# Navigating Large Scale Scalar Volumes

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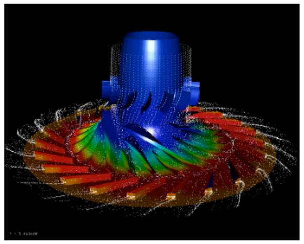
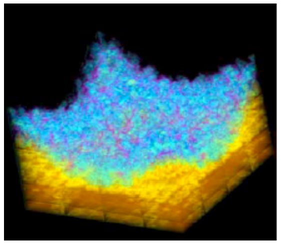
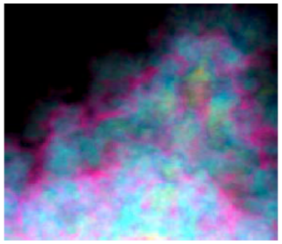
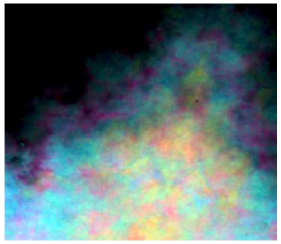
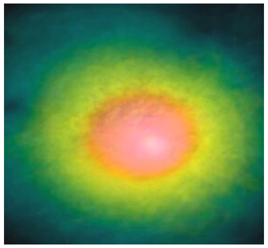
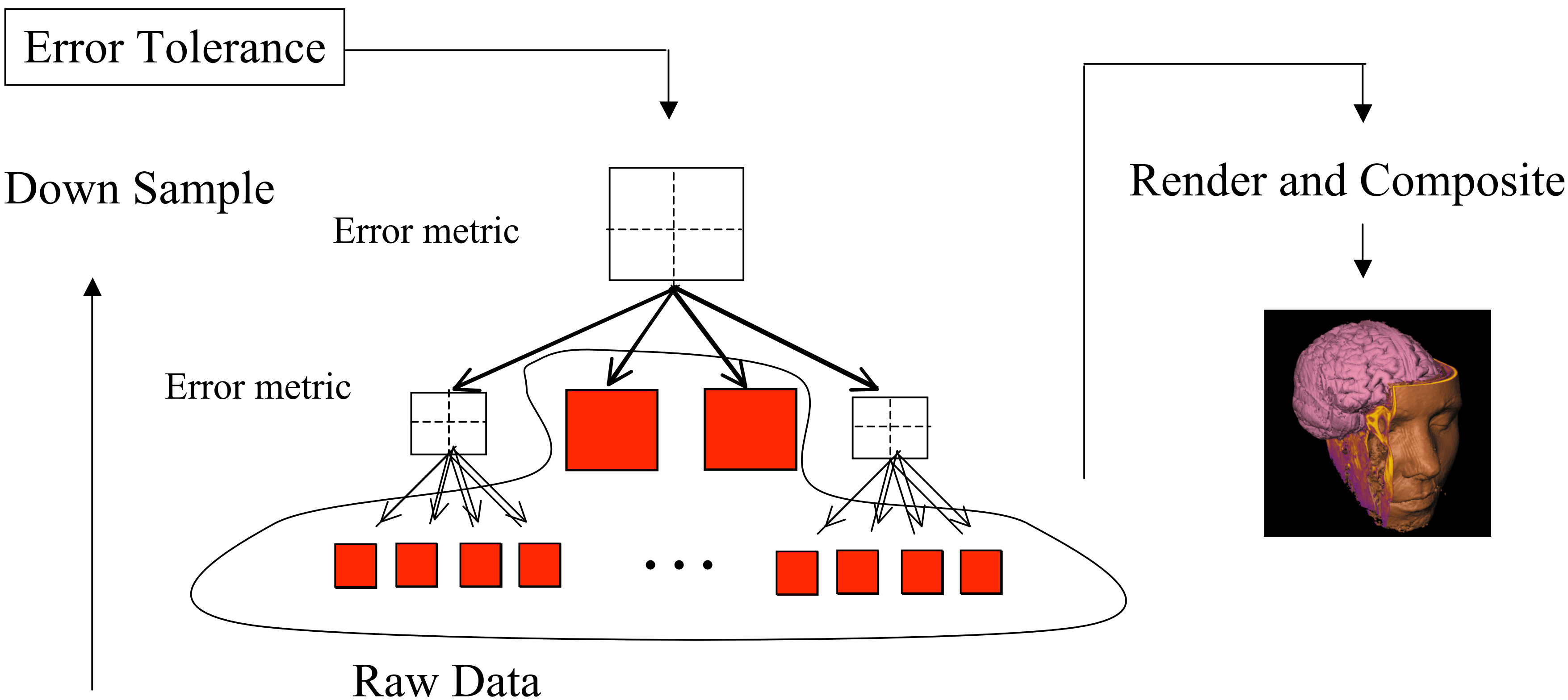






