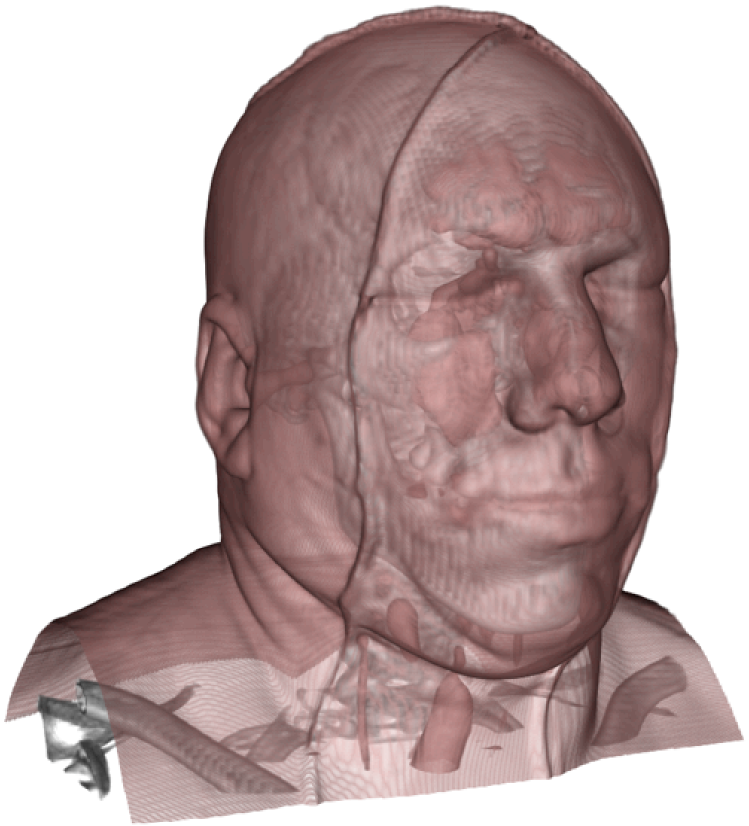
CS 5630/6630
Scientific Visualization

Volume Rendering II: Structured Grid Techniques

Structured Grids

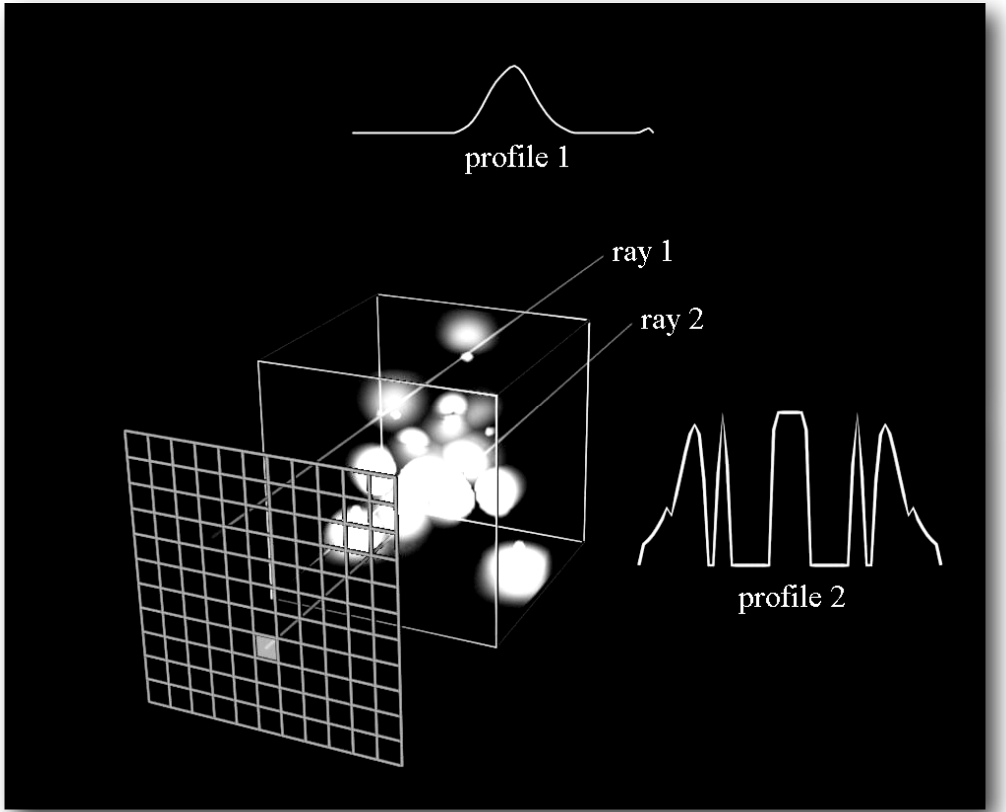
- Image-space techniques (backwards mapping)
  - Ray-Casting
- Object-space techniques (forwards mapping)
  - Splatting
  - Texture Slicing
- Hybrid
  - Shear-Warp



Ray-Casting

- Image-space technique
- Starts from image plane and goes into volume (backwards mapping)
- Render the image one pixel at a time
- More limited than of ray-tracing

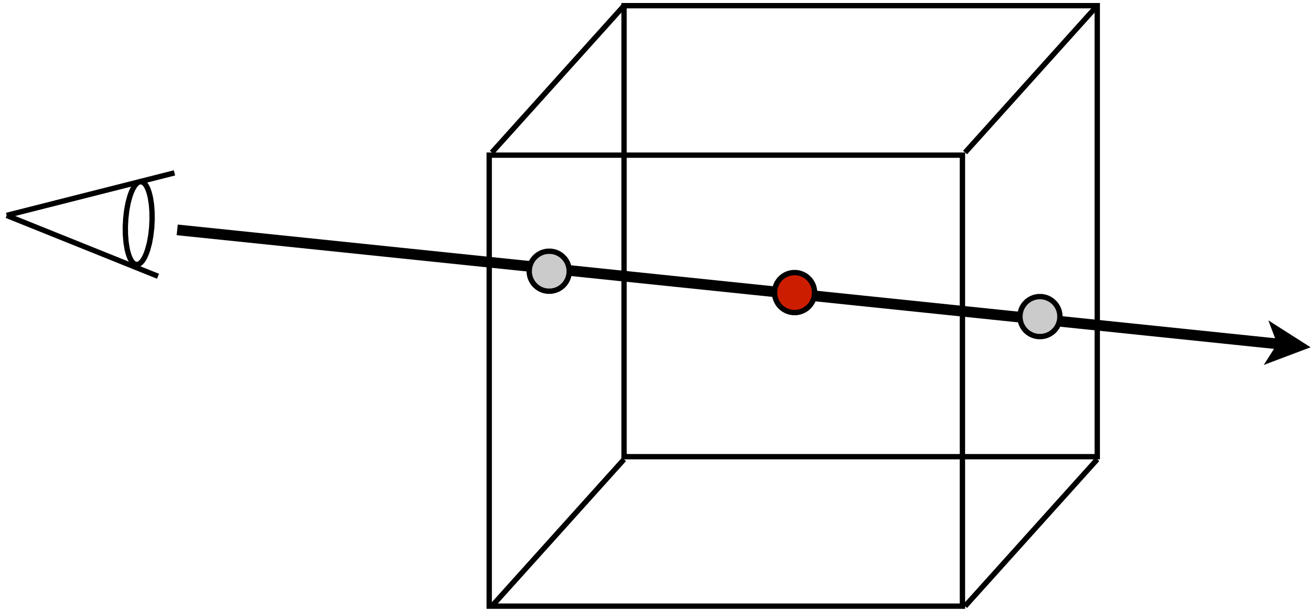
For each pixel:
Cast a ray from pixel to volume
Find sample via interpolation
For each sample:
Classify using transfer function
Compute volume rendering integral
Composite



[Drebin et al 88,Upson and Keeler 88]

Ray-casting

- Sampling
  - Where do you sample?
    - Cell boundaries
    - Internally to avoid artifacts
  - Use trilinear interpolation
  - Pre-classification vs. post-classification



Ray-Casting

- Advantages?

