
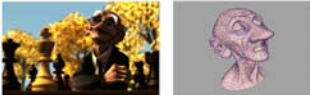


Computer Graphics


Geometric Modeling




Chapter 14




Geometric Modeling - Basics






Geometry

- Mathematical models of real world shapes
 - Most common: Boundary representations

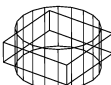


Freeform – smooth surface

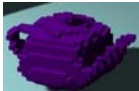


Mesh – polygonal surface


- Alternative: Volumetric representations



Primitive based

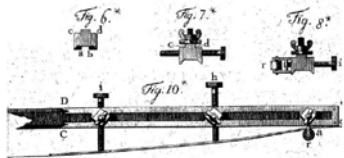


Voxel based




Splines – Free Form Curves

- Geometric meaning of coefficients (base)
 - Approximate/interpolate set of positions, derivatives, etc..



- Will see one example



Splines – Free Form Curves


- Usually parametric
 - $C(t)=[x(t),y(t)]$ or $C(t)=[x(t),y(t),z(t)]$
- Description = basis functions + coefficients

$$C(t) = \sum_{i=0}^n P_i B_i(t) = (x(t), y(t))$$

$$x(t) = \sum_{i=0}^n P_i^x B_i(t)$$

$$y(t) = \sum_{i=0}^n P_i^y B_i(t)$$


- Same basis functions for all coordinates



Hermite Cubic Basis

- Geometrically-oriented coefficients
 - 2 positions + 2 tangents
- Require $C(0)=P_0$, $C(1) = P_1$, $C'(0)=T_0$, $C'(1)=T_1$
- Define basis function per requirement

$$C(t) = P_0 h_{00}(t) + P_1 h_{01}(t) + T_0 h_{10}(t) + T_1 h_{11}(t)$$



Hermite Basis Functions

$$C(t) = P_0 h_{00}(t) + P_1 h_{01}(t) + T_0 h_{10}(t) + T_1 h_{11}(t)$$

- To enforce $C(0)=P_0$, $C(1) = P_1$, $C'(0)=T_0$, $C'(1)=T_1$ basis should satisfy

$$h_{ij}(t) i, j = 0,1, t \in [0,1]$$

curve	$C(0)$	$C(1)$	$C'(0)$	$C'(1)$
$h_{00}(t)$	1	0	0	0
$h_{01}(t)$	0	1	0	0
$h_{10}(t)$	0	0	1	0
$h_{11}(t)$	0	0	0	1

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Hermite Cubic Basis

- Can satisfy with cubic polynomials as basis

$$h_{ij}(t) = a_3 t^3 + a_2 t^2 + a_1 t + a_0$$

- Obtain - solve 4 linear equations in 4 unknowns for each basis function

$$h_{ij}(t); i, j = 0, 1, t \in [0, 1]$$

curve	$C(0)$	$C(1)$	$C'(0)$	$C'(1)$
$h_{00}(t)$	1	0	0	0
$h_{01}(t)$	0	1	0	0
$h_{10}(t)$	0	0	1	0
$h_{11}(t)$	0	0	0	1

Hermite Cubic Basis

- Four polynomials that satisfy the conditions

$$h_{00}(t) = t^2(2t-3)+1 \quad h_{01}(t) = -t^2(2t-3)$$

$$h_{10}(t) = t(t-1)^2 \quad h_{11}(t) = t^2(t-1)$$

Tensor Spline Surfaces

From Curves to Surfaces: Tensor Splines

- Curve is expressed as inner product of P_i coefficients and basis functions

$$C(u) = \sum_{i=0}^n P_i B_i(u)$$

- To extend curves to surfaces - treat surface as a curve of curves
- Assume P_i is not constant, but a function of second parameter v : $P_i(v) = \sum_{j=0}^m Q_{ij} B_j(v)$

$$C(u, v) = \sum_{i=0}^n \sum_{j=0}^m Q_{ij} B_j(v) B_i(u)$$

Bilinear Patches

- Bilinear interpolation of 4 3D points

$$P_{00}, P_{01}, P_{10}, P_{11}$$

- surface analog of line segment curve

Bilinear Patches

- Given $P_{00}, P_{01}, P_{10}, P_{11}$ associated parametric bilinear surface for $u, v \in [0, 1]$ is:

$$P(u, v) = (1-u)(1-v)P_{00} + (1-u)vP_{01} + u(1-v)P_{10} + uvP_{11}$$



- Questions:
 - What does an isoparametric curve of a bilinear patch look like?
 - When is a bilinear patch planar?

