CS559: Computer Graphics

Lecture 36: Subdivision Surfaces, Fractals, and Animation

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Spring 2008

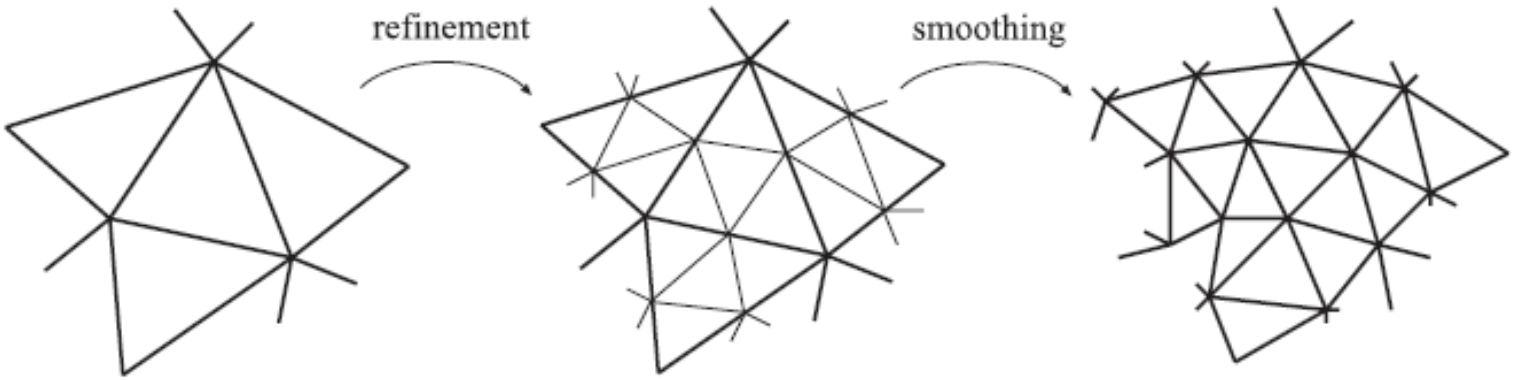
Many slides from James Kuffner's graphics class at CMU

Today

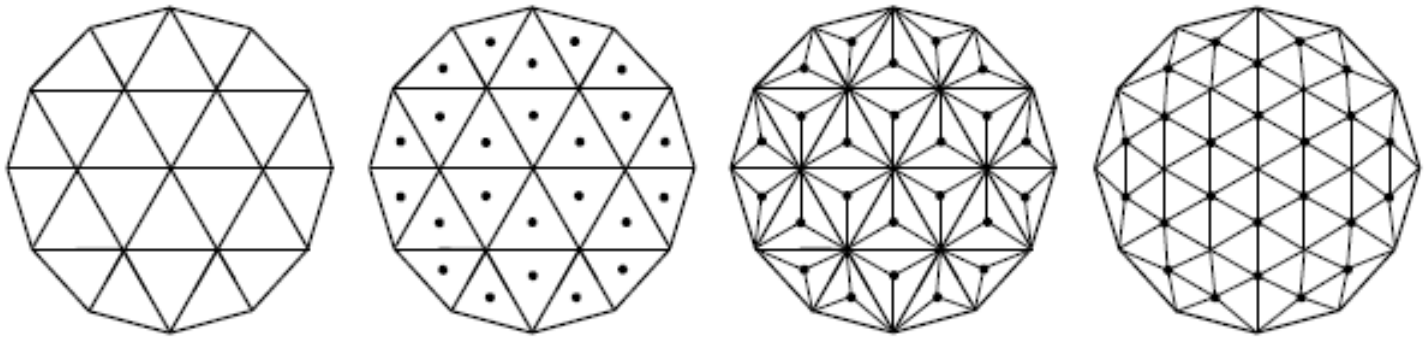
- Shape Modeling => animation

- Reading
  - Real-Time Rendering, 3e, 13.5.4, 13.5.5 (subdivision surfaces)
    - Linux: /p/course/cs559-lizhang/public/readings/13_surfs_gleicher.pdf
    - Windows: P:\course\cs559-lizhang\public\readings\13_surfs_gleicher.pdf
  - (Optional) Computer Rendering of Stochastic Models, Comm of ACM, June, 1982, p371-384
    - Linux: /p/course/cs559-lizhang/public/readings/p371-fournier.pdf
    - Windows: P:\course\cs559-lizhang\public\readings\p371-fournier.pdf
  - (Optional) Shirley, ch 16, overview of animation

