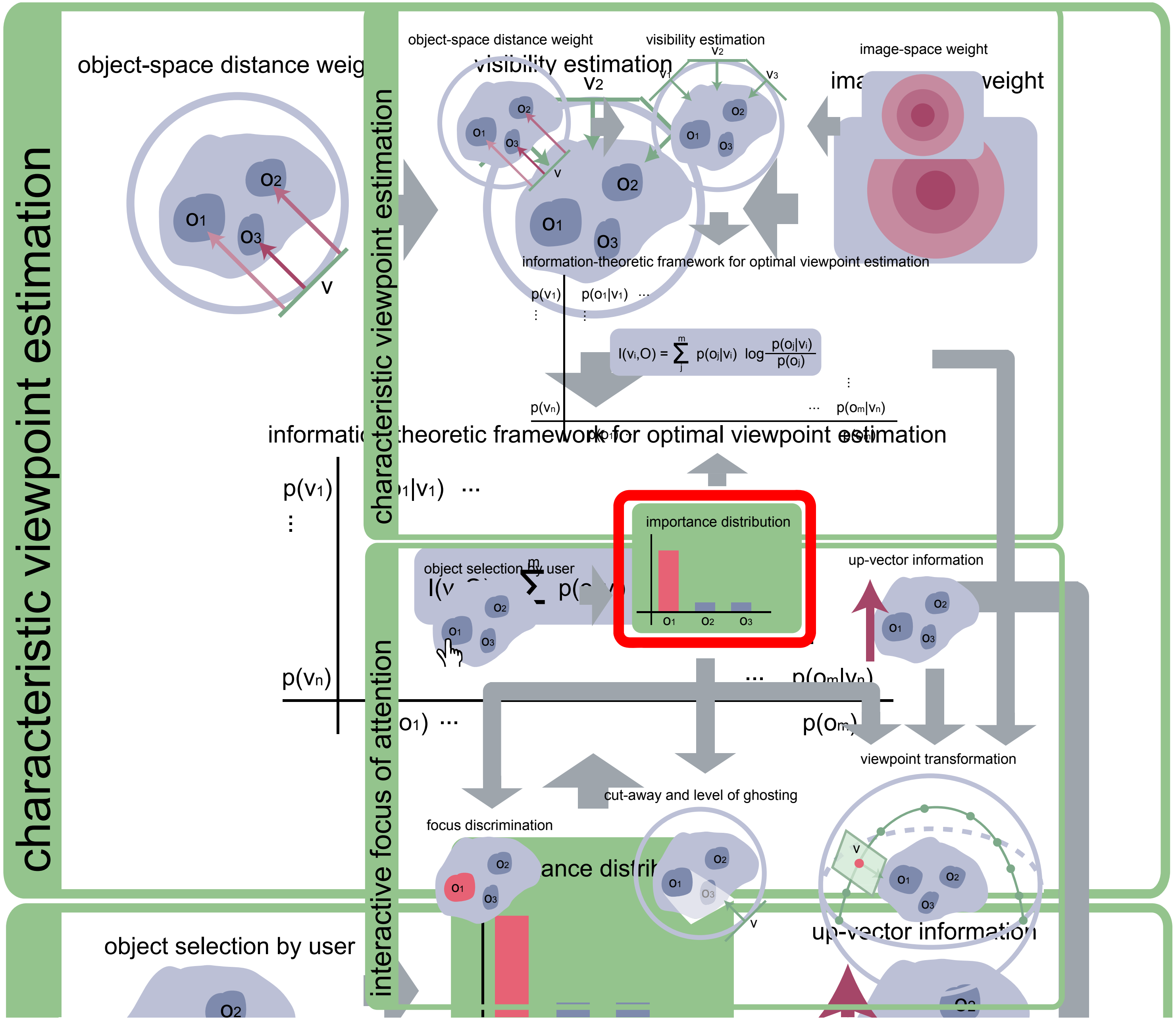
Importance-Driven Focus of Attention (1)

- Guided navigation between characteristic views

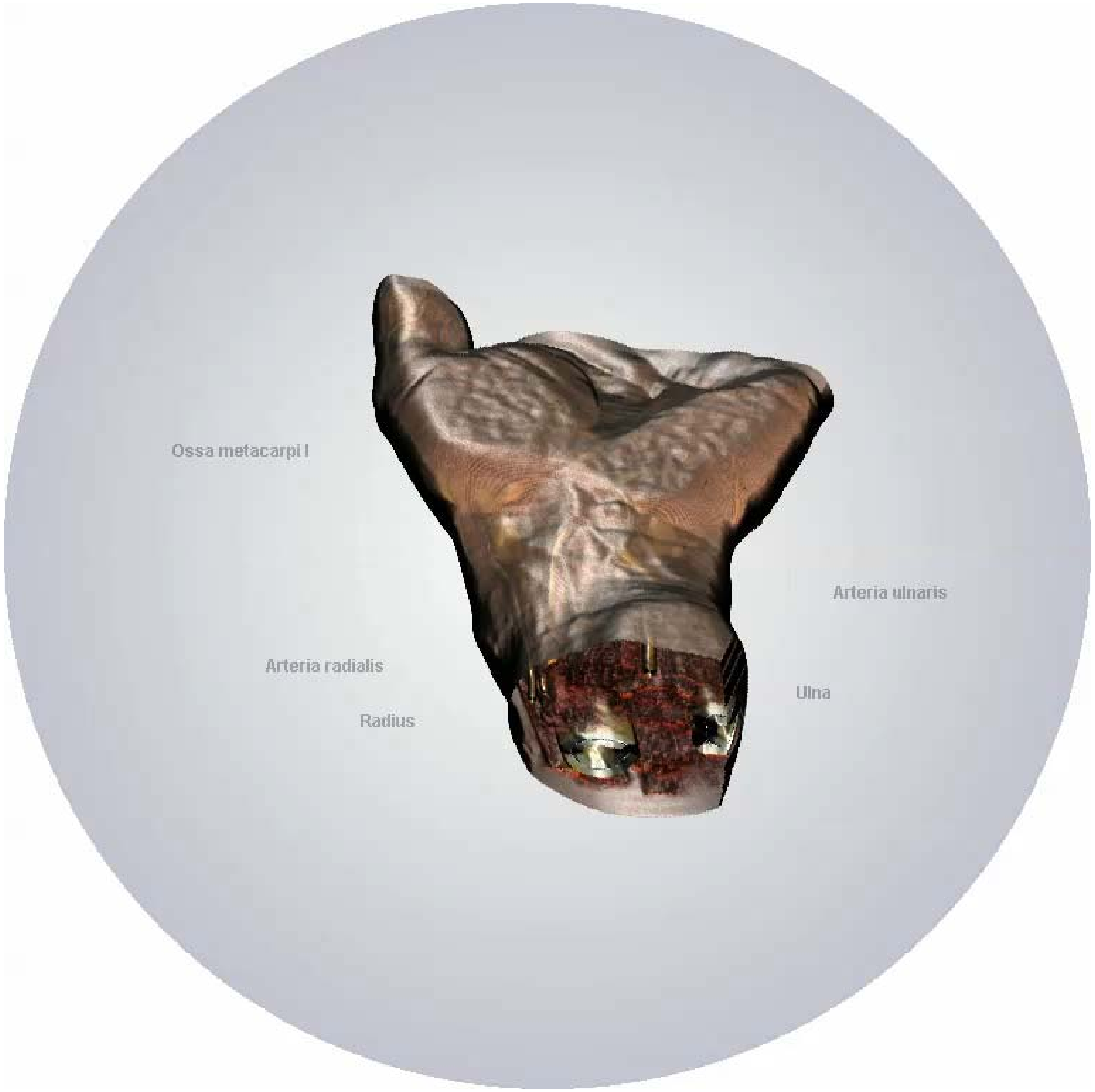
[Viola et al.]



Importance-Driven Focus of Attention (2)

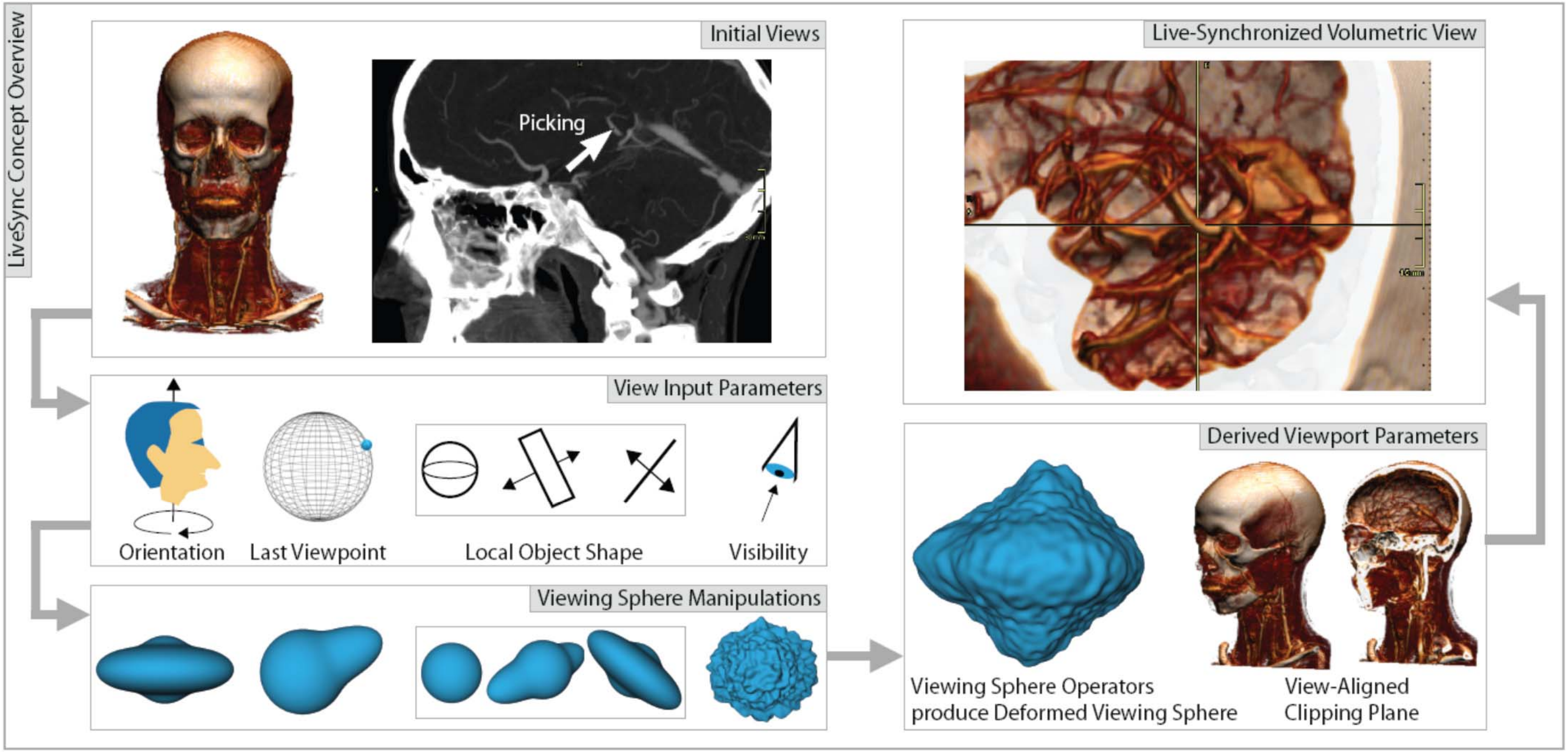


Importance-Driven Focus of Attention (3)



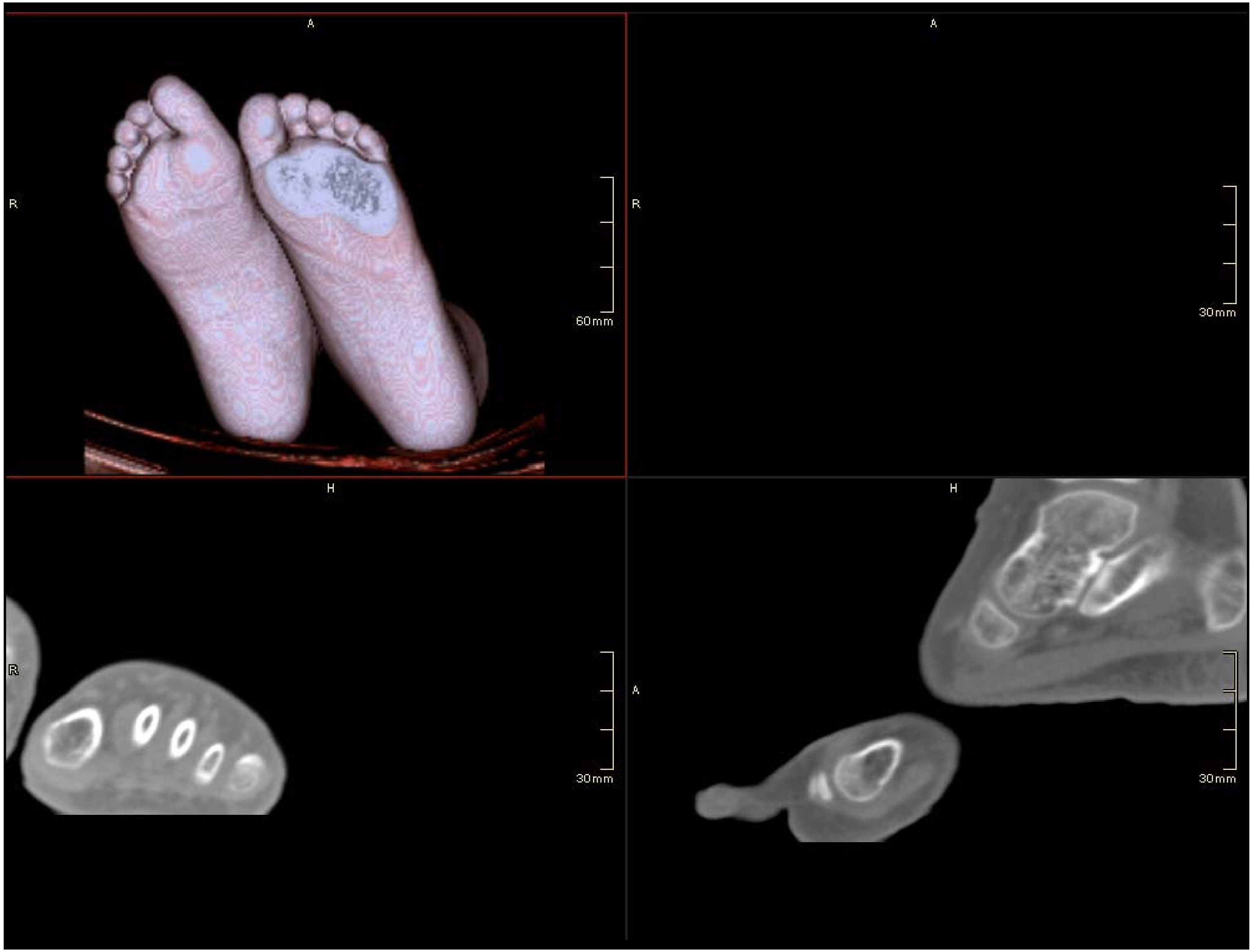
Knowledge-Based Navigation (1)

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



[Kohlmann et al.]

Knowledge-Based Navigation (2)



[Kohlmann et al.]

