

Volume Visualization Overview

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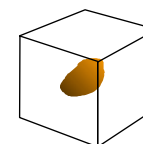
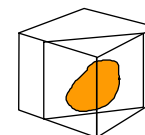
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Volume Visualization Techniques

- Planar Slicing
 - move slice through space
- Isosurface —surface from equal valued cells
 - change value over time
- Direct volume rendering
 - viewing “gas” using color/opacity
 - ray casting and splatting



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Volume Data

- Volume data is a set of data points in 3D
 - regularly spaced sampling is common from medicine
 - irregular sampling sometime occurs with finite element analysis problems
- Assume sampling from a *continuous* phenomena
- Regular sampling leads to division of volume into rectilinear voxels (volume data elements)
 - sometimes view the sample value as the center of a voxel, sometimes as a corner

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Isosurface Rendering

Often useful to construct a surface within a volume that represents a constant value, k

Three common algorithms

- Connectivity
- Marching Cubes [Lorenson&Cline 87]
- Dividing Cubes [Cline et al. 88]

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Connectivity Isosurface Algorithm

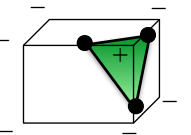
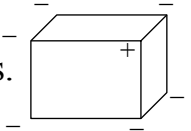
- Start with a “seed” voxel, recursively find neighboring voxels with same value
`connect( voxel(x,y,z) )`:
 - if `voxel(x,y,z)` intersects surface & is not marked
`mark (x,y,z)`
`connect (x+1, y, z)`
`connect (x-1, y, z)`
`connect (x, y+1, z)`
`connect (x, y-1, z)`
`connect (x, y, z+1)`
`connect (x, y, z-1)`
- Allows separation of surfaces with same value

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Marching Cubes Overview

- Label each voxel vertex + ($\geq k$) or - ($< k$)
- Assign index to each voxel based on vertices. 64 cases, 15 unique ones, but some ambiguous.
- For each voxel edge with +/− end points, linearly interpolate along edge to get estimate of position where value is k
- For each voxel with +/− edges, connect points to get polygon.
- Triangulate and display all such polygons

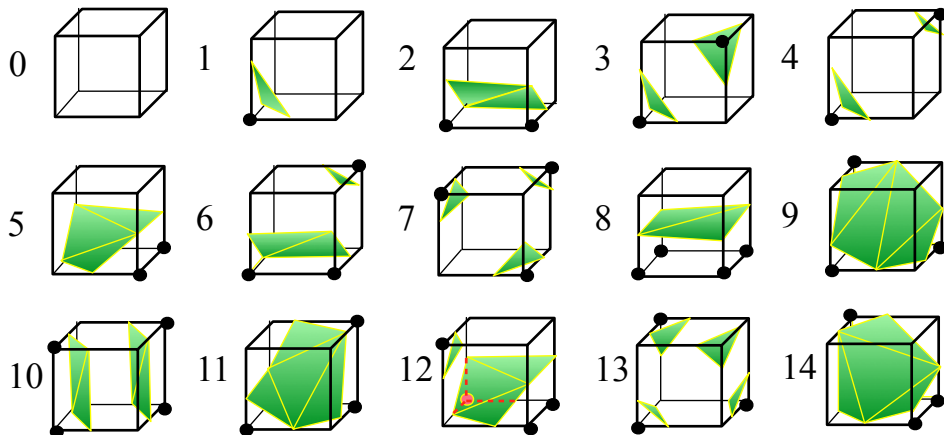


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Marching Cubes Basic Cases

- There are only 15 truly different cases

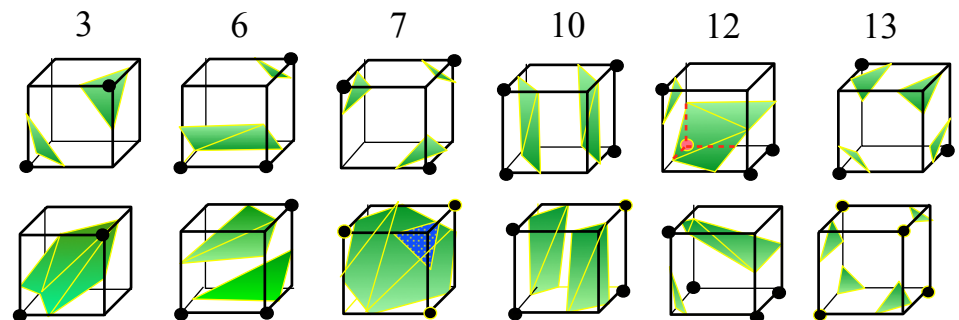


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Marching Cubes Ambiguous Cases

- Cube face with adjacent different vertices and diagonally opposite same vertices — 6 cases
- Inconsistent neighbor choices yields holes



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Marching Cubes

Computing Normals

- For each vertex, estimate a vector normal using forward differences:
 - $dx[i, j, k] = x[i+1, j, k] - x[i, j, k]$
 - $dy[i, j, k] = y[i, j+1, k] - y[i, j, k]$
 - $dz[i, j, k] = z[i, j, k+1] - z[i, j, k]$

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Other Isosurface Algorithms

- Dividing cubes - never generate triangles
 - if cube contains isosurface, project it to screen
if projection is smaller than a pixel, render it
else subdivide cube and recurse
- Marching tetrahedra
 - Divide each cube into 5 tetrahedra
 - Surface can only pass through a tetrahedron in 2 unique ways: both of which yield 1 triangle
 - 5 times as many objects, but each is much simpler

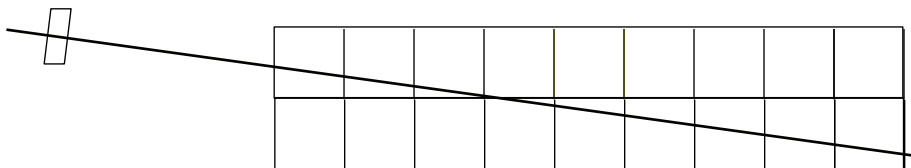
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Direct Volume Rendering

Ray Casting

- Figure out how each pixel is built from data values
- Ray intersects each voxel
 - value inside voxel is a *density*
 - distance ray travels through voxel determines *opacity* that is added to pixel's opacity value
 - if pixel opacity reaches 1, ray traversal terminates



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Direct Volume Rendering

Splatting

- Figure out how each data value contributes to each pixel
- Treat each voxel as a solid object, project its faces onto the display area (from back to front)
 - the color and opacity of the projected polygons are determined from the voxel's values
 - the projected polygons are *composed* according to their depths, opacities and colors

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