Basic Steps of Subdivision Surfaces



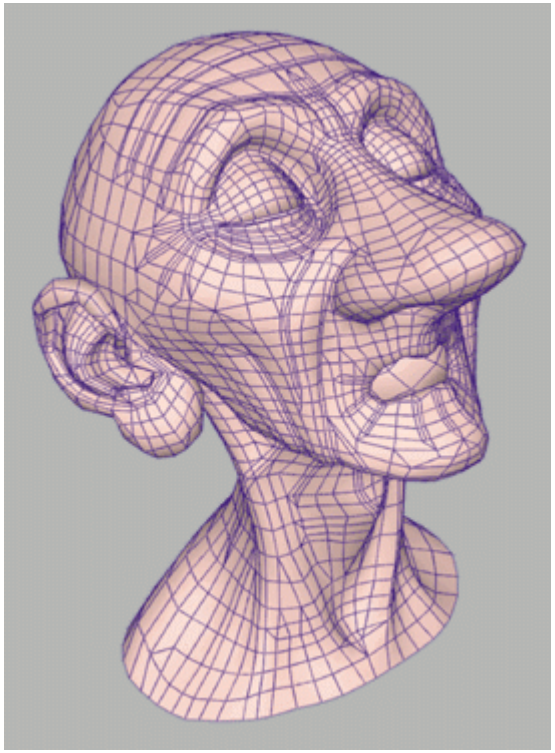
Loop Subdivision

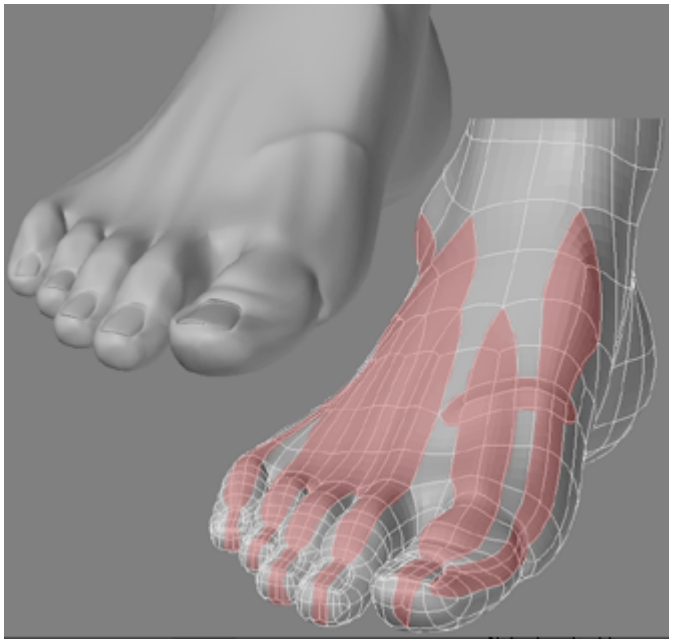


Sqrt(3) Subdivision

Geri's game

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

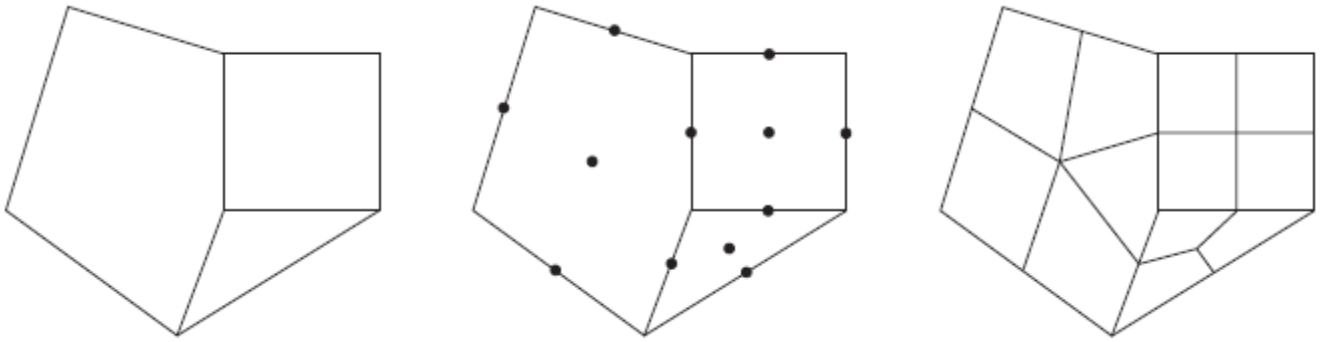




Catmull-Clark Subdivision

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

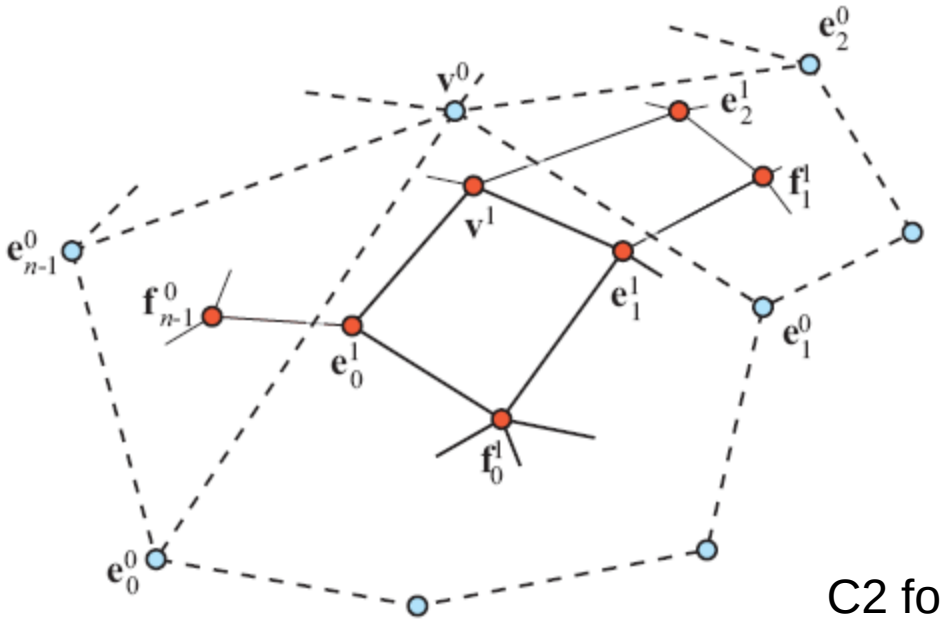
Catmull-Clark Subdivision



Regular vertices: valence = 4

After first insertion, we only have quads in the mesh

Catmull-Clark Subdivision



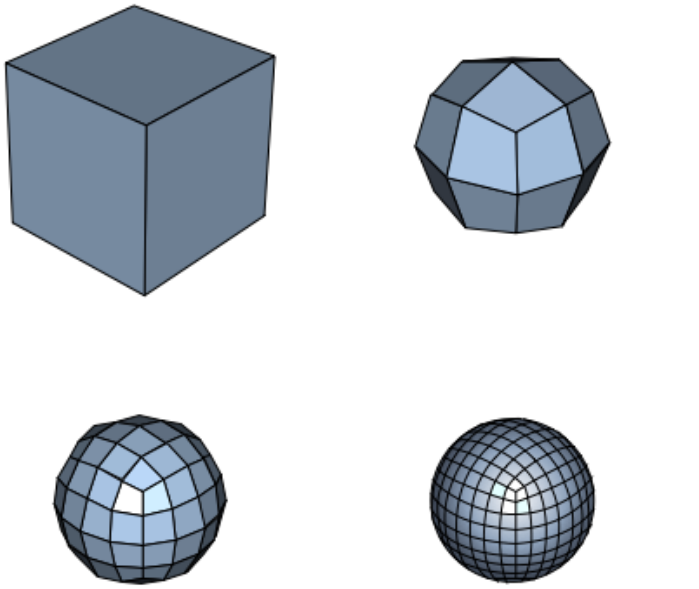
C2 for regular vertices
C1 for irregular vertices

For each face, add a new vertex at its centroid

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

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

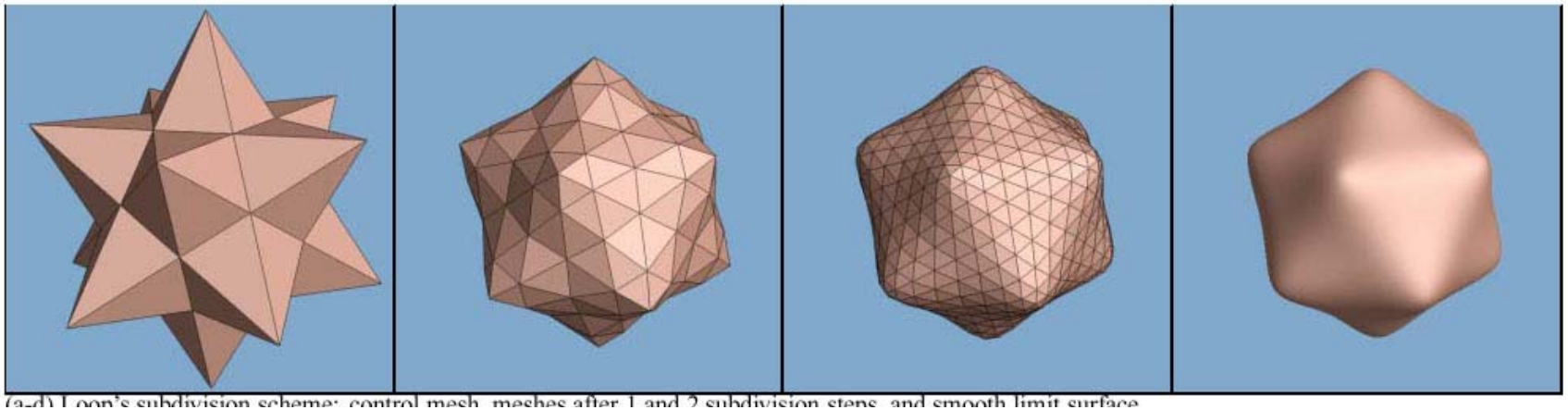
Example



Academy Award for Technical Achievement in 2006.