# Ultra Scale Data Exploration

- Large-scale data sets are common in both medical and scientific applications
- Large data size makes interactive visualization difficult
  - High memory/texture memory requirement
  - Slower rendering speed

# Multi-resolution Volume Rendering



# Research Questions

- How do we measure and compare the quality of different LOD selections?
- Are the computation resources effectively distributed?
- Can we visualize what are being visualized and make changes?

# Global LOD Quality Metric

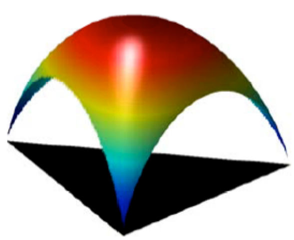
- Measure the amount of information contained in the selected LOD
  - Compare LODs
  - Decide whether the computation resources are distributed evenly to render-worthy blocks
  - LOD adjustment
- Approach: Employ information theory

# Shannon Entropy

- The source of information takes a sequence of symbol $\{a_1,a_2,a_3, \ldots, a_M\}$ with probabilities $\{p_1,p_2,p_3, \ldots, p_M\}$
- The amount of information contained is defined as:

$$H(X) = -\sum_{i=1}^{M} p_i \log p_i$$

- Maximize the entropy function when *Pi* are all equal



An example of three dimensional Probability vector {p1,p2,p3}

# LOD Entropy

$$H(X) = -\sum_{i=1}^{M} p_i \log p_i$$

- A LOD contains a sequence of blocks $B_i$ at particular resolutions
- $P_i$, the 'probability' of a data block $B_i$ at a particular resolution, is defined as:

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

- $\mathscr{C}_i$ and $\mathscr{D}_i$ are the block's contribution and distortion (if it is a low resolution block)

# LOD Entropy

$$H(X) = -\sum_{i=1}^{M} p_i \log p_i$$

- The value of the entropy function is maximized when *Pi* are all equal

$$p_i = \frac{\mathscr{C}_i \cdot \mathscr{D}_i}{S}$$

$\mathscr{C}i \nearrow \;\Rightarrow\; \mathscr{D}i \searrow$ (high resolution)

$\mathscr{C}i \searrow \;\Rightarrow\; \mathscr{D}i \nearrow$ (low resolution)

The entropy function prefers that a block's resolution matches its contribution to the final image

# Contribution and Distortion

- Contribution: the block's color ($\mu$), projection size (a), thickness (t), visibility (v)

$$\mathscr{C}_i = \mu \cdot t \cdot a \cdot v$$

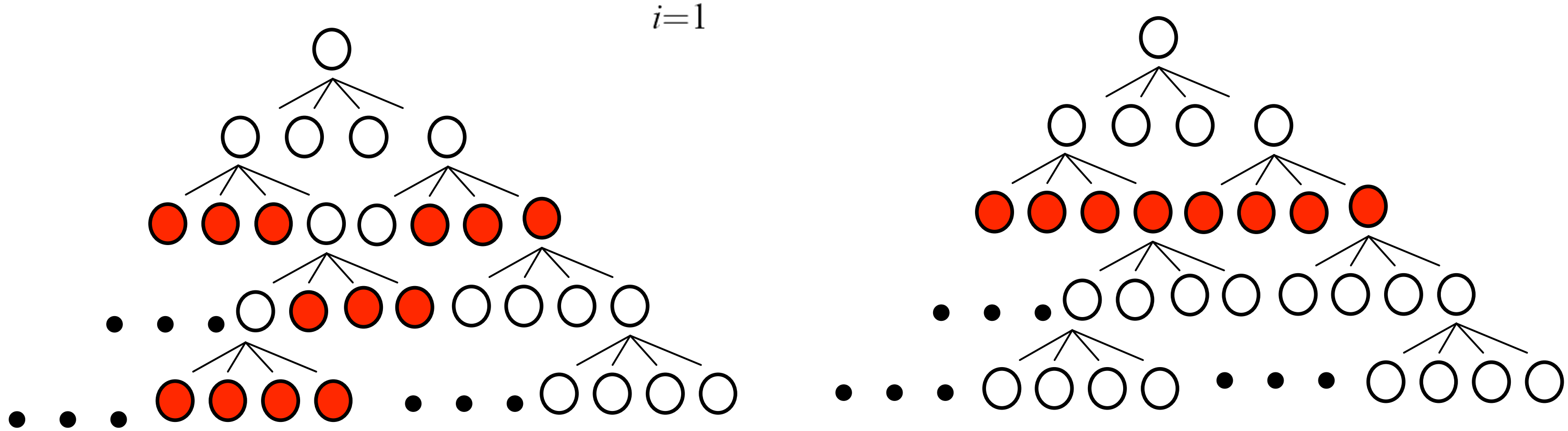
- Distortion: the difference between the block's data values and those of a higher resolution block

