

Procedural Modeling

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Modeling

- How do we ...
 - Represent 3D objects in a computer?
 - Construct such representations quickly and/or automatically with a computer?
 - Manipulate 3D objects with a computer?



H&B Figure 10.79



Fowler



H&B Figure 10.83b

Modeling

- How do we ...
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 - **Construct such representations quickly and/or automatically with a computer?**
 - Manipulate 3D objects with a computer?



H&B Figure 10.79



Fowler



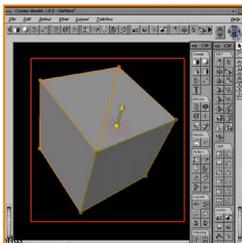
H&B Figure 10.83b

Model Construction

- Interactive modeling tools
 - CAD programs
 - Subdivision surface editors :)
- Scanning tools
 - CAT, MRI, laser, magnetic, robotic arm, etc.
- Computer vision
 - Stereo, motion, etc.
- Procedural generation
 - Sweeps, fractals, grammars

Interactive Modeling Tools

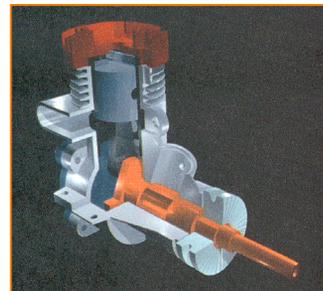
- User constructs objects with drawing program
 - Menu commands, direct manipulation, etc.
 - CSG, parametric surfaces, quadrics, etc.



Cosmoworlds, SGI

Interactive Modeling Tools

- Example: Mechanical CAD



H&B Figure 9.9

Model Construction

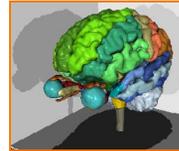


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Scanning tools



- Acquire geometry of objects with active sensors
 - CAT/MRI
 - Laser range scanner
 - Magnetic sensor
 - Robotic arm
 - etc.



Loresen

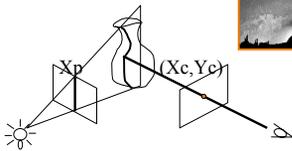


Stanford Graphics Laboratory

Scanning tools



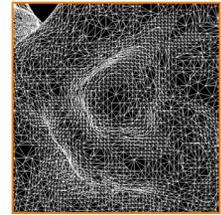
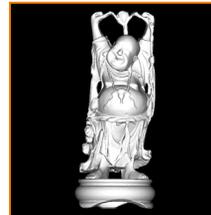
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 - etc.



Laser Range Scanning



- Example: 70 scans
 - Volumetric reconstruction



Stanford Graphics Laboratory

Scanning tools



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Scanning tools



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Model Construction

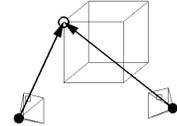


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Computer Vision



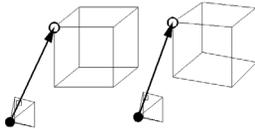
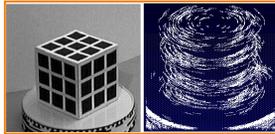
- Infer 3D geometry from images
 - Stereo
 - Motion
 - Constraints
 - etc.



Computer Vision



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Computer Vision



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Debevec96

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Procedural Modeling



- Goal:
 - Describe 3D models algorithmically
- Best for models resulting from ...
 - Repeating processes
 - Self-similar processes
 - Random processes
- Advantages:
 - Automatic generation
 - Concise representation
 - Parameterized classes of models

Procedural Modeling

- Sweeps
- Fractals
- Grammars



Example: Seashells

- Create 3D polygonal surface models of seashells

"Modeling Seashells,"
Deborah Fowler, Hans Meinhardt,
and Przemyslaw Prusinkiewicz,
Computer Graphics (SIGGRAPH 92),
Chicago, Illinois, July, 1992, p 379-387.



Fowler et al. Figure 7

Example: Seashells

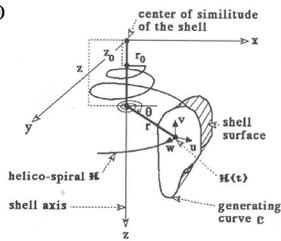
- Sweep generating curve around helico-spiral axis

Helico-spiral definition:

$$\Theta_{i+1} = \Theta_i + \Delta\Theta$$

$$r_{i+1} = r_i \lambda_r$$

$$z_{i+1} = z_i \lambda_z$$



Fowler et al. Figure 1

Example: Seashells

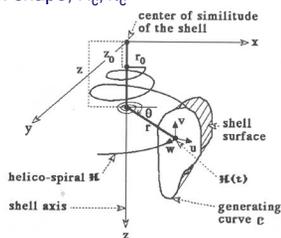
- Connect adjacent points to form polygonal mesh



Fowler et al. Figure 6

Example: Seashells

- Model is parameterized:
 - Helico-spiral: $z_0, \lambda_z, r_0, \lambda_r, N_0, \Delta\Theta$
 - Generating curve: shape, N_c, λ_c



Fowler et al. Figure 1

Example: Seashells

- Generate different shells by varying parameters



Different helico-spirals

Fowler et al. Figure 2

Example: Seashells



- Generate different shells by varying parameters



Different generating curves

Fowler et al. Figure 3

Example: Seashells



Generate many interesting shells with a simple procedural model!!



