Announcements

Programming Assignment 4 is out
No Class Thursday
(Office Hrs On Request)

Procedural Modeling

Procedural Terrain
L-Systems
Procedural Animation/Behavior

COMPUTER GRAPHICS

15-462

04/05/07

Database Amplification

- Procedural content generation is attractive because it allows for significant database amplification
- Limited input data produces rich & varied output
  - ie: Perlin noise function + basic math gives fire, clouds, wood, etc.
- If it can be generated on the fly…
  - Artist doesn't have to design it
  - Don't need to store/transmit it

“Implicit” vs. “Explicit” Procedural Models

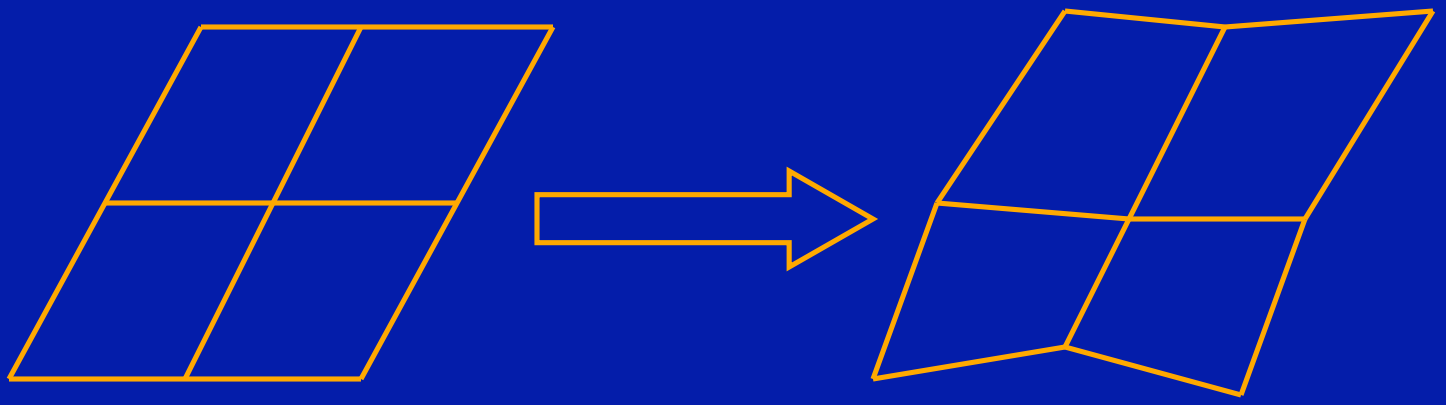
- Explicit:
  - Directly generate the points that make up an object
  - Good for Z-buffer/OpenGL style rendering
- Implicit:
  - Answer questions about particular points
  - Isocurve (2D) or Isosurface (3D)
  - Good for ray-tracing

Simple Explicit Procedural Model

- Begin with a regular mesh
- Perturb vertex geometry procedurally (typically pseudorandomly)
- Iterate this process until desired shape is achieved
- Very general technique that can also be used to add irregularity (“noise”) to arbitrary mesh objects

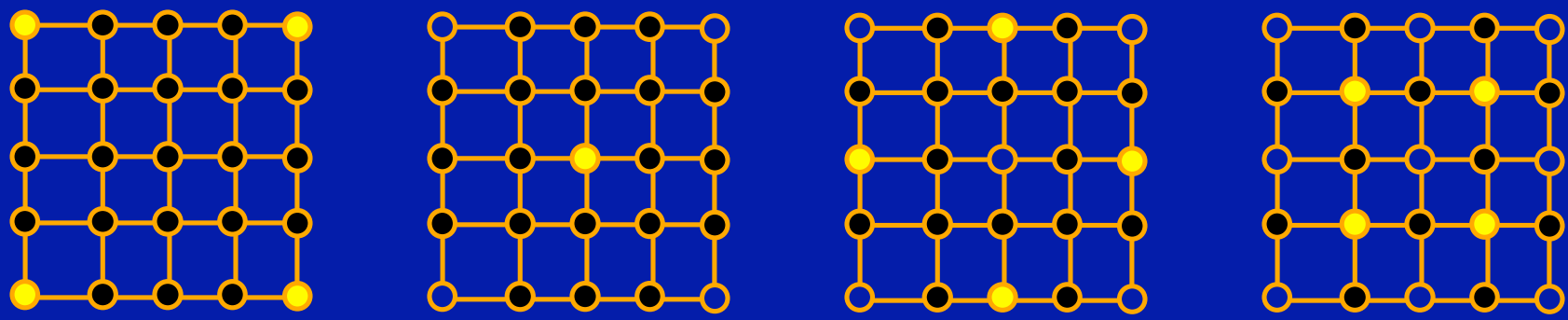
Procedural Terrain

- “Subdivide and displace”



Midpoint Displacement For Terrain

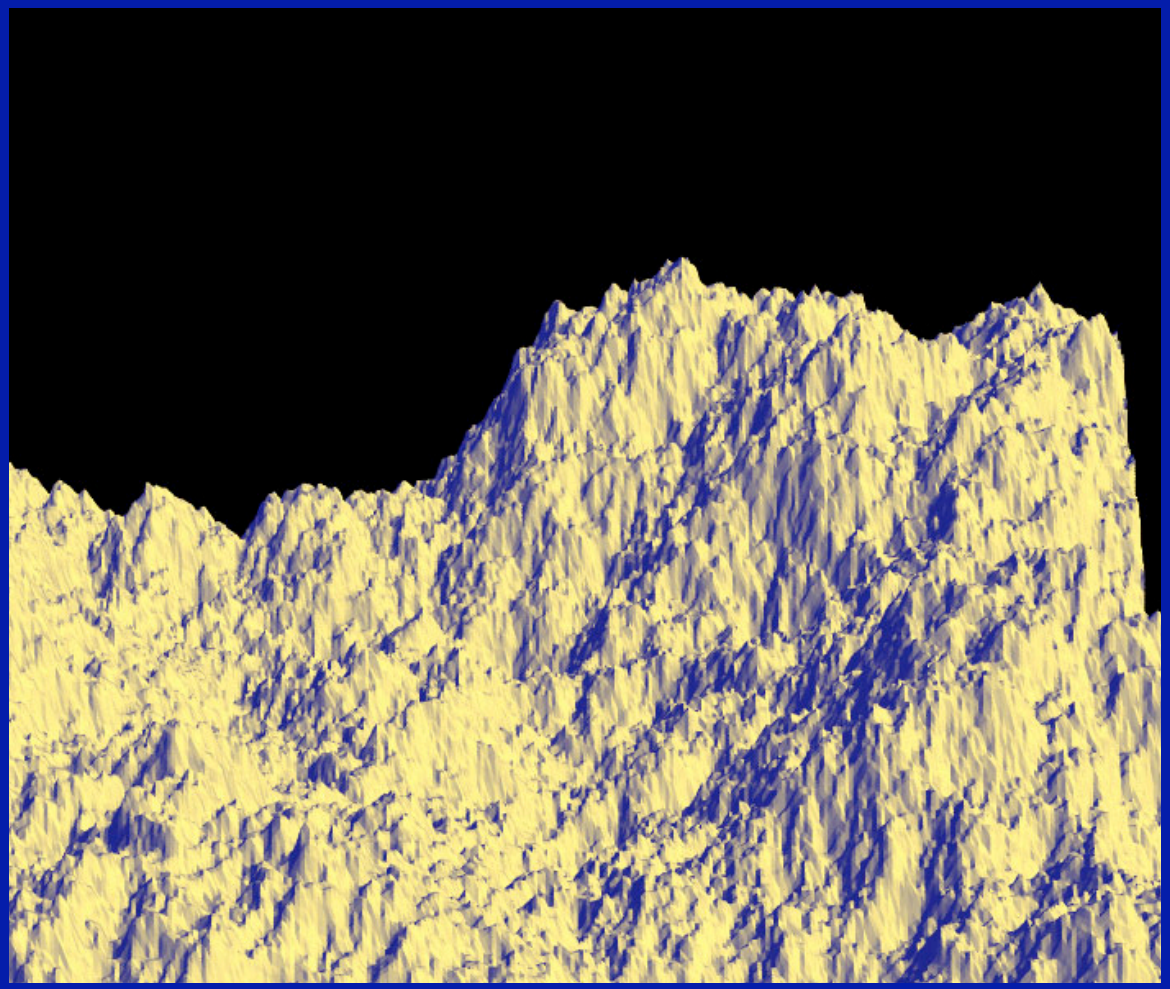
- Seed corners with values
- Perturb midpoint randomly from mean
- Recurse using a smaller window
- In 2D, best to use “diamond-square” recursion (to prevent axis-aligned artifacts)