$$d_{ij} = \sigma_{ij} \cdot \frac{\mu_i^2 + \mu_j^2 + C_1}{2\mu_i\mu_j + C_1} \cdot \frac{\sigma_i^2 + \sigma_j^2 + C_2}{2\sigma_i\sigma_j + C_2}$$

covariance luminance contrast

# LOD Comparisons using Entropy

$$H(X) = -\sum_{i=1}^{M} p_i \log p_i$$



H1 H2

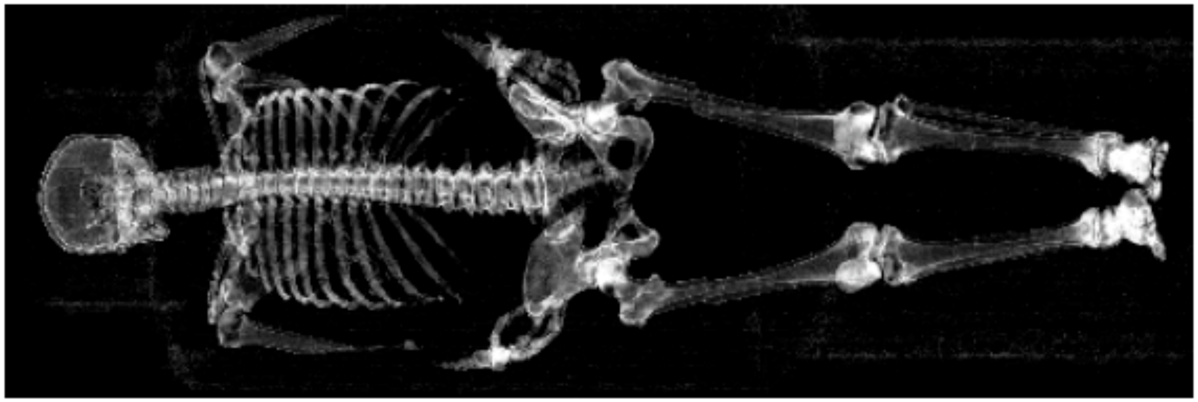
A higher entropy value indicates a balanced probability distribution, thus a better overall quality

