CS559: Computer Graphics

Lecture 25: Shape Modeling and Blending

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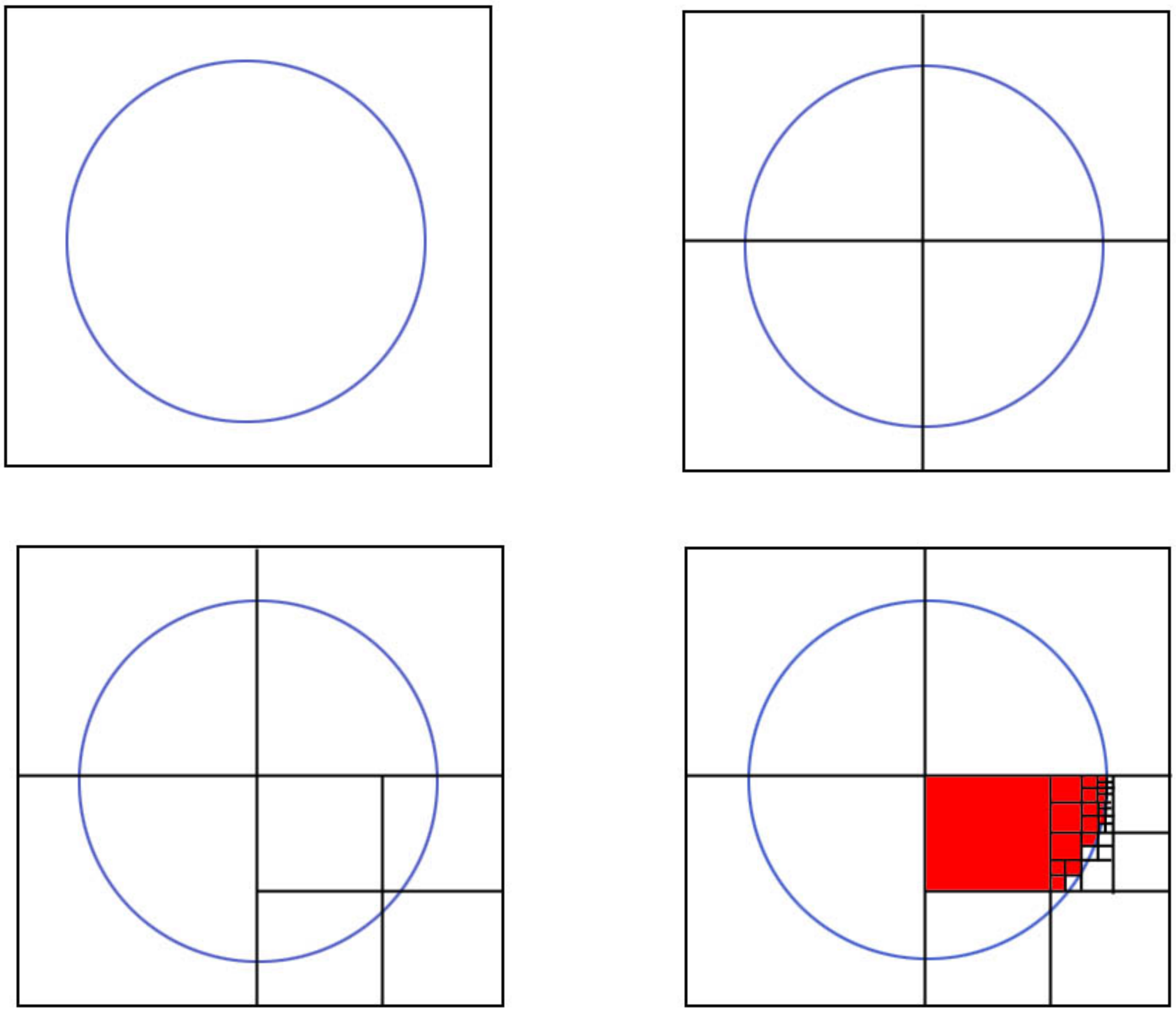
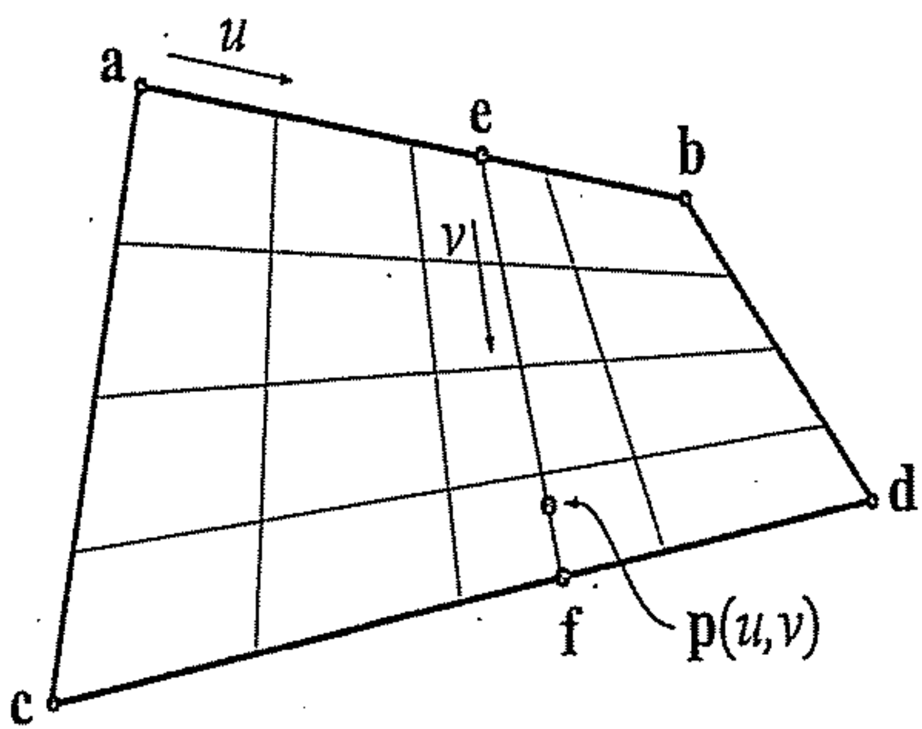
Spring 2010

Quadtree Idea



Bilinear Bezier Patch

- Define a surface that passes through a, b, c, d?



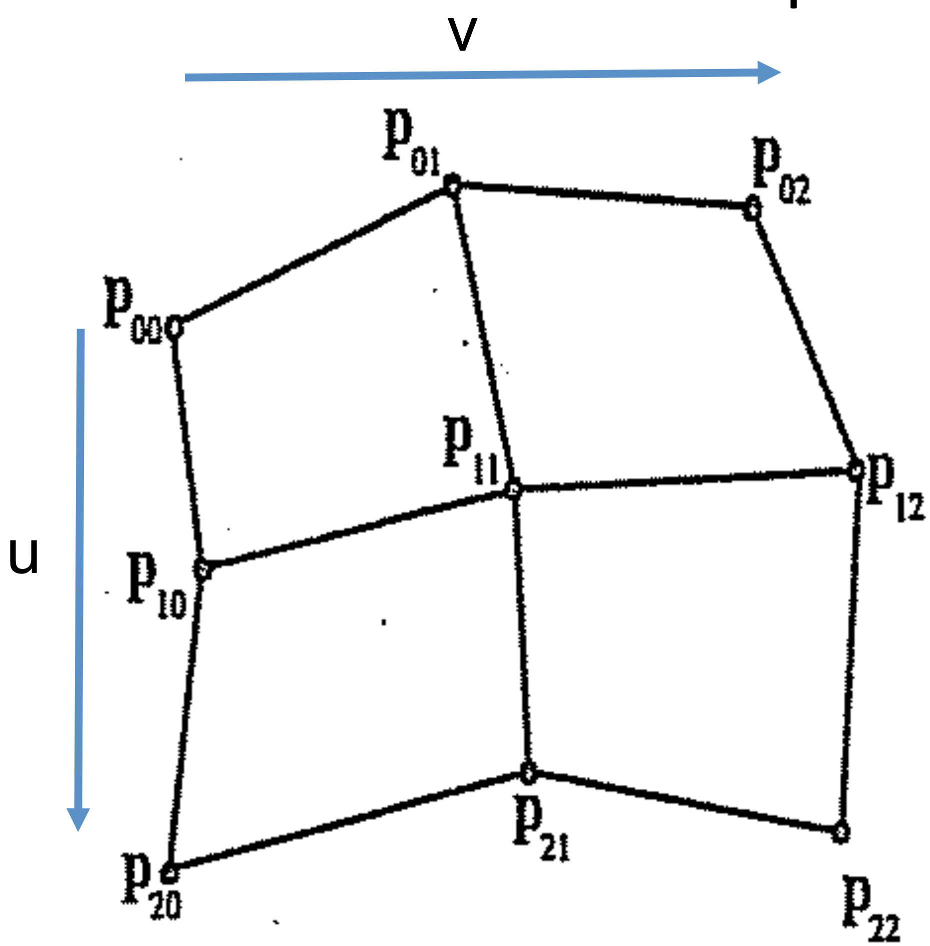
$$\mathbf{e} = (1-u)\mathbf{a} + u\mathbf{b},$$
$$\mathbf{f} = (1-u)\mathbf{c} + u\mathbf{d}.$$

Looks familiar?

$$\mathbf{p}(u,v) = (1-v)\mathbf{e} + v\mathbf{f}$$
$$= (1-u)(1-v)\mathbf{a} + u(1-v)\mathbf{b} + (1-u)v\mathbf{c} + uv\mathbf{d}.$$

Biquadratic Bezier Patch

- Define a surface that passes a 3x3 control lattice.



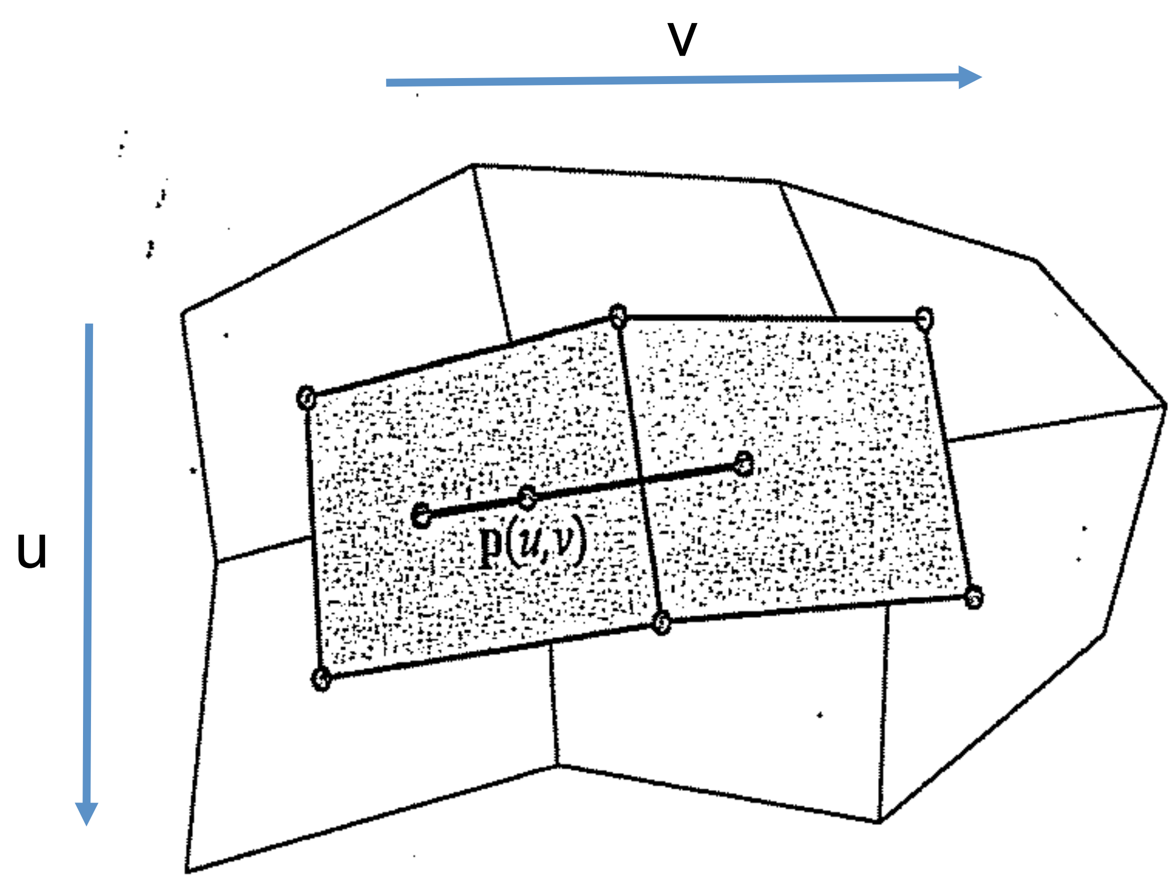
$p(u,0) = (1-u)^2\, p_{00} + 2(1-u)u\, p_{10} + u^2\, p_{20}$

$p(u,1) = (1-u)^2\, p_{01} + 2(1-u)u\, p_{11} + u^2\, p_{21}$

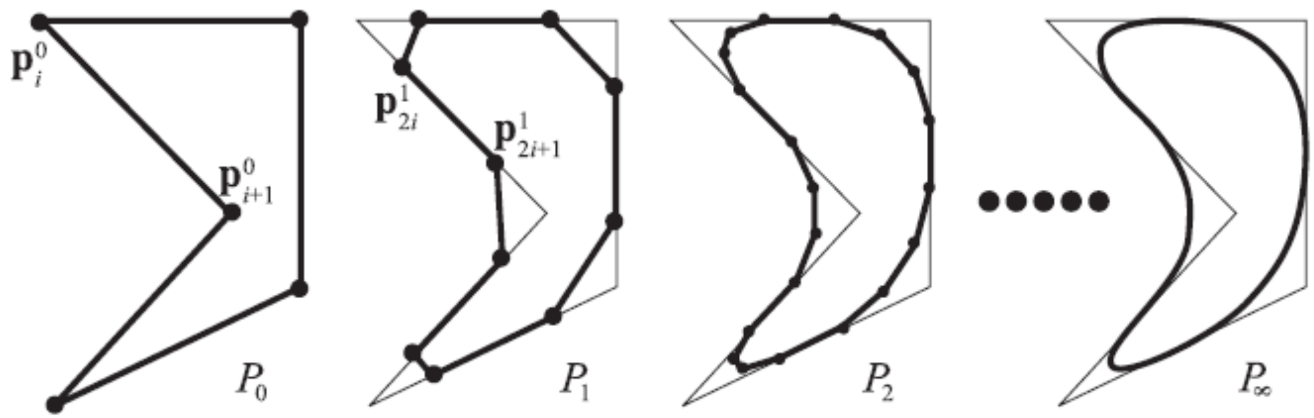
$p(u,2) = (1-u)^2\, p_{02} + 2(1-u)u\, p_{12} + u^2\, p_{22}$