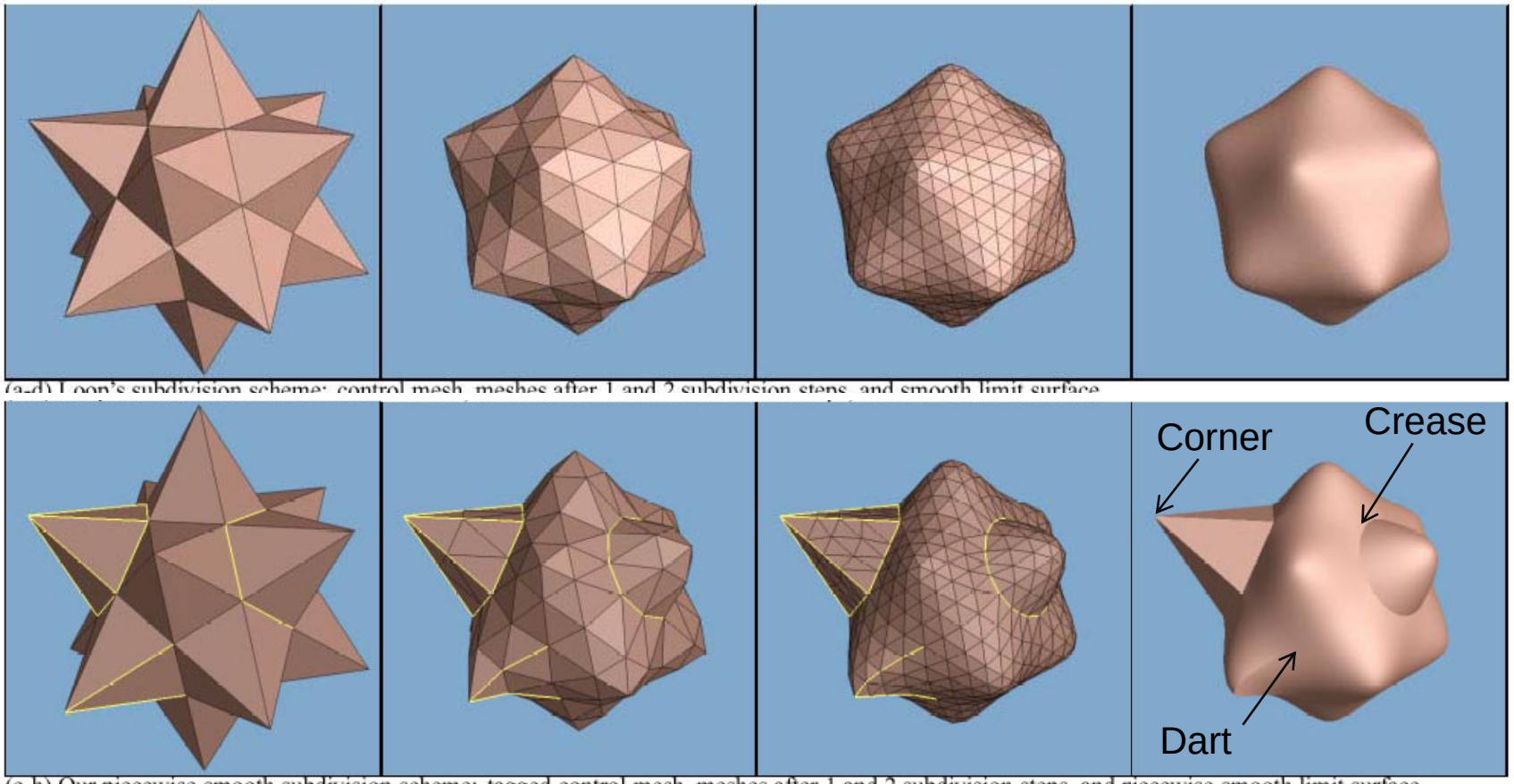
Standard subdivision is not enough

Standard subdivision



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

Piecewise smooth subdivision



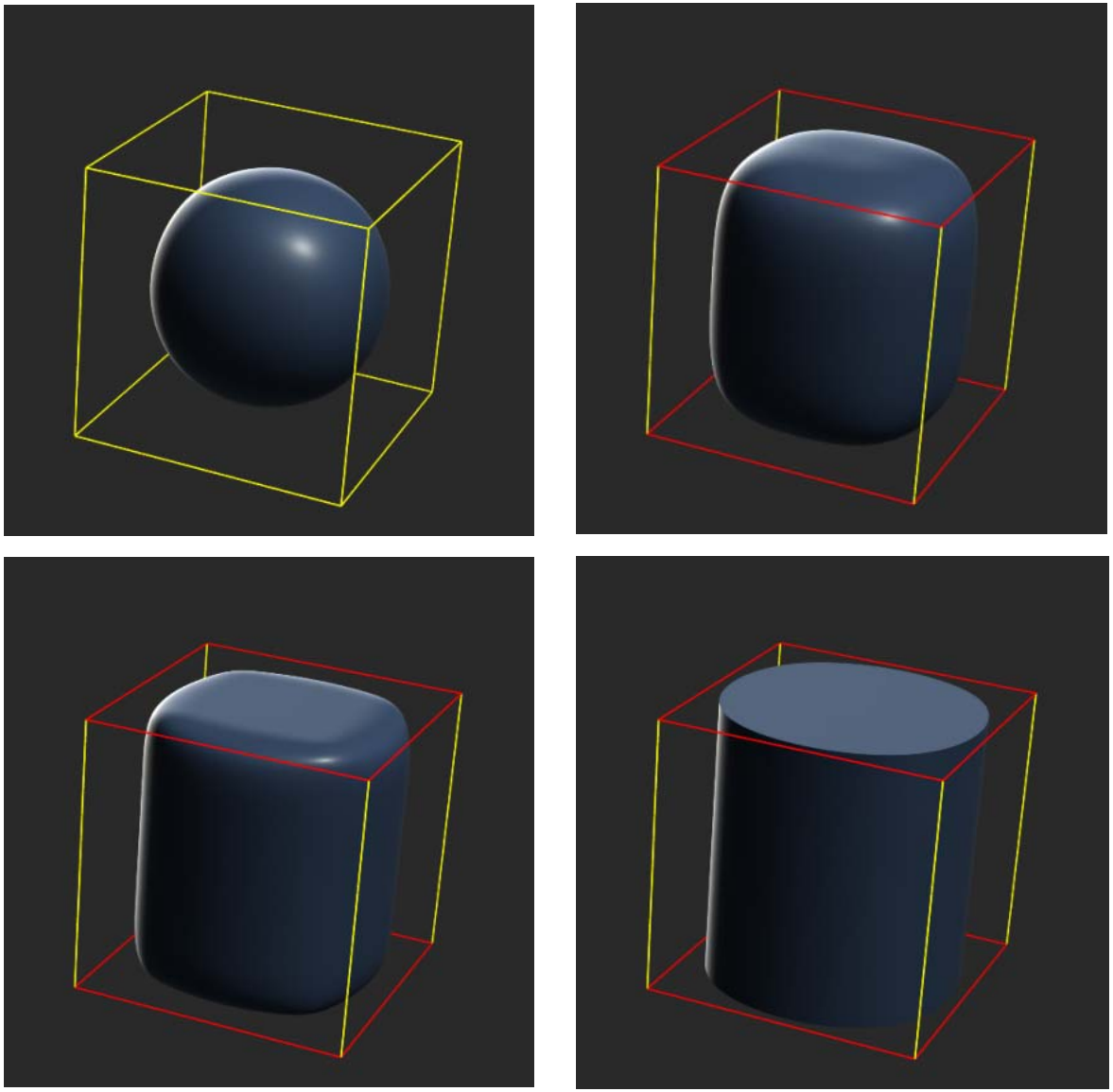
(e-h) Our piecewise smooth subdivision scheme: tagged control mesh, meshes after 1 and 2 subdivision steps, and piecewise smooth limit surface

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

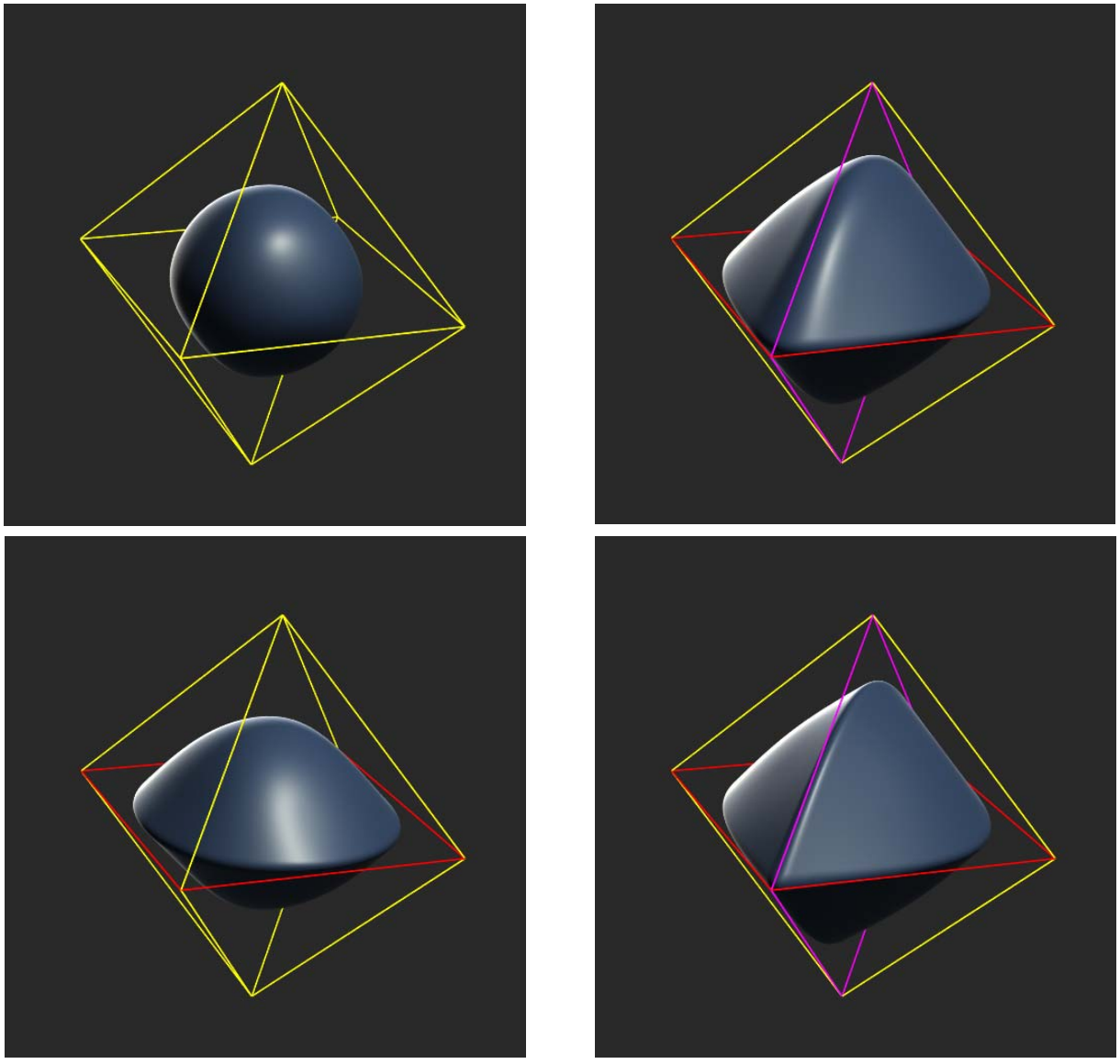
A dart is a vertex where a crease ends and smoothly blends into the surface.