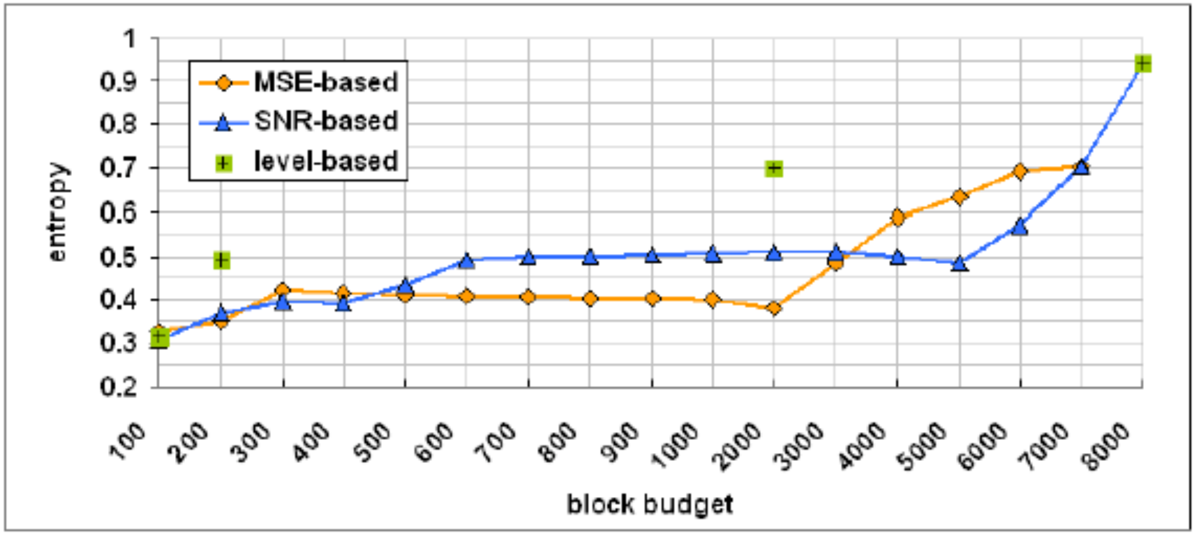
# Entropy vs. Quality

Entropy = 0.166  (34 blocks)

Entropy = 0.316 (259 blocks)

# Entropy vs. # of Blocks



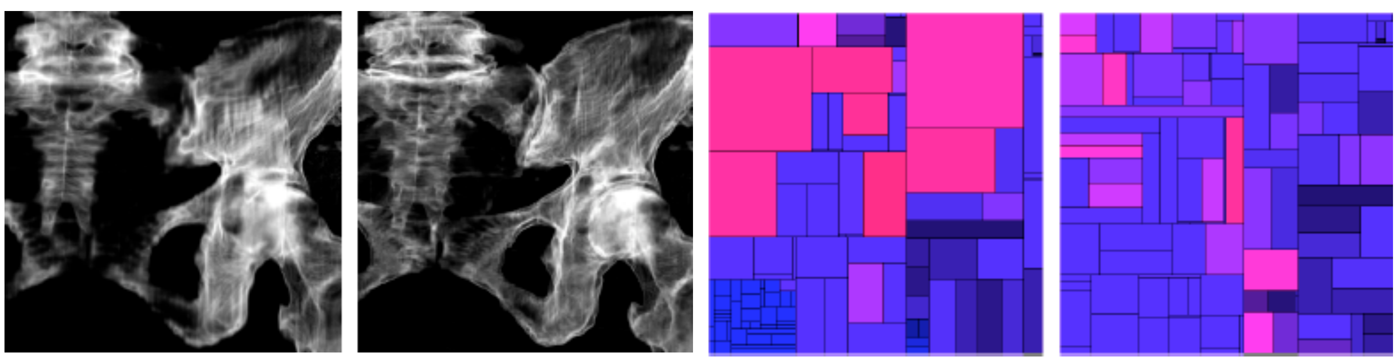


# Visual Representation of LOD Quality

- An optimal selection of LOD is an NP complete problem
- Fine tuning of LOD selection is often necessary
- Can we visualize what are being selected, and make adjustments if necessary?

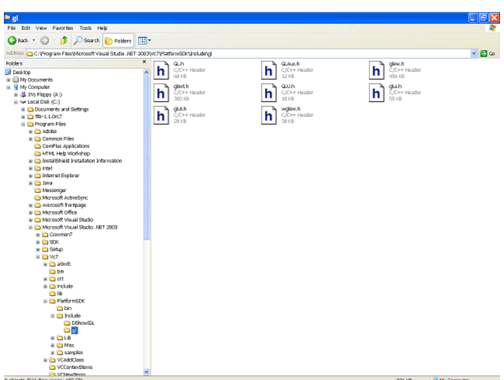
# LOD Map

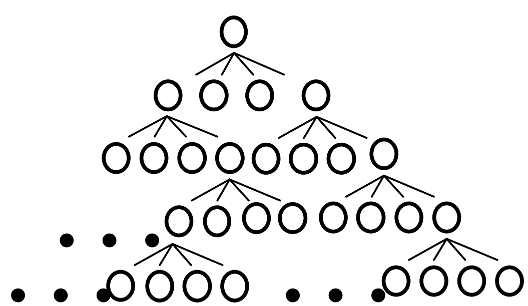
- A visual user interface to visualize the LOD selection
- Allow the user to see individual block’s contribution vs. distortion, i.e., visualize the entropy terms

