University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2010

Tamara Munzner

Spatial/Scientific Visualization

Week 12, Fri Apr 9

http://www.ugrad.cs.ubc.ca/~cs314/Vjan2010

News

- Reminders
  - H4 due Mon 4/11 5pm
  - P4 due Wed 4/13 5pm
- Extra TA office hours in lab 005 for P4/H4
  - Fri 4/9 11-12, 2-4 (Garrett)
  - Mon 4/12 11-1, 3-5 (Garrett)
  - Tue 4/13 3:30-5 (Kai)
  - Wed 4/14 2-4, 5-7 (Shailen)
  - Thu 4/15 3-5 (Kai)
  - Fri 4/16 11-4 (Garrett)

Cool Pixar Graphics Talk Today!!

- The Funnest Job on Earth: A Presentation of Techniques and Technologies Used to Create Pixar's Animated Films (version 2.0)
- Wayne Wooten, Pixar
- Fri 4/9, 4:00 to 5:30 pm, Dempster 110
  - great preview of CPSC 426, Animation :-)
  - overlaps my usual office hours :-(
  - poll: who was planning to come today?

Project 4

- I've now sent proposal feedback on proposals to everyone where I have specific concerns/responses
  - no news is good news
- global reminders/warnings
  - you do need framerate counter in your HUD!
  - be careful with dark/moody lighting
    - can make gameplay impossible
    - backup plan: keystroke to brighten by turning more/ambient light
  - reminder on timestamps
    - if you demo on your machine, I will check timestamps of files to ensure they match code you submitted through handin
    - they must match! do *not* change anything in the directory
    - clone code into new directory to keep developing or fix tiny bugs
      - so that I can quickly check that you've not changed anything else

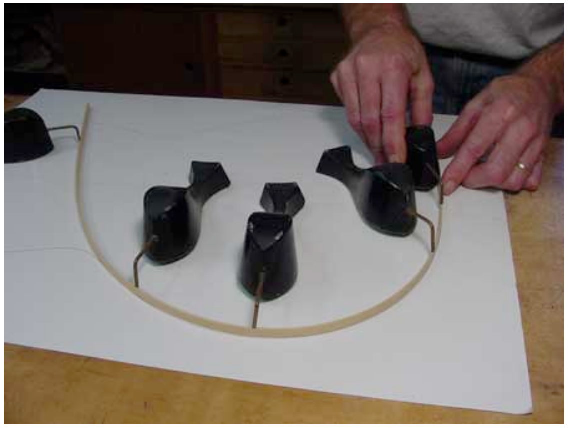
Review: GPGPU Programming

- General Purpose GPU
  - use graphics card as SIMD parallel processor
  - textures as arrays
  - computation: render large quadrilateral
  - multiple rendering passes

Review: Splines

- *spline* is parametric curve defined by *control points*
  - *knots:* control points that lie on curve
  - engineering drawing: spline was flexible wood, control points were physical weights

A Duck (weight)



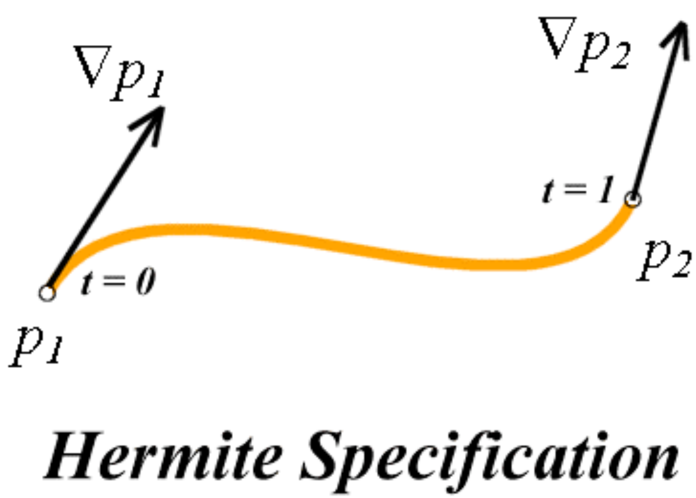
Ducks trace out curve

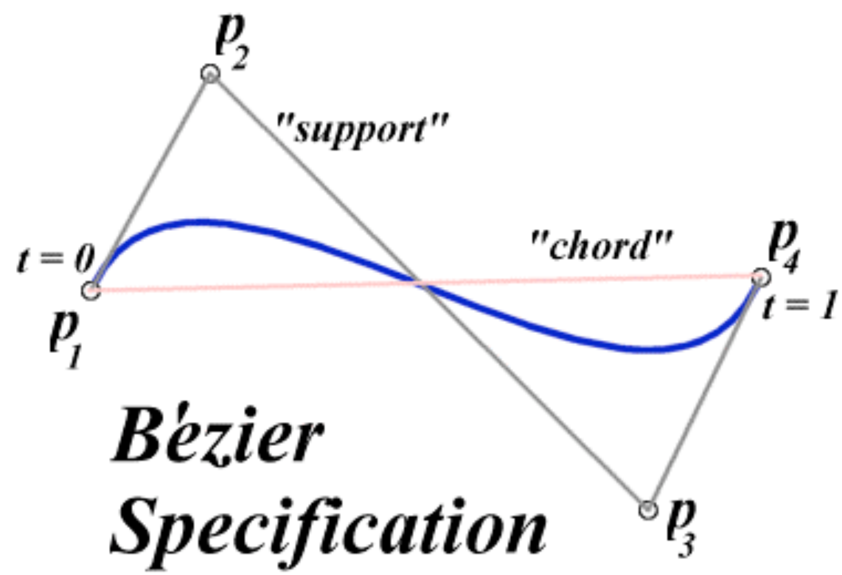
Review: Hermite Spline

- user provides
  - endpoints
  - derivatives at endpoints

Review: Bézier Curves

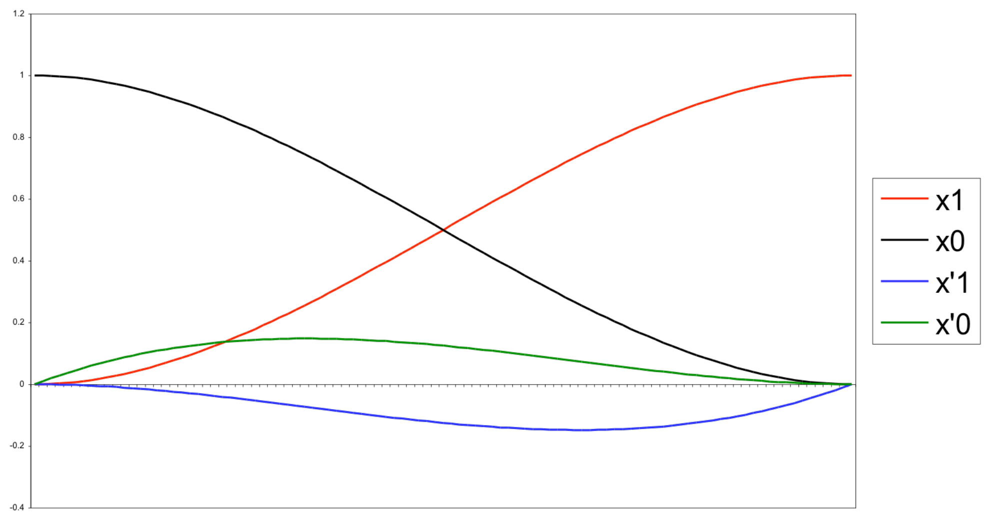
- four control points, two of which are knots
  - more intuitive definition than derivatives
- curve will always remain within convex hull (bounding region) defined by control points





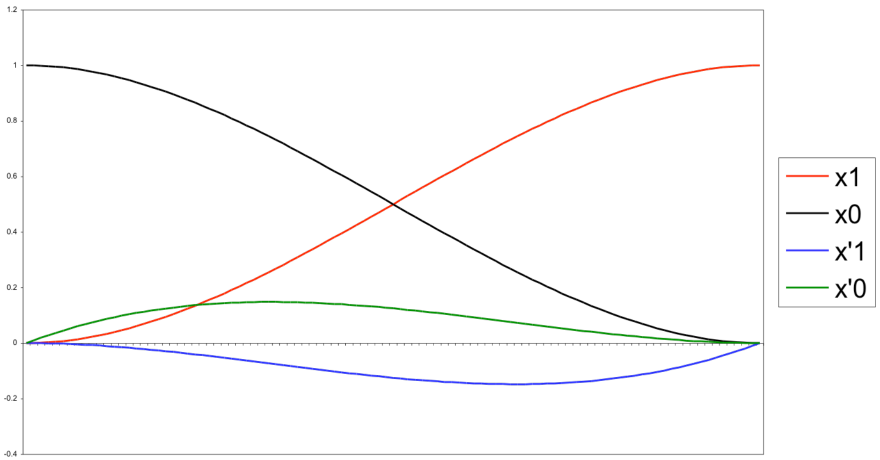
Review: Basis Functions

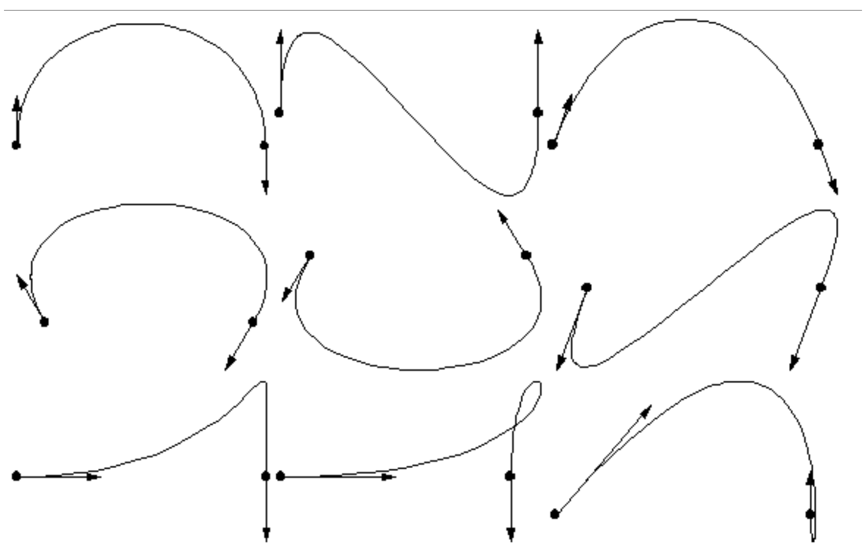
- point on curve obtained by multiplying each control point by some basis function and summing