Semisharpness



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

Semisharpness

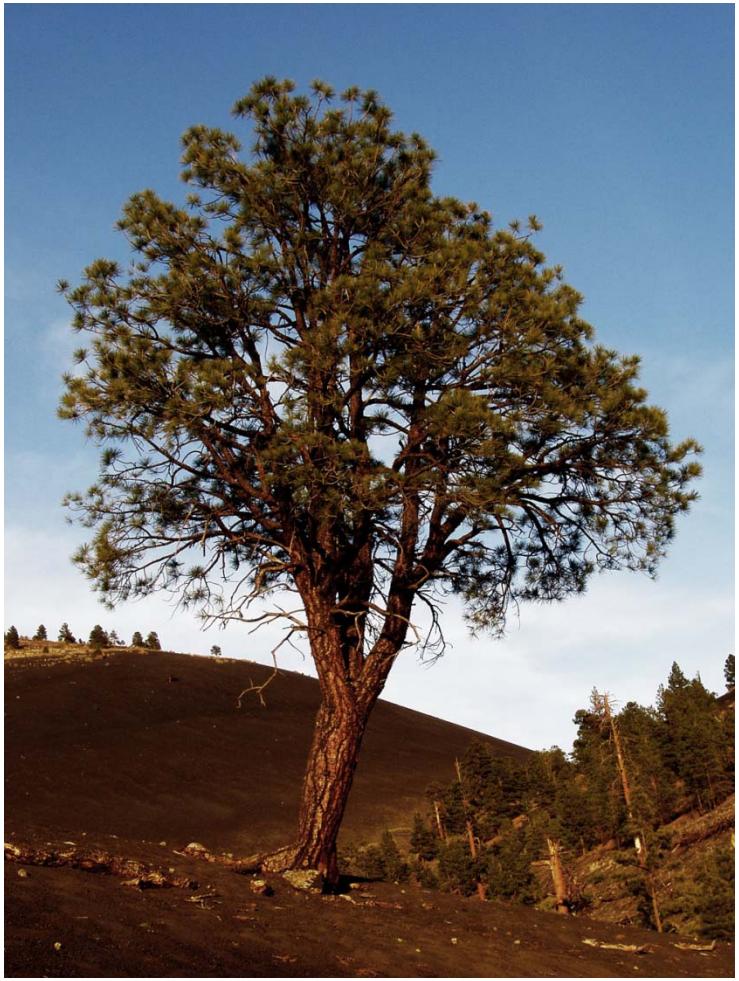


Derose et al, Subdivision Surfaces in Character Animation, SIGGRAPH 1998

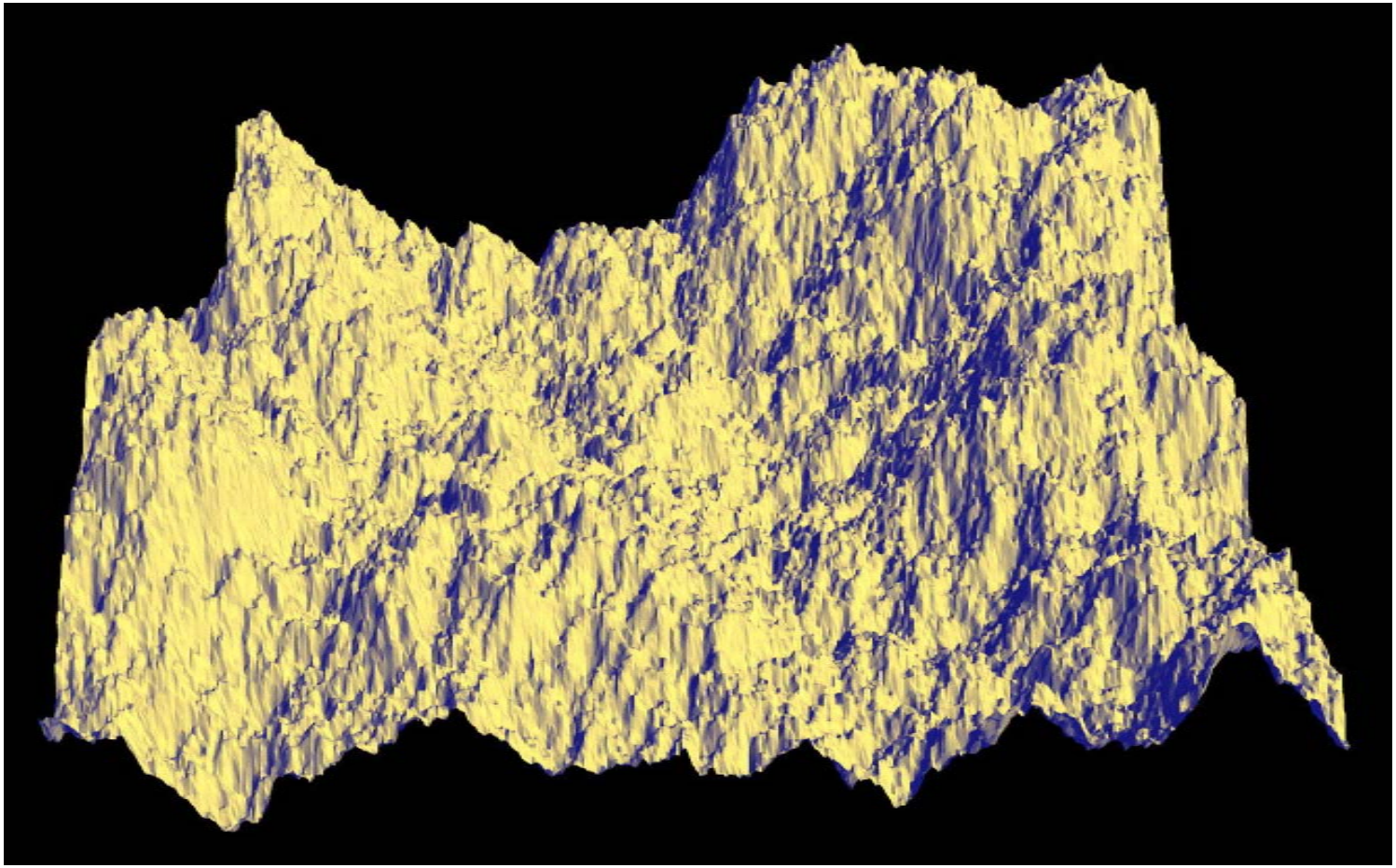
Piecewise smooth subdivision

Procedural Shape Modeling

Simple procedure



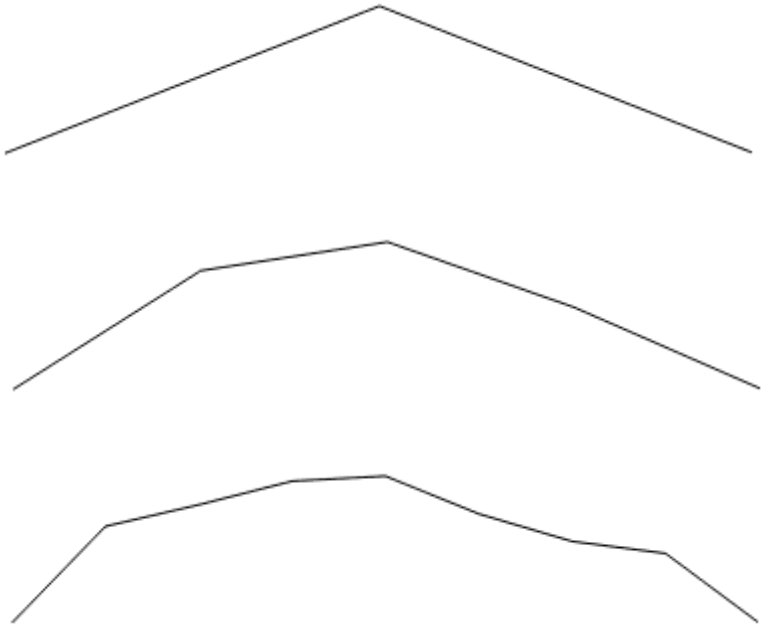
Procedural Terrain Modeling



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

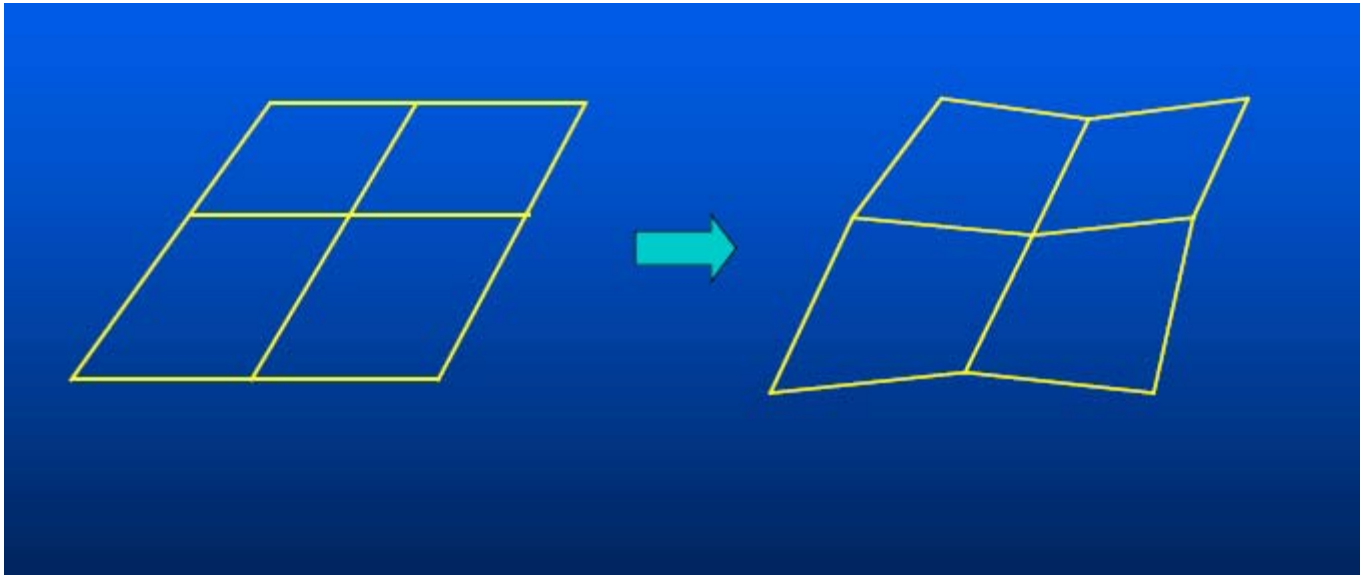
Want a function y=h(x)