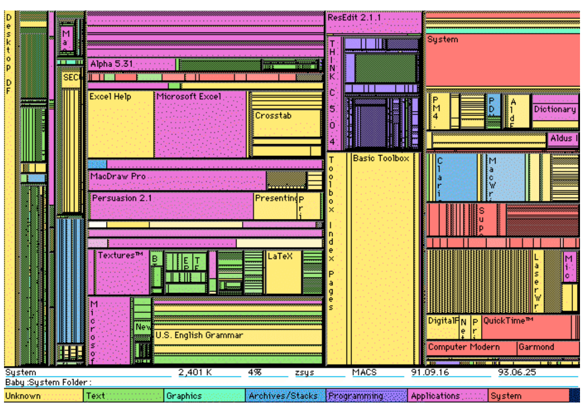


# Treemap

- A space-filling method to visualize hierarchical information [Shneiderman et al. 1992]
  - Recursive subdivision of a given display area
  - Information of each individual node
    - Color and size of its bounding rectangle



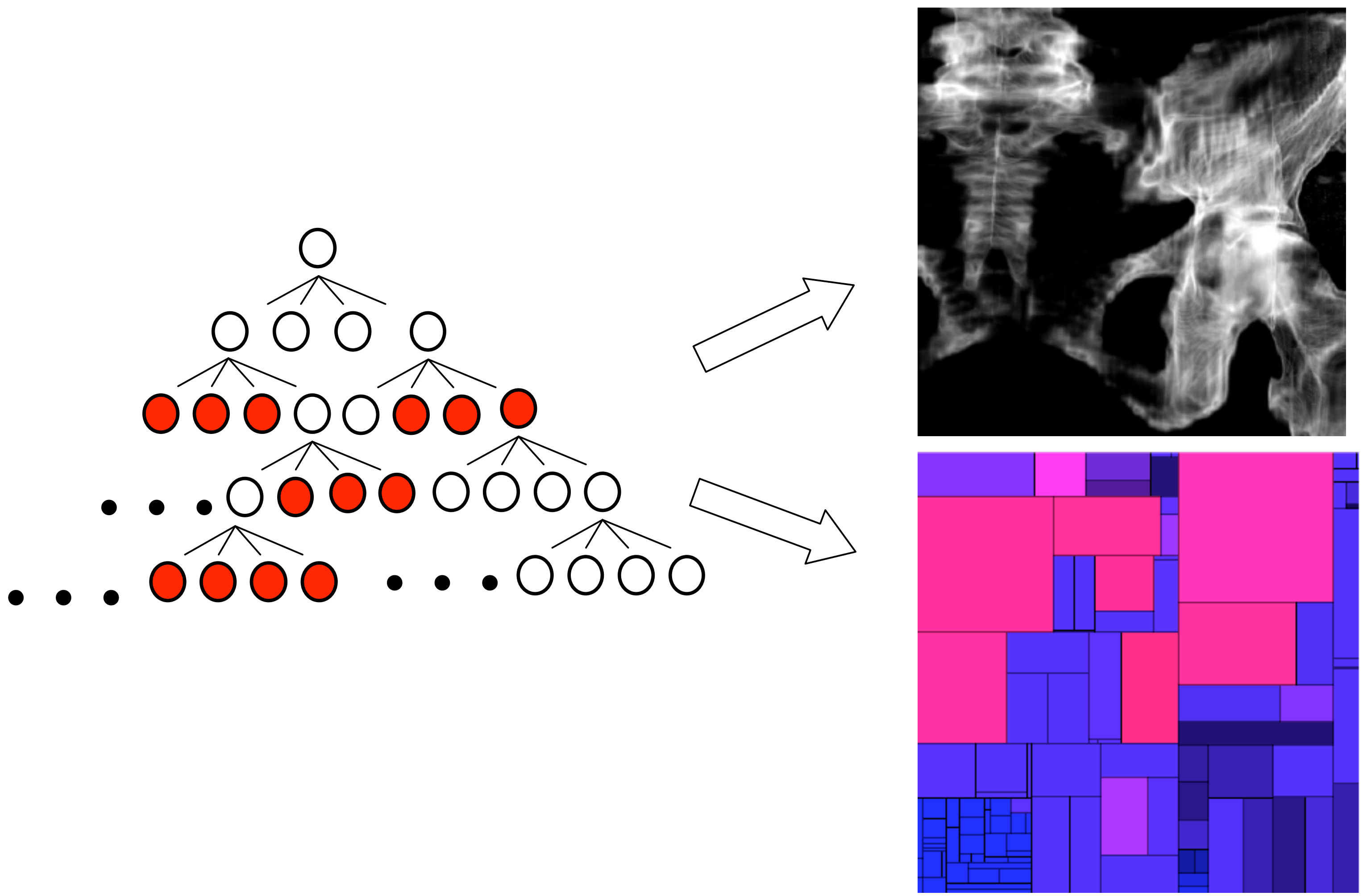




