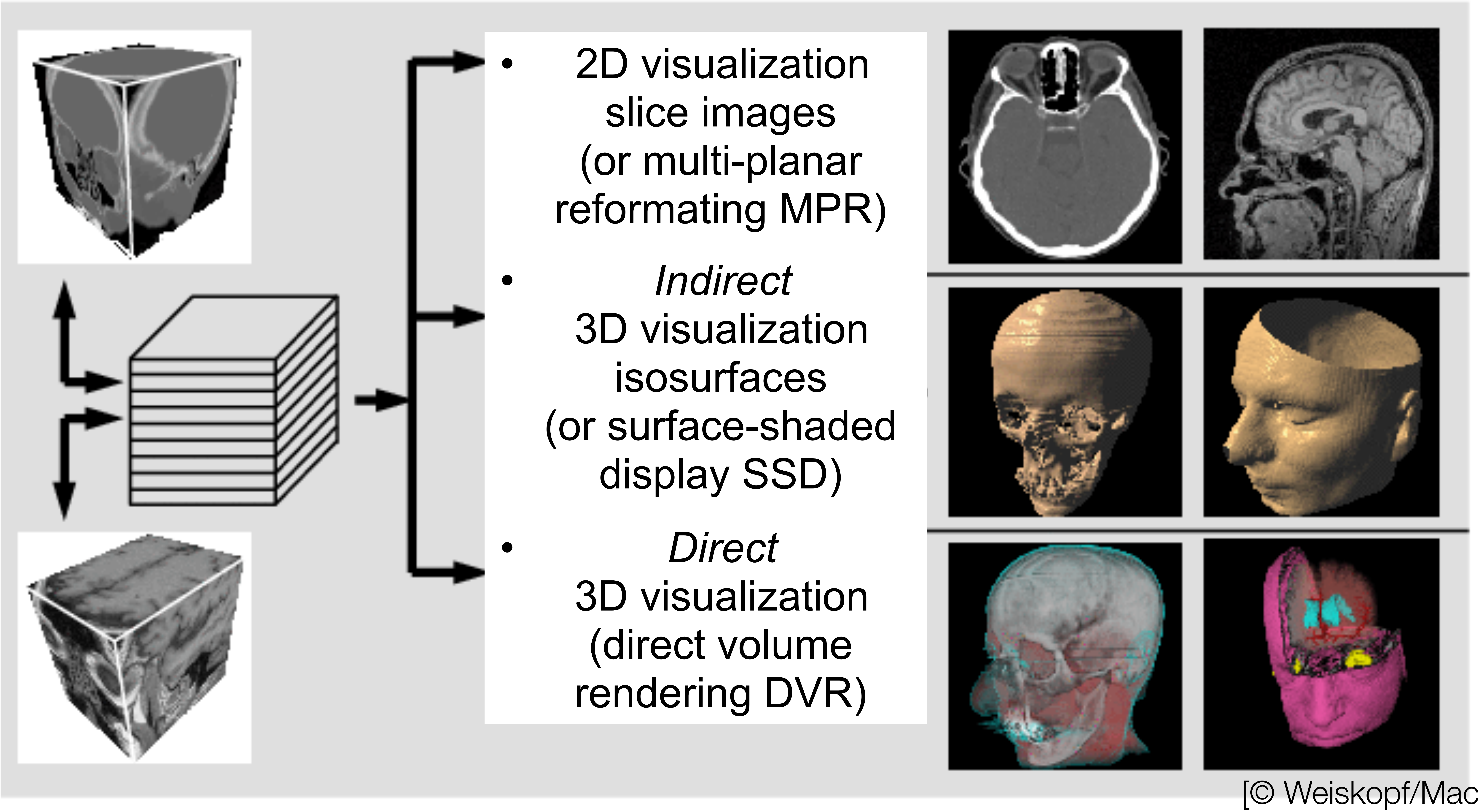
Data Visualization (CSCI 627/490)

Volume Rendering

Dr. David Koop

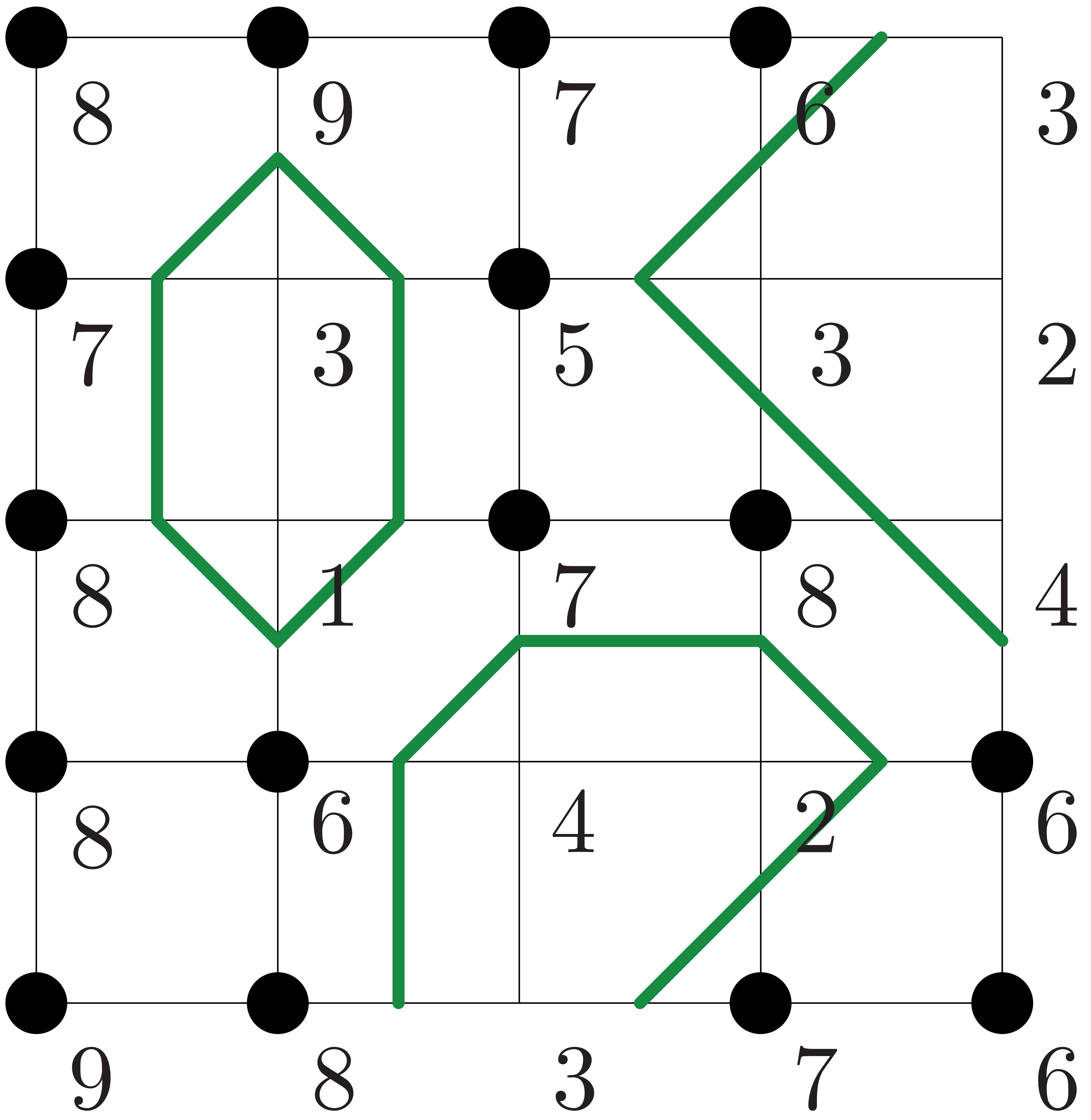
Visualizing Volume (3D) Data



- 2D visualization slice images (or multi-planar reformating MPR)
- *Indirect* 3D visualization isosurfaces (or surface-shaded display SSD)
- *Direct* 3D visualization (direct volume rendering DVR)

[© Weiskopf/Machiraju/Möller]

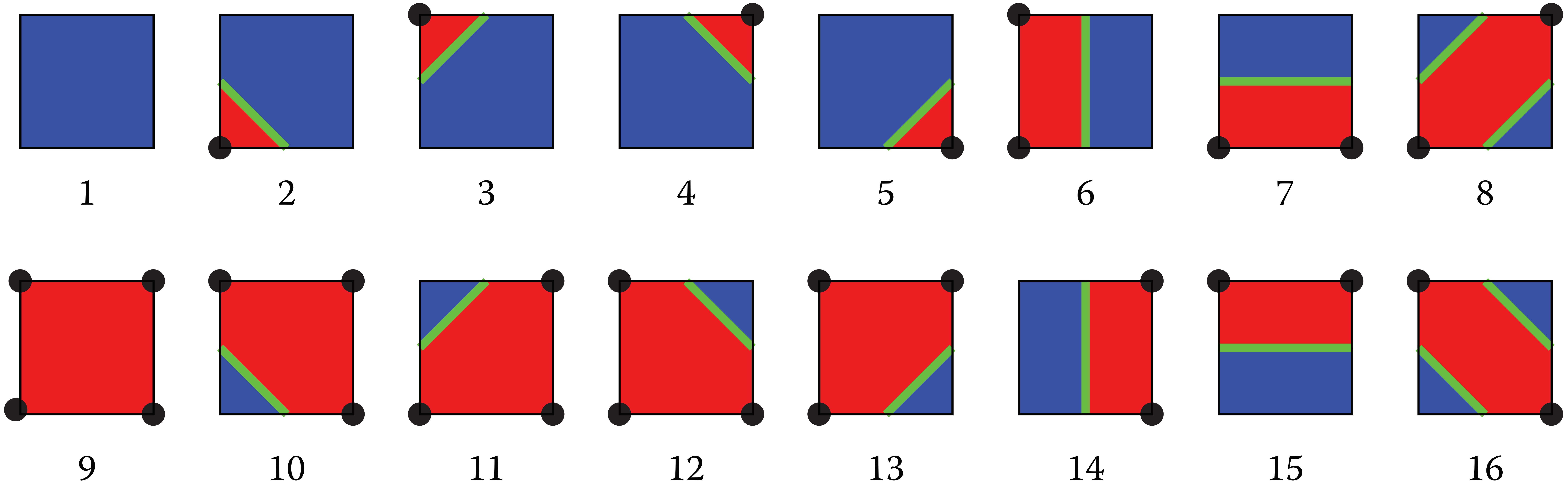
Generating Isolines (Isovalue = 5)



8	9	7	6	3
7	3	5	3	2
8	1	7	8	4
8	6	4	2	6
9	8	3	7	6

[R. Wenger, 2013]

