Module IV:
Art and Images

Representing Images Algorithmically:
Self-Similarity

Learning Goals [2 classes]
you should be able to

• define the term "self-similarity" and recognize self-similar structures in images and in nature
• simulate the progression of simple self-similar systems
• describe contributions of self-similar models to computer graphics and to the study of plants

Representing Images Algorithmically

example

• initiate: start with a (simple geometric) image
• generate:
  • find every piece in the image that matches the left side of the rule below
  • replace every such piece by the right side of the rule (rotated/resized to fit where the old piece was)

apply the algorithm

• draw the following initiator on a sheet of paper

• draw the result of applying the algorithm once to the initiator
• draw the result of applying the algorithm again to the result
Representing Images Algorithmically

**example**

- **initiate**: start with a (simple geometric) image
- **generate**:
  - find every piece in the image that matches the *left* side of the rule below
  - replace every such piece by the *right* side of the rule (rotated/resized to fit where the old piece was)

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**Exercise: Apply the Algorithm**

- draw the following *initiator* on your sheet of paper

![Initiator](image1)

- draw the result of applying the algorithm once to the initiator
- draw the result of applying the algorithm *again* to the result

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**Self-Similarity**

“when each piece of a shape is geometrically similar to the whole, both the shape and the cascade that generate it are called self-similar”

– Benoît Mandelbrot

![Self-Similarity](image2)

Sierpinski triangle
(four iterations)
Self-Similarity in Nature

Section of the Coast
Mountains– Google Maps

“...a new method for reconstructing the three-dimensional architecture of the human genome reveals a polymer analog of Hilbert’s curve at the megabase scale”
– Science magazine, Oct 2009

Self-Similarity in Art

repetitive patterns are self-similar

Kasai textile

Islamic Pattern
britton.disted.camosun.bc.ca/islam.pdf

see examples of work by
• Anne Erpino  www.annerpino.com
  • Science series: “Silent night”, “Wings”
  • Janet Park  www.infinite-art.com
Representing Images Algorithmically

another example

- **initiate**: start with a (simple geometric) image
- **generate**:
  - find every piece in the image that matches the *left* side of the rule below
  - replace every such piece by the *right* side of the rule (rotated/resized to fit where the old piece was)

```
  _____  ____________  
  |     |            |     
  |     |            |     
  |     |            |     
  |______|            |______|
```

Exercise: Apply the Algorithm

- draw the following *initiator* on your sheet of paper

```
  _____  ____________  
  |     |            |     
  |     |            |     
  |     |            |     
  |______|            |______|
```

- draw the result of applying the algorithm once to the initiator
- draw the result of applying the algorithm *again* to the result

Self-Similarity

“when each piece of a shape is geometrically similar to the whole, both the shape and the cascade that generate it are called self-similar”
– Benoit Mandelbrot

Koch snowflake (four iterations)

Self-Similarity in Plants

“two […] factors that organize plant structures and therefore contribute to their beauty [are] *developmental algorithms*, that is, the rules which describe plant development over time [and] *self-similarity*”
A Self-Similar System: Tree Structure

initiator

generators

G: (green)

B: (brown)

Self-Similar Systems

generators

seven levels of application

Connecting with Computer Science | cs.ubc.ca/~hoos/cpsc101
Self-Similar Systems

**enhancements**

- allow random choices among generators
- model (3D) arrangements of branches
- incorporate models of flowers, leaves, etc.
- add timing to obtain animation of model development

**random selection of generators**

 initiator: 

generators: 

G1: 

at each application of the generator, choose G1, G2 or G3 with equal probability

G2: 

G3: 

**random selection of generators: results**

**add buds and flowers**

- bud
- flower
- young fruit
- old fruit
**Self-Similar Systems**

*add buds and flowers*

**Self-Similar Systems**

*exercise: what structure is produced?*

**Self-Similar Systems**

*exercise: which produces the rose campion?*
Self-Similar Systems

corrections to computer graphics

• self-similar representations of natural phenomena, e.g., plants, coastlines, mountains
  • are highly compact, i.e., require a low number of bits
  • have nice scaling properties: when you zoom in, you can see more detail in a natural way
  • naturally support modeling of plant development

• Loren Carpenter created the world's first film based on self-similarity (1980):
  • kottke.org/09/07/vol-libre-an-amazing-cg-film-from-1980
  • self-similar representations have been used in movies since the early ‘80’s
  • fractal planet in the Genesis Sequence of Star Trek 2, the Wrath of Khan was created by the LucasFilm division of Pixar

Self-Similar Systems

corrections to botany

• self-similar systems have been used to
  • generate flowering structures we don’t see in nature
  • identify a unifying model which encompasses just those flowering structures found in nature
  • model and understand effects of environment on plants (e.g., growth as a function of light)

• structures D, E, F are seen in nature; examples are G, H, J respectively

Self-Similar Systems

contributions to botany

- structures A, B, C are not seen in nature

Self-Similar Systems

people

- Przemyslaw Prusinkiewicz ("Dr. P") at U. Calgary has applied self-similar systems both to plant science and computer graphics:
  - see., e.g., “Evolution and Development of Inflorescence Architectures” *Science* 316 (2007)
  - winner of the 1997 Computer Graphics Achievement Award
  - see also Dr. P’s Algorithmic Botany Lab: algorithmicbotany.org