Procedural Modeling

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C0S 426, Fall 1999

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.

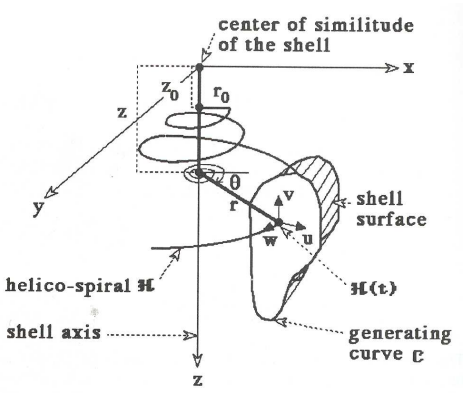
Fowler et al. Figure 7

Example: Seashells

- Sweep generating curve around helico-spiral axis

Helico-spiral definition:

$$\Theta_{i+1} = \Theta_i + \Delta\Theta$$
$$r_{i+1} = r_i \lambda_r$$
$$z_{i+1} = z_i \lambda_z$$



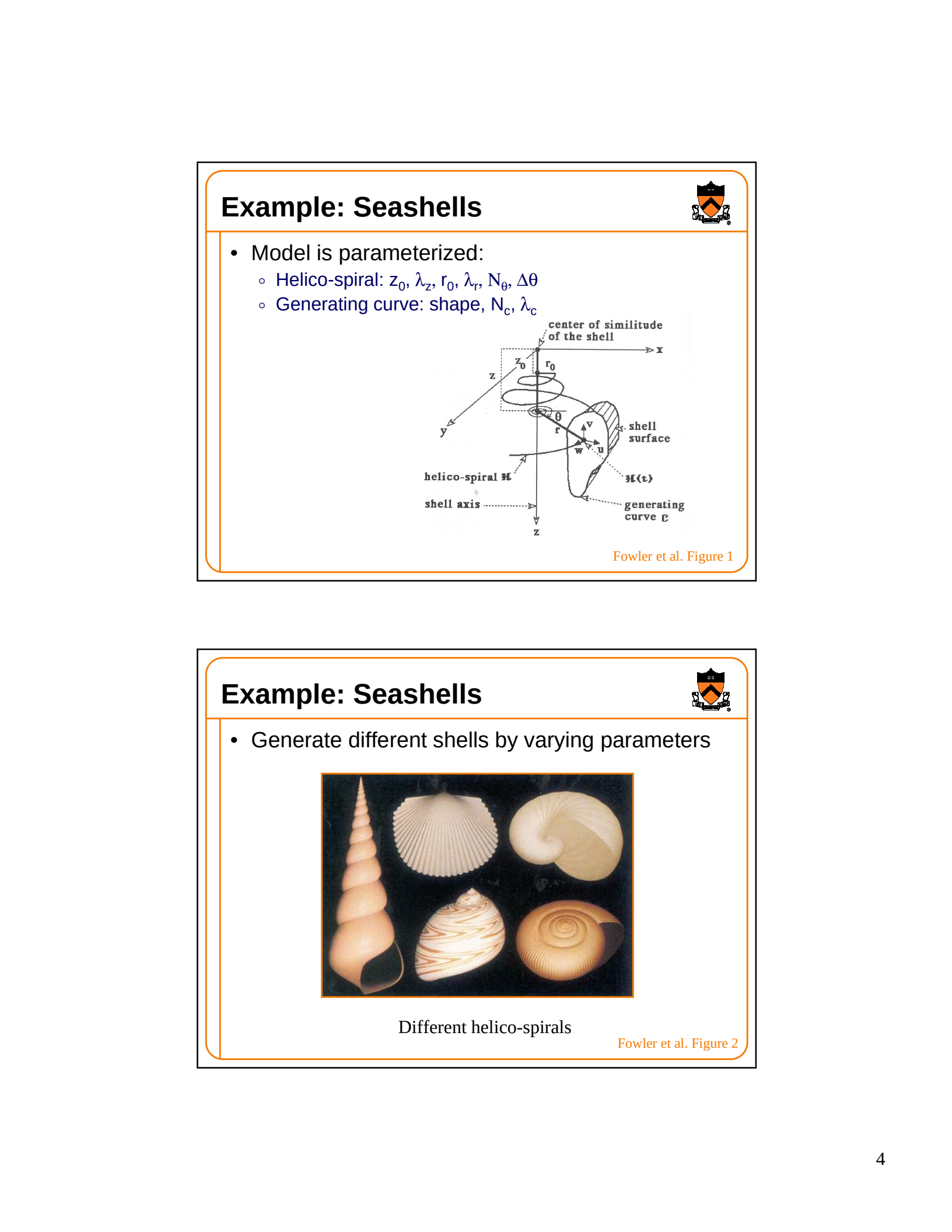
Fowler et al. Figure 1

Example: Seashells

- Connect adjacent points to form polygonal mesh

Fowler et al. Figure 6

Example: Seashells



- Model is parameterized:
  - Helico-spiral: z_0, λ_z, r_0, λ_r, N_θ, $\Delta\theta$
  - 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