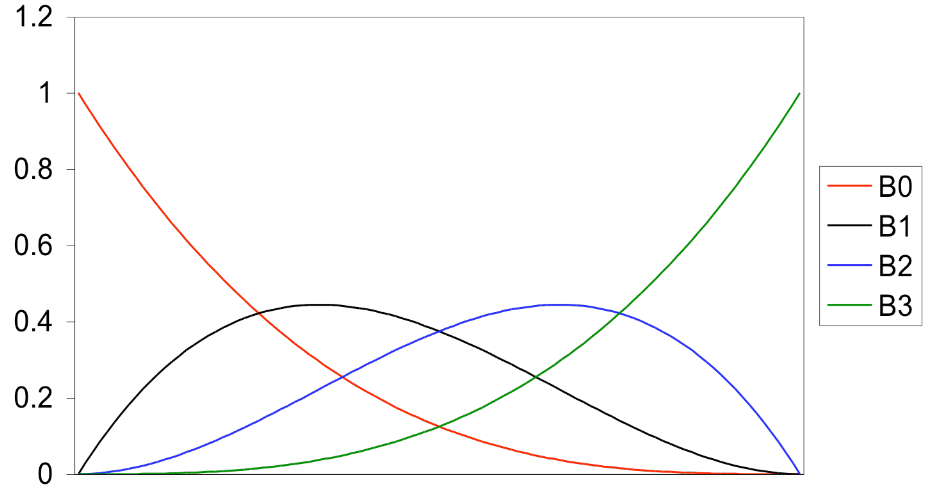
Review: Comparing Hermite and Bézier

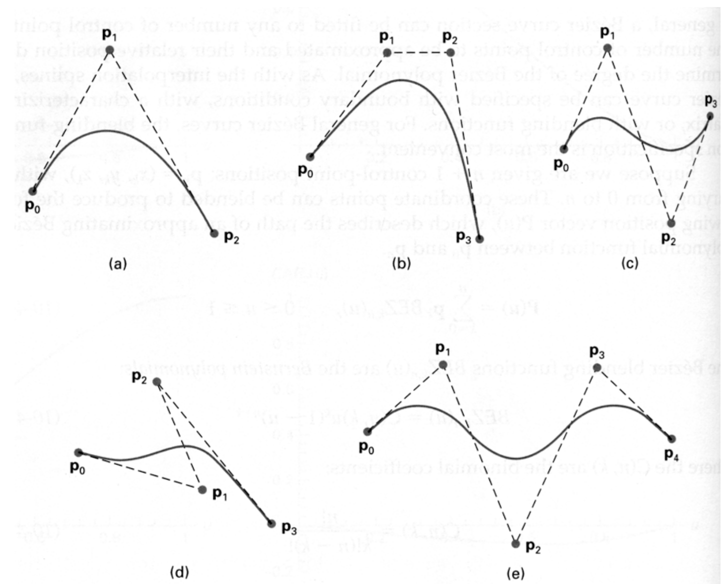
Hermite





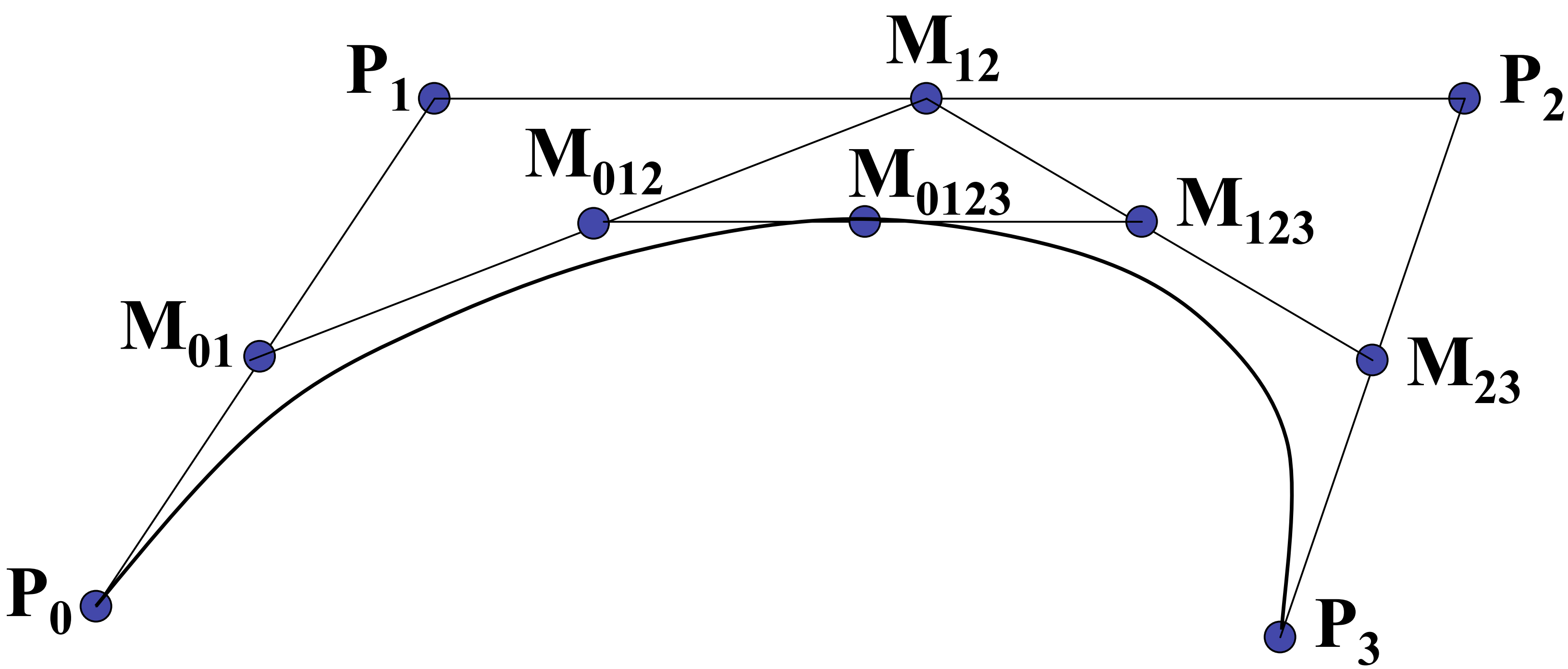
Bézier





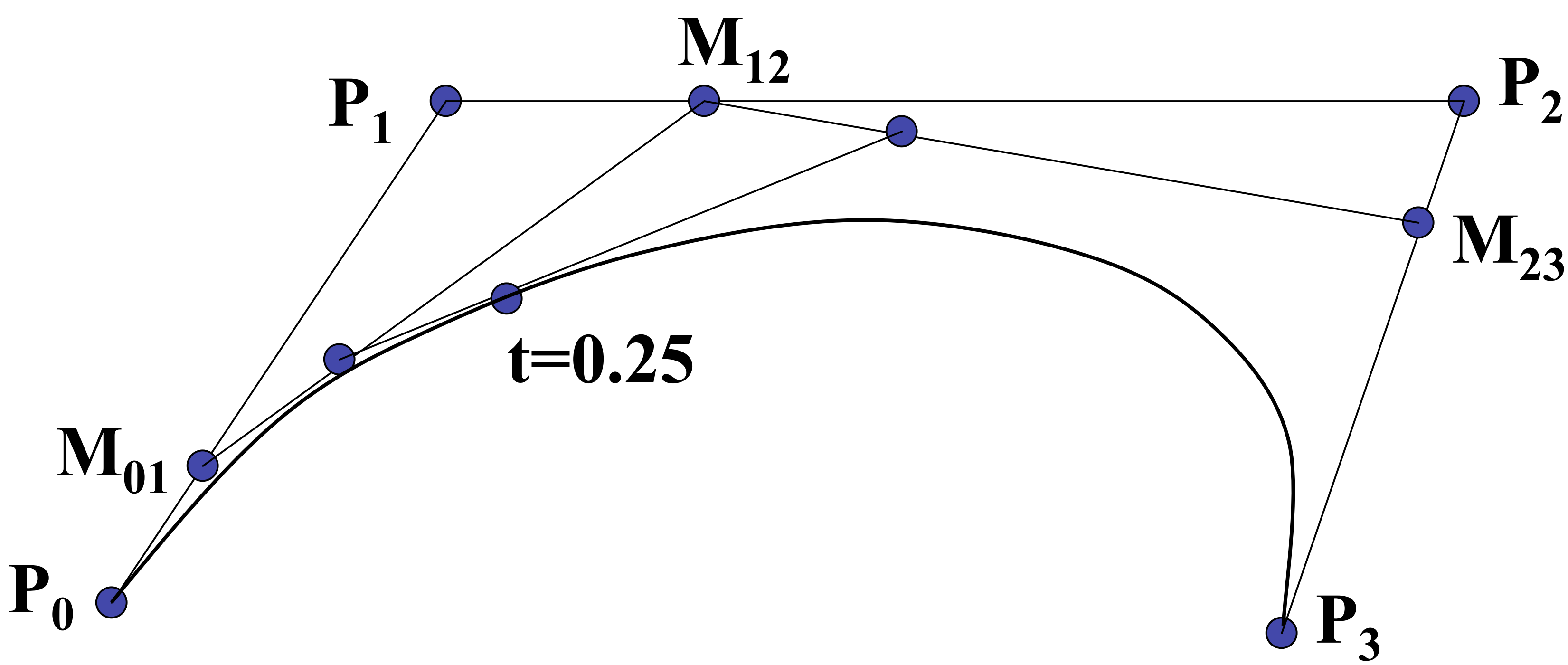
Review: Sub-Dividing Bézier Curves

- find the midpoint of the line joining M_{012}, M_{123}. call it M_{0123}



Review: de Casteljau's Algorithm

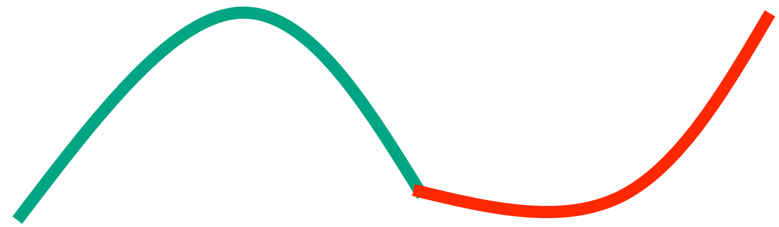
- can find the point on Bézier curve for any parameter value *t* with similar algorithm
  - for *t=0.25*, instead of taking midpoints take points 0.25 of the way



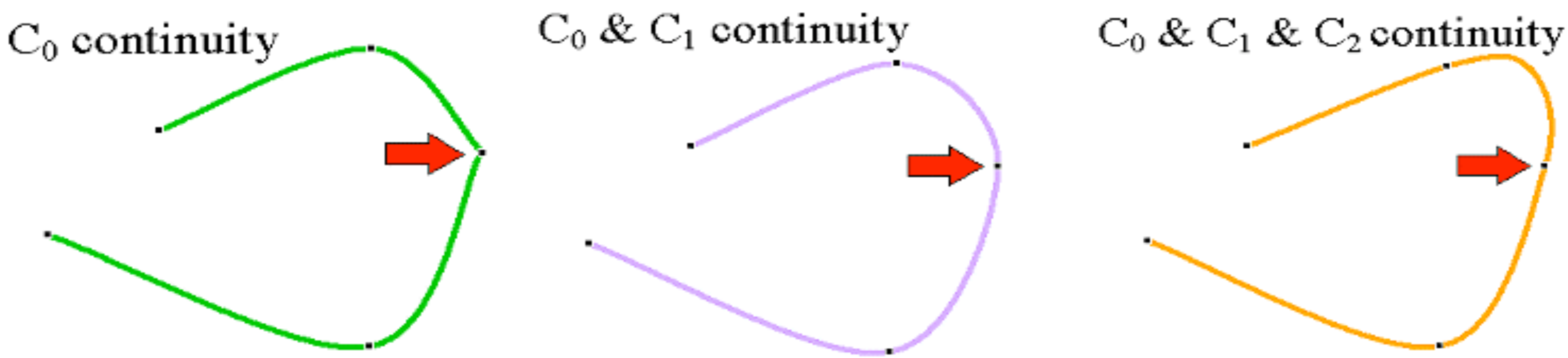
demo: www.saltire.com/applets/advanced_geometry/spline/spline.htm

Review: Continuity

- piecewise Bézier: no continuity guarantees



- continuity definitions
  - C^0: share join point
  - C^1: share continuous derivatives
  - C^2: share continuous second derivatives



Review: Geometric Continuity

- derivative continuity is important for animation
  - if object moves along curve with constant parametric speed, should be no sudden jump at knots
- for other applications, *tangent continuity* suffices
  - requires that the tangents point in the same direction
  - referred to as *G^1 geometric continuity*
  - curves could be made C^1 with a re-parameterization
  - geometric version of C^2 is G^2, based on curves having the same radius of curvature across the knot

Achieving Continuity

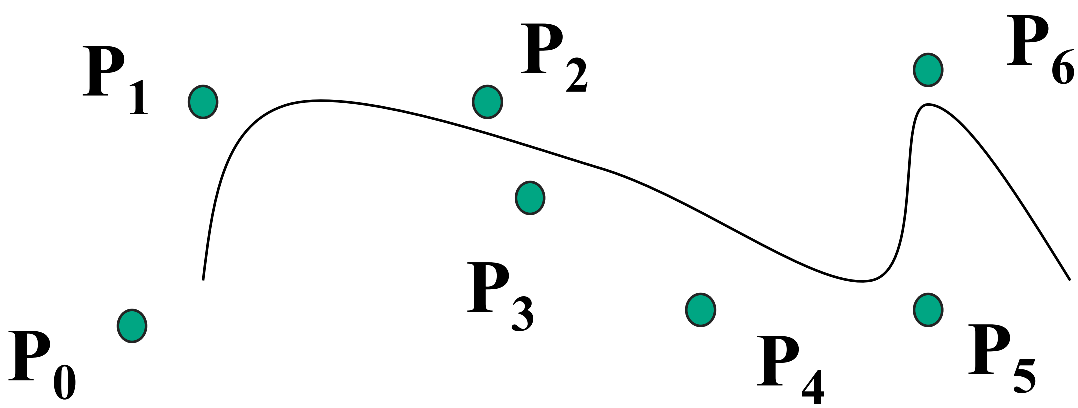
- Hermite curves
  - user specifies derivatives, so C^1 by sharing points and derivatives across knot
- Bezier curves
  - they interpolate endpoints, so C^0 by sharing control pts
  - introduce additional constraints to get C^1
    - parametric derivative is a constant multiple of vector joining first/last 2 control points
    - so C^1 achieved by setting $P_{0,3}=P_{1,0}=J$, and making $P_{0,2}$ and J and $P_{1,1}$ collinear, with $J-P_{0,2}=P_{1,1}-J$
    - C^2 comes from further constraints on $P_{0,1}$ and $P_{1,2}$
  - leads to...

B-Spline Curve

- start with a sequence of control points
- select four from middle of sequence

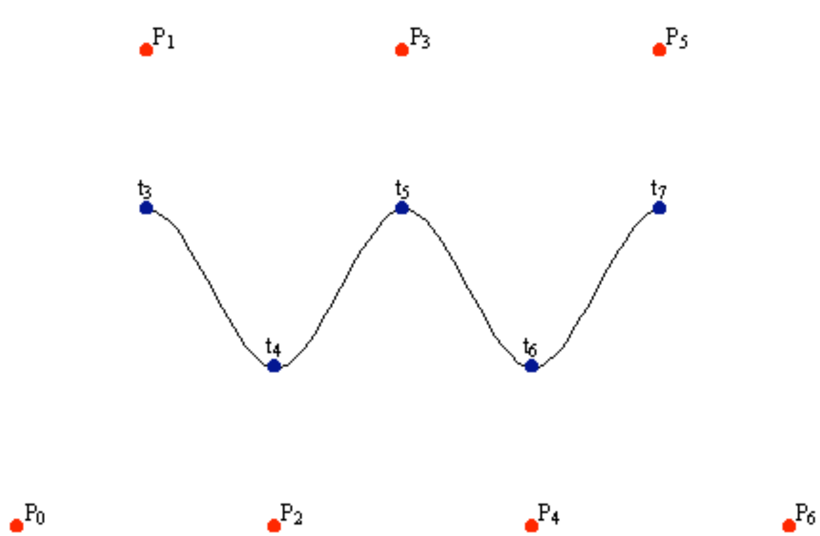
  (p_{i-2}, p_{i-1}, p_i, p_{i+1})

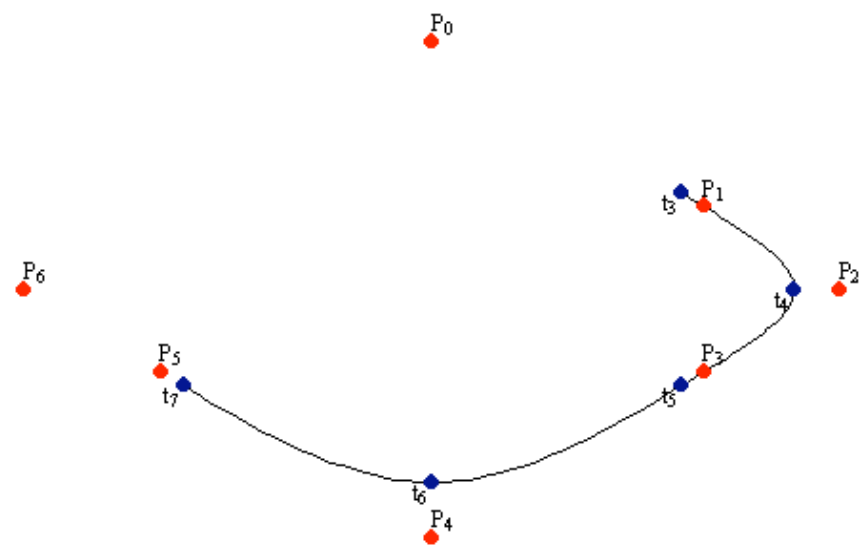
  - Bezier and Hermite goes between p_{i-2} and p_{i+1}
  - B-Spline doesn't interpolate (touch) any of them but approximates the going through p_{i-1} and p_i