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).
}

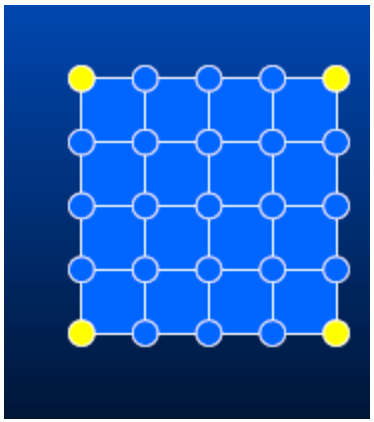
2D case

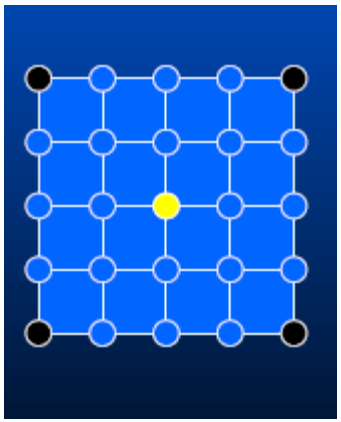
- Subdivide and Displace



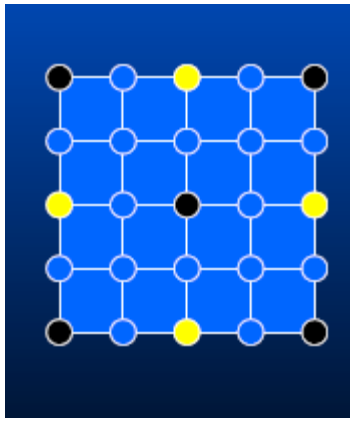
2D case

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

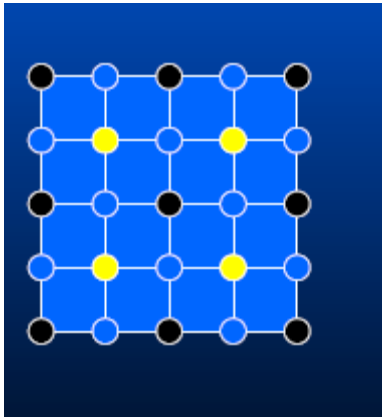




square

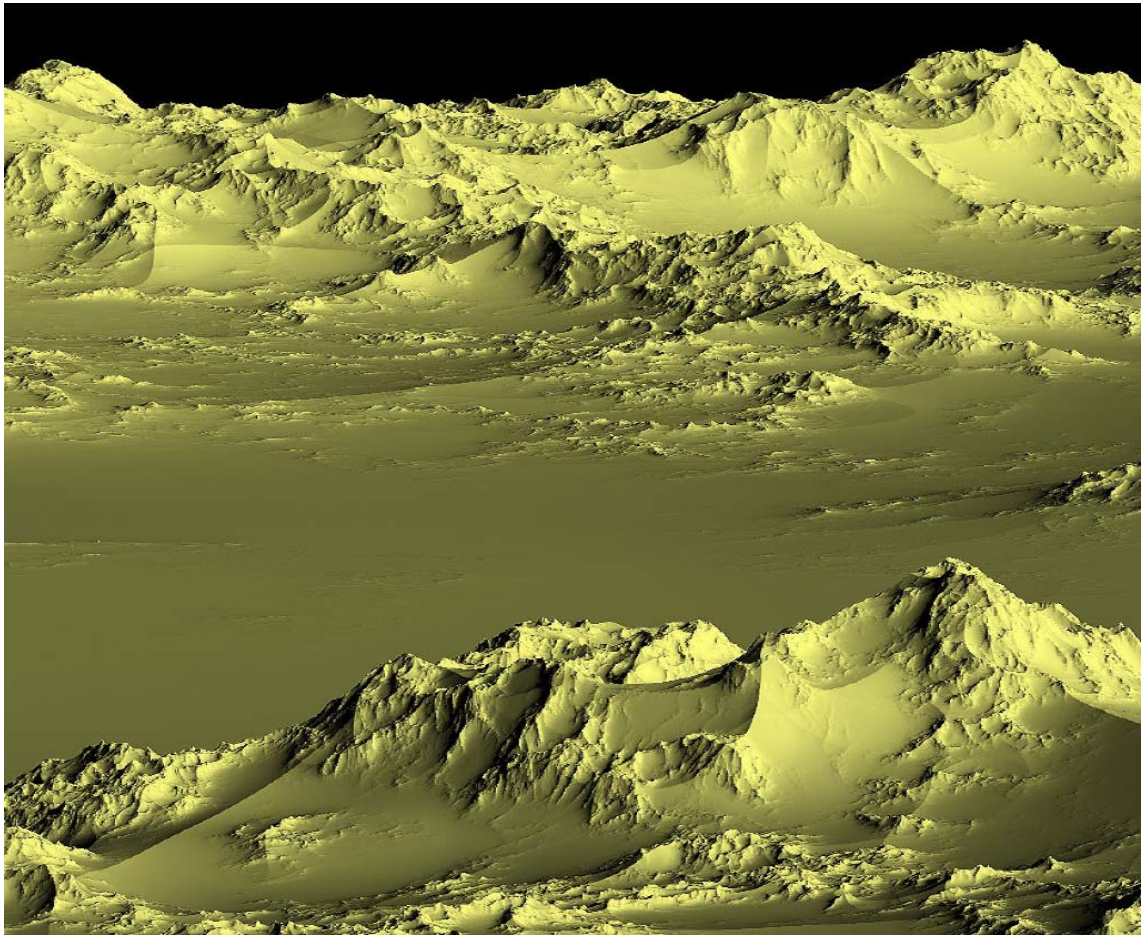


diamond



