



# Procedural Modeling

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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



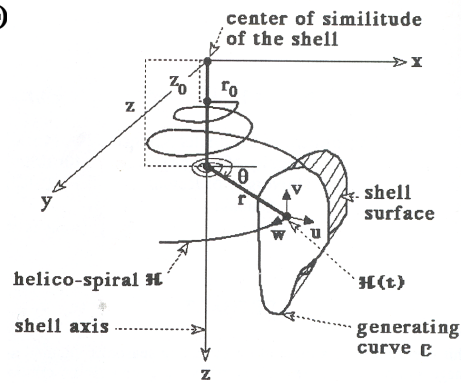
- Sweep generating curve around helico-spiral axis

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

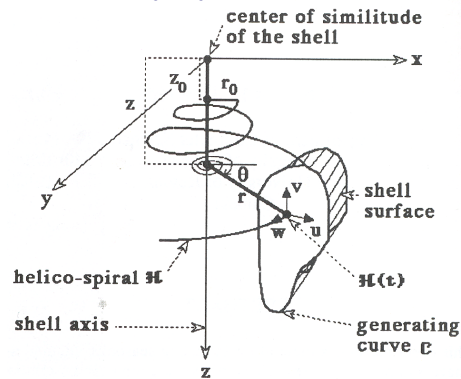


Fowler et al. Figure 6

## Example: Seashells



- Model is parameterized:
  - Helico-spiral:  $z_0, \lambda_z, r_0, \lambda_r, N_\theta, \Delta\theta$
  - Generating curve: shape,  $N_c, \lambda_c$



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



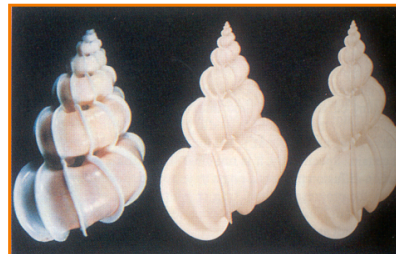
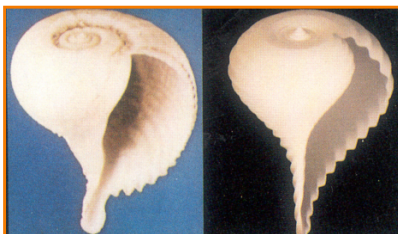
Different generating curves

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

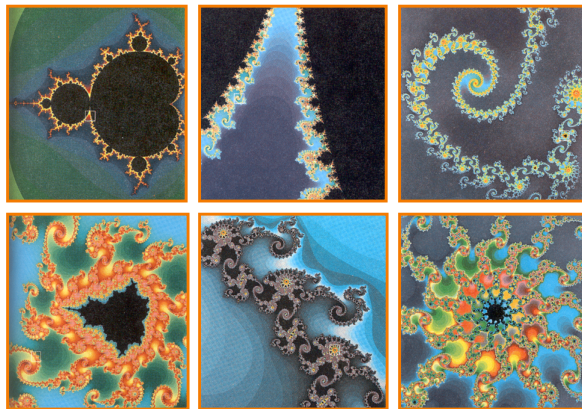


- Sweeps
- **Fractals**
- Grammars

## 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

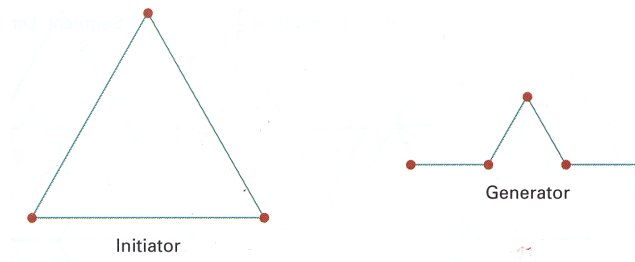


- Deterministically self-similar fractals
  - Parts are scaled copies of original
- Statistically self-similar fractals
  - Parts have same statistical properties as original

## Deterministic Fractal Generation



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

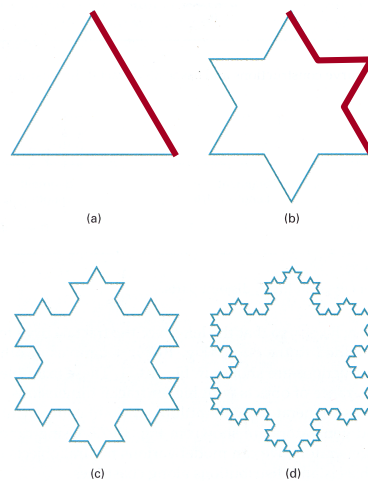


H&B Figure 10.68

## Deterministic Fractal Generation



- Apply generator repeatedly



Koch Curve

H&B Figure 10.69

## Deterministic Fractal Generation



- Useful for creating interesting shapes!