# LOD Map

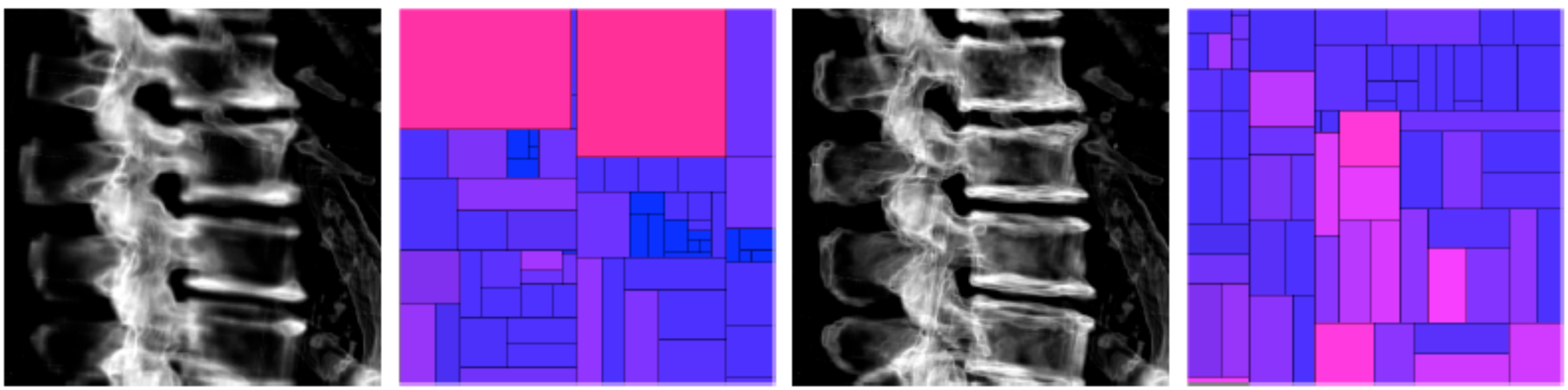
- Display the blocks belong to the selected LOD in a tree-map like manner
- Color (blue to red) is used to encode the block's distortion ($\mathscr{D}_i$)
- The contribution of the block (μ.t.a.v) is divided into two parts
  - The size of rectangle is to encode μ.t.a
  - The opacity of rectangle is to encode v

