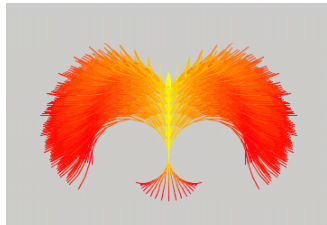


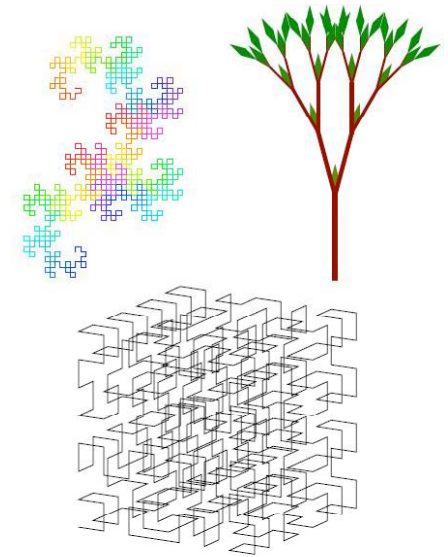
# Experimenting with Grammars to Generate L-Systems November 30, 2009

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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

- $\langle \text{sentence} \rangle \rightarrow \langle \text{subject} \rangle \langle \text{verb} \rangle \langle \text{direct obj} \rangle$
- $\langle \text{subject} \rangle \rightarrow \langle \text{noun} \rangle \mid \langle \text{article} \rangle \langle \text{noun} \rangle$
- $\langle \text{verb} \rangle \rightarrow \text{hit} \mid \text{ran} \mid \text{ate}$
- $\langle \text{direct obj} \rangle \rightarrow \langle \text{article} \rangle \langle \text{noun} \rangle \mid \langle \text{noun} \rangle$
- $\langle \text{noun} \rangle \rightarrow \text{Fritz} \mid \text{ball}$
- $\langle \text{article} \rangle \rightarrow \text{the} \mid \text{an} \mid \text{a}$
  
- Variables (shown in  $\langle \rangle$ ) are replaced by right side of arrow

## Example: Derive a sentence

- $\langle \text{sentence} \rangle \rightarrow \langle \text{subject} \rangle \langle \text{verb} \rangle \langle \text{direct obj} \rangle$   
 $\rightarrow \langle \text{noun} \rangle \langle \text{verb} \rangle \langle \text{direct obj} \rangle$   
 $\rightarrow \text{Fritz} \langle \text{verb} \rangle \langle \text{direct obj} \rangle$   
 $\rightarrow \text{Fritz hit} \langle \text{direct obj} \rangle$   
 $\rightarrow \text{Fritz hit} \langle \text{article} \rangle \langle \text{noun} \rangle$   
 $\rightarrow \text{Fritz hit the} \langle \text{noun} \rangle$   
 $\rightarrow \text{Fritz hit the ball}$

# Parts of an L-System (a type of grammar)

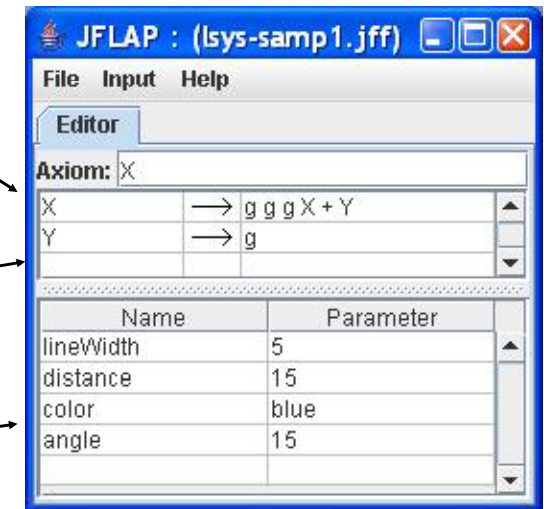
- Defined over an alphabet
- Three parts
  - Axiom (starting place)
  - Replacement rules (replaces all variables at once)
  - Geometric rules (for drawing)
    - g means move forward one unit with pen down
    - f means move forward one unit with pen up
    - + means turn right by the default angle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

