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> → <subject> <verb> <direct obj>
  → <noun> <verb> <direct obj>
  → Fritz <verb> <direct obj>
  → Fritz hit <direct obj>
  → Fritz hit the <noun>
  → 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

\[ X \]

\[ gggX+Y \]

\[ gggggX + Y + g \]

\[ gggggggX+Y+g+g \]

\[ gggggggggX+Y+g+g+g \]

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

\[ g[^{\sim+}Yg]gX \]

\[ g[^{\sim++}Yg]gg[^{\sim+}Yg]gX \]

\[ g[^{\sim+++}Yg]gg[^{\sim++}Yg]gg[^{\sim+}Yg]gX \]

\[ \ldots \]
Example - tree

\begin{itemize}
  \item \textbf{Axiom:} \( R \sim \#\# B \)
  \begin{align*}
    B \quad &\rightarrow \quad [\sim \#\# T L - B + + B ] \\
    L \quad &\rightarrow \quad [\{ - g + + g \% - - g \}] \\
    R \quad &\rightarrow \quad !@@ R \\
    T \quad &\rightarrow \quad T g
  \end{align*}
\end{itemize}

\begin{table}[h]
\begin{tabular}{|c|c|}
  \hline
  \textbf{Name} & \textbf{Parameter} \\
  \hline
  color & brown \\
  polygonColor & forestGreen \\
  \hline
\end{tabular}
\end{table}
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
- 1\textsuperscript{st}, 2\textsuperscript{nd} and 6\textsuperscript{th} 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