Fowler et al. Figures 4,5,7

Procedural Modeling



- Sweeps
- **Fractals**
- Grammars

Fractals



- Defining property:
 - Self-similar with infinite resolution



Mandelbrot Set

H&B Figure 10.100

Fractals



- Useful for describing natural 3D phenomenon
 - Terrain
 - Plants
 - Clouds
 - Water
 - Feathers
 - Fur
 - etc.



H&B Figure 10.80

Fractal Generation

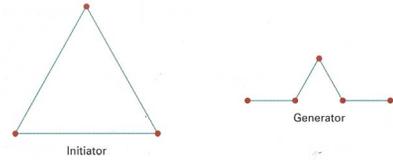


- Deterministically self-similar fractals
 - Parts are scaled copies of original
- Statistically self-similar fractals
 - Parts have same statistical properties as original

Deterministic Fractal Generation



- General procedure:
 - Initiator: start with a shape
 - Generator: replace subparts with scaled copy of original

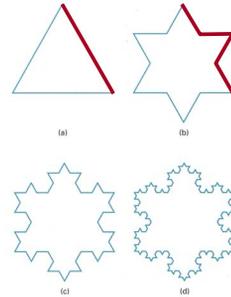


H&B Figure 10.68

Deterministic Fractal Generation



- Apply generator repeatedly

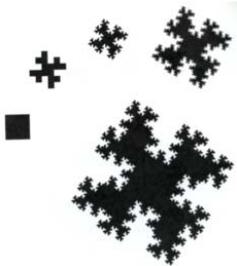


Koch Curve
H&B Figure 10.69

Deterministic Fractal Generation



- Useful for creating interesting shapes!

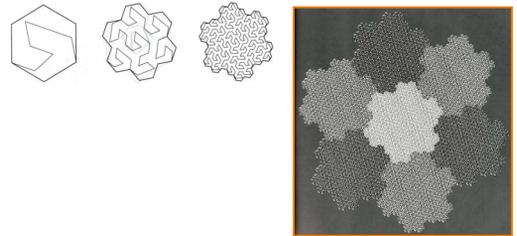


Mandelbrot Figure X

Deterministic Fractal Generation



- Useful for creating interesting shapes!

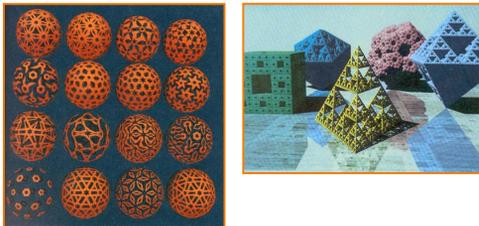


Mandelbrot Figure 46

Deterministic Fractal Generation



- Useful for creating interesting shapes!



H&B Figures 75 & 109

Fractal Generation

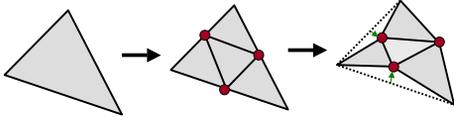


- Deterministically self-similar fractals
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Statistical Fractal Generation



- General procedure:
 - Initiator: start with a shape
 - Generator: replace subparts with a self-similar **random pattern**

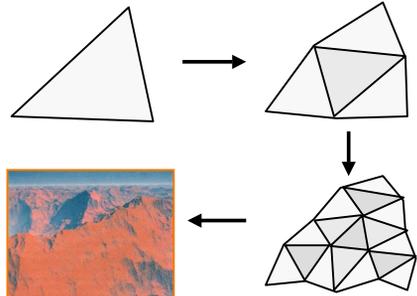


Random Midpoint Displacement

Statistical Fractal Generation



- Example: terrain



H&B Figure 10.83b

Statistical Fractal Generation



- Useful for creating mountains



H&B Figure 10.83a

Statistical Fractal Generation



- Useful for creating 3D plants

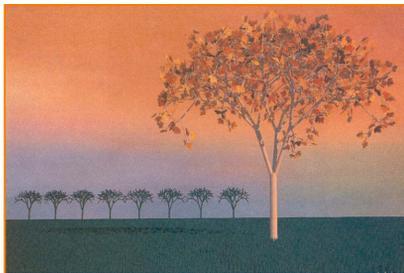


H&B Figure 10.82

Statistical Fractal Generation



- Useful for creating 3D plants



H&B Figure 10.79

Procedural Modeling



- Sweeps
- Fractals
- **Grammars**

Grammars



- Generate description of geometric model by applying production rules

$S \rightarrow AB$
$A \rightarrow Ba \mid a$
$B \rightarrow Ab \mid b$

ab
bab
baab
abaab
.
.
.

Grammars

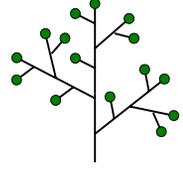


- Useful for creating plants

Tree \rightarrow Branch Tree \mid Leaf
Branch \rightarrow Cylinder \mid [Tree]



$C[CL]C[C[CL]][CL]C[[CL][CL]]$

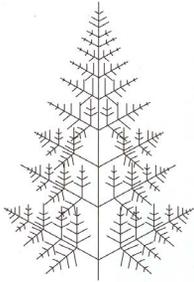


$C[*]C[*][*]$

Grammars



- Useful for creating plants



H&B Figure 10.77

Summary



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**Constructing
3D models
is hard!**



Jurassic Park