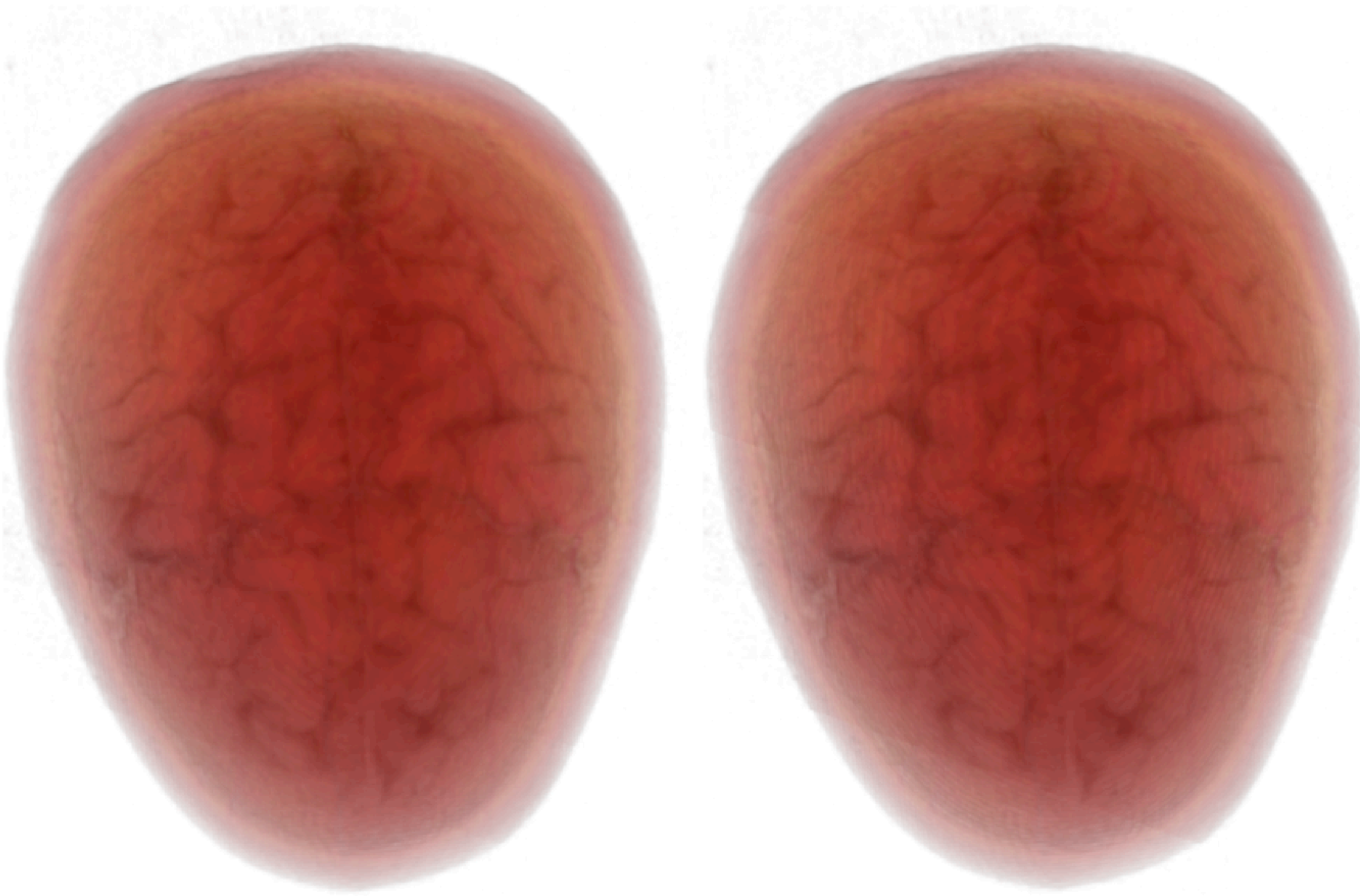
- Disadvantages?

Ray-Casting

- Advantages?
  - Its simple!
  - No hardware constraints
  - Easily parallelized
  - Easily extended for multiple scattering
- Disadvantages?
  - Its slow!
  - Must sample densely for high quality

Ray-casting

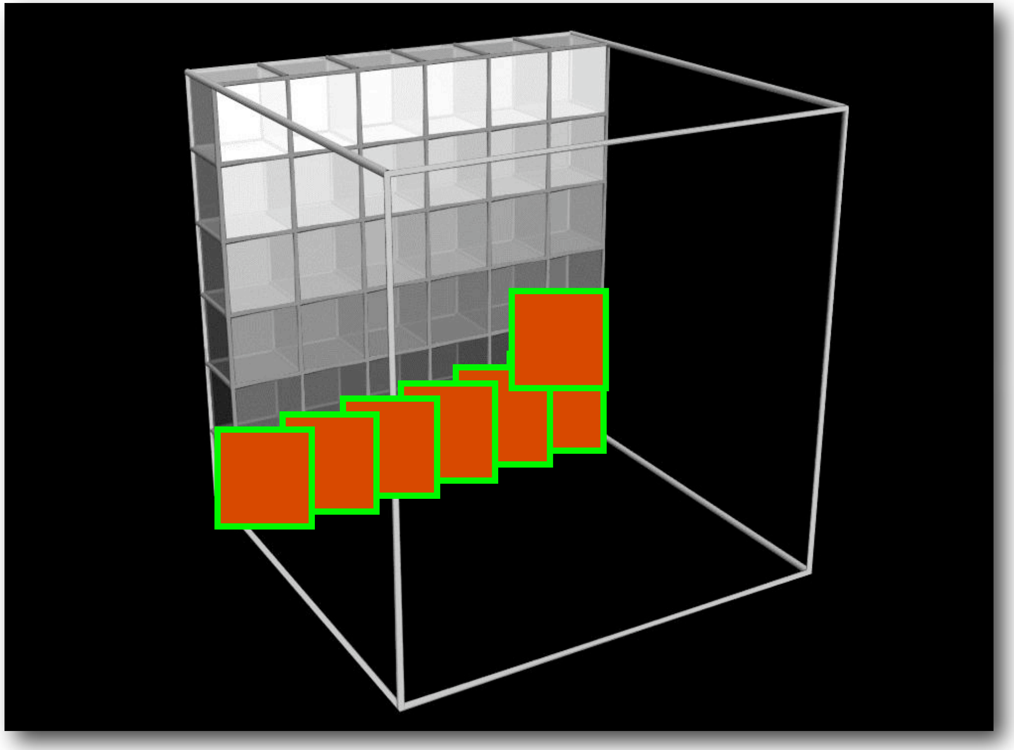
- VisTrails Example



Splatting

- Object-space technique
- Starts from the volume and goes to the image plane
- Render the image one voxel at a time
- Front-to-back or back-to-front

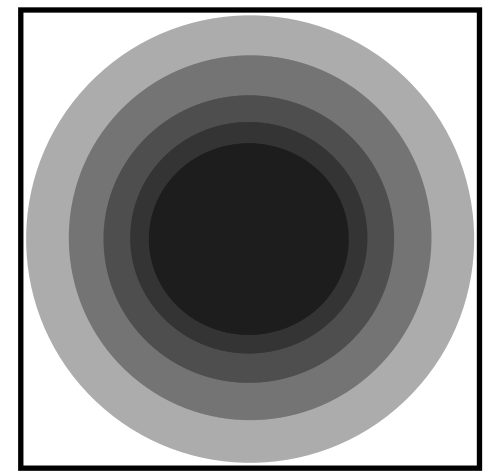
For each voxel in order:
Classify using transfer function
Generate a semi-transparent footprint
Project footprint to image plane
Composite

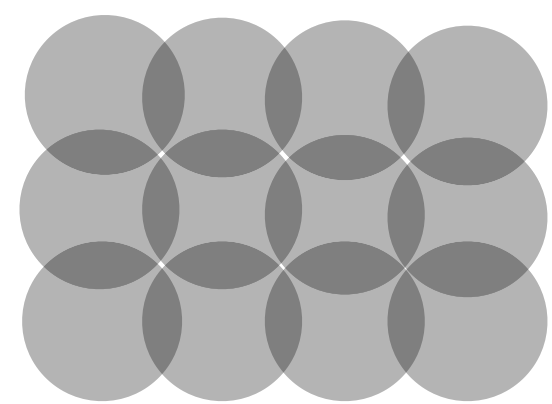


[Westover 89, Westover 90]