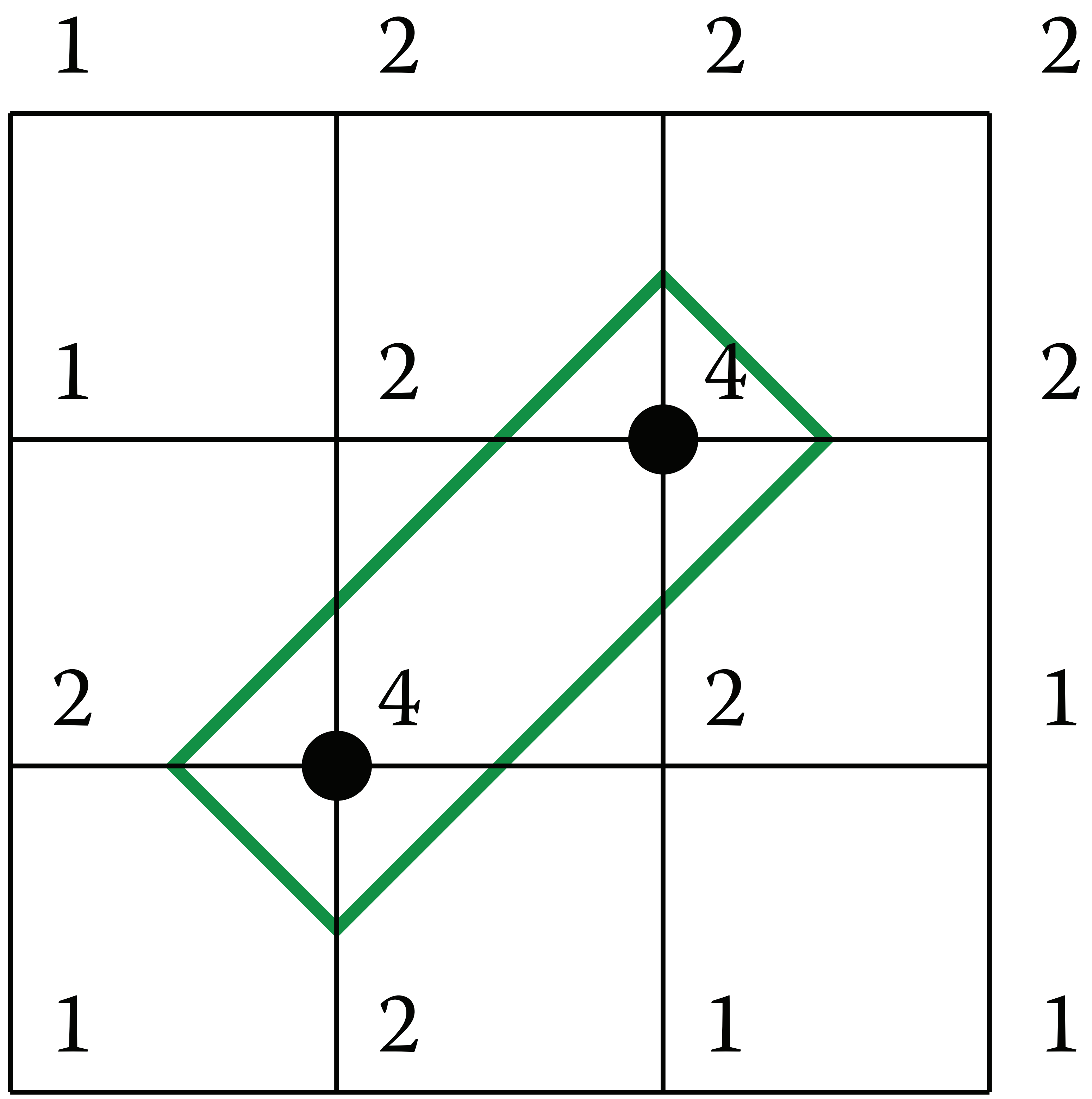
Marching Squares



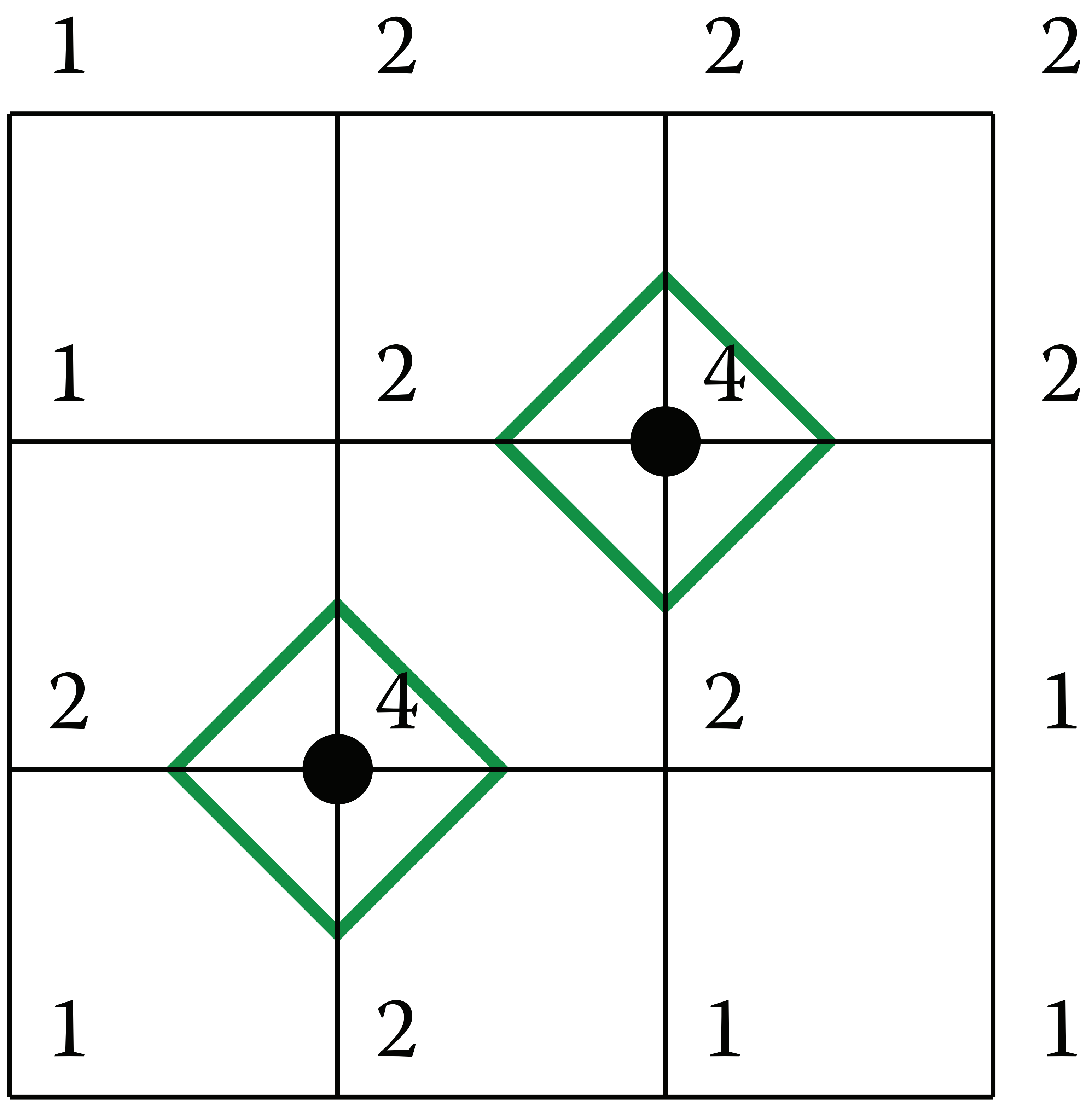
[R. Wenger, 2013]

Ambiguous Configurations

- Either works for marching squares, this isn't the case for 3D



1	2	2	2
1	2	4	2
2	4	2	1
1	2	1	1



1	2	2	2
1	2	4	2
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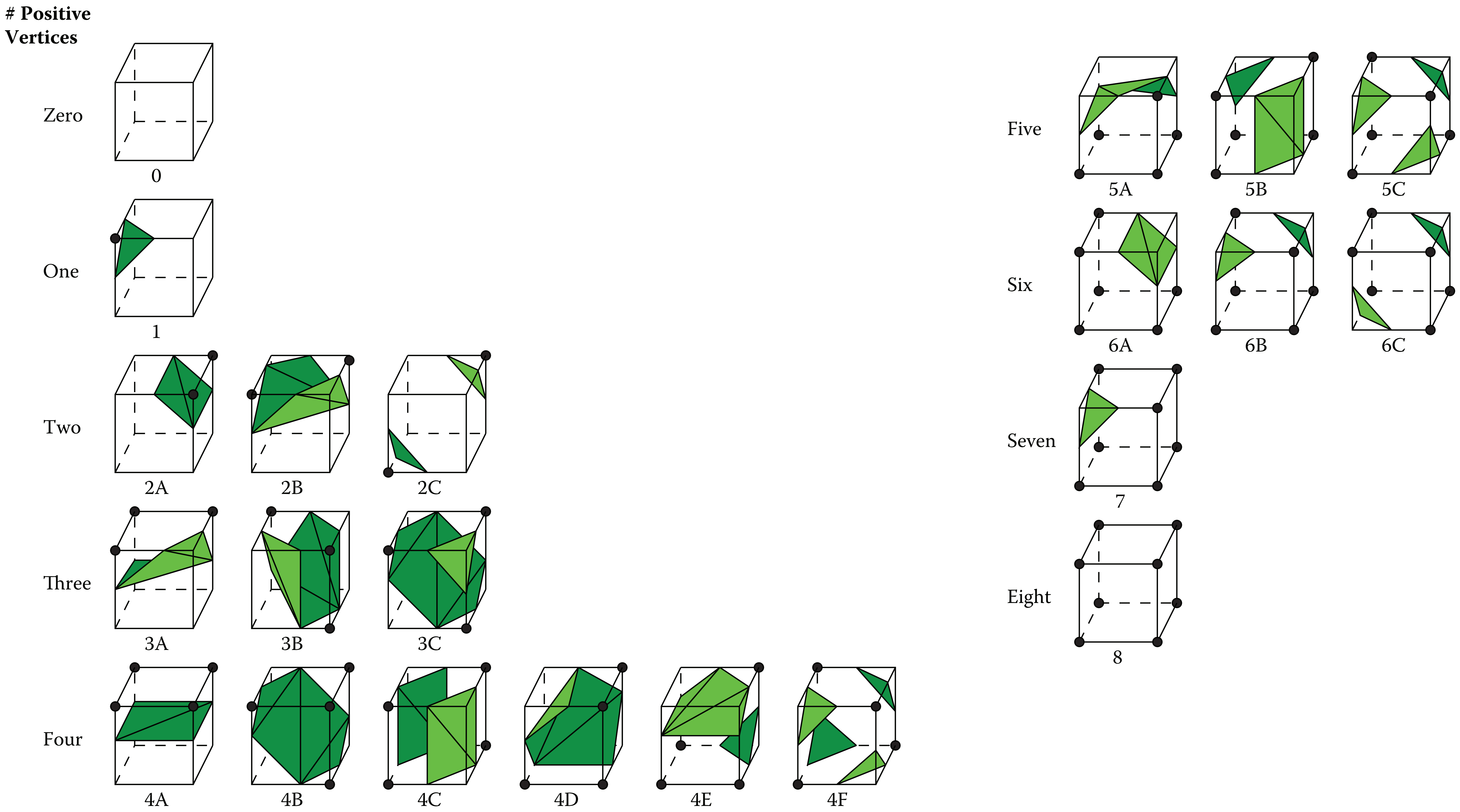
[R. Wenger, 2013]

3D: Marching Cubes

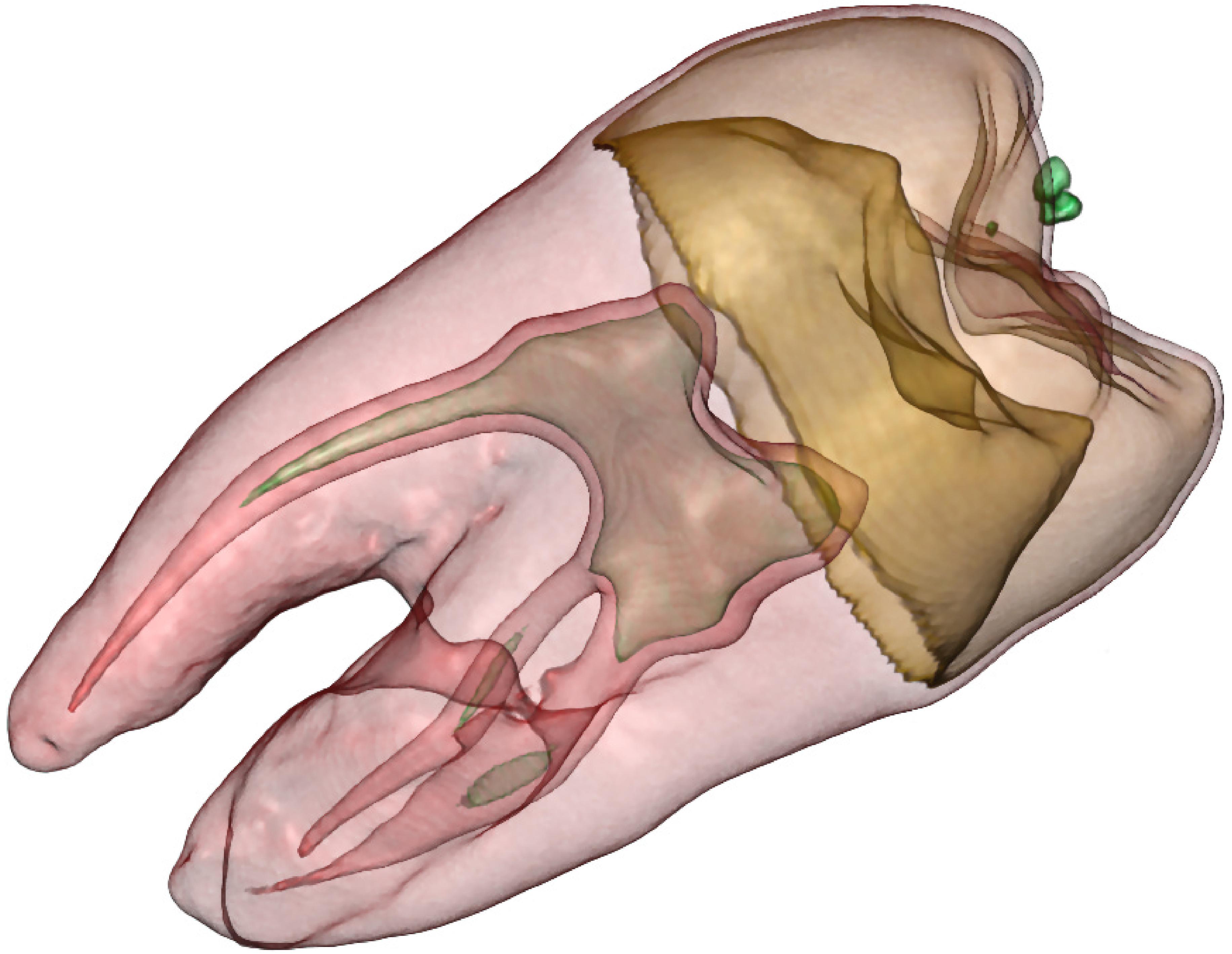
- Same idea, more cases [Lorensen and Cline, 1987]



[R. Wenger, 2013]