$p(u,v) = (1-v)^2\, p(u,0) + 2(1-v)v\, p(u,1) + v^2\, p(u,2)$

Different degree in different directions



Subdivision Curves: Approximating



Initial (Control) Curve: $P_0 = \{p_0^0, \ldots, p_{n-1}^0\},$

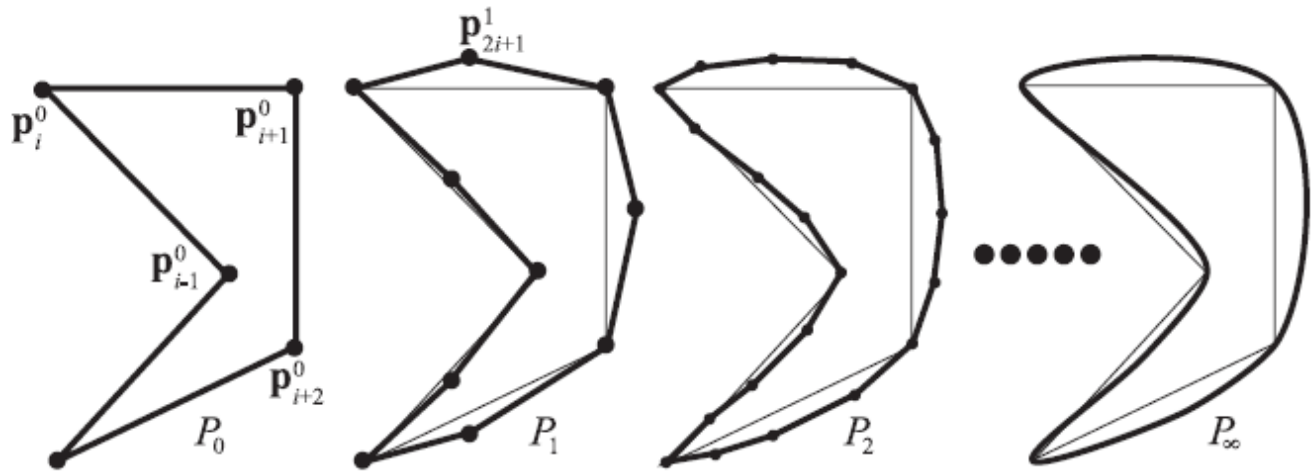
For each iteration k+1, add two vertices between: p_i^k and p_{i+1}^k

$$p_{2i}^{k+1} = \frac{3}{4}p_i^k + \frac{1}{4}p_{i+1}^k,$$

$$p_{2i+1}^{k+1} = \frac{1}{4}p_i^k + \frac{3}{4}p_{i+1}^k.$$

Approximating: Limit curve is very smooth (C2), but does not pass through control points

Subdivision Curves: Interpolating



Initial (Control) Curve: $P_0 = \{p_0^0, \ldots, p_{n-1}^0\}$,

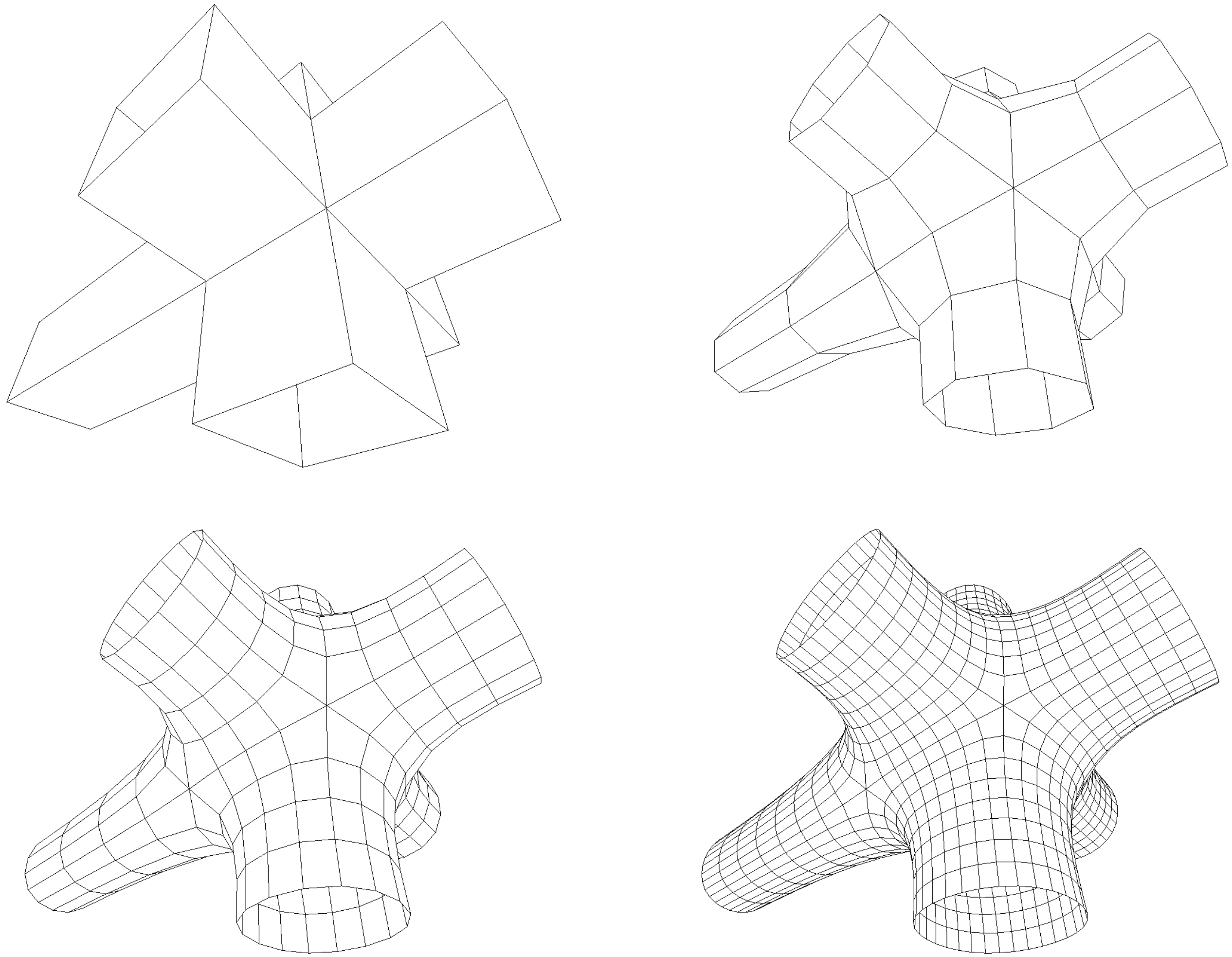
For each iteration k+1, add two vertices between: p_i^k and p_{i+1}^k

$$p_{2i}^{k+1} = p_i^k,$$

$$p_{2i+1}^{k+1} = (\frac{1}{2} + w)(p_i^k + p_{i+1}^k) - w(p_{i-1}^k + p_{i+2}^k).$$

Interpolating: for 0<w<1/8, limit curve is C1, and passes through control points

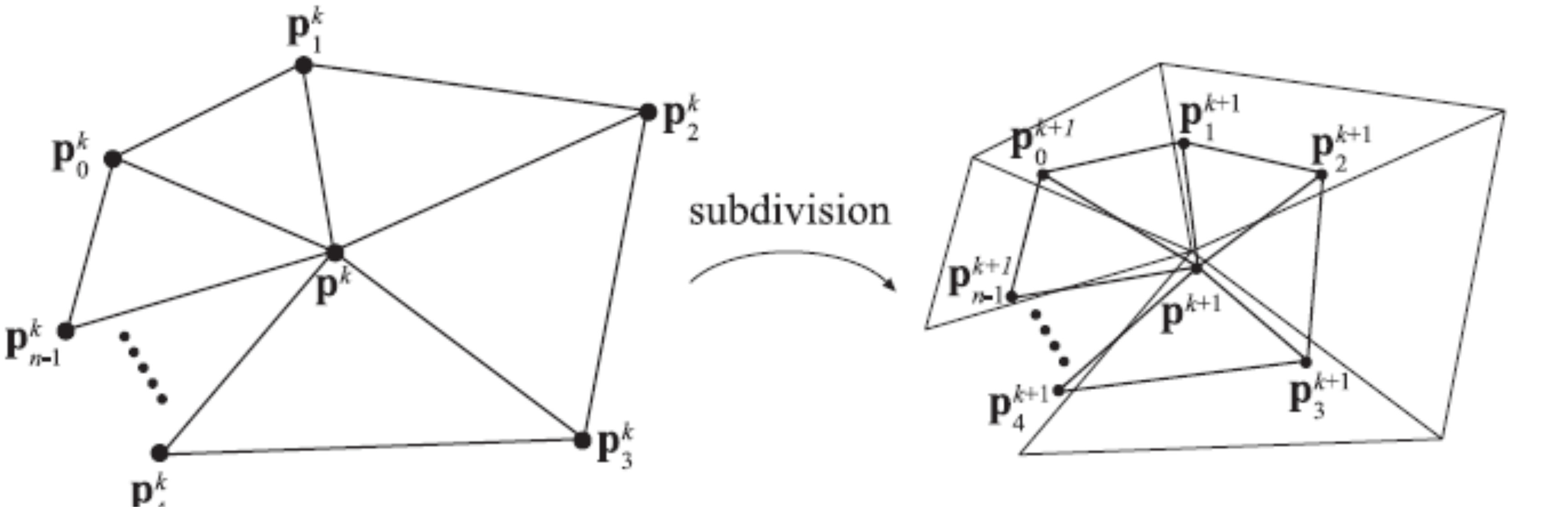
Subdivision Surfaces



Extend subdivision idea from curves to surfaces

RTR, 3e, figure 13.32

Loop Subdivision

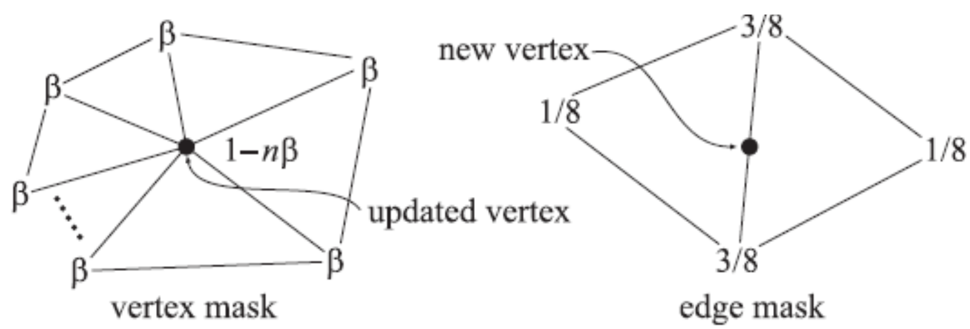


$$p^{k+1} = (1 - n\beta)p^k + \beta(p_0^k + \cdots + p_{n-1}^k),$$

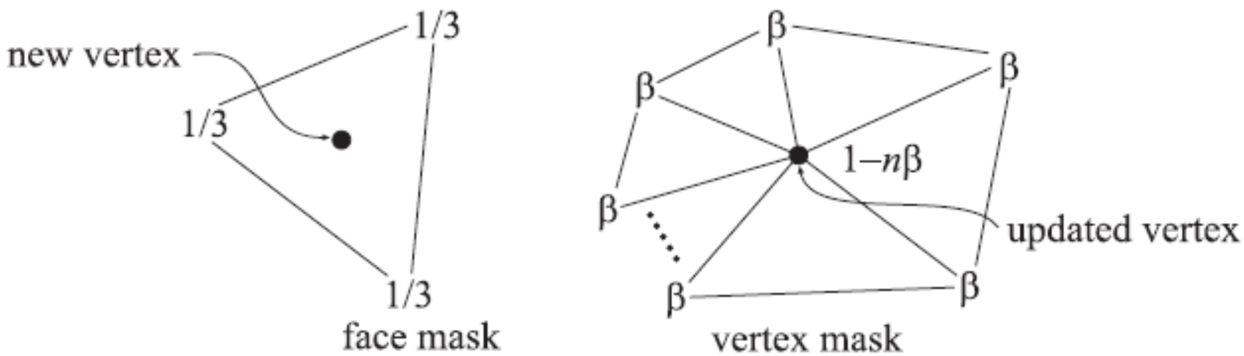
$$p_i^{k+1} = \frac{3p^k + 3p_i^k + p_{i-1}^k + p_{i+1}^k}{8}, \; i = 0 \ldots n-1.$$

$$\beta(n) = \frac{3}{n(n+2)}.$$

$$\beta(n) = \frac{1}{n}\left(\frac{5}{8} - \frac{(3 + 2\cos(2\pi/n))^2}{64}\right)$$



