Volume Visualization

Tutorial on Information Theory in Visualization

Ivan Viola

EUROGRAPHICS 2016

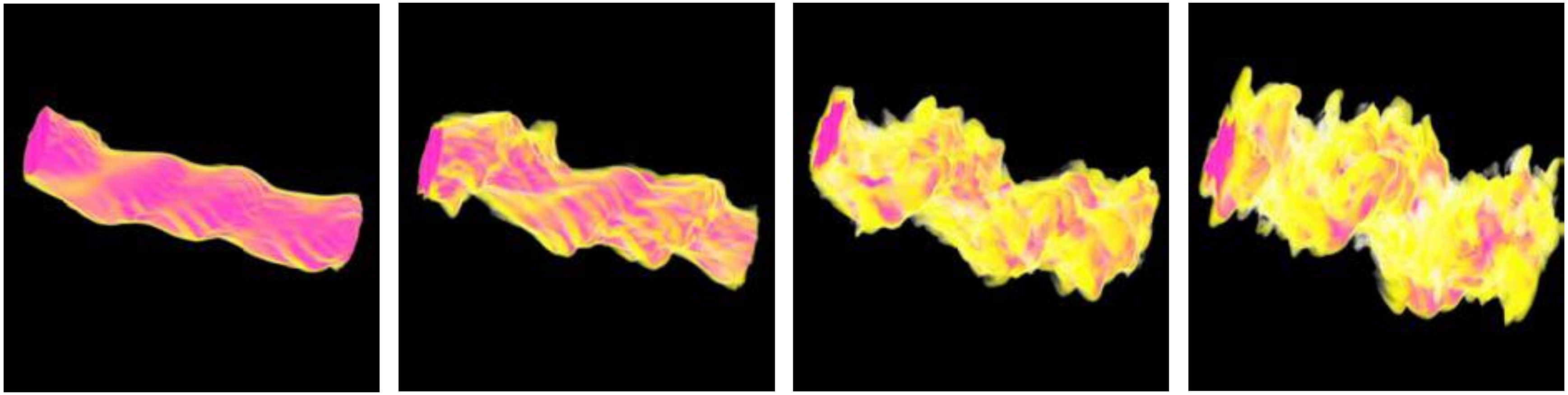
UdG UNIVERSITY OF OXFORD TU WIEN

Topics

- Time-Varying Data
- Level-of-Detail Selection
- Iso-Surfaces
- Splitting
- Transfer function specification
- Multimodal volume visualization

View Selection for Volume Data

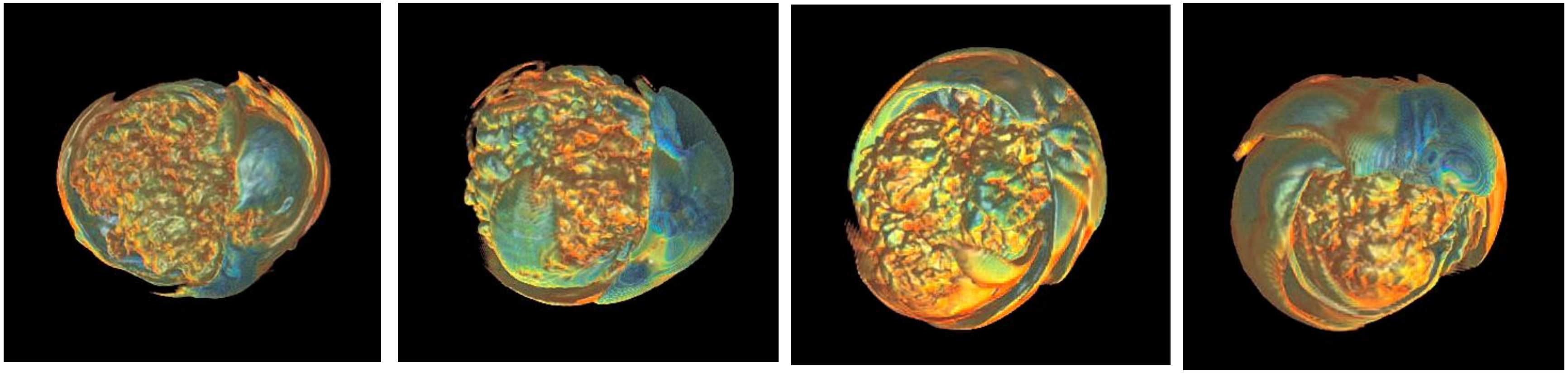
- 3D scalar fields (over time)
- Viewpoint quality: visibility of voxels
- Importance (noteworthiness) based on the opacity value
- Measure: Viewpoint Entropy
- View selection for time-series uses Conditional Entropy



[Bordoloi and Shen 2005]

Camera Path for Volumes over Time

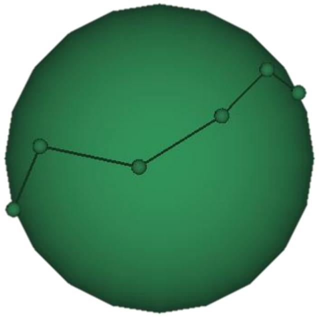
- Guided fly over interesting structures
- Voxel relevance is based on
  - Opacity
  - Curvature
  - Color from transfer function

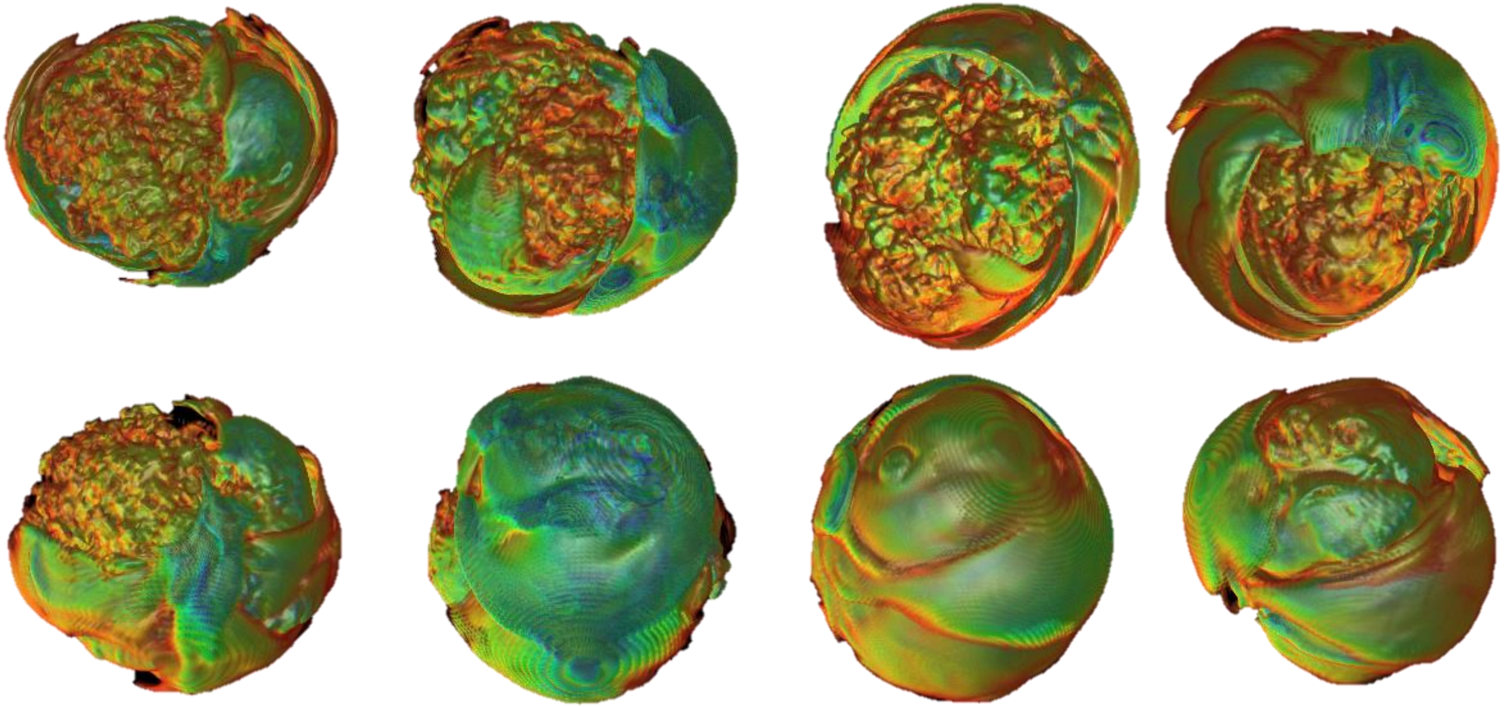


[Ji and Shen 2006]

Camera Path for Volumes over Time

- Evaluate the best path through recursion
- Acceleration limits the search space

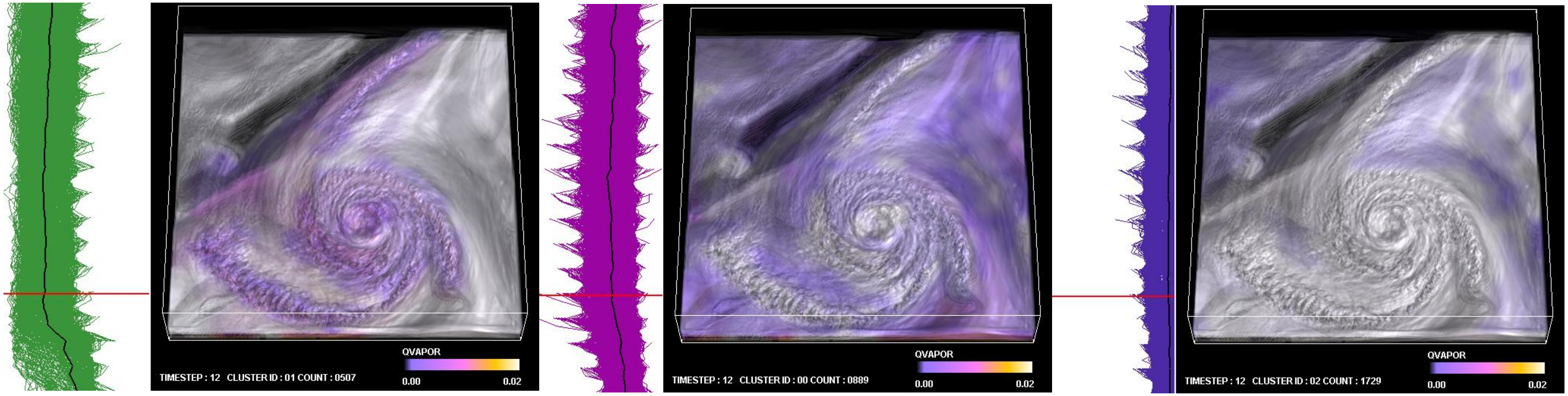




[Ji and Shen 2006]

Importance-Driven Visualization

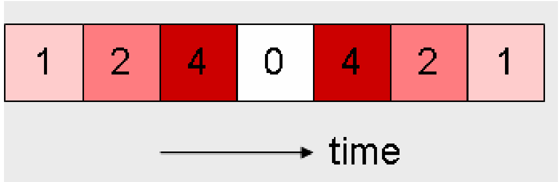
- Quantify data importance using conditional entropy
- Cluster the importance curves
- Leverage the importance in visualization