Recuse

2D case



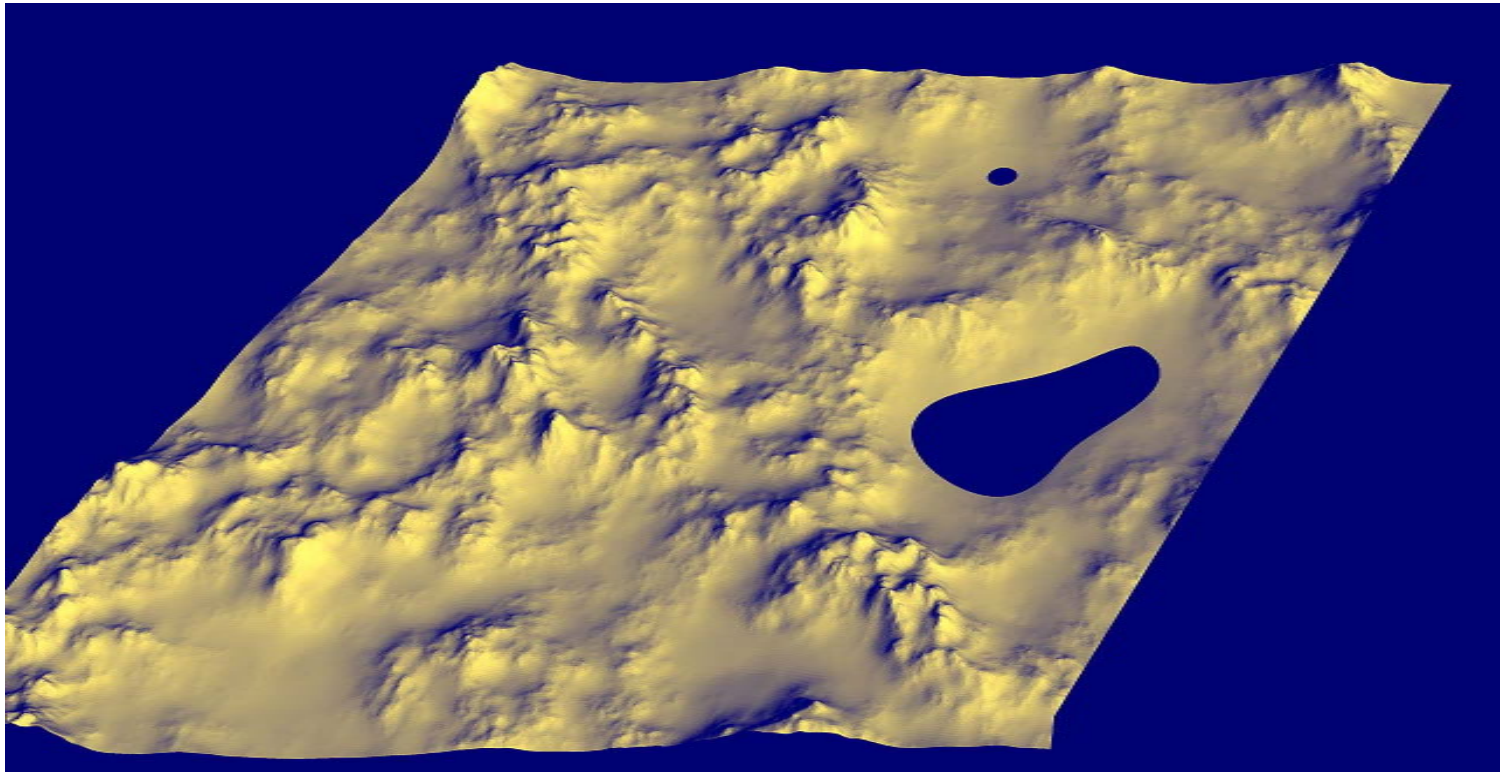
F.K. Musgrave

Texture mapping

F.K. Musgrave

Adding water

- Use an elevation threshold (z < z_water)



F.K. Musgrave


F.K. Musgrave


F.K. Musgrave

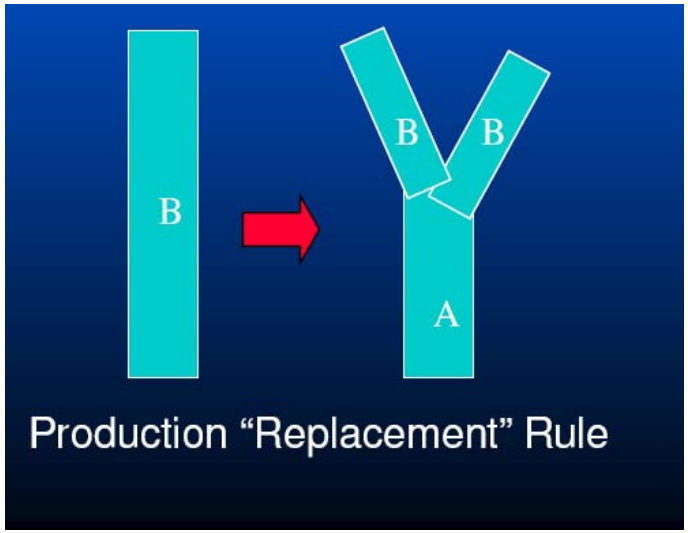
Fractal Plants (L-Systems)

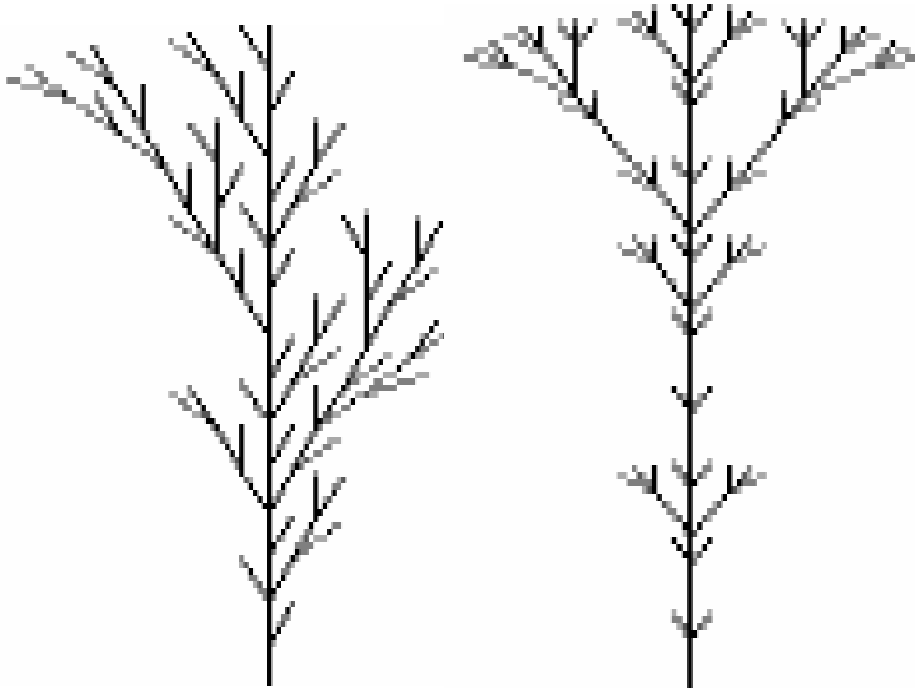
- Uses “production rules” applied to a seed “axiom”

- Example:

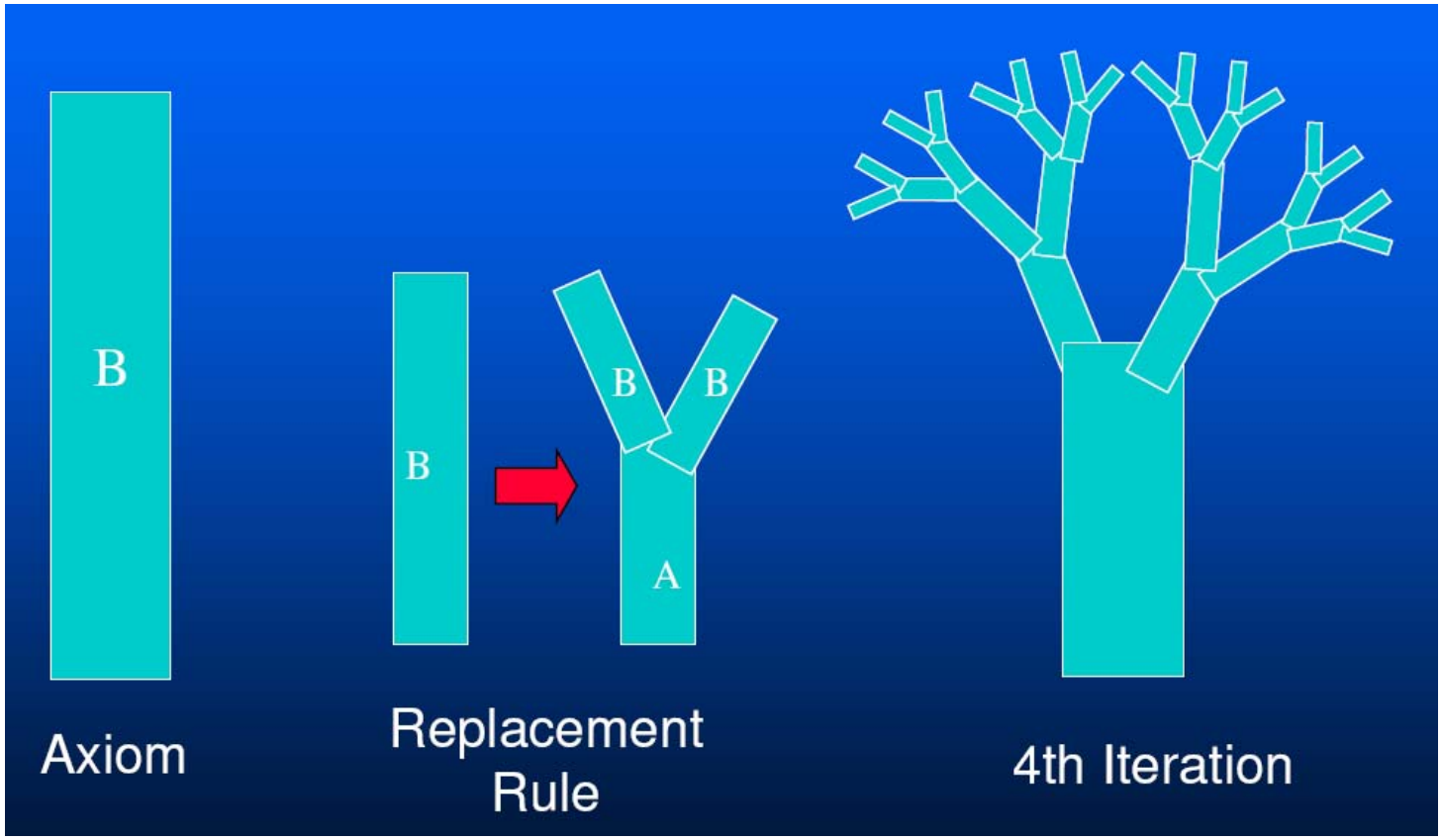
  Axiom: B

  Rule: B->ABB

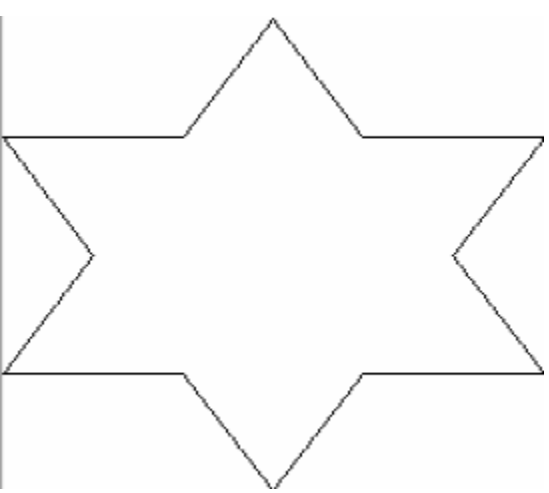


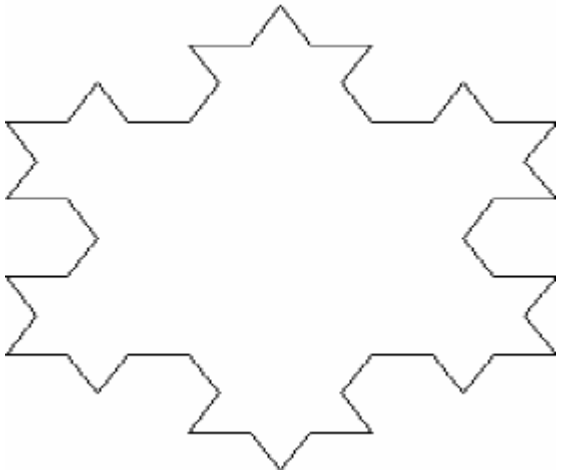


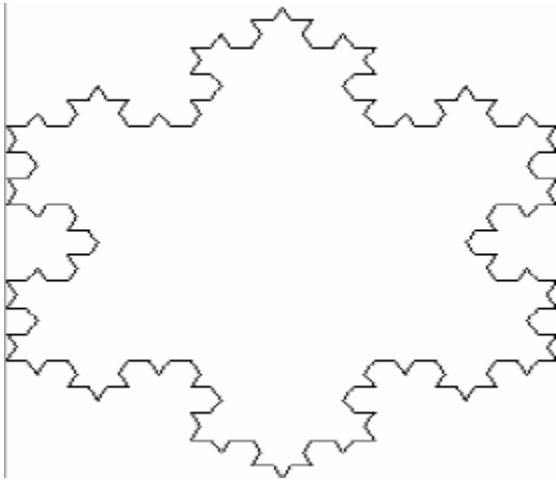
L-system Example

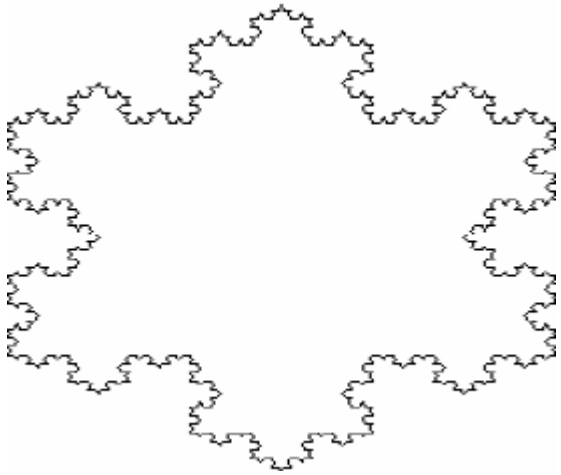


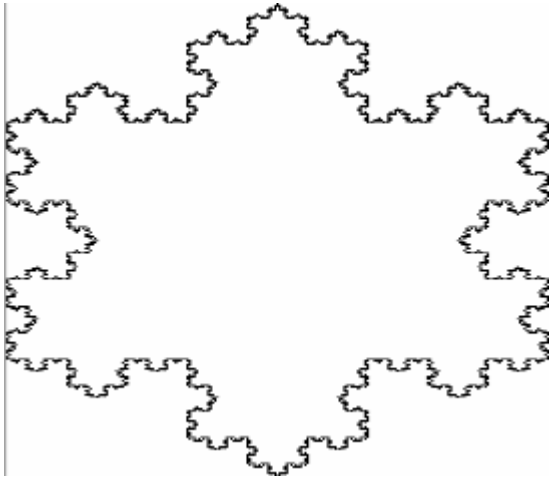
L-systems example: Koch snowflake





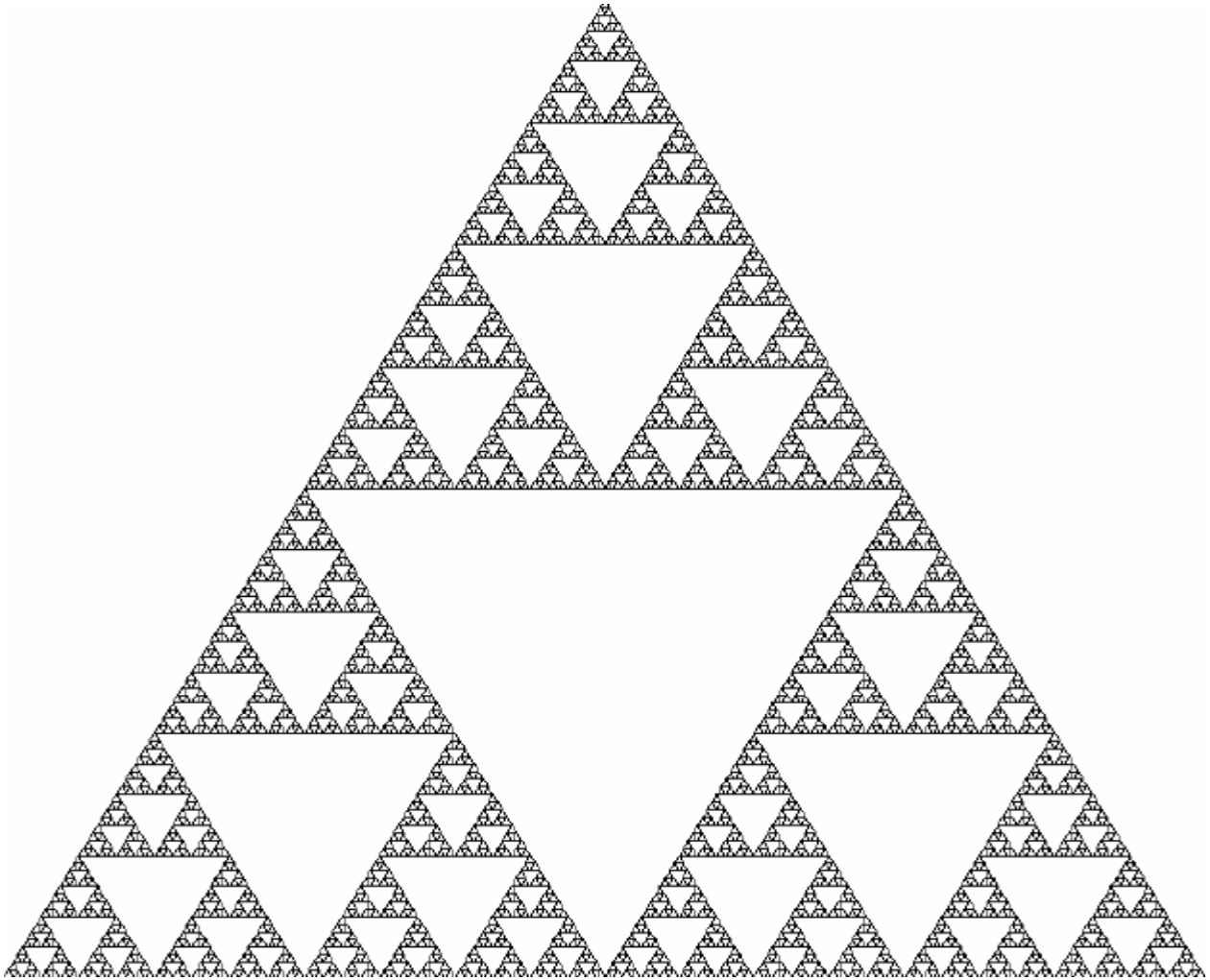