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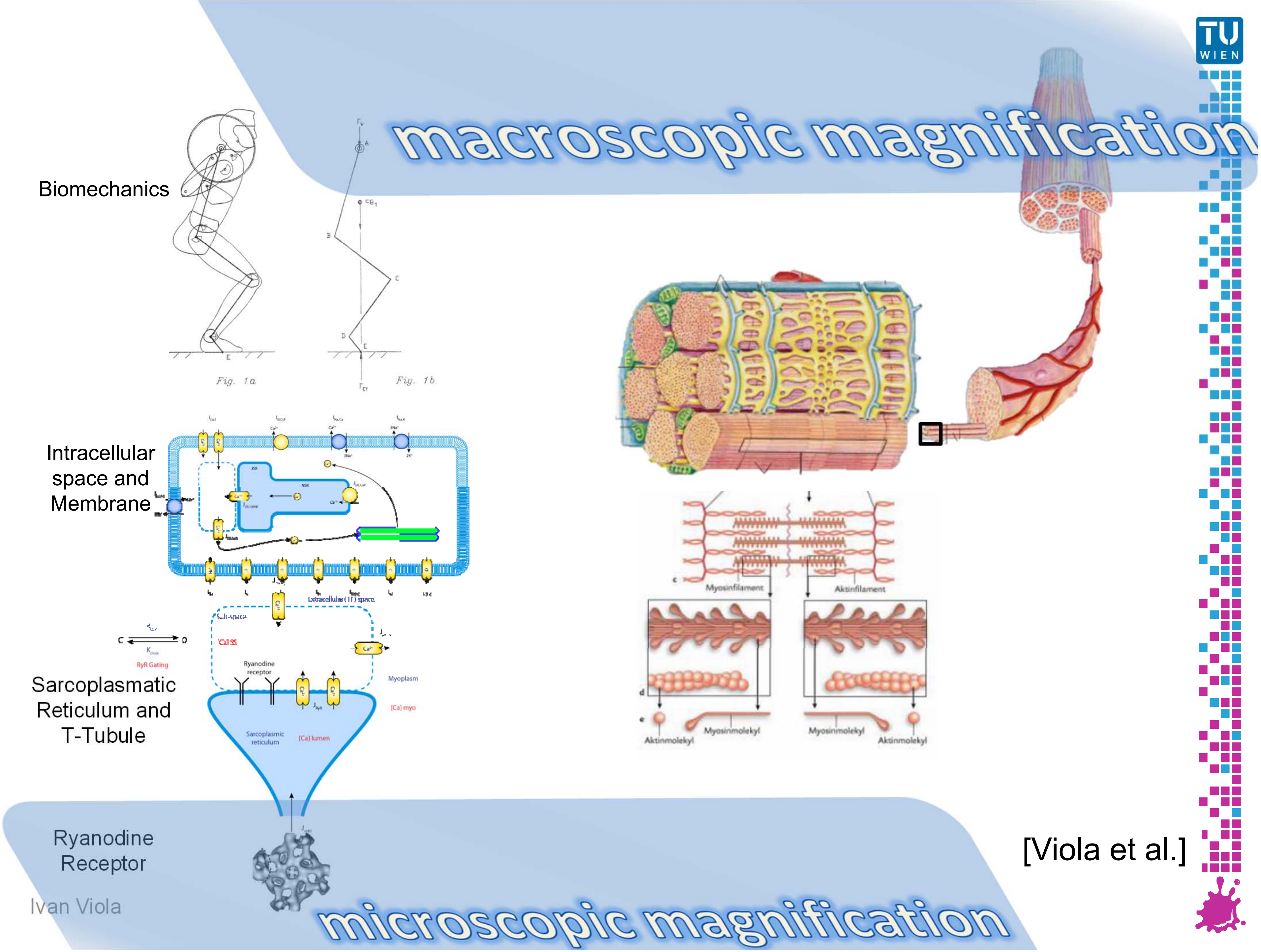
- Visual Analytics (↔ SciVis ↔ InfoVis)
- Interaction (Knowledge-assisted, User-centric)
- Scalability
-

Scalability

- Challenges [Keim, Thomas]
  - amount of data and dimensionality
  - numbers of data sources and heterogeneity
  - data quality and data resolution
  - dynamicity and novelty
  - data representation and visual resolution

- Examples
  - Focus+Context
  - Aggregation
  - Abstraction and Illustration


macroscopic magnification
Biomechanics
Fig. 1a
Fig. 1b
Intracellular space and Membrane
Sarcoplasmatic Reticulum and T-Tubule
Ryanodine receptor
Myoplasm
Sarcoplasmic reticulum
[Ca] lumen
[Ca] myo
RyR Gating
Ryanodine Receptor
Myosinfilament
Aktinfilament
Myosinmolekyl
Aktinmolekyl
microscopic magnification

[Viola et al.]

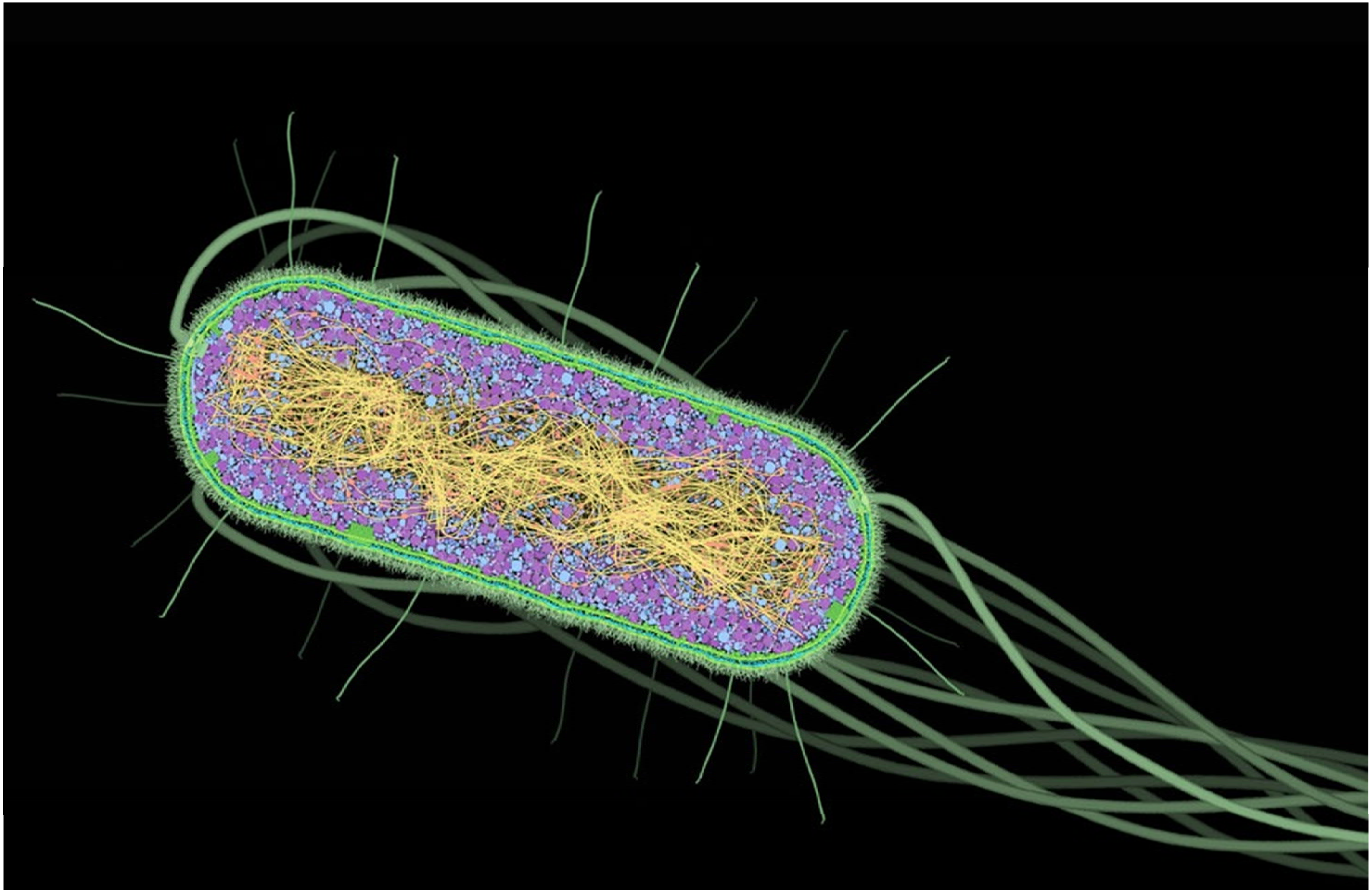
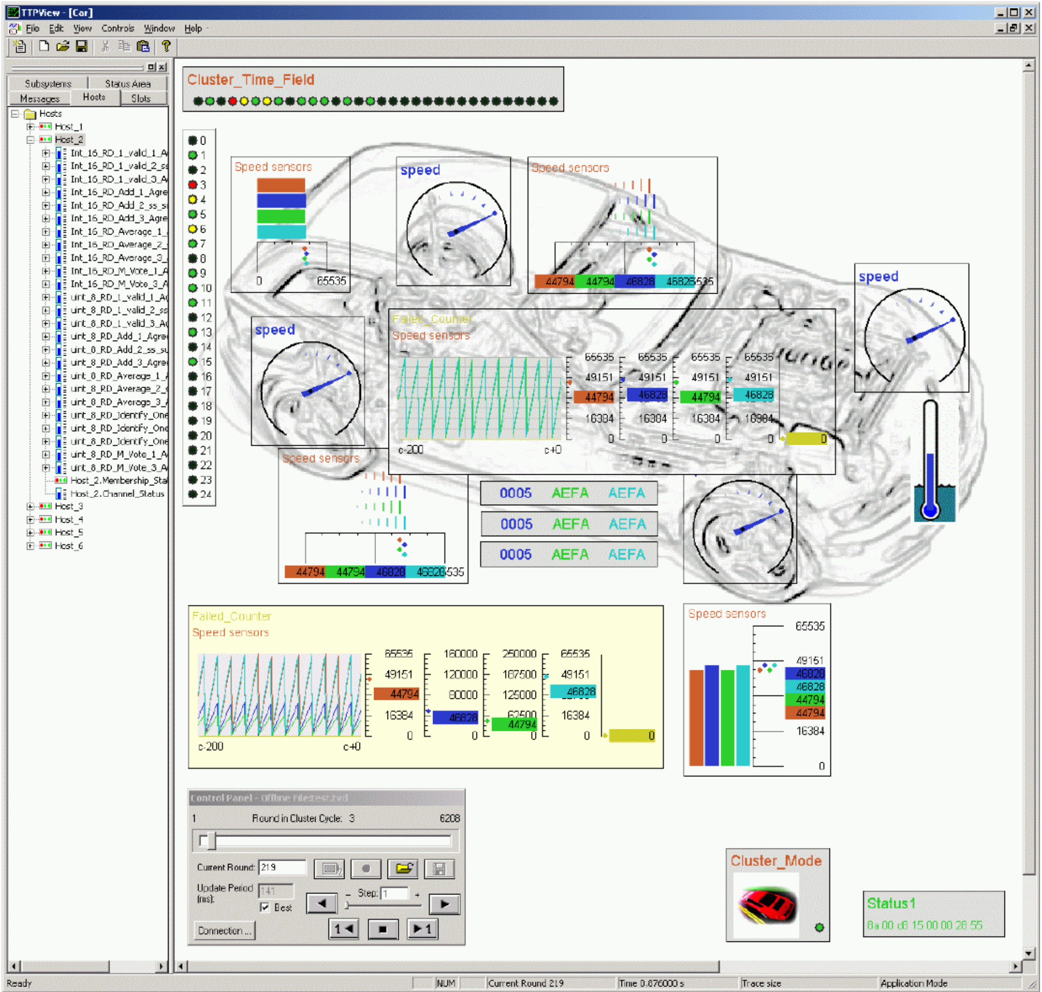


Illustration from *The Machinery of Life* by David S. Goodsell

Scalability - Process Visualization (1)

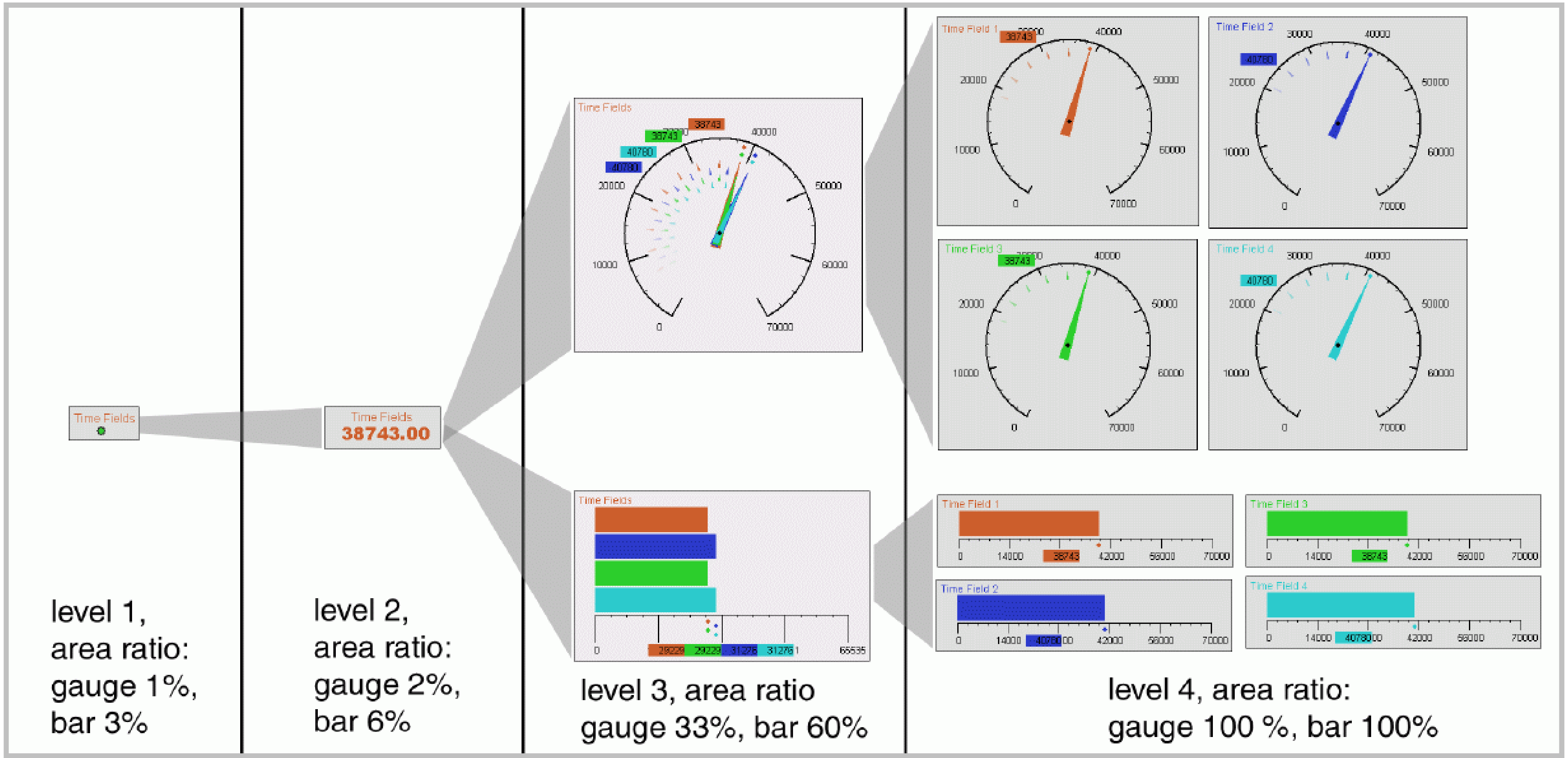
- Improving singular instruments
  - History encoding
  - Multi-instruments
  - Levels of detail (LOD)
- Improving the monitoring system
  - Focus+Context (F+C) rendering
  - Collision avoidance