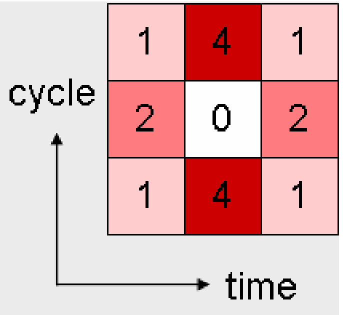


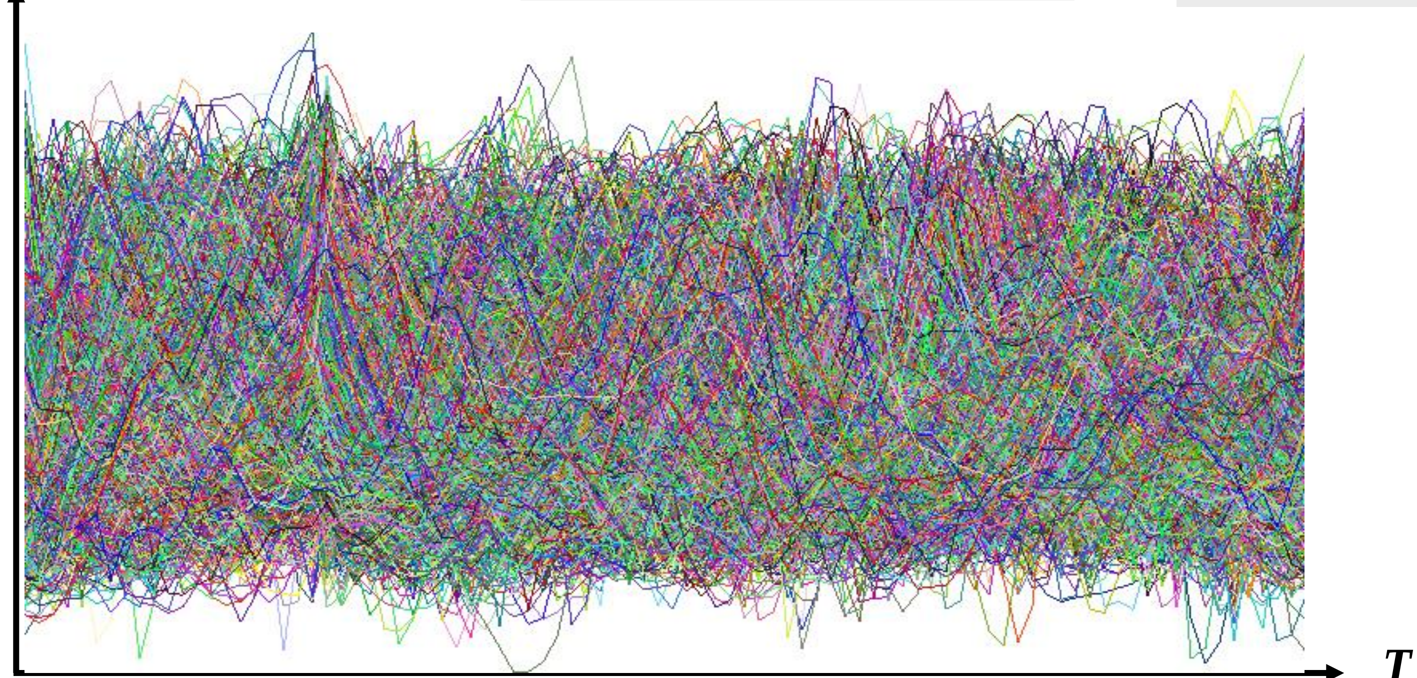
[Wang et al. 2008]

Importance-Driven Visualization

- Joint Feature-Temporal Histogram



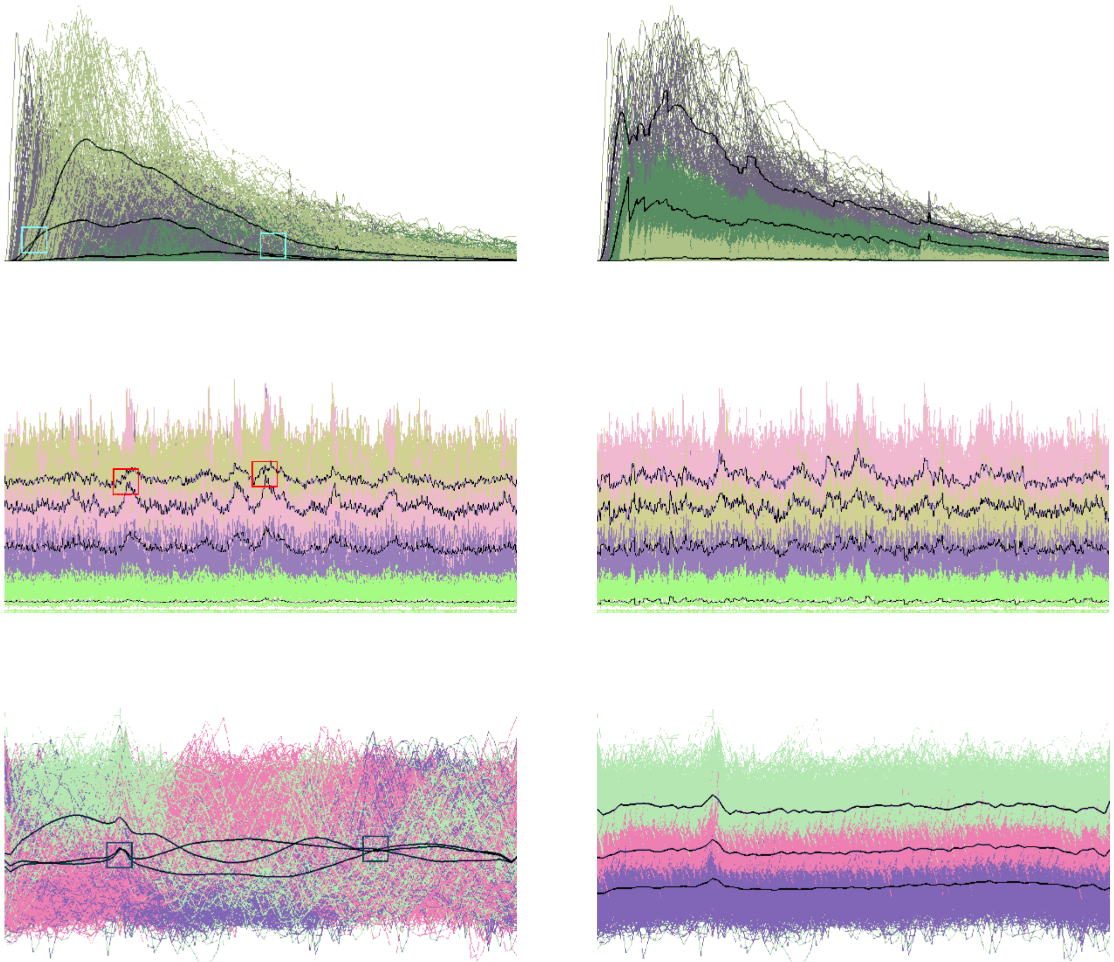




[Wang et al. 2008]

Importance-Driven Visualization

- Clustering Time-Steps vs. Time-Segments



599 time steps

50 segments

1200 time steps

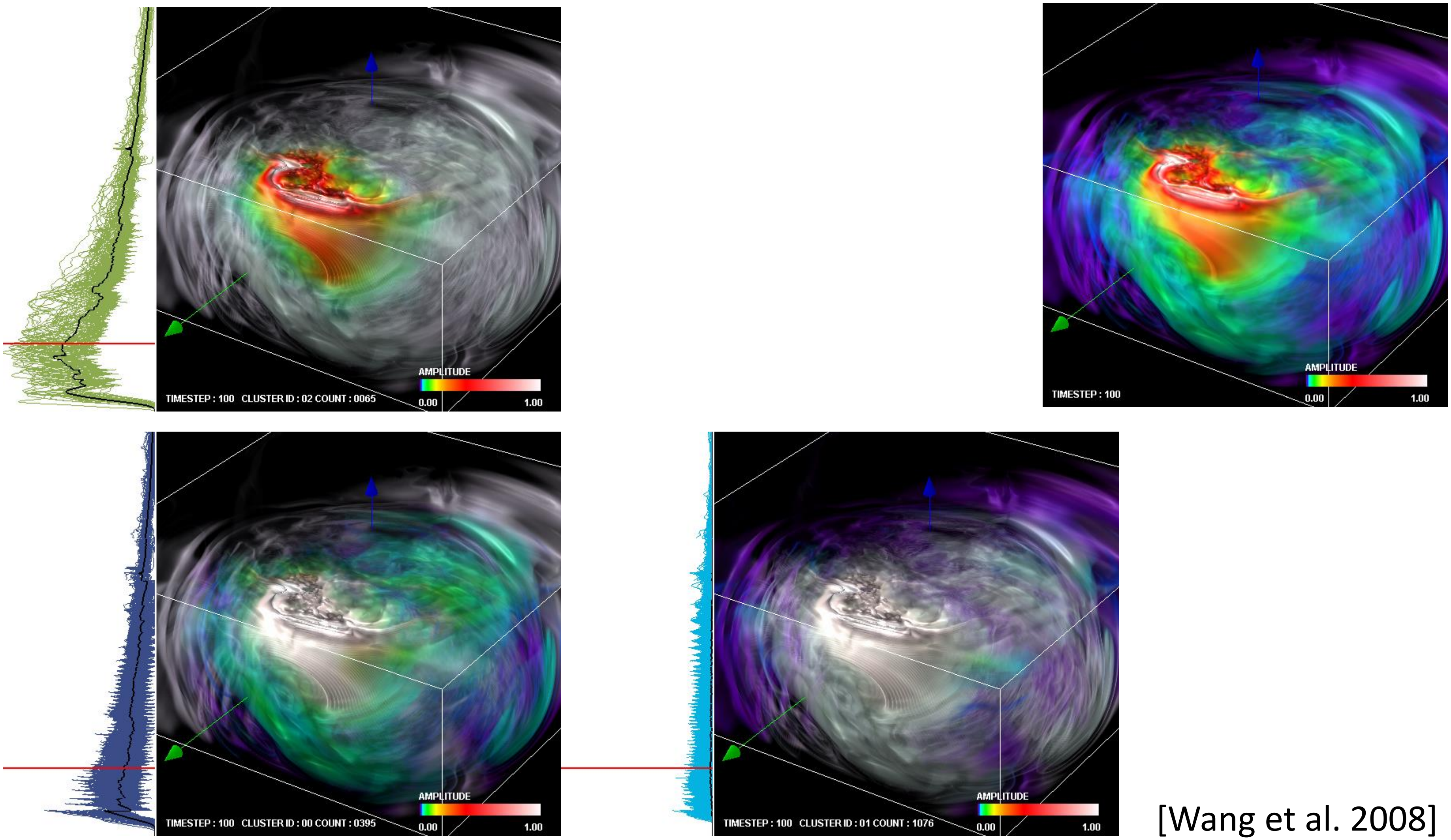
120 segments

90 time steps

90 segments

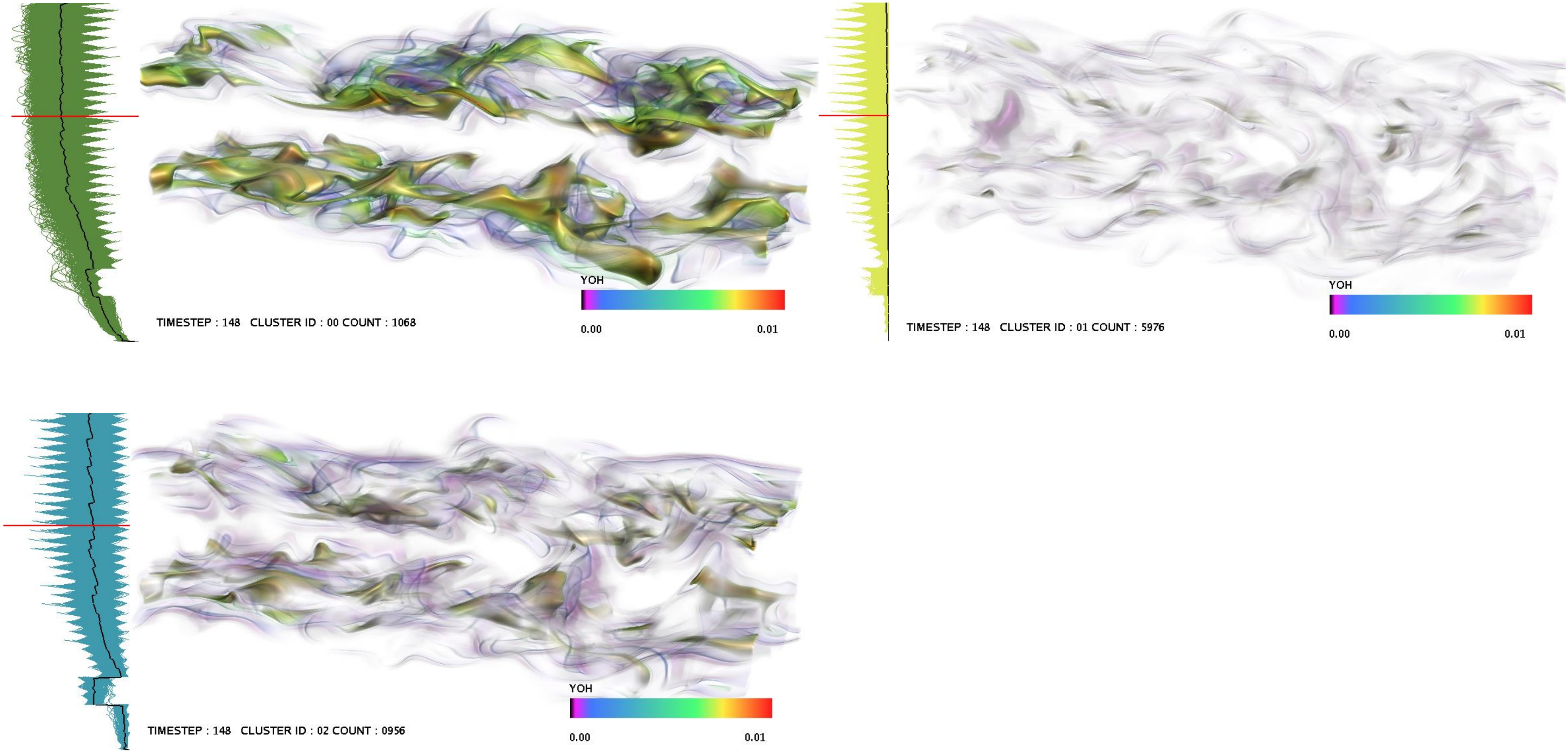
[Wang et al. 2008]