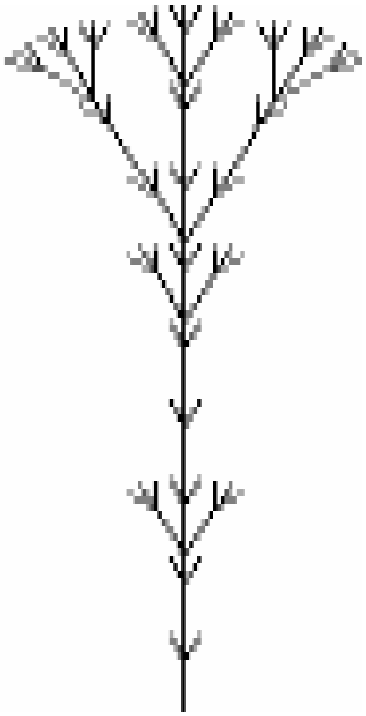
How to make the flake look less regular?

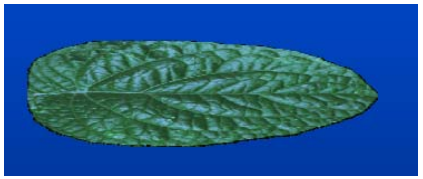
L-systems example: Serpinski Triangle



Procedural Trees and Bushes

- Define a branch structure
- Define a leaf



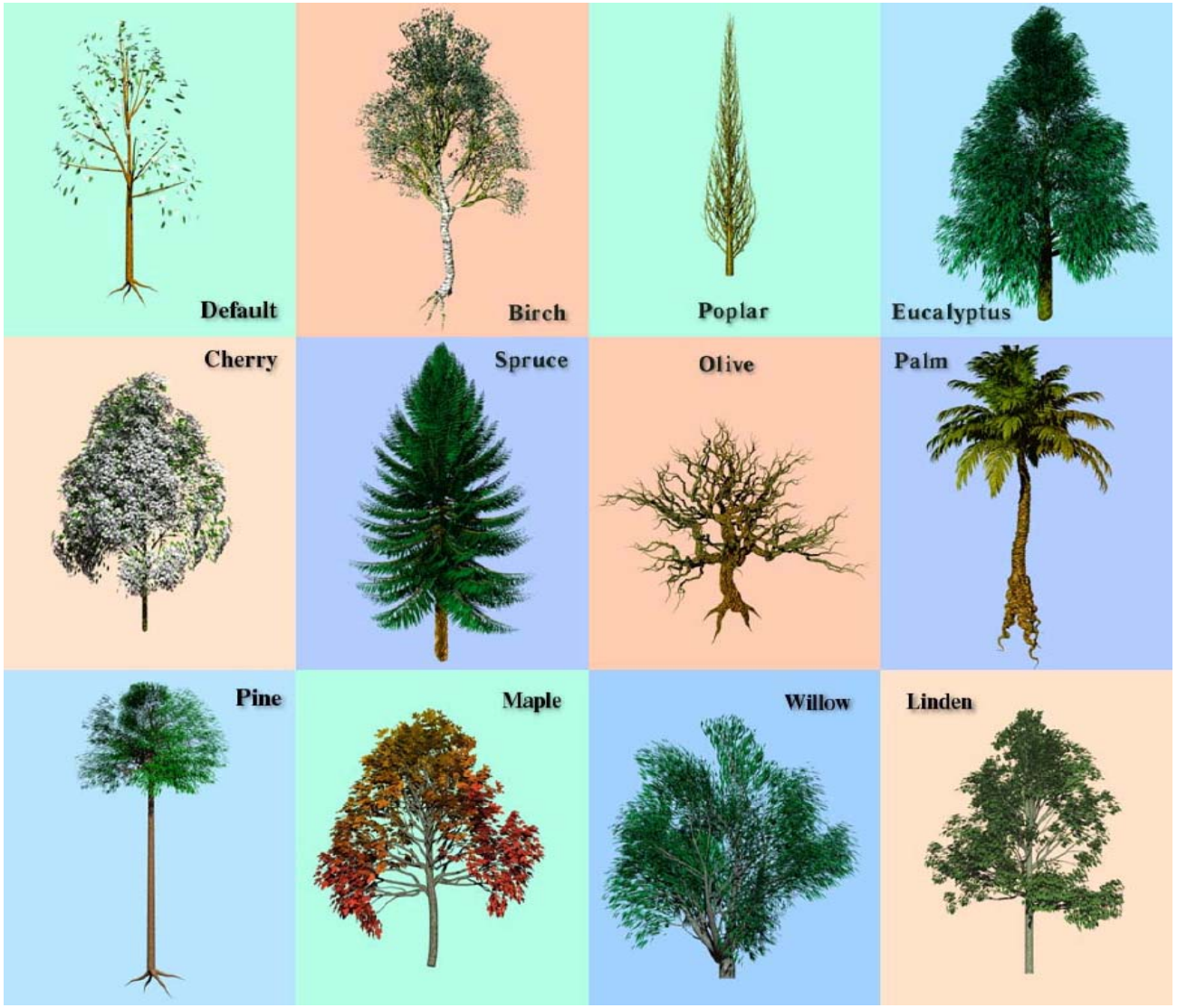


Algorithmic Plants

- 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