Experimenting with Grammars to Generate L-Systems

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L-Systems

- Model biological systems and create fractals
- Similar to Chomsky grammars, except all variables are replaced in each step, not just one!
- Successive strings are interpreted as strings of render commands and displayed graphically

English Grammar

- `<sentence>` $\rightarrow$ `<subject>` `<verb>` `<direct obj>`
- `<subject>` $\rightarrow$ `<noun>` $|$ `<article>` `<noun>`
- `<verb>` $\rightarrow$ hit $|$ ran $|$ ate
- `<direct obj>` $\rightarrow$ `<article>` `<noun>` $|$ `<noun>`
- `<noun>` $\rightarrow$ Fritz $|$ ball
- `<article>` $\rightarrow$ the $|$ an $|$ a

- Variables (shown in `< >`) are replaced by right side of arrow

Example: Derive a sentence

- `<sentence>` $\rightarrow$ `<subject>` `<verb>` `<direct obj>`
  $\rightarrow$ `<noun>` `<verb>` `<direct obj>`
  $\rightarrow$ Fritz `<verb>` `<direct obj>`
  $\rightarrow$ Fritz hit `<direct obj>`
  $\rightarrow$ Fritz hit `<article>` `<noun>`
  $\rightarrow$ Fritz hit the `<noun>`
  $\rightarrow$ Fritz hit the ball
Parts of an L-System (a type of grammar)

- Defined over an alphabet
- Three parts
  - Axiom (starting place)
  - Replacement rules (replaces all variables at once)
  - Geometric rules (for drawing)
    - \( g \) means move forward one unit with pen down
    - \( f \) means move forward one unit with pen up
    - \( + \) means turn right by the default angle
    - \( - \) means turn left by the default angle

Example – lsys-samp1

- Axiom
- Replacement Rules
- Geometric Rules

NOTE: Must use spaces as separator between symbols

Example – lsys-samp1 (cont)

- Derivation of strings

```
X
gggX+Y
ggggggX + Y + g
ggggggggggX+Y+g+g
```

More Geometric rules

- \% change direction 180 degrees
- ~ decrement the width of the next lines
- [ save in stack current state info
- ] recover from stack state info
- { start filled in polygon
- } end filled in polygon

Note: replace both \( X \) and \( Y \) each time
Example – lsys-samp2

Example – lsys-samp2 (cont)

Example – tree

Example – tree rendered
Stochastic Tree

- Add a rule $T \rightarrow T$
- Now there is a choice for $T$, draw a line or don’t

Same Stochastic L-System

- Rendered 3 times, each at 8th derivation

JFLAP

- JFLAP is available for free: www.jflap.org
- JFLAP was developed by many Duke undergraduates over many years, has many other parts to it for studying theoretical computer science concepts
- JFLAP is downloaded in over 160 countries.
- Duke School of Environment uses L-systems to model pine needles in Duke Forest

Exercise 1

- Write an L-system for the picture below.
- Symbols needed are: g, + and one variable
- Distance of the line is 100, rendering at 1 draws the first line, each additional render draws another line.
Exercise 2

- Write an L-system for the picture below.
- Symbols may need: g and +
- Distance is set to 10, angle to 90, first rendering draws smallest square, additional render draws next larger square

Exercise 3

- Write an L-system for the picture below.
- Symbols may need: g, %, +
- Distance set to 15, angle set to 45, side of square is length 30, first diagonal line is 60
- 1st, 2nd and 6th renderings shown

Exercise 4

- Write an L-system for the picture below (this is a sample tree to focus on branching, don’t look at the tree from before).
- Symbols may need: g, +, -, [ ]
- Angle set to 30, distance set to 20
- 3rd rendering shown

Exercise 5

- Write an L-system for the picture below.
- Symbols may need: g, +, -, [ ]
- Angle set to 90, distance set to 15
- Shows 1st, 2nd and 3rd renderings