Importance-Driven Visualization



[Wang et al. 2008]

Importance-Driven Visualization

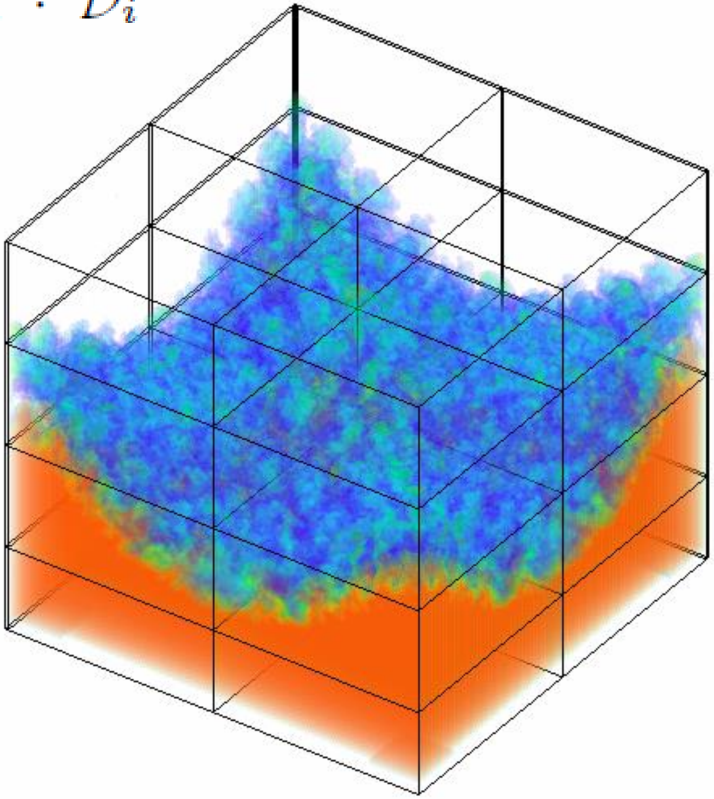


[Wang et al. 2008]

Multi-Resolution Volumes

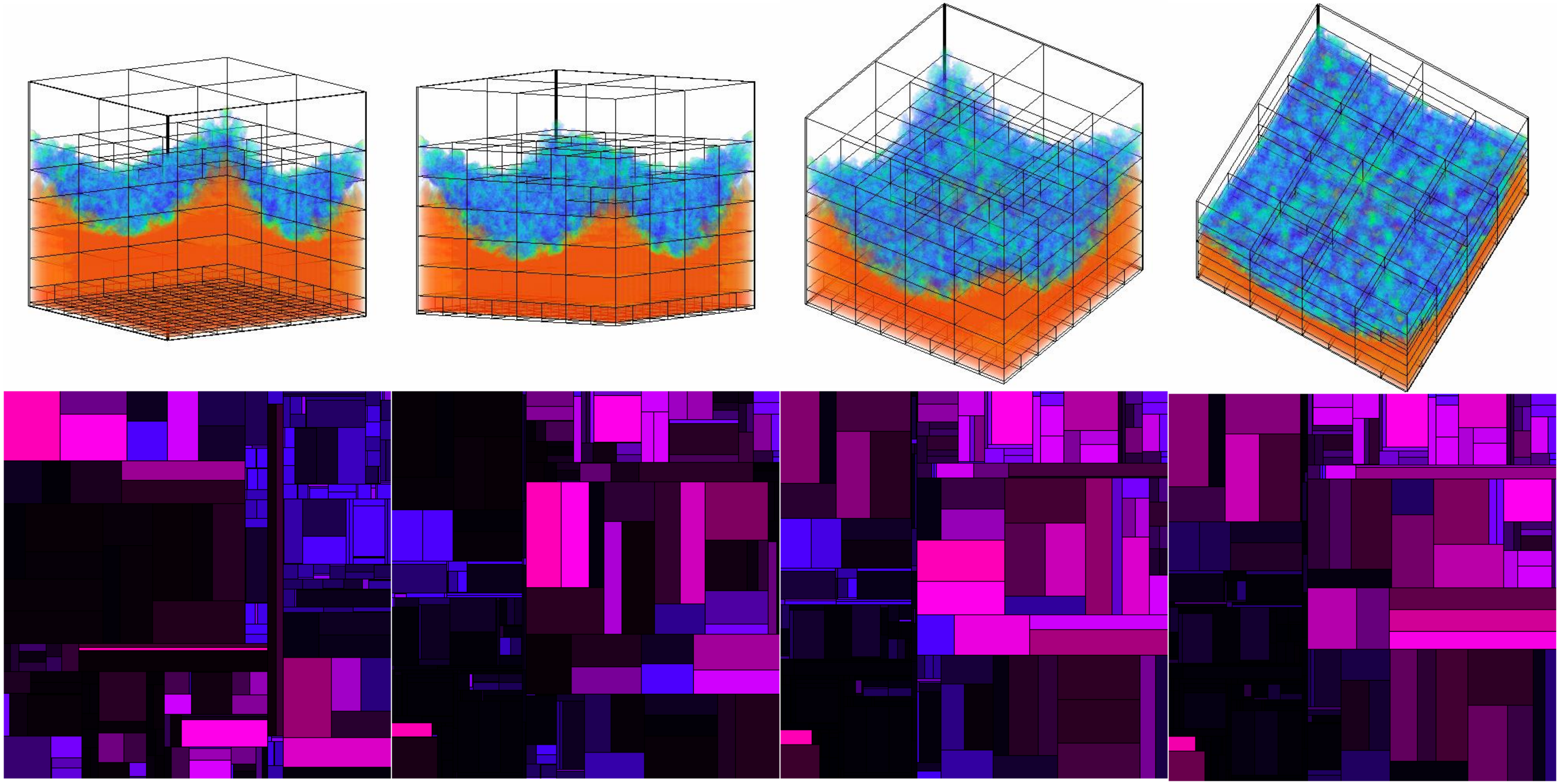
- Distortion (D) and Contribution (C) characteristics of a multiresolution block
- Level-of-Detail quality evaluated via Entropy measure
- Constraint is the block budget

$$p_i = \frac{\mathcal{C}_i \cdot \mathcal{D}_i}{\sum_{i=1}^{M} \mathcal{C}_i \cdot \mathcal{D}_i}$$



[Wang and Shen 2006]

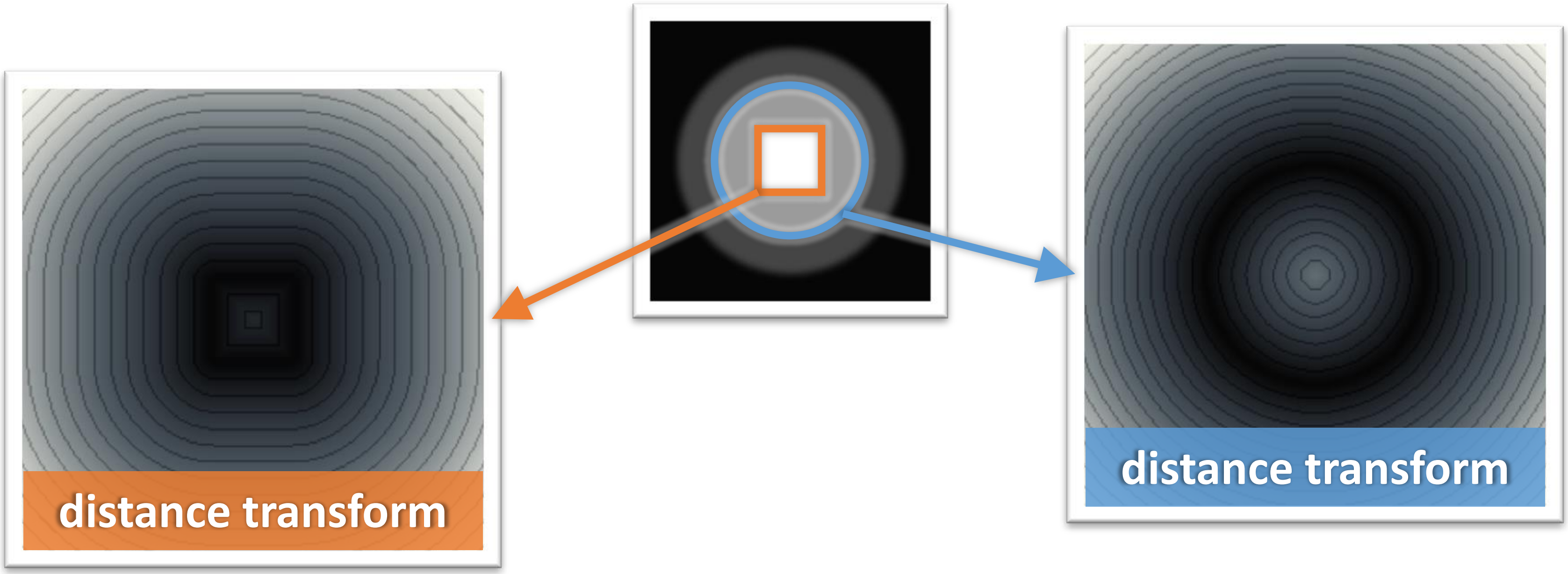
Multi-Resolution Volumes



[Wang and Shen 2006]

Iso-Surface Similarity Maps

- Compare iso-surfaces through evaluating mutual information of their distance volume
  - *X* and *Y* are **independent**: $I(X,Y) = 0$
  - *X* and *Y* are **identical**: $I(X,Y) = H(X) = H(Y)$