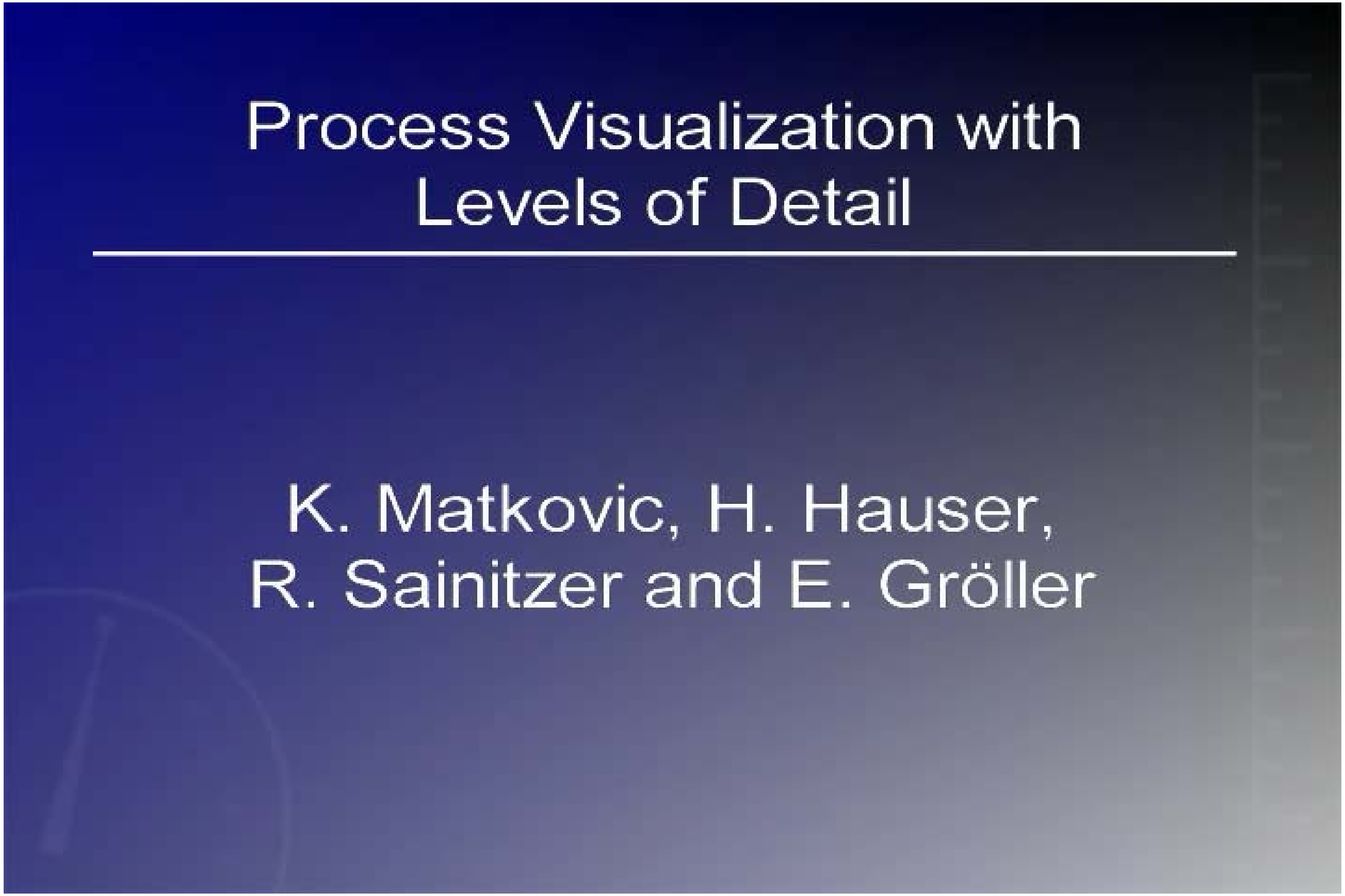
[Matković et al.]

Scalability - Process Visualization (2)

- Various instruments can be used to construct Levels of Detail (LODs)



Scalability - Process Visualization (3)



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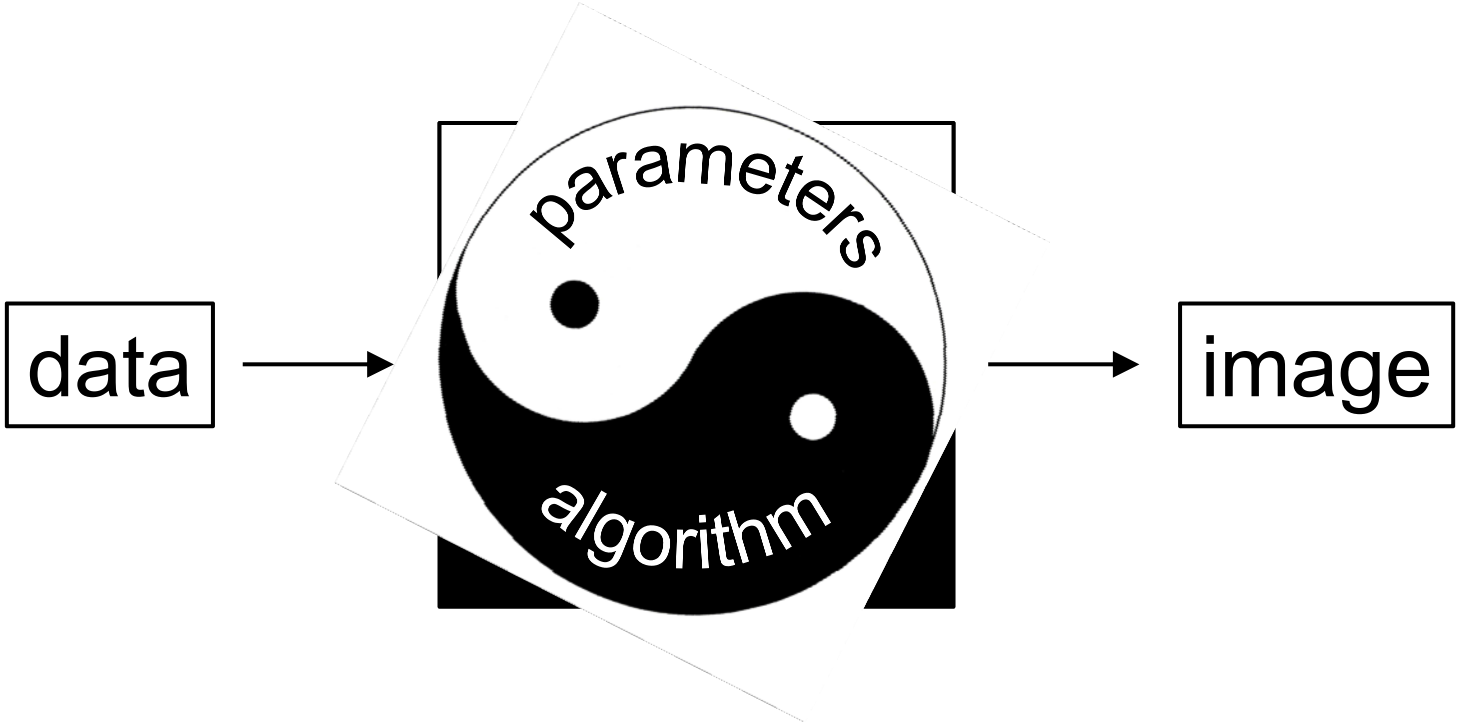
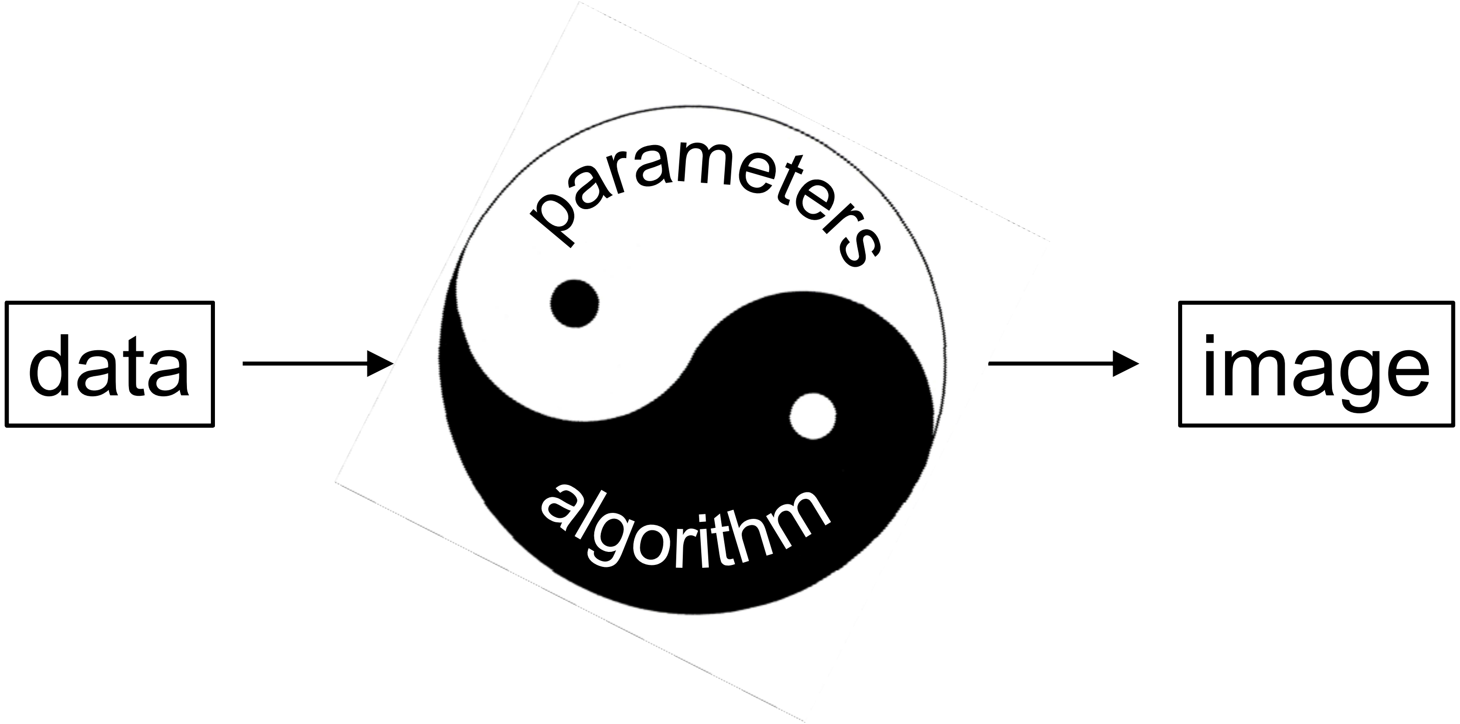
- Ensembles, Uncertainty, Parameter Spaces
- Multivariate, Heterogeneous Data
- Visual Analytics (↔ SciVis ↔ InfoVis)
- Interaction (Knowledge-assisted, User-centric)
- Scalability
- Visual Computing in the Cloud

Problem Solving: Algorithm + Parameters

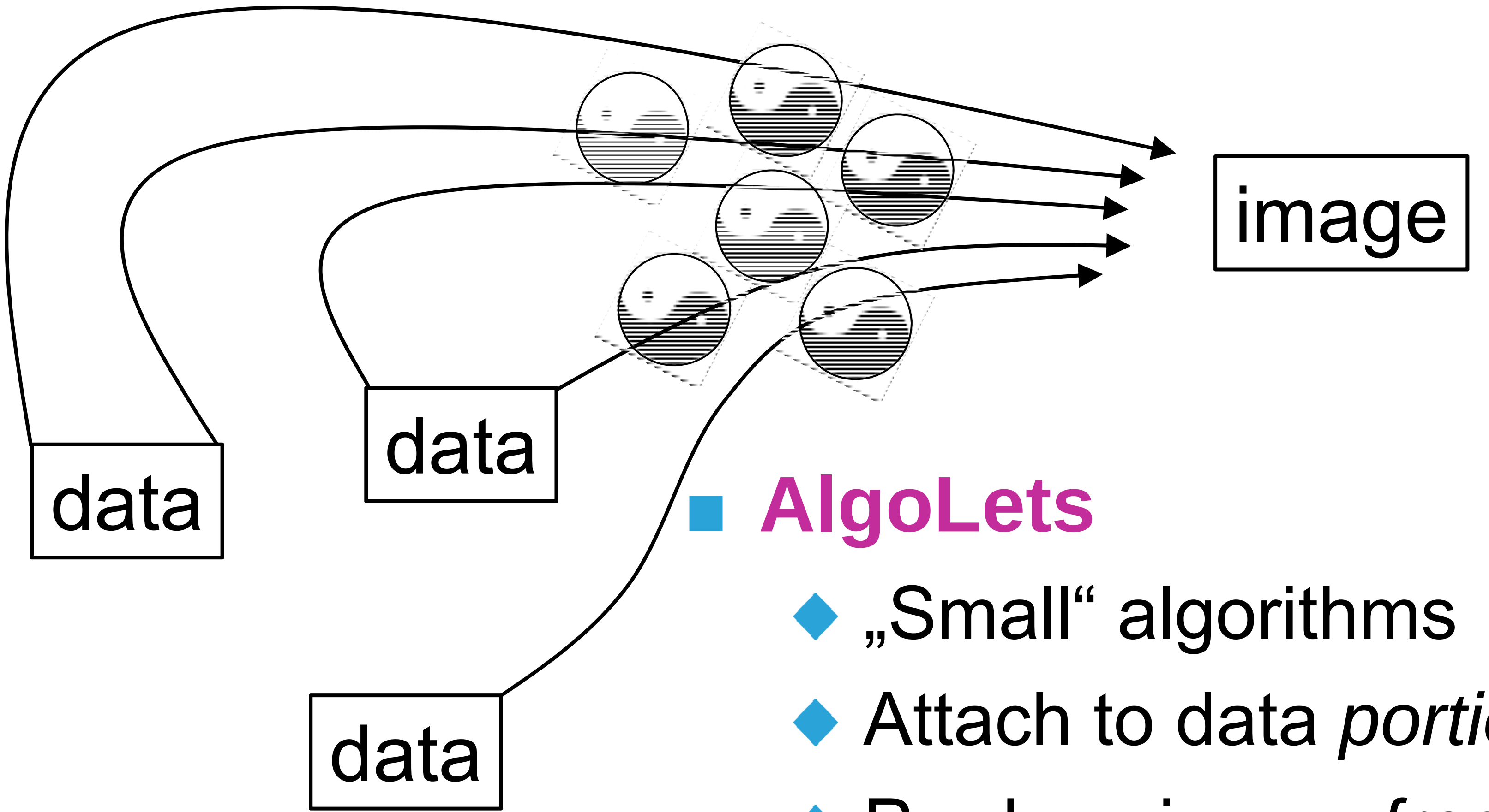


- Parameter space analysis
  - Robustness, stability: well established in other disciplines
  - Increased interest in visualization
    - Variations
    - Esembles
    - Knowledge-assisted visualization

AlgoLets: The Next Generation

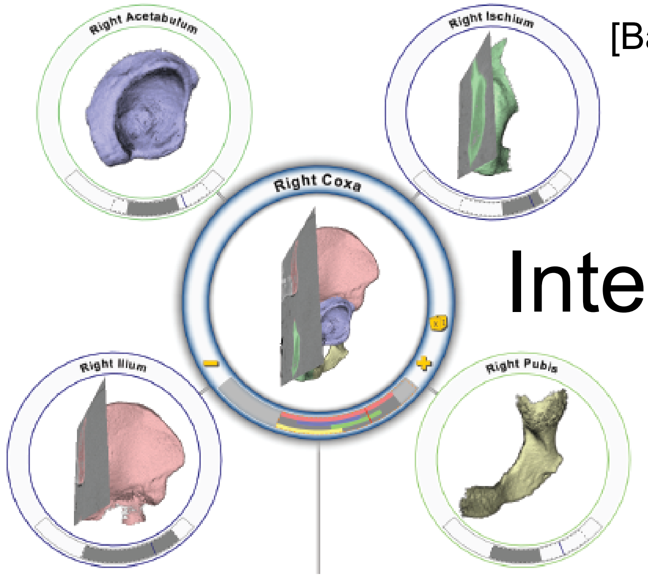


AlgoLets: The Next Generation



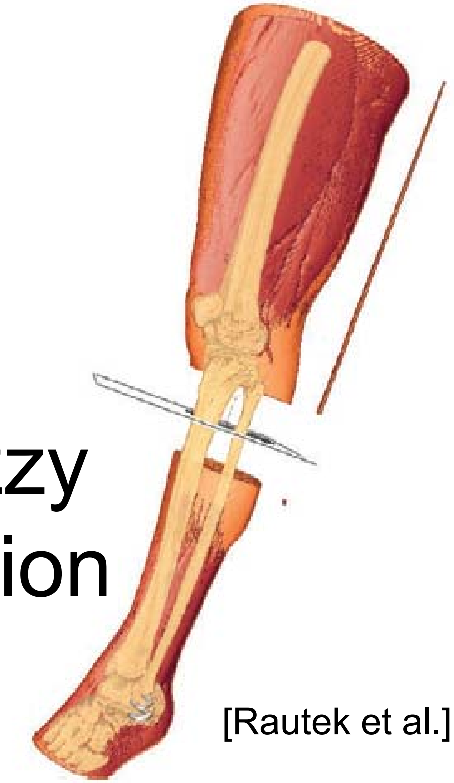
- **AlgoLets**
  - „Small“ algorithms
  - Attach to data *portions*
  - Produce image *fragments*
- Integration of fragments

Visual Computing: Topics for the Future ?