# LOD Map



# How Can LOD Map Help

Comparisons of different LOD selection schemes

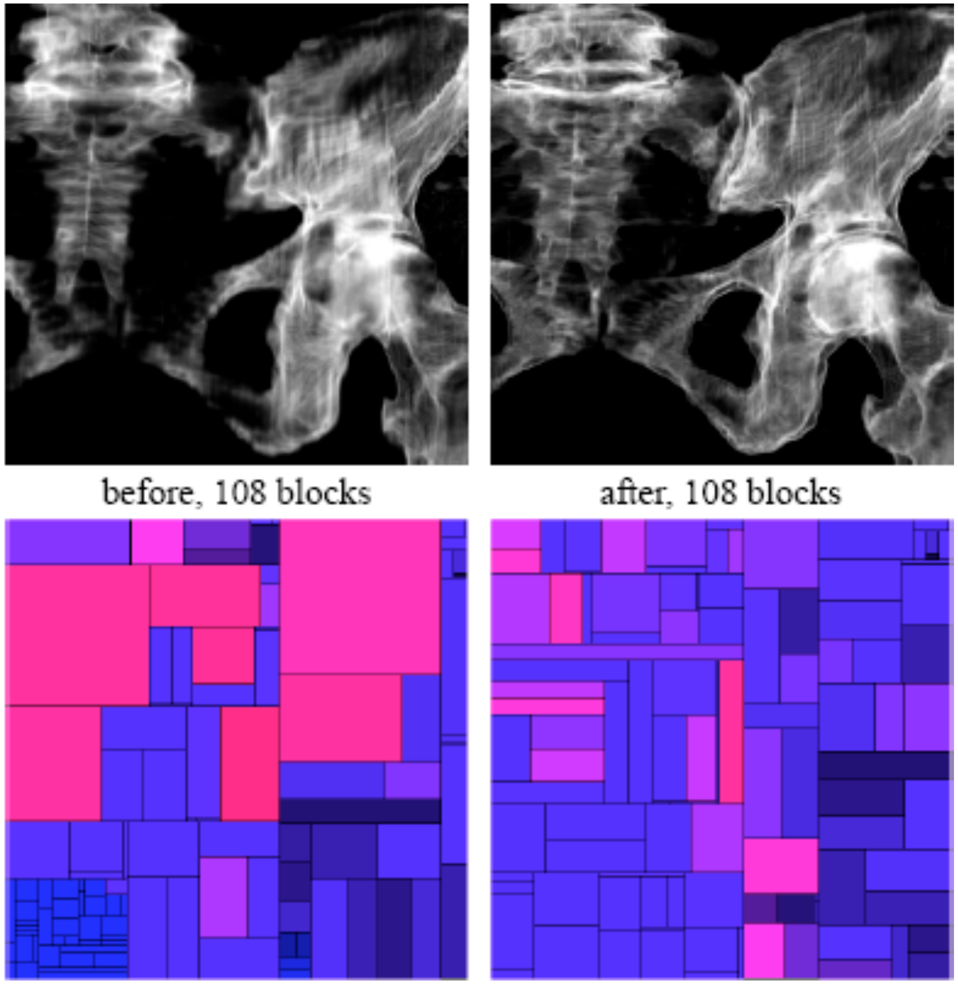


(a) MSE-based, 67 blocks (b) entropy = 0.163 (c) level-based, 67 blocks (d) entropy = 0.381

# How Can LOD Map Help

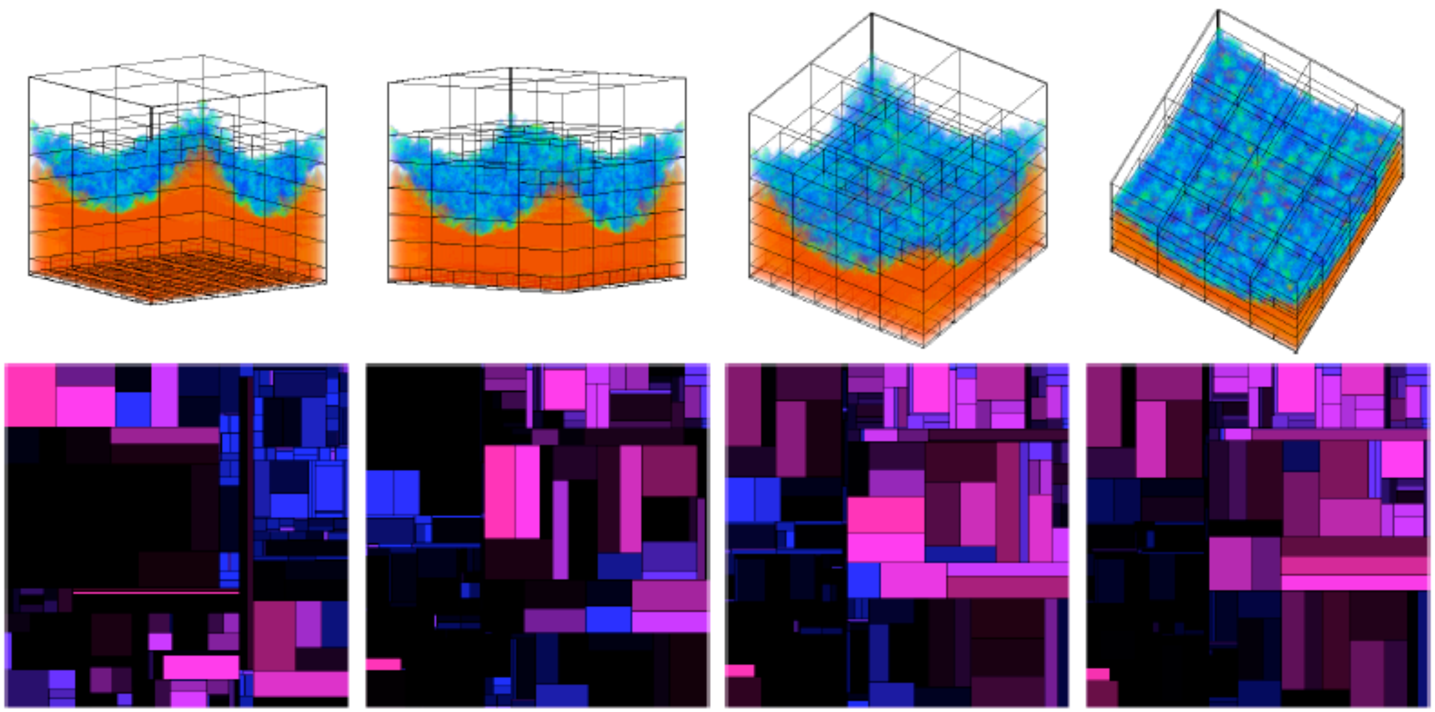
- Spot problematic regions in the current LOD
  - Large red rectangles – high contribution blocks rendered with low resolutions
    - Action: split the blocks and increase the resolutions
  - Small blue rectangles – low contribution blocks rendered with high resolutions
    - Action: join the blocks and reduce the resolutions
  - Dark rectangles – low visibility blocks
    - Action: join them and reduce the resolutions