Sqrt(3) subdivision



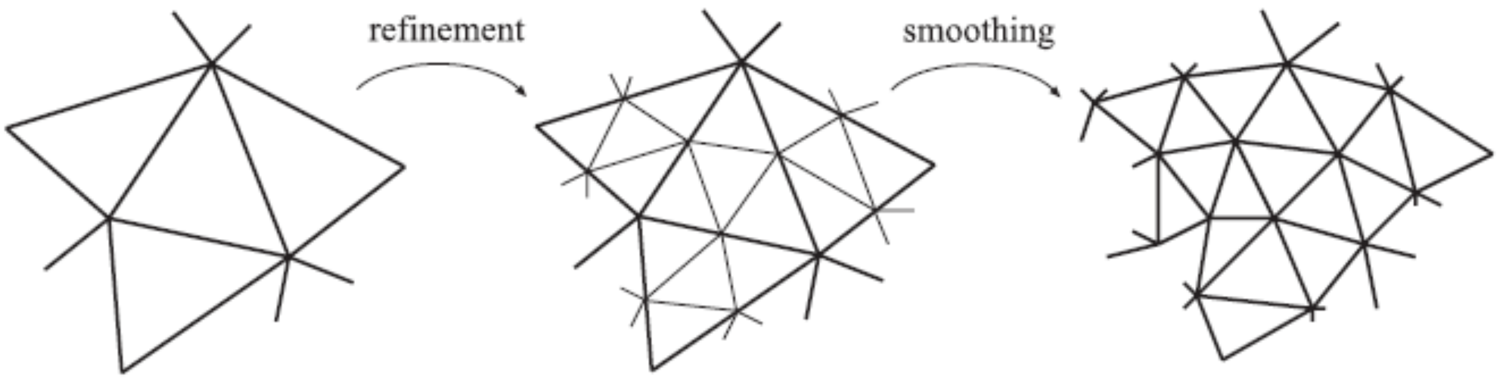
$$p_m^{k+1} = (p_a^k + p_b^k + p_c^k)/3$$

$$p^{k+1} = (1 - n\beta)p^k + \beta \sum_{i=0}^{n-1} p_i^k$$

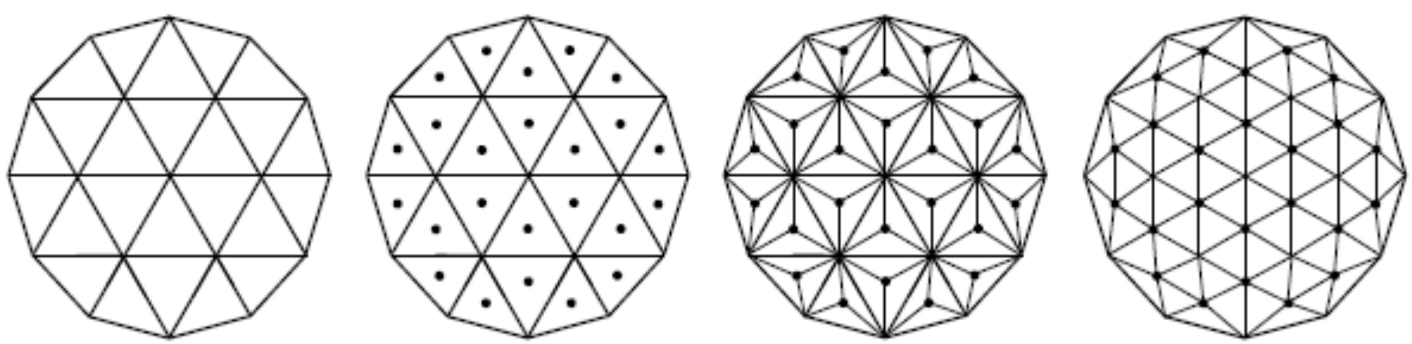
$$\beta(n) = \frac{4 - 2\cos(2\pi/n)}{9n}$$

C2 for regular vertices
C1 for irregular vertices

Basic Steps of Subdivision Surfaces



Loop Subdivision

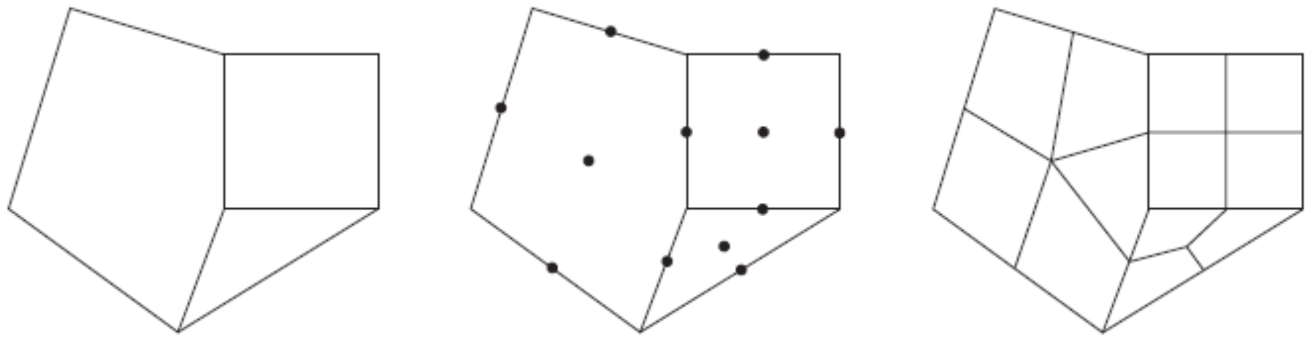


Sqrt(3) Subdivision

Catmull-Clark Subdivision

- Work for arbitrary polygons, not limited to triangles
- Used by Pixar in Geri's game, toy story2 and all subsequent featues

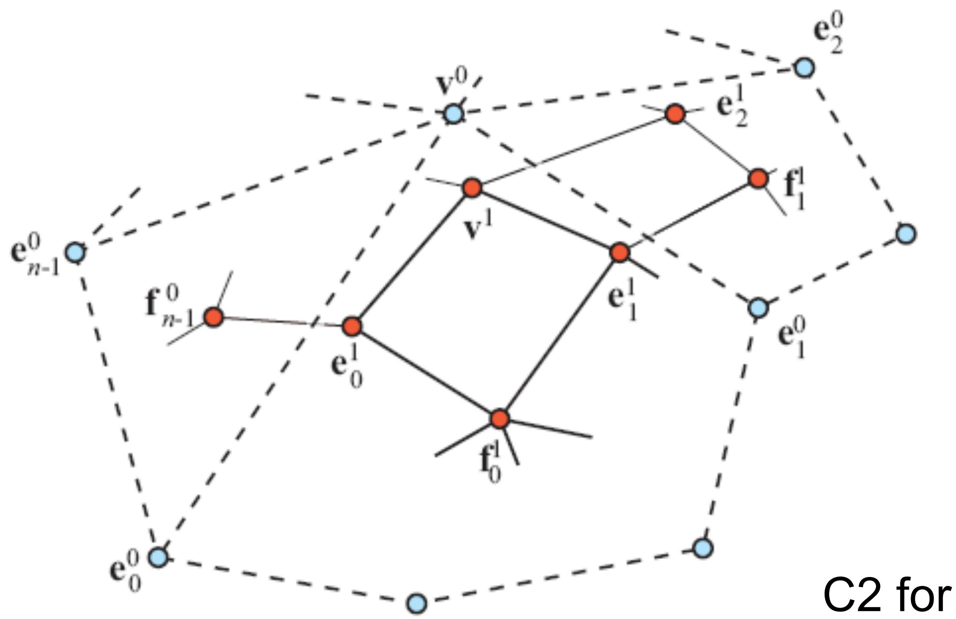
Catmull-Clark Subdivision



Regular vertices: valence = 4

After first insertion, we only have quads in the mesh

Catmull-Clark Subdivision



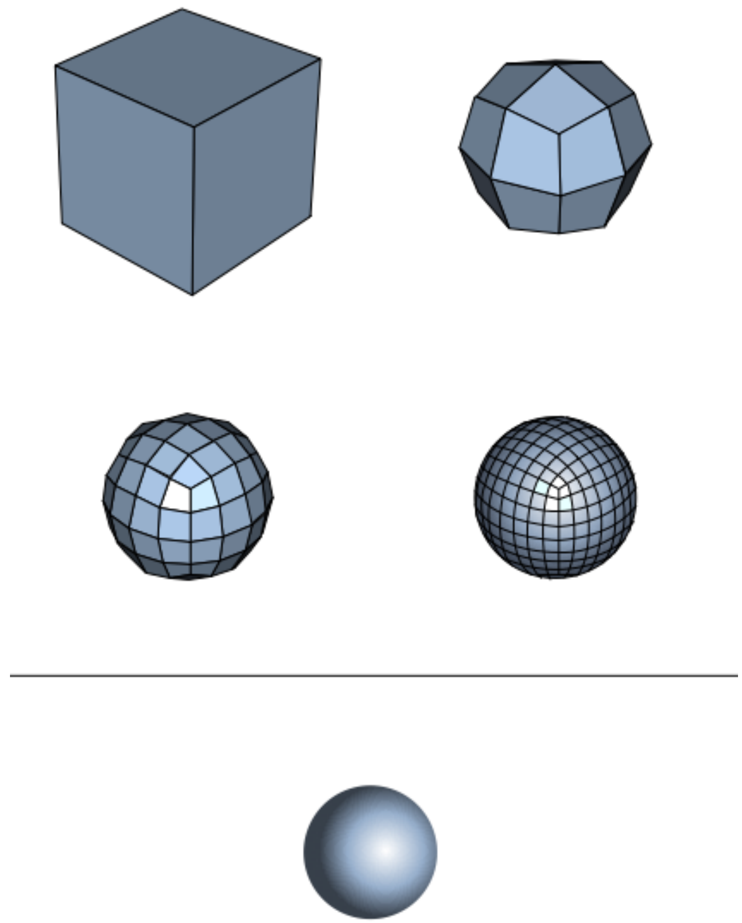
C2 for regular vertices
C1 for irregular vertices

For each face, add a new vertex at its centroid

For each edge, add an new vertex $$\mathbf{e}_j^{k+1} = \frac{\mathbf{v}^k + \mathbf{e}_j^k + \mathbf{f}_{j-1}^{k+1} + \mathbf{f}_j^{k+1}}{4}.$$

For each old vertex, update $$\mathbf{v}^{k+1} = \frac{n-2}{n}\mathbf{v}^k + \frac{1}{n^2}\sum_{j=0}^{n-1}\mathbf{e}_j^k + \frac{1}{n^2}\sum_{j=0}^{n-1}\mathbf{f}_j^{k+1},$$

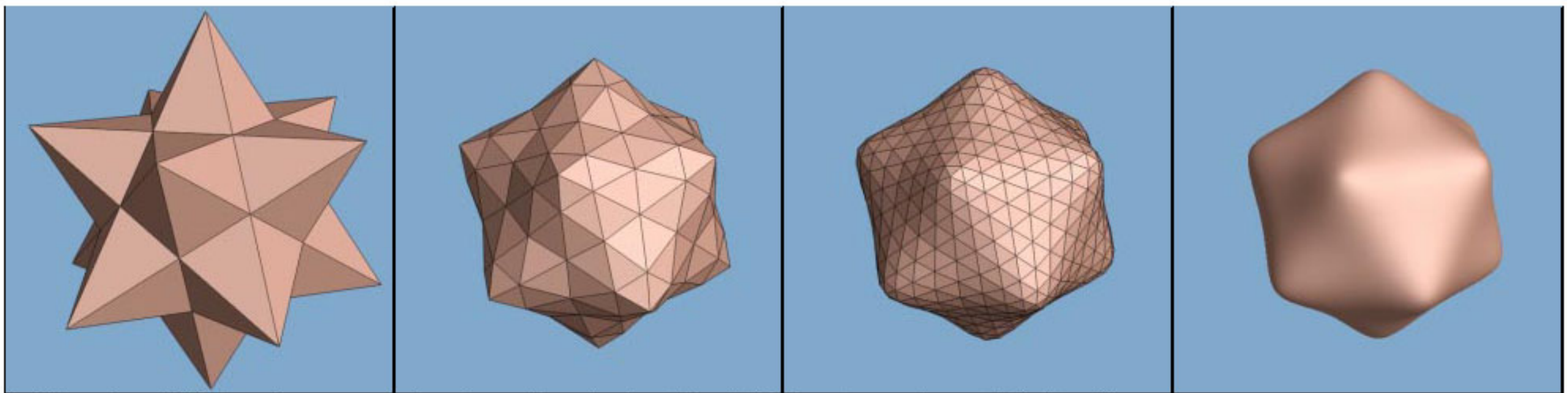
Example



Academy Award for Technical Achievement in 2006.

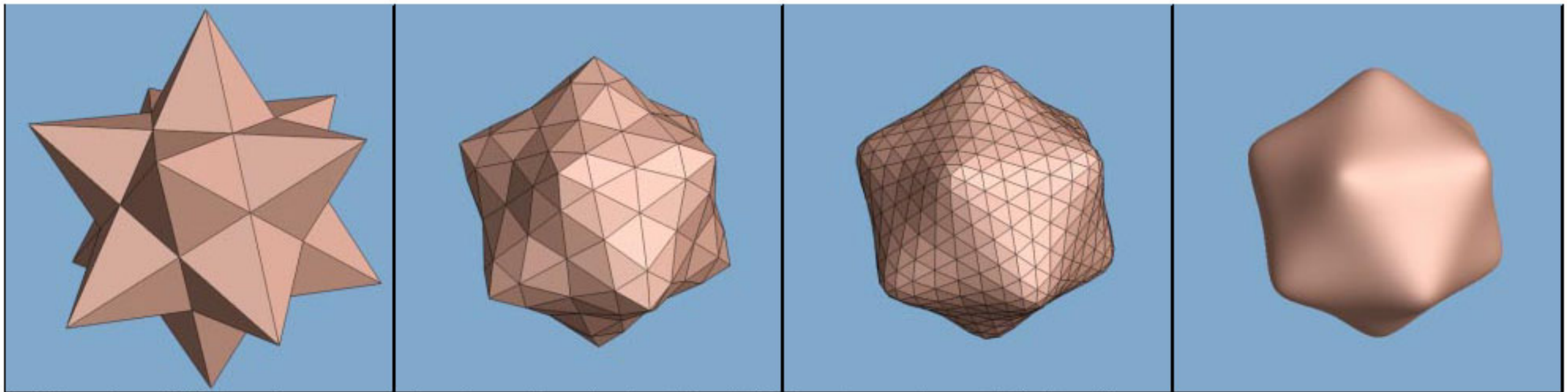
Standard subdivision is not enough

Standard subdivision

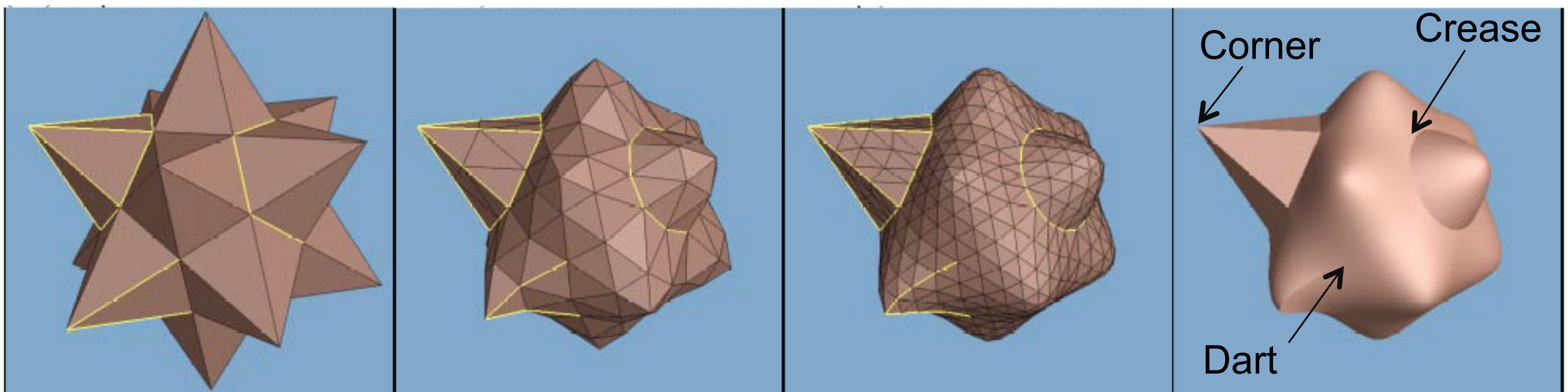


(a-d) Loop's subdivision scheme: control mesh, meshes after 1 and 2 subdivision steps, and smooth limit surface