# Example – lsys-samp1

- Axiom

- Replacement Rules

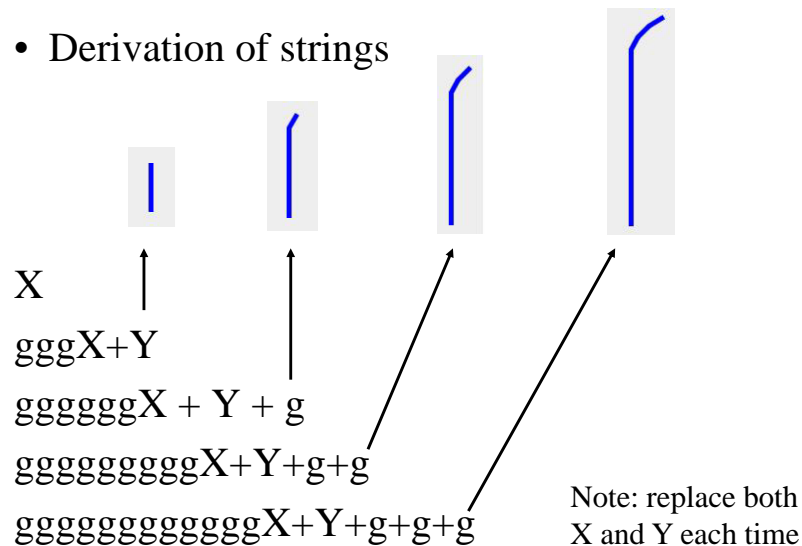
- Geometric Rules



NOTE: Must use spaces as separator between symbols

# Example – lsys-samp1(cont)

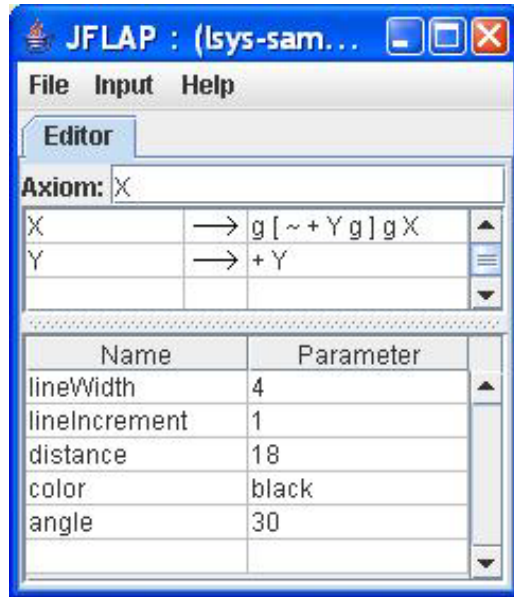
- Derivation of strings



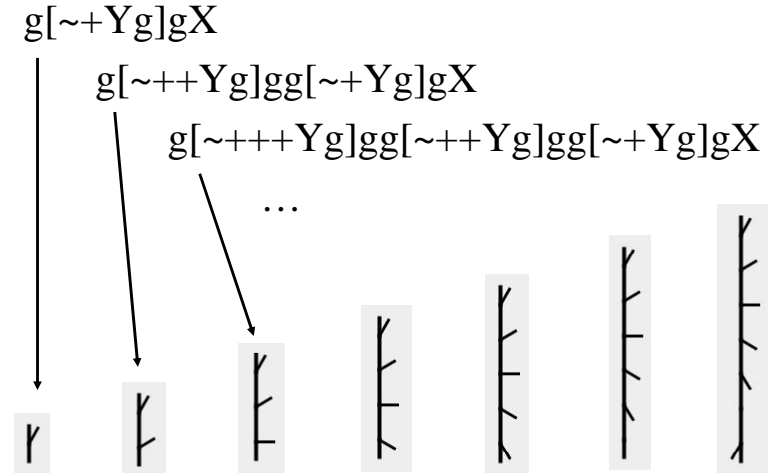
# More Geometric rules

- % 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

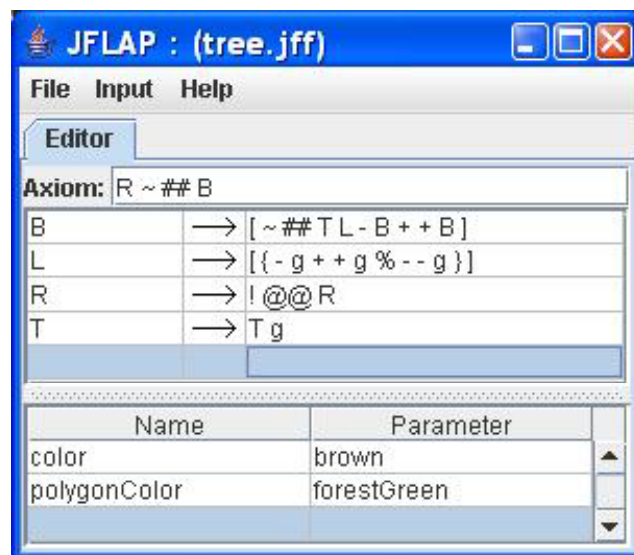
## Example – lsys-samp2



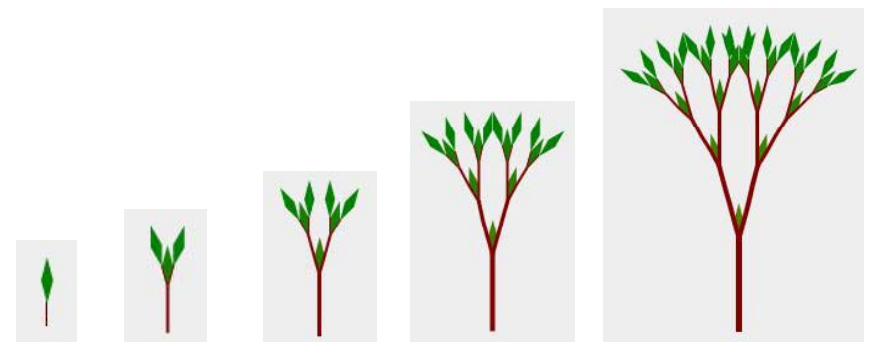
## Example – lsys-samp2 (cont)



## Example - tree

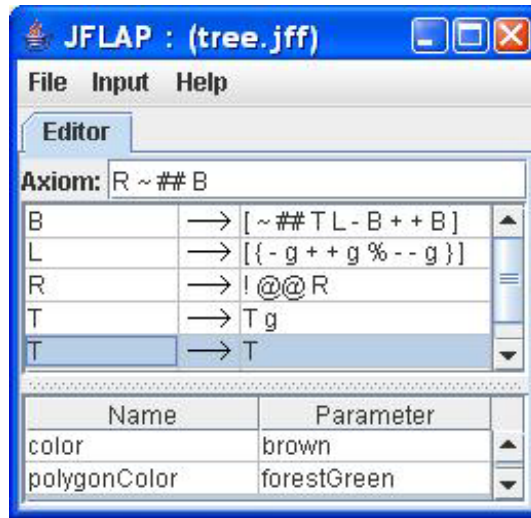


## Example – tree rendered



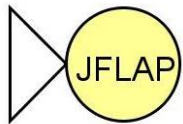
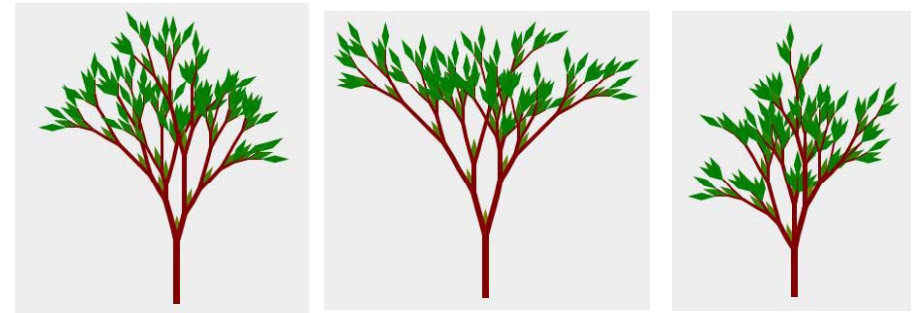
## Stochastic Tree

- 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 8<sup>th</sup> derivation

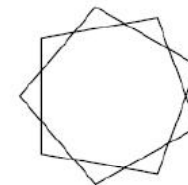


## JFLAP

- JFLAP is available for free:  
[www.jflap.org](http://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

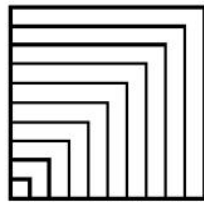
## Exercise 1

- 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.



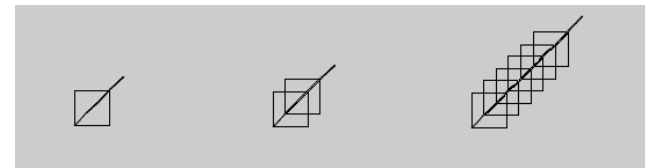
## Exercise 2

- 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



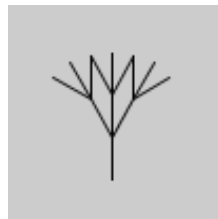
## Exercise 3

- 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<sup>st</sup>, 2<sup>nd</sup> and 6<sup>th</sup> 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
- 3<sup>rd</sup> 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 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> renderings