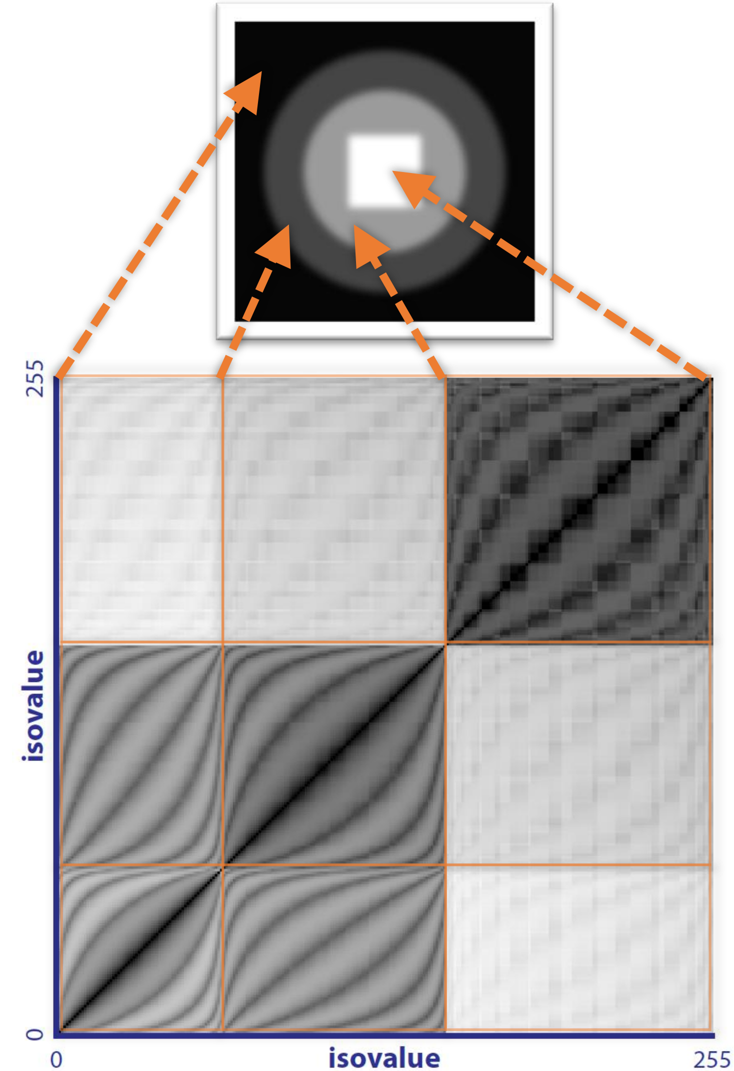


[Bruckner and Möller 2010]

Iso-Surface Similarity Maps

- Normalized measure

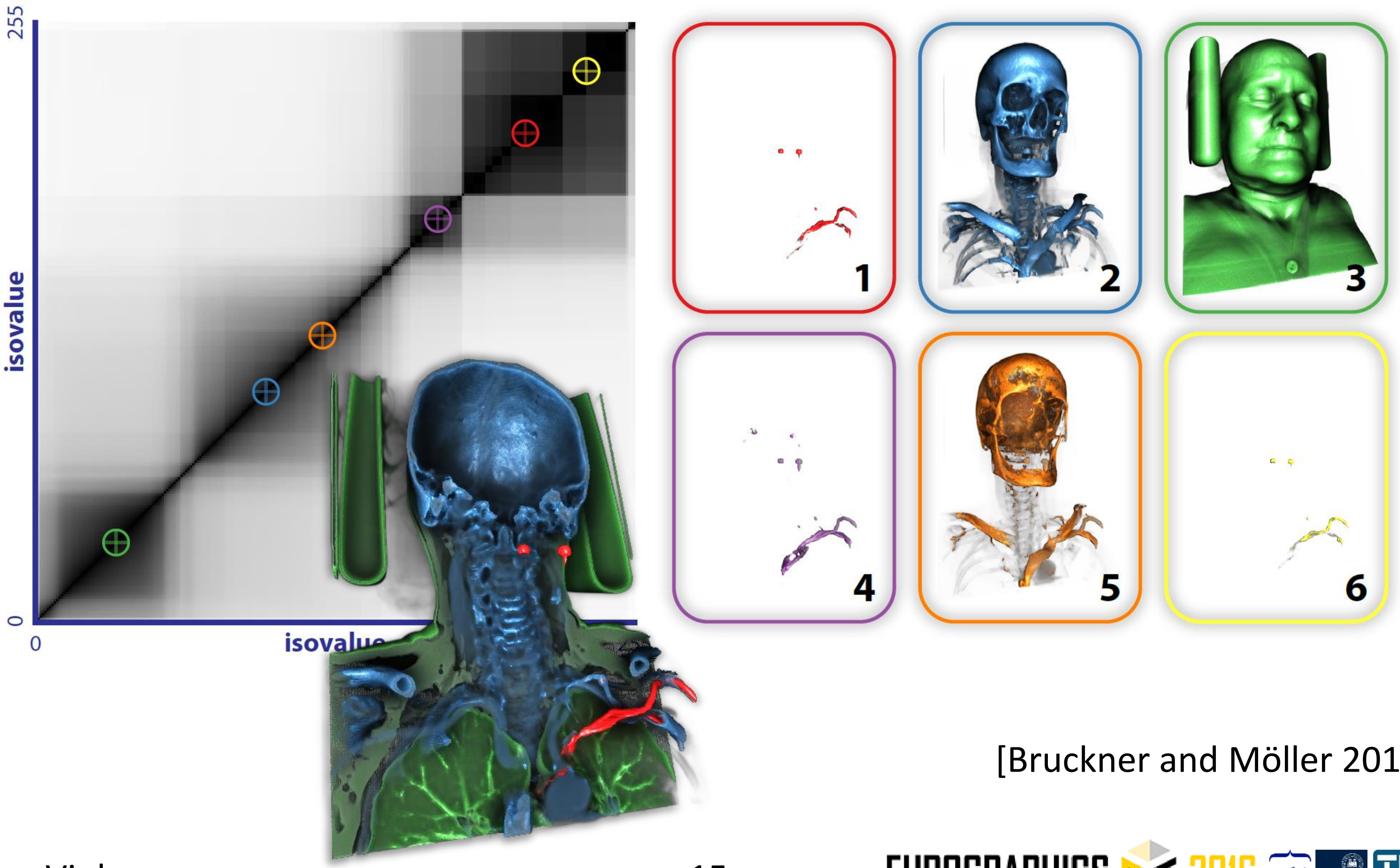
$$\hat{I}(X,Y) = \frac{2I(X,Y)}{H(X)+H(Y)}$$



[Bruckner and Möller 2010]

Iso-Surface Similarity Maps

- Selection of characteristic iso-surfaces



[Bruckner and Möller 2010]

Similarity-Based Exploded Views

- A two step process is proposed to automatically obtain the partitioning planes:
  - Explosion axis: selection of the most structured view
  - Partitioning of the data: slices are grouped according to the maximization of a similarity criterion

[Ruiz et al. 2008]

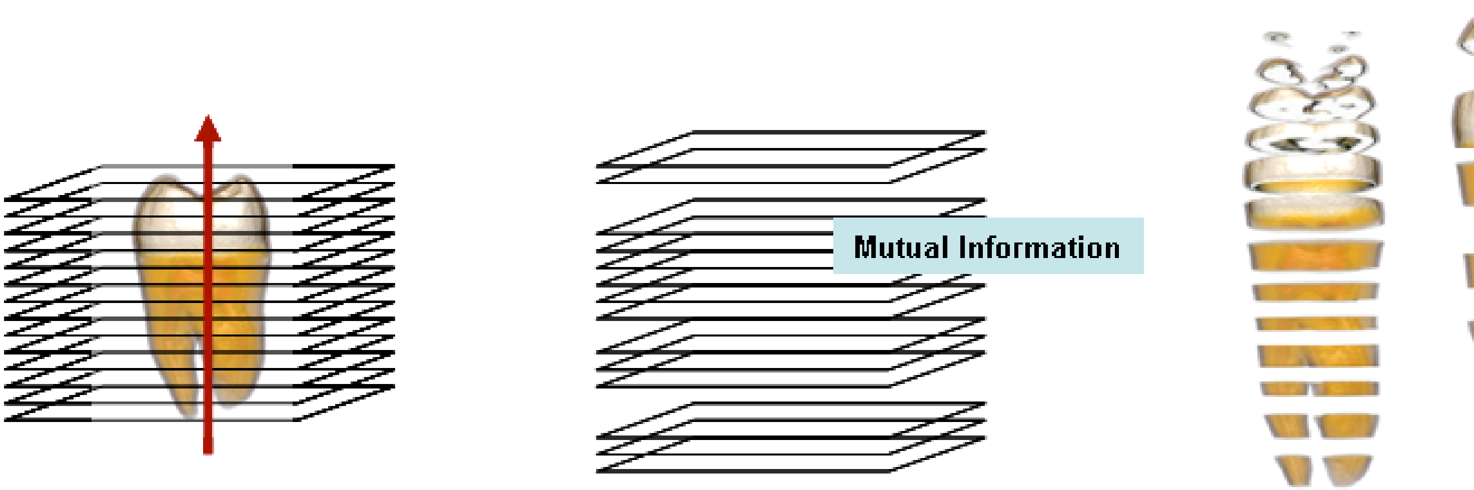
Similarity-Based Exploded Views

- **Structured View** measured through Entropy Rate
  measure of the randomness or unpredictability of a system

[Ruiz et al. 2008]

Similarity-Based Exploded Views

- **Bottom-up Grouping**: group the most similar slices or slabs through normalized mutual information
  degree of similarity or shared information between two slices or slabs