Fractal Noise Terrain

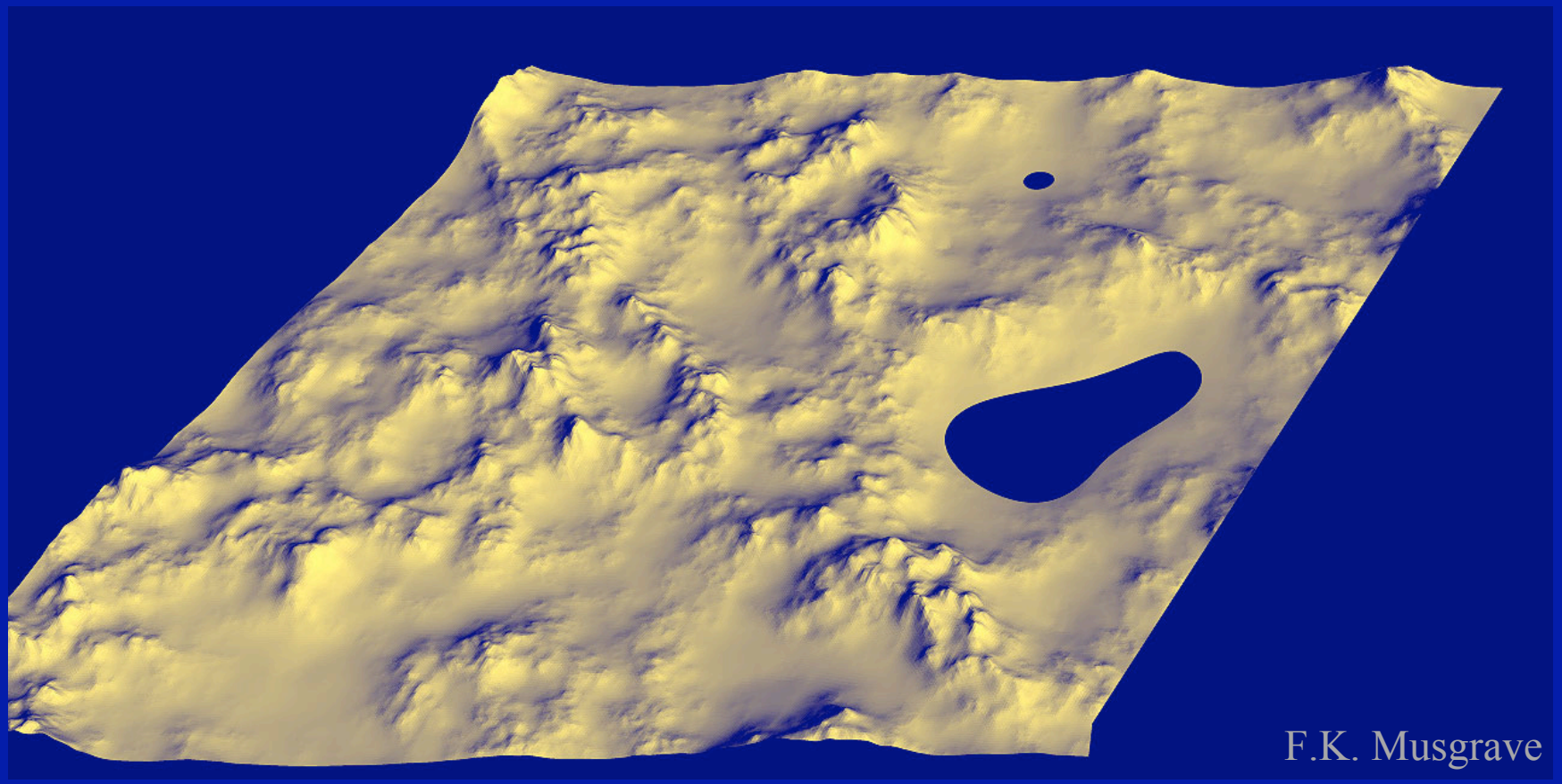
- Use fractal noise to generate terrain
- Can be made tileable over unit square:

$$F_{tileable}(x,y) = [$$
$$F(x,y) * (1-x) * (1-y) +$$
$$F(x-1,y) * x * (1-y) +$$
$$F(x-1,y-1) * x * y +$$
$$F(x,y-1) * (1-x) * y]$$



F.K. Musgrave

Adding Water



- Use an elevation threshold ($z < z_{water}$)

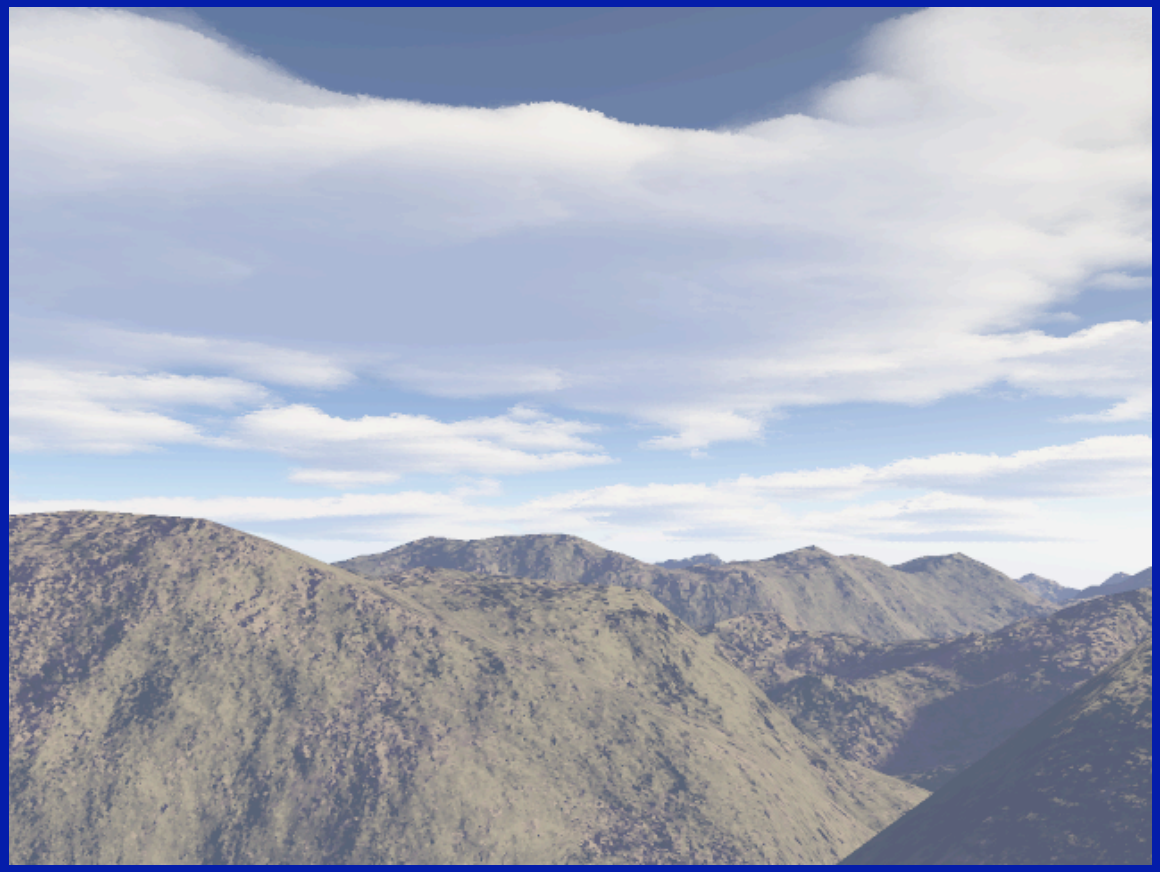
Terrain Example

Terrain Example

Terrain Example

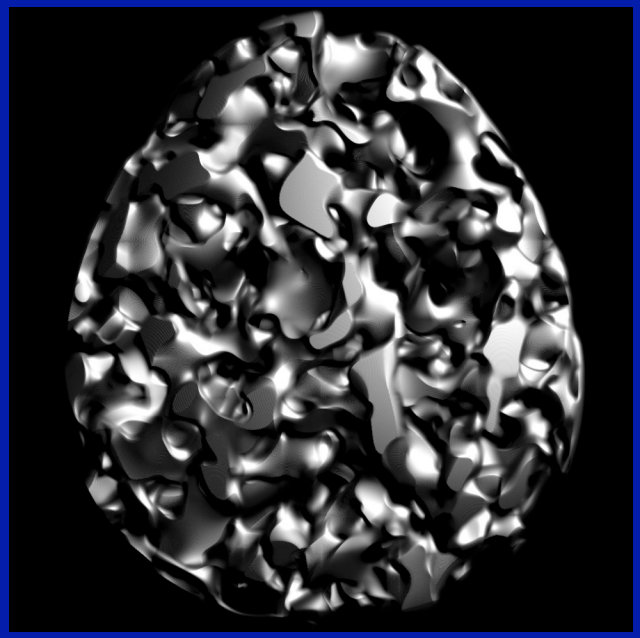
F.K. Musgrave

Terragen



- Commercial product (free for personal use)
- Website: http://www.planetside.co.uk/terragen/
- This image took ~3 minutes to set up

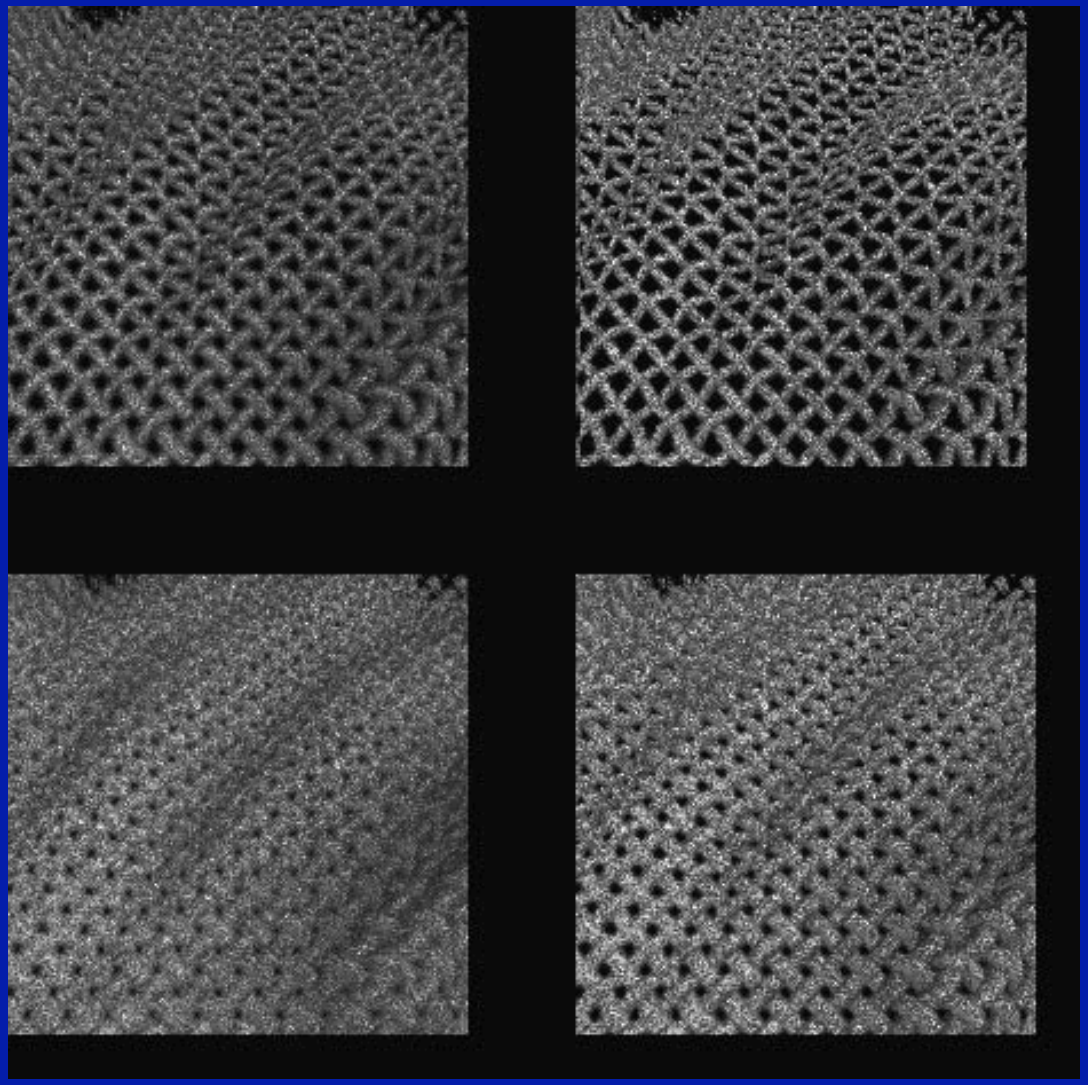
Hypertexture



- Implicit procedural model
- Treat the isosurface of a function as the boundary of an object
- Above: fractal egg