Multiple Isosurfaces

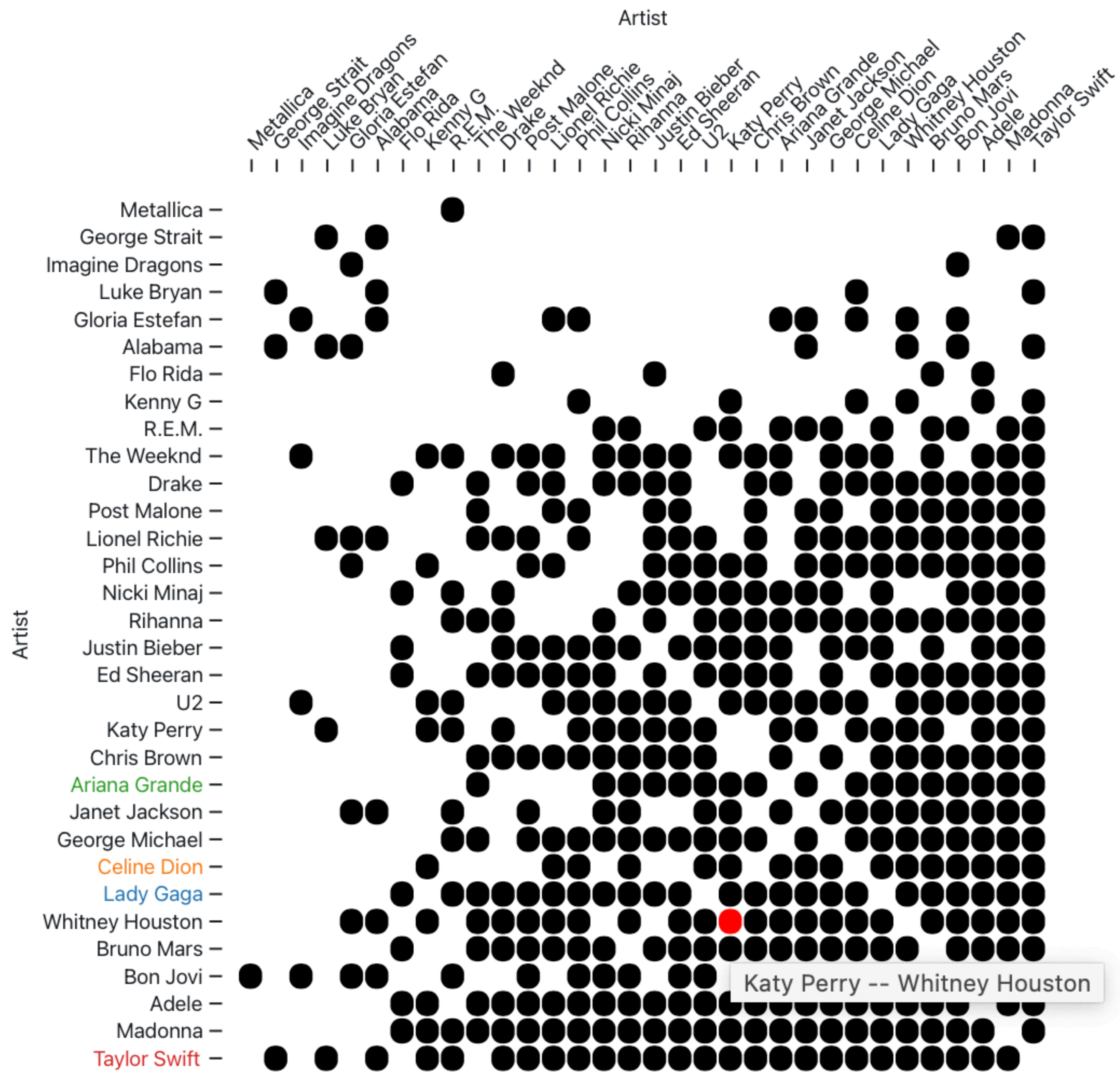
- Topographical maps have multiple isolines to show elevation trends
- Problem in 3D? **Occlusion**
- Solution? Transparent surfaces
- Issues:
  - Think about color in order to make each surface visible
  - Compositing: how do colors "add up" with multiple surfaces
  - How to determine good isovalues?



[J. Kniss, 2002]

Assignment 5

- Best-Selling Musical Artists
  - Multiple Views
  - Adjacency Matrix + Line Plot
  - Linked Highlighting
  - Filtering
- Due Wendesday, Nov. 23

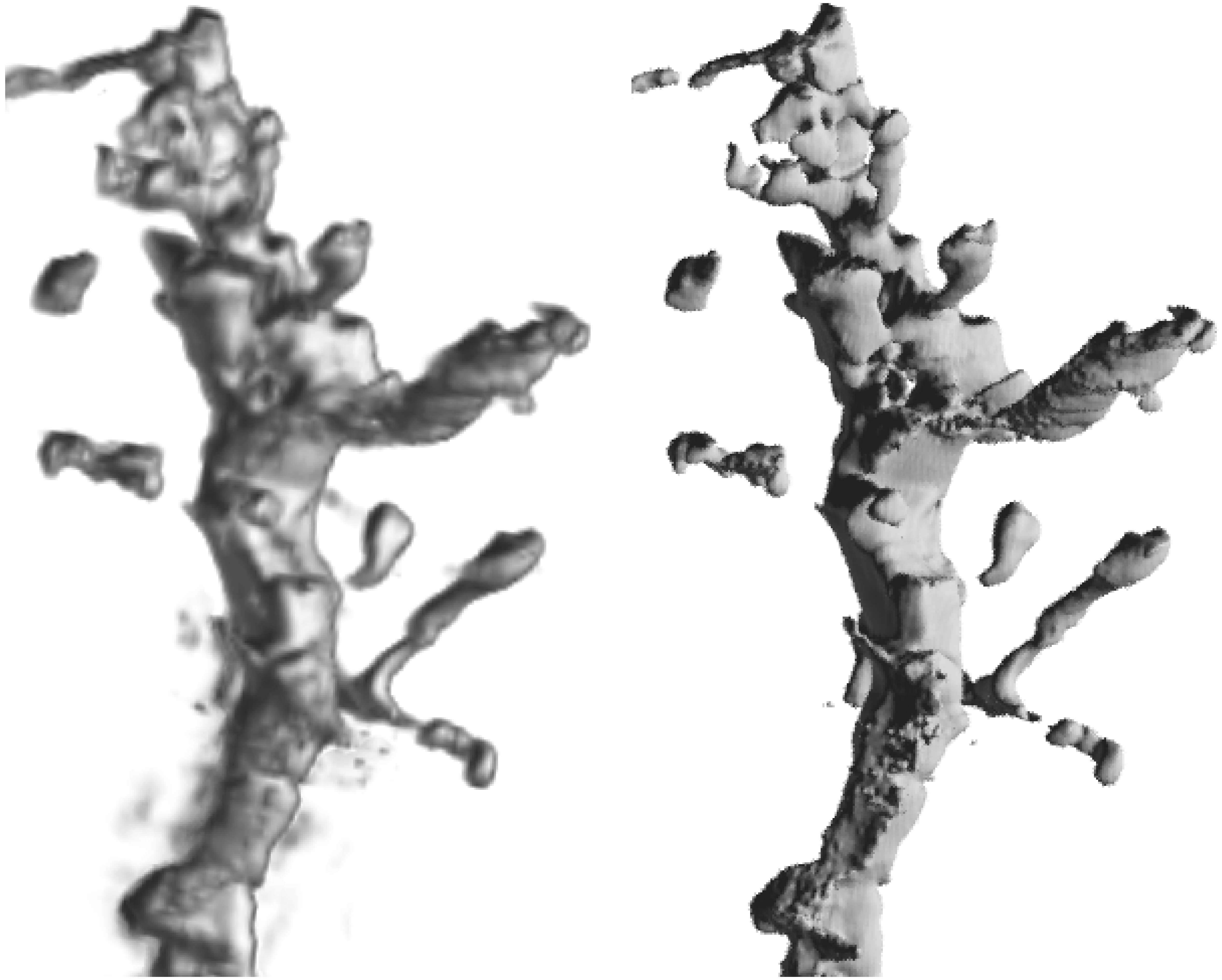


Projects

- Keep working on implementation
- Be creative
- Think about interaction
- Presentations on the last two days of class (Nov. 29 & Dec. 1)
  - Submit current visualization code (or a link) to Blackboard
  - Presentation preferences (Tuesday or Thursday)
  - Upload full code to Blackboard beforehand in case of technical issues

Volume Rendering

Volume Rendering vs. Isosurfacing



(a) Direct volume rendered

(b) Isosurface rendered

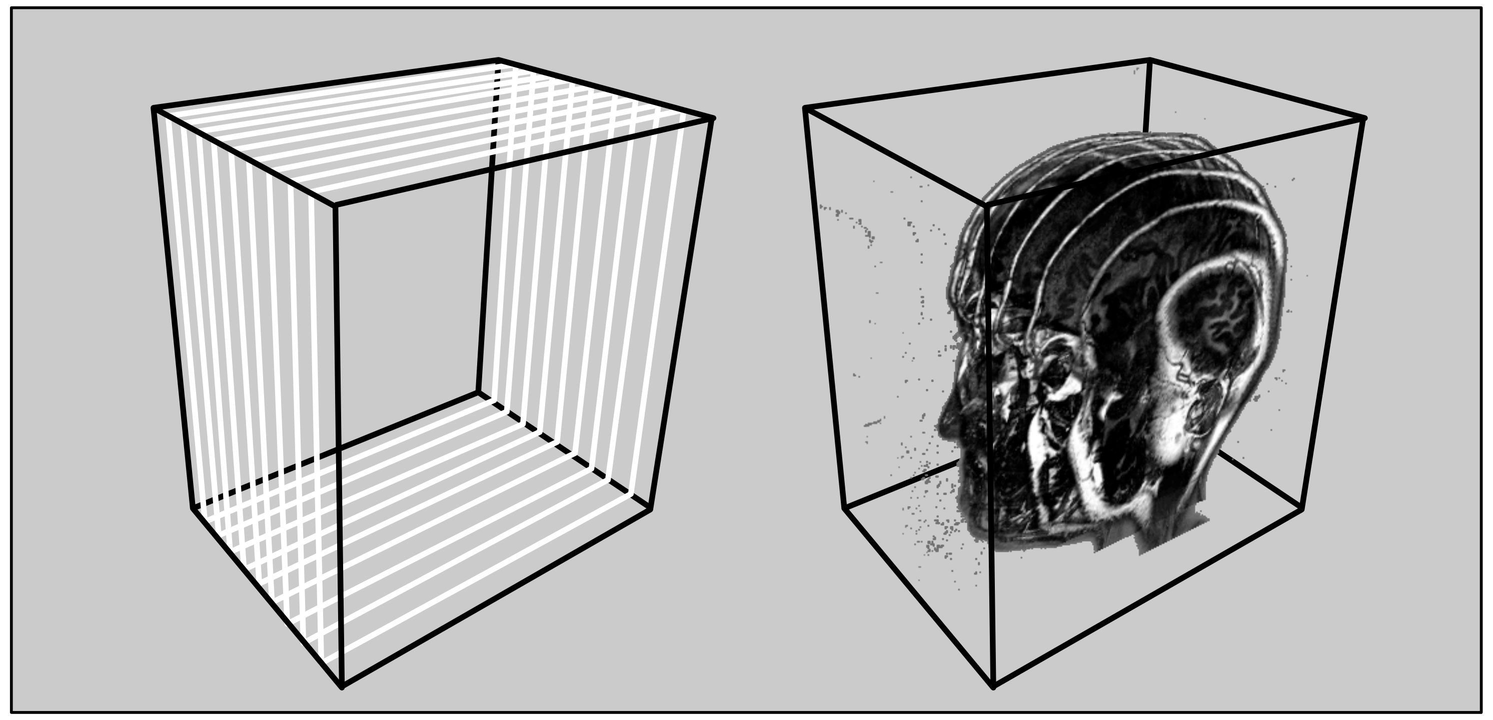
[Kindlmann, 1998]

(Direct) Volume Rendering

- Isosurfacing: compute a surface (triangles) and use standard computer graphics to render the triangles
- Volume rendering: compute the pixels shown directly from the volume information
- Why?
  - No need to figure out precise isosurface boundaries
  - Can work better for data with noise or uncertainty
  - Greater control over appearance based on values

