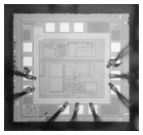
CS39N The Beauty and Joy of Computing

Lecture #11
Recursion III

2009-11-09

UC Berkeley Computer Science Lecturer SOE Dan Garcia

BATTERY-FREE IMPLANTABLE SENSOR



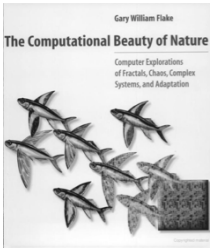
It has been a challenge to power electronic components implanted within a body. Researchers at UW have developed a new chip that needs less power, and can be powered from outside the body (1 meter away)

technologyreview.com/computing/23878

Lecture Overview

- Local vs Global drawing
- Example: Twig
- Example: C-Curve
- Lindenmayer (L) systems
  - Fibonacci & the golden mean
- Panspermia
- Summary

Great reference text!



Local vs Global Drawing

(394,27) pointing 48°

Goal: Draw a 100-length "+" from point (394,27) at 48°

- **Local (turtle) Drawing**
  - Concept of pen, sprite facing some direction
  - State! (where sprite ends)
  - Specify via local coords
  - Example
    - Move turtle to (394,27)
    - Face 48°
    - Pen down
    - Move 100
    - Pen up
    - Move -50
    - Turn right 90°
    - Move -50
    - Pen down
    - Move 100

"Turtle" Graphics invented by Papert

Scratch

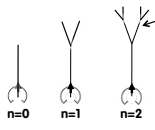
← Where sprite ends matters!

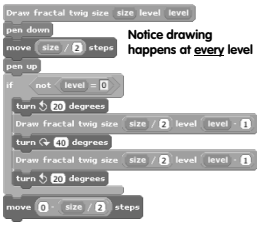
- **Global (god) Drawing**
  - No pen, just geometric primitives (DrawLine etc)
  - Stateless
  - Specify via global coords
  - Example
    - SW corner = (394,27)
    - Calculate NE corner
      - How? Simple trig, function of (394,27), 100, 48°
    - DrawLine (SW,NE)
    - Calculate NW corner
    - Calculate SE corner
    - DrawLine (NW,SE)

Example: Twig

- **Want to draw a twig**

Two copies of last recursion level rotated 20°



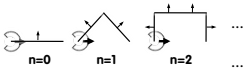


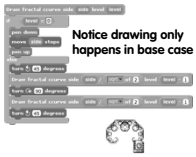
Notice drawing happens at every level

- Where does sprite end?
- Could add randomness
- Lots of variations
  - # branches
  - Angle

Example: C-curve, Dragon curve

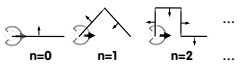
- **C-curve**
  - break a straight line up to form 90° angle
  - Left out, Right out

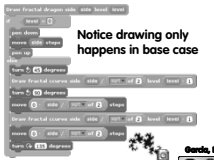




Notice drawing only happens in base case

- **Dragon curve**
  - break a straight line up to form 90° angle
  - Left out, Right in

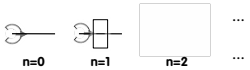


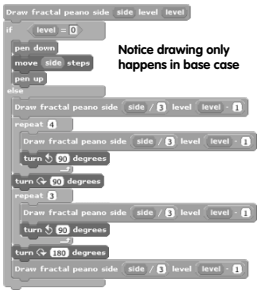


Notice drawing only happens in base case

Example: Peano Curve

- **Simple rewrite rule**
  - Replace every straight line w/9 smaller lines, each a third the size (like an 8 with side lines)





Notice drawing only happens in base case

- **As n→∞, notice…**
  - Space-filling!
  - Converging shape?

Lindenmayer (L) systems

- **Rewriting system for**
  - Modeling plant growth
  - Generating fractals, languages, …
- **Basics**
  - Variables (replaced each level)
  - Constants (not replaced)
  - Start (i.e., base case)
  - Rewrite rules (Recursive case)
  - **Example: Fibonacci**

Variables: A B

Start: A

Rules: (A → B, B → AB)

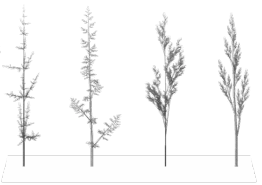
n = 0 : A (1)
n = 1 : B (1)
n = 2 : AB (2)
n = 3 : BAB (3)
n = 4 : ABBAB (5)
n = 5 : BABABBAB (8)
n = 6 : ABBABBABABBAB (13)
n = 7 : BABABBABABBABABBABAB (21)

- **Example: Dragon Curve**
  - Variables : X Y
  - Constants : F + −
  - Start: FX
  - Rules (angle : 90°)
    - (X → X+YF)
    - (Y → FX-Y)
      - F means "draw forward"
      - - means "turn left 90°"
      - + means "turn right 90°".
      - X and Y do not correspond to any drawing action and are only used to control the evolution of the curve

Panspermia

- **panspermia** /panˈspərmēə/
  - the theory that life on the earth originated from microorganisms or chemical precursors of life present in outer space and able to initiate life on reaching a suitable environment
- **Also, 1990 film by Karl Sims (famous computer graphics research and artist)**
  - "Attempts were made to bring together several concepts: chaos, complexity, evolution, self propagating entities, and the nature of life itself."

Scenes from Panspermia



L-systems plant growth

Summary

- **Fractals can model coastlines, clouds, plants, trees, natural growth**
  - Fibonacci 1st to see this
- **When authoring fractals, make sure you're clear when pen goes up/down and where begins/ends**
  - Scratch has Turtle graphics
- **Infinite recursion = fun**