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?
  - It’s simple!
  - No hardware constraints
  - Easily parallelized
  - Easily extended for multiple scattering

- Disadvantages?
  - It’s 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
  • Transfer to compositing buffer
  • Add voxel kernels within second sheet
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
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°
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