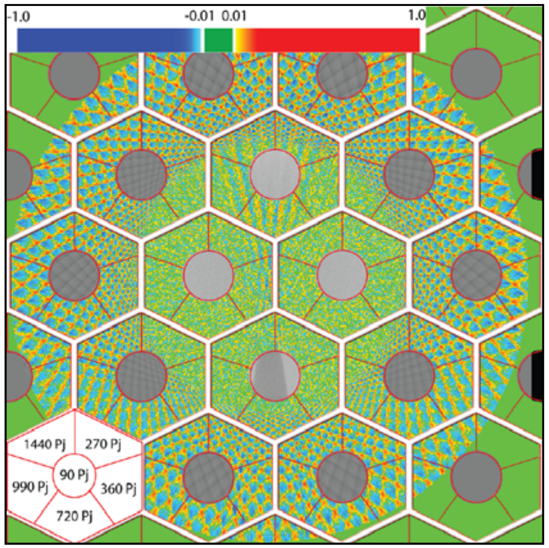
[Balabanian et al.]

Integrated Views



Fuzzy Visualization

[Rautek et al.]



Comparative Visualization

[Malik et al.]

if *distance to plane is not very low*
then *skin-style is opaque*

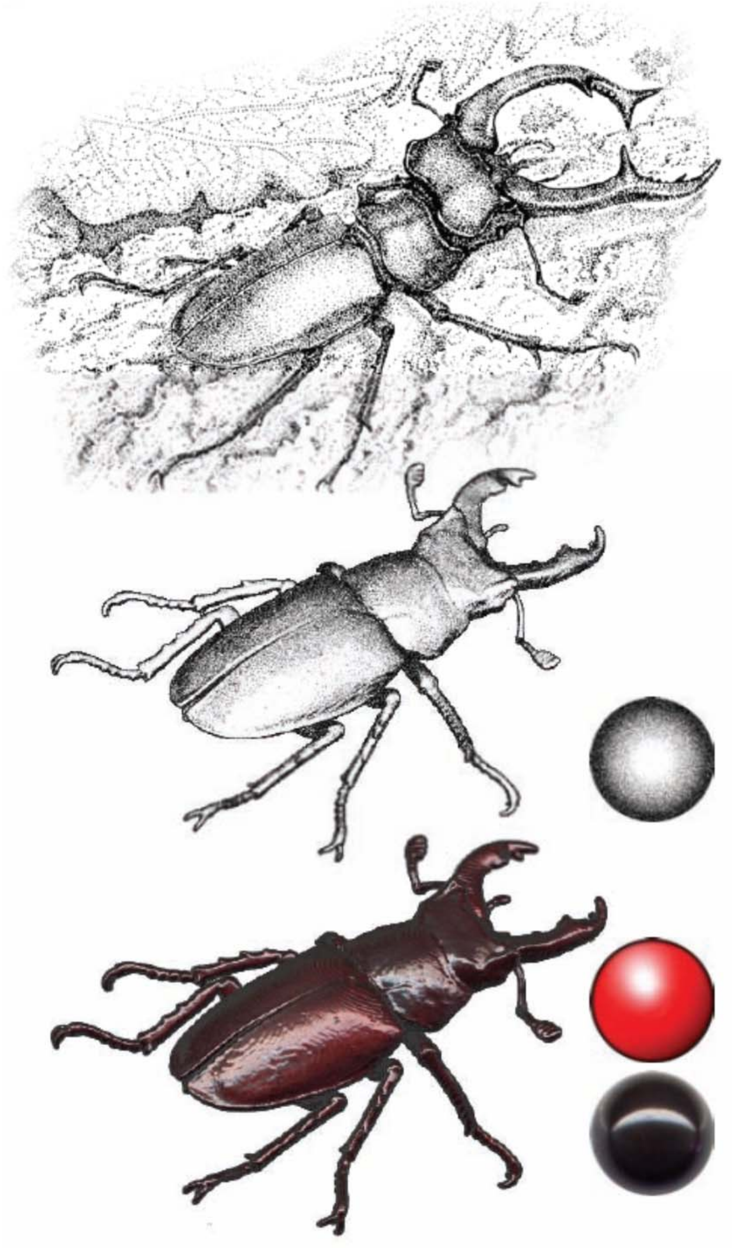
if *distance to plane is very low*
then *skin-style is transparent* and *muscle-style is transparent*

Challenges in Visual Computing

- New Data Sources - Novel Imaging Modalities
- Ensembles, Uncertainty, Parameter Spaces
- Multivariate, Heterogeneous Data
- Visual Analytics (↔ SciVis ↔ InfoVis)
- Interaction (Knowledge-assisted, User-centric)
- Scalability
- Visual Computing in the Cloud

Bring **visual computing**
into the workflow of users!!

Thank You for Your Attention



Questions ?
Comments?

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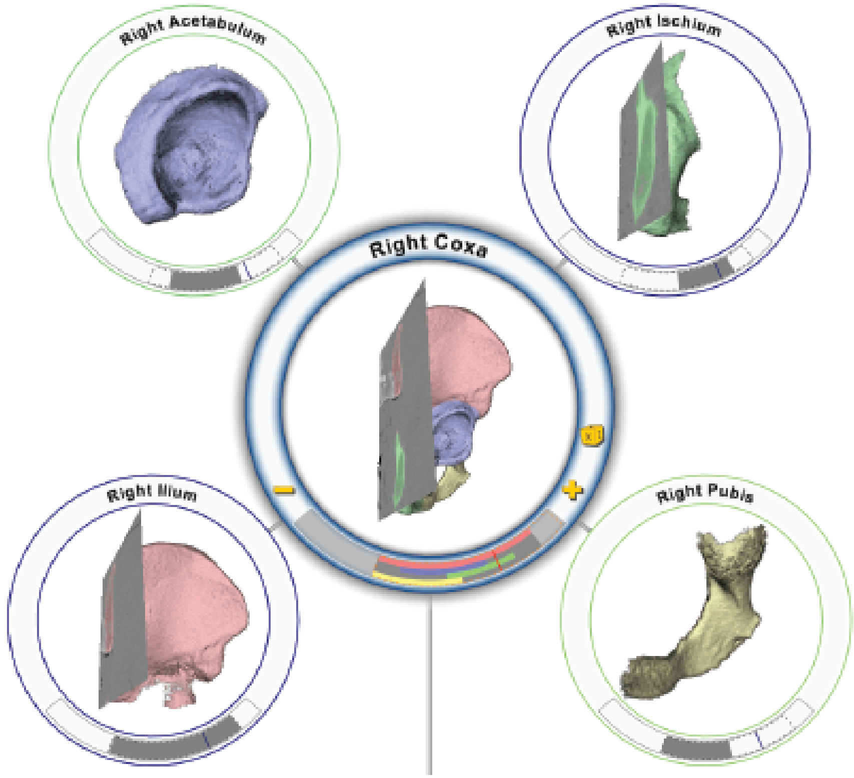
Werner Purgathofer
Peter Rautek
Hrvoje Ribičić
Georg Stonawski
Maurice Termeer
Roy van Pelt
Anna Vilanova
Ivan Viola
Jürgen Waser
...

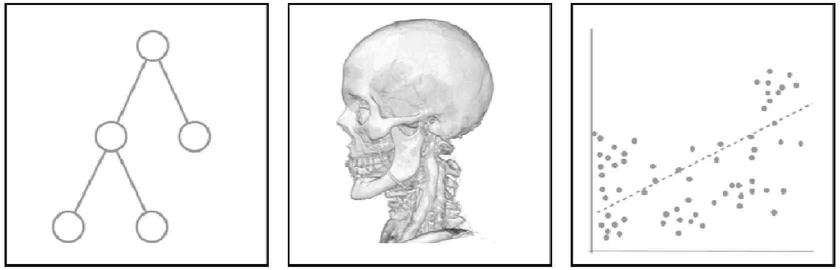


Integrated Views

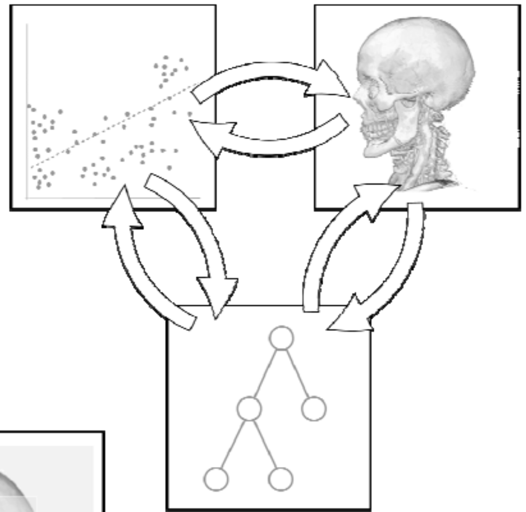
Balabanian, J-P., Viola, I., Gröller, E.: **Interactive Illustrative Visualization of Hierarchical Volume Data**. Proceedings of Graphics Interface 2010, May 31st–June 2nd, 2010, Ottawa, Ontario, Canada, pp . 137–144

Views - Linked Views - Integrated Views

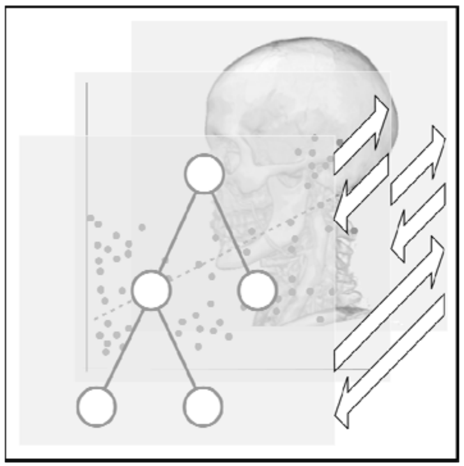
- Separate views
  - \+ Remove overload
  - − Loss of context



- Linked views
  - \+ Re-establish context
  - − Scalability??

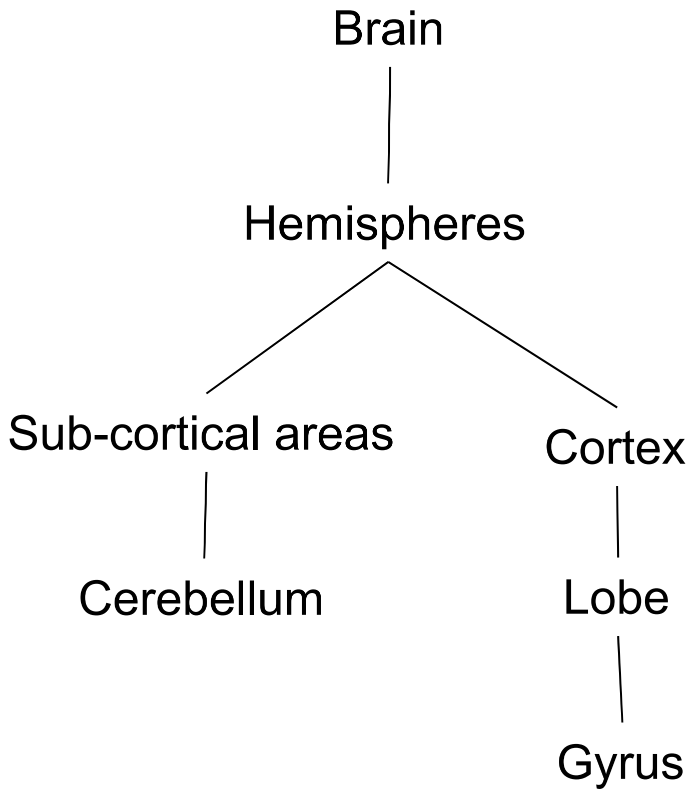


- Integrated views

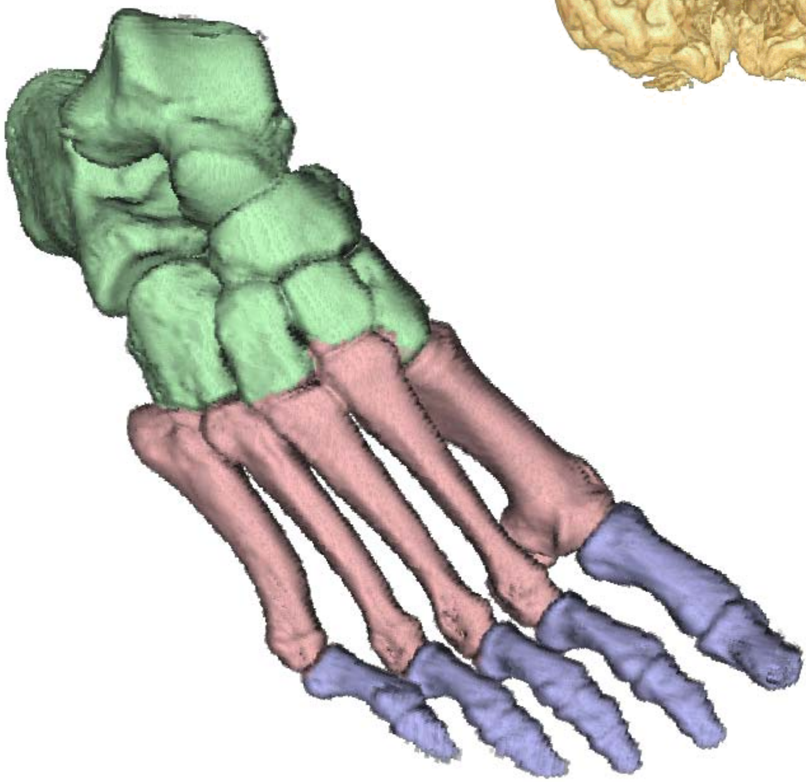


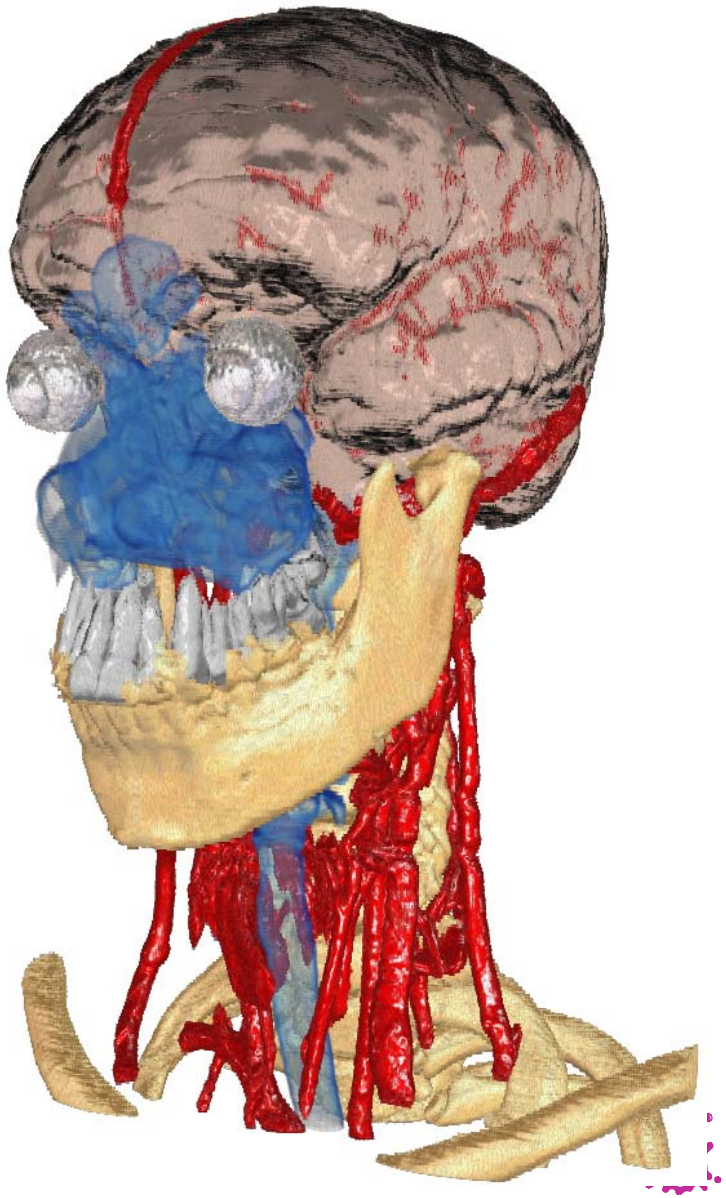
[Balabanian 2010]

