Subdivision surfaces

CS 417 Lecture 21

Subdivision curves

Figure 2.1: *Example of subdivision for curves in the plane. On the left 4 points connected with straight line segments. To the right of it a refined version: 3 new points have been inserted "inbetween" the old points and again a piecewise linear curve connecting them is drawn. After two more steps of subdivision the curve starts to become rather smooth.*

[Schröder & Zorin SIGGRAPH 2000 course 23]

Subdivision surfaces

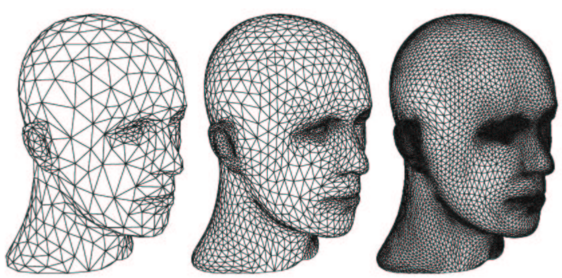
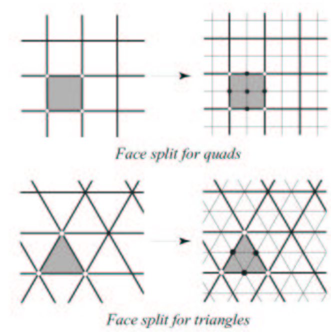


Figure 2.2: *Example of subdivision for a surface, showing 3 successive levels of refinement. On the left an initial triangular mesh approximating the surface. Each triangle is split into 4 according to a particular subdivision rule (middle). On the right the mesh is subdivided in this fashion once again.*

[Schröder & Zorin SIGGRAPH 2000 course 23]

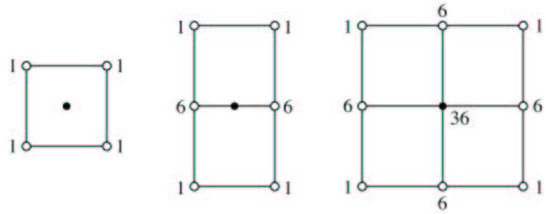
Subdivision of meshes

- Quadrilaterals
  - Catmull-Clark 1978
- Triangles
  - Loop 1987

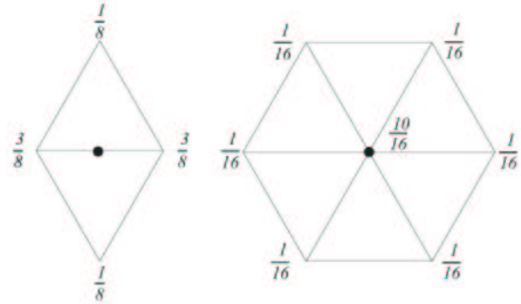


[Schröder & Zorin SIGGRAPH 2000 course 23]

Catmull-Clark regular rules



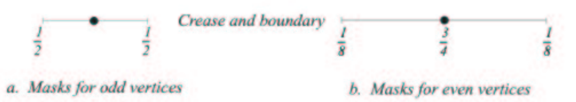
Loop regular rules



[Schröder & Zorin SIGGRAPH 2000 course 23]

Creases

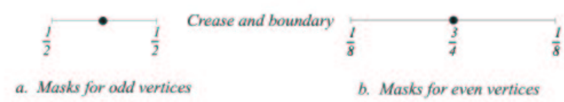
- With splines, make creases by turning off continuity constraints
- With subdivision surfaces, make creases by marking edges "sharp"
  - use different rules for vertices with sharp edges
  - these rules produce B-splines that depend only on vertices along crease



[Schröder & Zorin SIGGRAPH 2000 course 23]

Boundaries

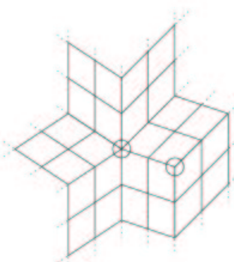
- At boundaries the masks do not work
  - mesh is not manifold; edges do not have two triangles
- Solution: same as crease
  - shape of boundary is controlled only by vertices along boundary



[Schröder & Zorin SIGGRAPH 2000 course 23]

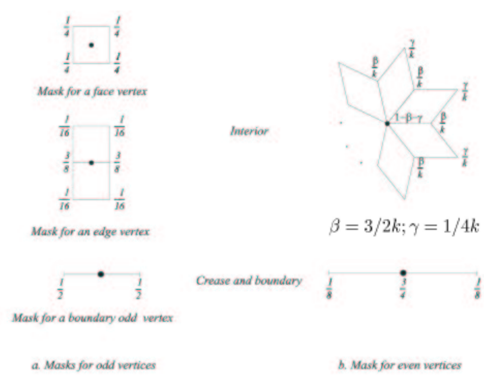
Extraordinary vertices

- Vertices that don't have the "standard" valence
- Unavoidable for most topologies
- Difference from splines
  - treatment of extraordinary vertices is really the only way subdivision surfaces are different from spline patches