B-Spline

- by far the most popular spline used
- C_0, C_1, and C_2 continuous





demo: www.siggraph.org/education/materials/HyperGraph/modeling/splines/demoprog/curve.html

B-Spline

- locality of points

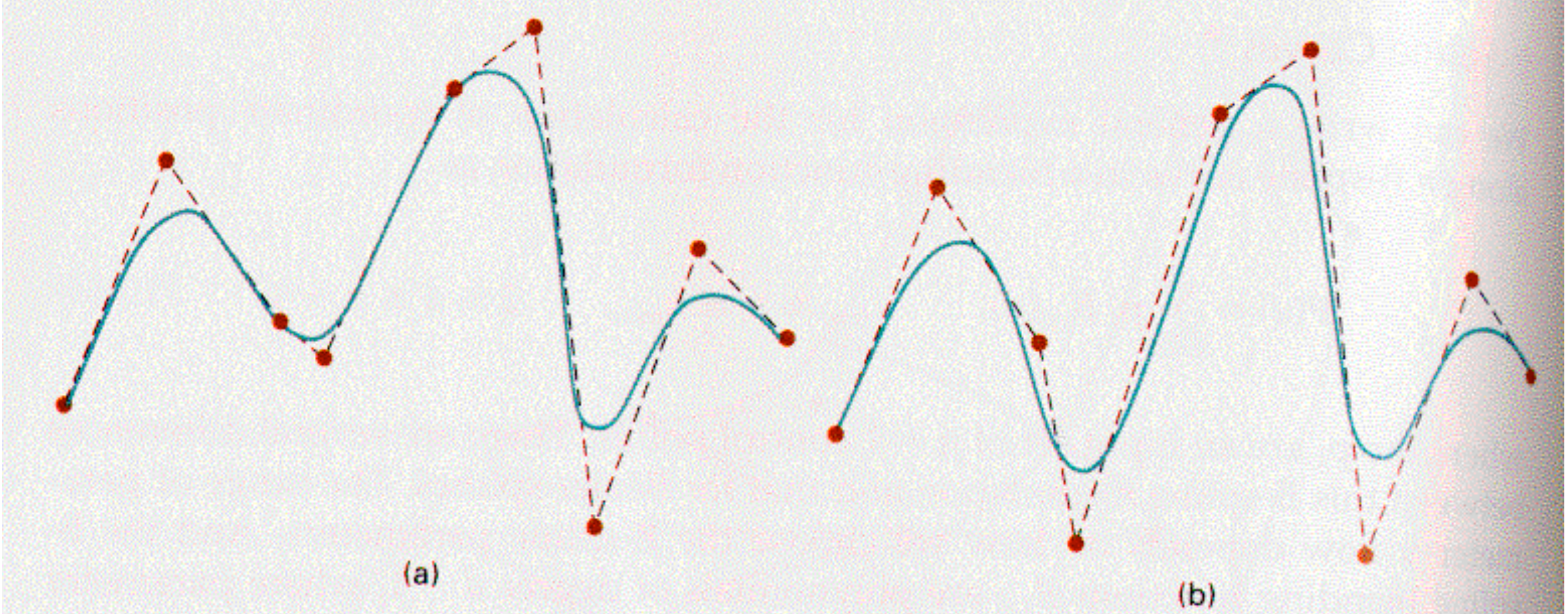


Figure 10-41
Local modification of a B-spline curve. Changing one of the control points in (a) produces curve (b), which is modified only in the neighborhood of the altered control point.

Geometric Modelling

- much, much more in CPSC 424!
  - offered next year

Spatial/Scientific Visualization

Reading

- FCG Chapter 28 Spatial Field Visualization
  - Chap 23 (2nd ed)

Surface Graphics

- objects explicitly defined by surface or boundary representation
  - mesh of polygons

200 polys 1000 polys 15000 polys

Surface Graphics

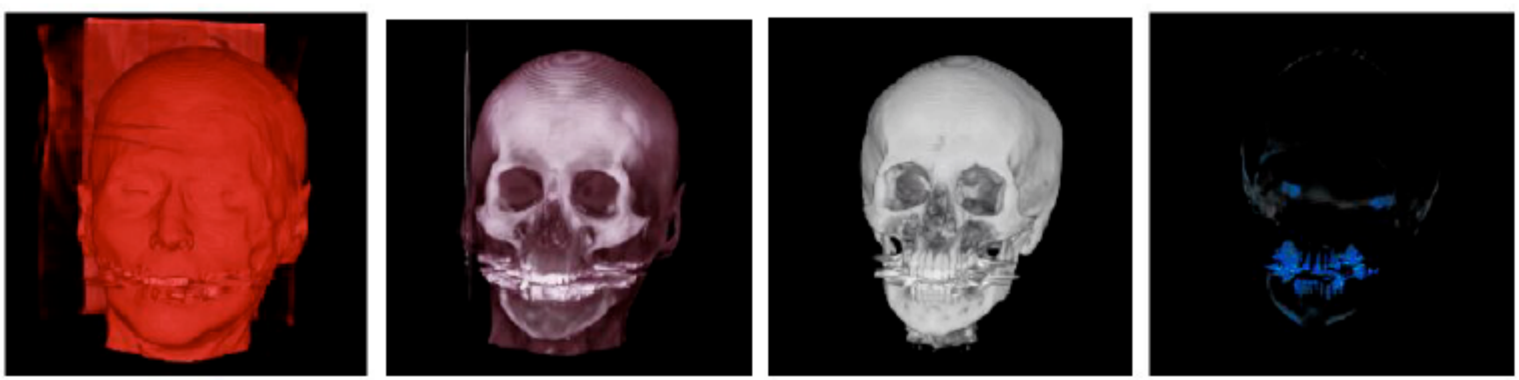
- pros
  - fast rendering algorithms available
  - hardware acceleration cheap
  - OpenGL API for programming
  - use texture mapping for added realism
- cons
  - discards interior of object, maintaining only the shell
  - operations such cutting, slicing & dissection not possible
  - no artificial viewing modes such as semi-transparencies, X-ray
  - surface-less phenomena such as clouds, fog & gas are hard to model and represent

Volume Graphics

- for some data, difficult to create polygonal mesh
- voxels: discrete representation of 3D object
  - volume rendering: create 2D image from 3D object
- translate raw densities into colors and transparencies
  - different aspects of the dataset can be emphasized via changes in transfer functions

Volume Graphics

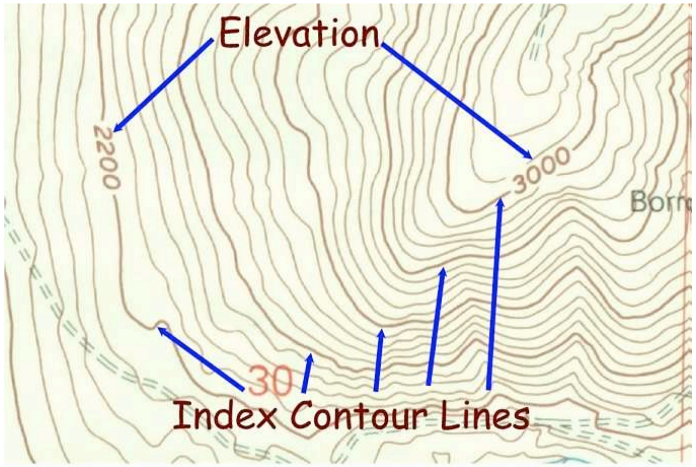
- pros
  - formidable technique for data exploration
- cons
  - rendering algorithm has high complexity!
  - special purpose hardware costly (~$3K-$10K)

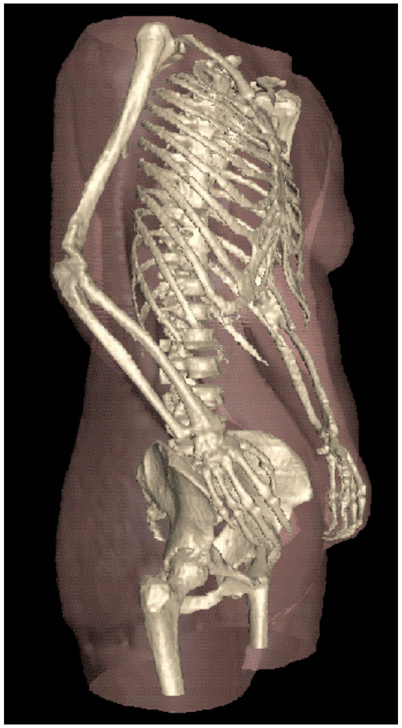


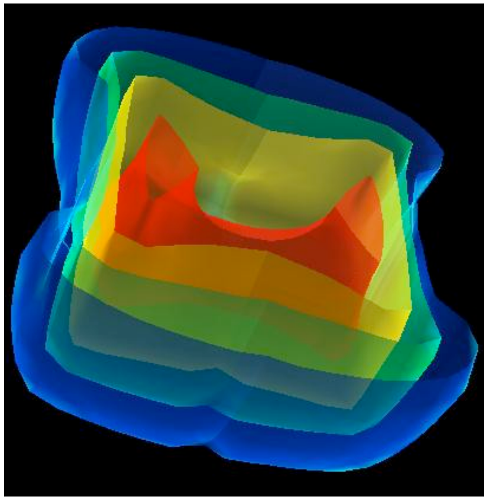
volumetric human head (CT scan)

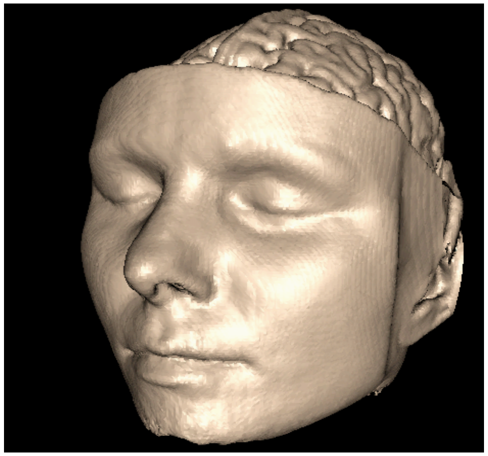
Isosurfaces

- 2D scalar fields: isolines
  - contour plots, level sets
  - topographic maps
- 3D scalar fields: isosurfaces

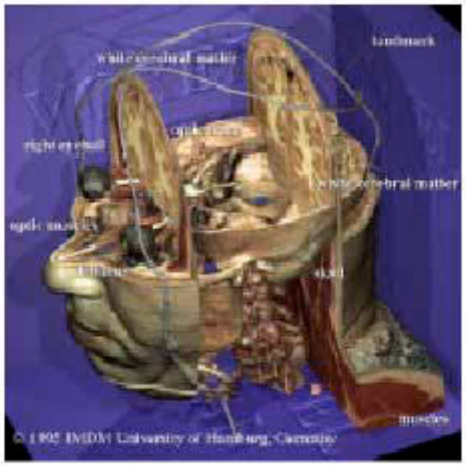




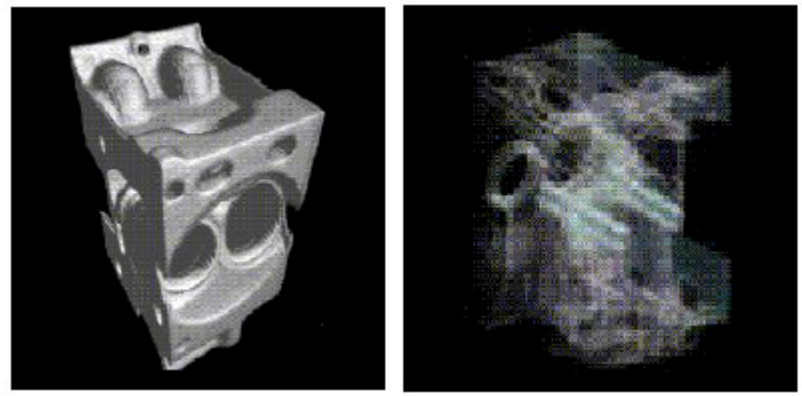




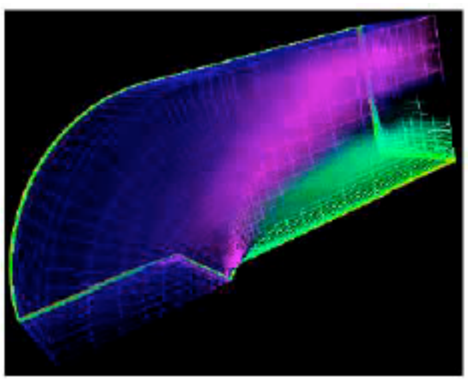
Volume Graphics: Examples



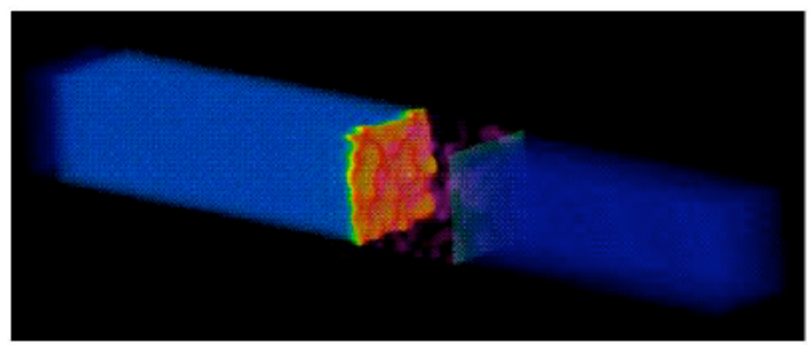
anatomical atlas from visible human (CT & MRI) datasets