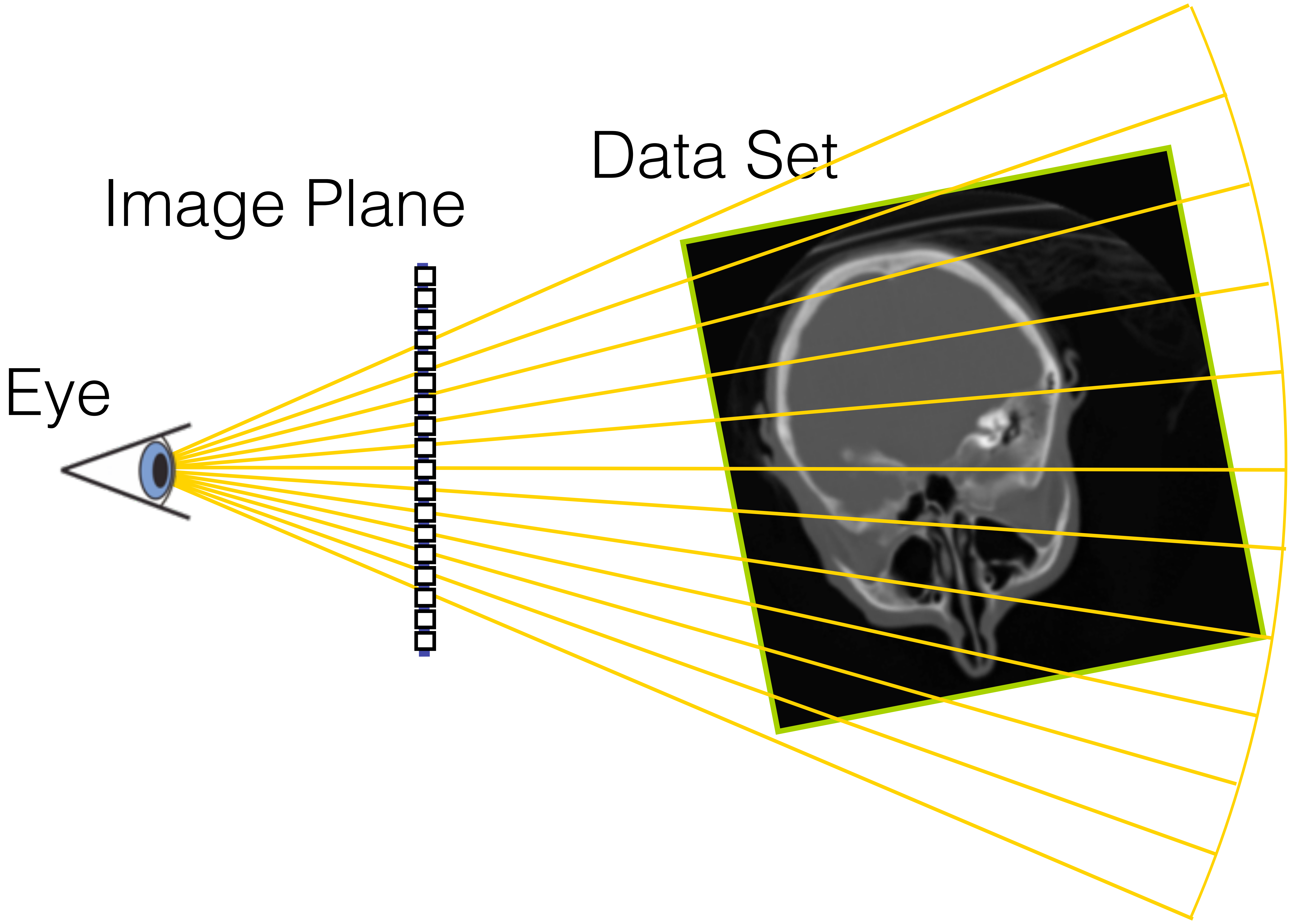
Types of Volume Rendering Algorithms

- Ray casting
  - Similar to ray tracing, but use rays from the viewer
- Splatting:
  - Object-order, voxels splat onto the image plane
- Shear Warp:
  - Object-space, slice-based, parallel viewing rays
- Texture-Based:
  - 2D Slices: stack of texture maps
  - 3D Textures



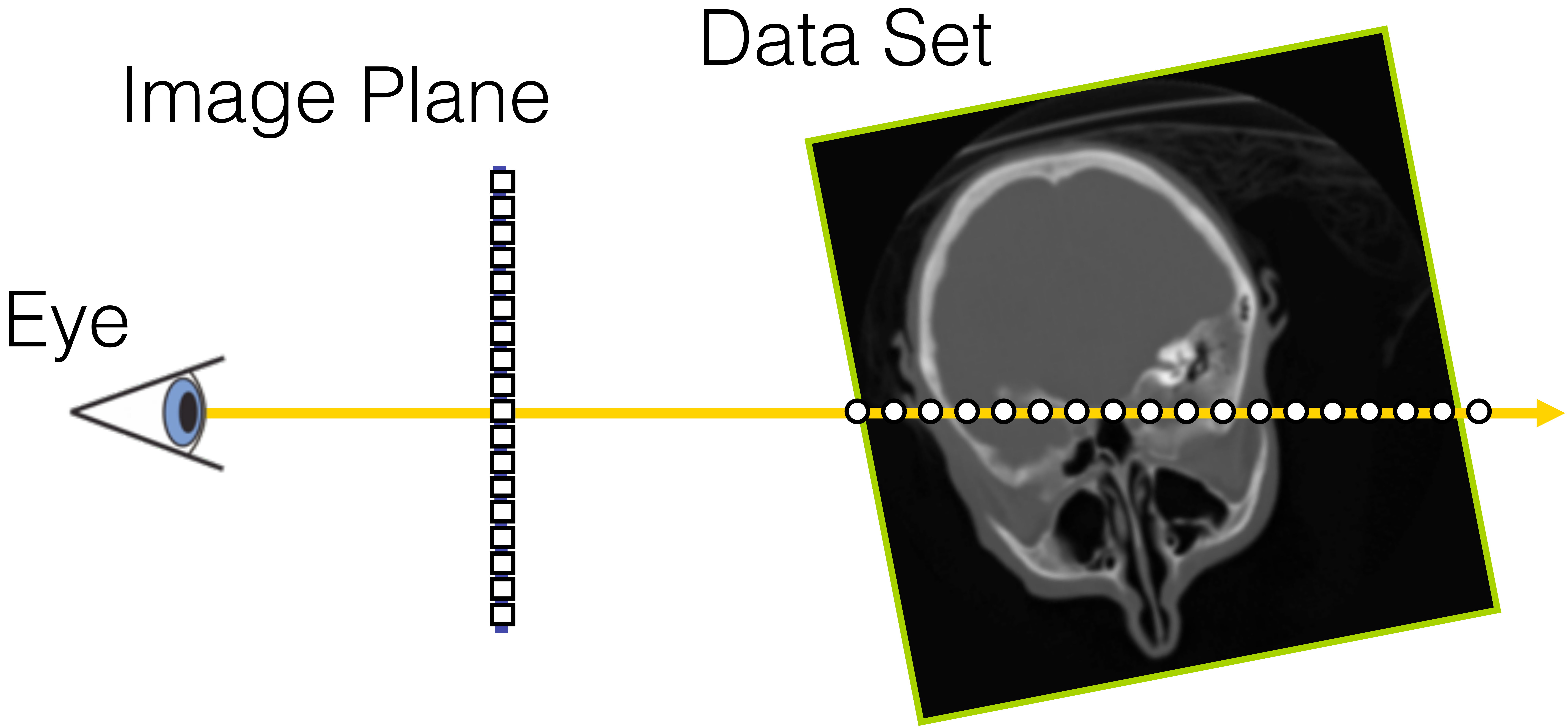
[via Möller]

Volume Ray Casting



[Levine]

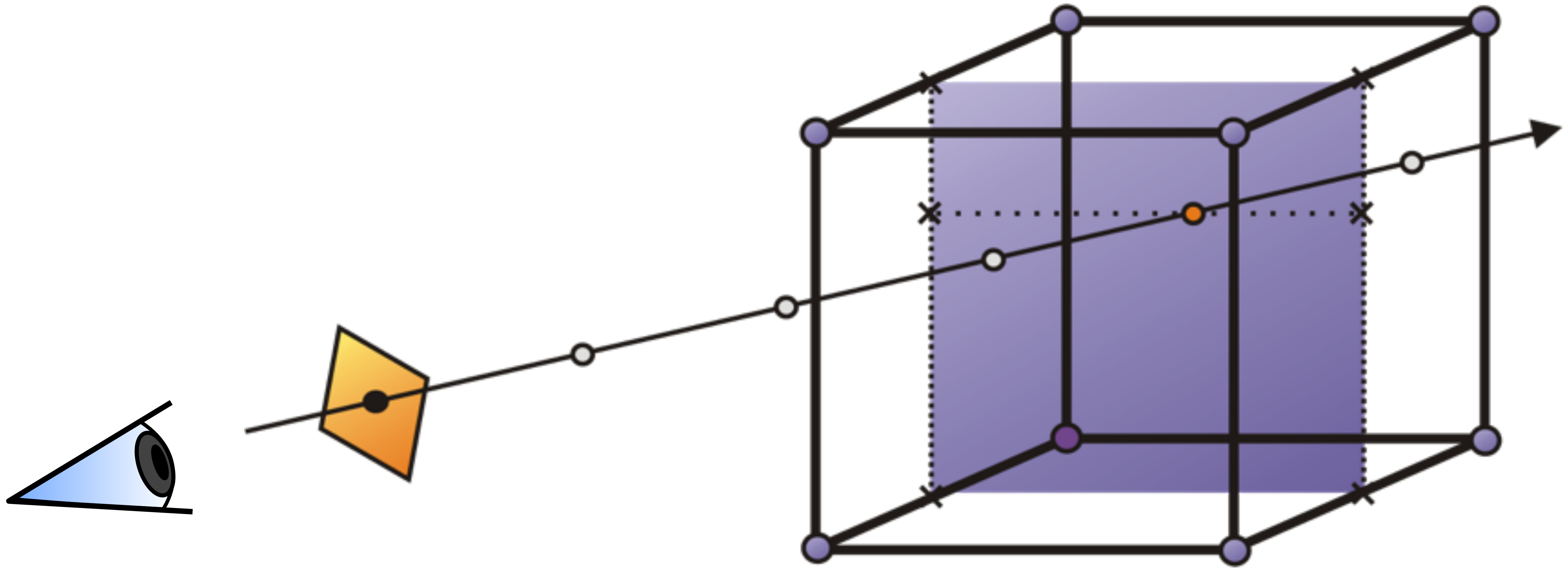
Volume Ray Casting



[Levine]

How?

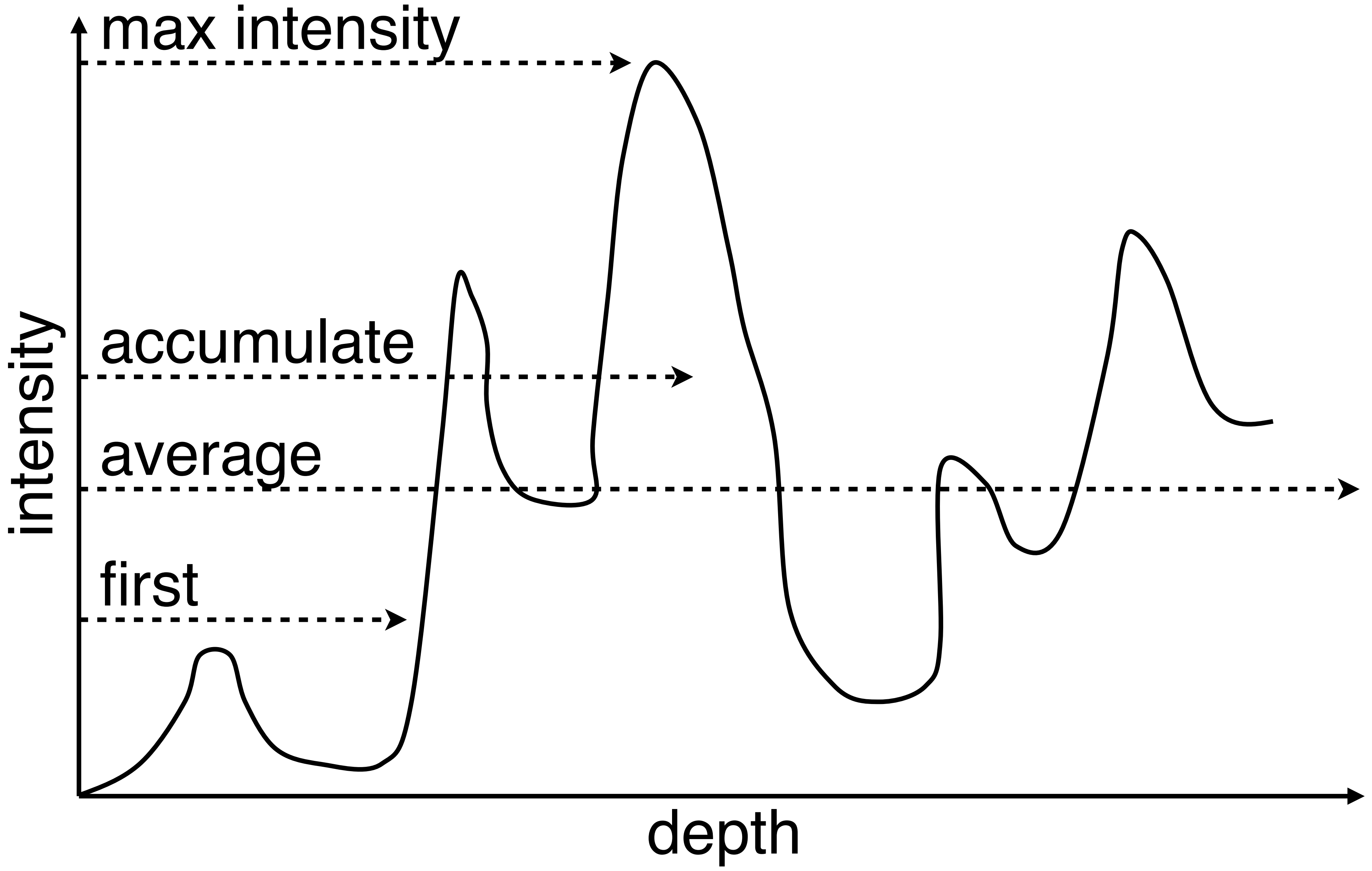
- Approximate volume rendering integral: light absorption & emission
- Sample at regular intervals along each ray
- Trilinear interpolation: linear interpolation along each axes (x,y,z)



- Not the only possibility, also "object order" techniques like splatting or texture-based and combinations like shear-warp