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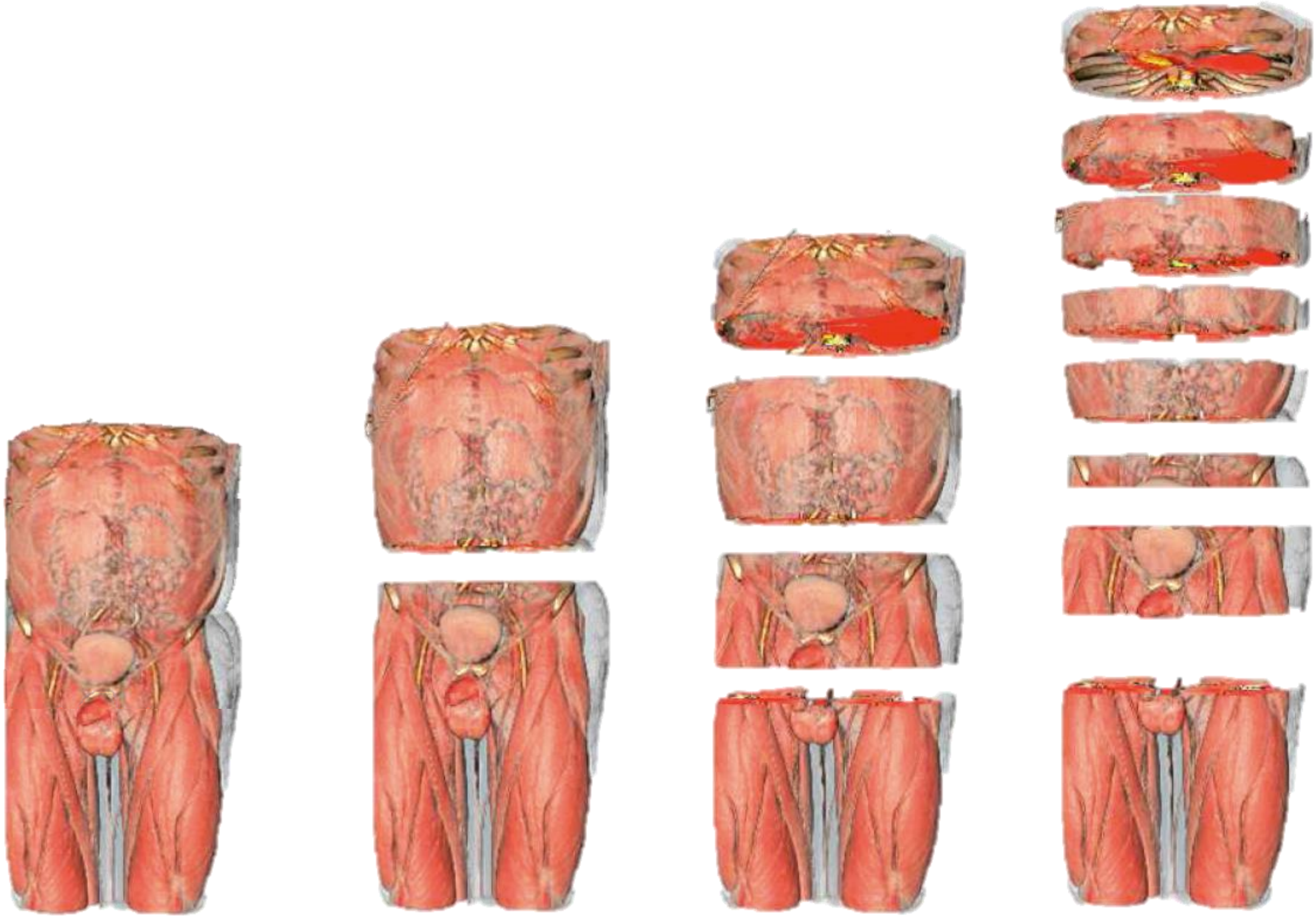
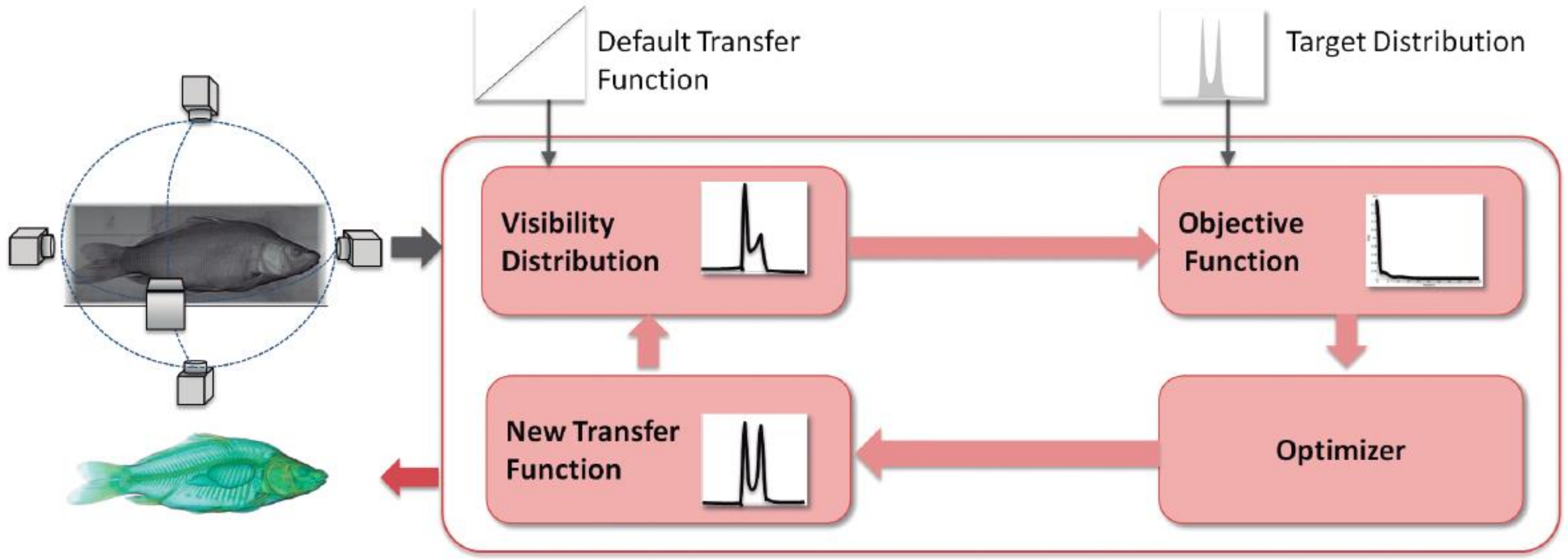
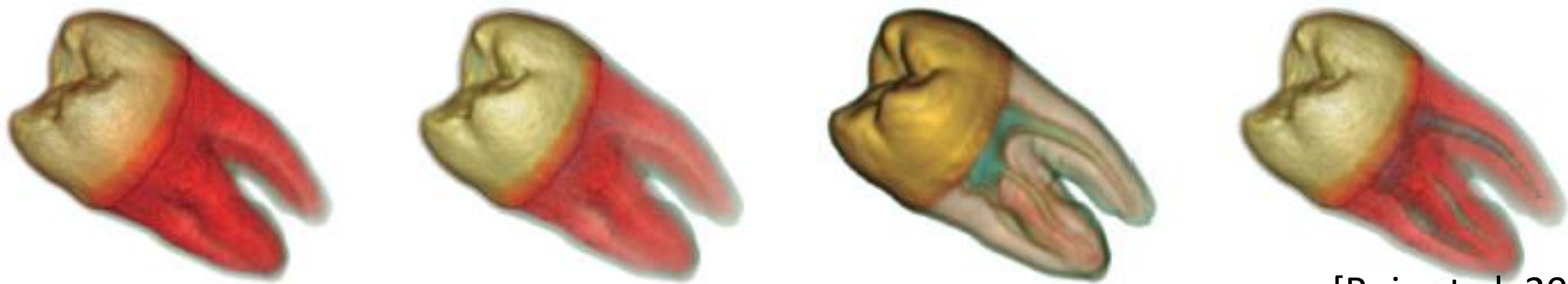
Similarity-Based Exploded Views



[Ruiz et al. 2008]

Transfer Functions for Scalar Fields





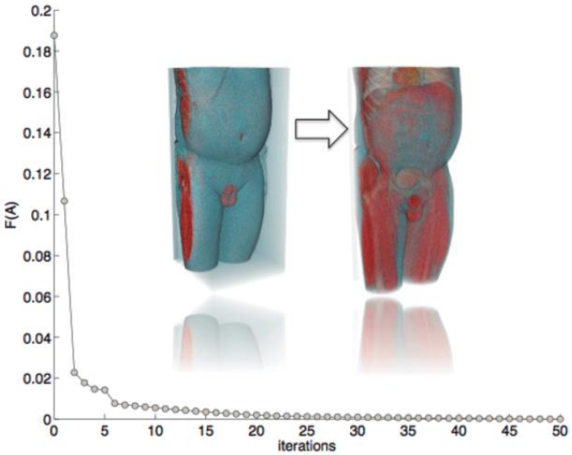
[Ruiz et al. 2011]

Transfer Functions for Scalar Fields

- Target Function: Intuitive specification of visual prominence for density values
- Minimize informational divergence between the average projected visibility distribution from all viewpoints and a target distribution
- Optimizer: Steepest Gradient Descent

$$A^t = A^{t-1} - s^{t-1} \nabla F(A)$$

$$\nabla F(A) = \left(\frac{\partial\, F(A)}{\partial \alpha_0}; \frac{\partial\, F(A)}{\partial \alpha_1}; \frac{\partial\, F(A)}{\partial \alpha_{n-1}} \right)$$



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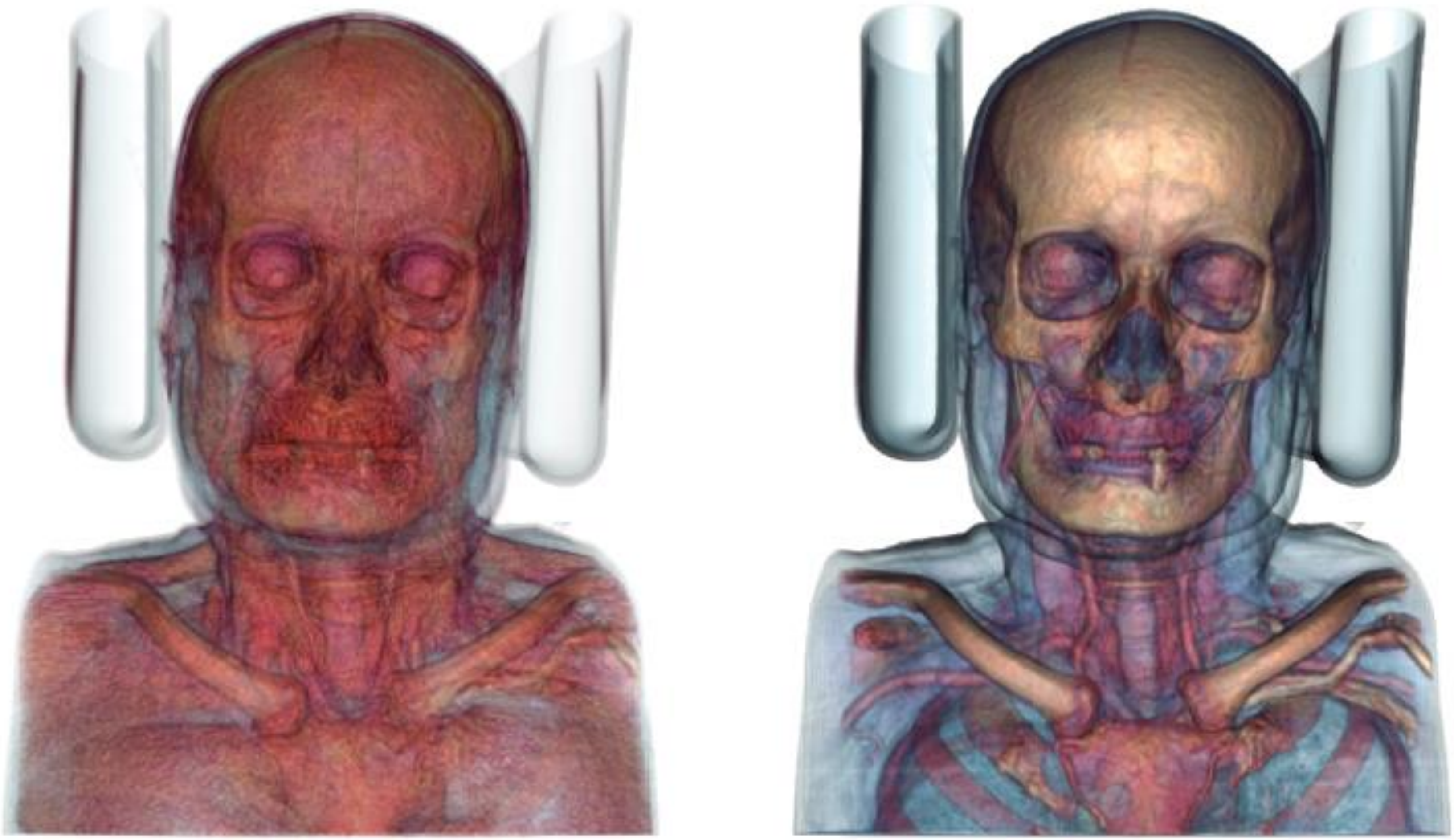

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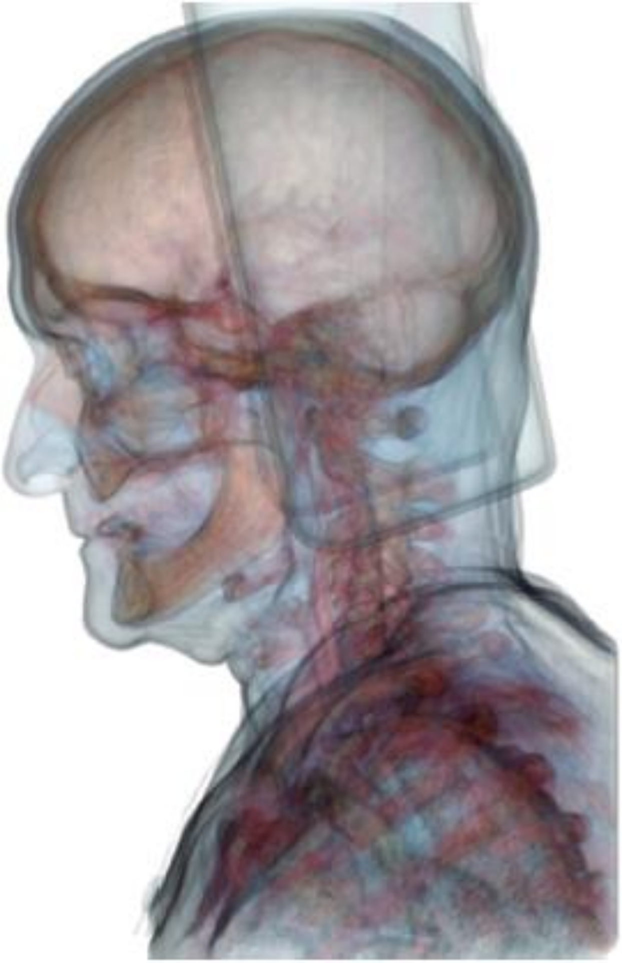
Transfer Functions for Scalar Fields