industrial CT - structural failure, security applications



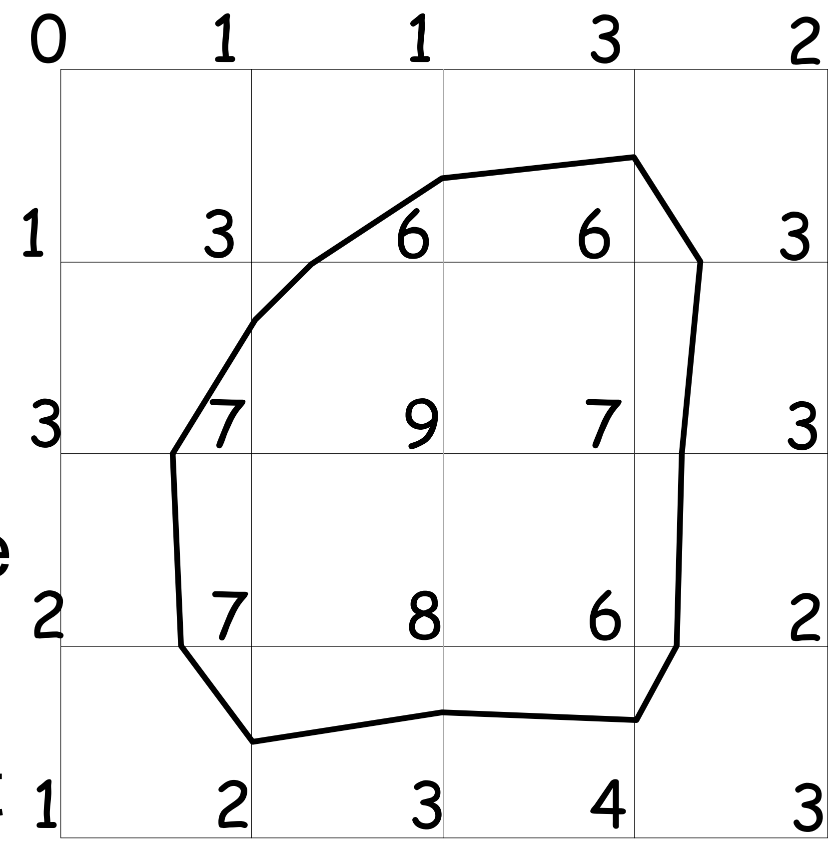
flow around airplane wing



shockwave visualization: simulation with Navier-Stokes PDEs

Isosurface Extraction

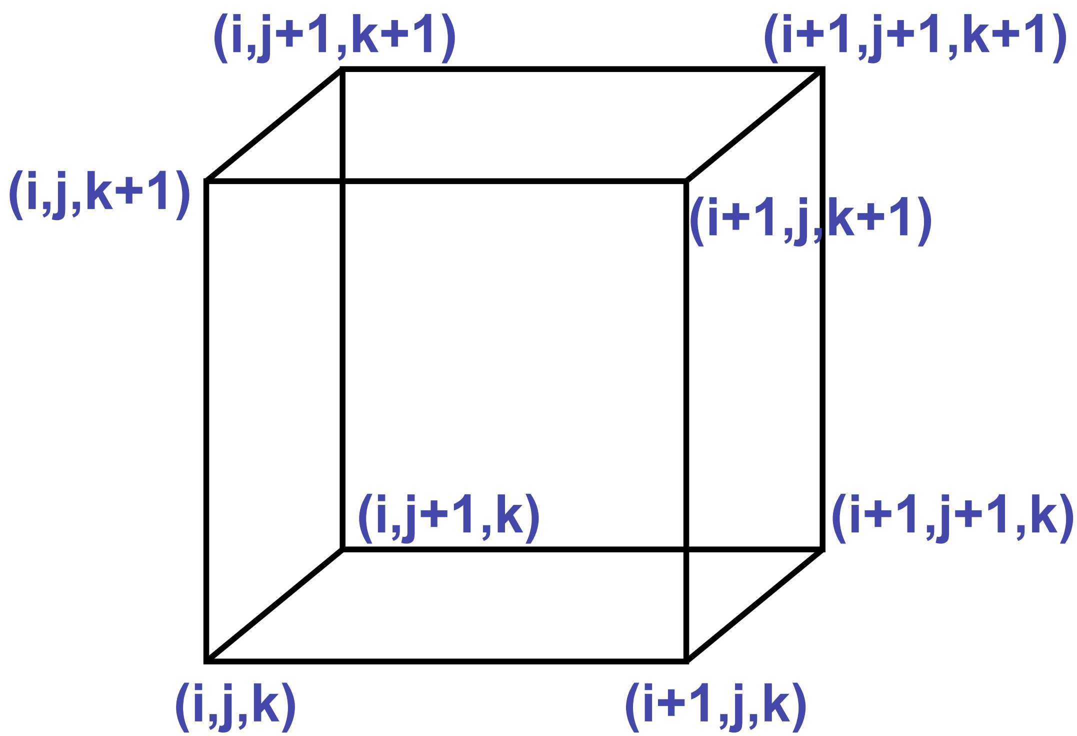
- array of discrete point samples at grid points
  - 3D array: voxels
- find contours
  - closed, continuous
  - determined by iso-value
- several methods
  - marching cubes is most common



Iso-value = 5

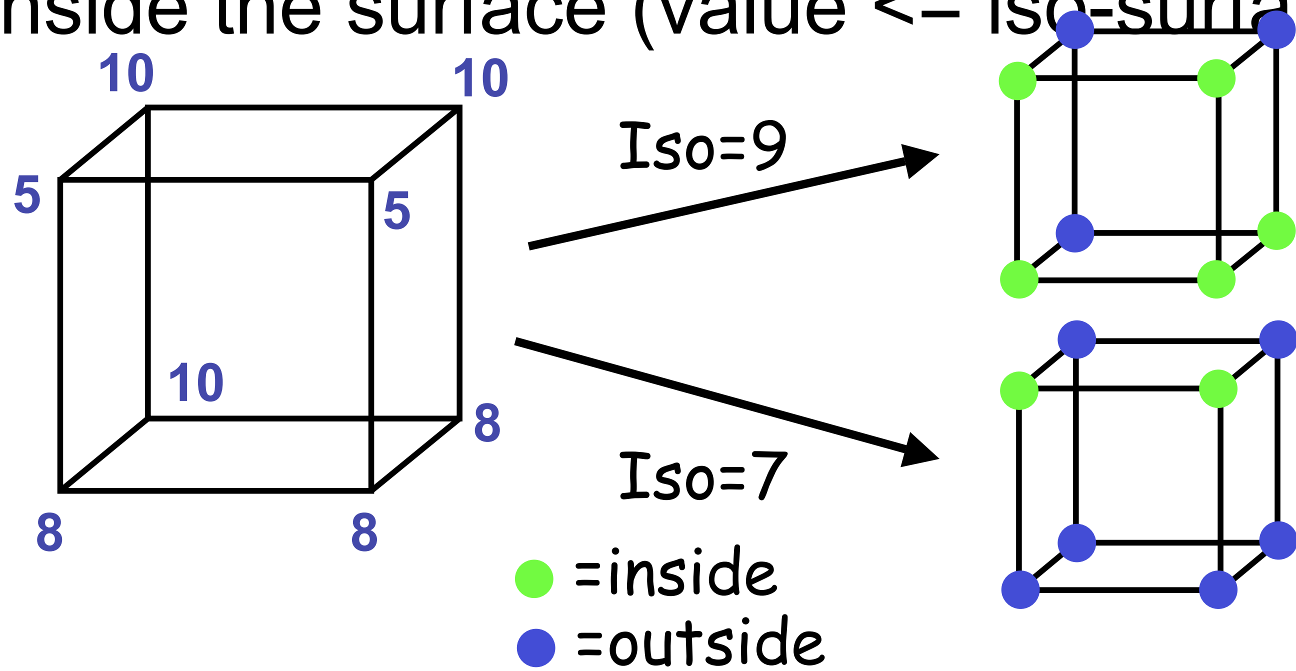
MC 1: Create a Cube

- consider a cube defined by eight data values



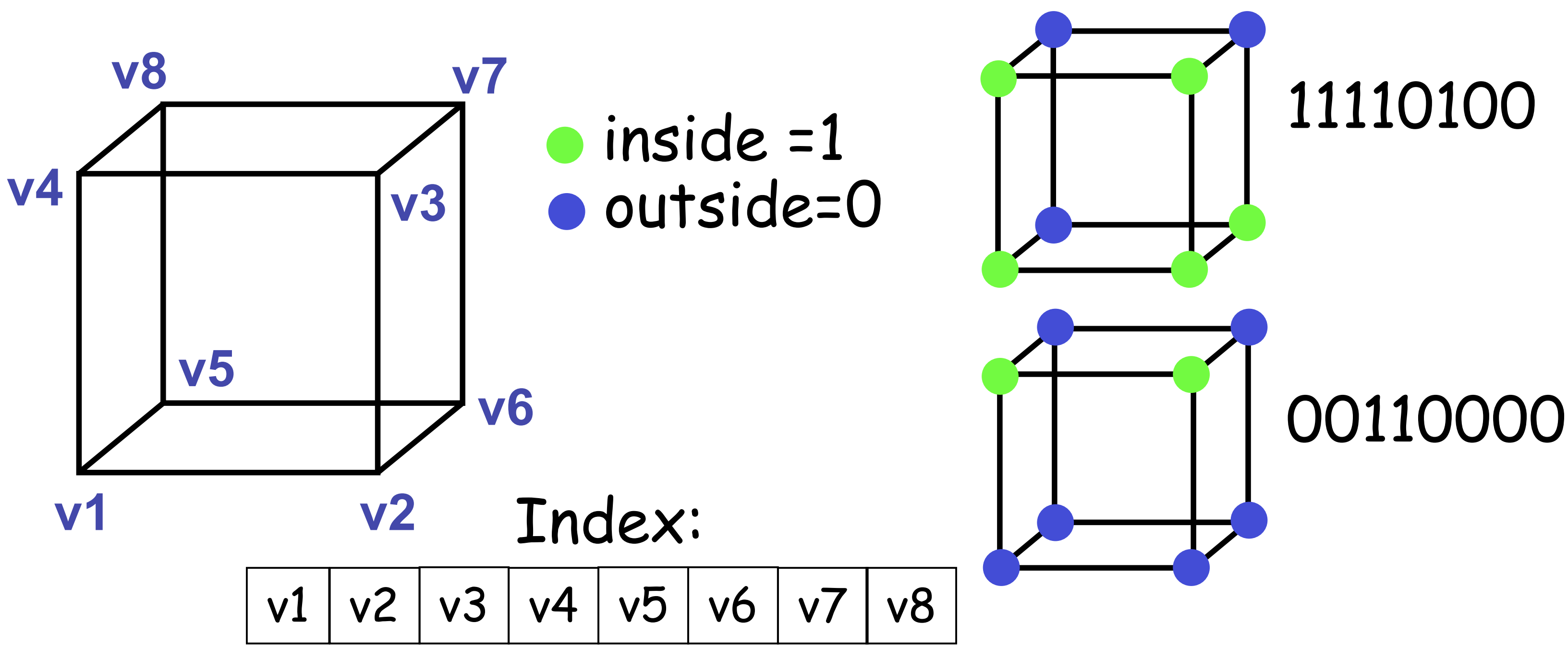
MC 2: Classify Each Voxel

- classify each voxel according to whether lies
  - outside the surface (value > iso-surface value)
  - inside the surface (value <= iso-surface value)



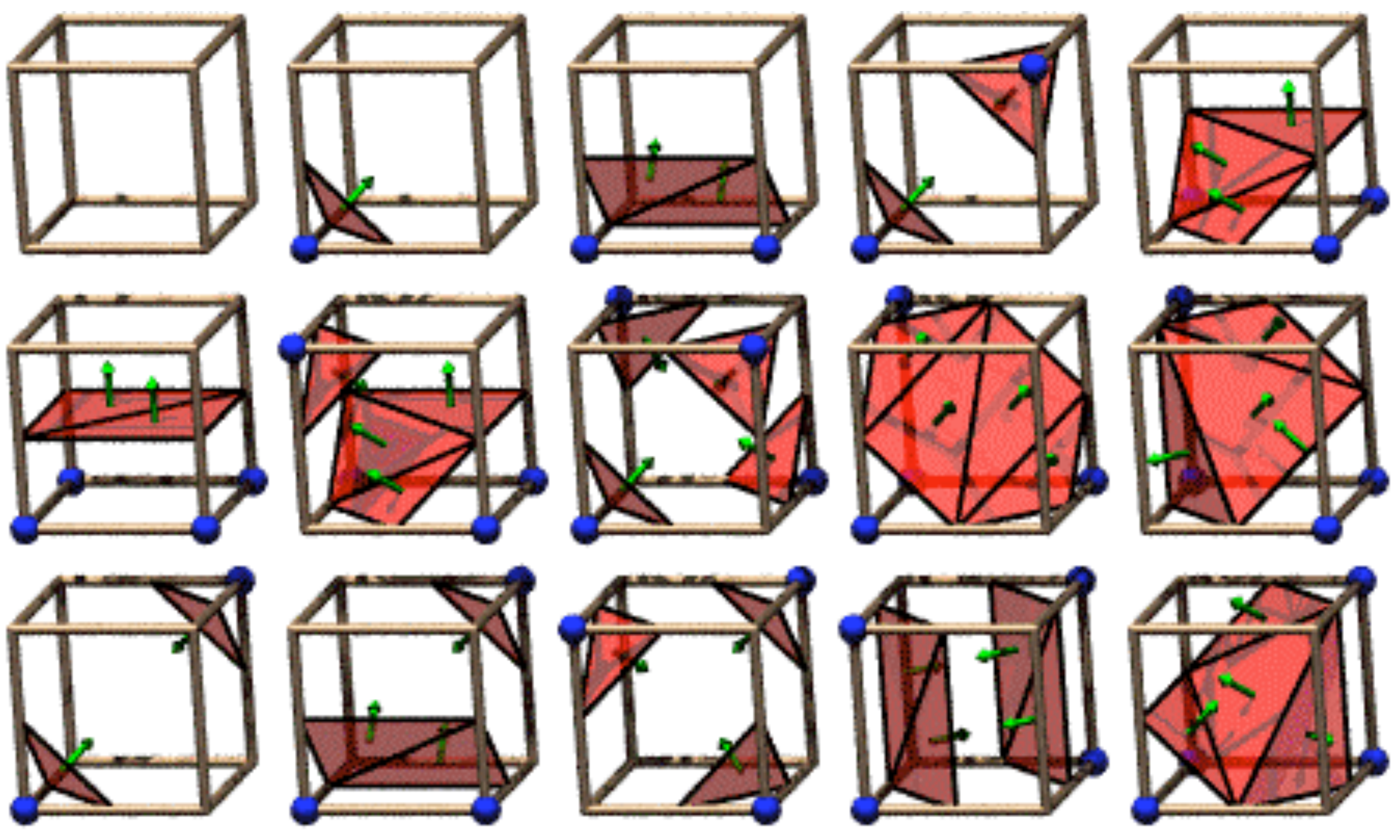
MC 3: Build An Index

- binary labeling of each voxel to create index



MC 4: Lookup Edge List

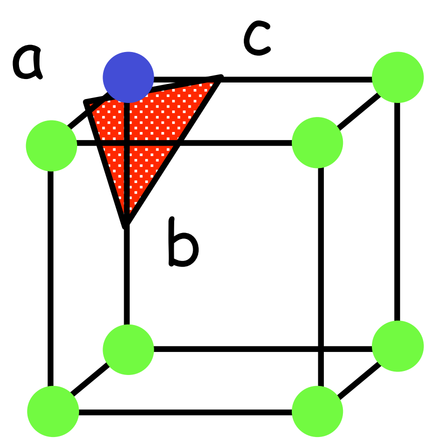
- use index to access array storing list of edges
  - all 256 cases can be derived from 15 base cases