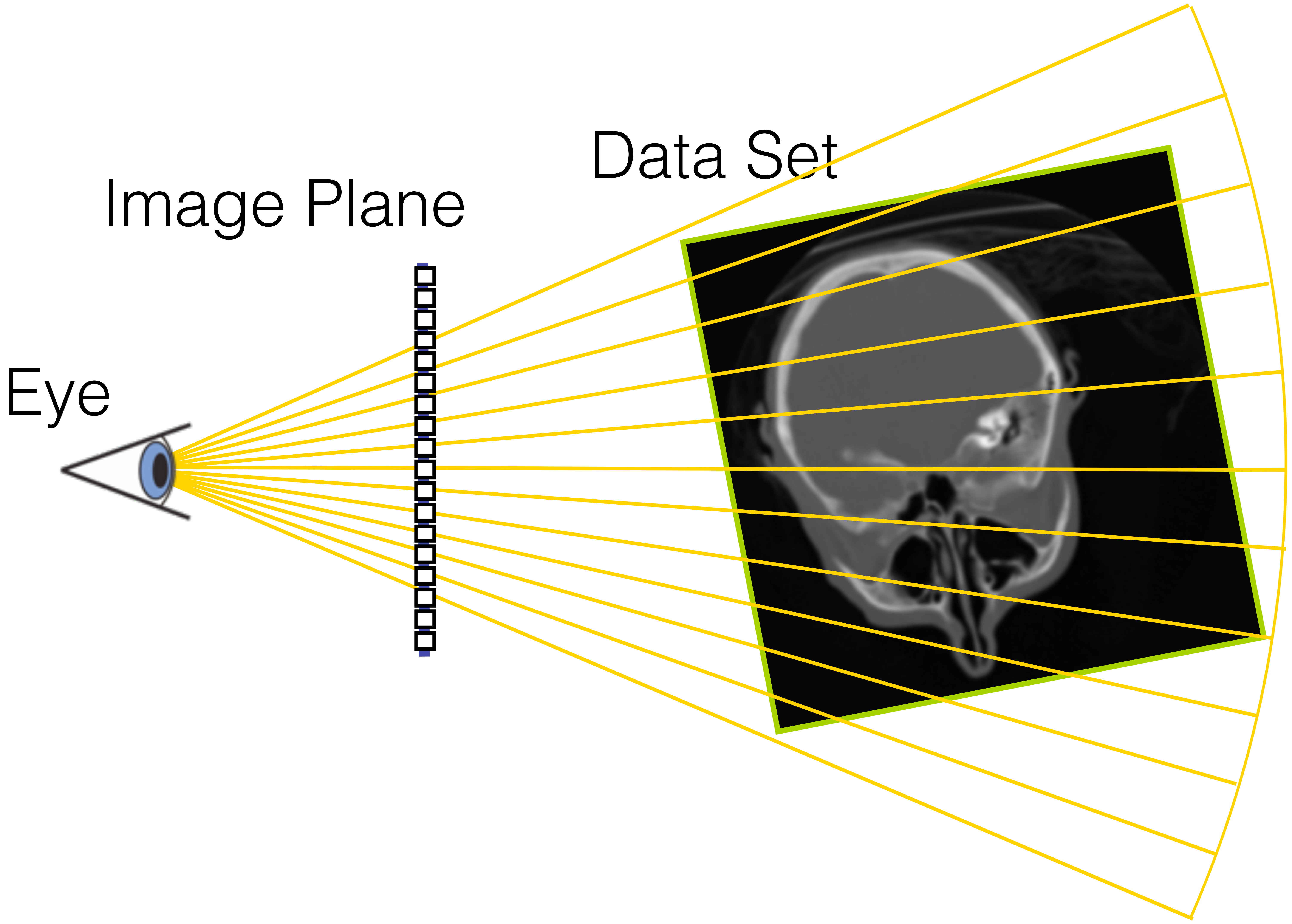
Compositing

- Need **one pixel** from all values along the ray
- Q: How do we "add up" all of those values along the ray?
- A: Compositing!
- Different types of compositing
  - First: like isosurfacing, first intersection at a certain intensity
  - Max intensity: choose highest val
  - Average: mean intensity (density, like x-rays)
  - Accumulate: each voxel has some contribution



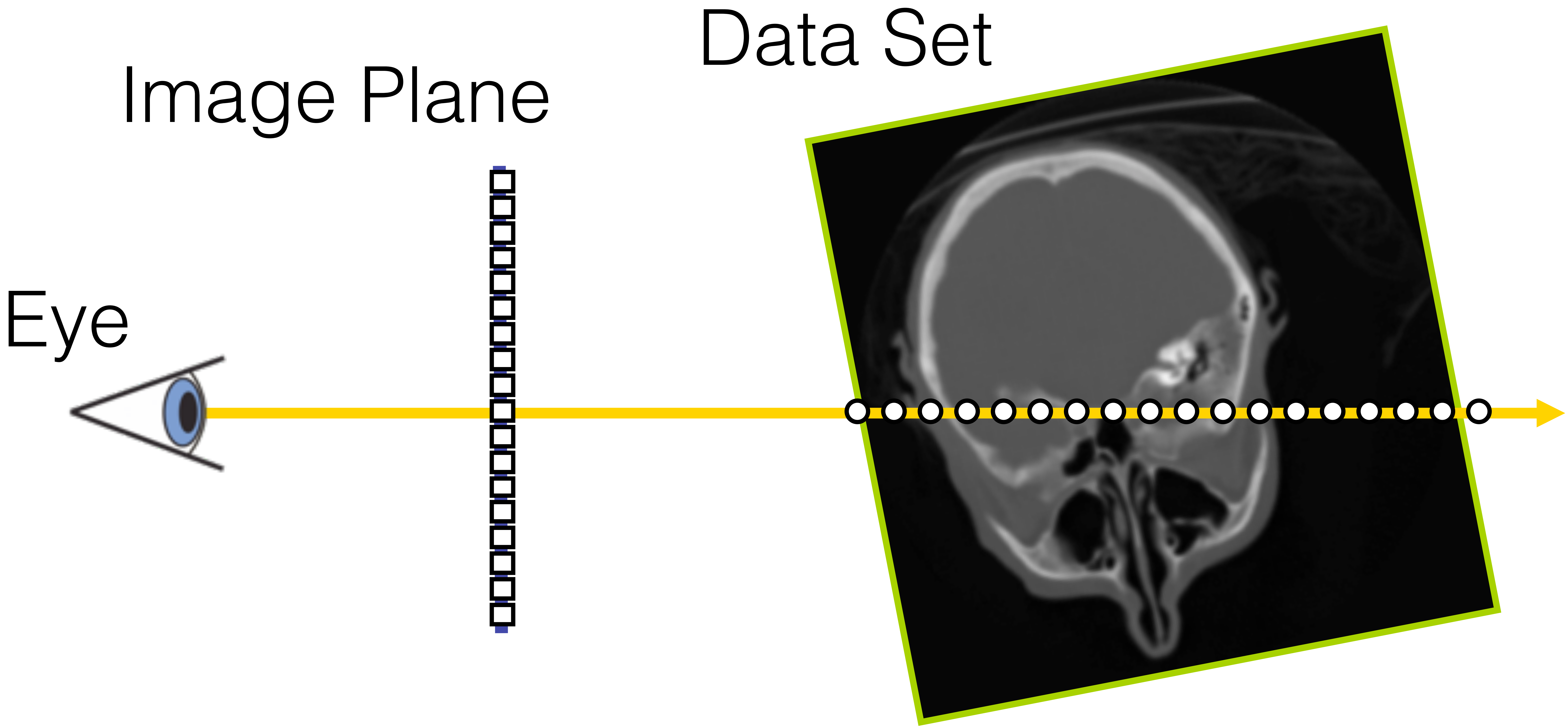
[Levine and Weiskopf/Machiraju/Möller]

Volume Ray Casting



[Levine]

Volume Ray Casting



[Levine]

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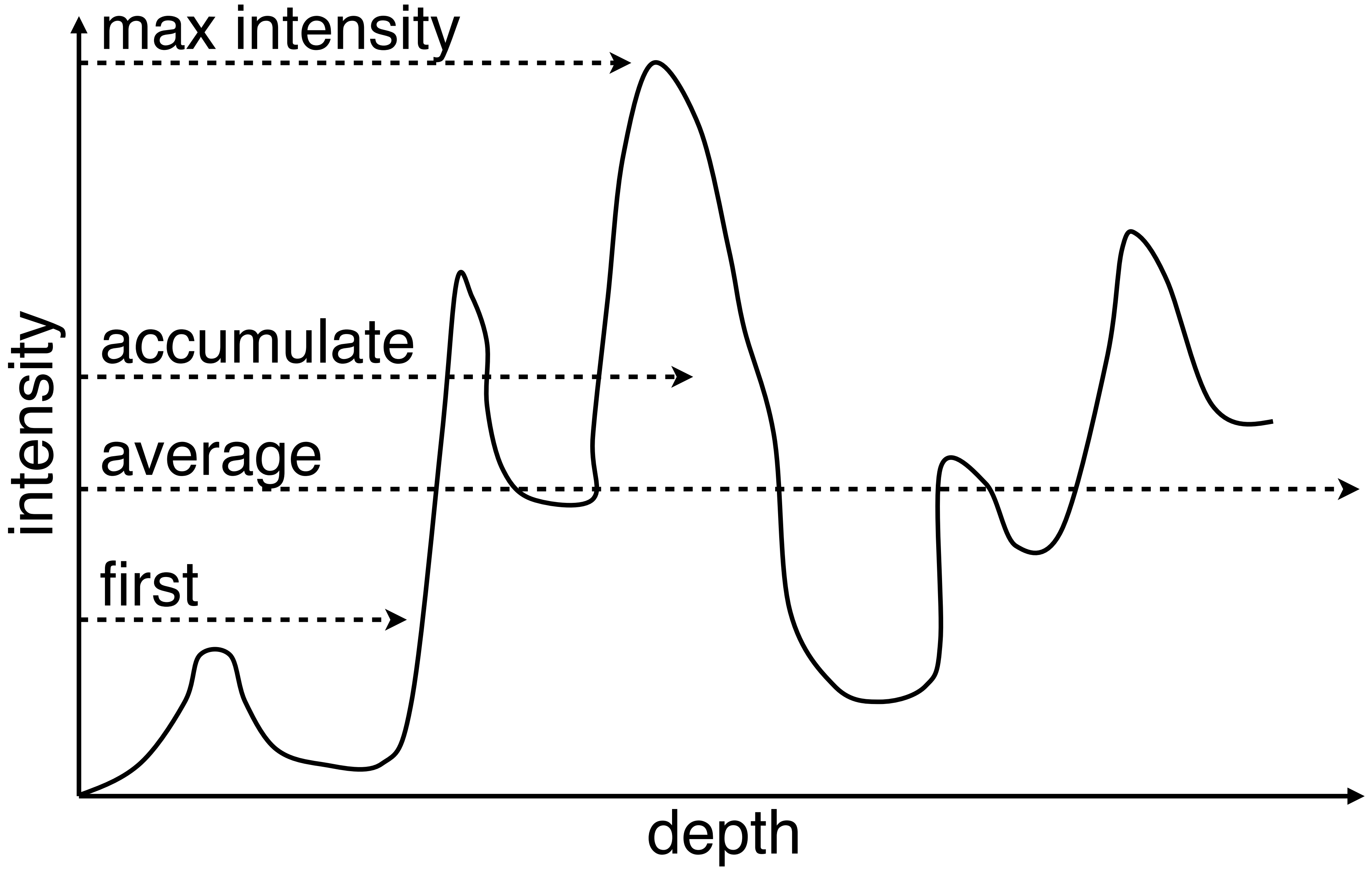
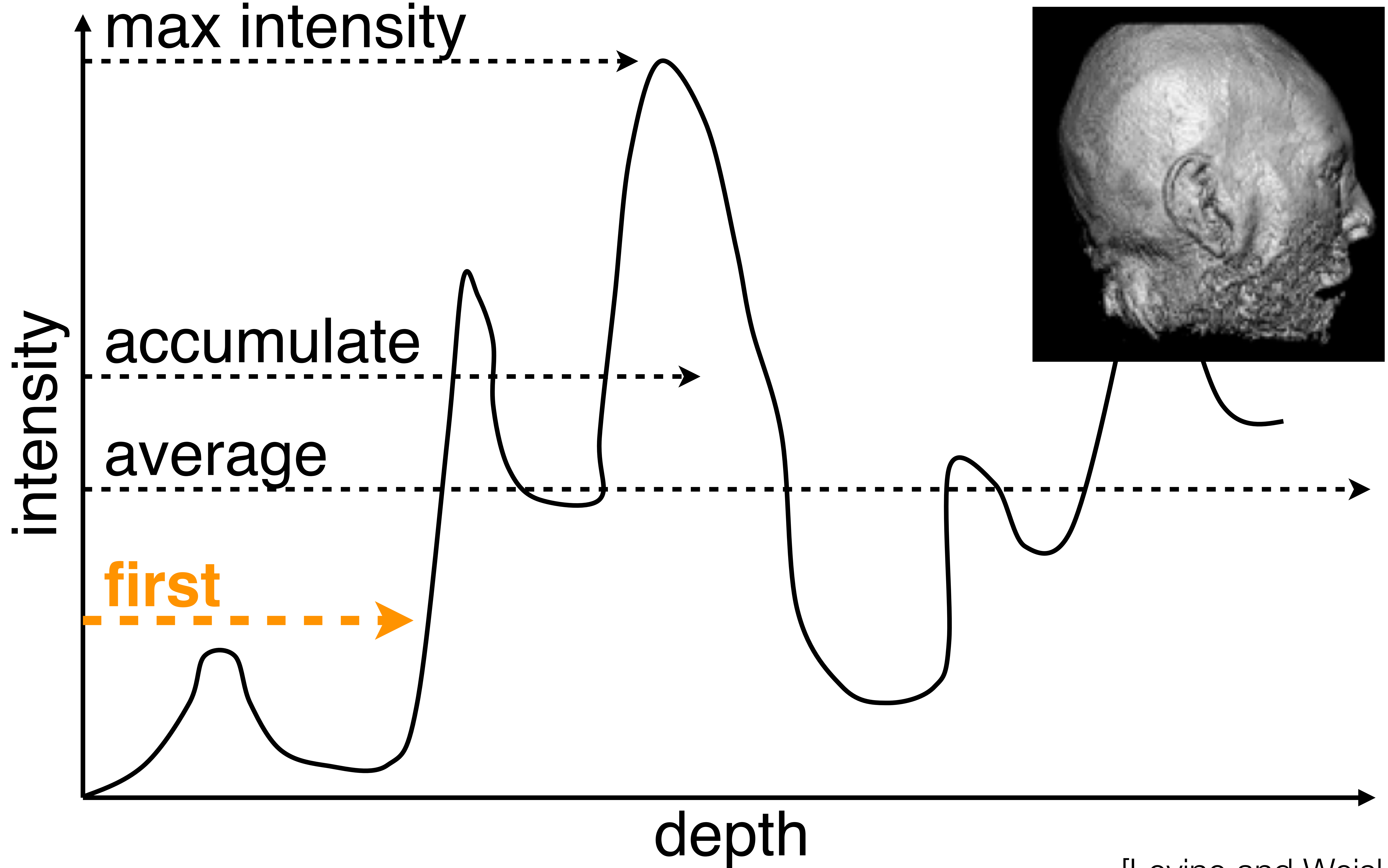