Side-by-side view

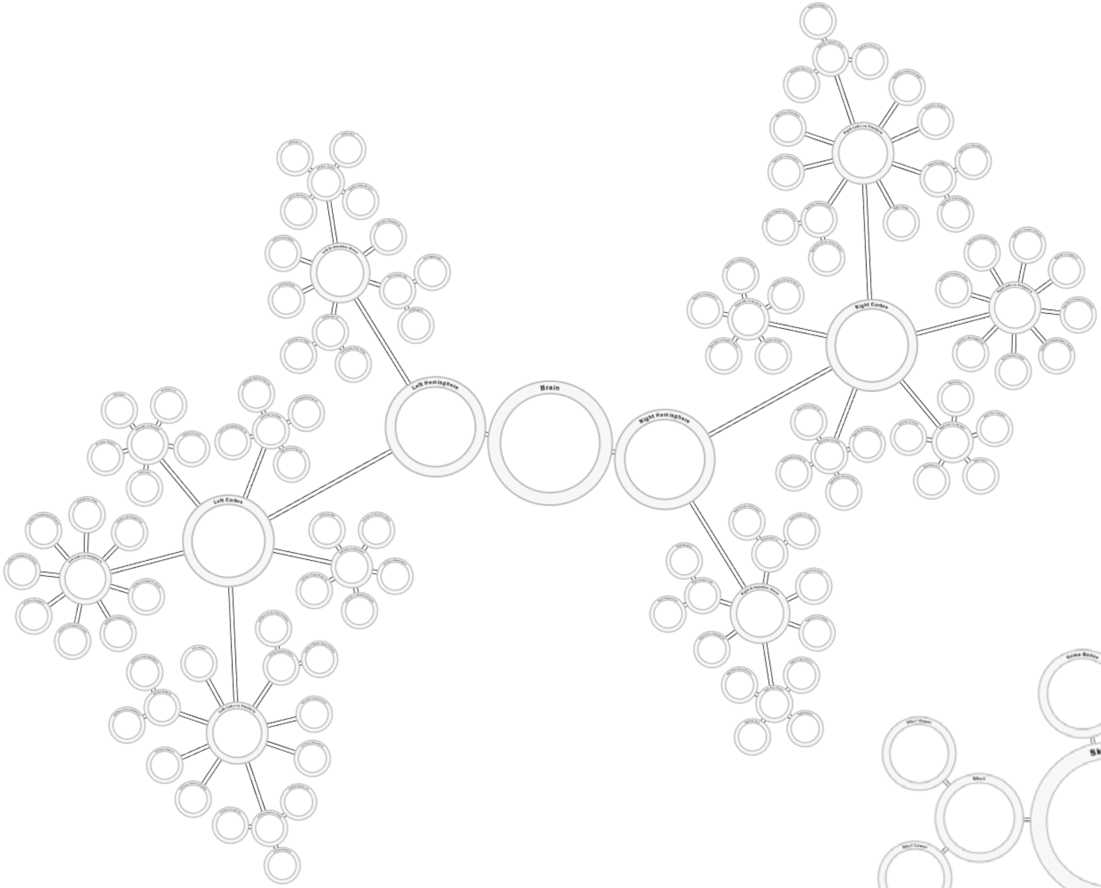


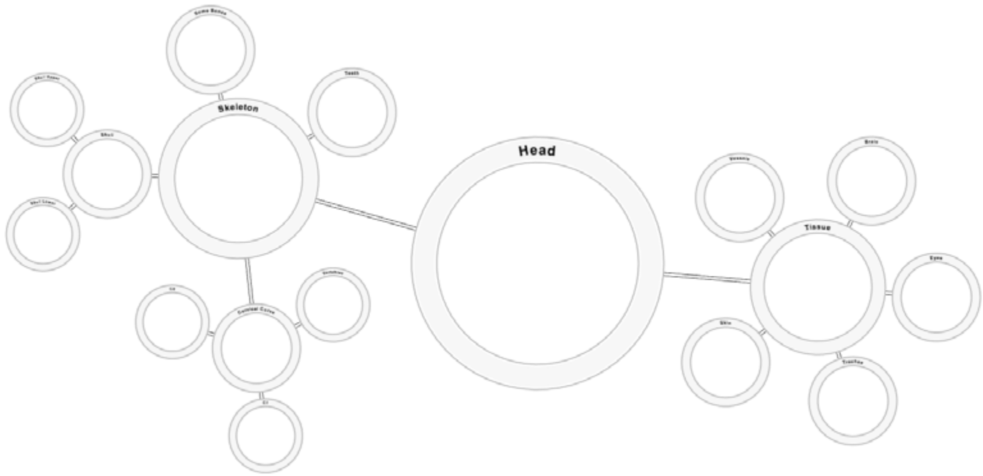
Volume Rendering





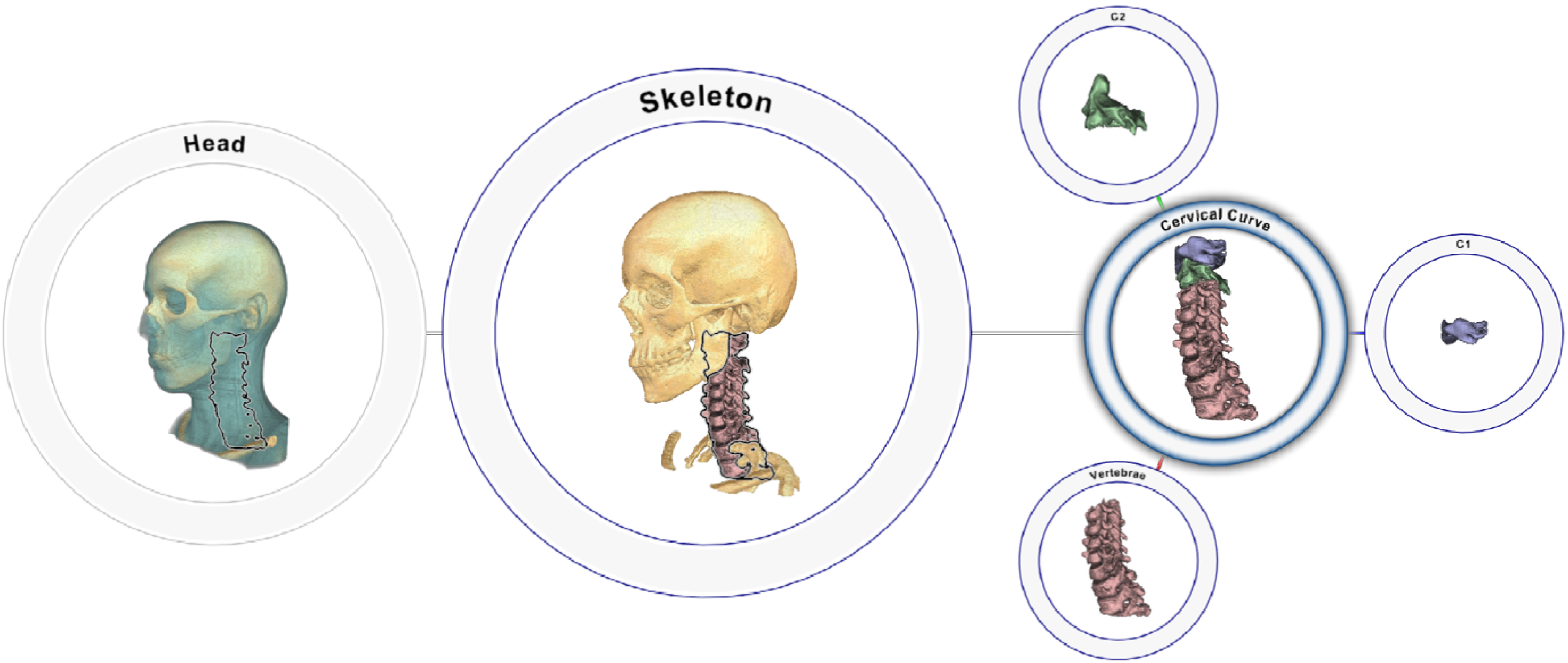
Hierarchical Layout





Balloon layout

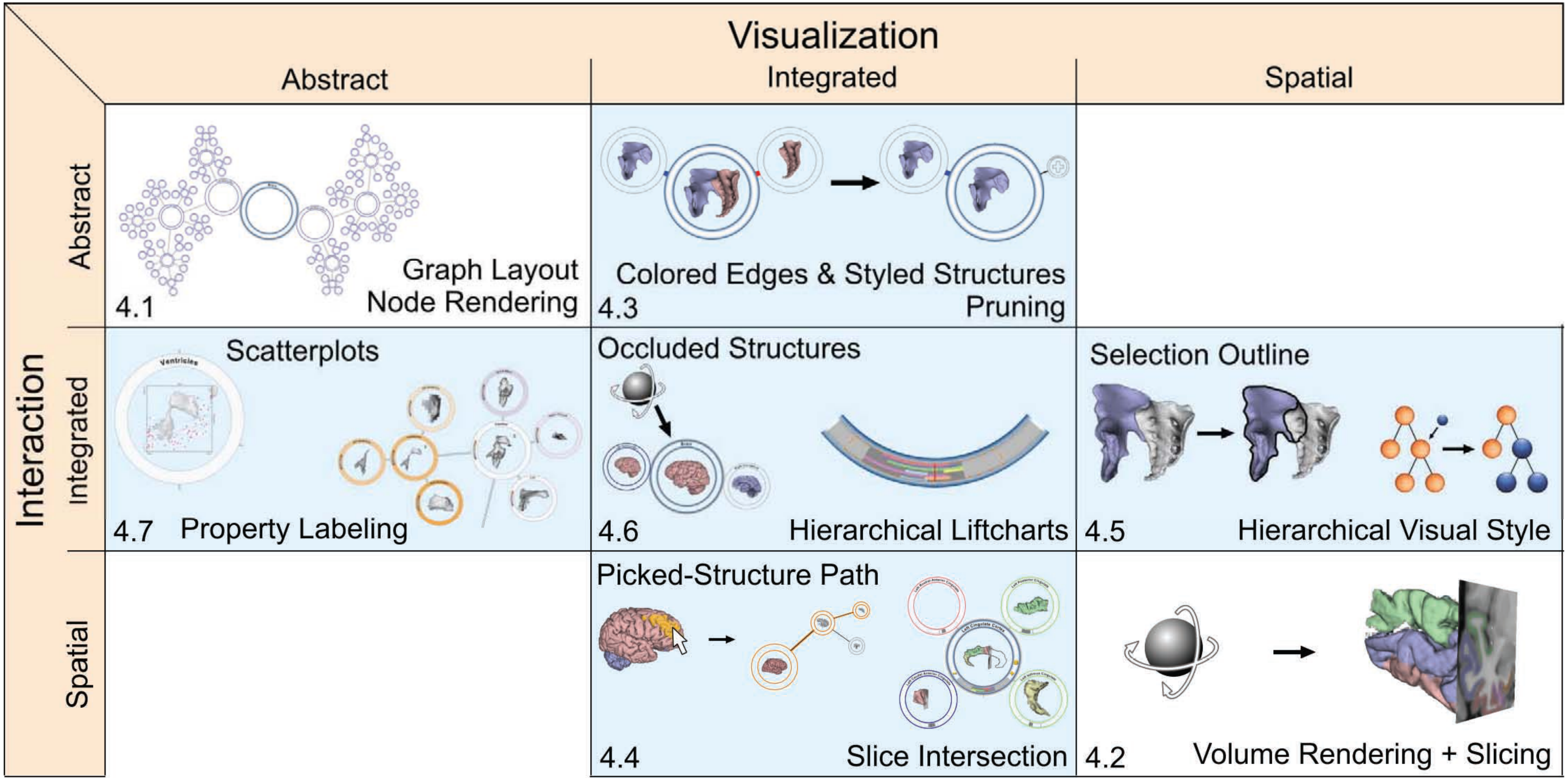
Integrated View

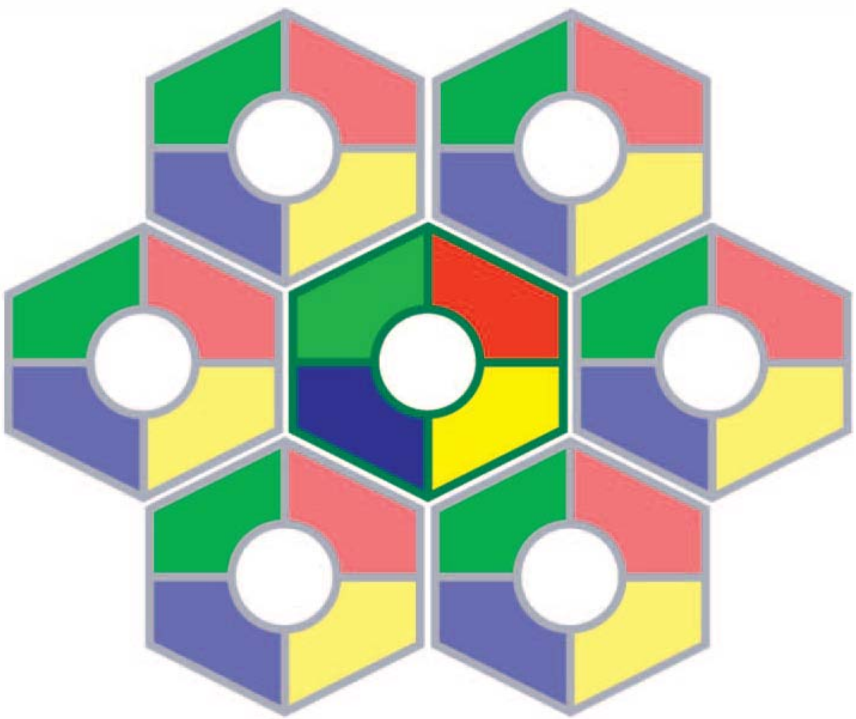


Structure visibility

Blue nodes indicate visible structures
Gray nodes indicate occluded structures

Integrated Visualization and Interaction





Comparative Visualization

Malik, M.M., Heinzl, Ch.; Gröller, E.: **Comparative Visualization for Parameter Studies of Dataset Series**. IEEE Transactions on Visualization and Computer Graphics, 16(5):829–840, 2010.