Piecewise smooth subdivision



(a-d) Loop's subdivision scheme: control mesh, meshes after 1 and 2 subdivision steps, and smooth limit surface



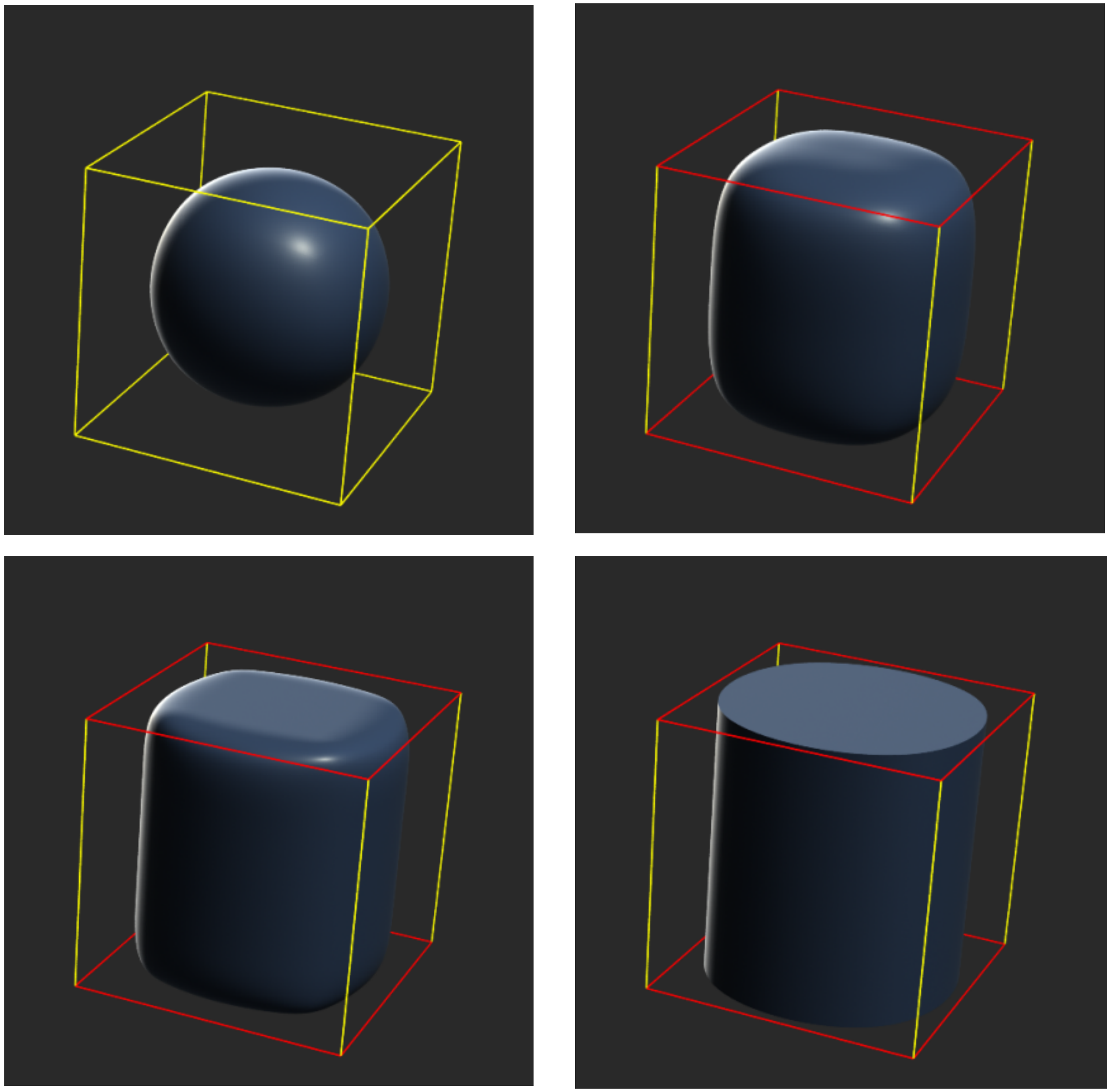
(e-h) Our piecewise smooth subdivision scheme: tagged control mesh, meshes after 1 and 2 subdivision steps, and piecewise smooth limit surface

Crease: a smooth curve on the surface, where the continuity across the curve is C0.

A corner is a vertex where three or more creases come together

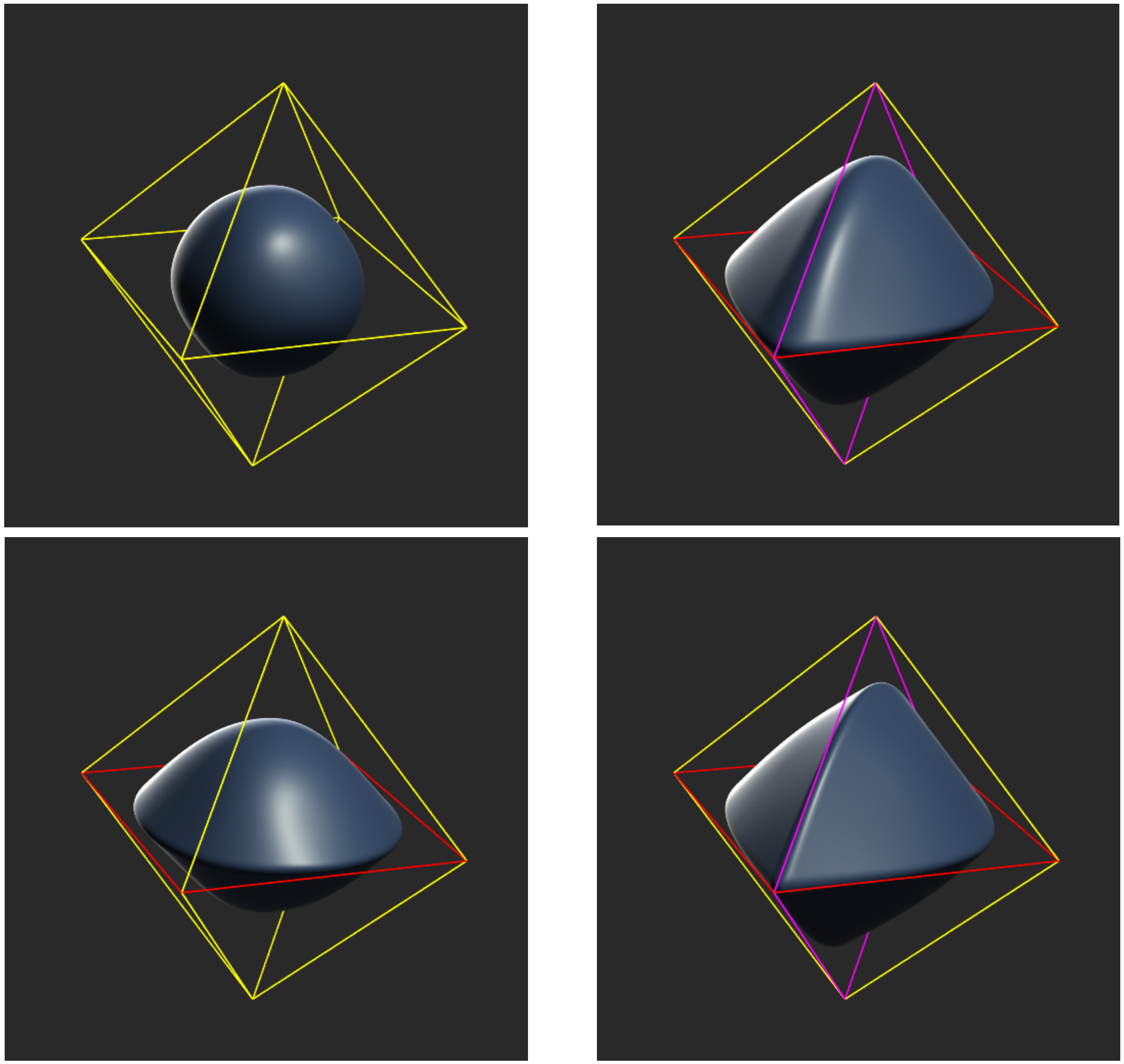
A dart is a vertex where a crease ends and smoothly blends into the surface.

Semisharpness



Derose et al, Subdivision Surfaces in Character Animation, SIGGRAPH 1998

Semisharpness

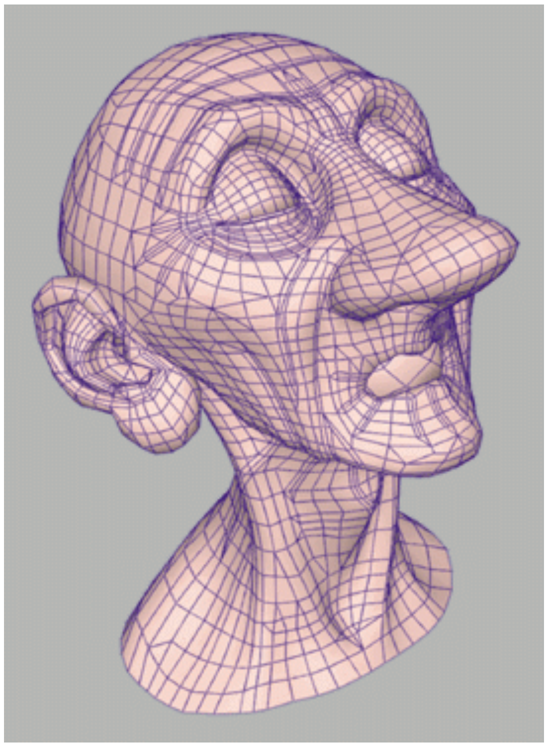


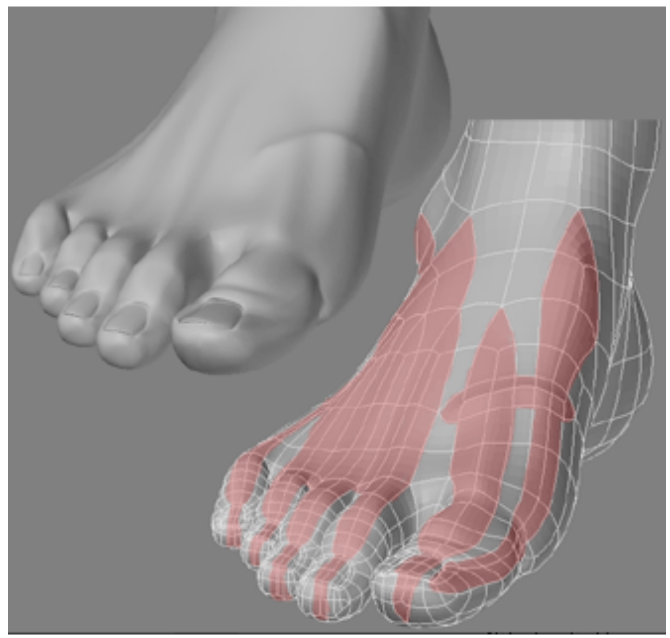
Derose et al, Subdivision Surfaces in Character Animation, SIGGRAPH 1998