# LOD Adjustment



# How Can LOD Map Help

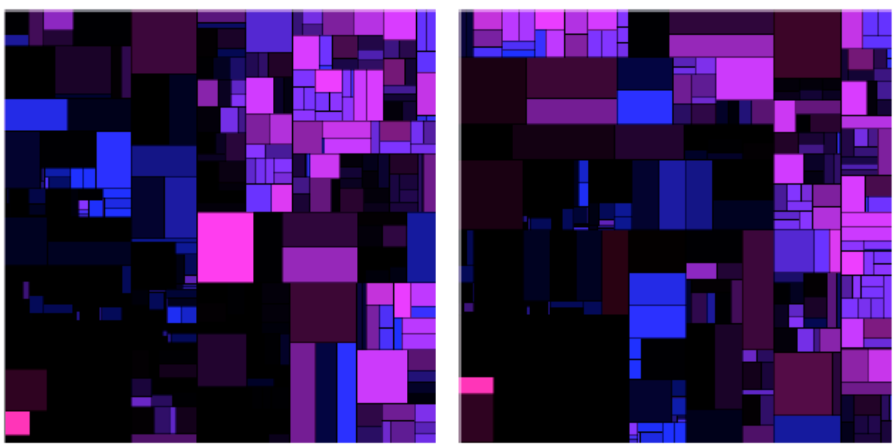
- View selection on the fly - High entropy and brighter LOD map for better views



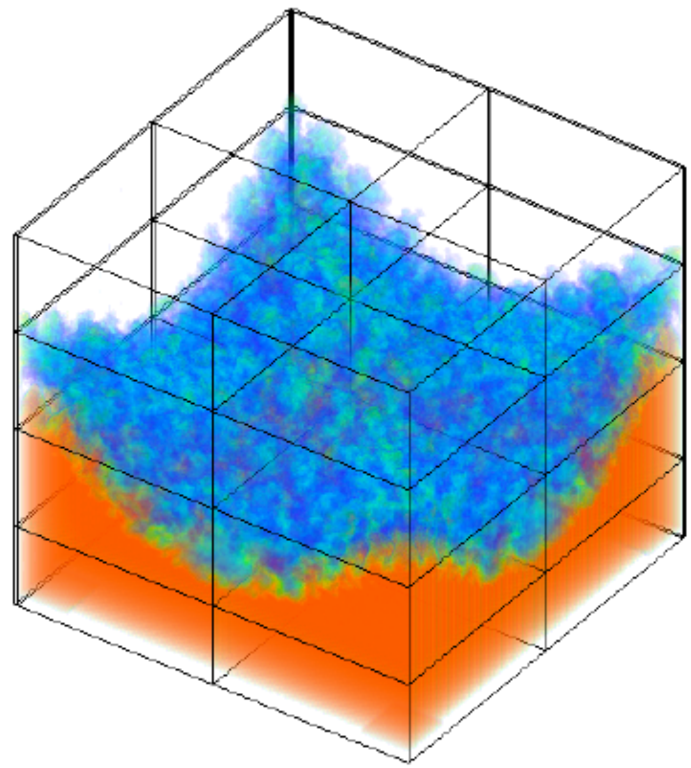
(a) entropy = 0.330 (b) entropy = 0.343 (c) entropy = 0.384 (d) entropy = 0.390

# How Can LOD Map Help

• Budget Control - Render fewer blocks, i.e., lower Resolutions in certain regions, for the same entropy



(a) entropy = 0.448, 365 blocks (b) entropy = 0.476, 274 blocks



# Summary

- Entropy is used as a way to quantify the LOD quality
- LOD Map is used to provide visual feedback for the LOD adjustment
- An image based metric is used to measure the actual contribution of a block to the final image

# Acknowledgements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WHERE DISCOVERIES BEGIN