Splatting

- Footprint selection
  - Projected area on image plane
  - Needs to be simple and fast
  - Use a circle!
    - Rotationally invariant
    - Opacity convolved with a Gaussian function
    - How big should the circle be?
      - Diameter of 1.6 times voxel size
    - How should it be represented?
      - Textured, screen-aligned quadrilateral

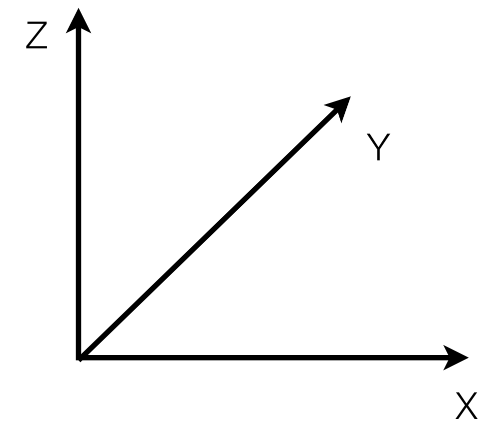


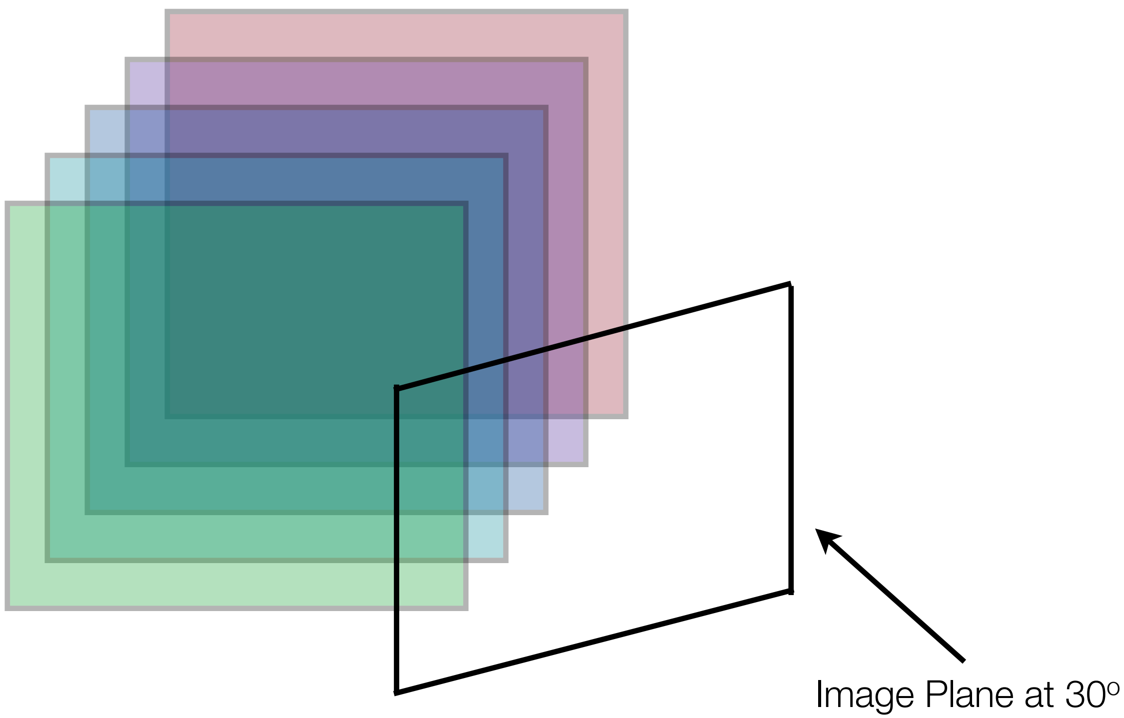


[Crawfis and Max 93]

Splatting

- Visibility ordering
  - Sheet-aligned splatting
    - Choose the closest axis aligned slices
    - Traverse slices front-to-back

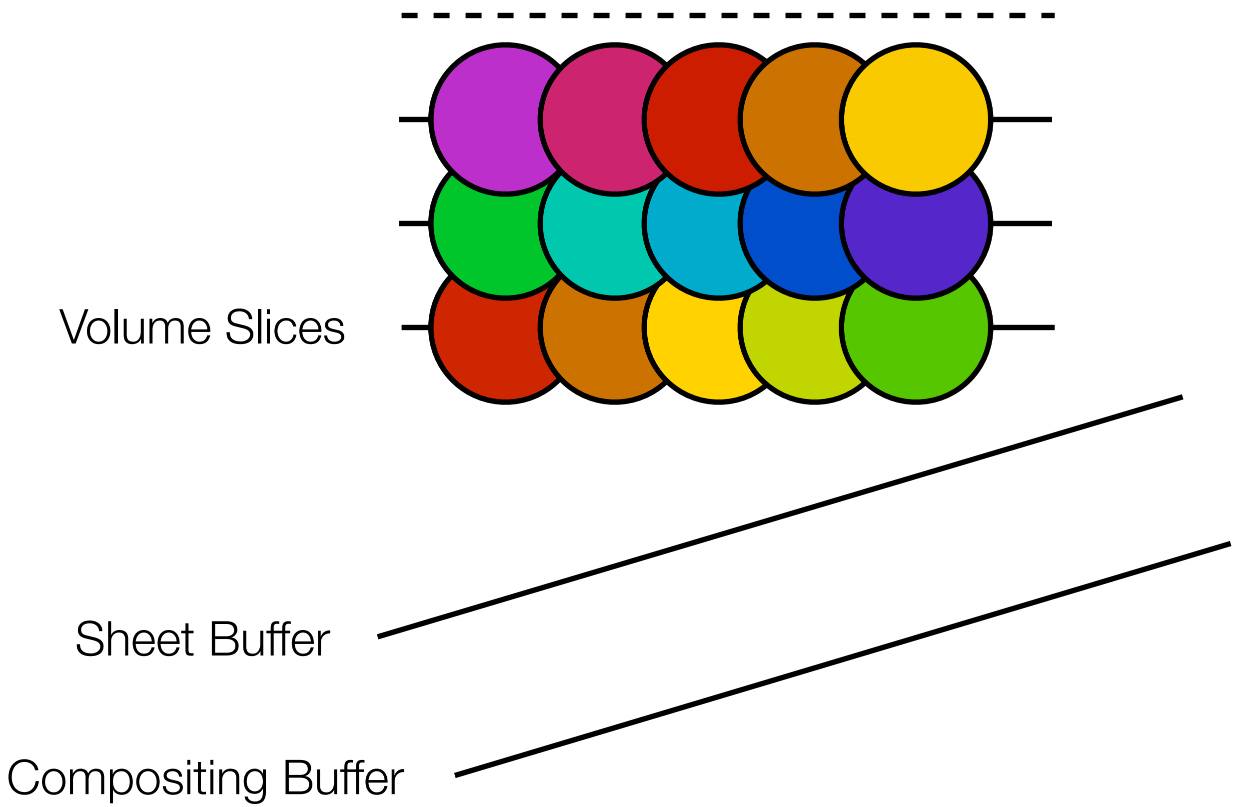




[Westover 90]