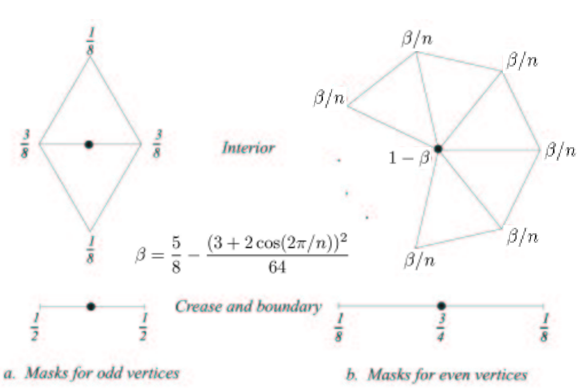
[Schröder & Zorin SIGGRAPH 2000 course 23]

Full Catmull-Clark rules (quad mesh)



[Schröder & Zorin SIGGRAPH 2000 course 23]

Full Loop rules (triangle mesh)

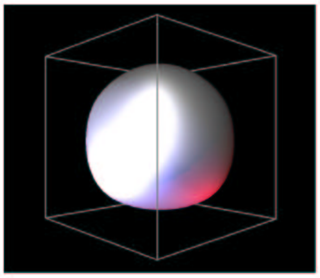


[Schröder & Zorin SIGGRAPH 2000 course 23]

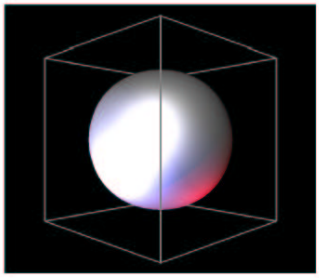
Relationship to splines

- In regular regions, behavior is identical
- At extraordinary vertices, achieve C^1
  - near extraordinary, different from splines
- Linear everywhere
  - mapping from parameter space to 3D is a linear combination of the control points
  - "emergent" basis functions per control point
    - match the splines in regular regions
    - "custom" basis functions around extraordinary vertices

Loop vs. Catmull-Clark



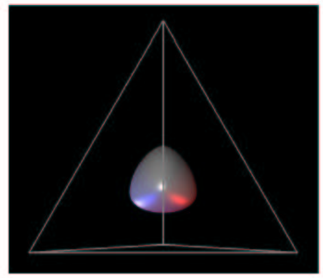
Loop



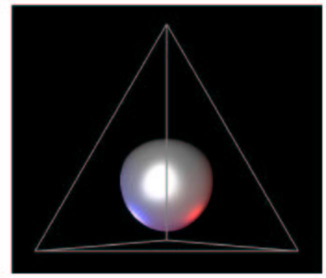
Catmull-Clark

[Schröder & Zorin SIGGRAPH 2000 course 23]

Loop vs. Catmull-Clark



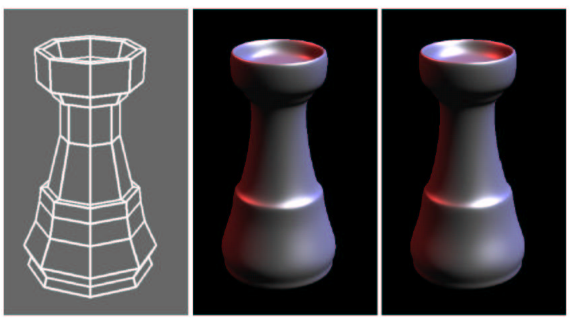
Loop



Catmull-Clark

[Schröder & Zorin SIGGRAPH 2000 course 23]

Loop vs. Catmull-Clark

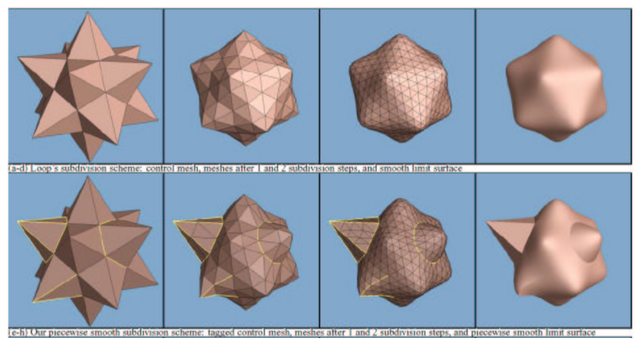


Loop
(after splitting faces)

Catmull-Clark

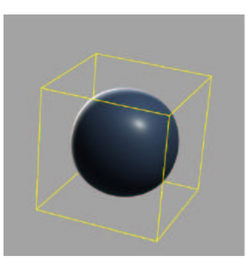
[Schröder & Zorin SIGGRAPH 2000 course 23]

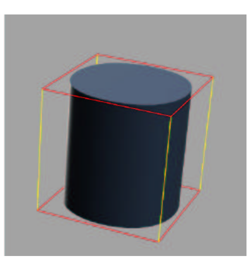
Loop with creases



[Hugues Hoppe]

Catmull-Clark with creases





[DeRose et al. SIGGRAPH 1998]

Geri's Game

- Pixar short film to test subdivision in production
  - Catmull-Clark (quad mesh) surfaces
  - complex geometry
  - extensive use of creases
  - subdivision surfaces to support cloth dynamics

[DeRose et al. SIGGRAPH 1998]