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Model Construction

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Princeton University
C0S 426, Fall 2001

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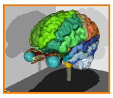
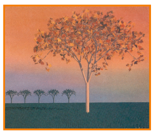
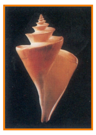
Modeling

- 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?


Lorensen


H&B Figure 10.79


Fowler


H&B Figure 10.83b

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Modeling

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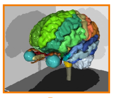
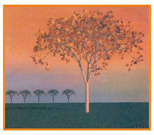
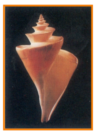
  - **Construct such representations quickly and/or automatically with a computer?**
  - Manipulate 3D objects with a computer?


Lorensen


H&B Figure 10.79


Fowler


H&B Figure 10.83b

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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

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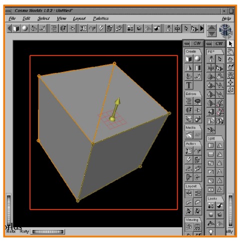
Interactive Modeling Tools

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


Cosmoworlds, SGI

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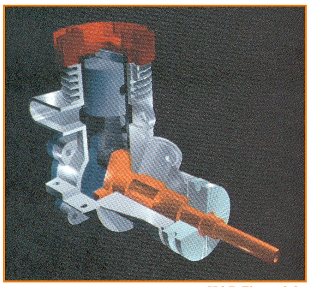
Interactive Modeling Tools

- Example: Mechanical CAD


H&B Figure 9.9

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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.

Stanford Graphics Laboratory

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Scanning tools

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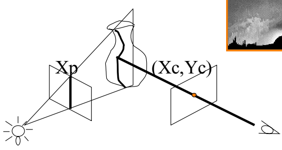

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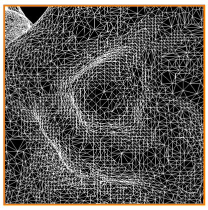
Laser Range Scanning

- Example: 70 scans
  - Volumetric reconstruction



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Scanning tools

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Scanning tools

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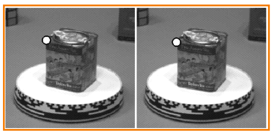
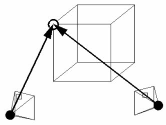
Computer Vision

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





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Computer Vision

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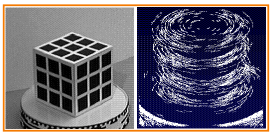

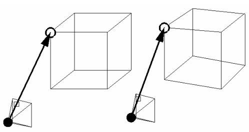

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Computer Vision

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Debevec96

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Model Construction

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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

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Procedural Modeling

- Sweeps
- Fractals
- Grammars

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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

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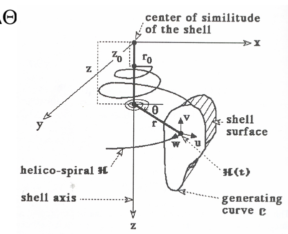
Example: Seashells

- 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

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Example: Seashells

- Connect adjacent points to form polygonal mesh

Fowler et al. Figure 6

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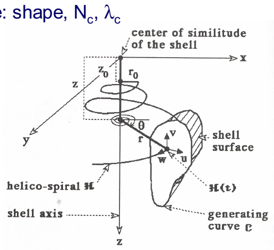
Example: Seashells

- Model is parameterized:
  - Helico-spiral: z_0, λ_z, r_0, λ_r, N_θ, $\Delta\theta$
  - Generating curve: shape, N_c, λ_c



Fowler et al. Figure 1

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Example: Seashells

- Generate different shells by varying parameters

Different helico-spirals

Fowler et al. Figure 2

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Example: Seashells

- Generate different shells by varying parameters

Different generating curves

Fowler et al. Figure 3

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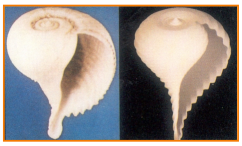
Example: Seashells

Generate many interesting shells with a simple procedural model!