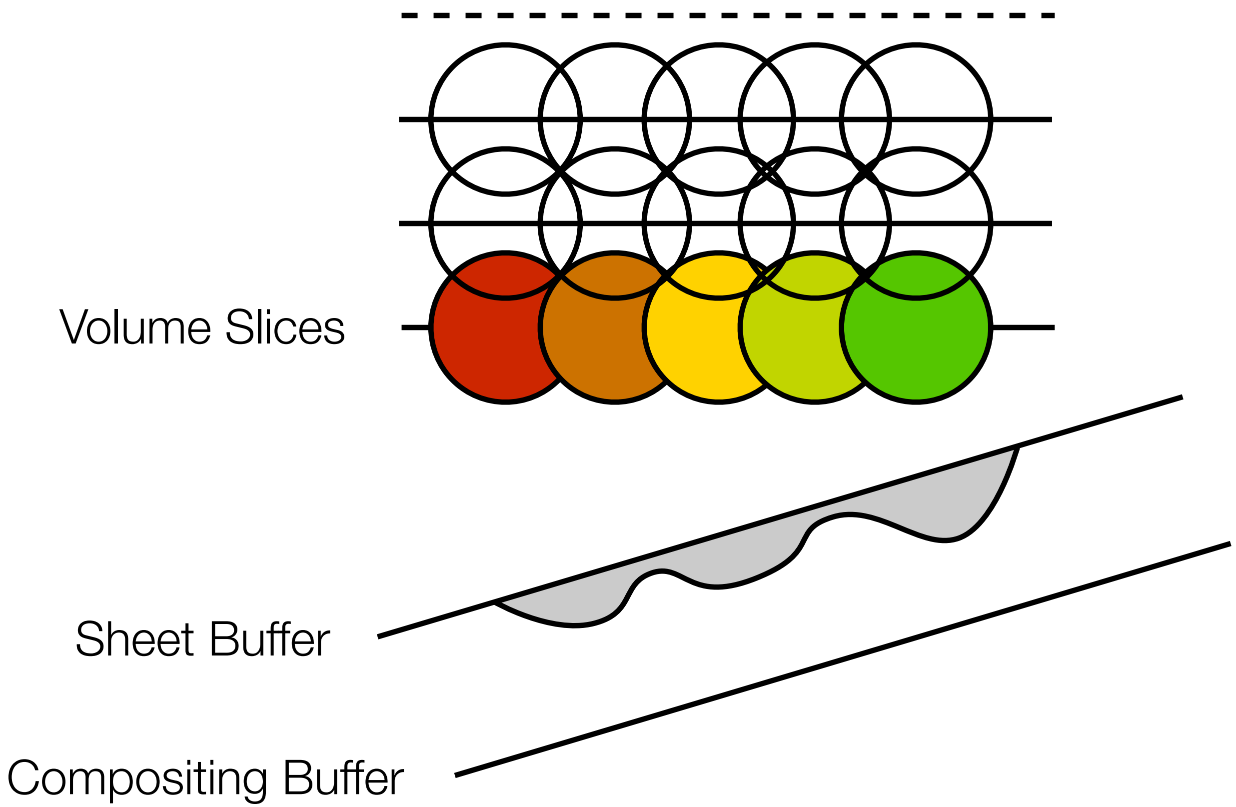
Splatting

- Sheet-aligned splatting



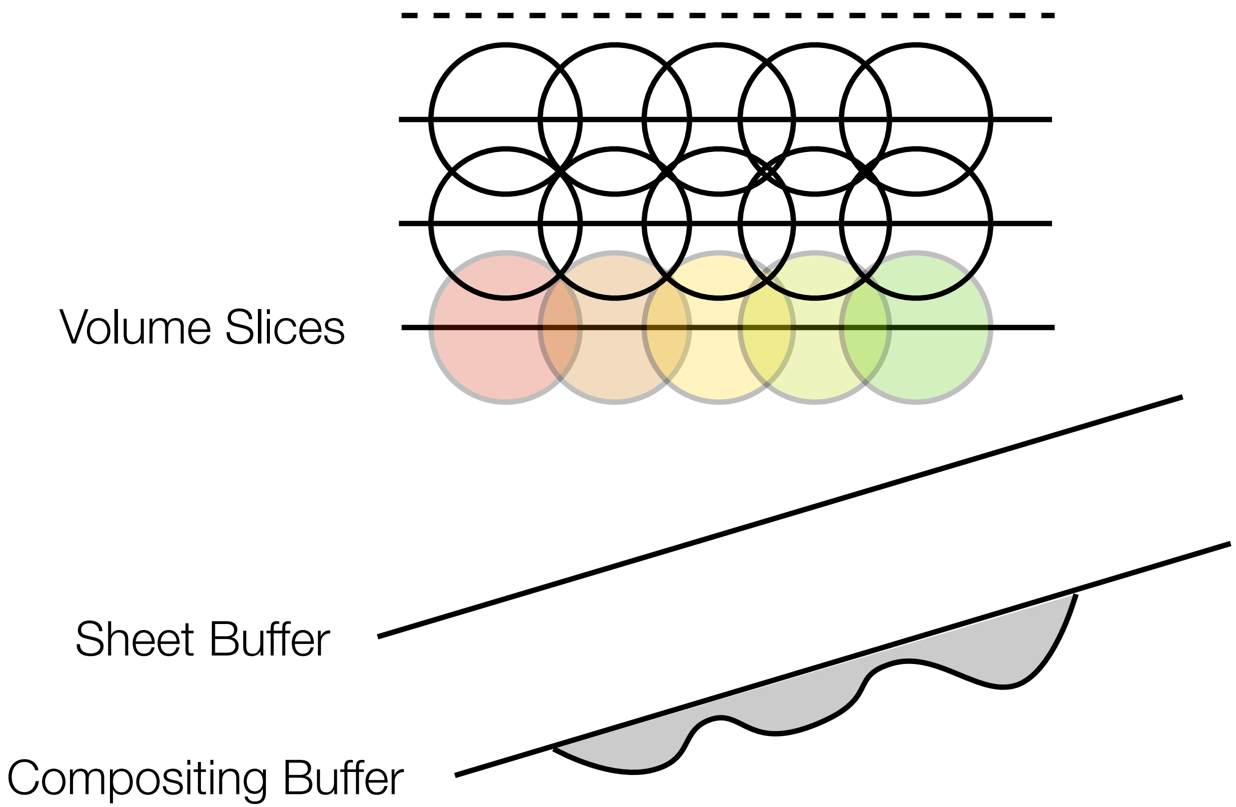
Splatting

- Sheet-aligned splatting
  - Add voxel kernels within first sheet



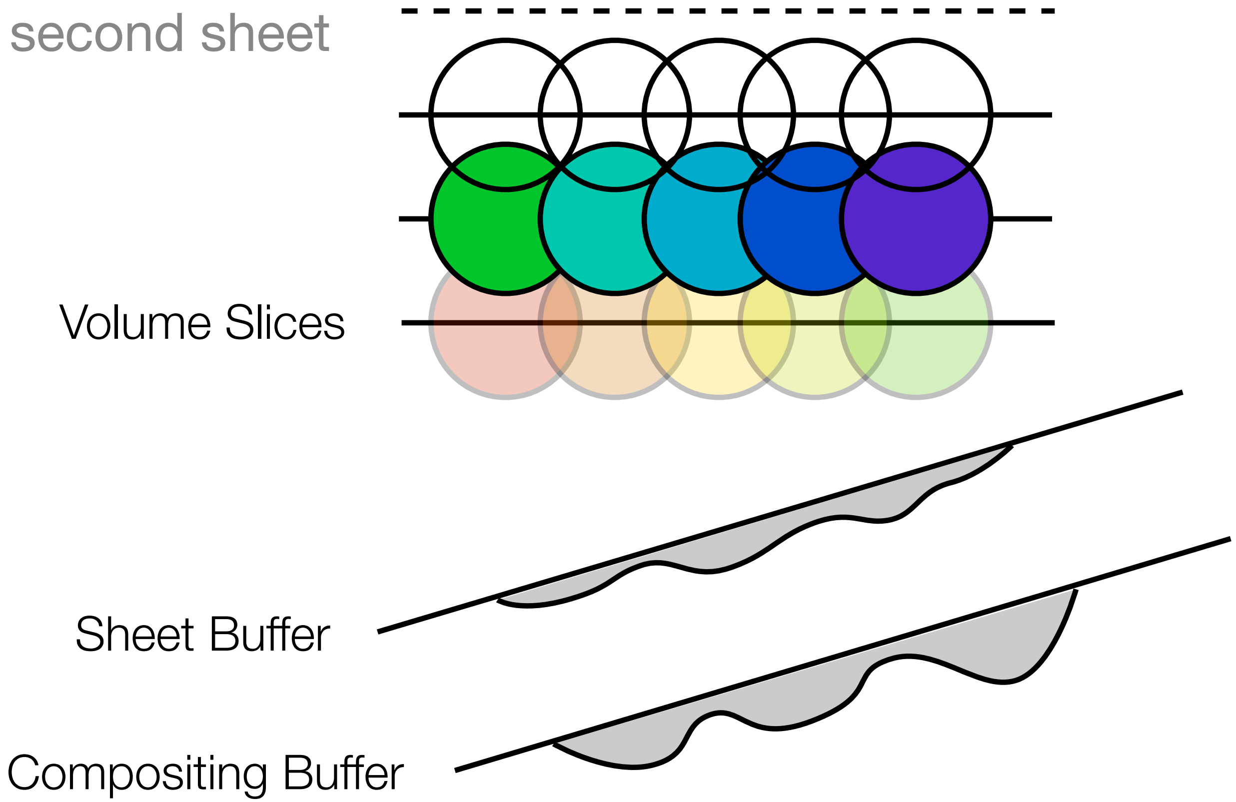
Splatting

- Sheet-aligned splatting
  - Add voxel kernels within first sheet
  - Transfer to compositing buffer