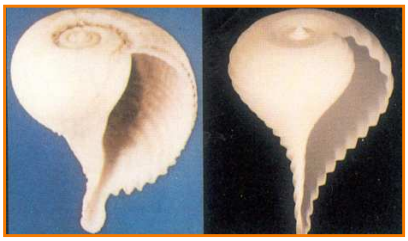
- Generate different shells by varying parameters

Different generating curves

Fowler et al. Figure 3

Example: Seashells

Generate many interesting shells with a simple procedural model!



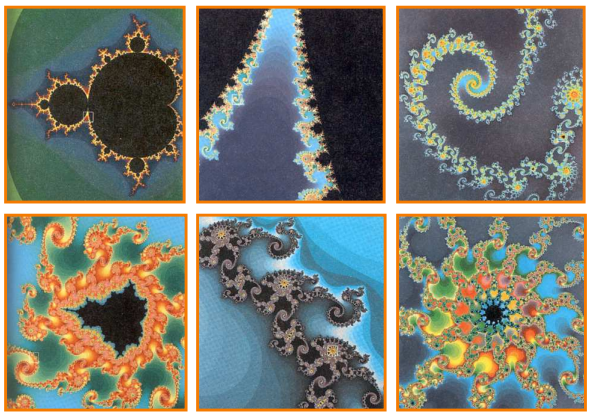
Fowler et al. Figures 4,5,7

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.

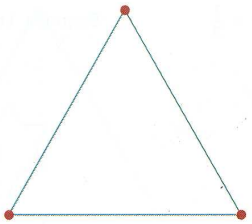
H&B Figure 10.80

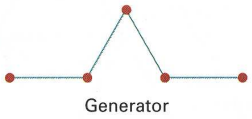
Fractal Generation

- 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

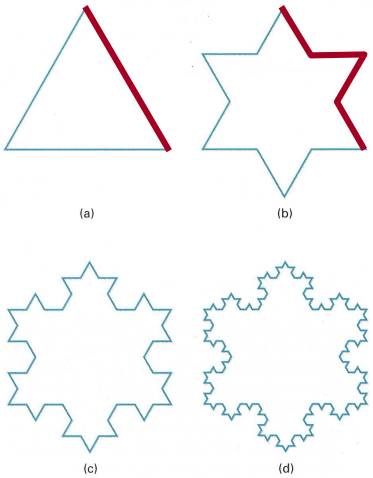




H&B Figure 10.68

Deterministic Fractal Generation

- Apply generator repeatedly

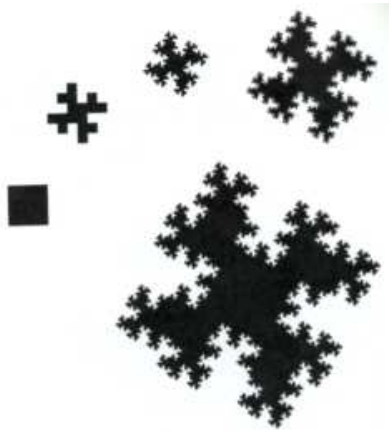


Koch Curve

H&B Figure 10.69

Deterministic Fractal Generation

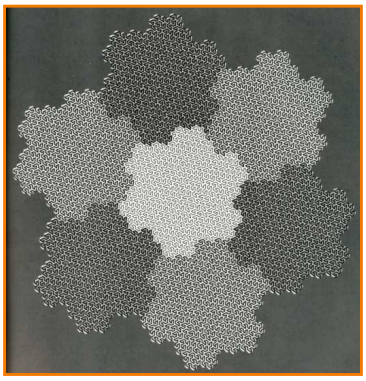
- Useful for creating interesting shapes!



Mandelbrot Figure X

Deterministic Fractal Generation

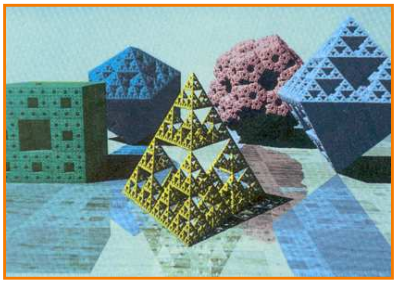
- Useful for creating interesting shapes!



Mandelbrot Figure 46

Deterministic Fractal Generation

- Useful for creating interesting shapes!