The 15 Cube Combinations

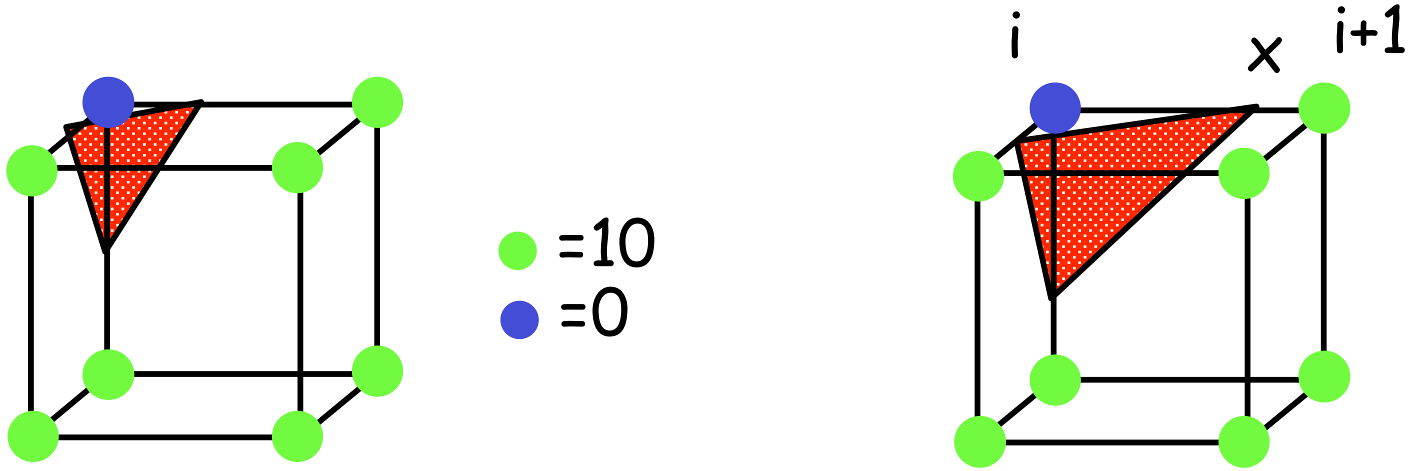
MC 4: Example

- index = 00000001
- triangle 1 = a, b, c



MC 5: Interpolate Triangle Vertex

- for each triangle edge
  - find vertex location along edge using linear interpolation of voxel values



T=5

$$x = i + \left(\frac{T - v[i]}{v[i+1] - v[i]} \right)$$

T=8

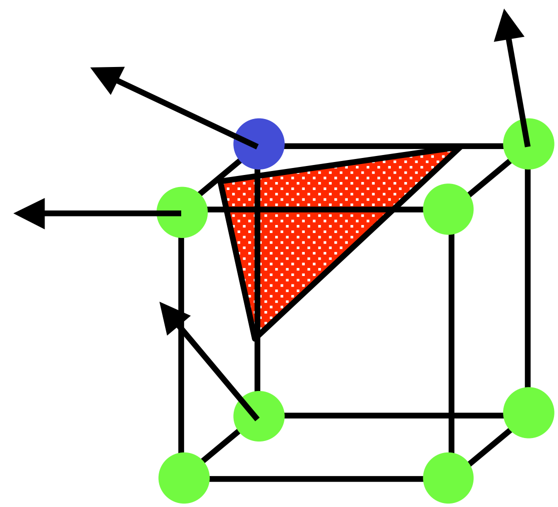
MC 6: Compute Normals

- calculate the normal at each cube vertex
  - use linear interpolation to compute the polygon vertex normal

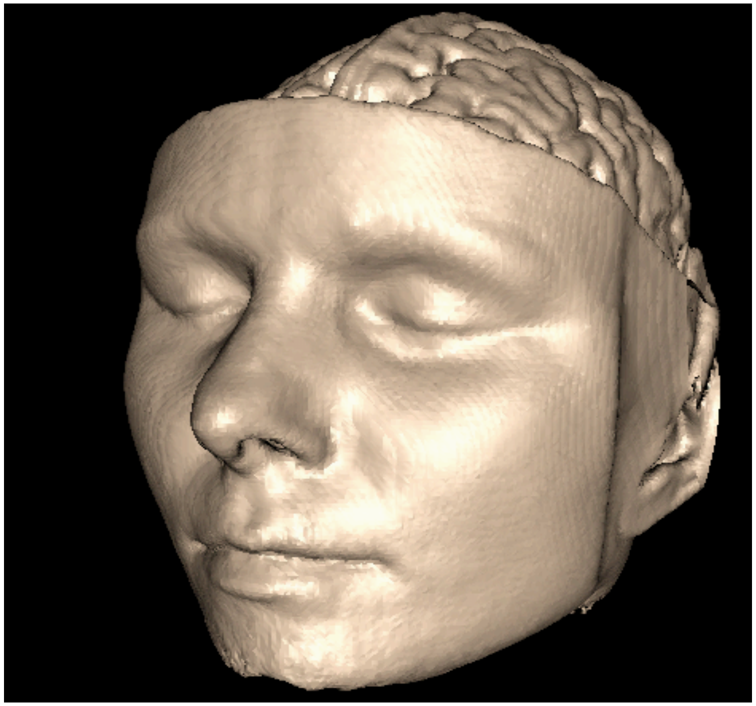
$$G_x = v_{i+1,j,k} - v_{i-1,j,k}$$

$$G_y = v_{i,j+1,k} - v_{i,j-1,k}$$

$$G_z = v_{i,j,k+1} - v_{i,j,k-1}$$

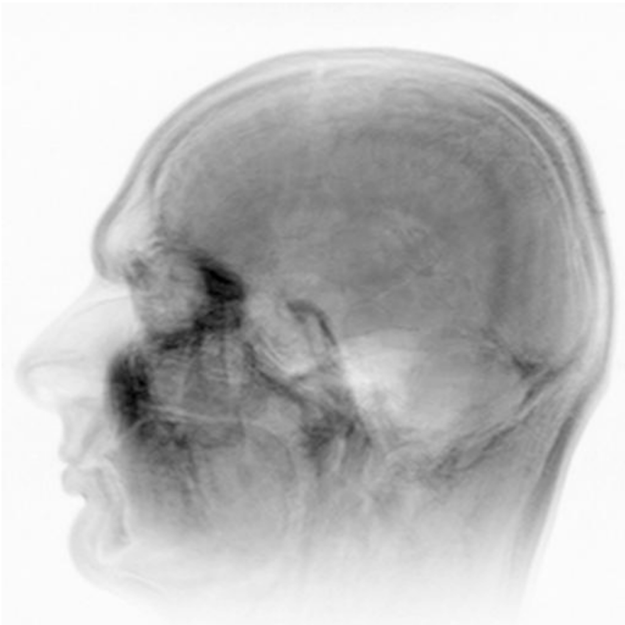


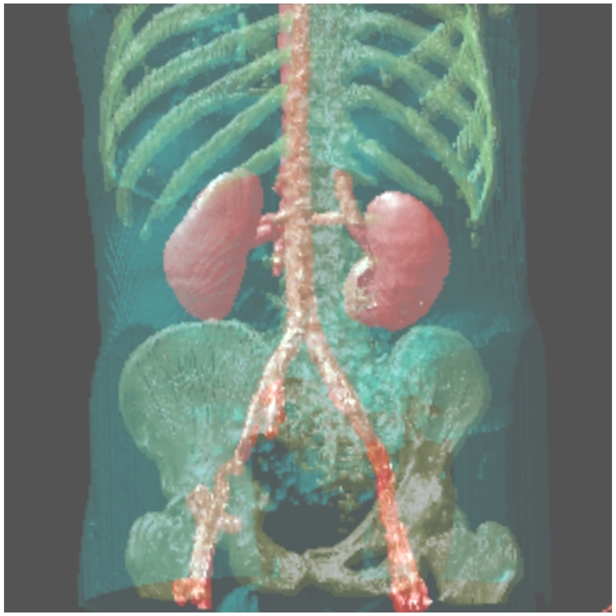
MC 7: Render!



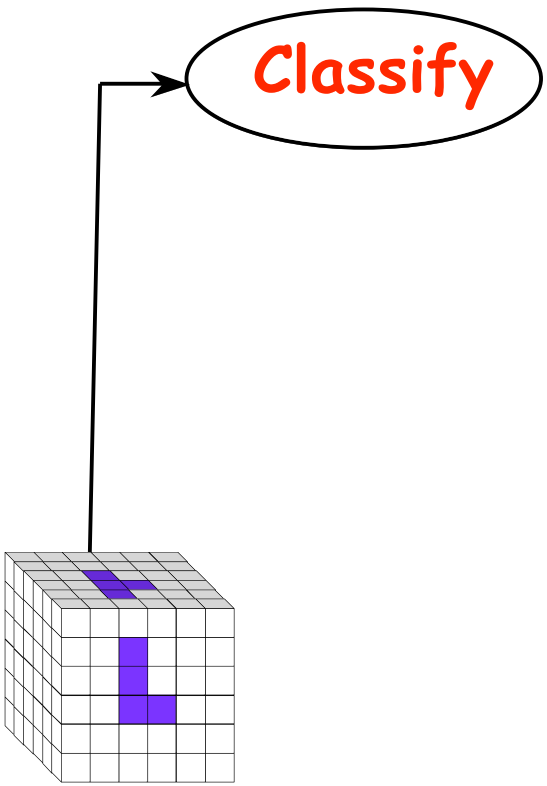
Direct Volume Rendering

- do not compute surface



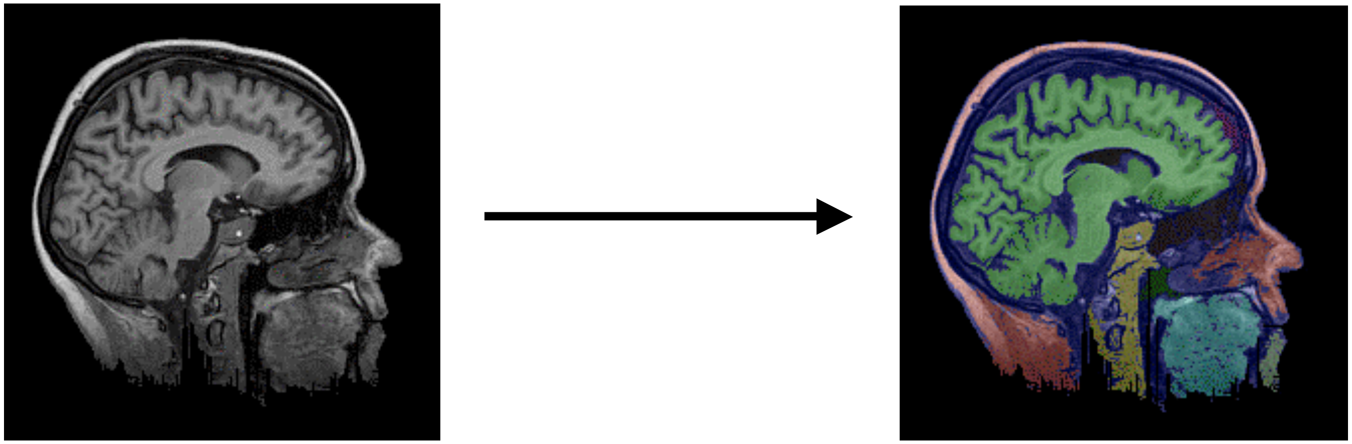


Rendering Pipeline



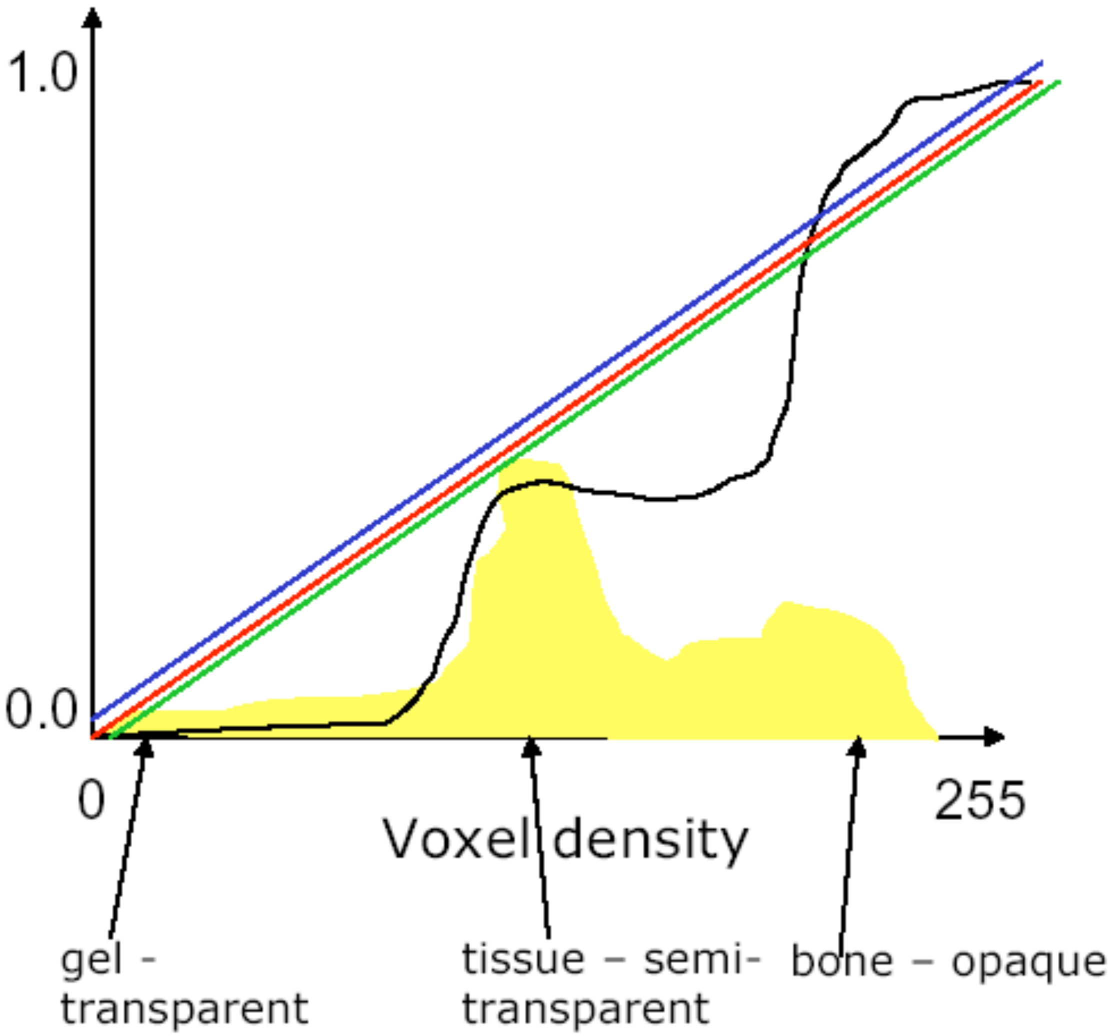
Classification

- data set has application-specific values
  - temperature, velocity, proton density, etc.
- assign these to color/opacity values to make sense of data
- achieved through transfer functions