Splatting

- Sheet-aligned splatting
  - Add voxel kernels within first sheet
  - Transfer to compositing buffer
  - Add voxel kernels within second sheet



Splatting

- Sheet-aligned splatting
  - Add voxel kernels within first sheet
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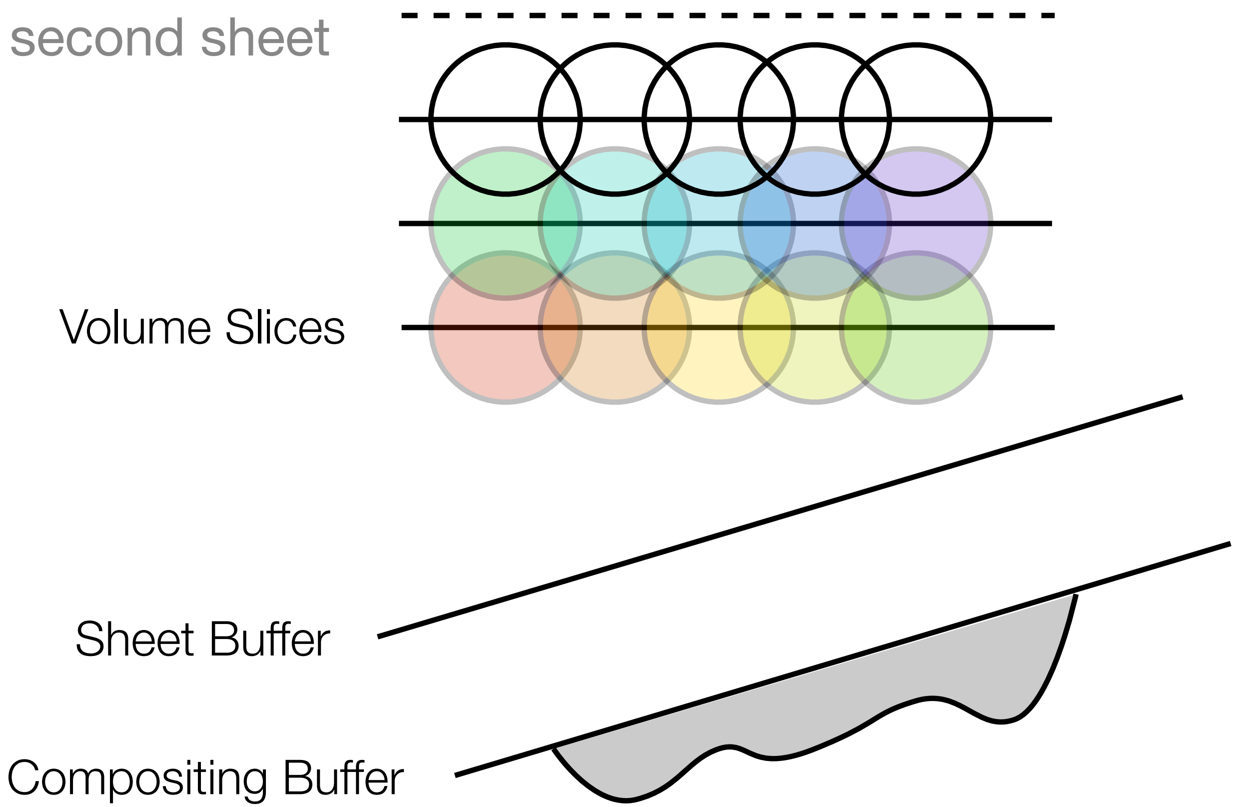


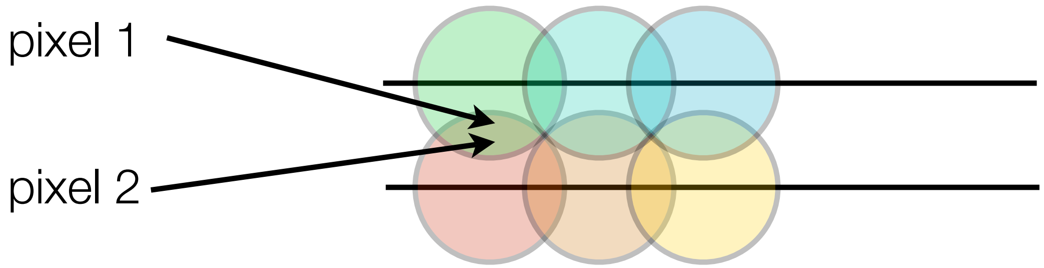
Splatting

- Advantages

- Disadvantages

Splatting

- Advantages
  - Fast! The voxel interpolation is in 2D
  - Footprints can be preintegrated
  - Only relevant voxels need projecting, can be performed out-of-core
- Disadvantages
  - Blurry when zoomed
  - Slows when zoomed
  - Compositing can be incorrect in overlap



Texture Slicing

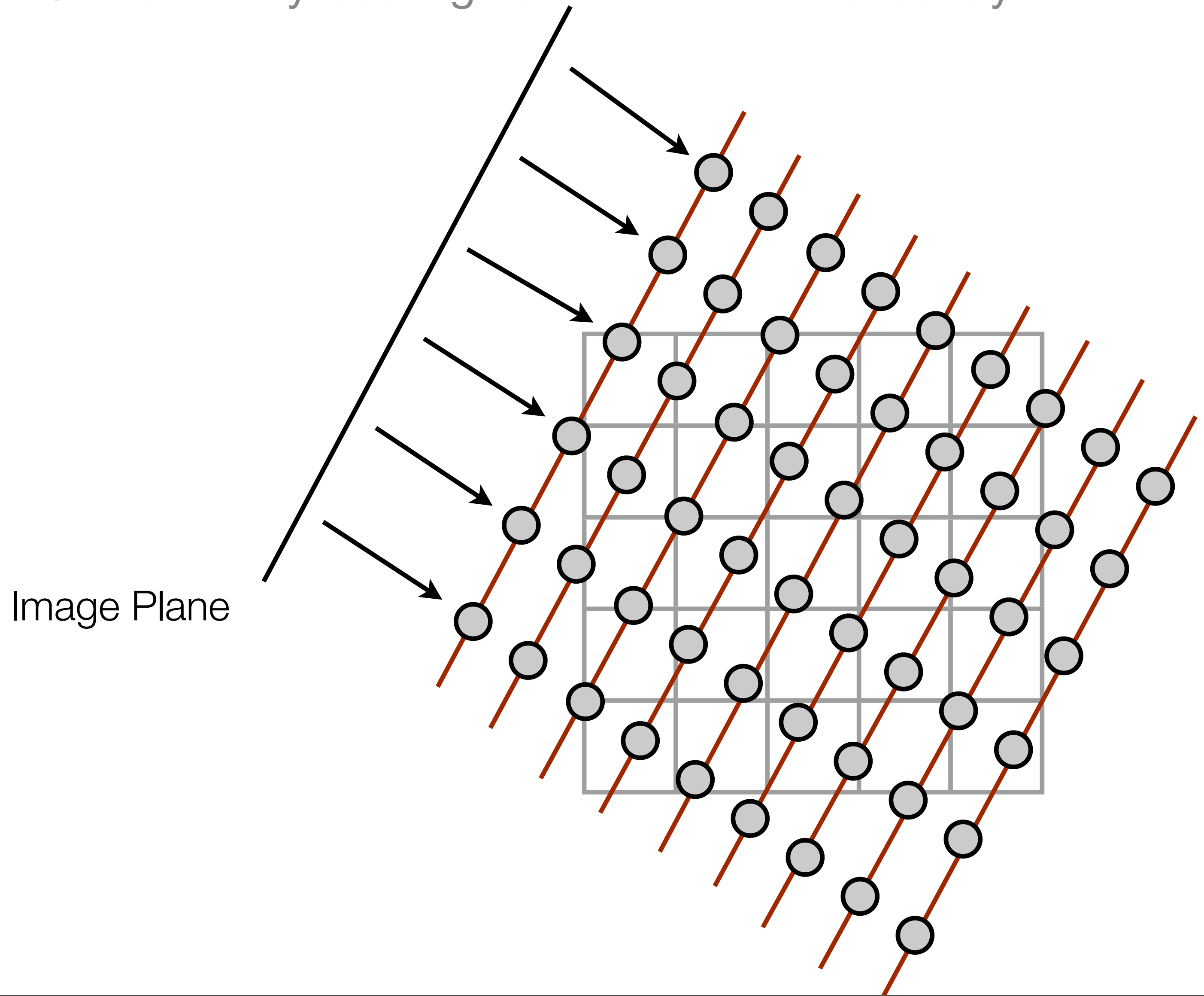
- Object-space technique
- Store volume in texture memory of GPU
- Slices volume using proxy geometry