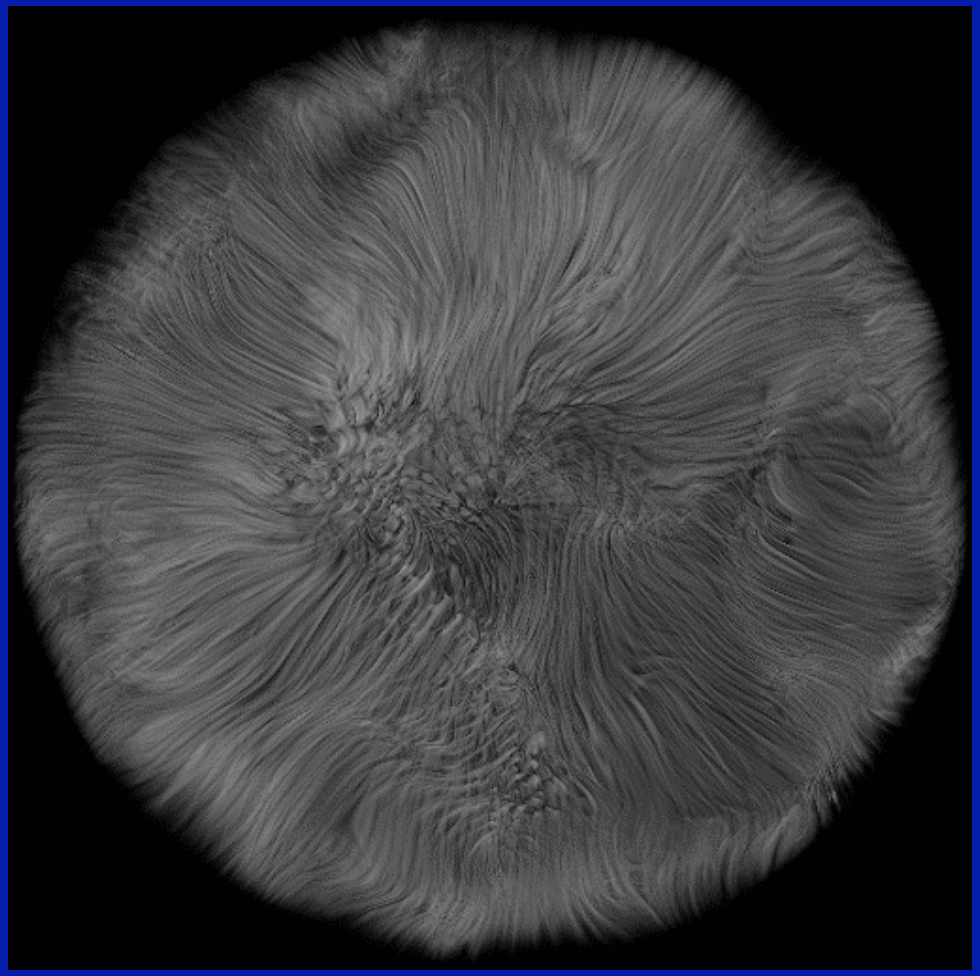
Photo: K. Perlin

Hypertexture Example



K. Perlin

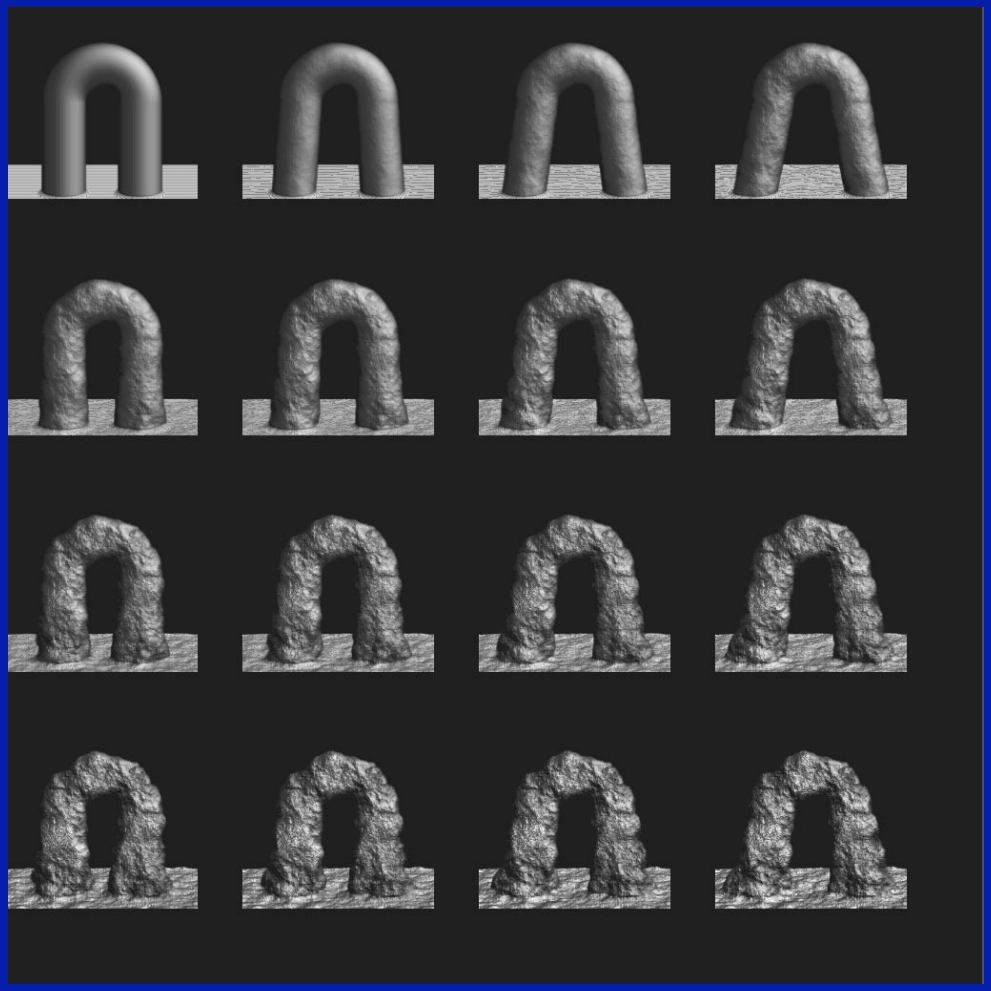
Hypertexture Example



K. Perlin

Architexture

- Sweep the path of a line drawing with a sphere
- Apply hypertexture to resulting shape



K. Perlin

L-Systems (Background)

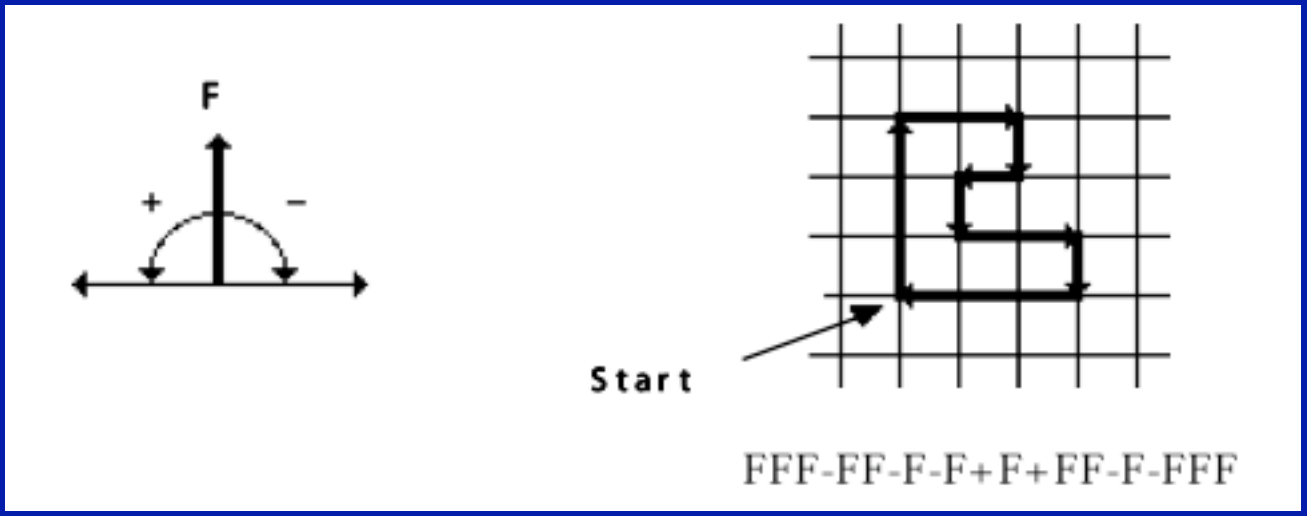
- Developed by A. Lindenmayer to model the development of plants
- Based on parallel string-rewriting rules
- Excellent for modeling organic objects and fractals

L-Systems (Basics)