[Levine and Weiskopf/Machiraju/Möller]

Types of Compositing



[Levine and Weiskopf/Machiraju/Möller]

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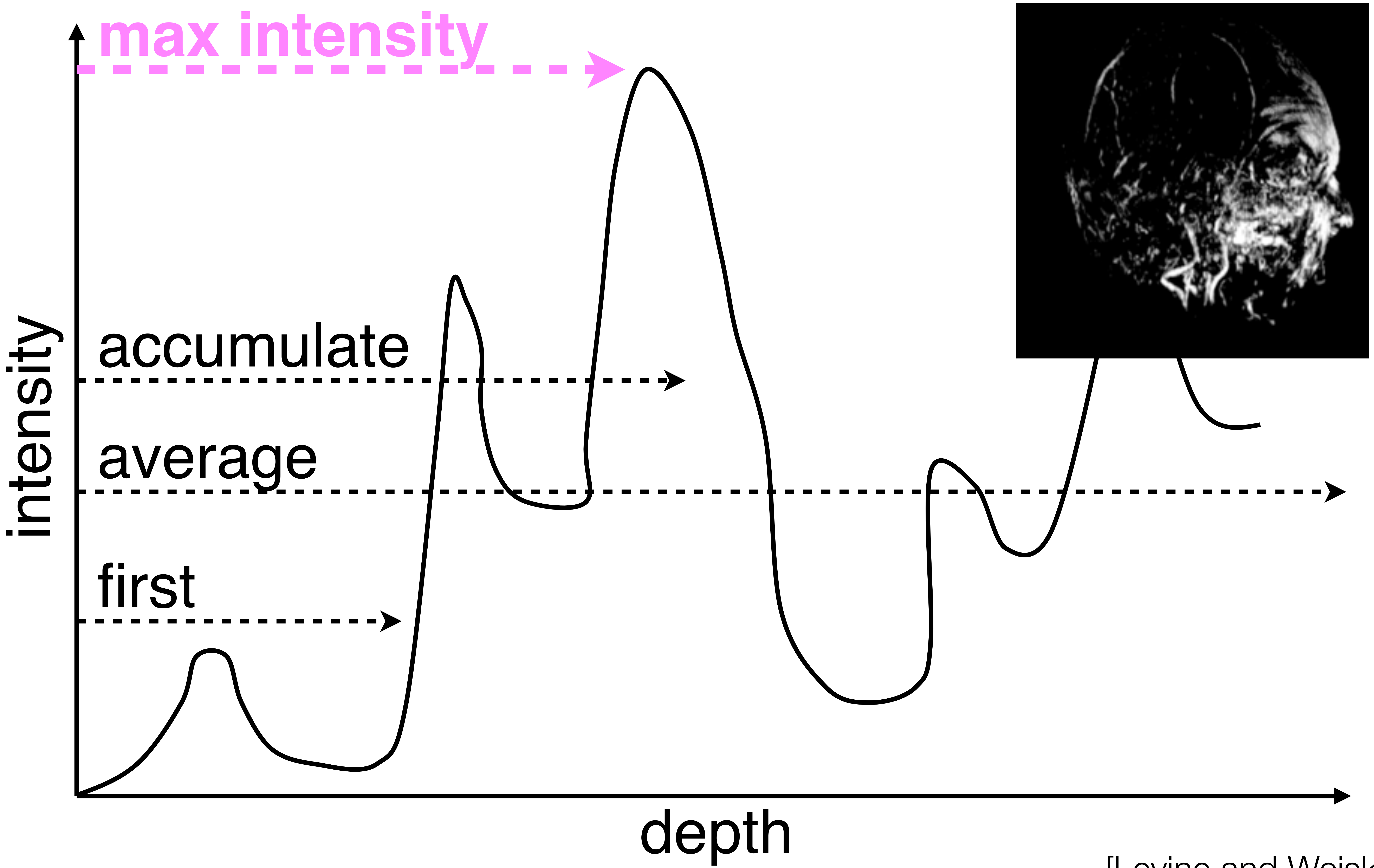

[Levine and Weiskopf/Machiraju/Möller]

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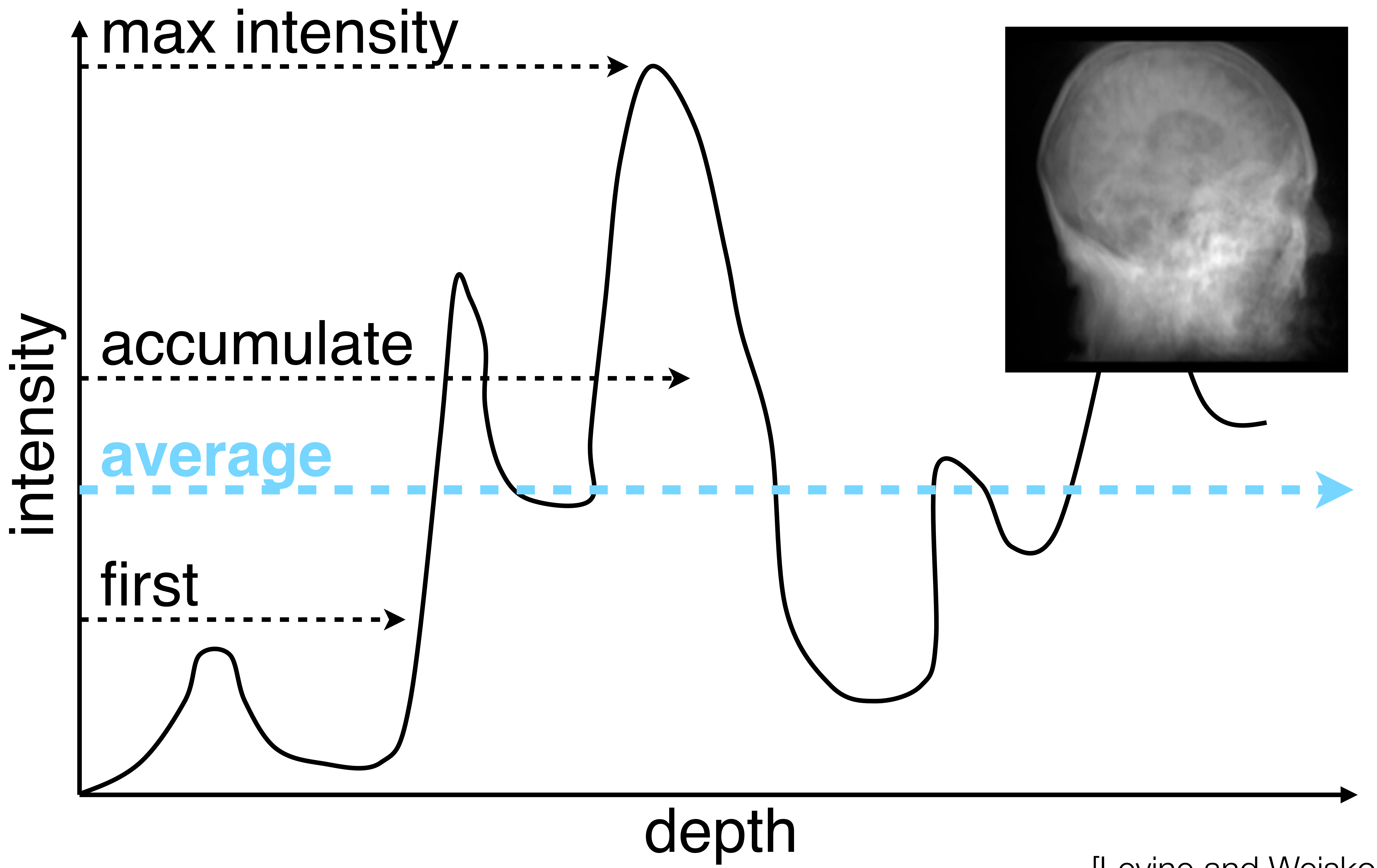
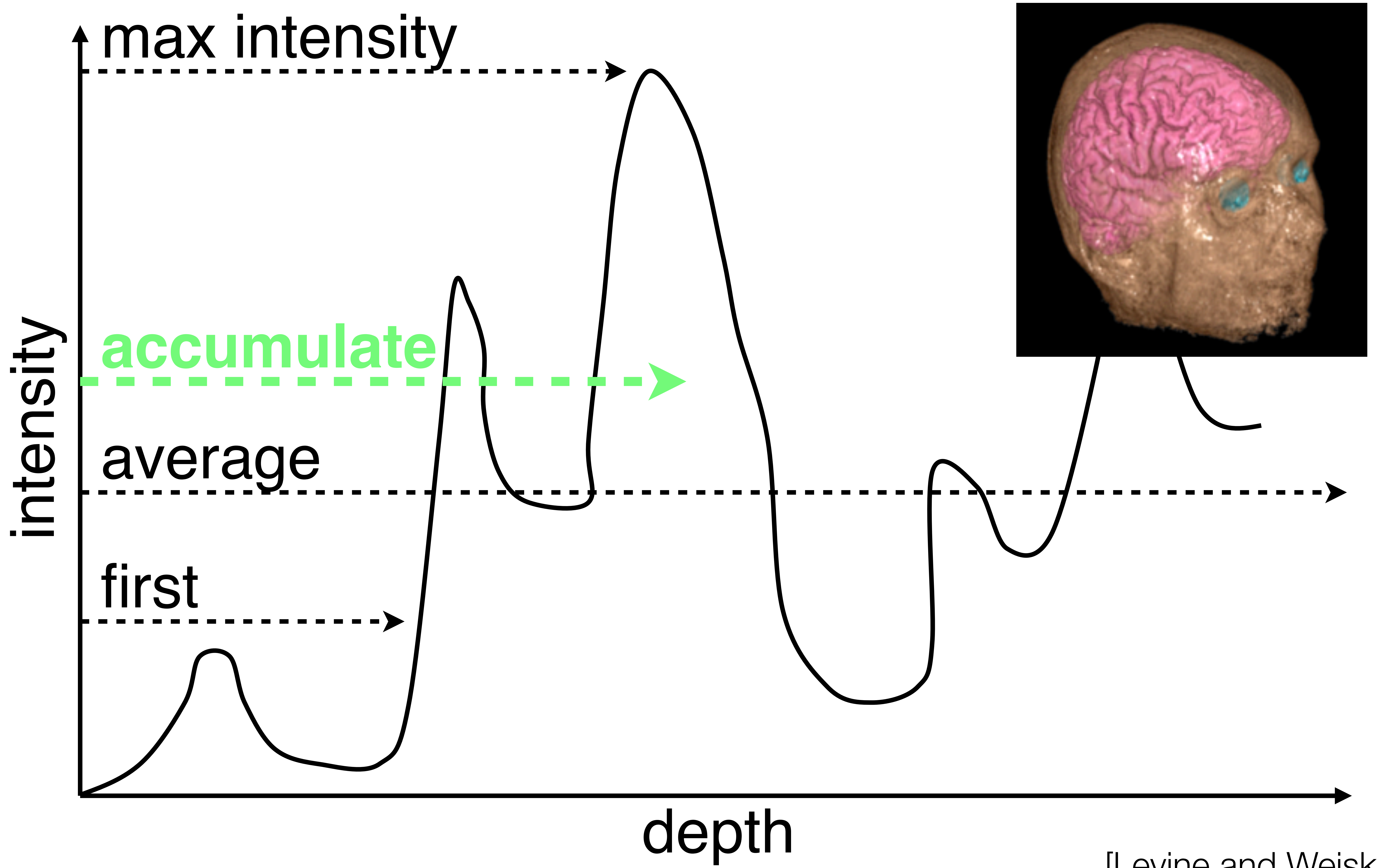


[Levine and Weiskopf/Machiraju/Möller]