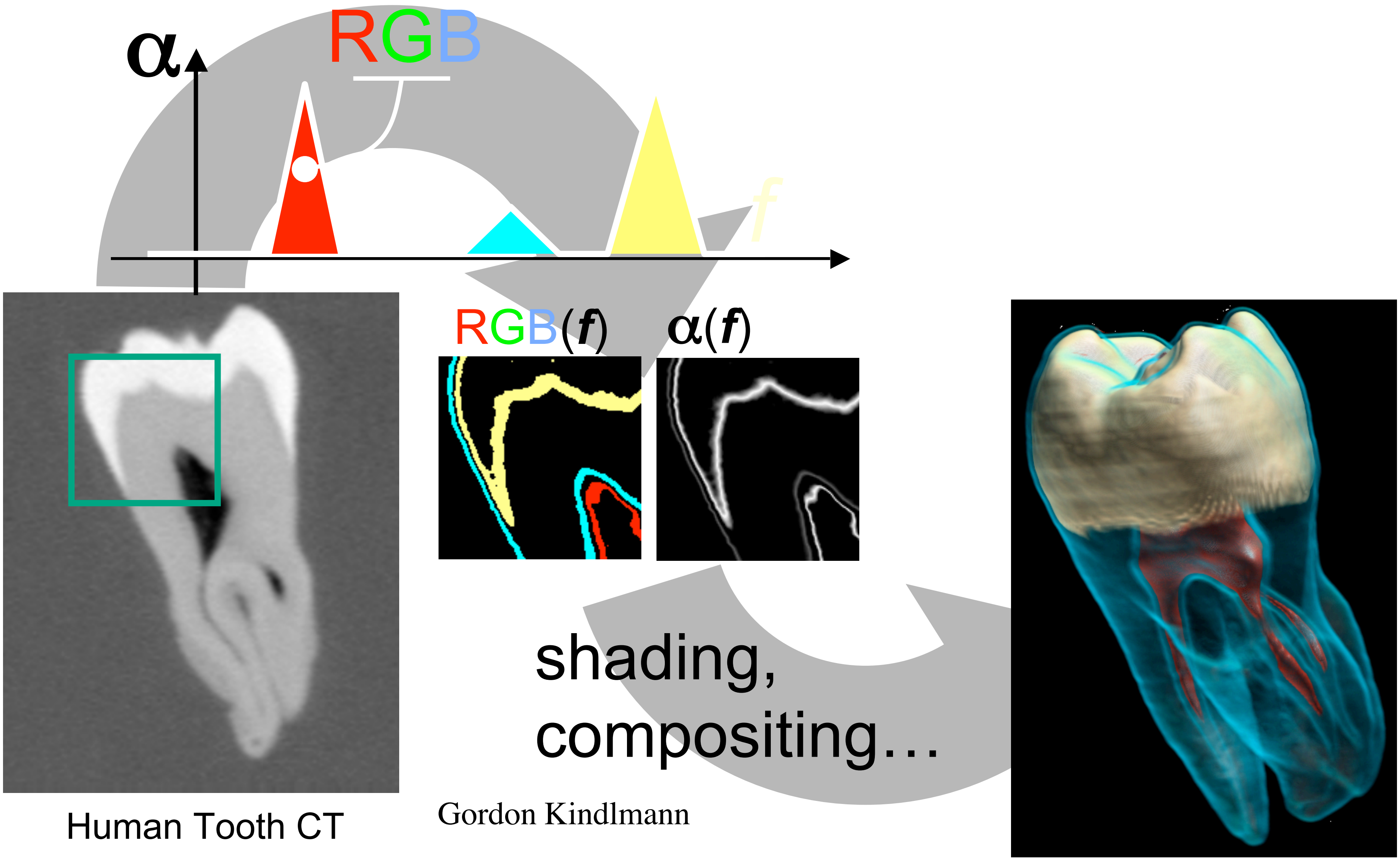


Transfer Functions

- map data value to color and opacity



Transfer Functions

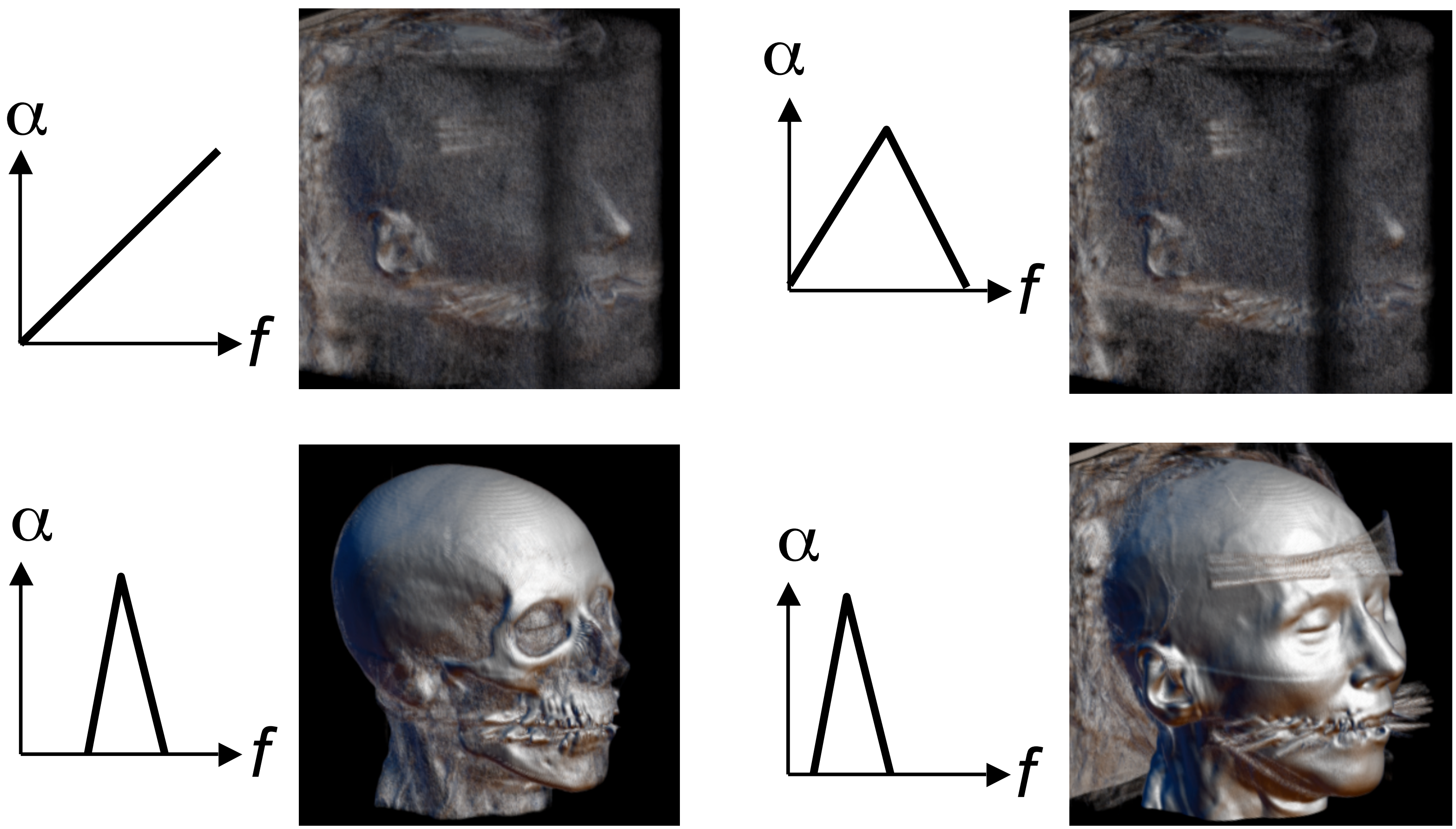


Human Tooth CT

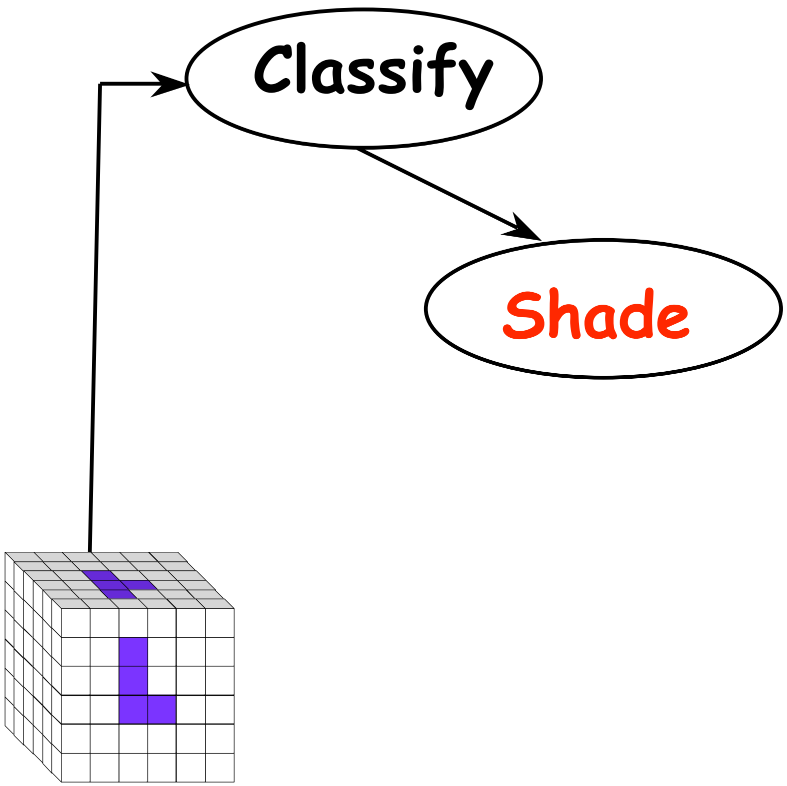
Gordon Kindlmann

Setting Transfer Functions

- can be difficult, unintuitive, and slow

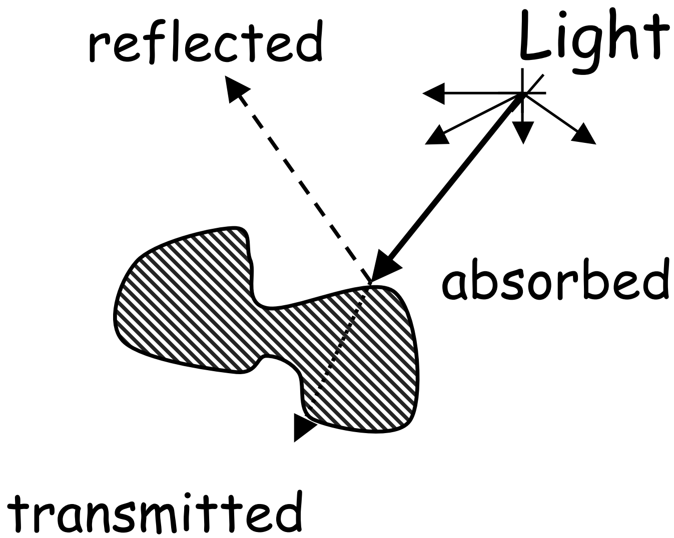


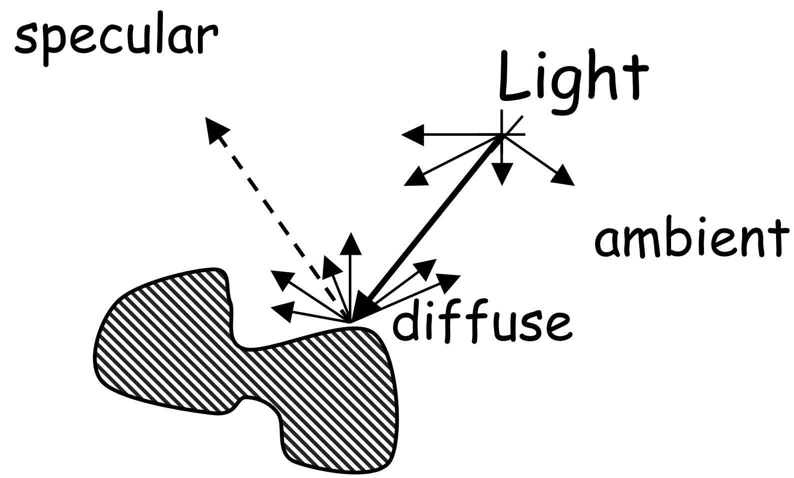
Rendering Pipeline



Light Effects

- usually only consider reflected part



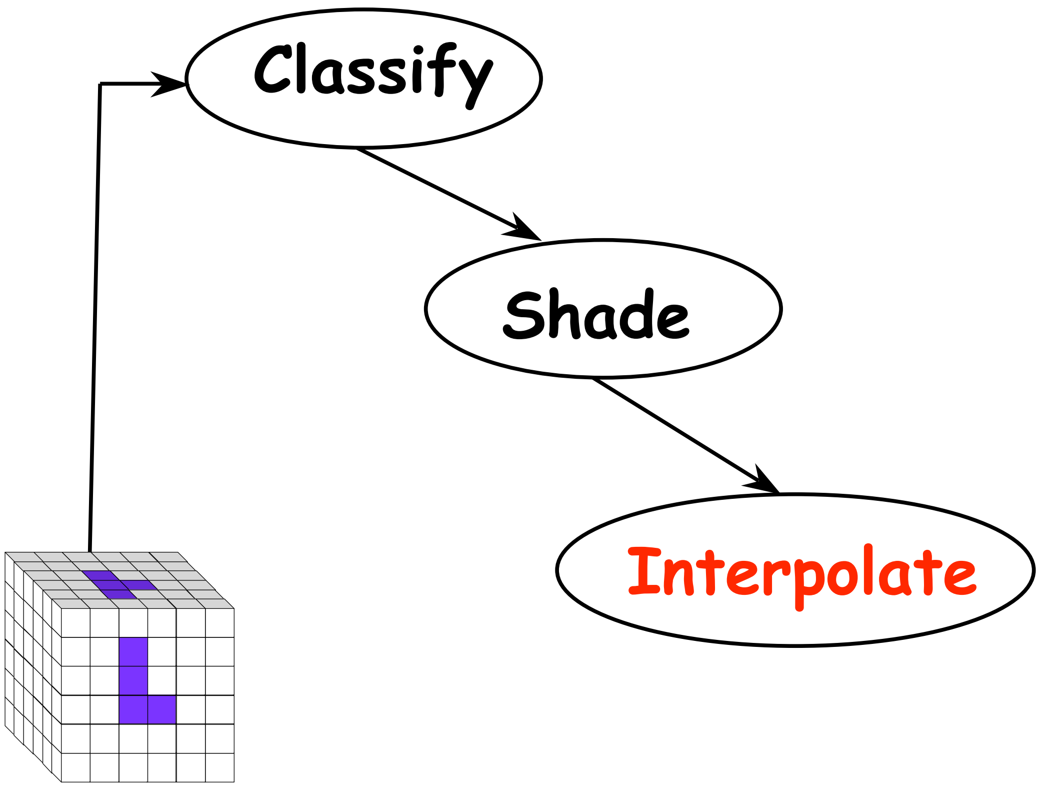


Light=refl.+absorbed+trans.

Light=ambient+diffuse+specular

$$I = k_a I_a + k_d I_d + k_s I_s$$

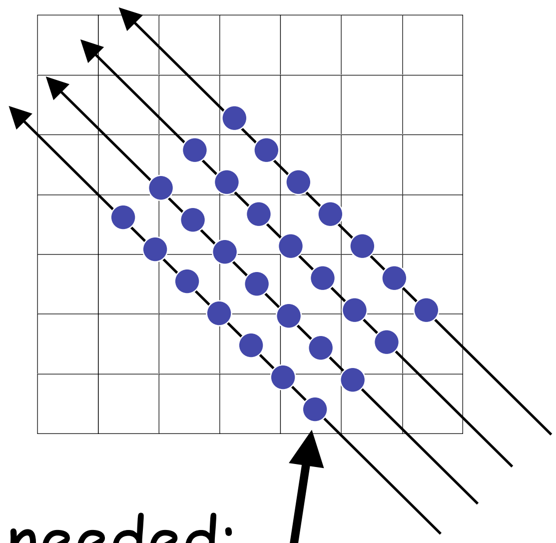