Piecewise smooth subdivision

Geri's game

- http://www.youtube.com/watch?v=QC-KHaSh0rI

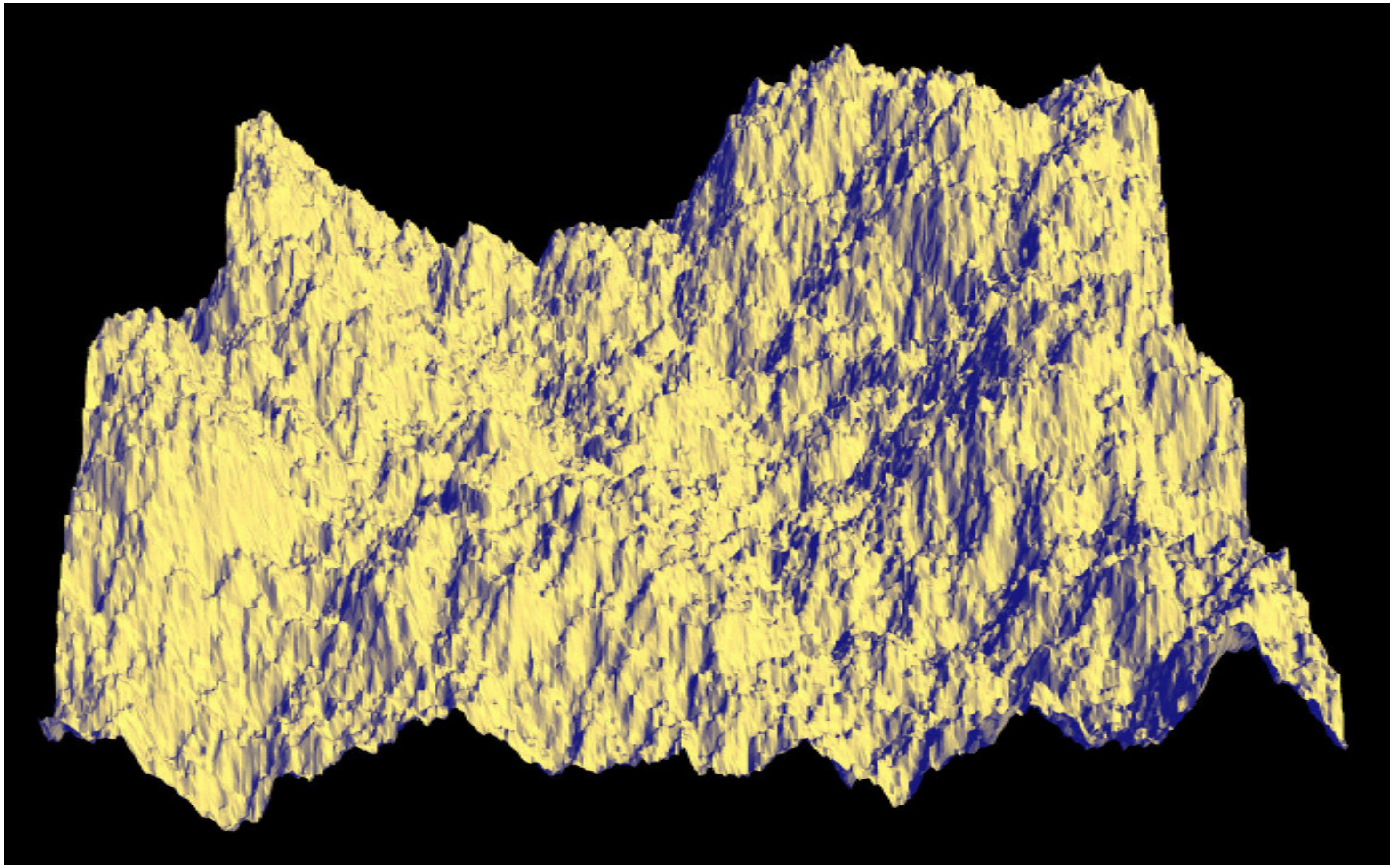




Procedural Shape Modeling

Simple procedure

Procedural Terrain Modeling

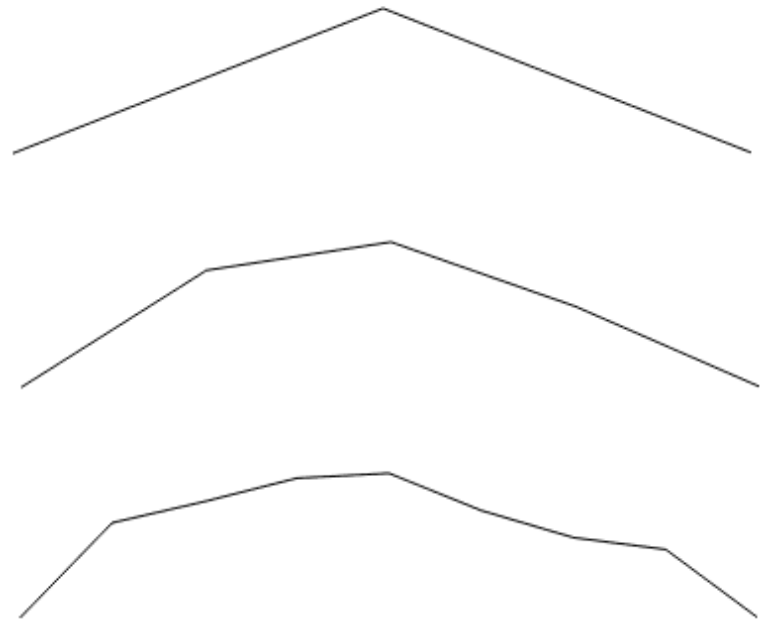


F.K. Musgrave

- Has a gross structrure
- Also with some randomness
- Want a height map z=h(x,y)

1D case

Want a function y=h(x)



Start with a single horizontal line segment.
Repeat for a sufficiently large number of times
{
    Find the midpoint of the line segment.
    Displace the midpoint in Y by a random amount.
    Recursively apply this operation for the resulting two segments
        with reduced range for the random numbers (by a factor 0<f<1).
}

1D case

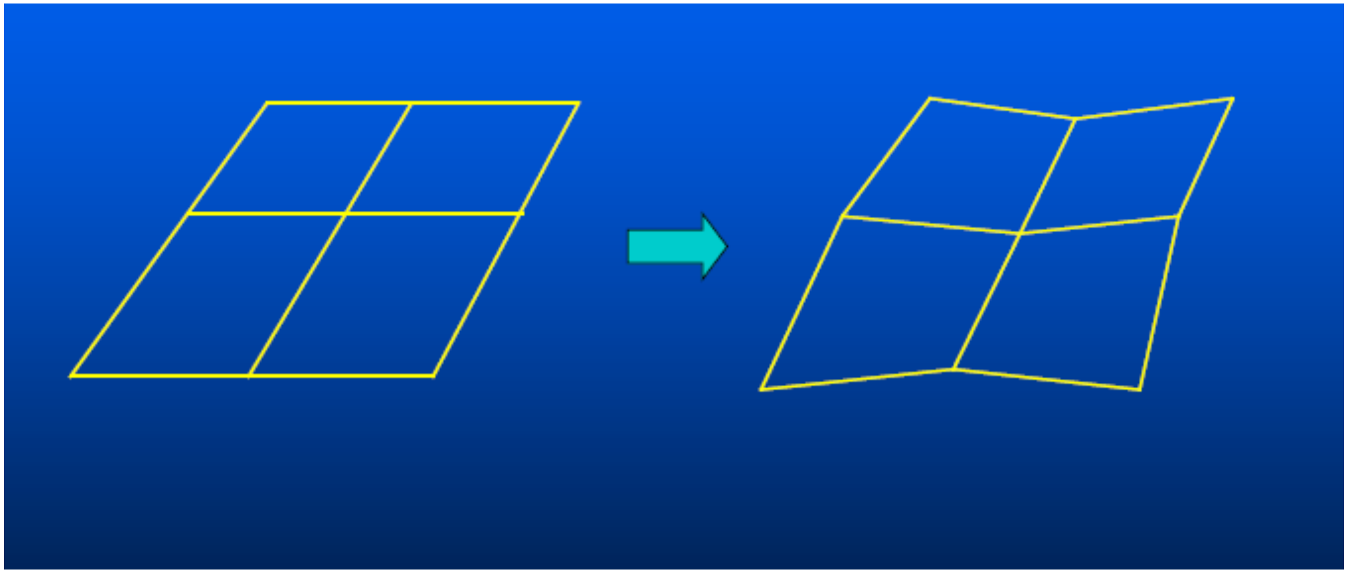
Want a function y=h(x)

Results with different f

Start with a single horizontal line segment.
Repeat for a sufficiently large number of times
{
    Find the midpoint of the line segment.
    Displace the midpoint in Y by a random amount.
    Recursively apply this operation for the resulting two segments
        with reduced range for the random numbers (by a factor 0<f<1).
}

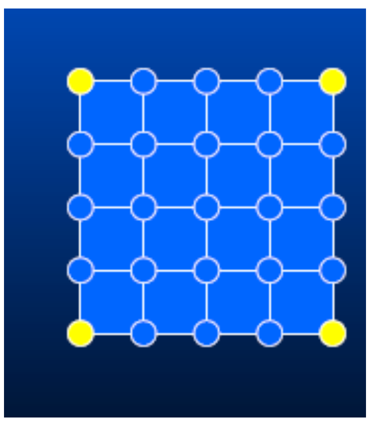
2D case

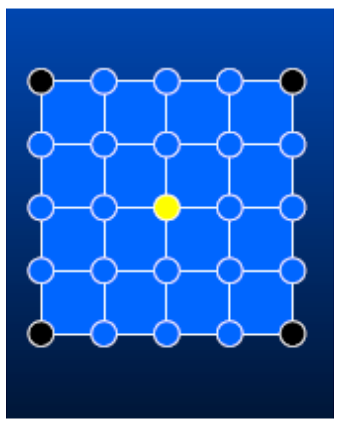
- Subdivide and Displace



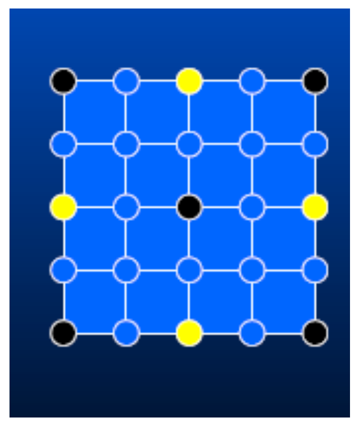
2D case

- Subdivide and displace
  - Seed corners with values
  - Perturb midpoint randomly
  - Recurse using a smaller window
  - In 2D, best to use “diamond-square” recursion