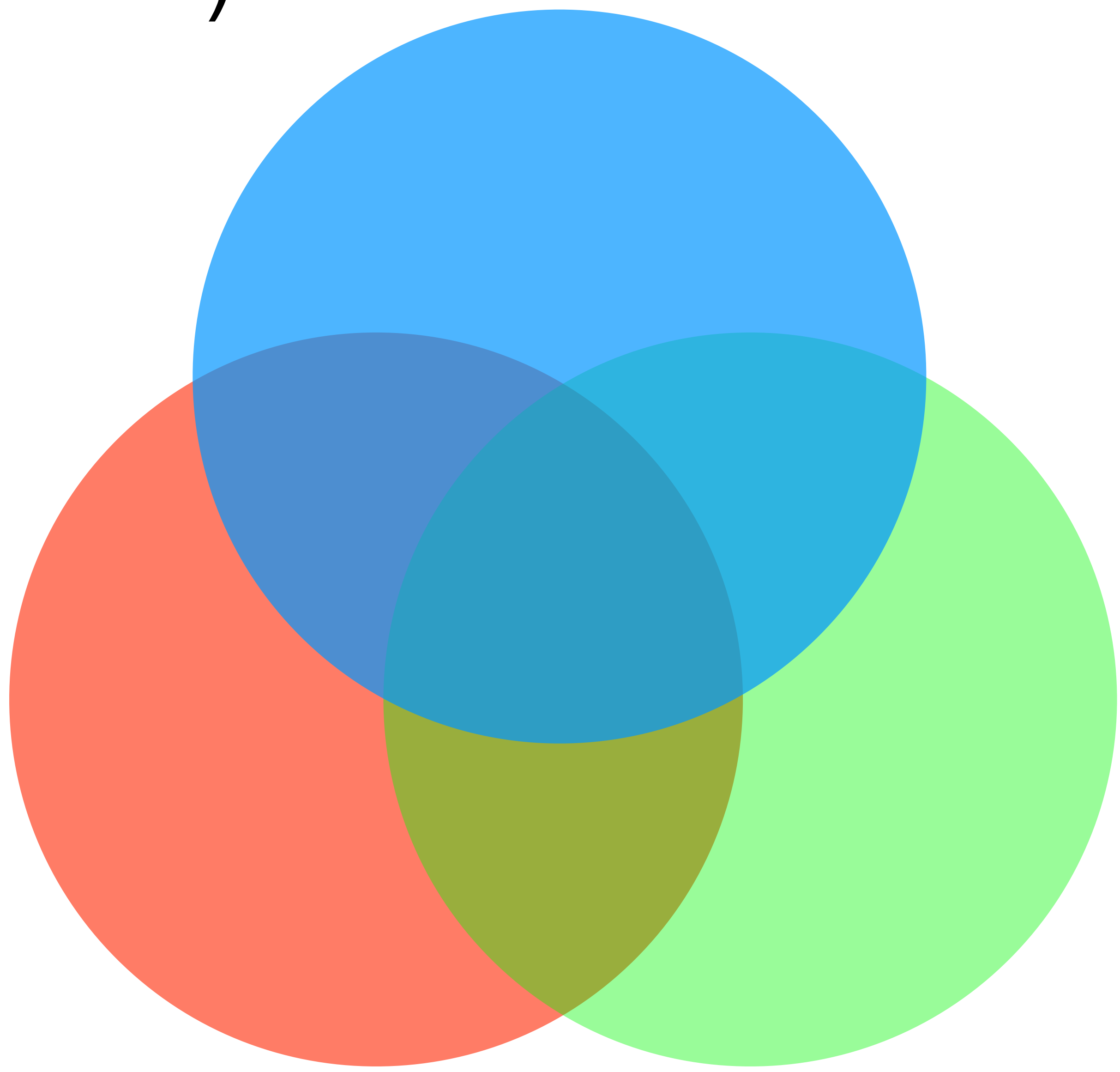
Types of Compositing



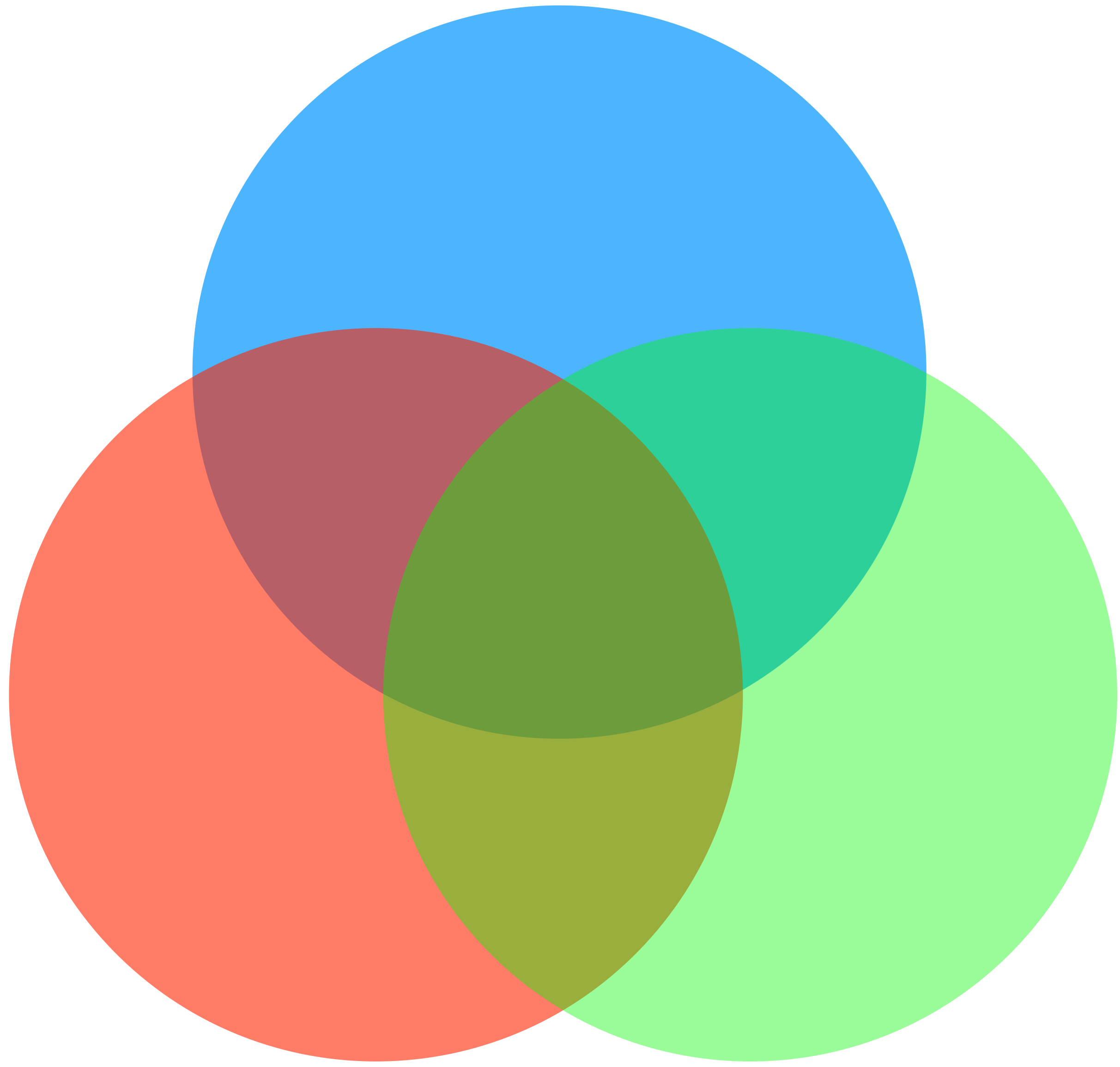
[Levine and Weiskopf/Machiraju/Möller]

Accumulation

- If we're not just calculating a single number (max, average) or a position (first), how do we determine the accumulation?
- Assume each value has an associated color (c) and opacity (α)
- Over operator (back-to-front):
  - $c = \alpha_f \cdot c_f + (1\text{-}\alpha_f) \cdot \alpha_b \cdot c_b$
  - $\alpha = \alpha_f + (1\text{-}\alpha_f) \cdot \alpha_b$
- Order is important!



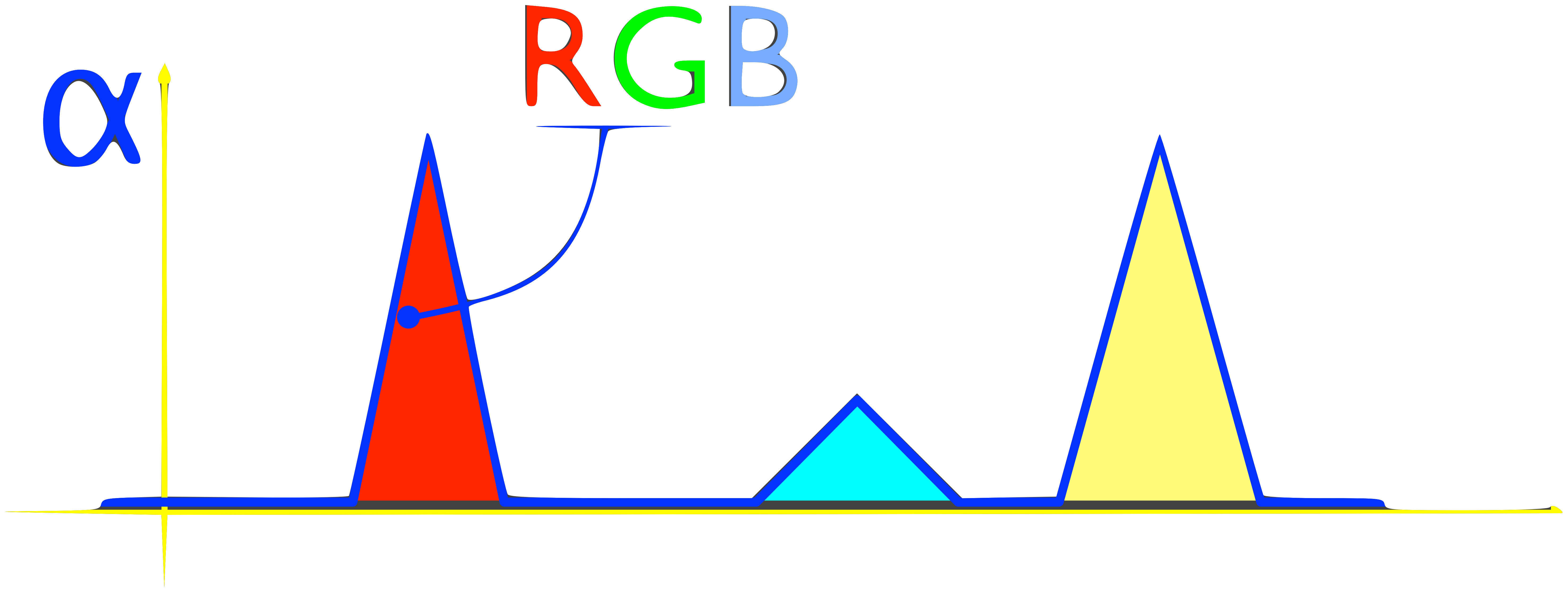
Blue Last



Blue First

Transfer Functions

- Where do the colors and opacities come from?
- Idea is that each voxel emits/absorbs light based on its scalar value
- …but users get to choose how that happens
- x-axis: color region definitions, y-axis: opacity