Store volume in 3D texture or 2D textures
For each viewpoint:
    Create proxy geometry parallel to image plane
    Render proxy geometry
    Sample textures for classification
    Composite

[Cullip and Neumann 93,
Cabral et al. 94,
Guan and Lipes 94,
Wilson et al. 94]

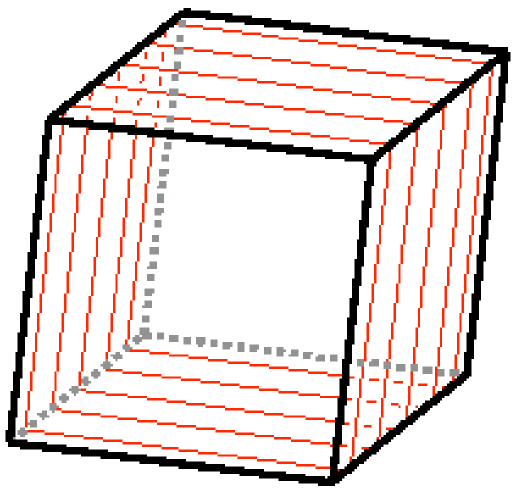
Texture Slicing

- Similar to ray-casting but with simultaneous rays

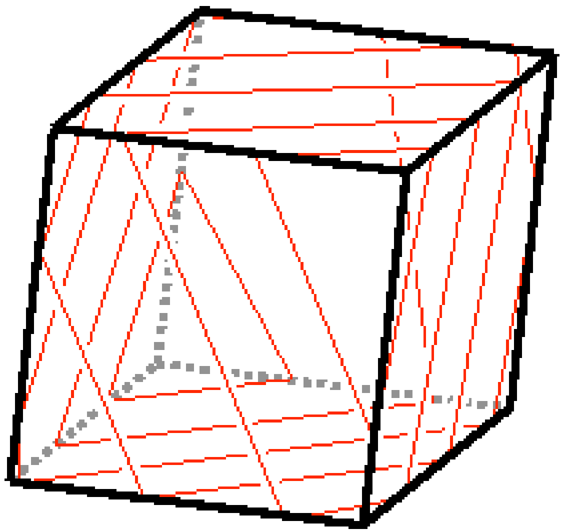


Texture Slicing

- 2D textures
  - Axis aligned slicing
- 3D textures
  - View aligned slicing



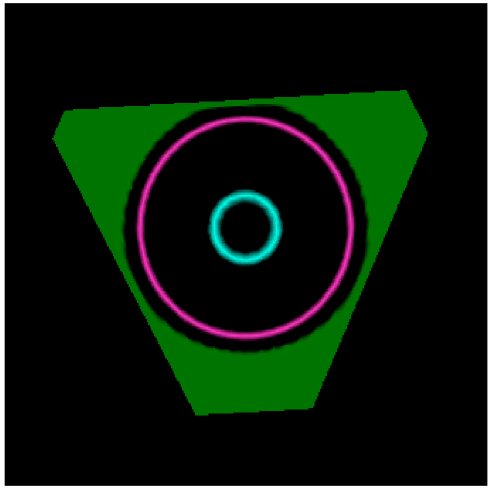
2D



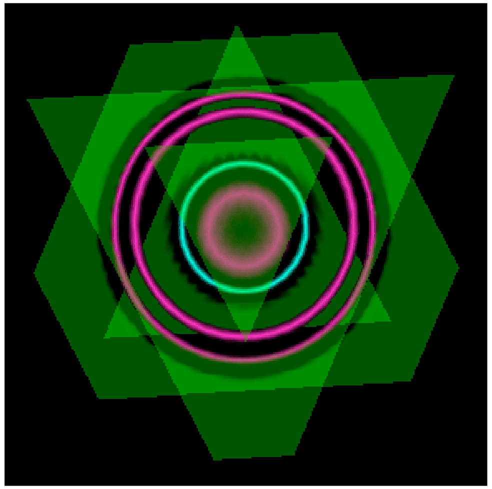
3D

Texture Slicing

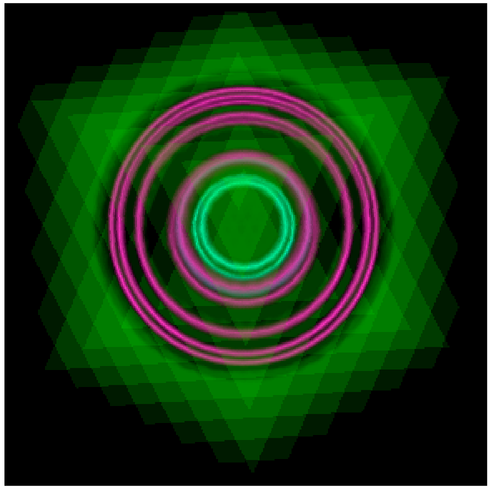
- Sampling



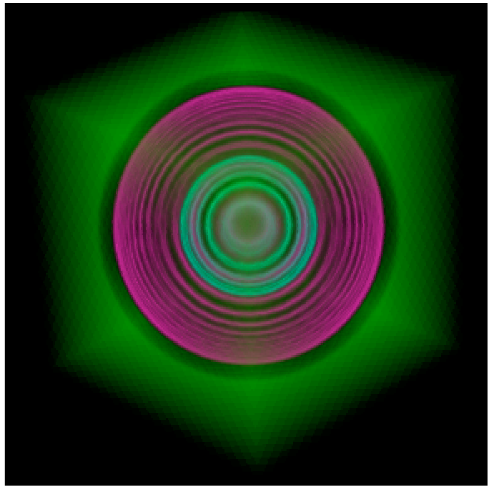
1 Slice



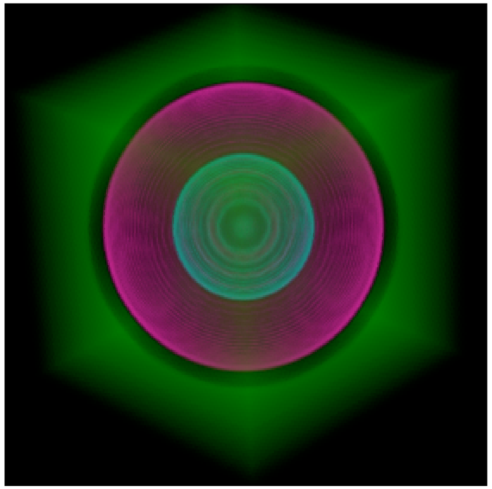
5 Slices



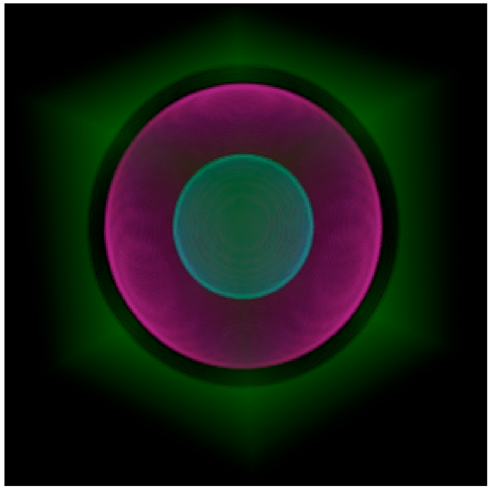
20 Slices



45 Slices



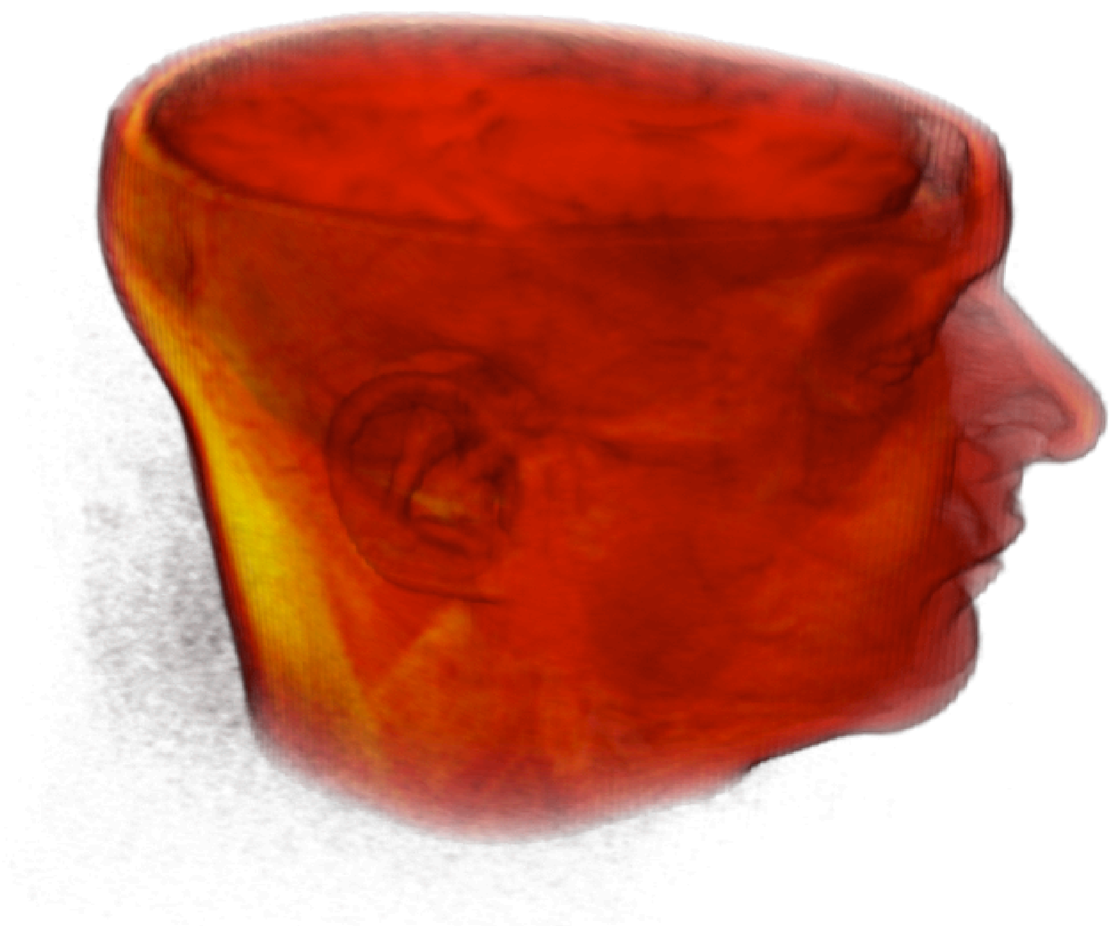
85 Slices