Rendering Pipeline



Interpolation

2D

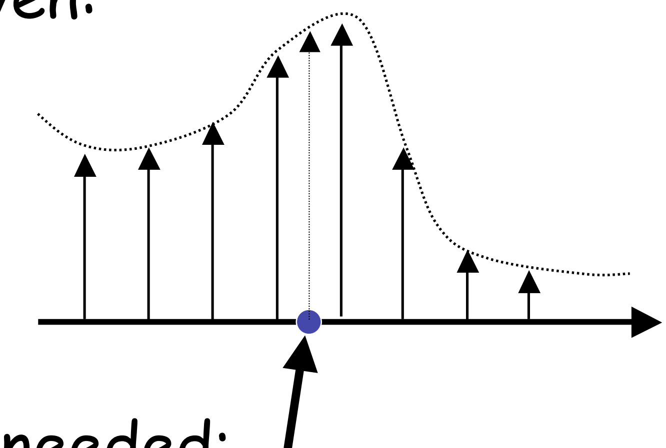
- given:



- needed:

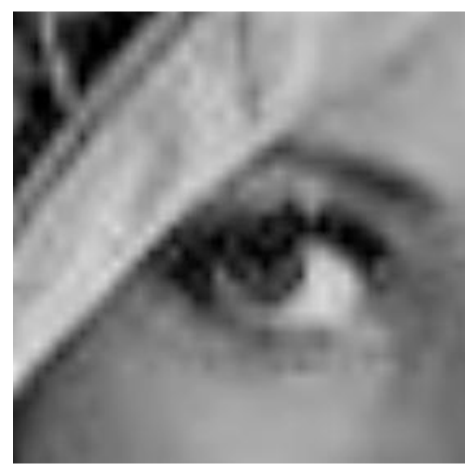
1D

- given:



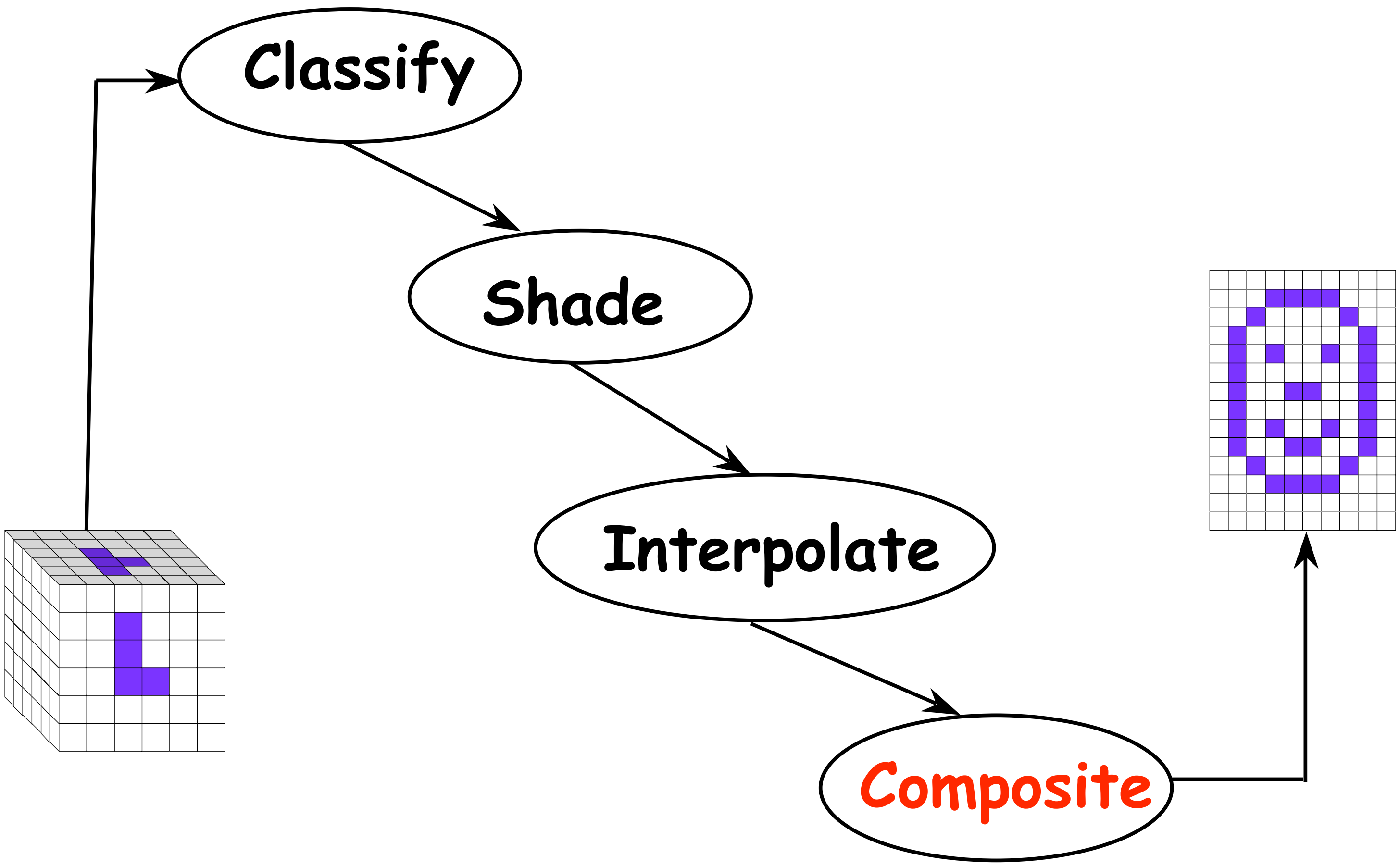
- needed:

nearest neighbor



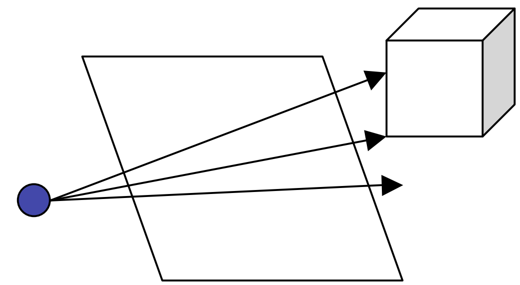
linear

Rendering Pipeline

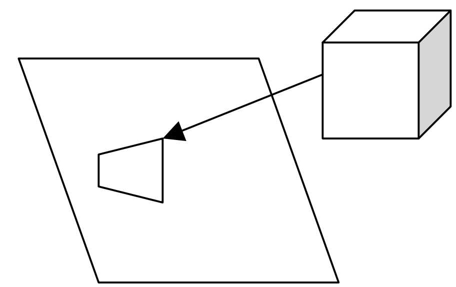


Volume Rendering Algorithms

- ray casting
  - image order, forward viewing

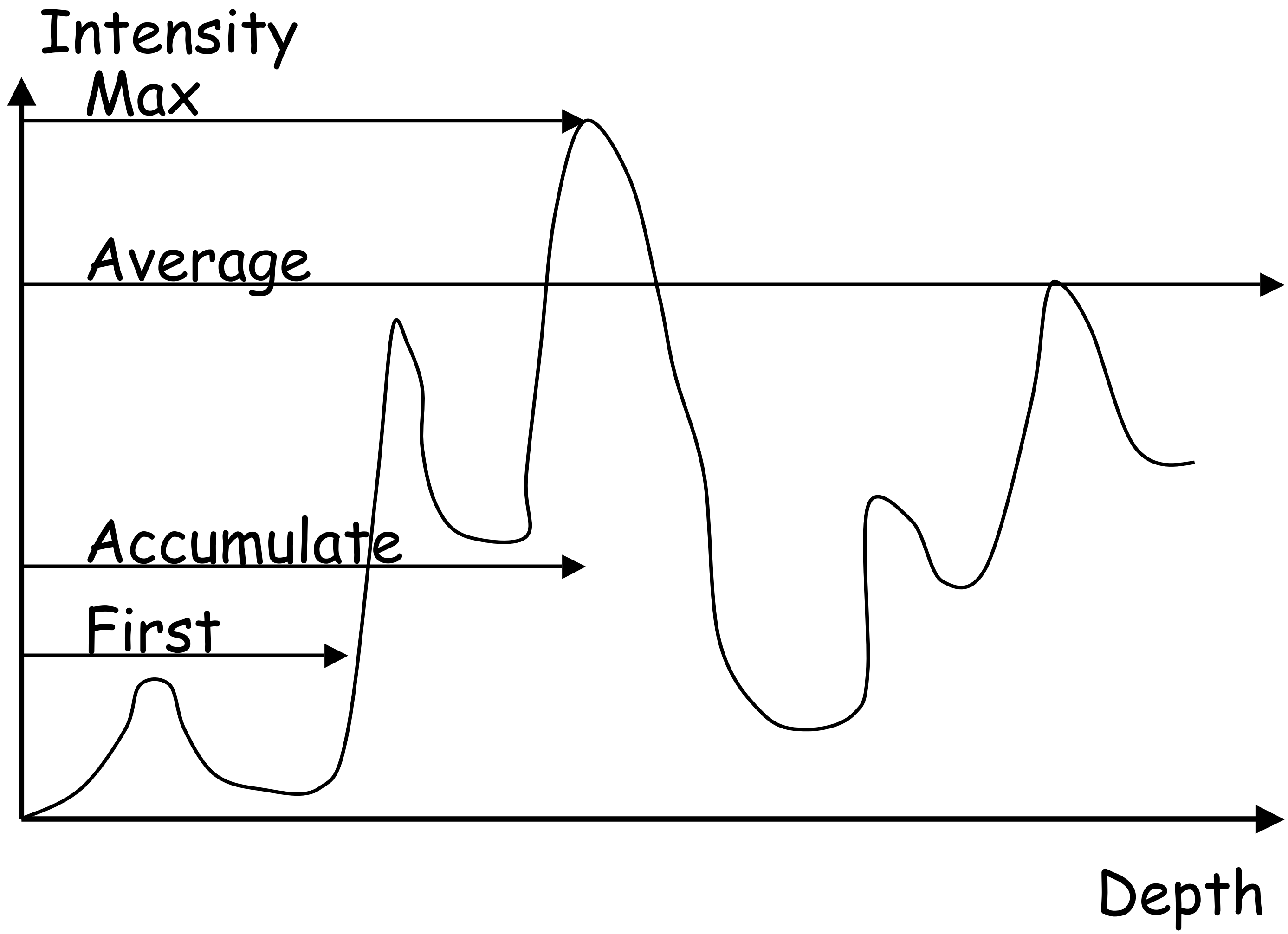


- splatting
  - object order, backward viewing



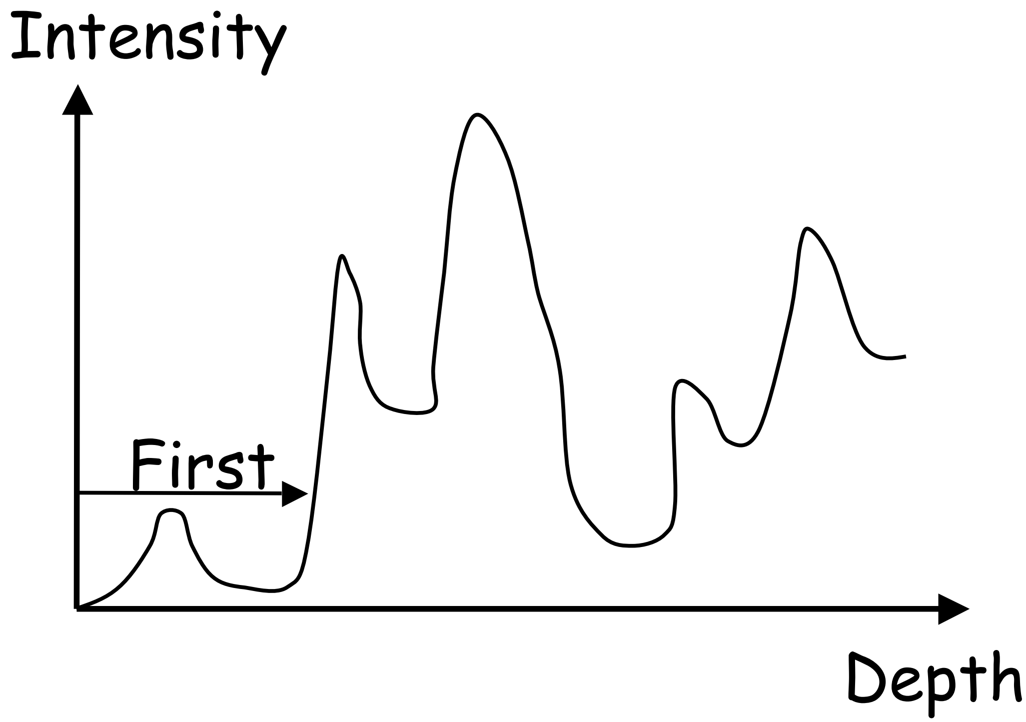
- texture mapping
  - object order
  - back-to-front compositing