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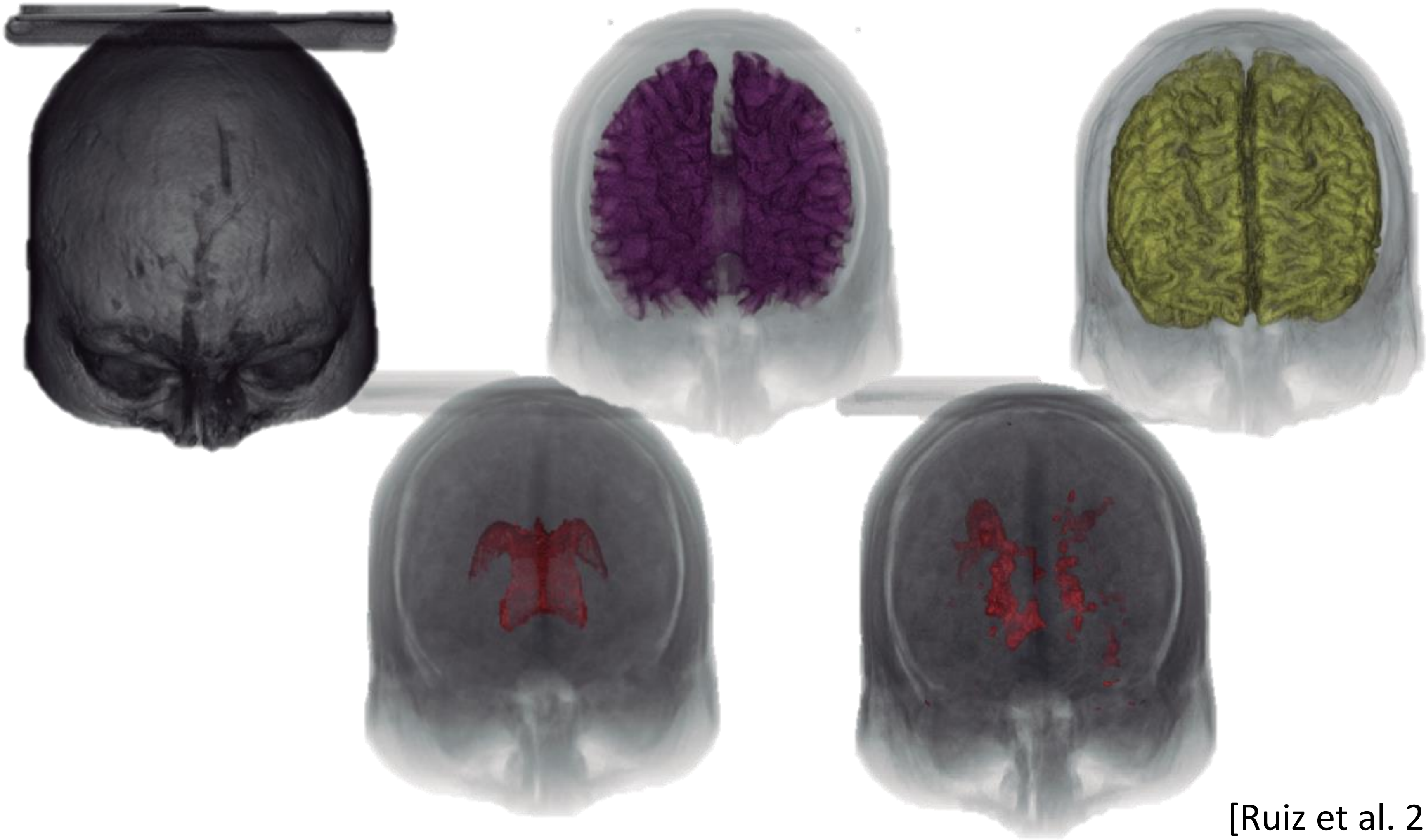
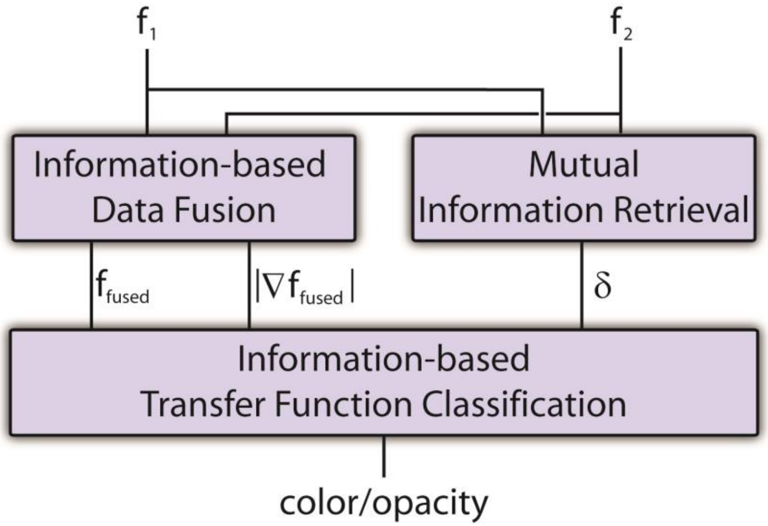
Transfer Functions for Scalar Fields



[Ruiz et al. 2011]

Multimodal Data Fusion

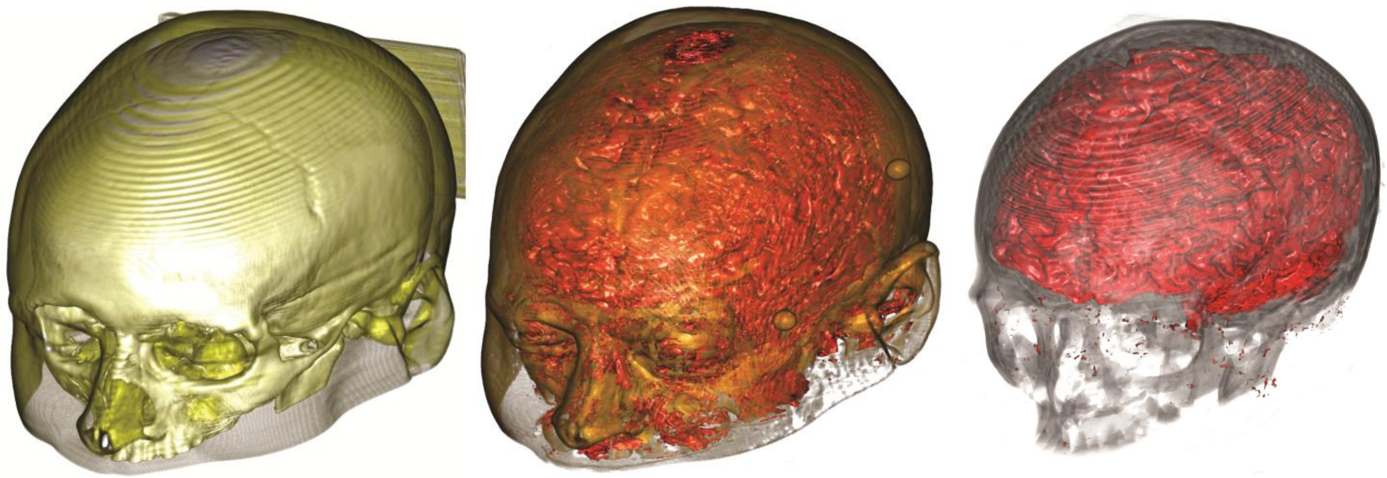


$$I(f) = -log_2(P(f))$$

$$\gamma(f_1, f_2) = \frac{I(f_2)}{I(f_1) + I(f_2)}$$

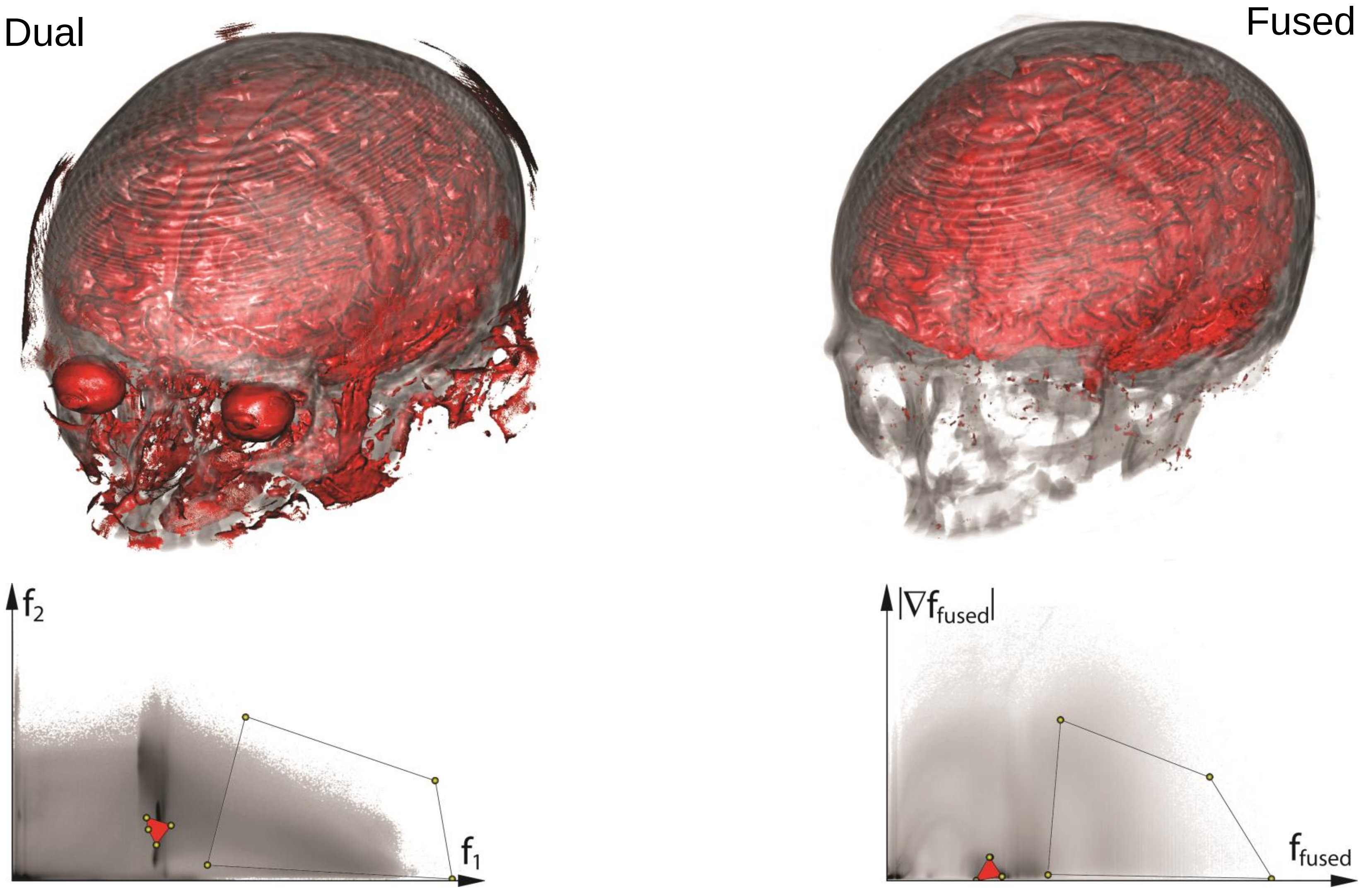
$$f_{fused} = (1-\gamma) * f_1 + \gamma * f_2$$

$$\nabla f_{fused} = (1-\gamma) * \nabla f_1 + \gamma * \nabla f_2$$



[Haidacher et al. 2008]