Fowler et al. Figures 4,5,7

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Procedural Modeling

- Sweeps
- Fractals
- Grammars

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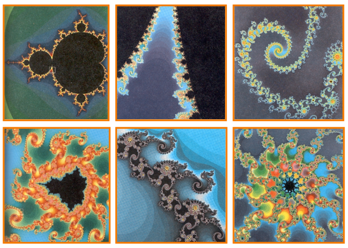
Fractals

- Defining property:
  - Self-similar with infinite resolution



Mandelbrot Set

H&B Figure 10.100

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Fractals

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

H&B Figure 10.80

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Fractal Generation

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

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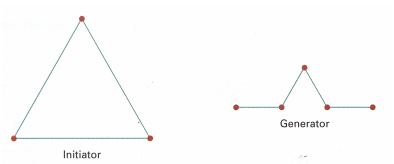
Deterministic Fractal Generation

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



H&B Figure 10.68

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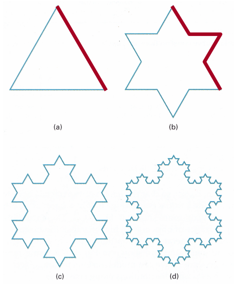
Deterministic Fractal Generation

- Apply generator repeatedly



Koch Curve

H&B Figure 10.69

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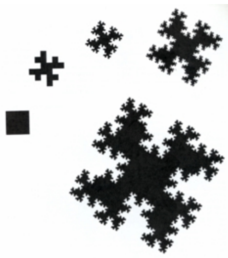
Deterministic Fractal Generation

- Useful for creating interesting shapes!



Mandelbrot Figure X

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Deterministic Fractal Generation

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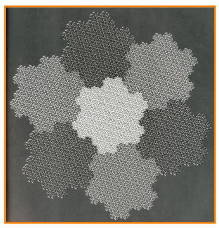

Mandelbrot Figure 46

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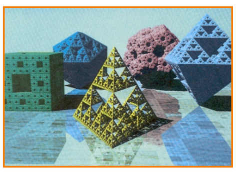
Deterministic Fractal Generation

- Useful for creating interesting shapes!



H&B Figures 75 & 109

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Fractal Generation

- Deterministically self-similar fractals
  - Parts are scaled copies of original

- Statistically self-similar fractals
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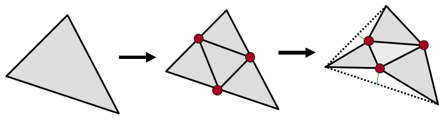
Statistical Fractal Generation

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



Random Midpoint Displacement

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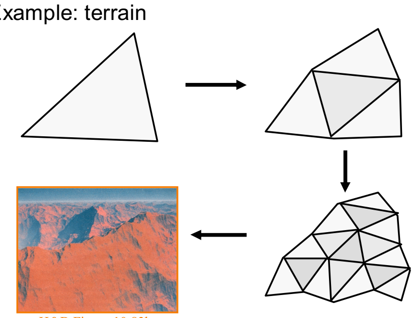
Statistical Fractal Generation

- Example: terrain



H&B Figure 10.83b

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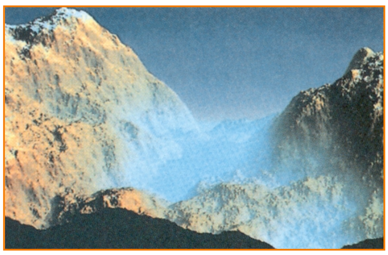
Statistical Fractal Generation

- Useful for creating mountains



H&B Figure 10.83a

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Statistical Fractal Generation

- Useful for creating 3D plants

H&B Figure 10.82

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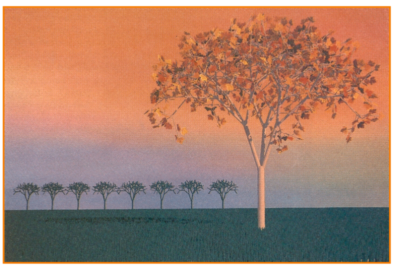
Statistical Fractal Generation

- Useful for creating 3D plants



H&B Figure 10.79

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Procedural Modeling

- Sweeps
- Fractals
- Grammars

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Grammars

- Generate description of geometric model by applying production rules

S → AB
A → Ba | a
B → Ab | b

ab
bab
baab
abaab
.
.
.

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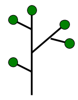
Grammars

- Useful for creating plants

Tree → Branch Tree | Leaf
Branch → Cylinder | [Tree]



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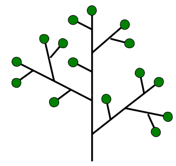

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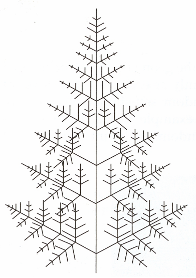
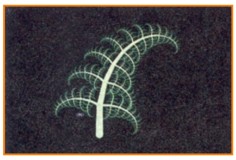
45

Grammars

- Useful for creating plants





H&B Figure 10.77

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Summary

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Constructing 3D models is hard!

Jurasic Park