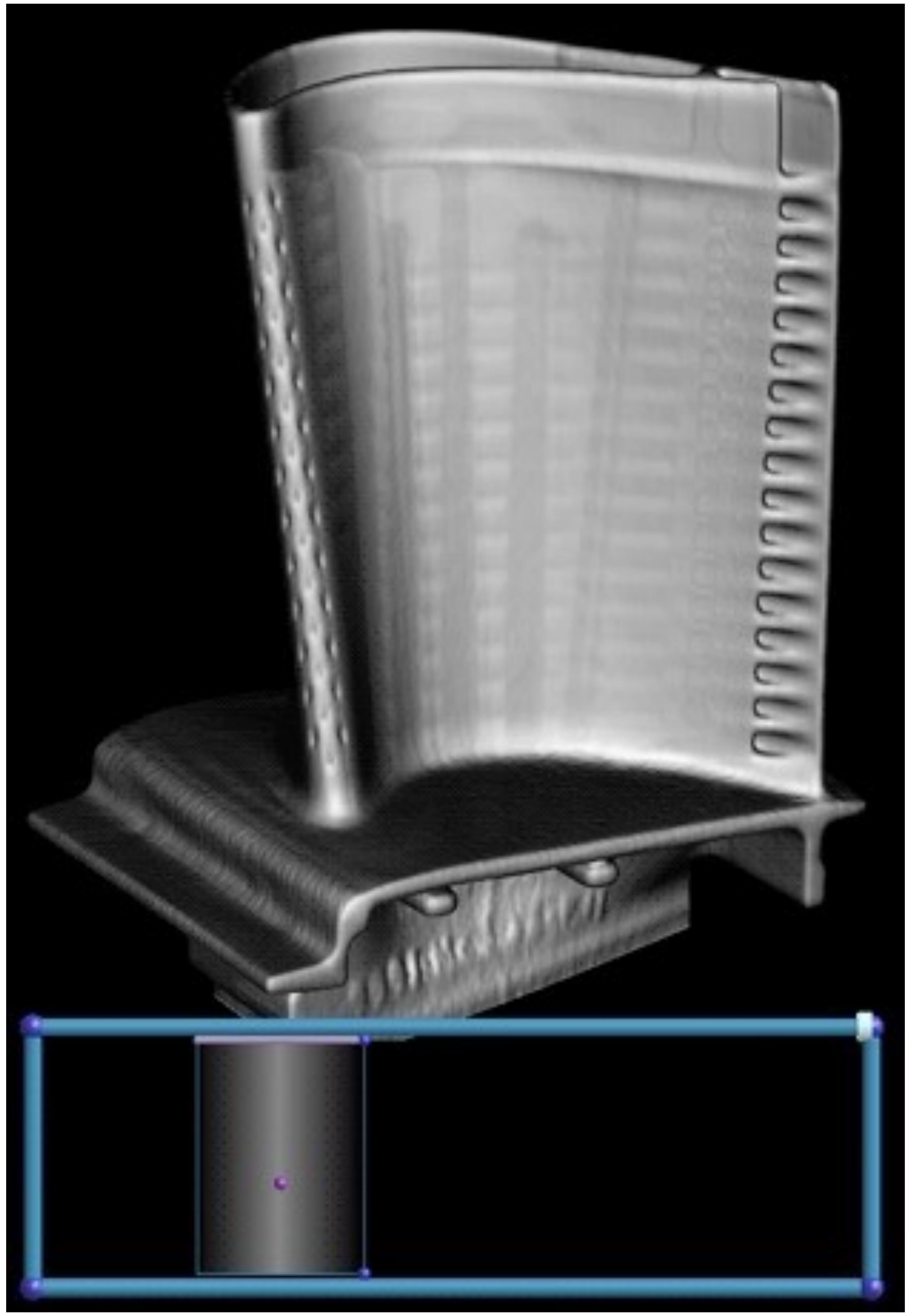


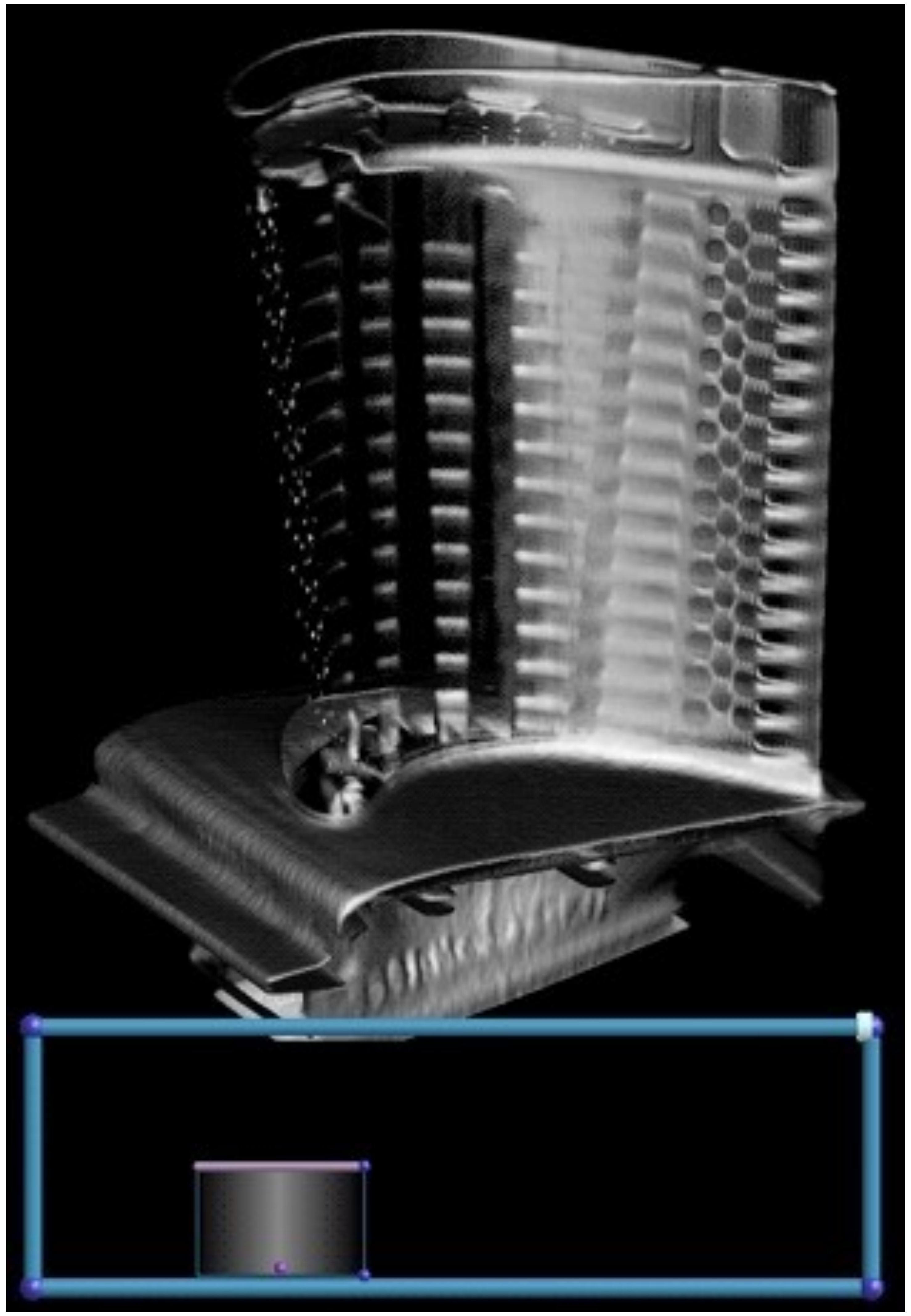
[Kindlmann]

Transfer Function Design

- Transfer function **design** is non-trivial!
- Lots of tools to help visualization designers to create good transfer functions
- Histograms, more attributes than just value like gradient magnitude

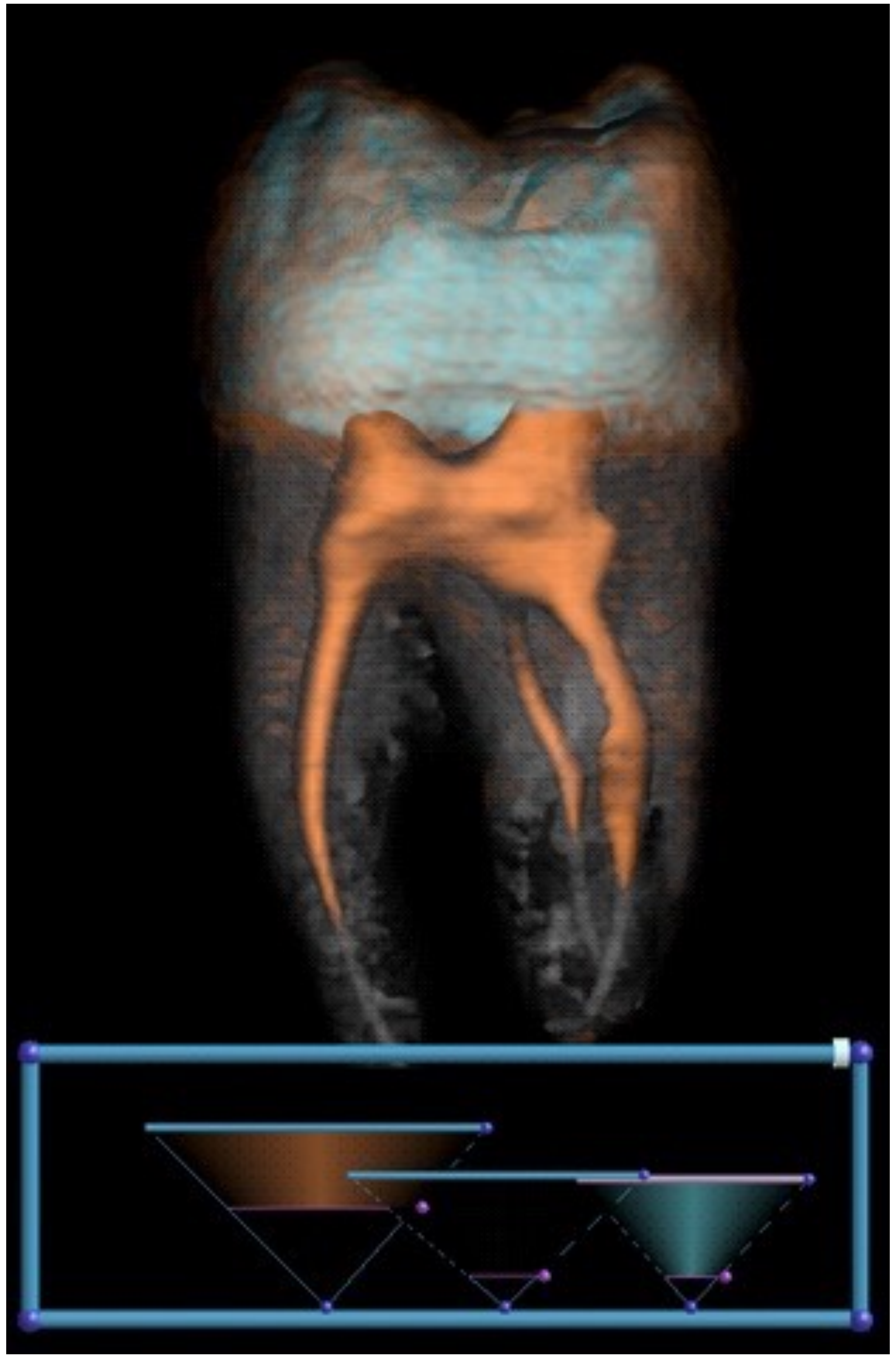
Multidimensional Transfer Functions

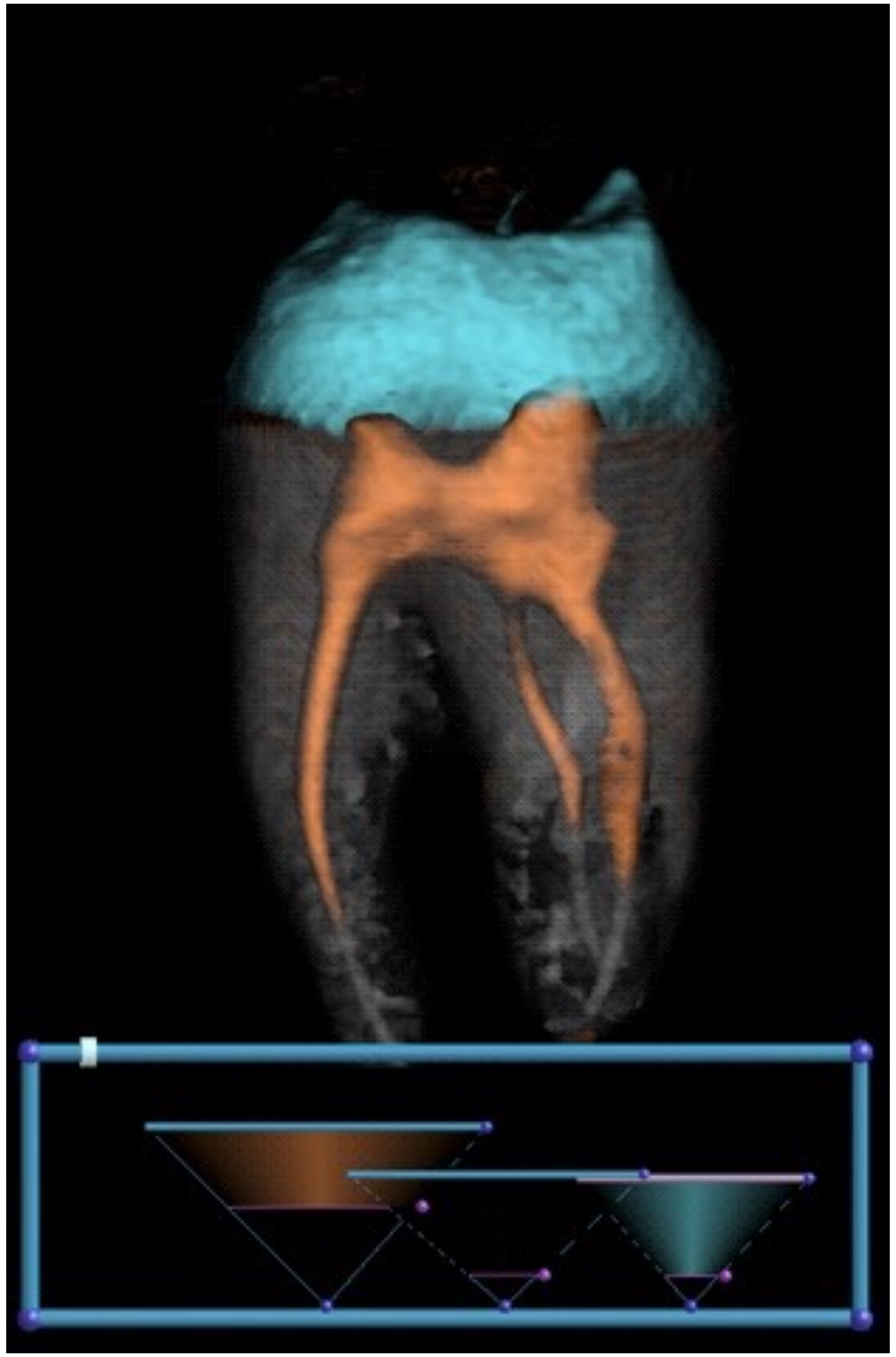




[J. Kniss]

Multidimensional Transfer Functions





[J. Kniss]

ParaView Examples