Volume Visualization with Ray Casting

www.cs.technion.ac.il/~zdevir/volume/Volume.ppt
Volume Rendering

• render an image a volume
  ✦ CT, X-ray, PET, MRI scans
  ✦ Clouds
  ✦ Compressible fluids
• volume represented by 3D cell grid
Volume Rendering

**Typical sizes**
- 128x128x128
- 256x256x256

**Display approaches**
- Extract surfaces
- Ray trace
Ray Casting

• Generate image directly from density data
• Cast ray through density volume
• Accumulate colors as ray passes through semi-transparent cells
Accumulate illuminated densities

Density: \( D(t) = D(x(t), y(t), z(t)) \)

Illumination: \( I(x, y, z) \)

Phase function: \( P(\cos \theta) \)

\( I(t)D(t)P(\cos \theta) \)
\( I(t) \)

Radiation from light source
Attenuated, shadowed by volume

Only needed where internal shadows are important
e.g., clouds, fire, smoke
Attenuation along a ray

\[ -\tau \int_{t_1}^{t_2} D(s) ds \]

\( \tau \) converts density to attenuation

\[ \int_{t_1}^{t_2} \left( e^{-\tau \int_{t_1}^{t} D(s) ds} \right) I(t) D(t) P(\cos \theta) dt \]
Outgoing light

- light reflected in view direction from light source
- incoming light filtered by the voxel
- light emitted by the voxel
Ray casting algorithm

For every pixel in output image
- shoot ray into volume
- at evenly spaced ray locations, obtain color and opacity by interpolation
- merge color and opacities
  - front to back
  - back to front
Visualization pipeline

• Shade volume data
• compute local gradient -> voxel normal
• produce RGB intensity for every voxel
• determine opacity of each voxel
  - application dependent
  - e.g. X-ray absorption coefficient
• Ray cast volume
Voxel values

- $C(X)$ - shade
- $a(X)$ - opacity
- $C_{out} = C_{in}(1-a(X_i)) + c(X_i)a(X_i)$

Often parallel projection is used to simplify calcs
Packages

- AVS: Application Visualization System
- IBM Data Explorer (DX)
- Data Visualizer
Display issues

How to represent:

• Temporal information
• Non-spatial information
• Multi-dimensional information
Examples
Examples
Examples
Examples

Developer Edition

Rapid application development for Developers
Speed-ups

• Hierarchical spatial enumeration
• adaptive termination
Hierarchical Spatial Enumeration

Level 0 containing 4 x 4 x 4 cells

Voxel (5, 5, 5)

Cell (i, j, k) on level m having value V_m(i)

Level 2 containing one cell

Voxel (1, 1, 1)

Cell (1, 1, 1)
Traversing Volume
Examples
Examples