Ray Traversal Schemes



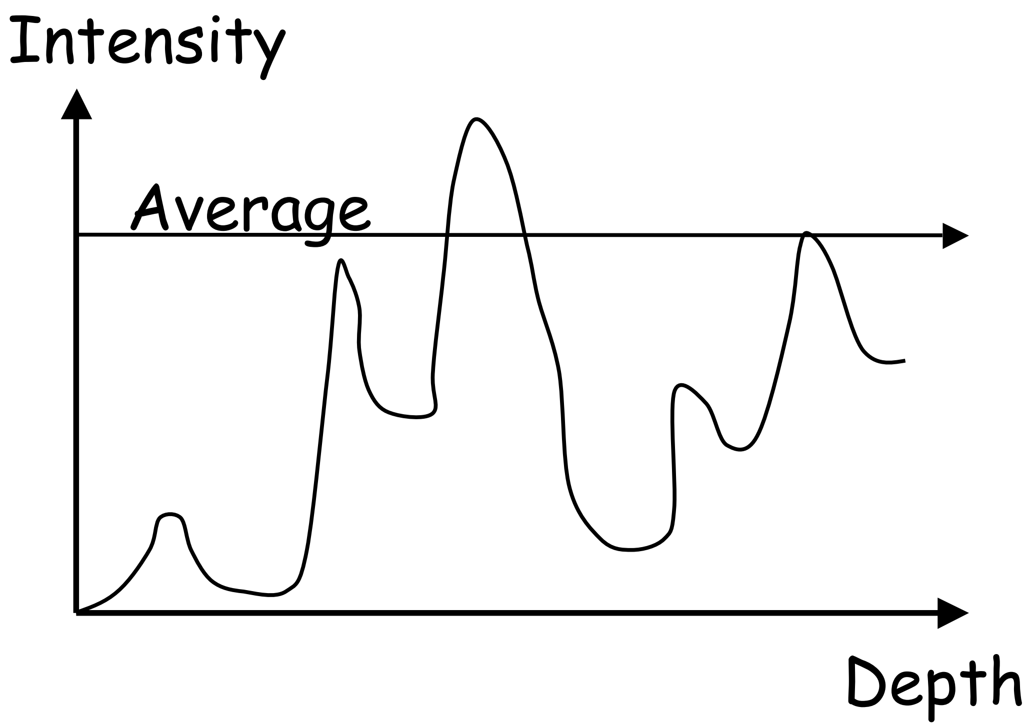
Ray Traversal - First

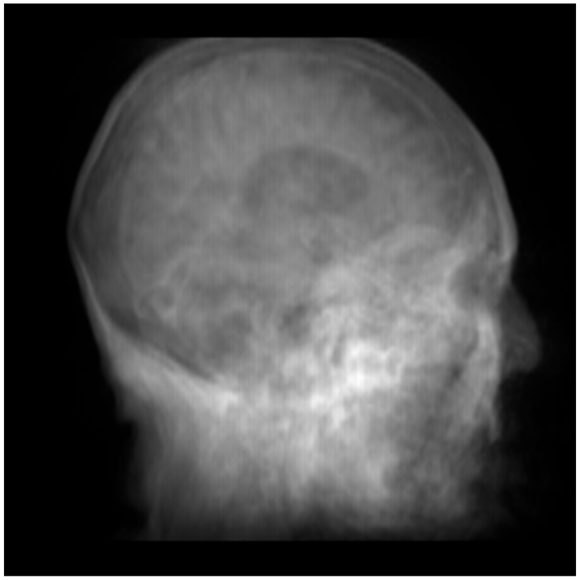
- first: extracts iso-surfaces (again!)



Ray Traversal - Average

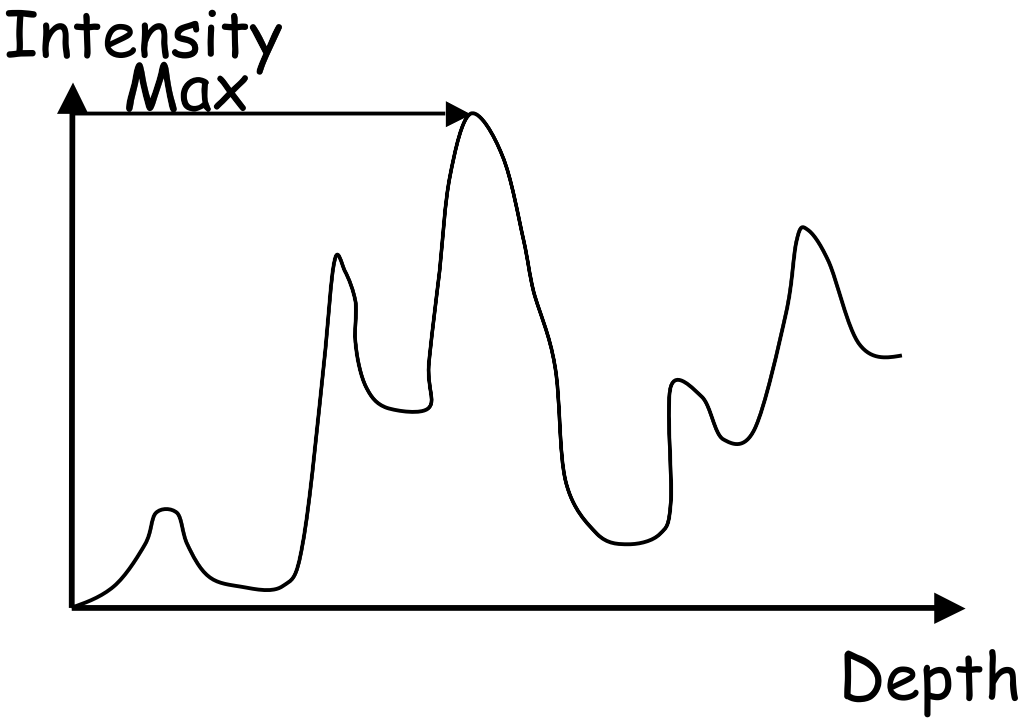
- average: looks like X-ray





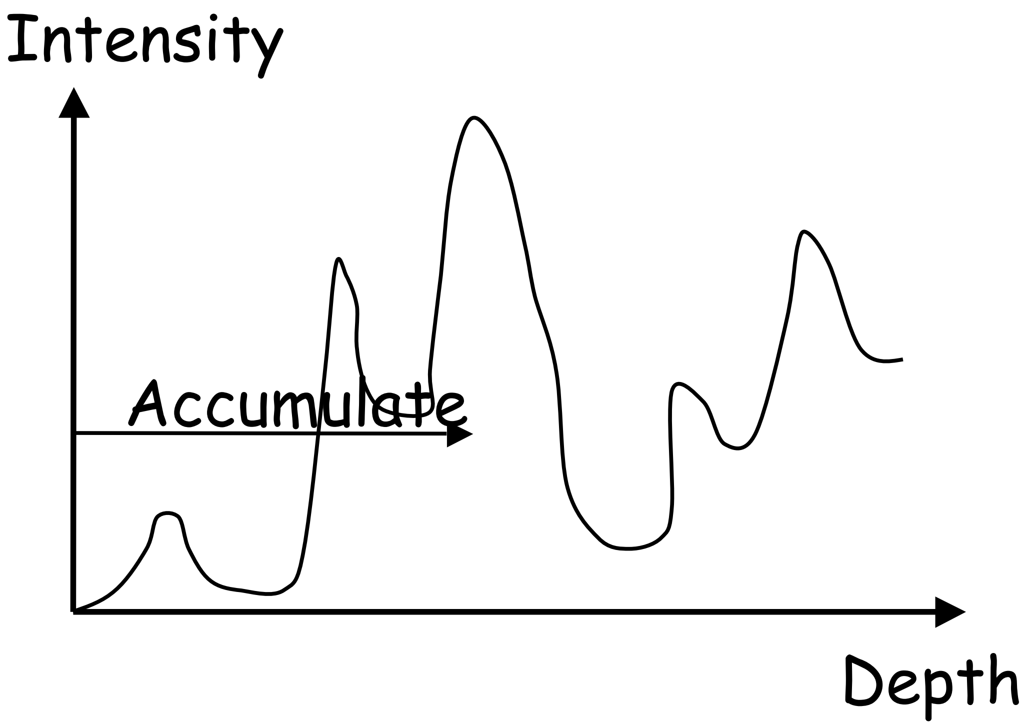
Ray Traversal - MIP

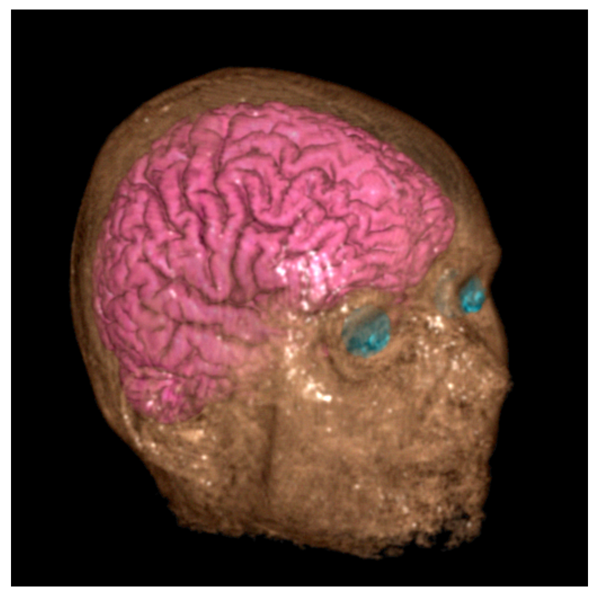
- max: Maximum Intensity Projection
  - used for Magnetic Resonance Angiogram



Ray Traversal - Accumulate

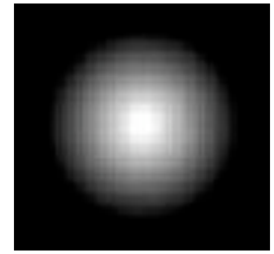
- accumulate: make transparent layers visible

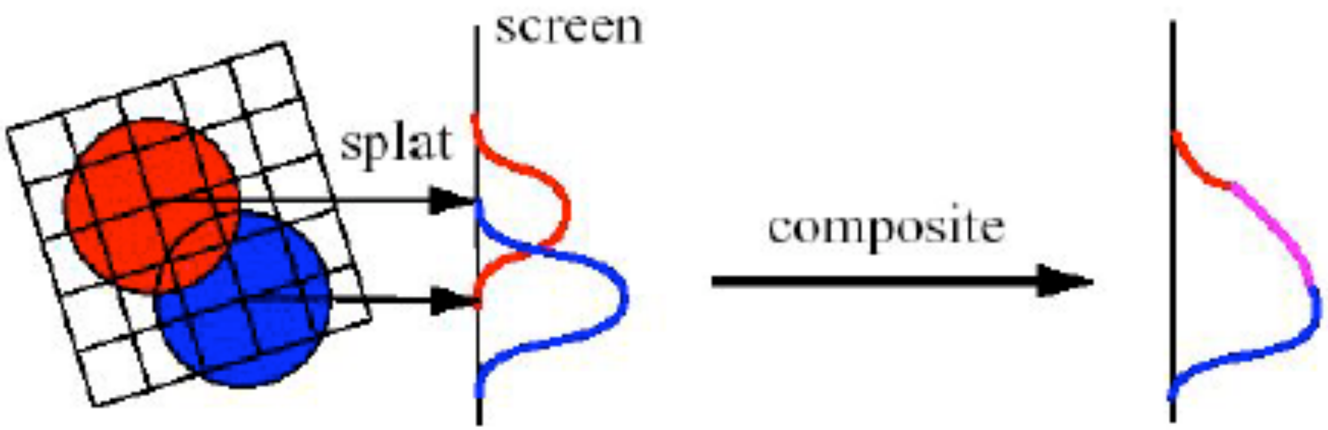




Splatting

- each voxel represented as fuzzy ball
  - 3D gaussian function
  - RGBa value depends on transfer function
- fuzzy balls projected on screen, leaving footprint called splat
  - composite front to back, in object order





Texture Mapping

- 2D: axis aligned 2D textures
  - back to front compositing
  - commodity hardware support
  - must calculate texture coordinates, warp to image plane
- 3D: image aligned 3D texture
  - simple to generate texture coordinates