Dataset Series

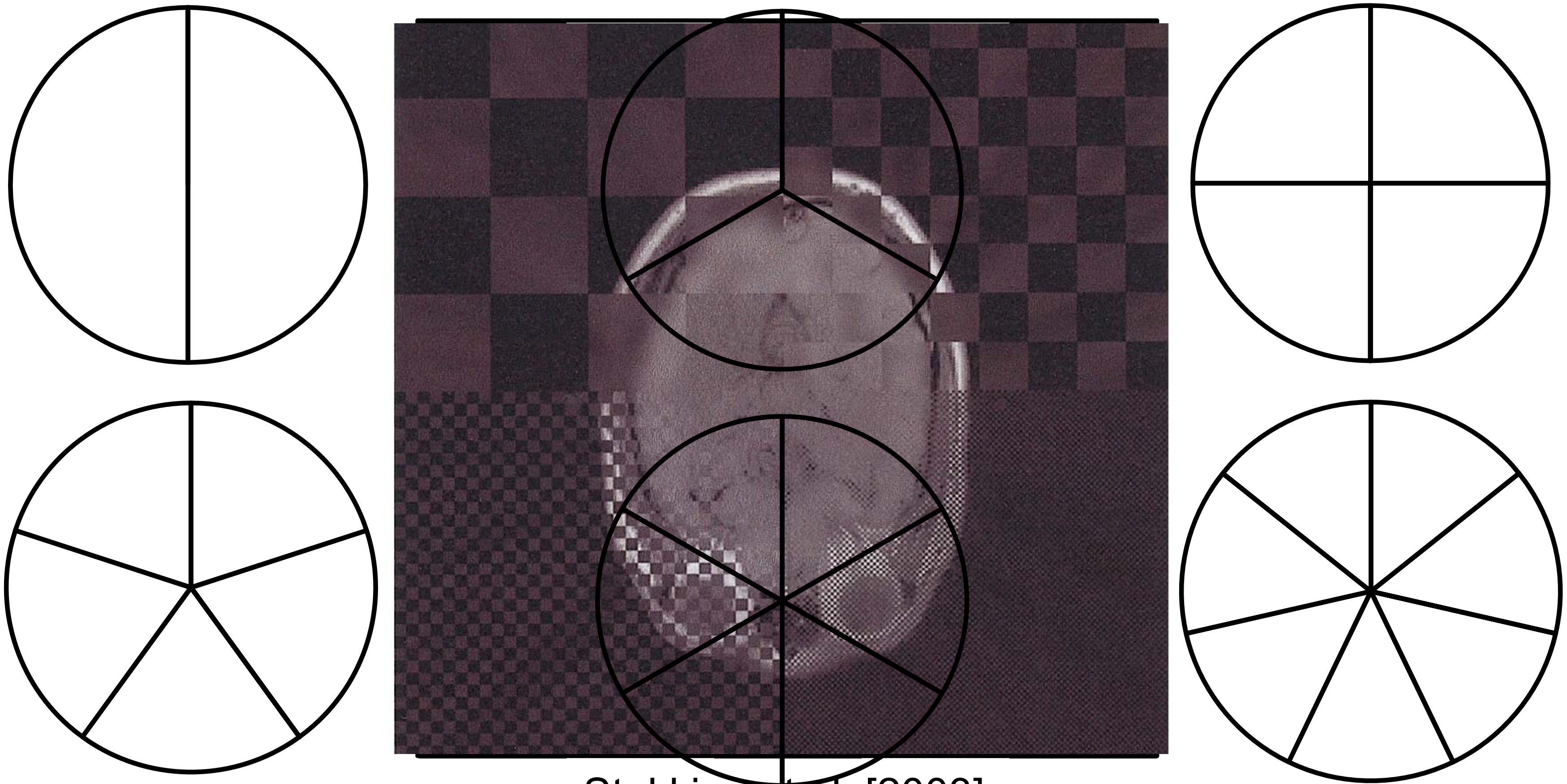
Parameters	Dataset Resolution	No of Datasets	Series Size
Voltage	1000 * 1000 * 882	4	8.21 GB
No of Projections	1000 * 1000 * 882	6	9.86 GB
Current	856 * 856 * 882	6	7.22 GB
Integration Time	800 * 800 * 882	5	5.26 GB
Pre- and Post Filter Plates	848 * 848 * 882	15	17.72 GB
Mean Value Measurement	1000 * 1000 * 882	3	4.93 GB
Orientation	1000 * 1000 * 882	5	8.21 GB

Orientation 0 degrees

Orientation 90 degrees

Comparative Slice View

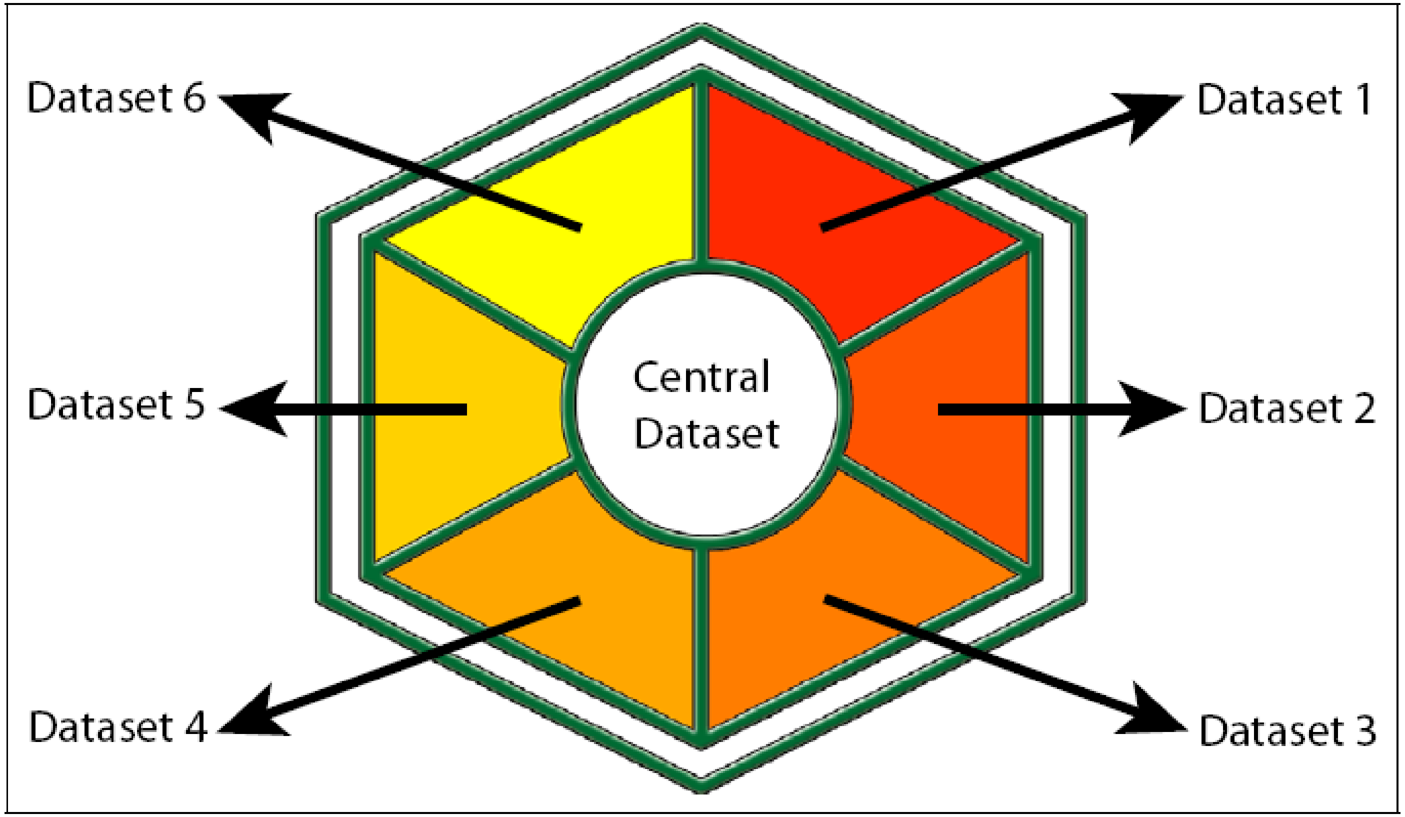
- Viewing two datasets on a single screen
- Viewing multiple datasets on a single screen



Stokking et al. [2003]

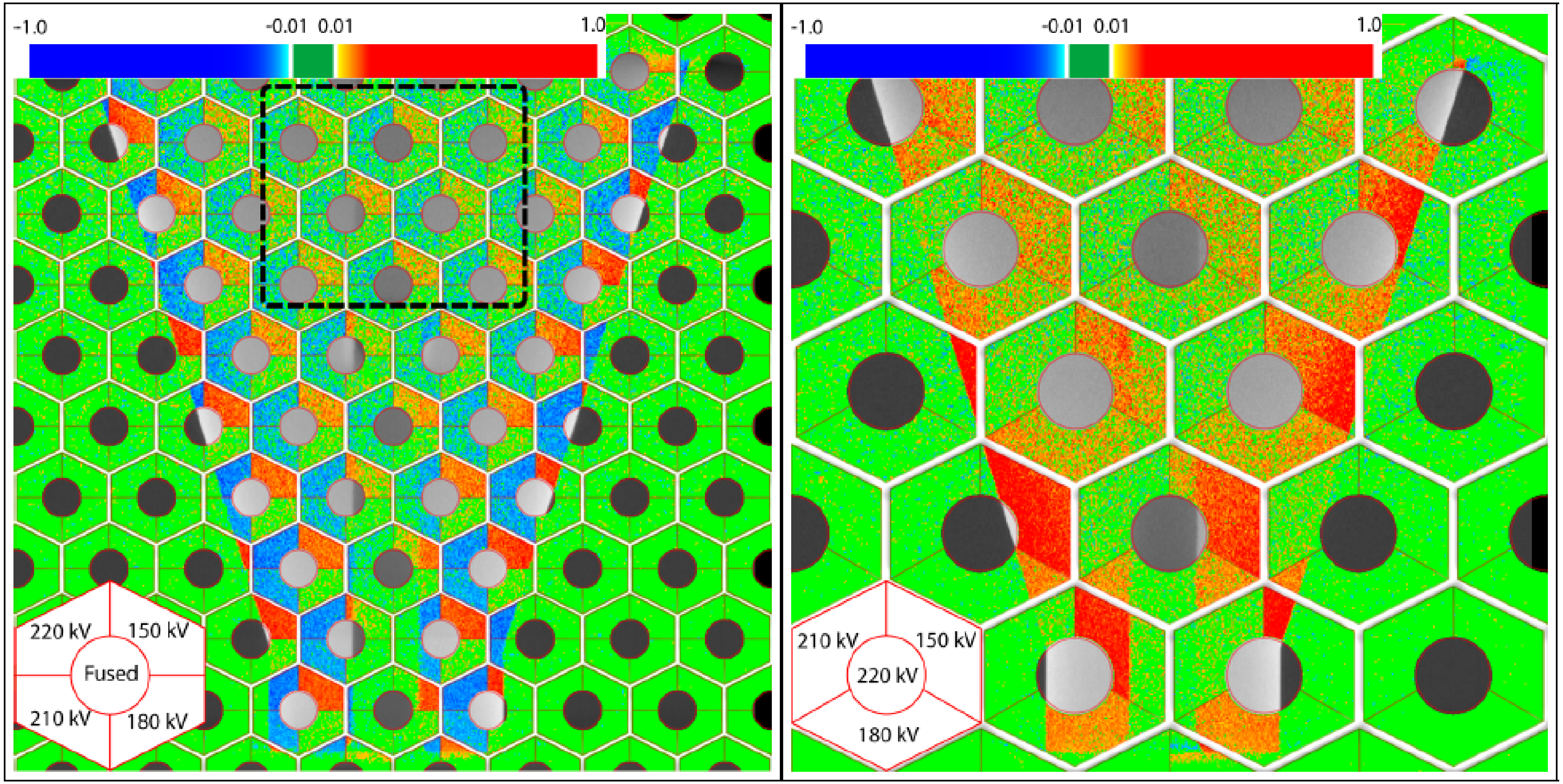
Visualization (Multi-image View)

- Each slice shows part of each dataset

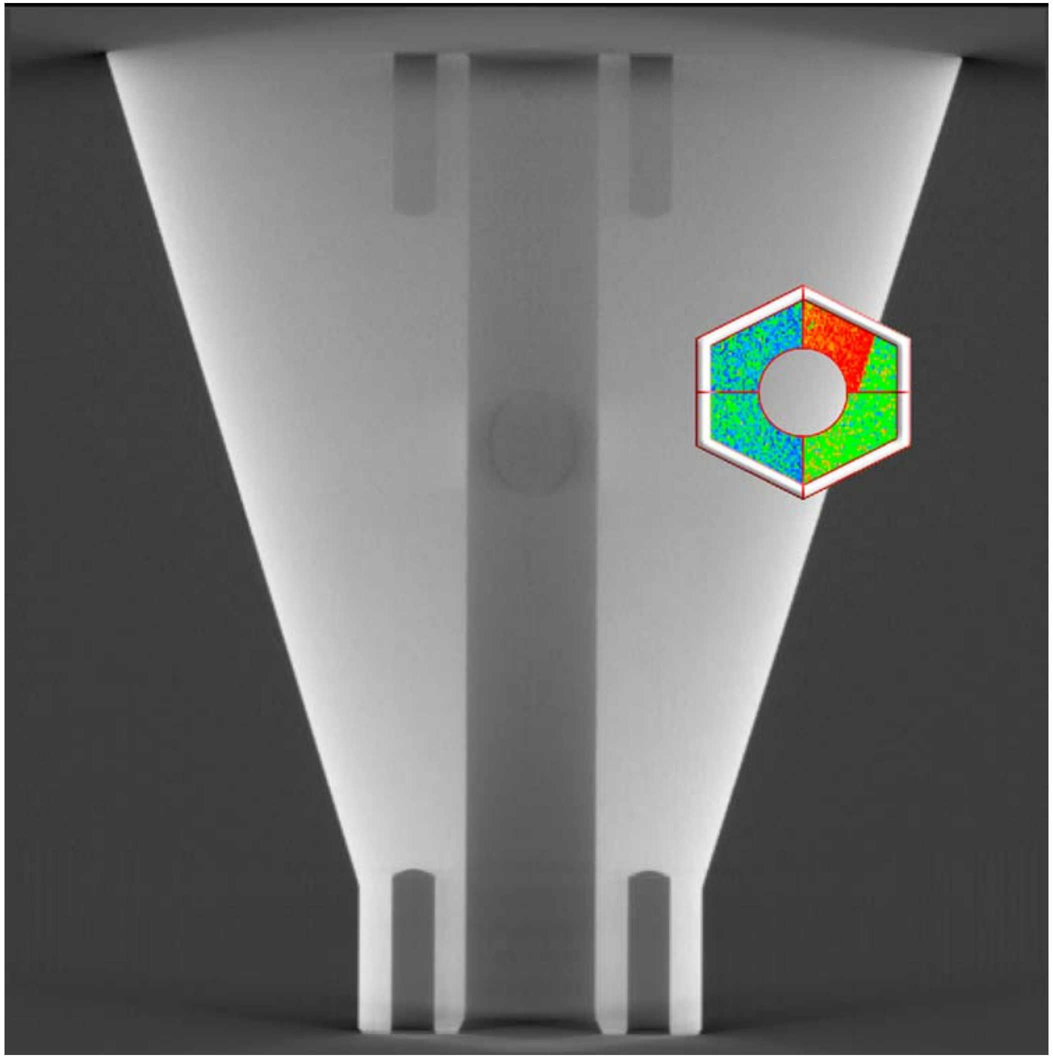


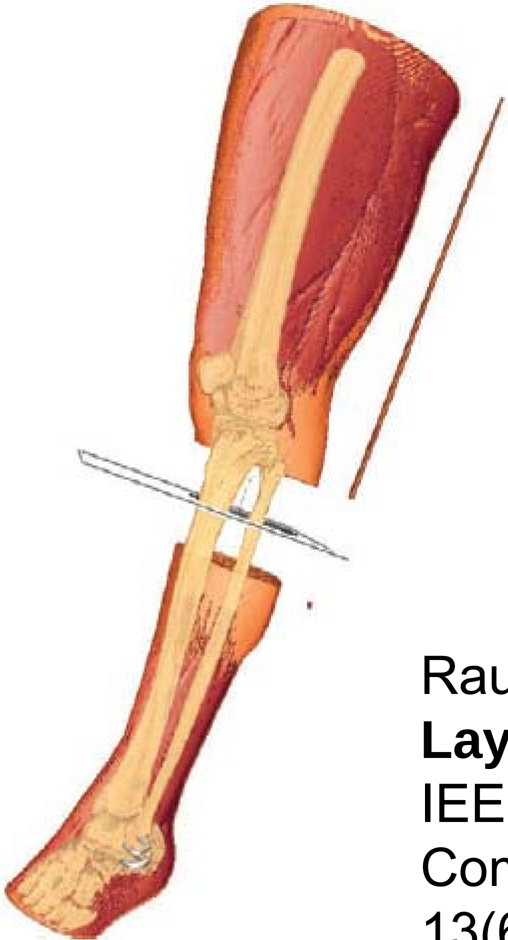
Comparative Slice View (Multi-image View)

- Direct density visualization
- Relative density visualization



Video: Comparative Visualization - Interaction





Fuzzy Visualization

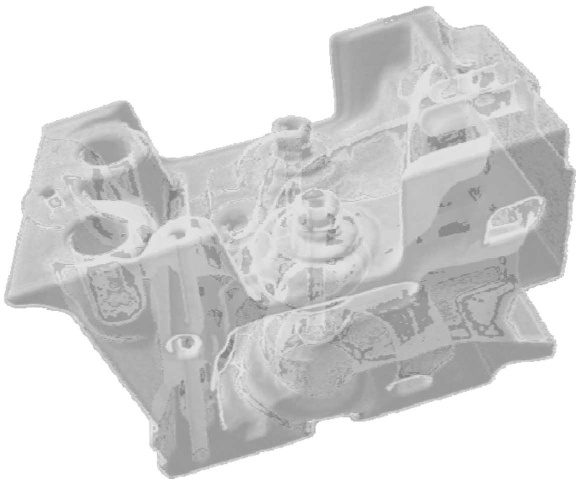
Rautek, P., Bruckner, S., Gröller, E.: **Semantic Layers for Illustrative Volume Rendering**. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2007), 13(6):1336-1343, 2007