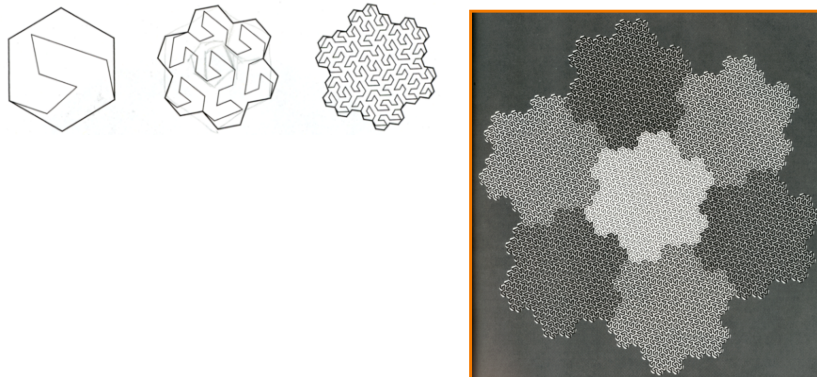


Mandelbrot Figure X

## Deterministic Fractal Generation



- Useful for creating interesting shapes!

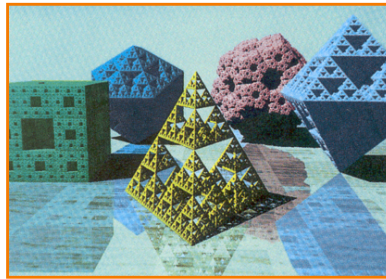
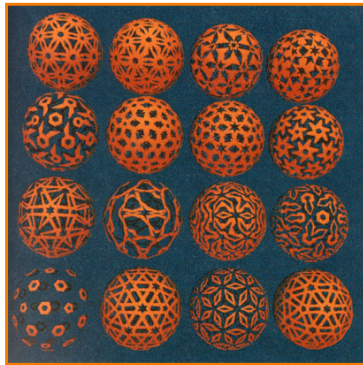


Mandelbrot Figure 46

## Deterministic Fractal Generation



- Useful for creating interesting shapes!



H&B Figures 75 & 109

## Fractal Generation

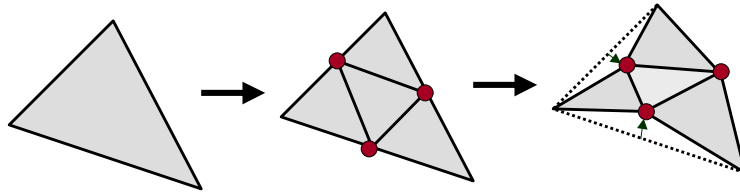


- Deterministically self-similar fractals
  - Parts are scaled copies of original
- Statistically self-similar fractals
  - Parts have same statistical properties as original

## Statistical Fractal Generation



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

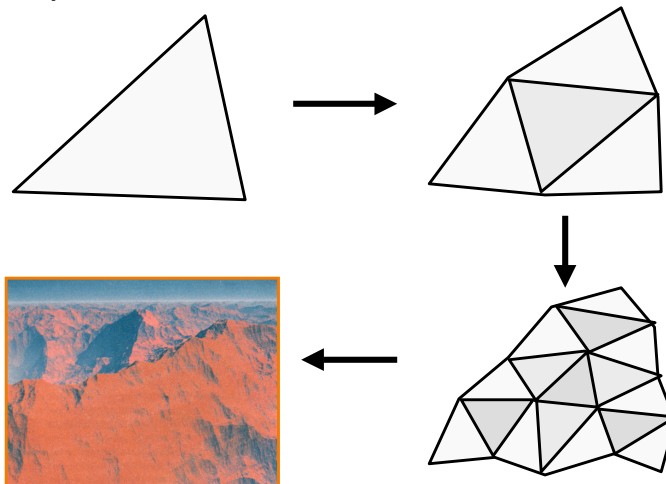


Random Midpoint Displacement

## 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

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

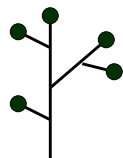
ab  
 bab  
 baab  
 abaab  
 .  
 .  
 .

## Grammars

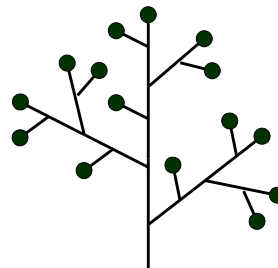


- Useful for creating plants

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



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

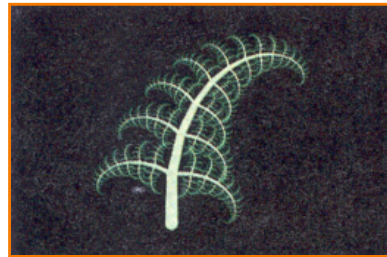
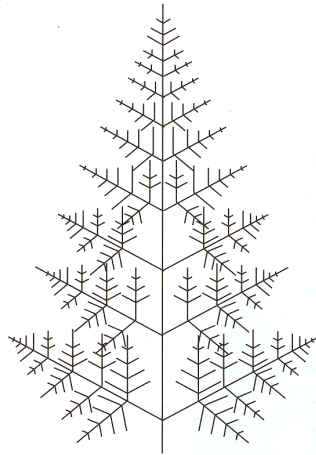


$C[*]C[*][*]$

## Grammars



- Useful for creating plants

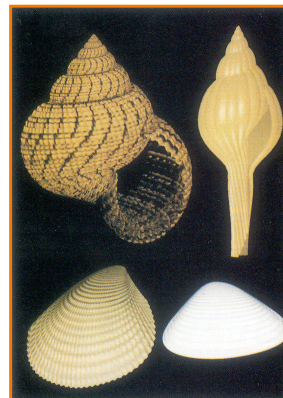


H&B Figure 10.77

## Summary



- 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