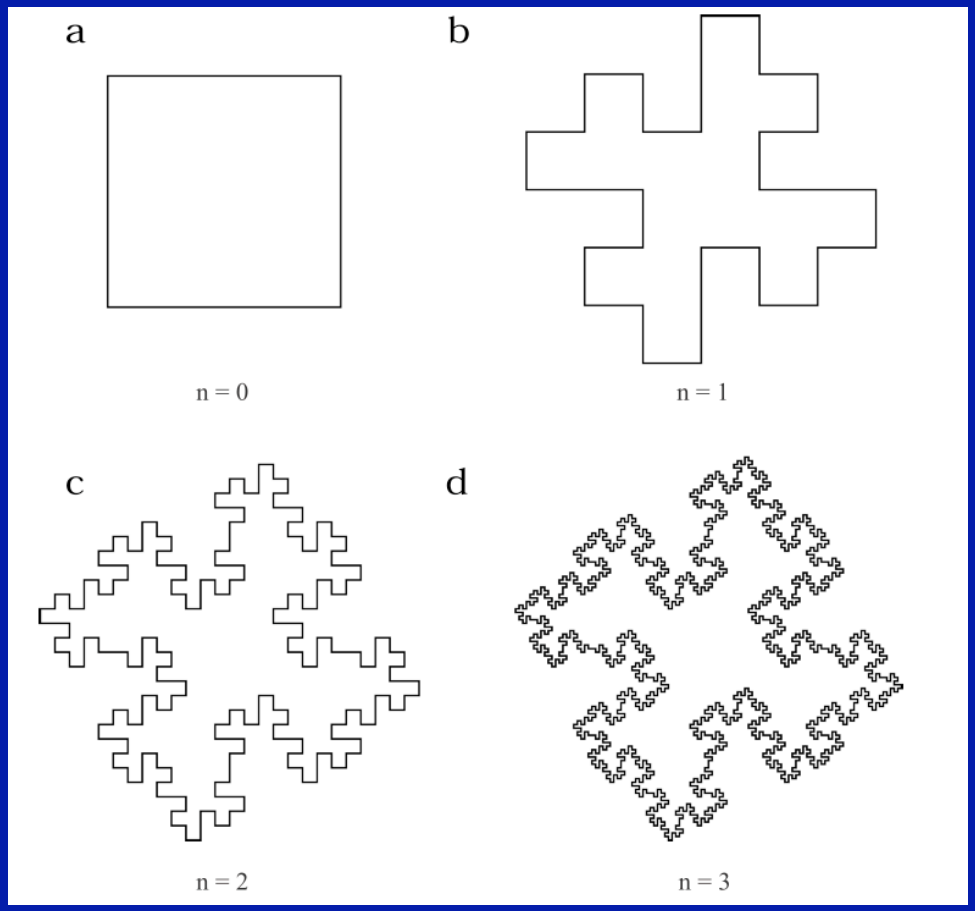
- Begin with a set of “productions” (replacement rules) and a “seed” axiom
- In parallel, all matching productions are replaced with their right-hand sides
- Ex:
  - Rules: B->ACA
    A->B
  - Axiom: AA
  - Sequence: AA,BB,ACAACA,BCBBCB,etc.
- Strings are converted to graphic representations via interpretation as turtle graphics commands

L-Systems (Basic Example)

- Turtle Commands:
  - F_x: move forward one step, drawing a line
  - f_x: move forward one step, without drawing a line
  - $+_x$: turn left by angle ∂
  - $-_x$: turn right by angle ∂

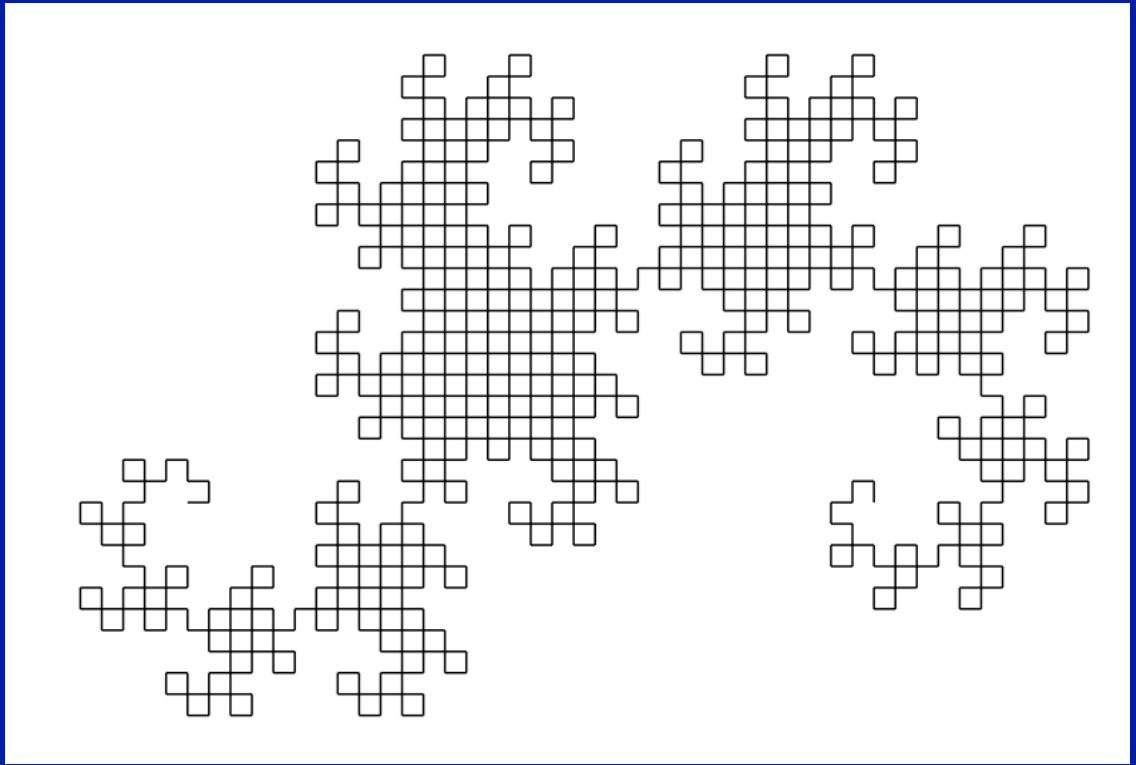


L-Systems (Koch Snowflake)



- Axiom: F-F-F-F ∂:90 degrees
- F➔F-F+F+FF-F-F+F

L-Systems (Dragon Curve)

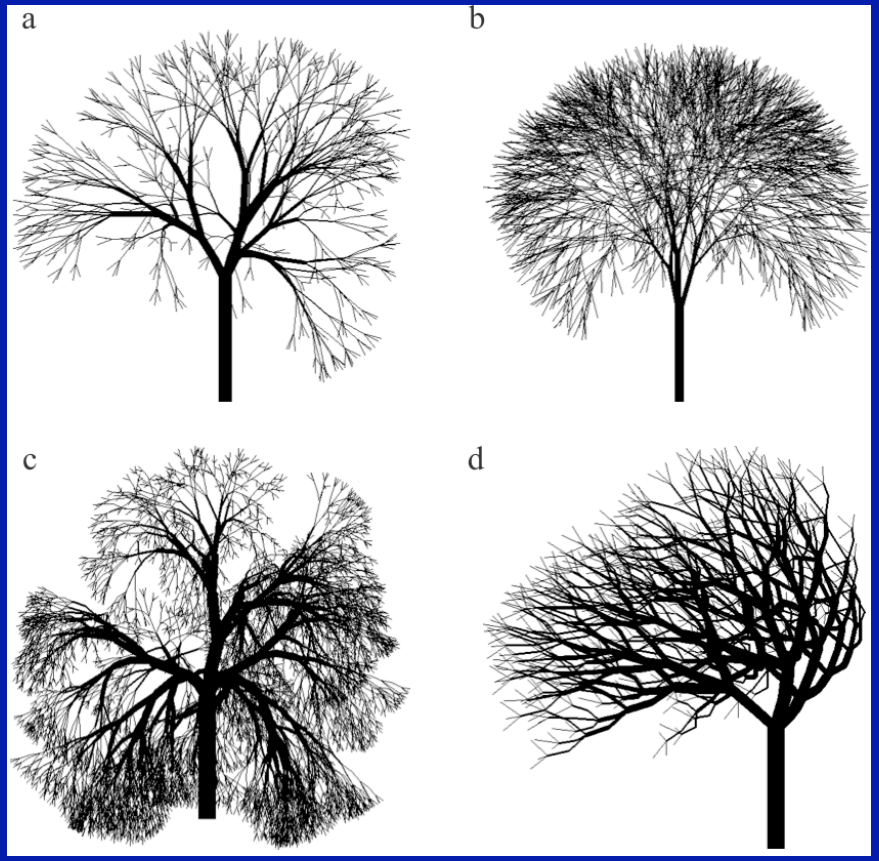


- Axiom:F_l ∂:90 degrees n:10 iterations
- $F_l \rightarrow F_l+F_r+$
- $F_r \rightarrow F_l-F_r-$

L-Systems (Extensions)

- Basic L-Systems have inspired a large number of variations
- Context sensitive: productions look at neighboring symbols
- Bracketed: save/restore state (for branches)
- Stochastic: choose one of n matching productions randomly
- Parametric: variables can be passed between productions