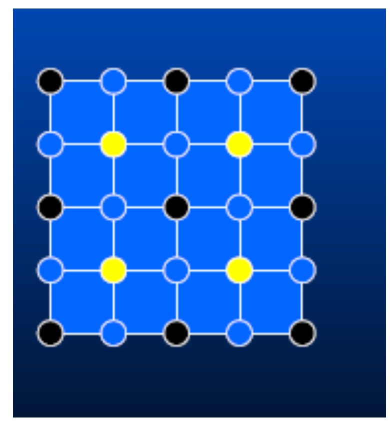




square

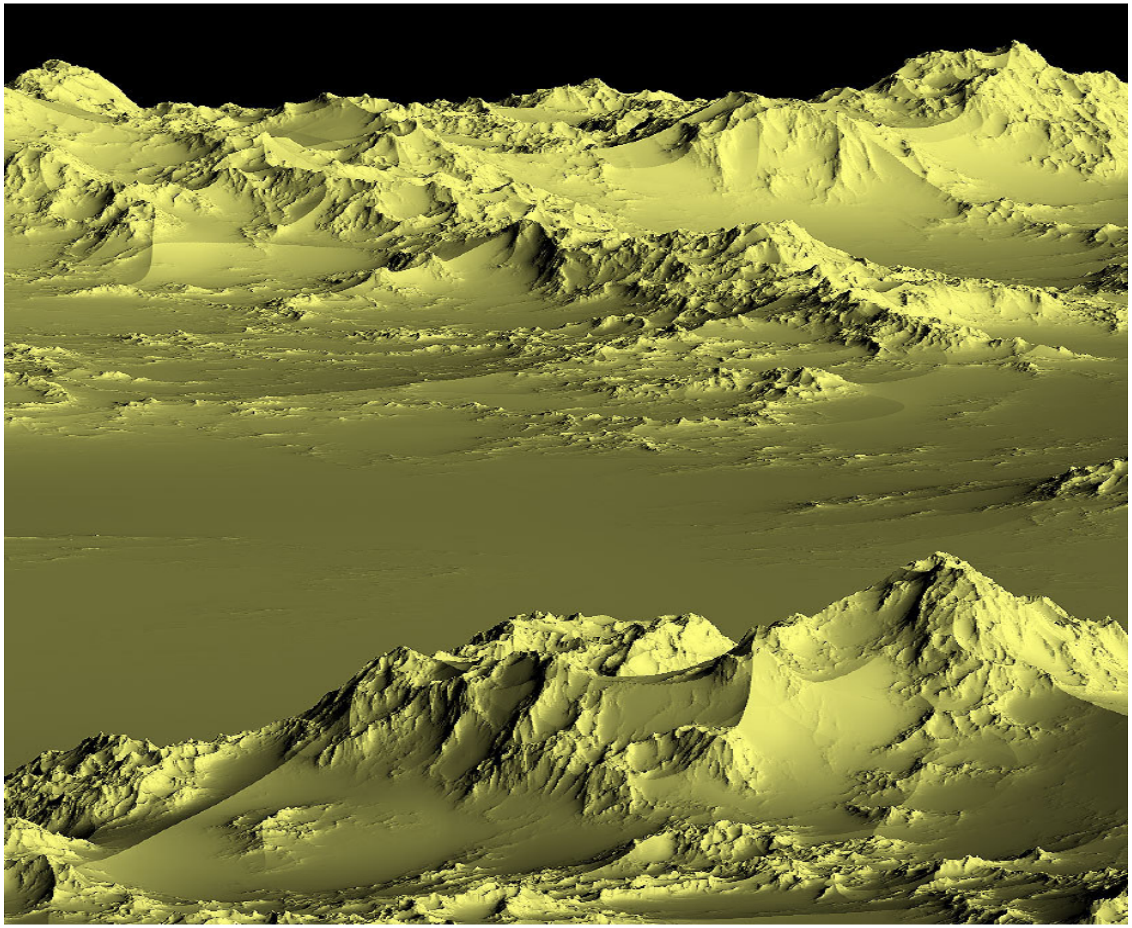


diamond



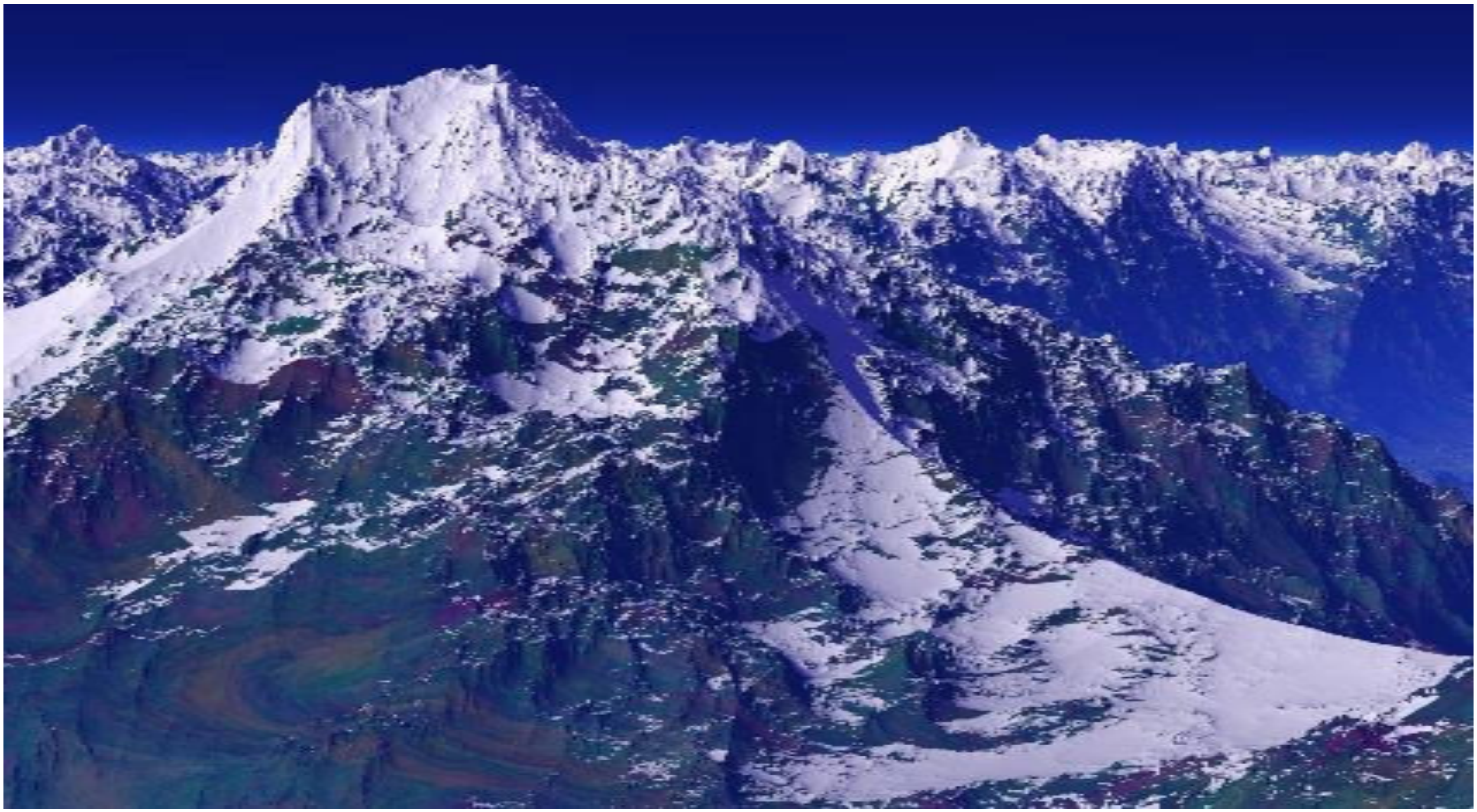
Recuse

2D case



F.K. Musgrave

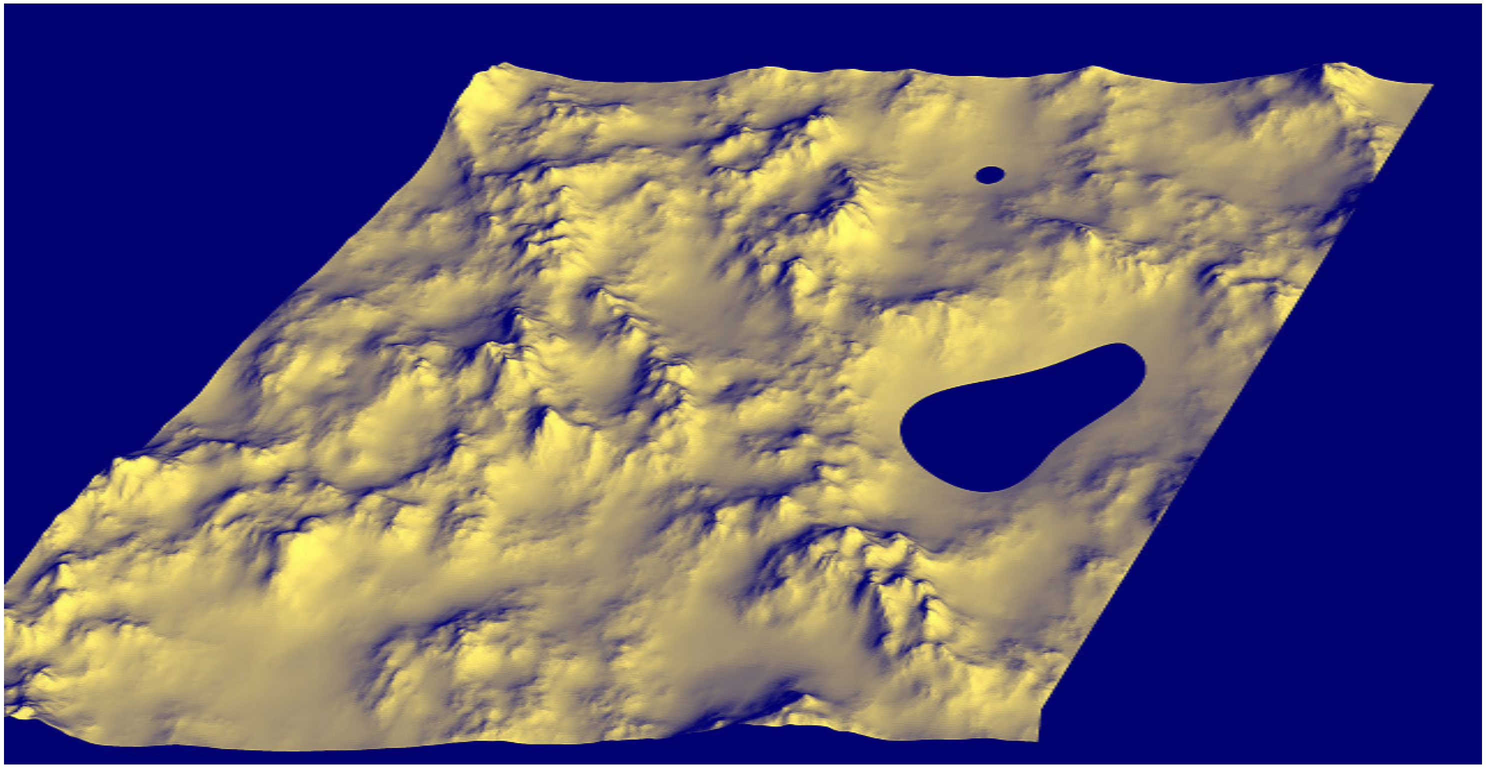
Texture mapping



F.K. Musgrave

Adding water

- Use an elevation threshold ($z < z\_water$)



F.K. Musgrave


F.K. Musgrave


F.K. Musgrave

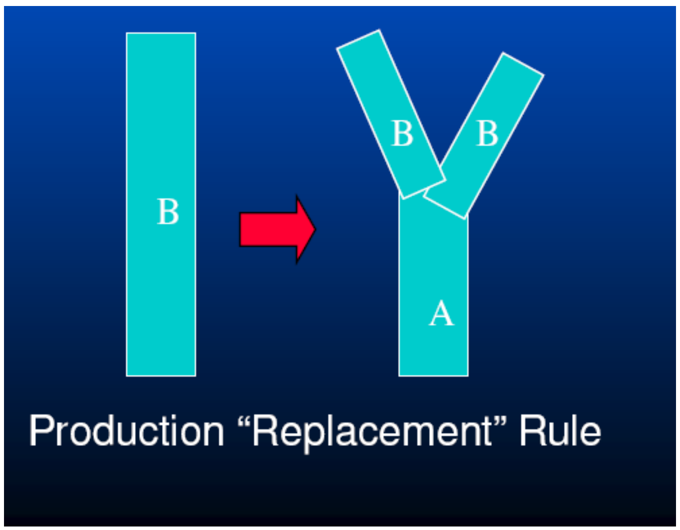
Fractal Plants (L-Systems)

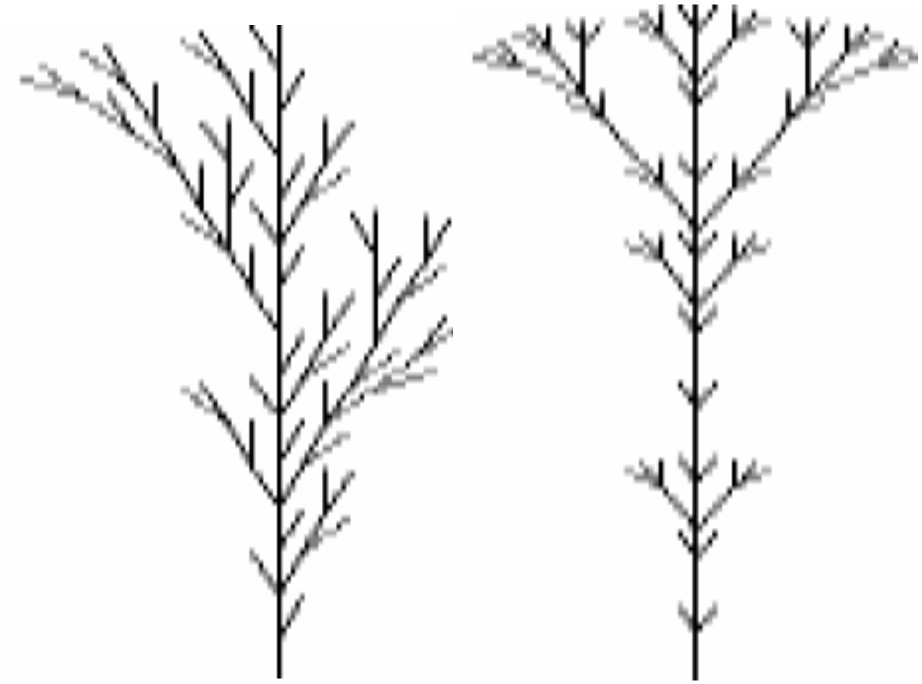
- Uses "production rules" applied to a seed "axiom"

- Example:

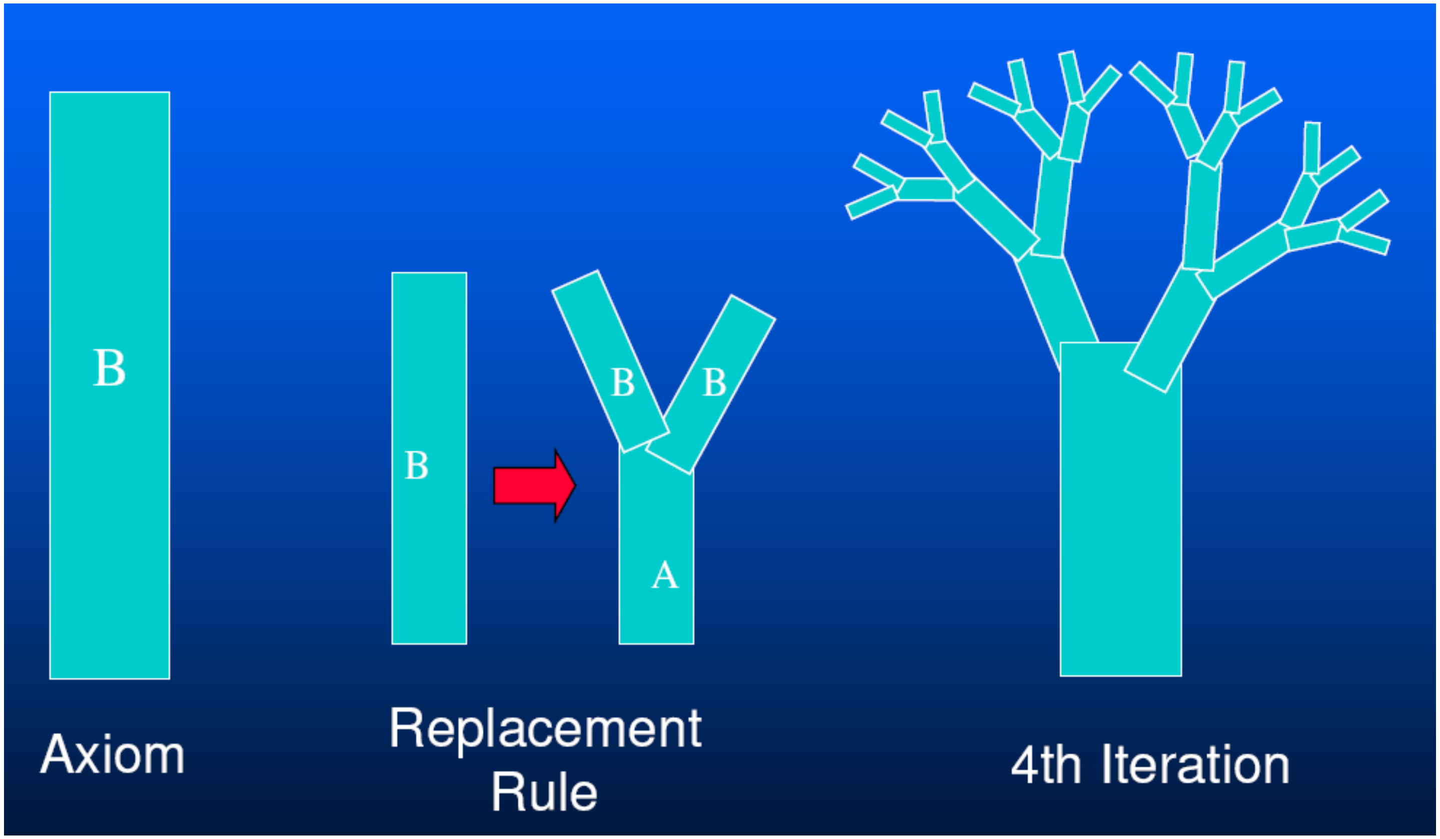
  Axiom: B

  Rule: B->ABB

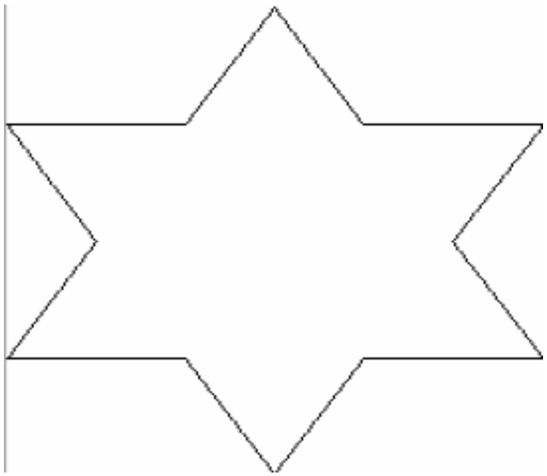
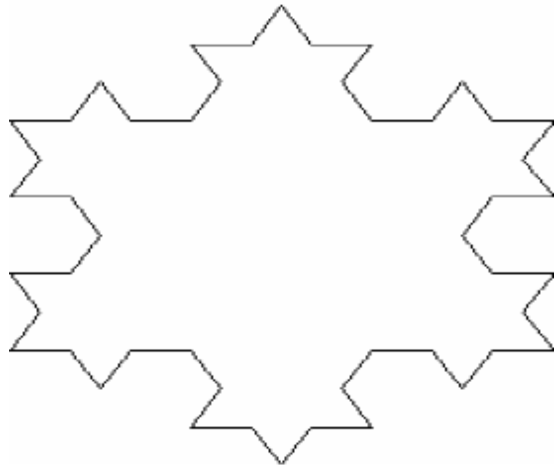
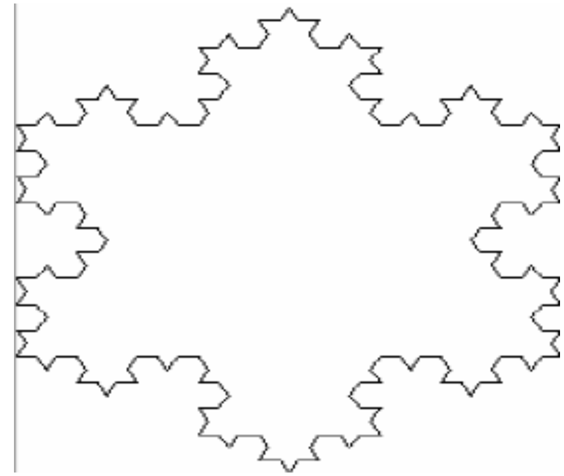
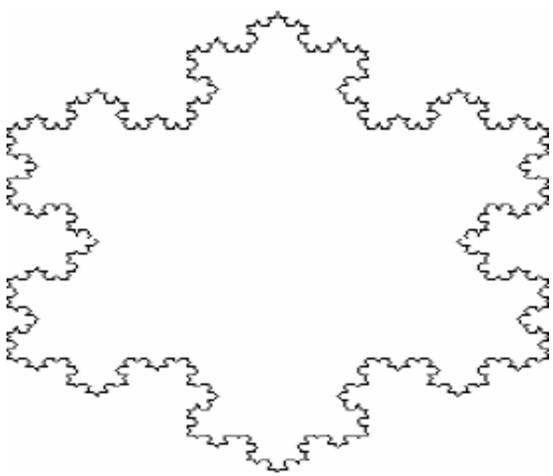
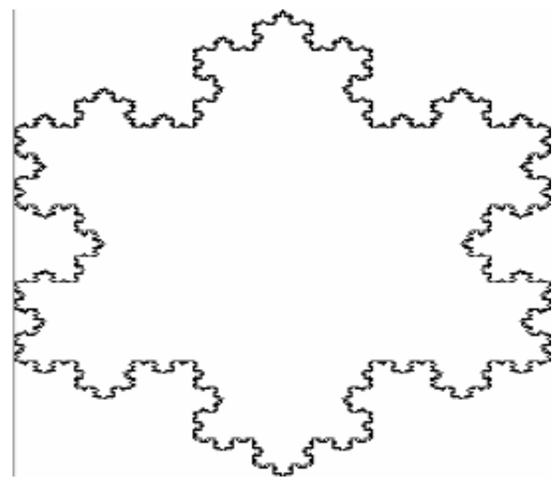




