SUBDIVISION SURFACES. 11/27/01

Announcements:

Project 2 Demo Signups
Quiz Grading
Project 3
Readings
Texture Lecture - read Shirley and Haines & Moller

Today -

Subdivision Surfaces

- not a new idea
  - Catmull - Clark & Doo - Sabin late 70s
  - Mathematics long before that
- came back to graphics ≈ 1998
  - A few breakthroughs
  - A few high profile successes
  - Pent-Up frustrations with Alternatives

What happend in 1998?

Geri's game - PIXAR
paper by DeRose, Kass, and Truong
shows you can do everything with subdivision

Jos Stam - Exact Evaluation methods
shows that can be efficient for just about Anything

Why Subdivision
- Alternatives: Tensor Product Surfaces
  Polygons

Why not NURBS? (remember 2 lectures ago?)
- fixed topology
- can't stitch together
- can't trim
- can't get sharp creases
- can't get more detail locally
- how to get nice parameterizations?

That's a high price to pay! what do we get?
- smoothness
- parametric - have coordinates (for texturing) even if "weird"
- compute exactly - know tangents and positions for all points

Why not just use polygons?
- not smooth

Use more polygons to get smoothness?
as you add more and more polygons, gets closer and closer to being smooth

How to get more polygons?
make a rule about how to compute given current set

Subdivision:
initial shape
rule to divide each element into smaller pieces

apply rule over and over until done

Example: (2d points, curves)
given points i, $i+1$, insert new point $\frac{P_i + P_{i+1}}{2}$
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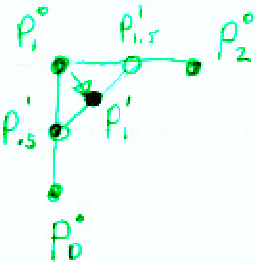
in the limit this shape is continuous

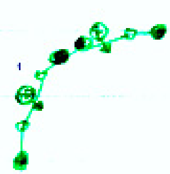
Example:
Quadratic Bezier Curves (from Shirley p. 208)
(remember, Bezier's interpolate end points)

Given: P_0, P_1, P_2 move P_1, insert $P_{.5}$, $P_{1.5}$

$$P_{.5} = \frac{1}{2}(P_0 + P_1)$$
$$P_{1.5} = \frac{1}{2}(P_1 + P_2)$$
$$P_1 = \frac{1}{2}(P_{.5} + P_{1.5})$$



now subdivide
$P_0, P_{.5}, P_1$
$P_1, P_{1.5}, P_2$



IN THE LIMIT WE GET A SMOOTH CURVE!

The problems:

1. What should the rules be (the "Subdivision Scheme")
   How can we be sure we get something that converges?
2. How much do we need to subdivide?
3. What if we don't want to do ∞ subdivision steps?
4. How to deal with different levels of detail? (some close together points, some far away points)

SUBDIVISION SCHEMES

Many Different ones - find one that fits your needs

- interpolating vs. approximating
- triangles vs. quads
- how are "extra-ordinary points handled?

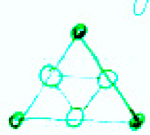
Support: the set of points that influence the new point position computation

EXAMPLE 1: BUTTERFLY SCHEME

INTERPOLATING

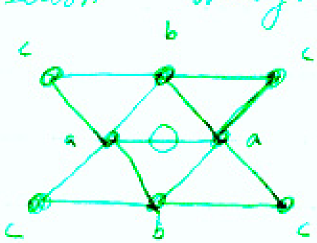
C1 "almost everywhere"

Triangles: Split Edges



1 Triangle ⇒ 4

new position = weighted average of 8 neighbors



$a = \frac{1}{2}$ $b = \frac{1}{8}$ $c = -\frac{1}{16}$

What about points that have more or less than 8 neighbors?

Need special rules! (see papers)

Where are points on the limit surface?
Easy! – since the surface interpolates, positions of the controls or current mesh = position of point on limit surface

What are the normals?
can't subdivide forever!
no problem – have a formula (a different "mask")

Butterfly details in Zamastitra article

Why not Butterfly ?

C1 ← and not at extra-ordinary points

modified rules do better

"ugly"

interpolating curves / surfaces never look as good

Loop Scheme —

Popular

Approximating

Triangles (each edge gets split)

Catmull - Clark surfaces

Approximating Scheme

Generally on Quads - breaks non-quads into ~~non~~ quads

generalizes cubic B-Splines -

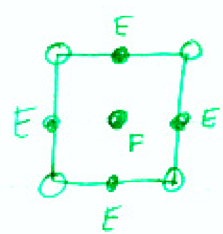
gives same shapes!

can convert B-Splines ⇒ CAT-Clark

Idea: each polygon →

new "face point"

new "edge points"



F = Centroid of Polygon

E = Average of center of V's and center of F's

$V = \frac{n-2}{n} v_i + \frac{1}{n^2}\sum e + \frac{1}{n^2}\sum f$

notice, we get n quads!

Need methods for exact evaluation!

"regular case" = no problem, use B-Spline formulas

given controls easy to compute "final" position and normals

What about extra-ordinary points?
subdivide until they become ordinary!

These things are phenomenally popular!

Everything in a PIXAR MOVIE (more or less)

Why?
SUBDIVIDE ANY MESH
any topology
cut, stitch, ... all you like
No cracking
Nice, smooth surfaces
Make creases by modifying subdivision rules
don't move on first few iterations
Add extra-details only where needed
add points only at certain levels!
Evaluate exactly, anywhere!
Jos Stam paper '98