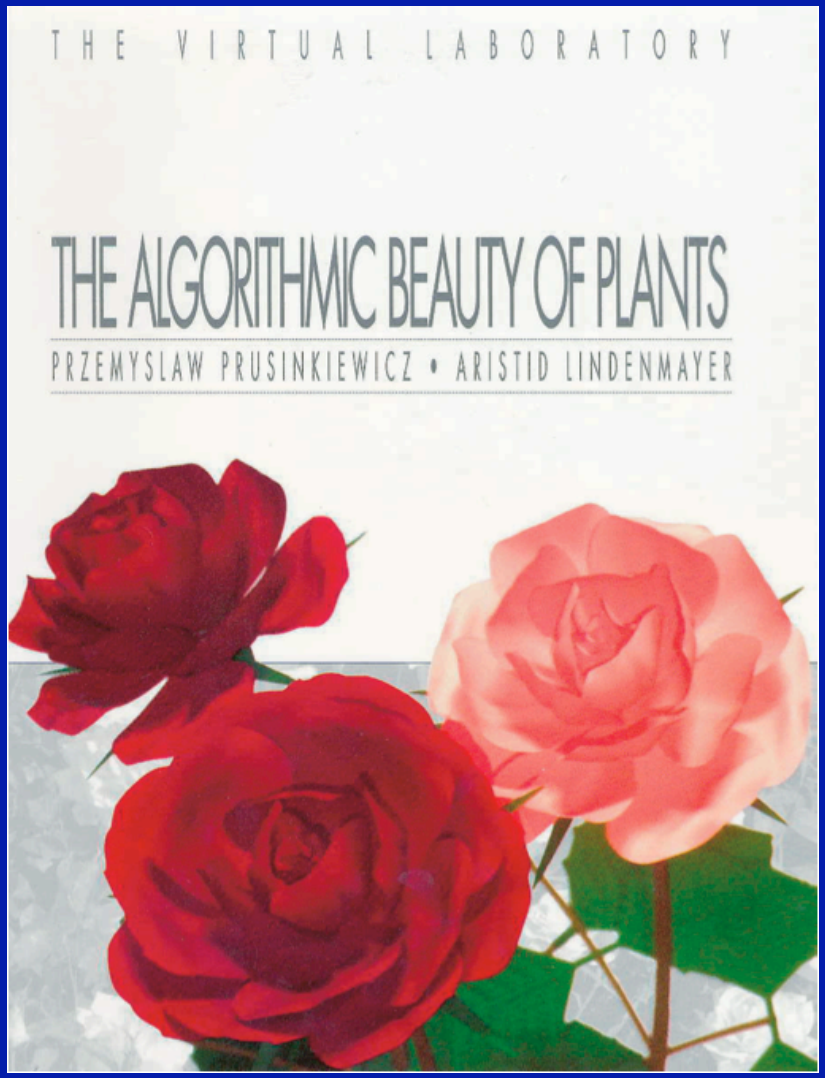
L-Systems For Plants



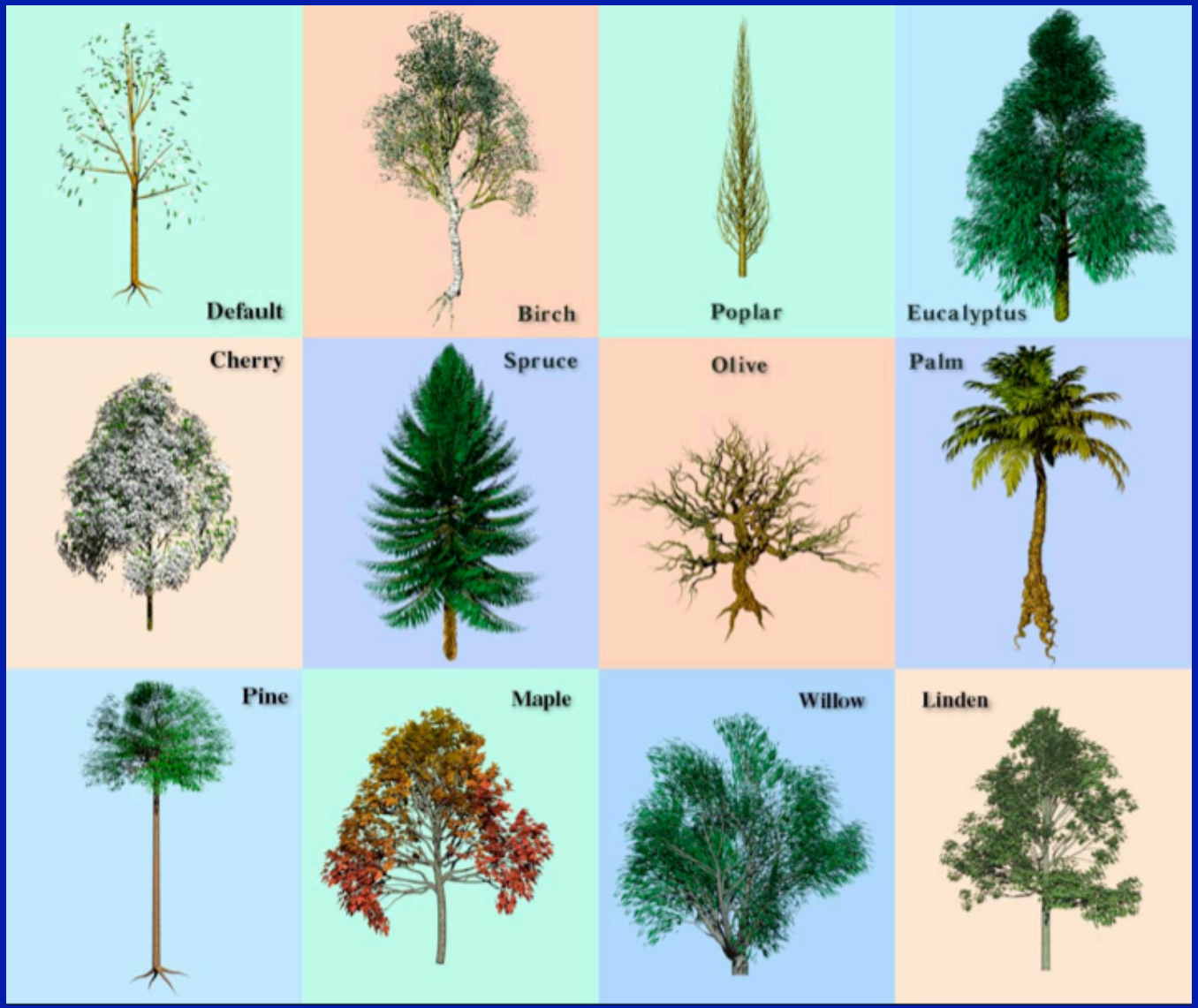
- L-Systems can capture a large array of plant species
- Designing rules for a specific species can be challenging

Algorithmic Botany

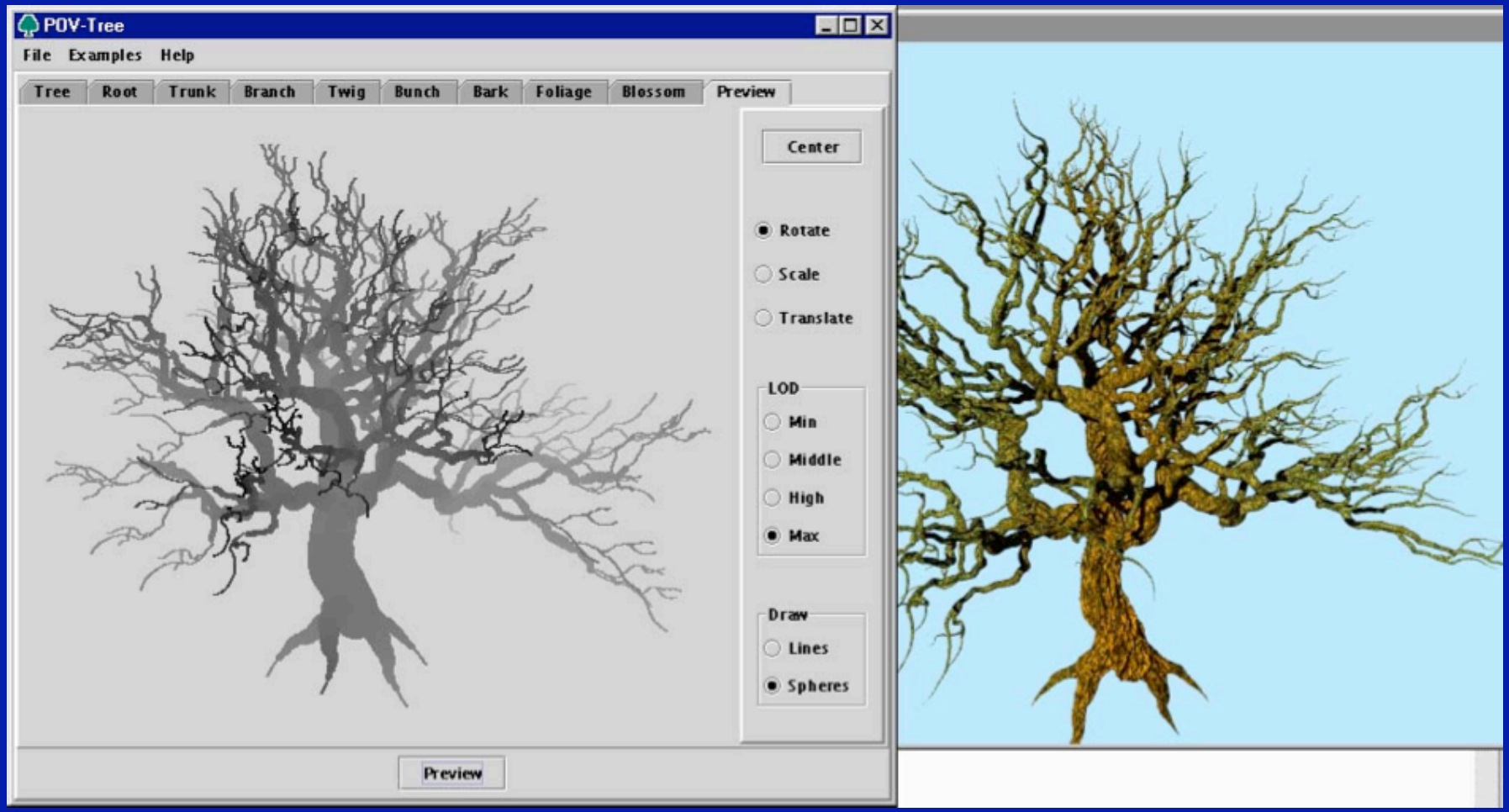
- **http://algorithmicbotany.org/papers/**
- Free 200pg ebook
- Covers many variants of L-Systems, formal derivations, and exhaustive coverage of different plant types



PovTree


Default
Birch
Poplar
Eucalyptus
Cherry
Spruce
Olive
Palm
Pine
Maple
Willow
Linden