L-system Example

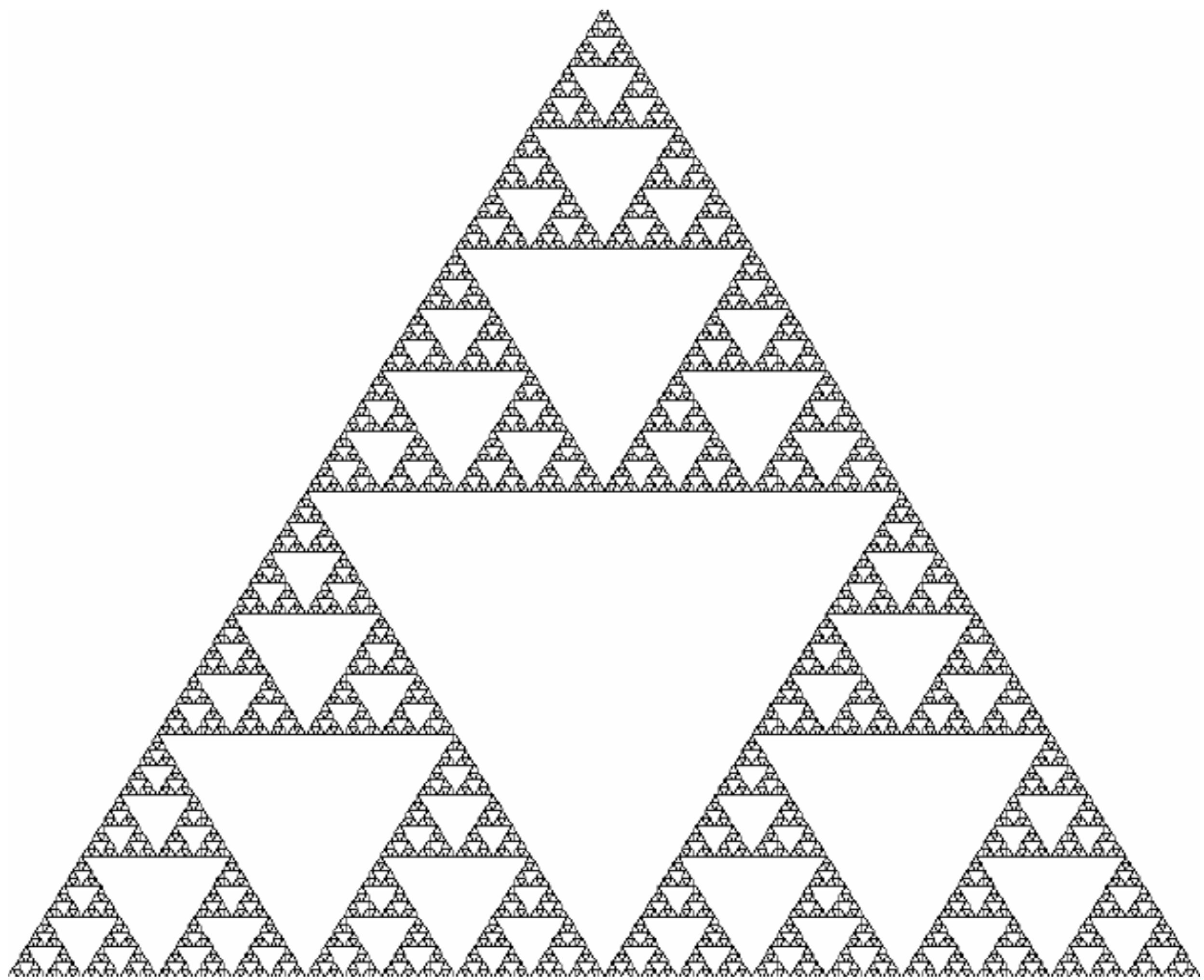


L-systems example: Koch snowflake

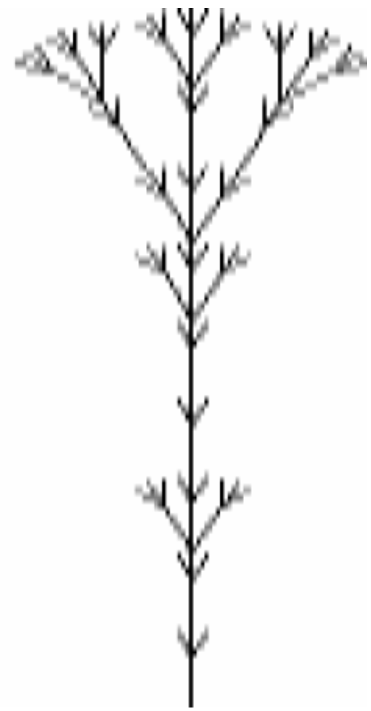
How to make the flake look less regular?

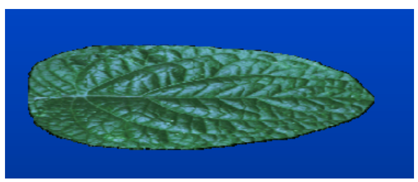
L-systems example: Serpinski Triangle



Procedural Trees and Bushes

- Define a branch structure
- Define a leaf



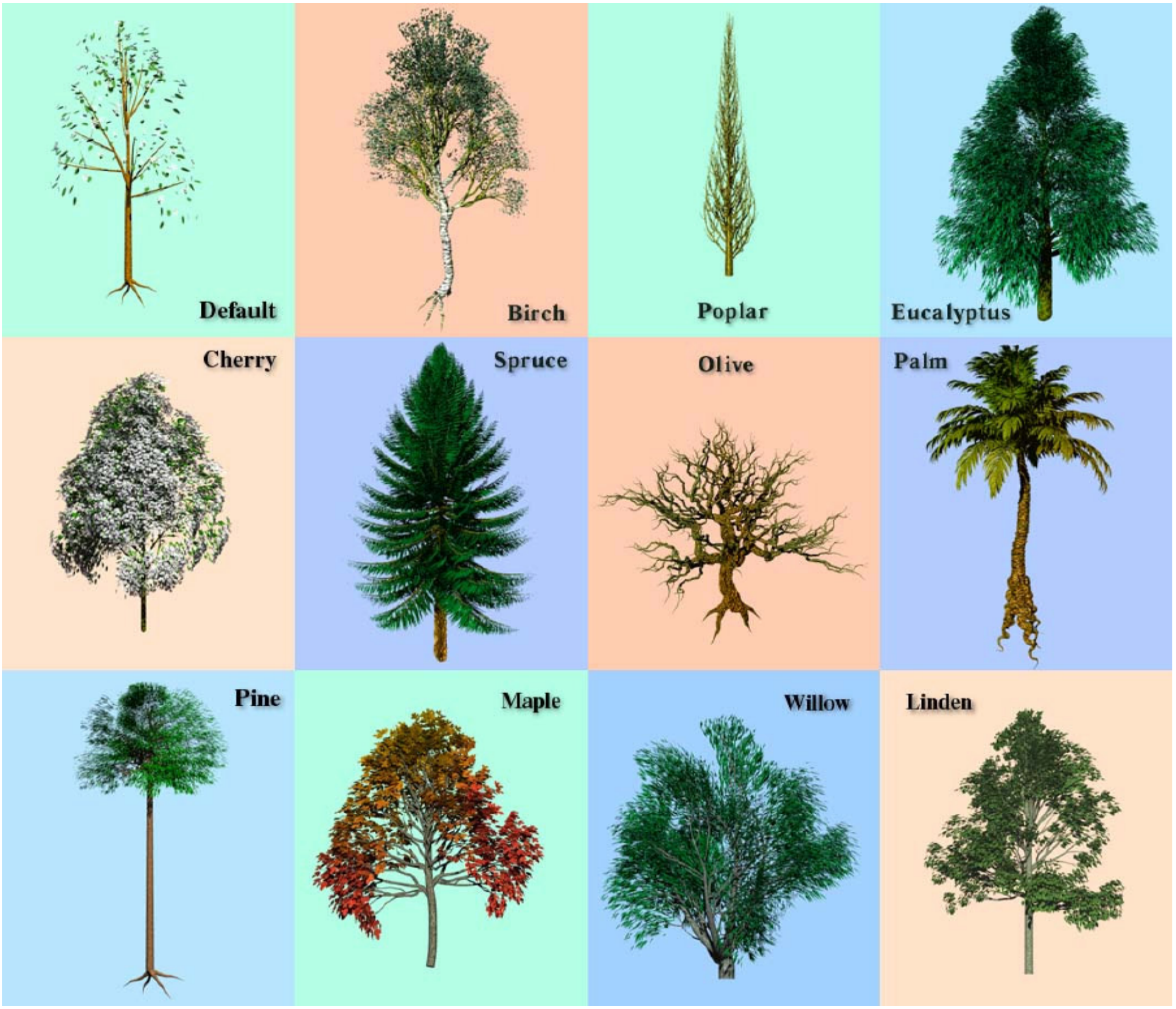


Algorithmic Plants

- excellent web resource with free online book: http://algorithmicbotany.org/

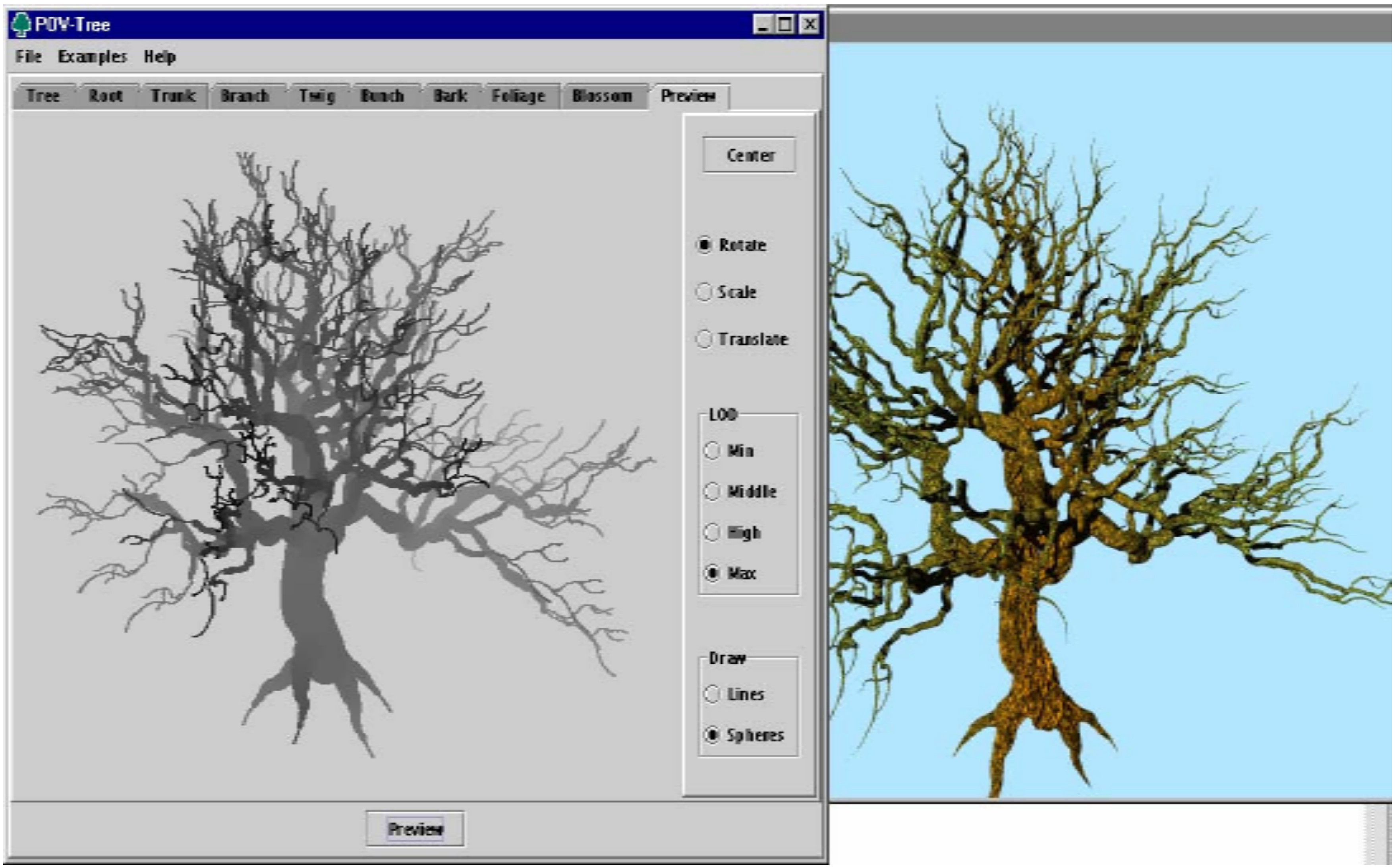
- Numerous papers by Przemyslaw Prusinkiewicz and colleagues

Procedural Trees from PovTree



http://propro.ru/go/Wshop/povtree/tutorial.html

Interactive Fractal Tree Design



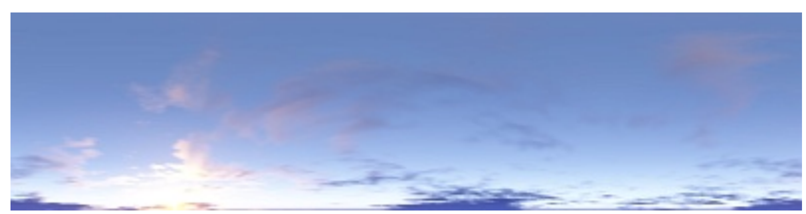
Popular Modeling Techniques

- Polygon meshes
  - Surface representation, Parametric representation
- Prototype instancing
  - Swipe Shape
- Volume enumeration schemes
  - Volume, Parametric or Implicit
- Parametric curves and surfaces
  - Surface, Parametric
- Subdivision curves and surfaces
- Procedural models

Project 3

- Technical Challenge 1: sky box/sky dome
  - Render the environment within a box or hemisphere with sky texture
  - Google “sky box texture”, you can get many images for this.