Multimodal Data Fusion



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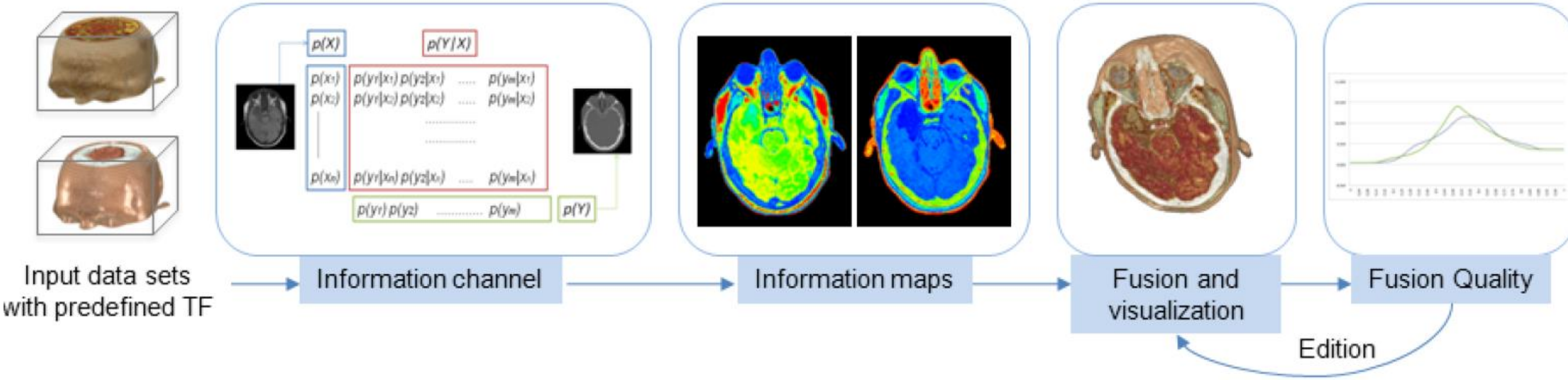
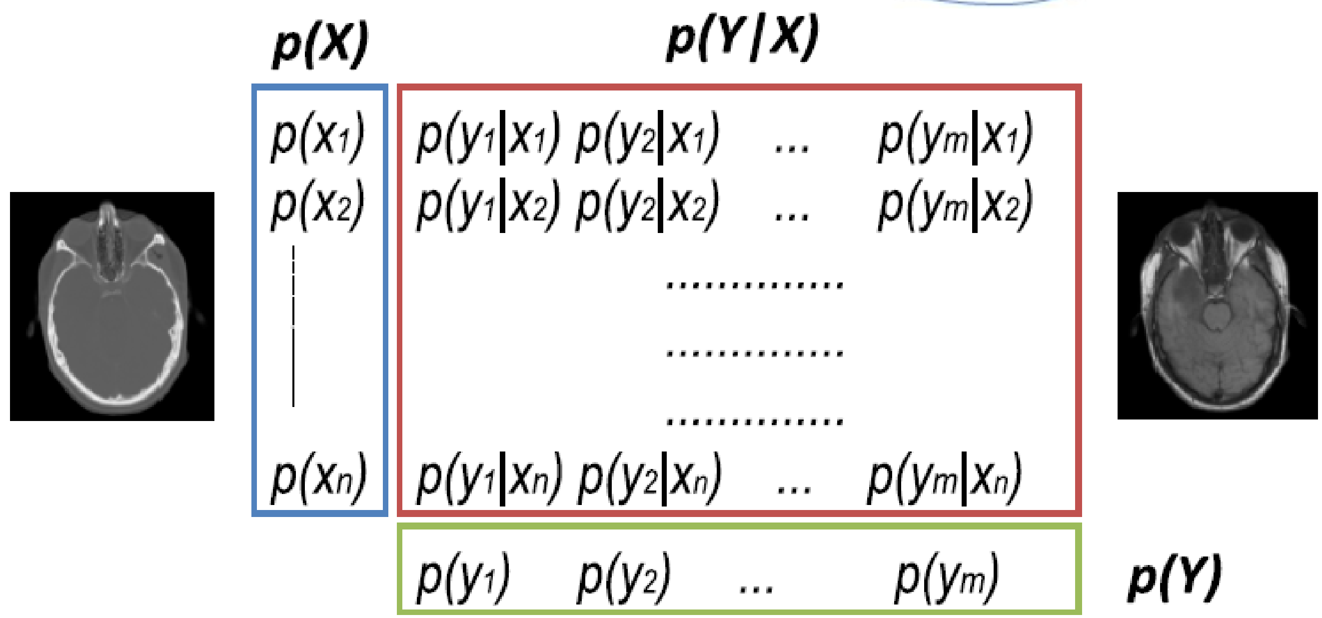
Multimodal Visual Fusion





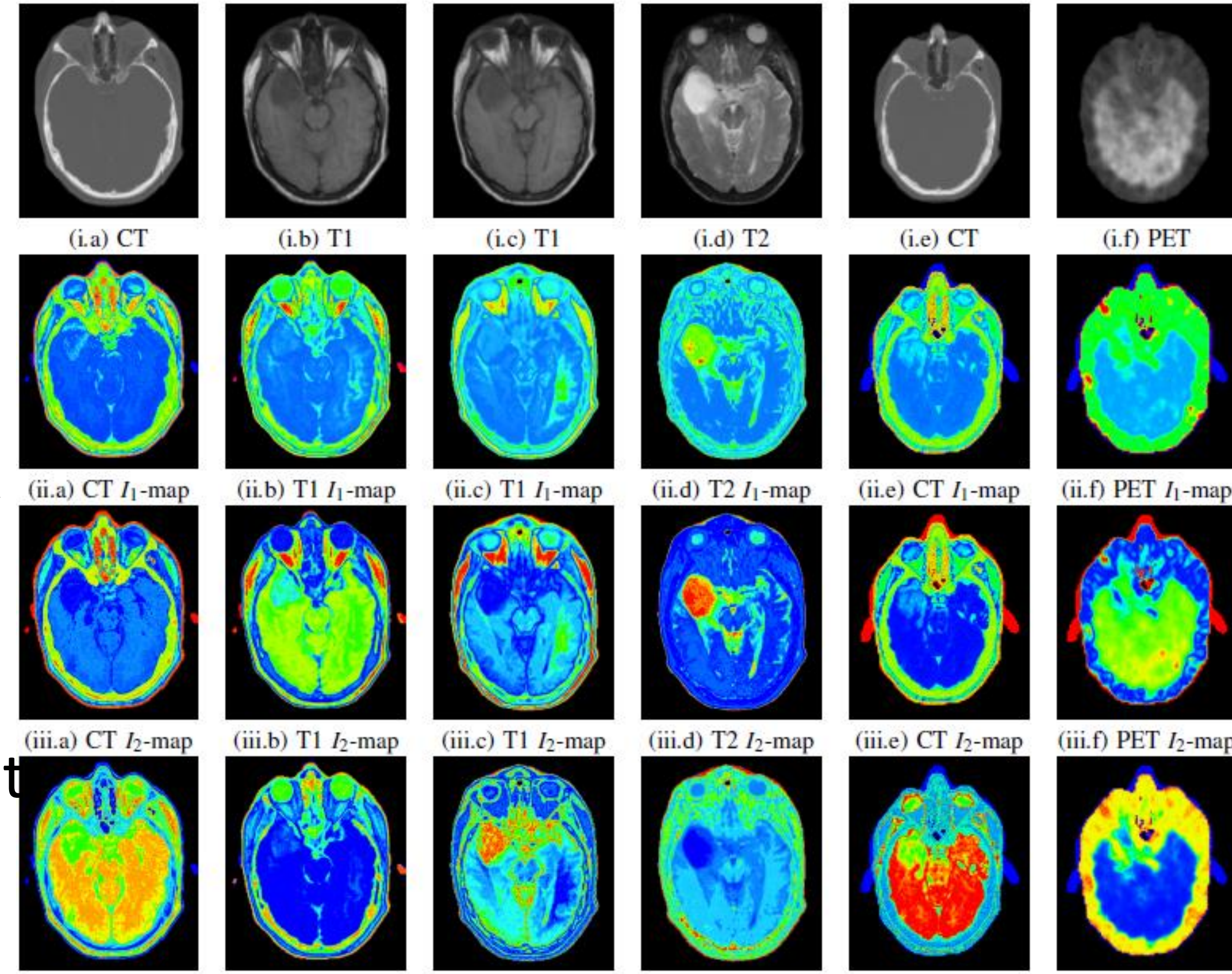
[Bramon et al. 2012]

Multimodal Visual Fusion

Surprise
I_1

Predictability
I_2

Entanglement
I_3



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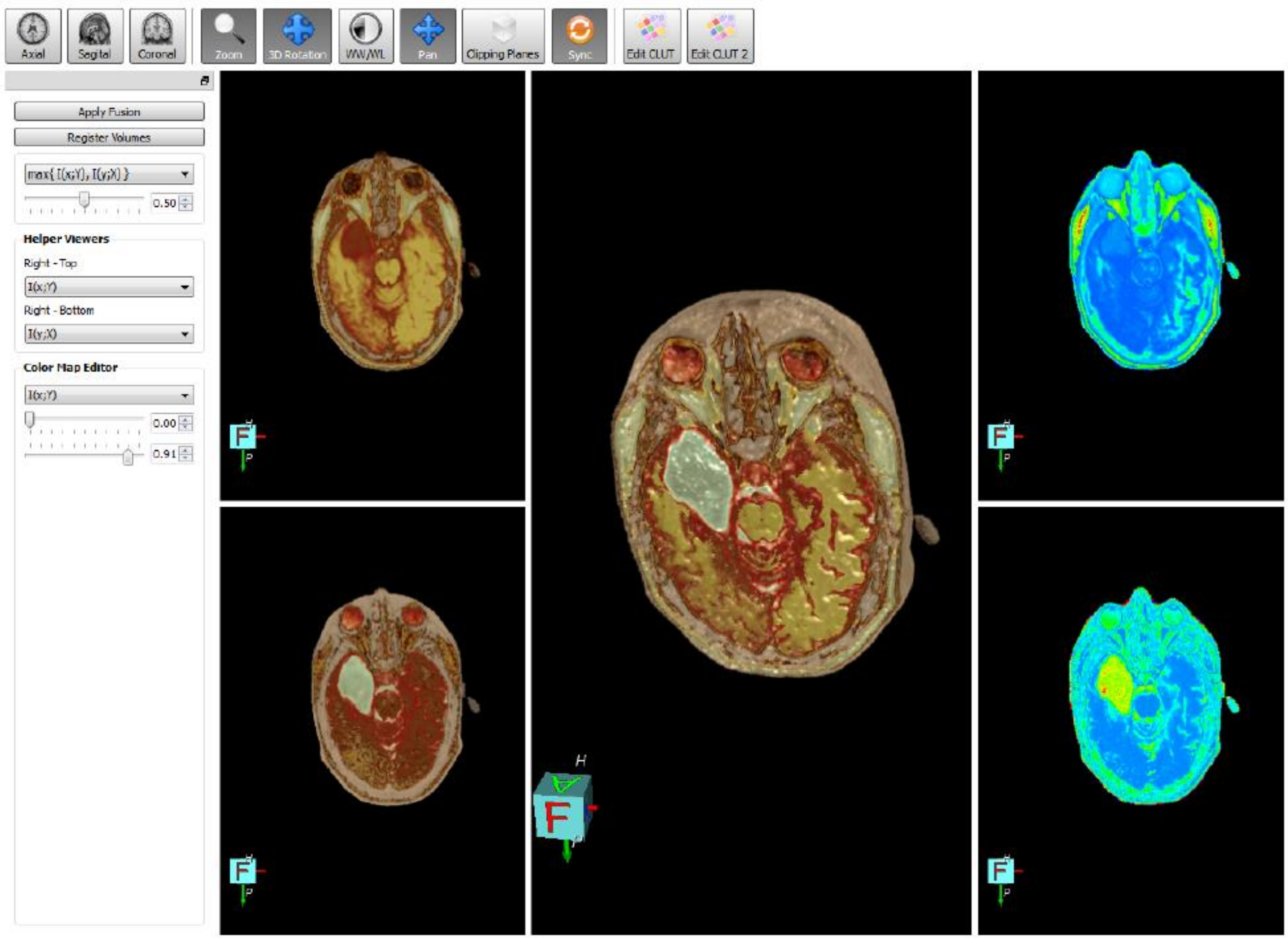
Multimodal Visual Fusion



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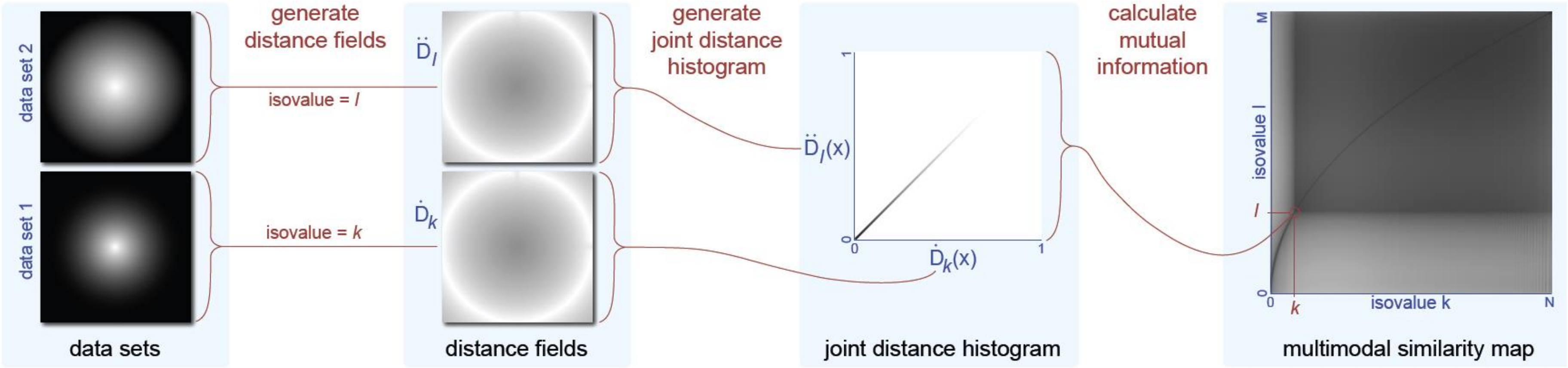
Multimodal Surface Fusion