170 Slices

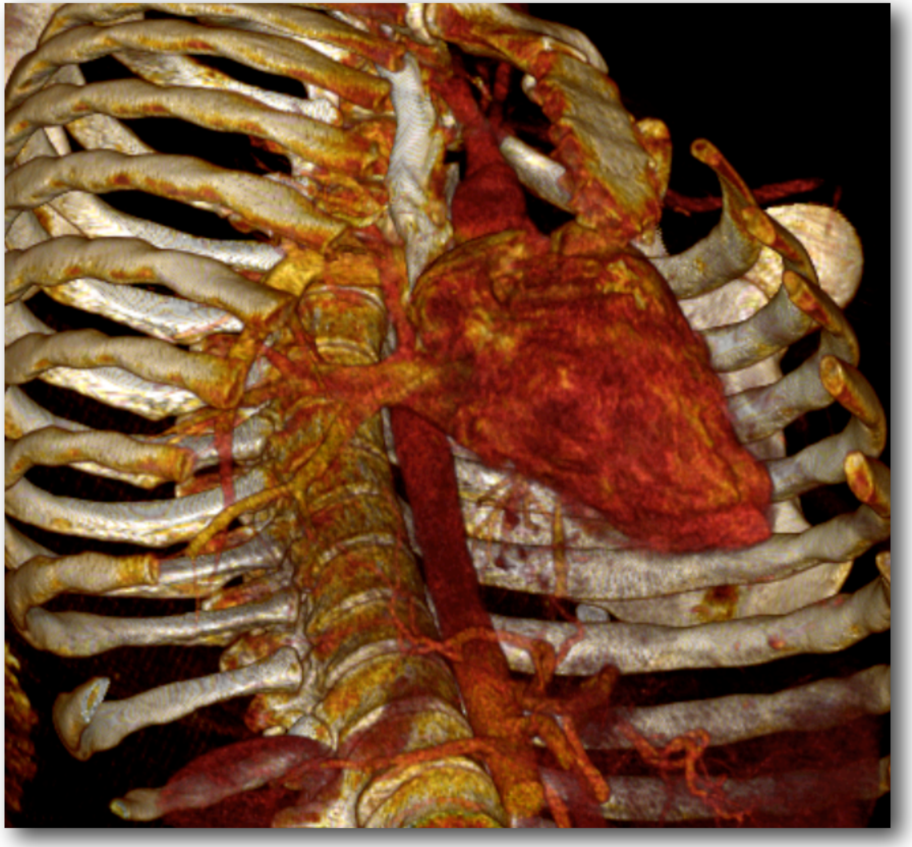
Texture Slicing

- VisTrails demo



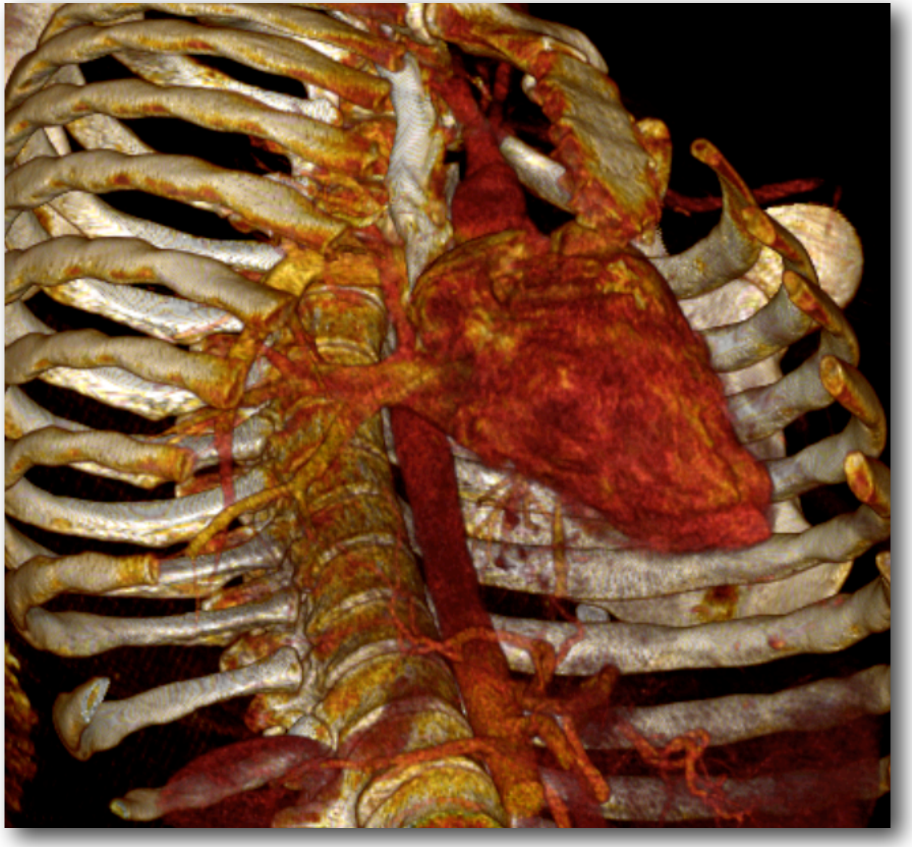
Texture Slicing

- Advantages
- Disadvantages



Texture Slicing

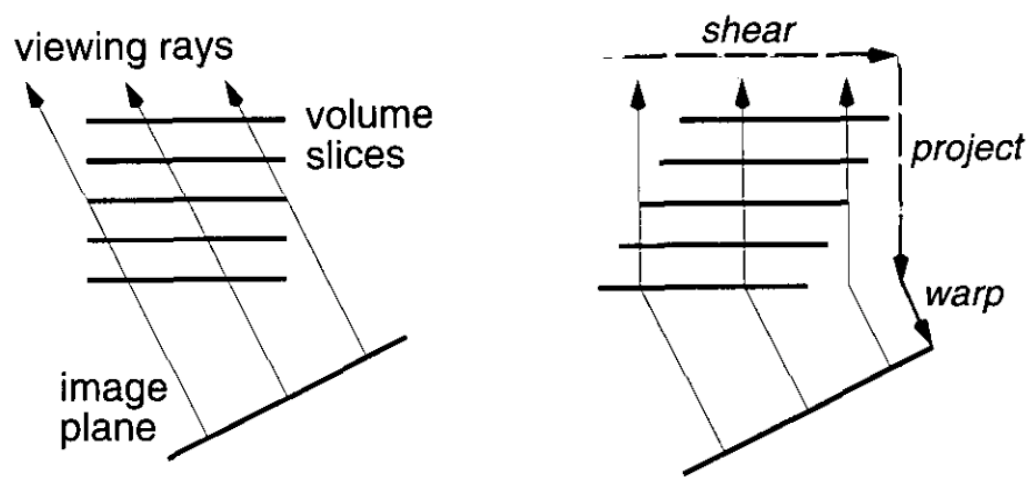
- Advantages
  - Really fast!
- Disadvantages
  - Correct illumination and shadowing is hard
  - Requires a lot of texture memory



Shear-warp

- Hybrid object-space and image-space technique
- Axis aligned slices are fast
- Shear and warp volume such that the rays are parallel to each other and perpendicular to the image

For each viewpoint:
Pick axis aligned slices
Shear along volume slices
Transform to align with image plane
Project to image plane
Composite



[Cameron and Undrill 92, Yagel and Kaufman 92, Schroeder and Stoll 92, Lacroute and Levoy 94]

Shear-warp

- Advantages

- Disadvantages

Shear-warp

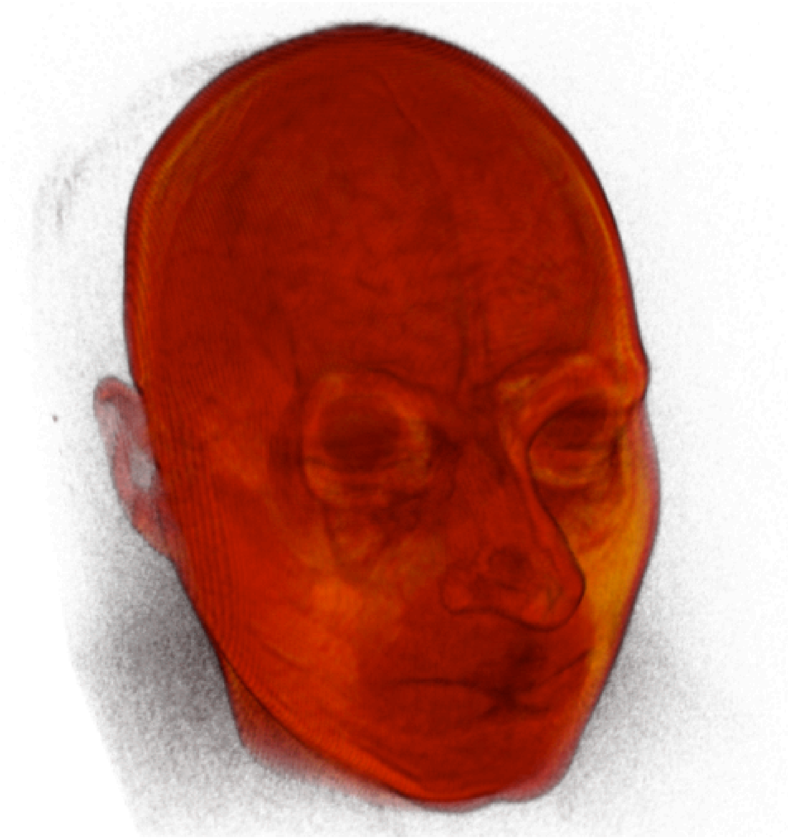
- Advantages
