3D Modeling Overview

CS 417 Lecture 17

Announcements

- Prelim 1 makeup
  - 7:30 to 9:15 (extra time to match main prelim)
  - Upson 207
- Program 2 grading
  - tomorrow 12:00–1:00 and Friday 3:40–5:20
  - sign up for 20 minute slots on web site
- Prof. office hours
  - cancelled tomorrow
  - available Friday before noon but email ahead

Modeling in 3D

- Representing subsets of 3D space
  - volumes (3D subsets)
  - surfaces (2D subsets)
  - curves (1D subsets)
  - points (0D subsets)

Representing geometry

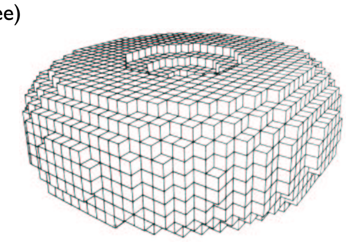
- In order of dimension…
- Points: trivial case
- Curves
  - normally use parametric representation
  - line—just a point and a vector (like 2D)
  - more general curves: usually use splines
    - generalization from 2D is very simple
    - **p**(t) is now from R to R^3
    - control points arranged in 3D
    - things like convex hull still work…

Representing geometry

- Surfaces
  - this case starts to get interesting
  - implicit and parametric representations both useful
  - example: plane
    - implicit: vector from point perpendicular to normal
    - parametric: point plus scaled tangent
  - example: sphere
    - implicit: distance from center equals r
    - parametric: write out in spherical coordinates
      - messiness of parametric form not unusual

Representing geometry

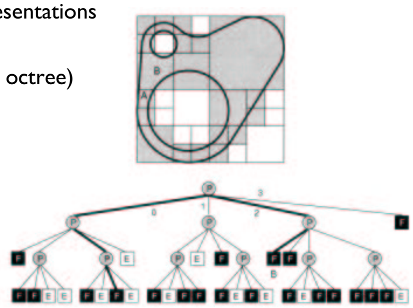
- Volumes
  - occupancy representations
    - uniform
    - adaptive (e.g. octree)



[Foley et al.]

Representing geometry

- Volumes
  - occupancy representations
    - uniform
    - adaptive (e.g. octree)



[Foley et al.]

Representing geometry

- Volumes
  - boundary representations (B-reps)
    - just represent the boundary surface
    - more precise
    - more convenient for many applications
    - must be closed (watertight) to be meaningful
      - an important constraint to maintain in many applications

Representing geometry

- Volumes
  - CSG (Constructive Solid Geometry)
    - apply boolean operations on solids
    - simple to define
    - simple to compute in some cases
      - [e.g. ray tracing]
    - difficult to compute stably with B-reps
      - [e.g. coincident surfaces]

Tangents and normals

- Very useful concepts
  - applicable to smooth sets only
- Tangent: line that locally approximates
  - that is, zoom in and it looks like it lies in the set
  - curve: tangent line (1 tangent vector)
  - surface: tangent plane (2 tangent vectors)

Derivatives and tangents

- (This topic is a brief view of differential geometry)
- Curves (parametric)
  - tangent vector is the derivative of the parametric equation
  - a 3D vector
  - length of derivative is the "speed"
    - not important for geometric tangent
    - unless it is zero…

Derivatives and tangents

- Surfaces (parametric)
  - represented by function from R^2 to R^3
  - derivative is therefore a 3x2 matrix
    - the "Jacobian matrix"
  - interpret as two 3-vectors
    - they are a basis for the tangent plane
    - lengths are speeds along two axes
  - normal is the perpendicular to the tangents

Derivatives and tangents

- Surfaces (implicit)
  - f(t) is from R^3 to R
  - derivative is 1 by 3 “gradient vector”
    - now a basis for the normal space
      - reason: derivative perpendicular is 0
    - length is “confidence” or “stability”
      - not important for geometry
      - unless it is zero…
  - tangents
    - build them from the normal

Tangents, normals, and frames

- Often convenient to define a coordinate frame at a point on a surface or curve
  - that is, a point and an ONB
- Curves
  - can easily construct frame with u aligned with tangent

Tangents, normals, and frames

- For surfaces
  - can construct ONB with u, v, being the tangents and w being the normal
  - parameterization (if available) can determine u, v
- For points, volumes
  - they don’t really have tangents and normals
  - in some sense all vectors are normal to point and tangent to volume