Interactive Design With PovTree

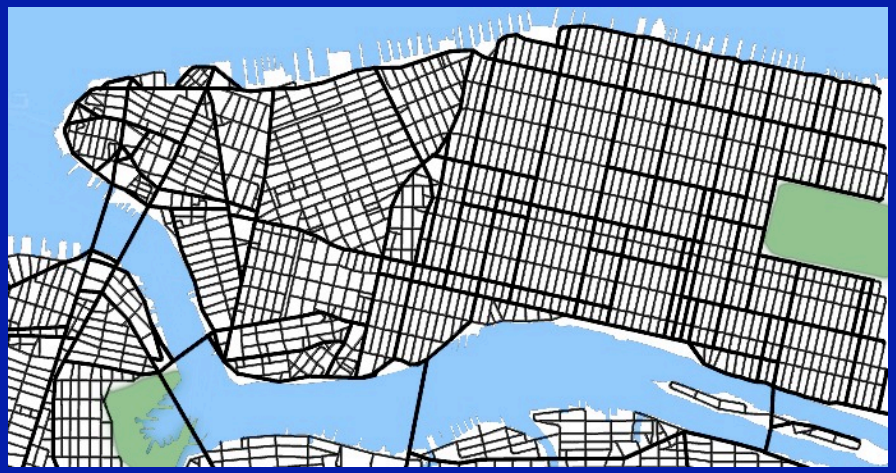


- http://propro.ru/go/Wshop/povtree/povtree.html
- http://arbaro.sourceforge.net/

SpeedTree

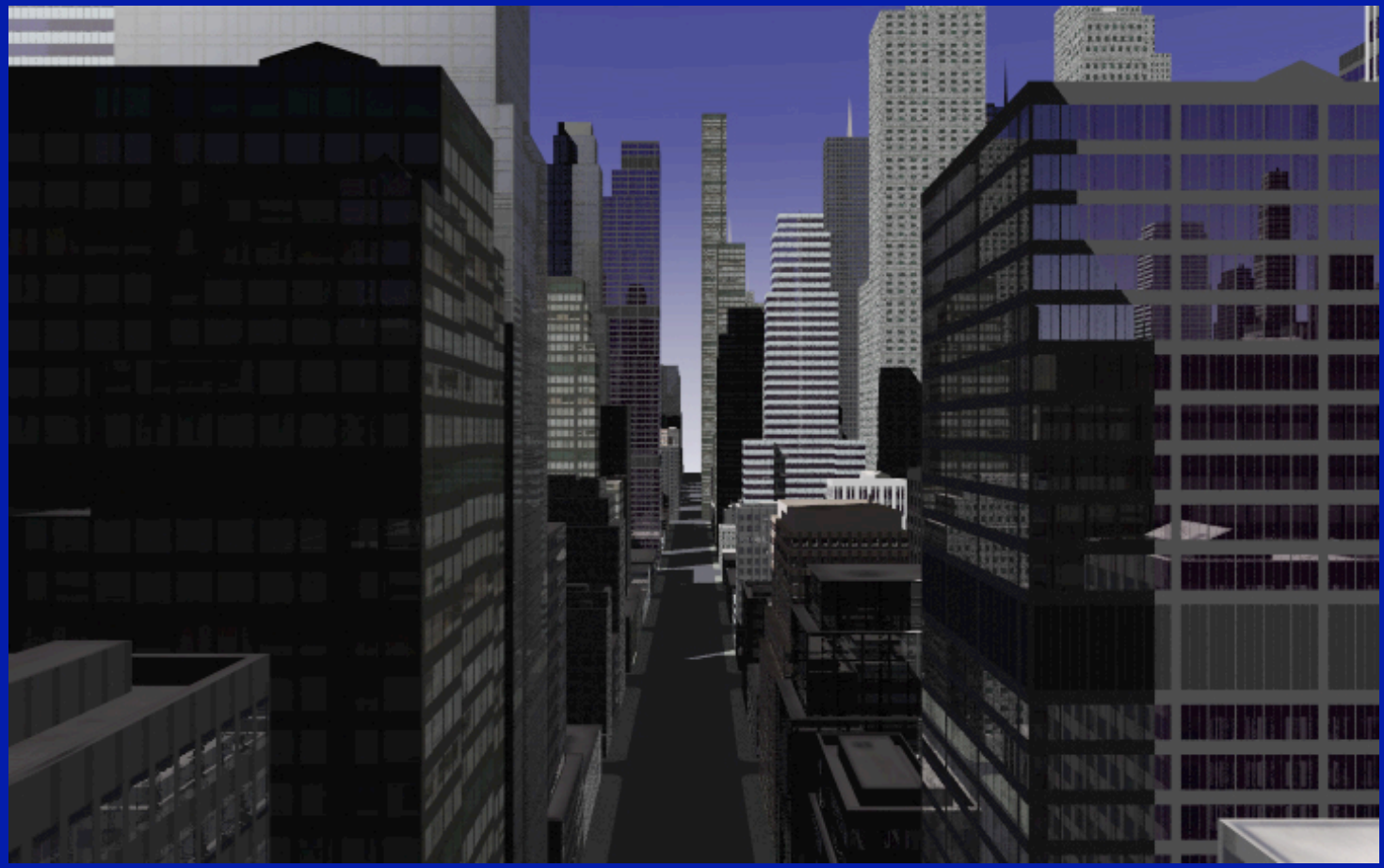
- Fast procedural foliage is important for real-time applications
- http://www.speedtree.com/

L-Systems for Cities [Parish01]



- Start with a single street
- Branch & extend w/ parametric L-System
- Parameters of the string are tweaked by goals/constraints
- Goals control street direction, spacing
- Contraints allow for parks, bridges, road loops

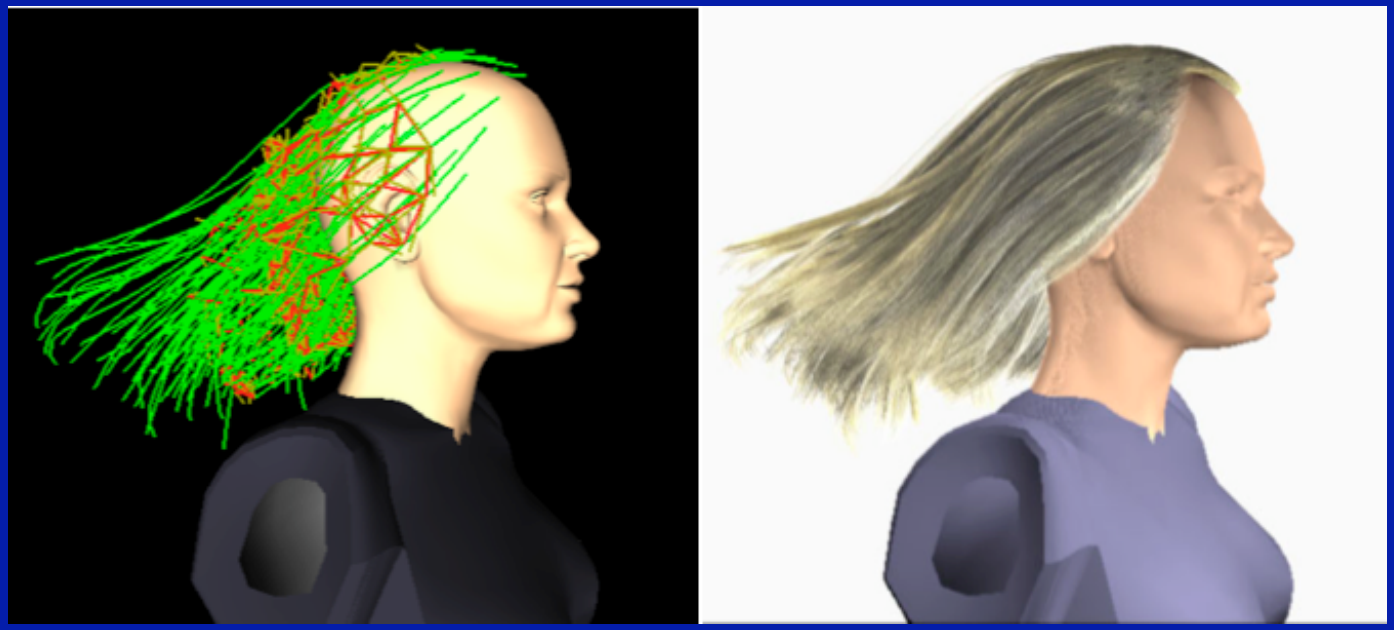
L-Systems for Cities (2)



- Once we have streets, we can form buildings with another L-System
- Building shapes are represented as CSG operations on simple shapes

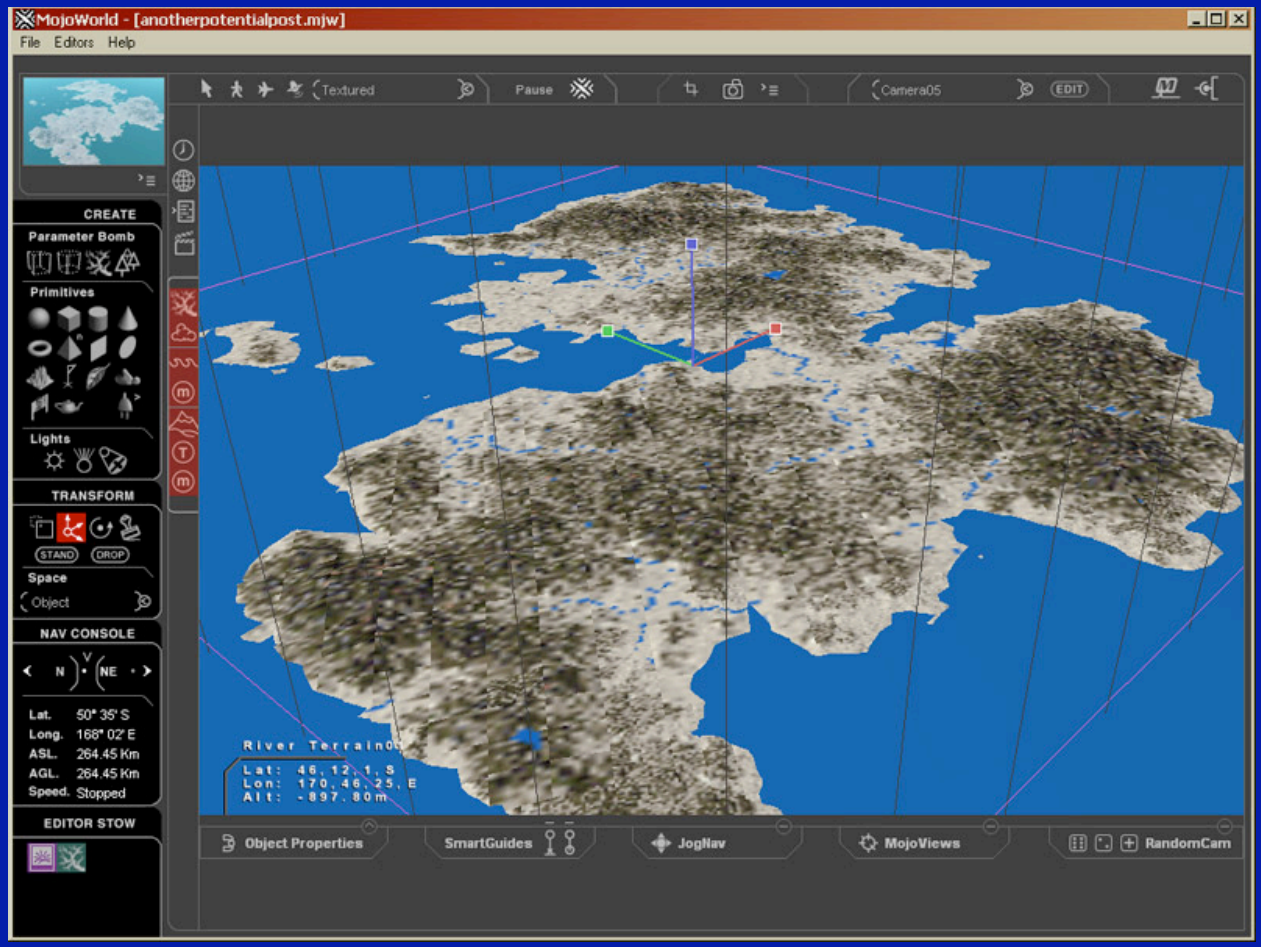
Procedural Hair [Chang02]