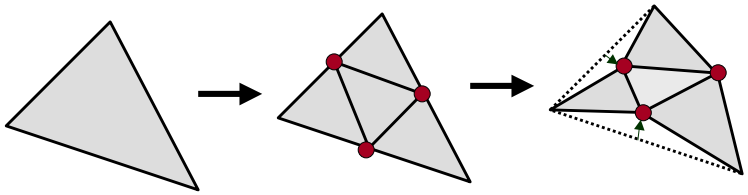
H&B Figures 75 & 109

Fractal Generation

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

Statistical Fractal Generation

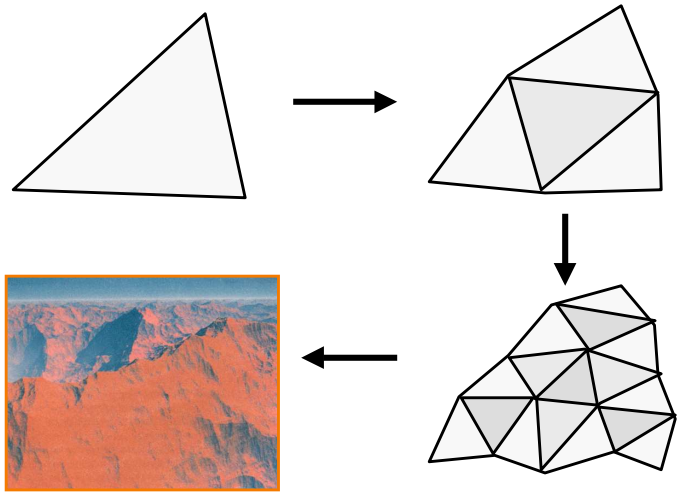
- General procedure:
  - Initiator: start with a shape
  - Generator: replace subparts with a self-similar random pattern



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

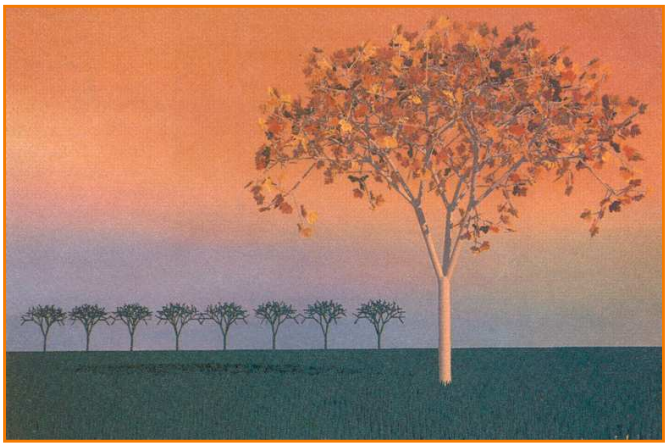
Statistical Fractal Generation

- 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

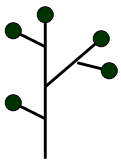
$S \rightarrow AB$
$A \rightarrow Ba \mid a$
$B \rightarrow Ab \mid b$

ab
bab
baab
abaab
.
.
.

Grammars

- Useful for creating plants

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



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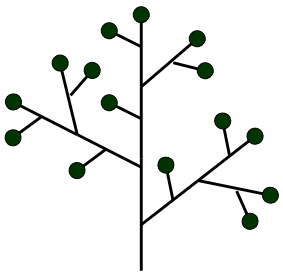

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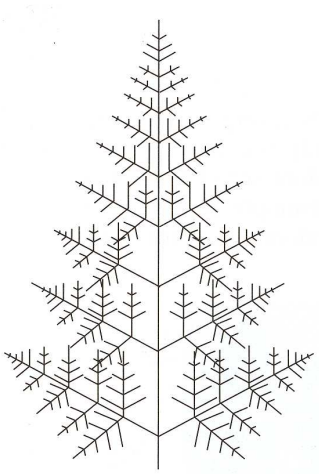
Grammars

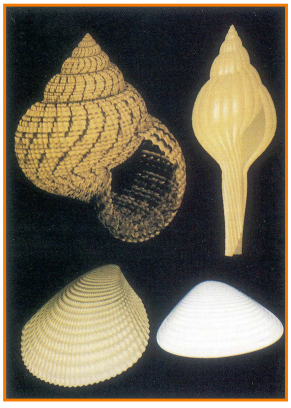
- Useful for creating plants



H&B Figure 10.77

Summary

- Procedural modeling
  - Sweeps
  - Fractals
  - Grammars
  - Others
- Features
  - Automatic
  - Concise
  - Parameterized
- Applications
  - Modeling geometry resulting from processes that can be simulated algorithmically



Fowler et al. Figure 10