Constructing frames

- From two vectors, say **v** and **w**
  - want to preserve **w** and **v**-**w** plane
  - **v** = **v** / ||**v**||
  - **w** = **w** / ||**w**||
  - **u** = **v** x **w**
  - **u** = **u** / ||**u**||
    - now **u** and **w** are orthonormal
  - **v** = **w** x **u**
    - v is in the old **v**-**w** plane
    - now all three are a right handed ONB

Constructing frames

- From single vector, say **w**
  - **w** = **w** / ||**w**||
  - **v** = arbitrary but not parallel to w
    - good option = 1 in **w**’s smallest component
  - **u** = **v** x **w**
  - **u** = **u** / ||**u**||
    - now **u** and **w** are orthonormal
  - **v** = **w** x **u**
    - now all three are a right handed ONB

Specific surface representations

- Swept surfaces
  - parametric
  - extrusions
  - surfaces of revolution

[Hearn & Baker]

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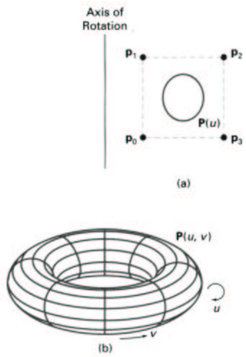
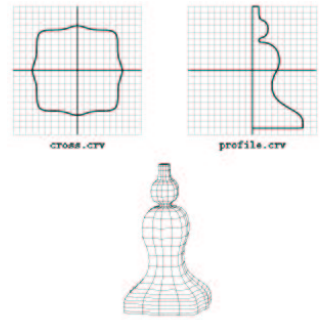


[Hearn & Baker]

Specific surface representations

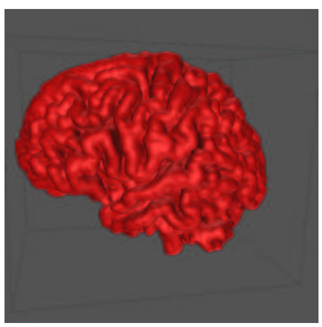
- General swept surfaces
  - varying radius
  - varying cross-section
  - curved axis



[Snyder 1992]

Specific surface representations

- Isosurface of volume data
  - medical imaging
    - e.g., density data from CT or MRI
  - numerical simulation
    - e.g., implicit fluid surface



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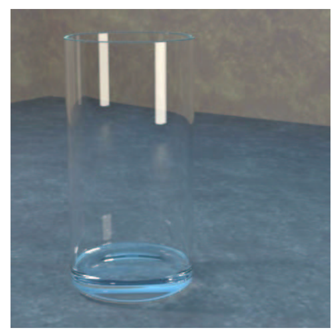
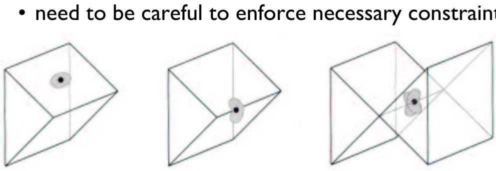


[Enright et al . 2002]

Specific surface representations

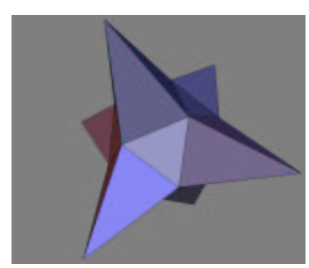
- Triangle or polygon meshes
  - parametric (per face)
  - very widely used
    - final representation for pipeline rendering
    - these days restricting to triangles is common
  - rather unstructured
    - need to be careful to enforce necessary constraints



[Foley et al.]

Specific surface representations

- Subdivision surfaces
  - based on polygon meshes (quads or triangles)
  - rules for subdividing surface by adding new vertices
  - converges to continuous limit surface
  - relationship to spline subdivision



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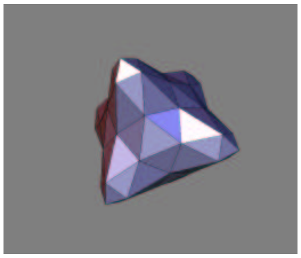

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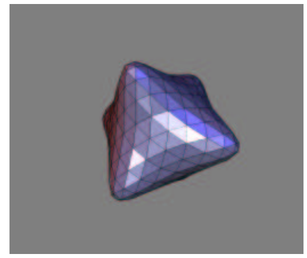

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