  - All voxels in a slice are scaled uniformly
  - Sampling rate is uniform
  - Cache-efficient
  - Can be performed out-of-core
- Disadvantages
  - Starts to break down near 45^{o}

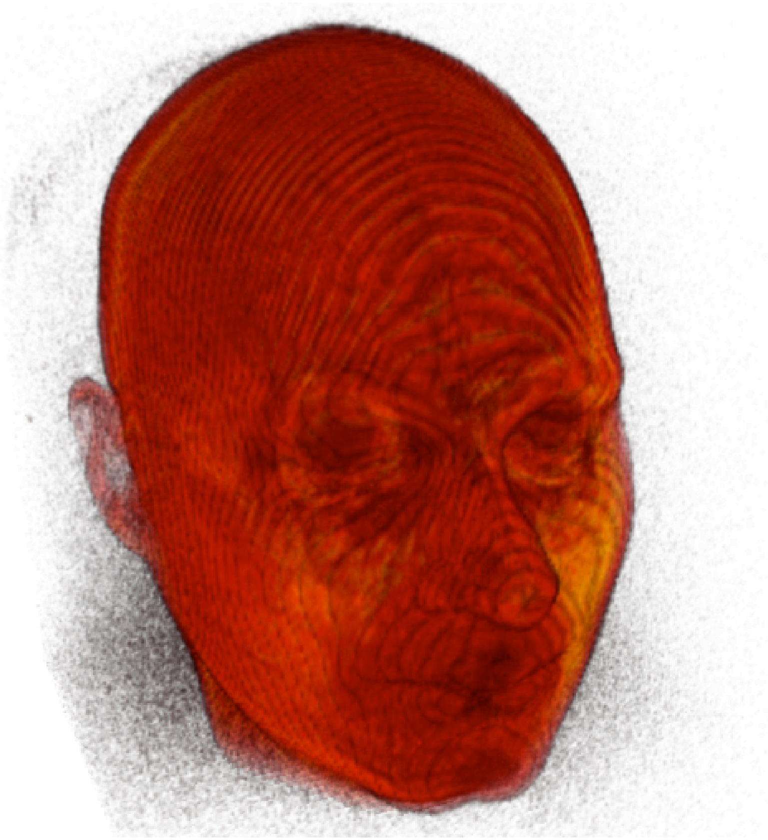
Acceleration Techniques

- Early ray termination [Levoy 90]
  - Stop compositing if high opacity has been reached (front-to-back)
- Empty space skipping [Levoy 90]
  - Skip regions in mesh deemed unimportant by transfer function
- Adaptive sampling [Roettger 98]
  - Vary the size of sample by importance of the region
- Level-of-detail [Levoy 90]
  - Use less samples
- GPU programming
  - Ray-casting on the GPU [Roettger 98]
  - Lookup tables [Engel 01]
  - Texturing [Cabral 94, Crawfis and Max 93]

Acceleration Techniques

- VisTrails demo





Summary

- Structured Grids
  - Ray-casting is most flexible
  - Texture slicing is fastest
  - Splatting and shear-warp can be done out-of-core