- Generate a model with a few hundred guide hairs
- Each hair is a rigid chain w/ revolute joints
- Use breakable springs between nearby hairs to simulate hairstyles
- Create triangle strips between adjacent hairs to simulate collisions
- Interpolate between guide hairs to produce many other hairs



Procedural Hair (Examples)

MojoWorld



- Commercial application for creating photorealistic procedural planets
- http://www.pandromeda.com/

Procedural Planets

E. DeGuili

Procedural Planets

R. Fry

Procedural Planets

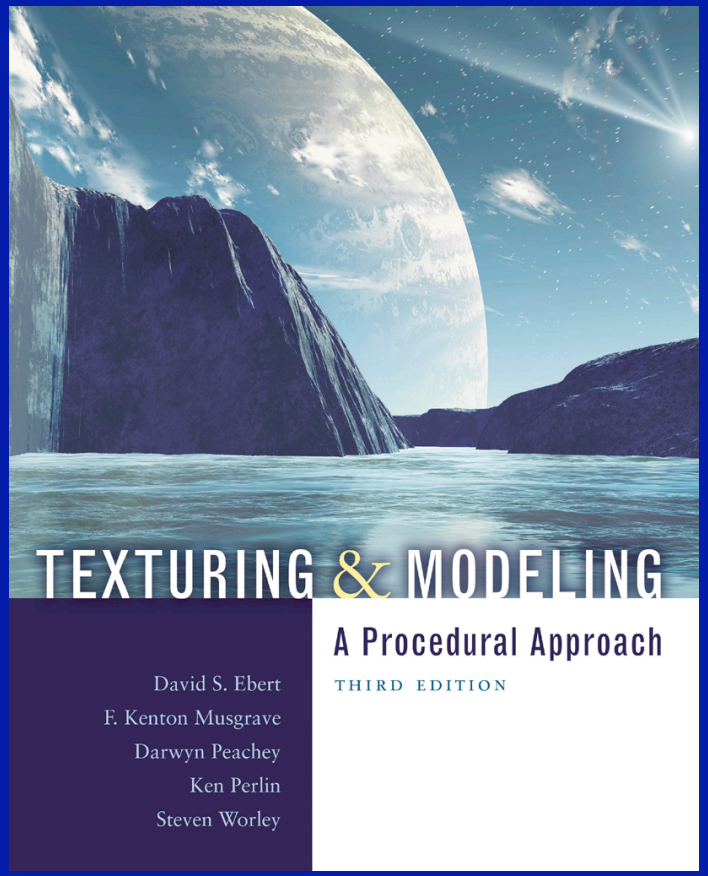
Y. Dinda

Procedural Planets

F.K. Musgrave

Texturing and Modeling: A Procedural Approach

- D.S. Ebert et al
- 3rd Ed, 2003
- Excellent reference



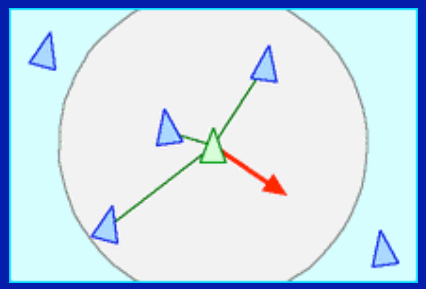
- http://www.mkp.com/tm3
- http://www.texturingandmodeling.com/

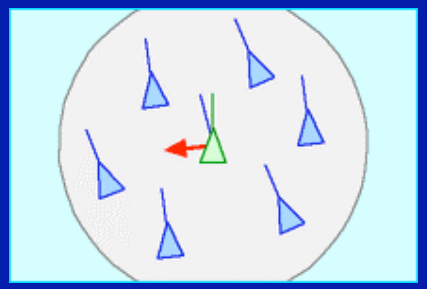
Procedural Animation

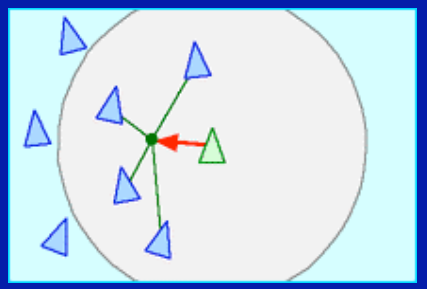
- Particle Systems
- Ragdoll Physics
- Fluid simulation
- Flocking/crowd simulations

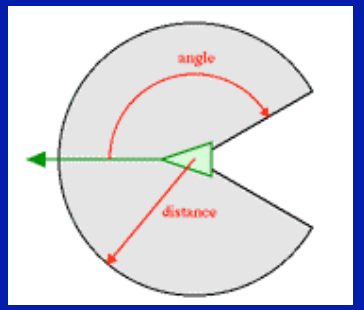
Procedural Flocking (Boids)

- Simulate the movement of a flock of birds in 3-space
- Separation: move to avoid crowding local neighbors
- Alignment: steer towards average heading of neighbors
- Cohesion: steer towards average position of neighbors
- Limited Senses: only neighbors in forward-facing arc are observable