- Isosurface Similarity Maps extended to support Multi-Modal Data



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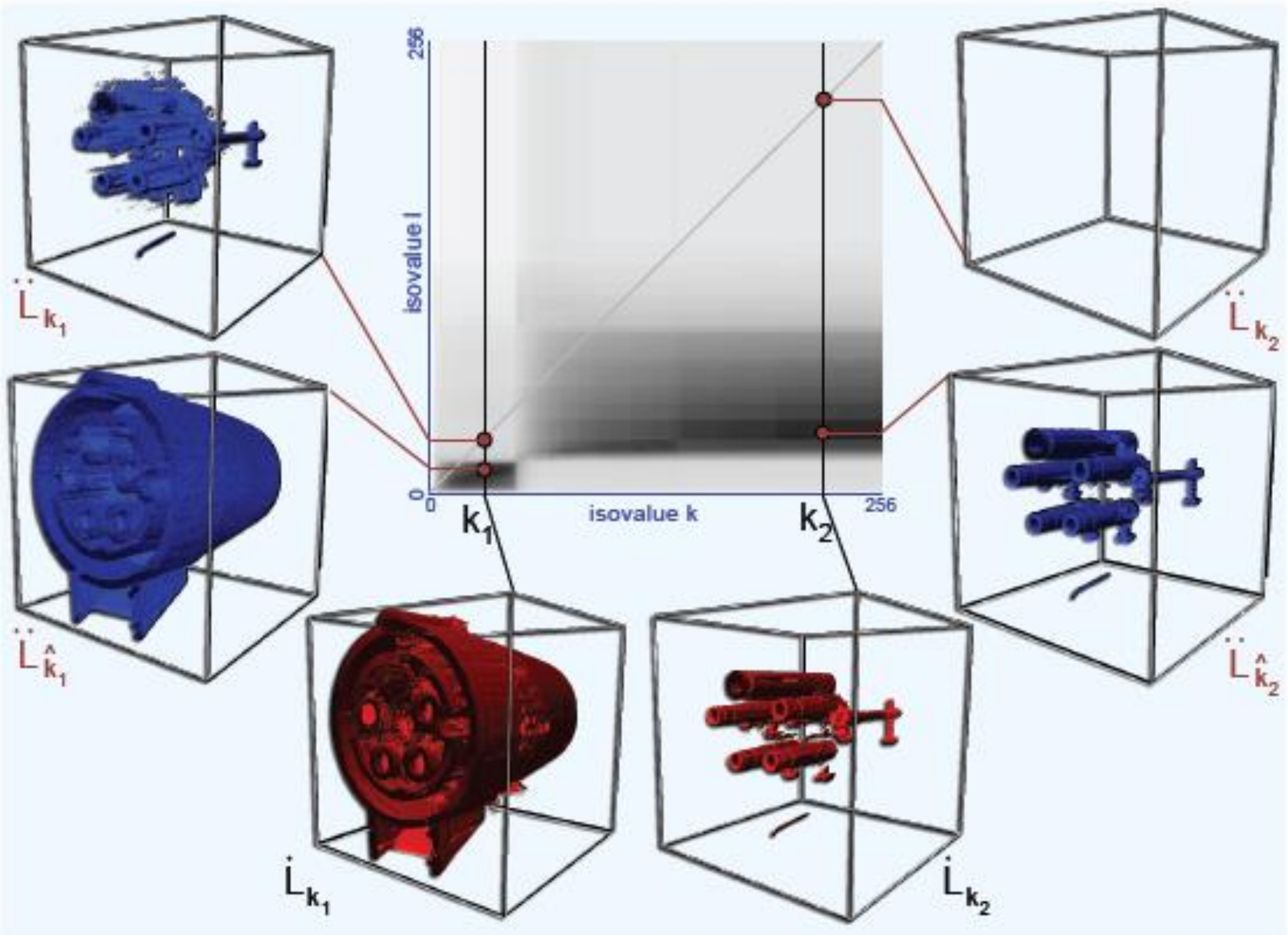
Multimodal Surface Fusion



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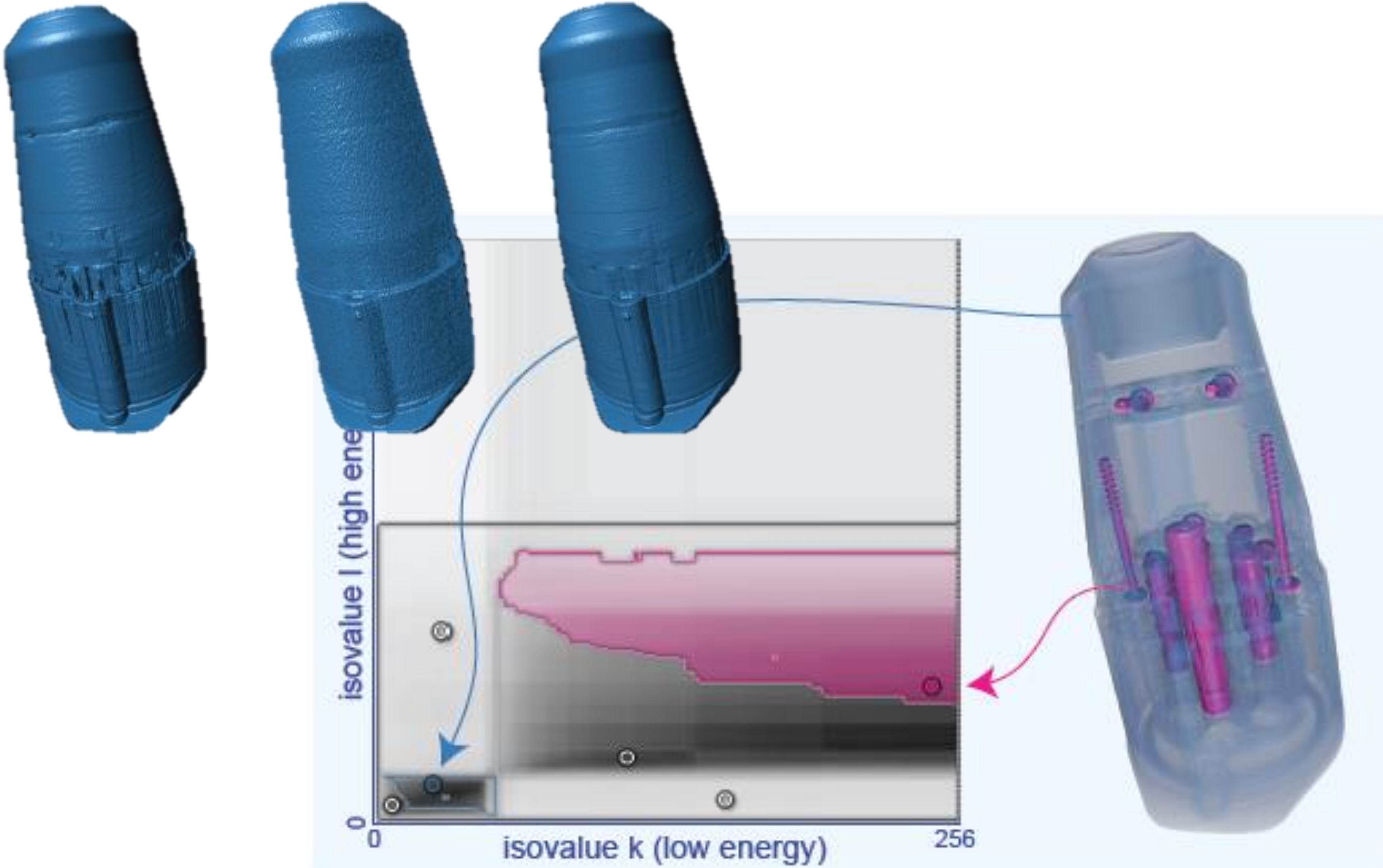
Multimodal Surface Fusion



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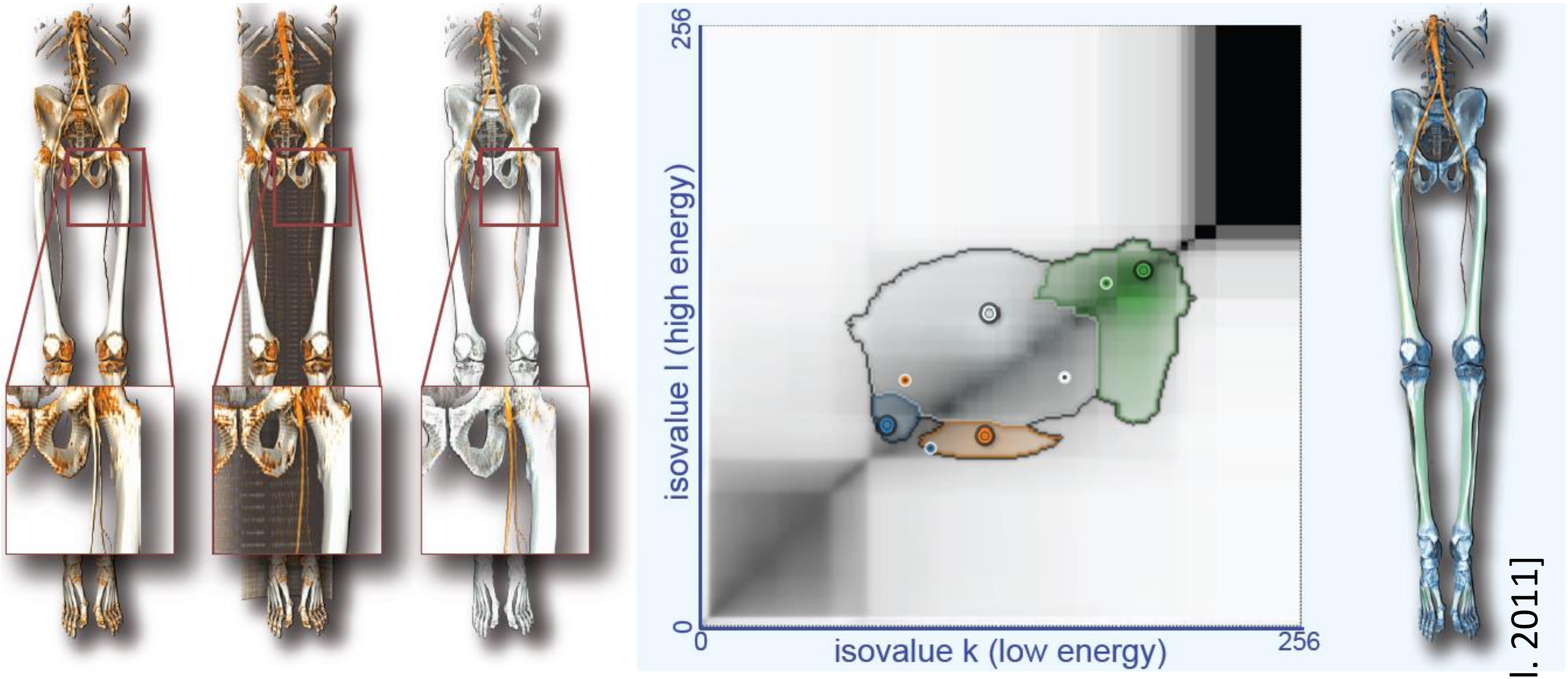
Multimodal Surface Fusion



[Haidacher et al. 2011]

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