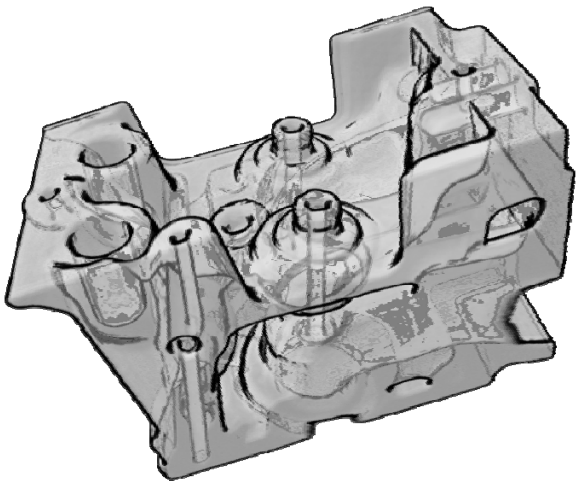
if *distance to plane is not very low*
then *skin-style is opaque*

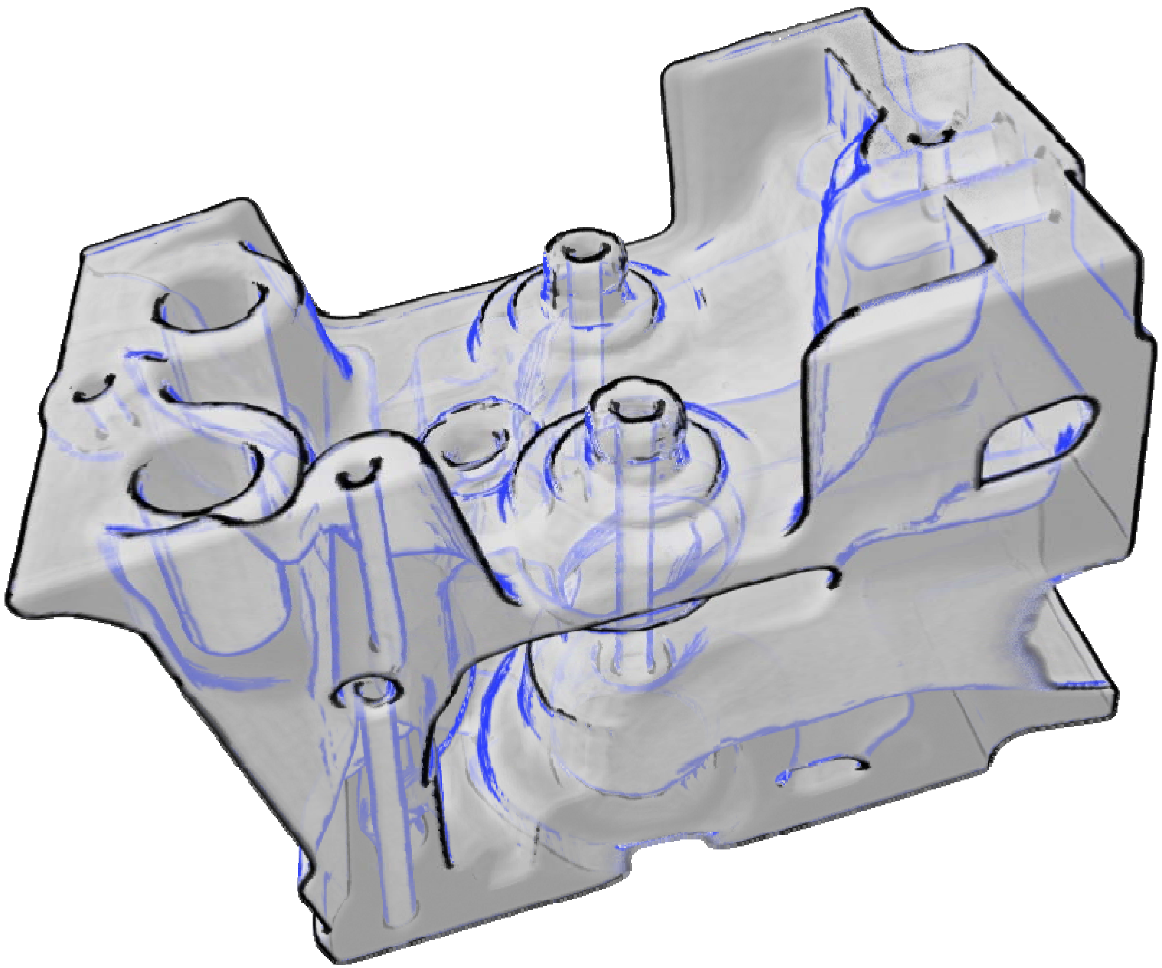
if *distance to plane is very low*
then *skin-style is transparent* and *muscle-style is transparent*

Curvature Based Selective Application

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



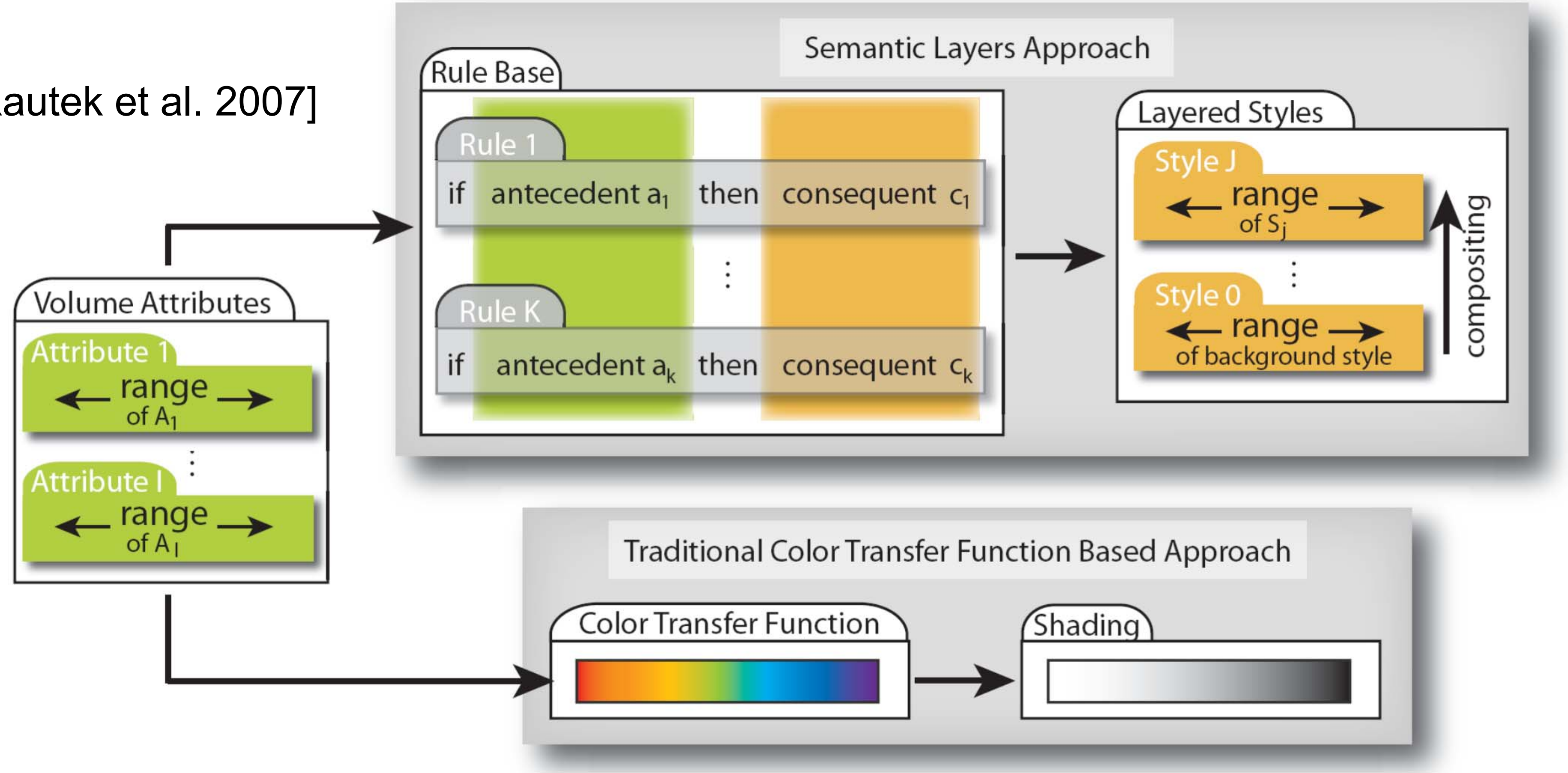




Semantic Layers for Illustrative Volume Rendering (1)

- 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

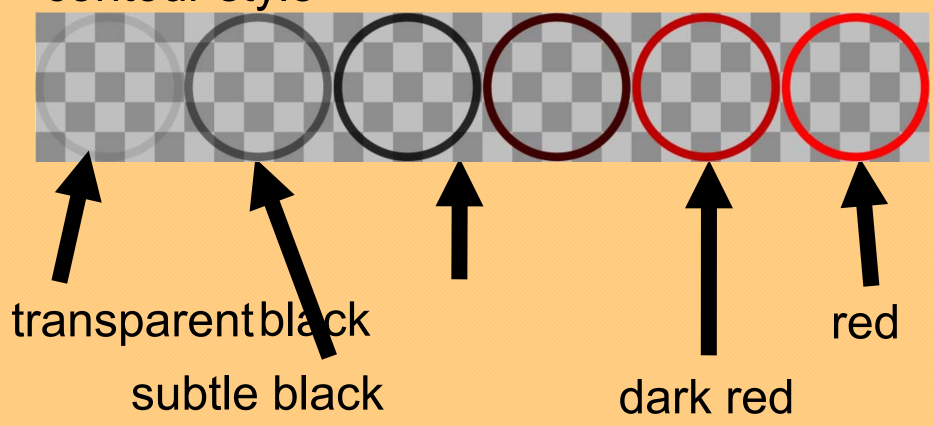
density:
low – … – high

curvature:
negative – zero – positive

etc.

illustrative styles

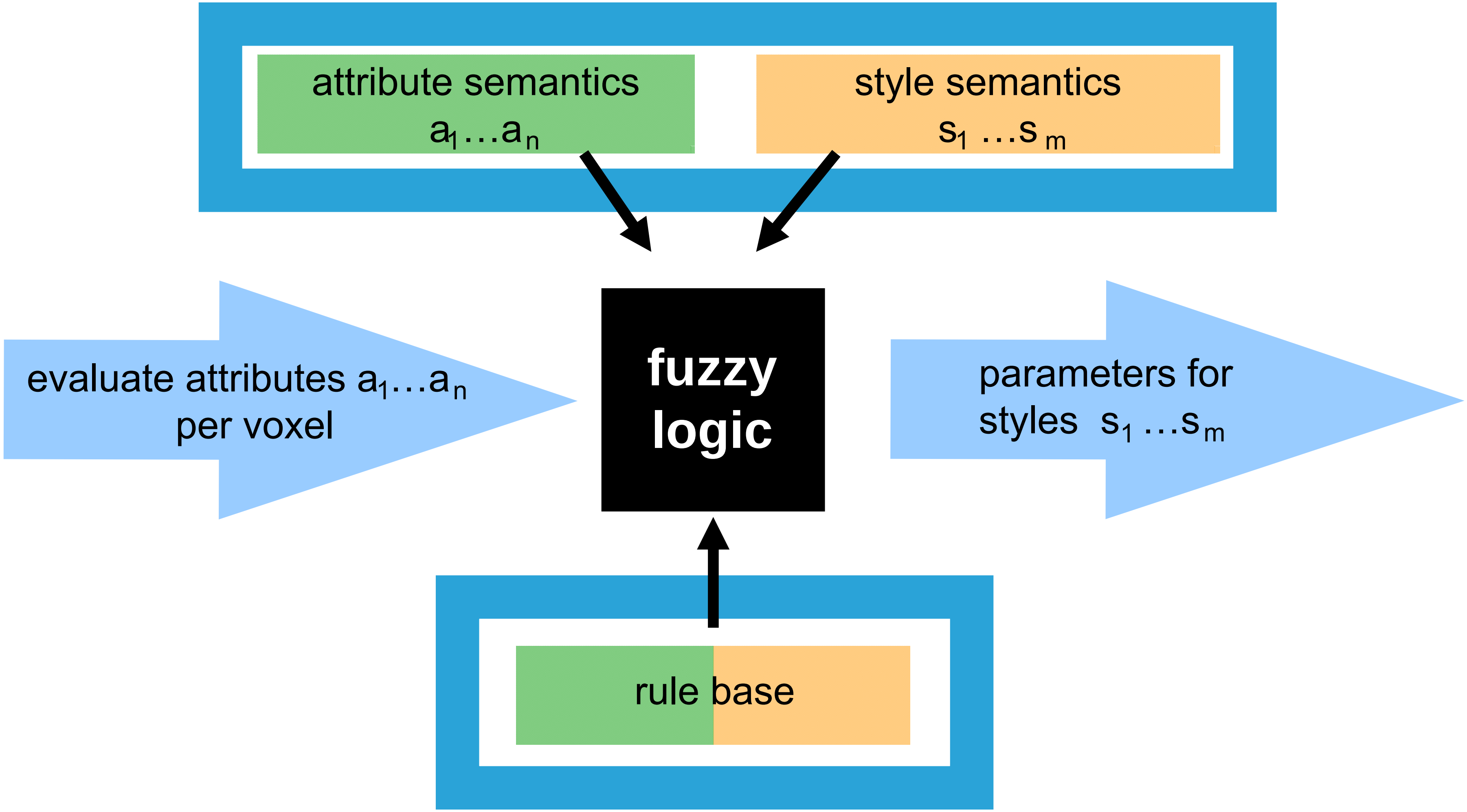
contour style



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

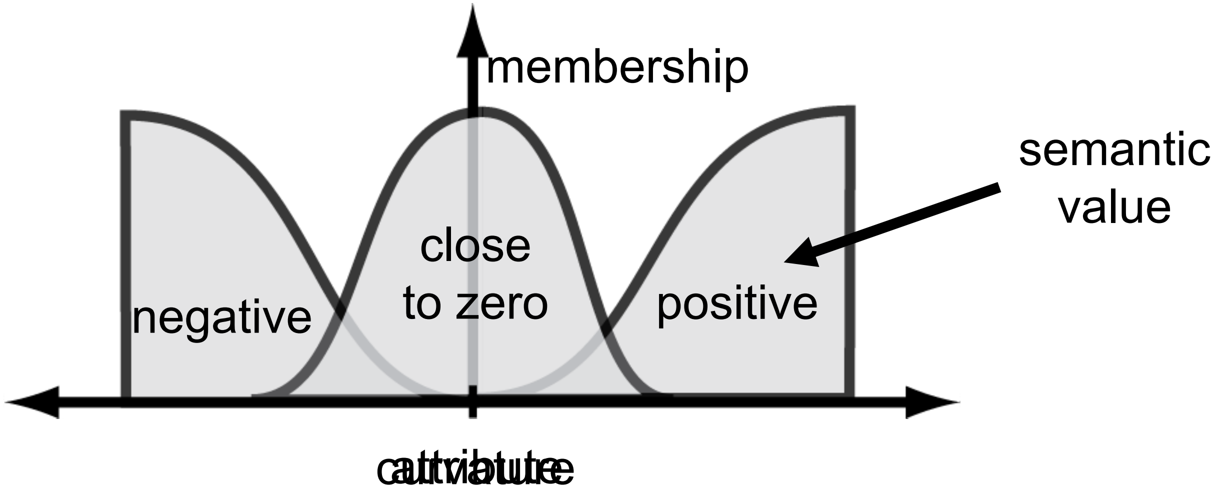
- Make use of semantics!