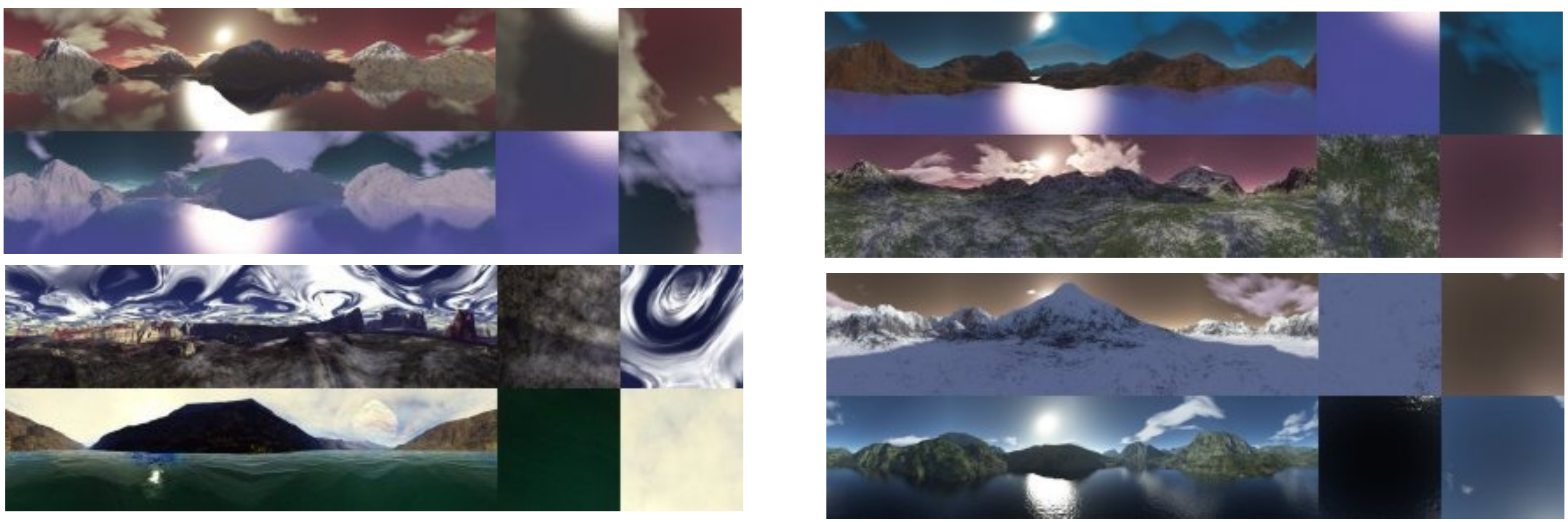


http://mpan3.homeip.net/earth

Project 3

- Technical Challenge: sky box/sky dome
  - Render the environment within a box or hemisphere with sky texture
  - Google “sky box texture”, you can get many images for this.



http://skymatter.thegamecreators.com/?f=pack1

Cross-tree using alpha

Side view

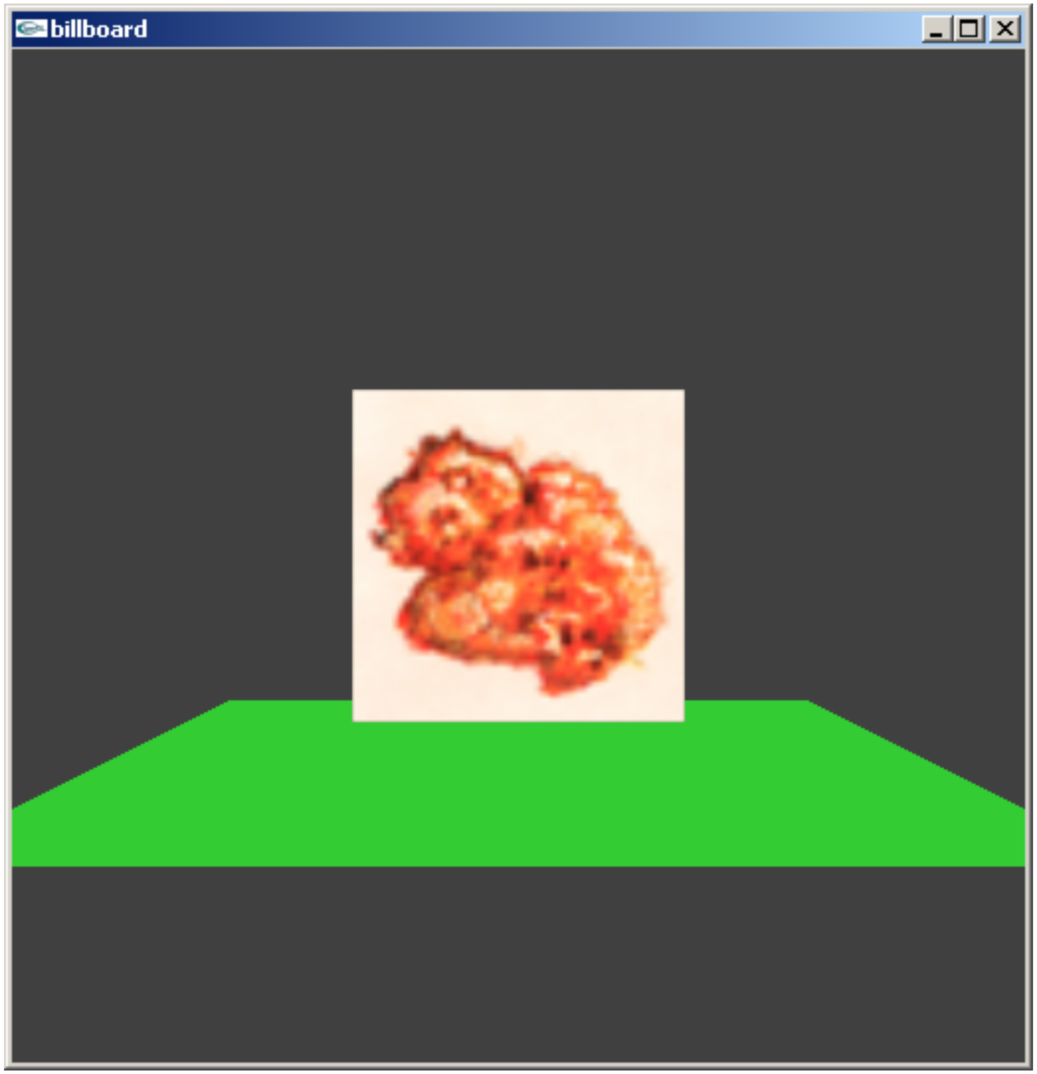
Top View

```
glEnable(GL_ALPHA_TEST);
glAlphaFunc(GL_GREATER, 0.05);
```

Recap on Texture mapping

- Computing Perspective Correct Texture Coord
- Sampling Texture Values (Mipmap, …)
- OpenGL single texture mapping
- Projector Texture Mapping
- Bump Map
- Displacement Map
- 3D Texture
- Environment Map
- Multi-texturing
- Shadow map

Blending



Billboard

Blending in OpenGL

Source --- In coming fragment color: (Rs, Gs, Bs, As)

*

Modulate Source color by (Sr, Sg, Sb, Sa)

+

Destination --- Current Frame buffer color: (Rd, Gd, Bd, Ad)

*

Modulate Destination color by (Dr, Dg, Db, Da)

↓

Final Color: (?, ? , ?, ?)

Example:

```
glEnable(GL_BLEND);
glBlendFunc(GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);
```

Blending in OpenGL

Source --- In coming fragment color:	(Rs, Gs, Bs, As)
	*
Modulate Source color by	(Sr, Sg, Sb, Sa)
	+
Destination --- Current Frame buffer color:	(Rd, Gd, Bd, Ad)
	*
Modulate Destination color by	(Dr, Dg, Db, Da)
	↓
Final Color:	(?, ? , ?, ?)

Example:

```
glEnable(GL_BLEND);
glBlendColor(0.3,0.4,0.5,0.6);
glBlendFunc(GL_CONSTANT_COLOR, GL_ONE_MINUS_CONSTANT_COLOR);
```

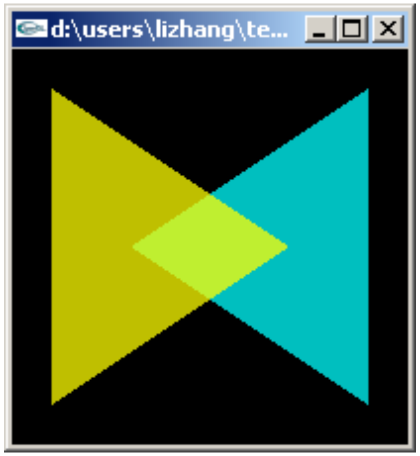
Other choices

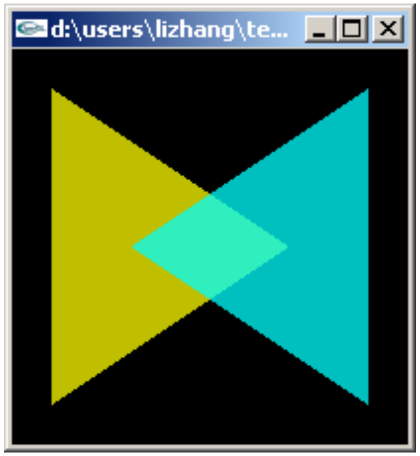
Table 6-1 : Source and Destination Blending Factors

Constant	Relevant Factor	Computed Blend Factor
GL_ZERO	source or destination	(0, 0, 0, 0)
GL_ONE	source or destination	(1, 1, 1, 1)
GL_DST_COLOR	source	(Rd, Gd, Bd, Ad)
GL_SRC_COLOR	destination	(Rs, Gs, Bs, As)
GL_ONE_MINUS_DST_COLOR	source	(1, 1, 1, 1)-(Rd, Gd, Bd, Ad)
GL_ONE_MINUS_SRC_COLOR	destination	(1, 1, 1, 1)-(Rs, Gs, Bs, As)
GL_SRC_ALPHA	source or destination	(As, As, As, As)
GL_ONE_MINUS_SRC_ALPHA	source or destination	(1, 1, 1, 1)-(As, As, As, As)
GL_DST_ALPHA	source or destination	(Ad, Ad, Ad, Ad)
GL_ONE_MINUS_DST_ALPHA	source or destination	(1, 1, 1, 1)-(Ad, Ad, Ad, Ad)
GL_SRC_ALPHA_SATURATE	source	(f, f, f, 1); f=min(As, 1-Ad)

Red Book ch 6

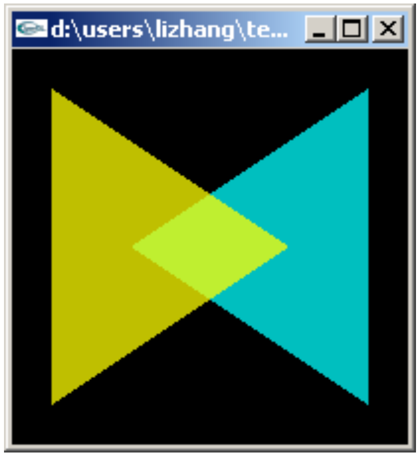
Blending depends on Order

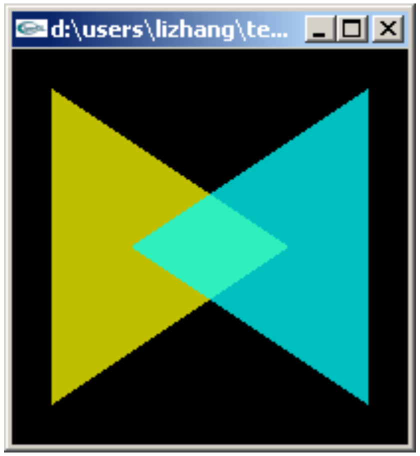




- In 3D, the problem is tricky
  - If an opaque obj is in front of a translucent obj
    - Draw opaque
  - If a translucent obj is in front of an opaque
    - Blend

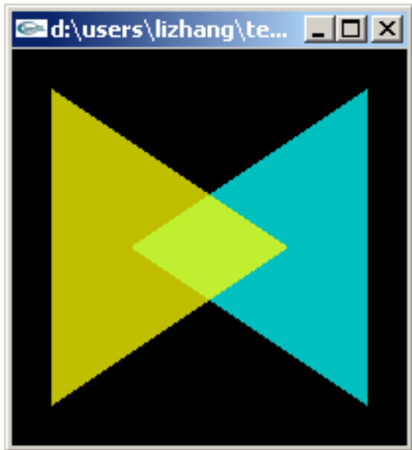
Blending depends on Order

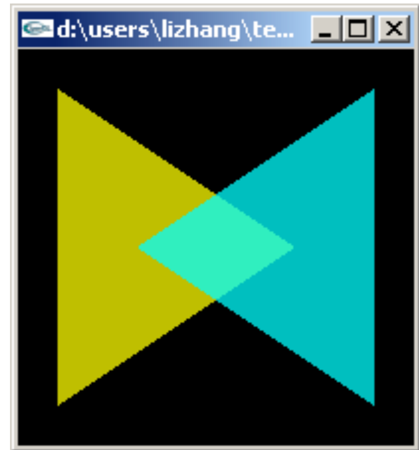




- Solution
  - A-buffer
  - BSP tree

Blending depends on Order





- Hack
  - Draw opaque ones first
  - Freeze depth map, glDepthMask(GL_FALSE);
  - Draw transparent ones
    - If behind the depth map, hide
    - If in front of depth map, blend
- When will it introduce artifacts?