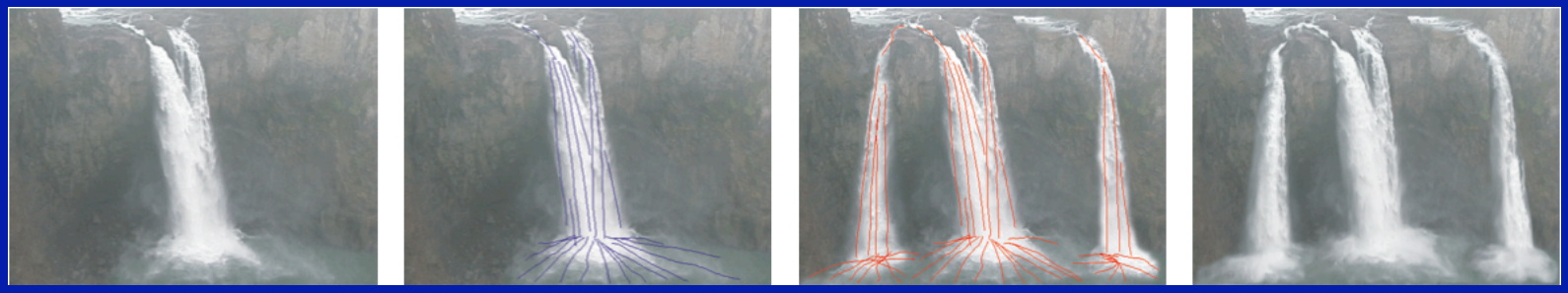


Boids Example

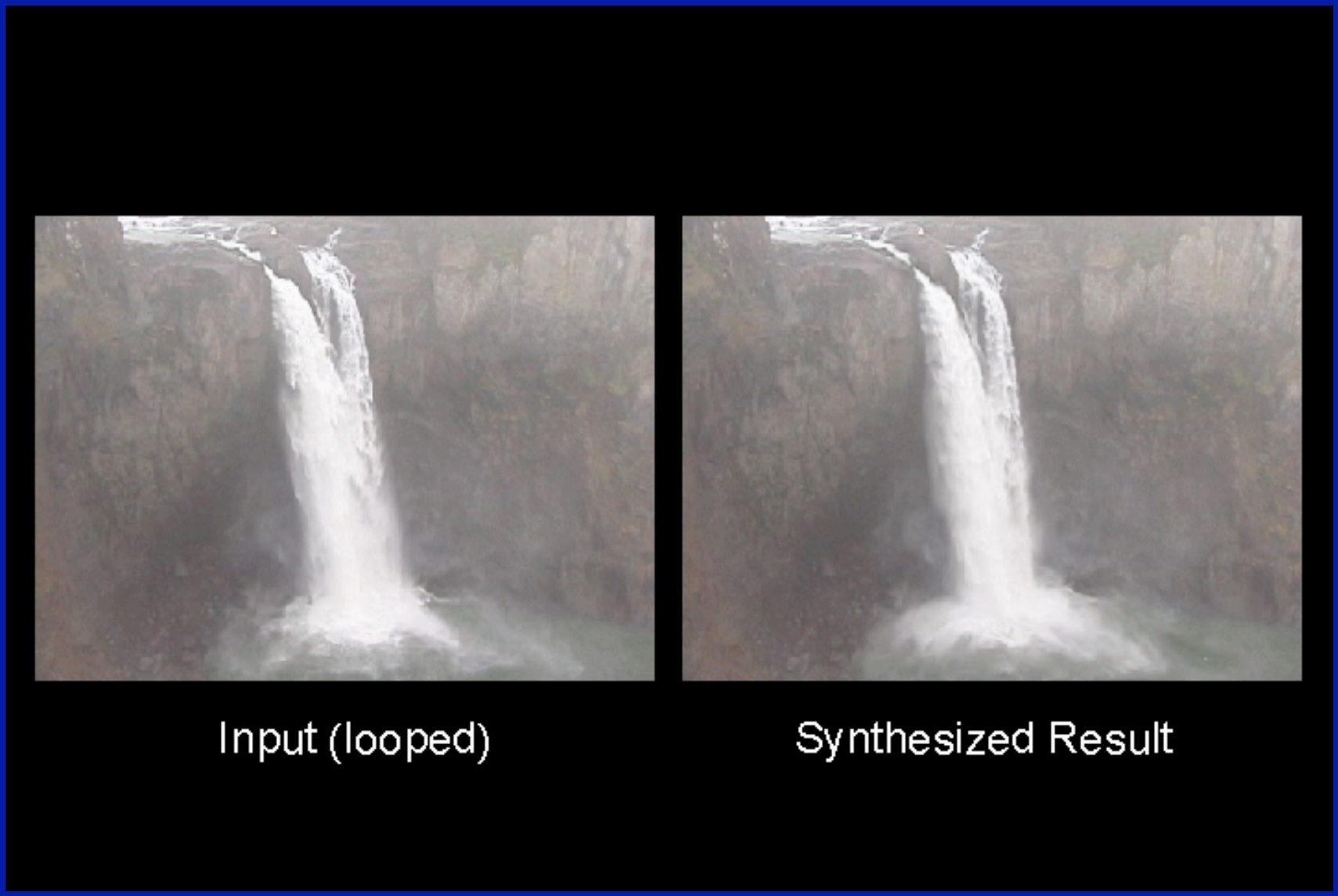
- Open example

Flow-Based Video Synthesis And Editing [Bhat04]

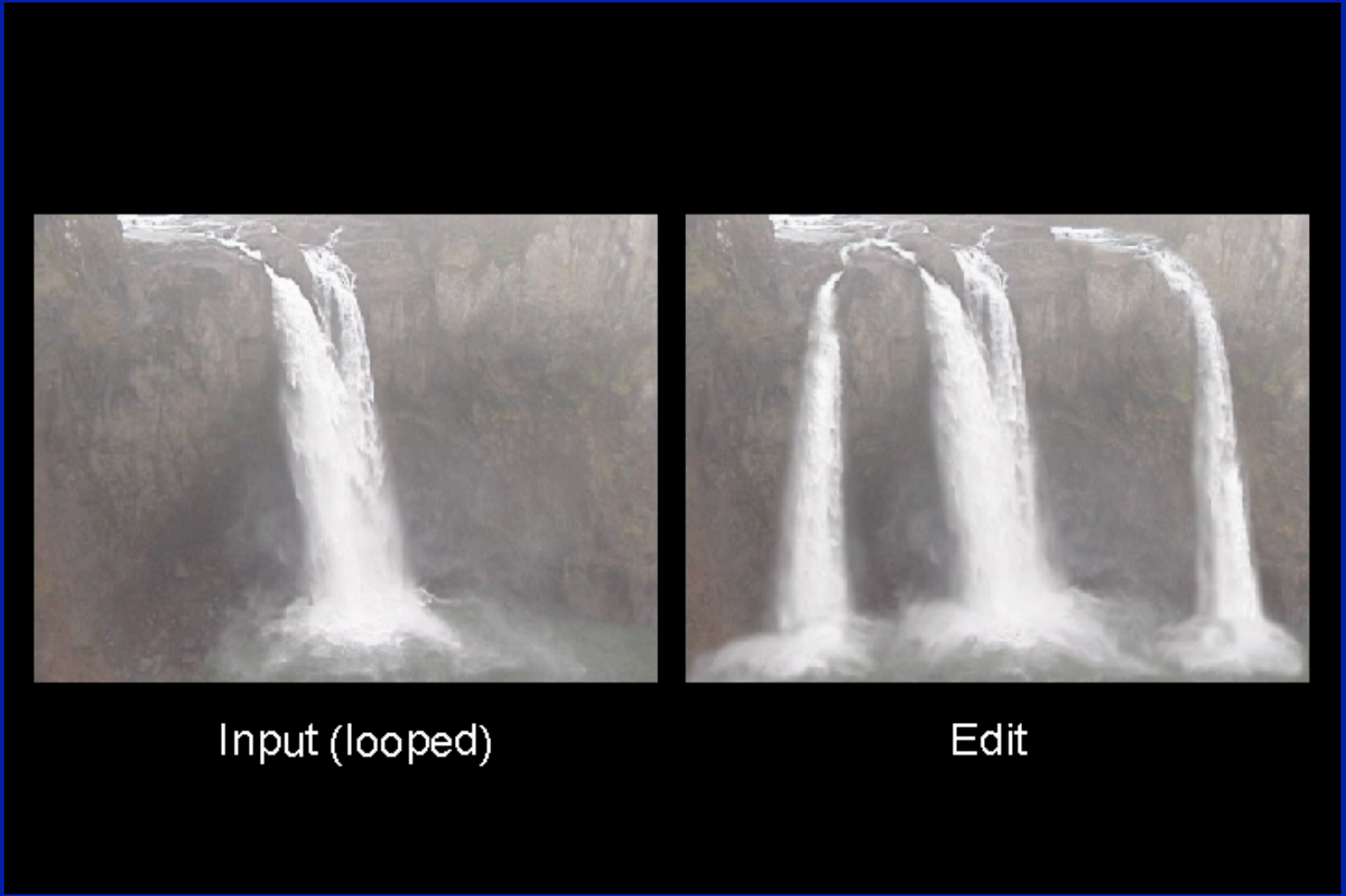
- Allows animator to easily create loops and variants of flowing natural phenomena (water,smoke,etc)
- Artist draws a set of flow lines on the original image
- Algorithm computes textures for a particle system that uses these flow lines
- Sequence of textures is transformed to prevent linear discontinuities
- Artist can then draw additional flow lines to create new variants



Flow-Based Synthesis (Example)



Flow-Based Synthesis (Example)



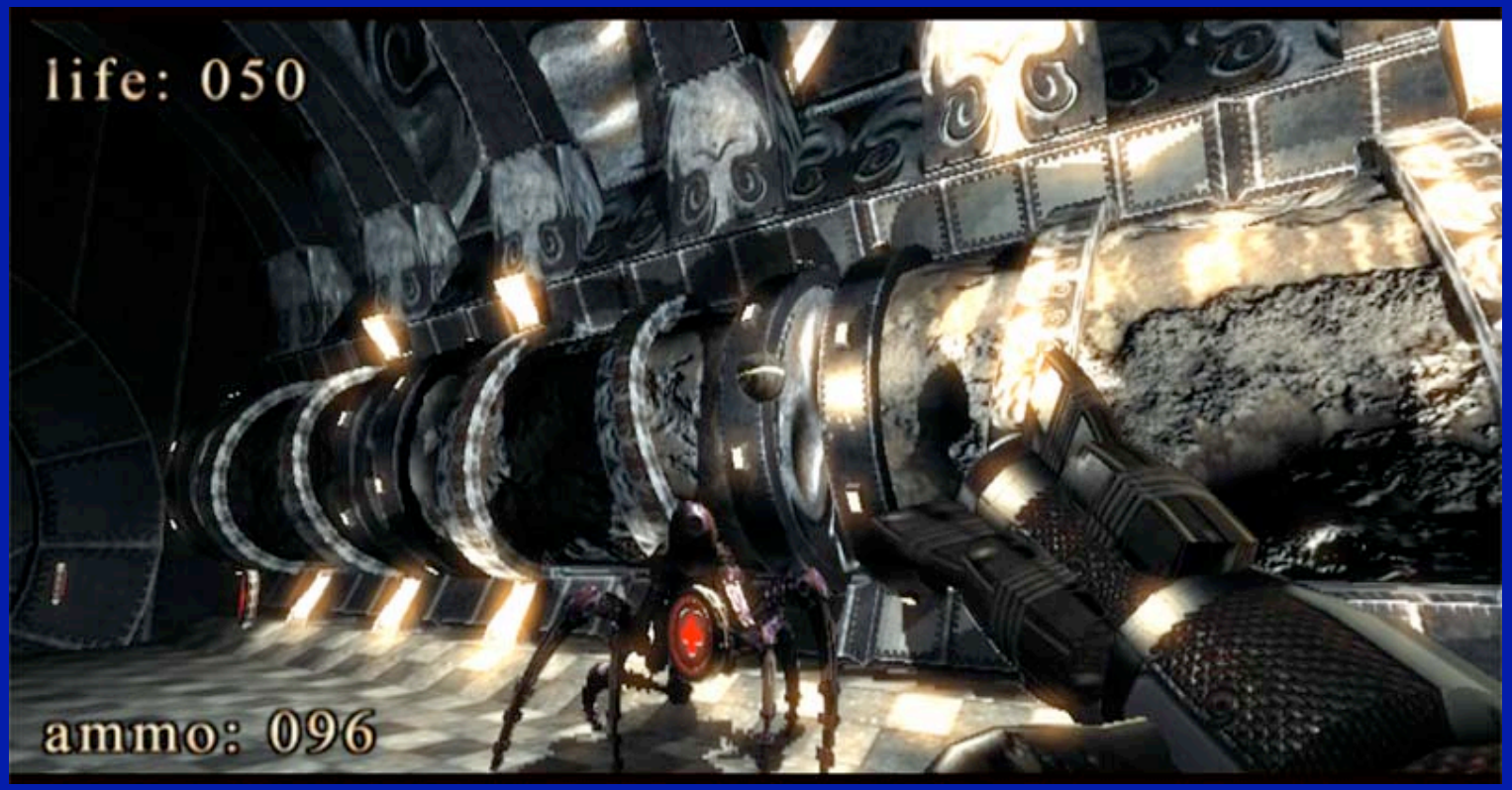
Procedural Content: Games

- Reduces cost of art assets
  - Current AAA title costs upwards of $10M
- Reduces download/storage size
- Reduces memory throughput to GPU
- Provides enhanced replayability

Games: Rogue-like

- All level layouts are procedurally generated
- Inspired games like Diablo, .hack, etc.

Games: .kkrieger



- Demoscene FPS game
- Total file size: 97,280 bytes

Games: Spore

- Multiple sub-games of creature/civilization gameplay
- Editors for creatures,buildings,vehicles
- Procedural behavior, animation, and texturing (driven by player-created models)

Spore E3 2006 Video

- Show video

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