Fuzzy Logic as a Black Box

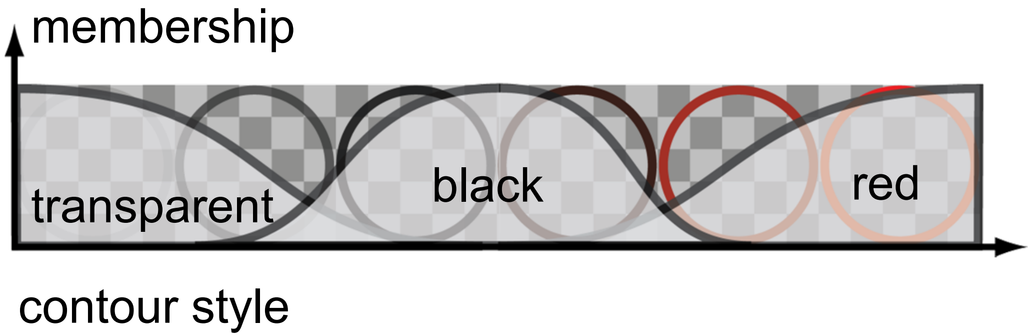


Membership Functions

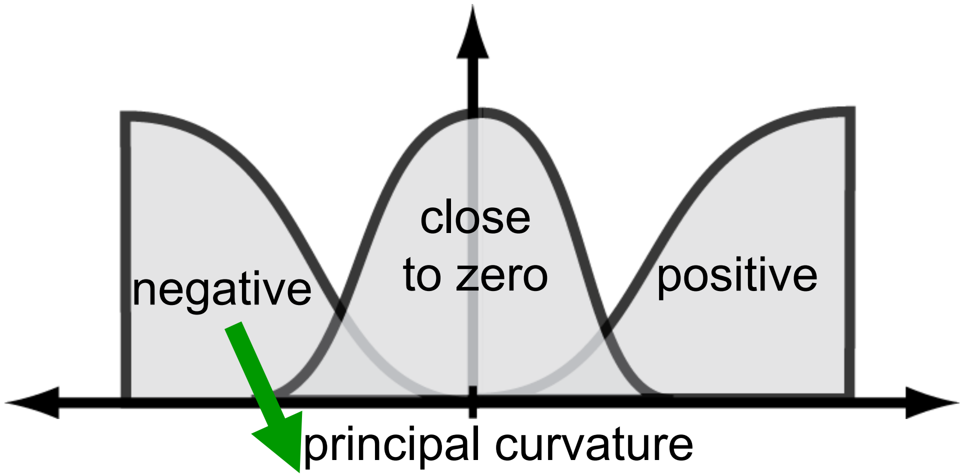
- if-part: semantics for volume attributes



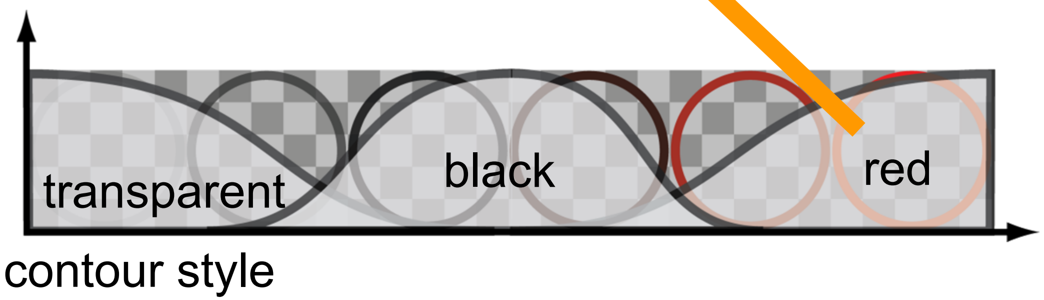
- then-part: semantics for visual appearance



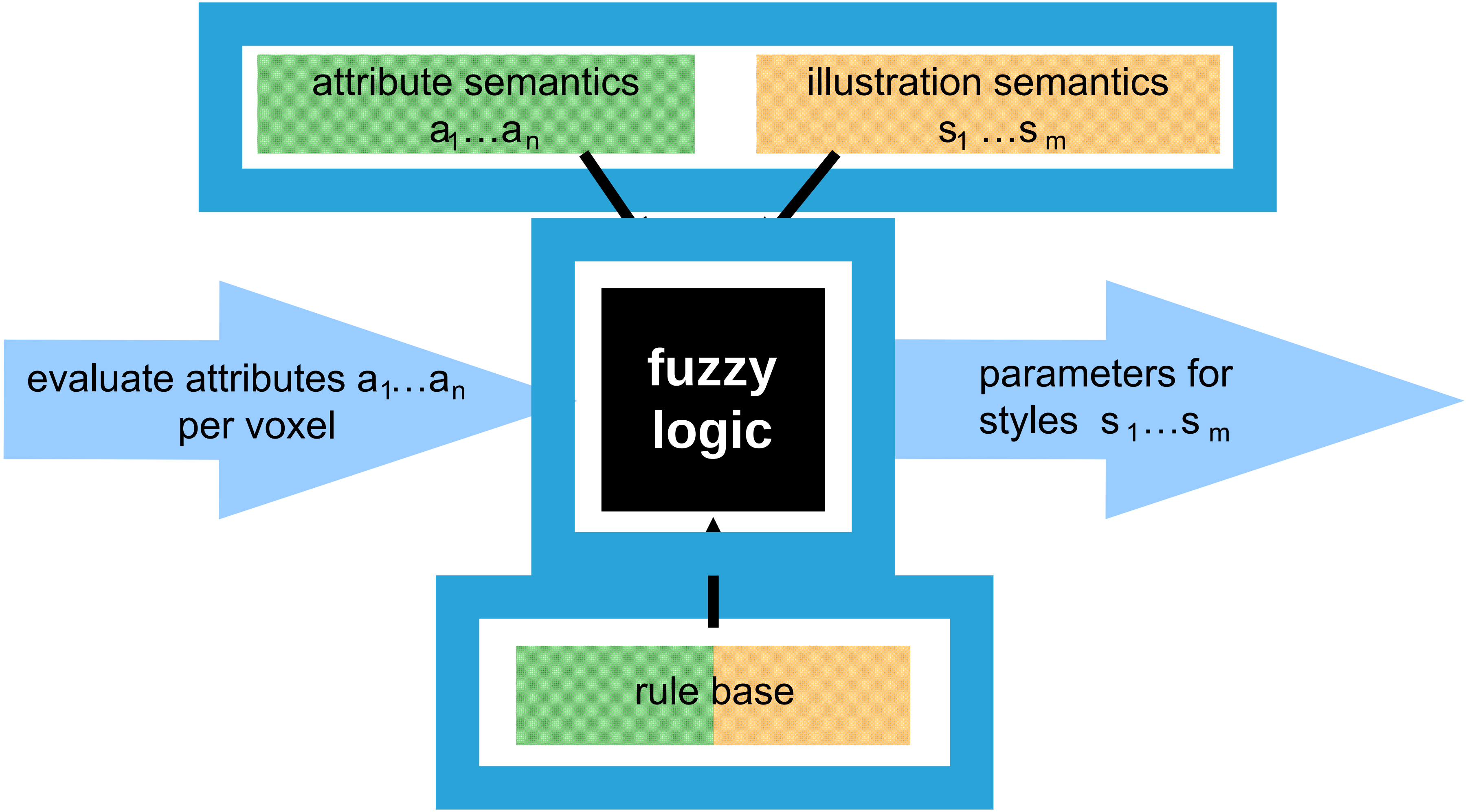
Rule Base



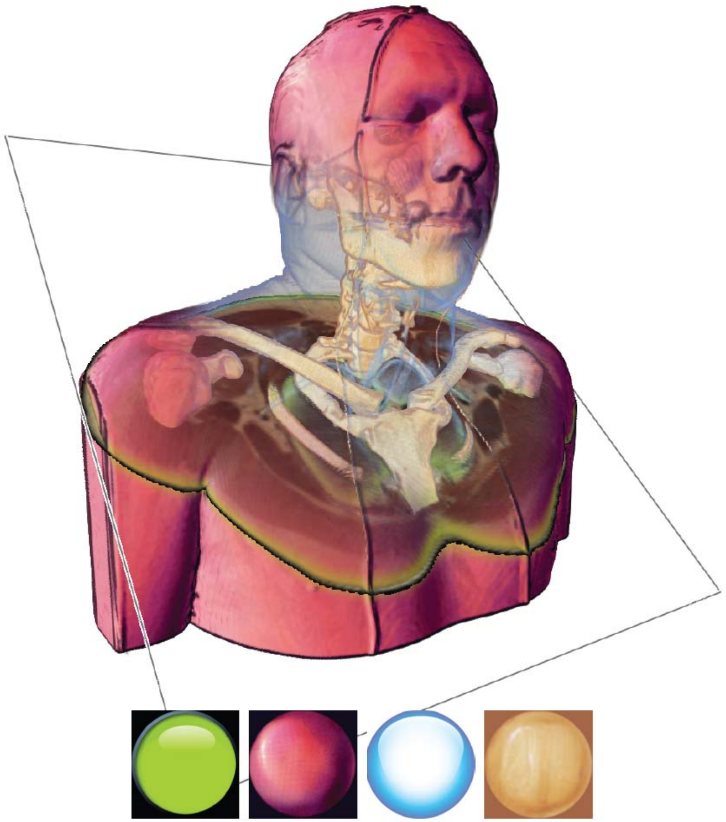
- if (principal curvature is negative and density is high and gradient magnitude is high) or distance to user focus is low
  then contour style is red



Fuzzy Logic Inside the Black Box



Semantics Driven Illustrative Rendering

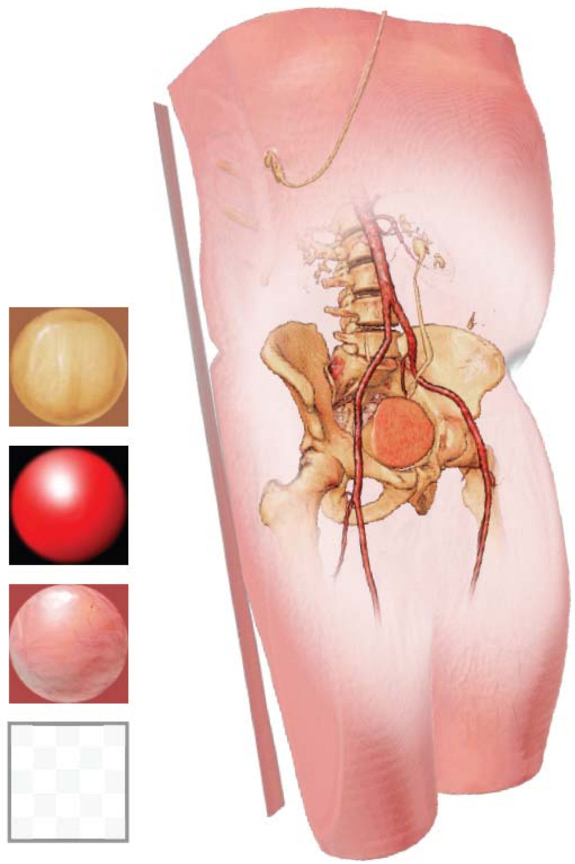


if *penetration depth is low* and *distance to focus is low*
then *skin-style is transparent white*

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

References (1)

- Matkovic, K., Hauser, H., Sainitzer, R., Gröller, E.: Process Visualization with Levels of Detail. IEEE Symposium on Information Visualization 2002 Proceedings, 2002, pp. 67-70.
- Viola, I., Feixas, M., Sbert, M., Gröller, E.: Importance-Driven Focus of Attention. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2006), 12(5):933-940, 2006.
- Balabanian, J-P., Viola, I., Ona, E., Patel, R., Gröller, E.: Sonar Explorer: A New Tool for Visualization of Fish Schools from 3D Sonar Data. Data Visualization – EUROVIS 2007, Proceedings Eurographics / IEEE-VGTC Symposium on Visualization (2007), pp. 155-162.
- Rautek, P., Bruckner, S., Gröller, E.: Semantic Layers for Illustrative Volume Rendering. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2007), 13(6):1336-1343, 2007.
- Kohlmann, P., Bruckner, S., Kanitsar, A., Gröller, E.: LiveSync: Deformed Viewing Spheres for Knowledge-Based Navigation. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2007), 13(6):1544-1551, 2007.
- Termeer, M., Bescós, J.O., Breeuwer, M., Vilanova, A., Gerritsen, F., Gröller, E.: CoViCAD: Comprehensive Visualization of Coronary Artery Disease. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2007), 13(6):1632-1639, 2007.
- Kohlmann, P., Bruckner, S., Kanitsar, A., Gröller, E.: LiveSync++: Enhancements of an Interaction Metaphor. Proceedings Graphics Interface 2008, pp. 81–88.
- Termeer, M., Bescós, J.O., Breeuwer, M., Vilanova, A., Gerritsen, F., Gröller, E., Nagel, E.: Visualization of Myocardial Perfusion Derived from Coronary Anatomy. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2008), 14(6):1595–1602, 2008.
- Balabanian, J-P., Viola, I., Gröller, E.: Interactive Illustrative Visualization of Hierarchical Volume Data. Proceedings of Graphics Interface 2010, May 31st–June 2nd, 2010, Ottawa, Ontario, Canada, pp . 137–144.
- Malik, M.M., Heinzl, C.; Gröller, E.: Comparative Visualization for Parameter Studies of Dataset Series. IEEE Transactions on Visualization and Computer Graphics, 16(5):829–840, 2010.
- Waser, J., Fuchs, R., Ribičić, H., Schindler, B., Blöschl, G., Gröller, E.: World Lines. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2010), 16(6):1458–1467, 2010.

References (2)

- van Pelt, R., Bescós, J.O., Breeuwer, M., Clough, R.E., Gröller, E., ter Haar Romenij, B., Vilanova, A.: Exploration of 4D MRI Blood-Flow using Stylistic Visualization. IEEE Transactions on Visualization and Computer Graphics 16(6):1339–1347, 2010.
- Berger, W., Piringer, H., Filzmoser, P., Gröller, E.: Uncertainty-Aware Exploration of Continuous Parameter Spaces Using Multivariate Prediction. Computer Graphics Forum, 30(3):911–920, 2011.
- Waser, J., Ribičić H., Fuchs, R., Hirsch, Ch., Schindler, B., Blöschl, G., Gröller, E.: Nodes on Ropes: A comprehensive Data and Control Flow for Steering Ensemble Simulations. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2011), 17(12):1872–1881, 2011.
- Muigg, Ph., Hadwiger, M., Doleisch, H., Gröller, E.: Interactive Volume Visualization of General Polyhedral Grids. IEEE Transactions on Visualization and Computer Graphics (Proc. Visualization 2011), 17(12):2115–2124, 2011.
- van Pelt, R., Bescós, J.O., Breeuwer, M., Clough, R.E., Gröller, E., ter Haar Romenij, B., Vilanova, A.: Interactive Virtual Probing of 4D MRI Blood-Flow. IEEE Transactions on Visualization and Computer Graphics 17(12):2153–2162, 2011.
- Ribičić, H., Waser, J., Gurbat, R., Sadransky, B., Gröller, E.: Sketching Uncertainty into Simulations. IEEE Transactions on Visualization and Computer Graphics, 18(12):2255–2264, 2012. doi: 10.1109/TVCG.2012.261.

Trends in Visual Computing

- Abstract: Data Visualization uses computer-supported, interactive, visual representations of (abstract) data to amplify cognition. Visualization is an essential part of Visual Computing which in turn is concerned with the acquisition, representation, processing, analysis, synthesis, and usage of visual information. The talk discusses various challenges in visual computing. In recent years data complexity and variability has increased considerably. This is due to new data sources as well as the availability of uncertainty, error and tolerance information. Visual steering supports decision making in the presence of alternative scenarios. Multiple, related simulation runs are explored through branching operations. To account for uncertain knowledge about the input parameters, visual reasoning employs entire parameter distributions. This can lead to an uncertainty-aware exploration of (continuous) parameter spaces. Multivariate and heterogeneous data call for visual analysis and knowledge-assisted interaction. To cope with intensified scalability issues and distributed processing approaches, advanced strategies are required like comparative visualization, integrated views and inclusion of fuzzy sets in the visualization process. Examples concerning the aforementioned topics will be presented in the talk.