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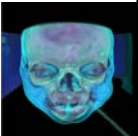
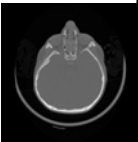
Geometry Creation (Meshes)

- Reconstruction: Capture real life shapes & convert to mesh
 - Inputs:
 - Points (laser scanner)
 - 3D images
- Modeling (user driven)
- Will see two examples
 - Marching Cubes – reconstruction from images
 - Subdivision – generating smooth meshes from coarse user-given “cages”

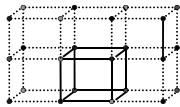
Reconstruction from Volume Data

- Volume data – view as voxel grid with values at vertices
 - Defines implicit function in 3D
 - interpolate grid values
- Shape defined by isosurface
 - isosurface = set of points with constant isovalue α
 - separates values above α from values below
- Reconstruction – Extract triangulation approximating isosurface

Voxels

- Voxel – cube with values at eight corners
 - Each value is above or below isovalue α
- $2^8=256$ possible configurations (per voxel)
 - reduced to 15 (symmetry and rotations)
- Each voxel is either:
 - Entirely inside isosurface
 - Entirely outside isosurface
 - Intersected by isosurface
- MC main observation: Can extract triangulation independently per voxel



Basic MC Algorithm

- For each voxel produce set of triangles
 - Based on above/below corner configuration
 - Empty for non-intersecting voxels
 - Approximate surface inside voxel

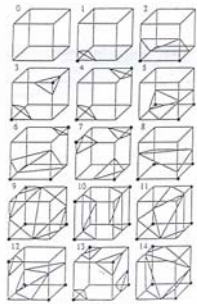



Figure 1. Configurations.

Configurations

- For each configuration add 1-4 triangles to isosurface
- Isosurface vertices computed by:
 - Interpolation along edges (according to grid values)
 - better shading, smoother surfaces
 - Default – mid-edges

Example



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Example

Consistency Problem

- Can produce non-manifold
 - Isovalue surfaces with "holes"
- Example:
 - Voxel with configuration 6 sharing face with complement of configuration 3

Ambiguous Faces

- Face containing two diagonally opposite marked grid points and two unmarked ones
- Two locally valid interpretations
- Source of MC consistency problem

Consistency

- Problem:
 - Connection of isosurface points on shared face done one way on one face & another way on the other
- Need consistency → use different triangulations
- If choices are consistent get topologically correct surface

Solution

- For each problematic configuration have more than one triangulation
- Distinguish different cases by choosing pairwise connections of four vertices on common face
 - Example:

Asymptotic Decider

- "Guess" value at quad center
- Use bilinear interpolation to obtain

$$B(s, t) = (1-s) \begin{pmatrix} B_{00} & B_{01} \\ B_{10} & B_{11} \end{pmatrix} \begin{pmatrix} 1-t \\ t \end{pmatrix}$$

$$\{(s, t): 0 \leq s \leq 1, 0 \leq t \leq 1\}$$

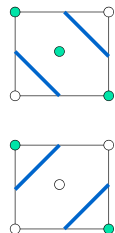
• B_{ij} - isovalues at face corners

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Ambiguous Faces

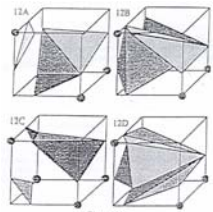
- If center value closer to "green" choose
- Else



The diagrams illustrate a decision rule for ambiguous faces. In the top diagram, a green dot is in the upper-left triangle and a white dot is in the lower-right triangle. In the bottom diagram, a white dot is in the upper-left triangle and a green dot is in the lower-right triangle.

Various Cases

- Some configurations have no ambiguous faces → no modifications
- Other configurations need modifications according to number of ambiguous faces
 - Apply decoder to each face to decide on triangulation template



The diagrams show four different triangulation templates for a square face, labeled 12A, 12B, 12C, and 12D. Each diagram shows a square face with a diagonal line and a shaded region representing a triangulation template.

Figure 11.