L-Systems
Procedural Modeling

Idea: Detailed meshes are hard to build by hand, so let’s create a function that builds out meshes for us.

Same idea as Perlin noise but in 3D!
Another Example: Fractals

Iterated function system leads to infinite detail
4D Fractals

Can be created using quaternions

https://www.youtube.com/watch?v=eS7qCfttmBk
Turtle Graphics

• Graphics system implemented in LOGO (1967)
• Cursor is “turtle” with position and orientation
• Code moves turtle, creating a line trail
Turtle Graphics

Simple code generates very complex results
L-Systems

- Recursive definition of an object using a string rewriting system and formal grammar
- Invented by botanist, Aristid Lindenmayer
- Designed to model plants
- Przemyslaw Prusinkiewicz brought concepts to graphics
L-System Definition

**Axiom**: Starting string

**Variables**: Set of symbols to be rewritten according to rules

**Terminals**: Set of symbols that have no rewriting rules

**Rules**: Set of substitutions possible for variables
Using L-Systems in Graphics

1. Associate actions (e.g. draw line, rotate, etc) with each variable and terminal
2. Recursively expand the axiom $n$ times
   1. Execute actions of resulting string
   2. Generate image from string
Example: Koch Curve

Rule:
\[ F = F - F + + F - F \]

- \( F \): Draw line segment scaled by \( 1/3 \)
- \(-\): Turn 60° left
- \(+\): Turn 60° right
Example: 2D Tree

F – Move Forward
L0, L1, L2 – Draw Leaf
T – Draw Terminating Leaf
"+" – Turn Right
"-" – Turn Left
"[" – Push
"]" – Pop

Axiom: L0
1. L0 → F [ − F L1 ] F [ + F L2 ] F L0 (center branch)
2. L1 → F [ − F L1 ] F [ + F T ] F L1 (left half of tree)
Parameterized L-Systems

Action specified by symbol can be parameterized:
Parameterized L-Systems

Not just parameterized symbols!

• Randomized rule-selection
• Parameterization based on depth
• Changes in parameters over time
L-System Examples
SpeedTree

Leading vegetation generator:
http://www.speedtree.com/

https://www.youtube.com/watch?v=N2wmmdKzp8E

TreeIt (a free L-System I use):
http://www.evolved-software.com/treeit/treeit
Generating Cities

Same idea with different symbols and rules

• Good idea to having working understanding of the modeled system

https://graphics.ethz.ch/Downloads/Publications/Papers/2001/p_Par01.pdf
City Generation

What are the “rules” for generating a city?
City Generation

What are the “rules” for generating a city?

Based on terrain, types of buildings and plots, population, architecture style, and city history (i.e. planned versus sprawling)
Example: Home Free

https://www.youtube.com/watch?v=ahBSQrX1yOE
Example: Infamous
Additional Reading

http://algorithmicbotany.org/papers/graphical.gi86.pdf

http://algorithmicbotany.org/papers/