



L-Systems



L-Systems

- Propostos por Lindenmayer em 1968 como forma de especificar a forma e desenvolvimento de plantas.
- No entanto a sua utilização não se restringe a plantas, sendo comum encontrar exemplos com fractais, e estruturas arquitectónicas.
- Os L-Systems são baseados em gramáticas e sistemas de reescrita de strings, com a singularidade que as substituições ocorrem em paralelo.



L-Systems

- Exemplo: números de Fibonacci
 - $F_0 = 0, F_1 = 1$
 - $F_n = F_{n-1} + F_{n-2}, n > 1$

Através de um L-System:

- variáveis: A, B
- axioma: A
- regras:
 - $A \rightarrow B$
 - $B \rightarrow AB$

Passo 0 : A
Passo 1 : B
Passo 2 : AB
Passo 3 : BAB
Passo 4 : ABBAB
Passo 5 : BABABBAB
Passo 6 : ABBABBABABBAB
Passo 7 : BABABBABABBABBABABBAB

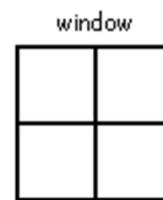


Turtle Graphics

- Permitem associar facilmente um significado gráfico aos símbolos utilizados.
- Desenho baseado na noção de estado e operações sobre o estado
 - Estado: posição e orientação da tartaruga
 - Operações: andar em frente, virar à esquerda, virar à direita,...

```
to draw-a-box
```

```
  forward 10  
  turn 90  
  forward 10  
  turn 90  
  forward 10  
  turn 90  
  forward 10  
  turn 90
```



```
to draw-a-window
```

```
  draw-a-box  
  turn 90  
  draw-a-box  
  turn 90  
  draw-a-box  
  turn 90  
  draw-a-box
```



L-Systems

- Koch Snowflake



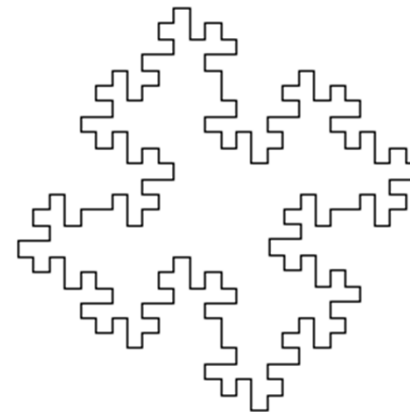
- Ângulo: 60
- Axioma: $F - - F - - F$
- Regra: $F \rightarrow F + F - - F + F$





L-Systems

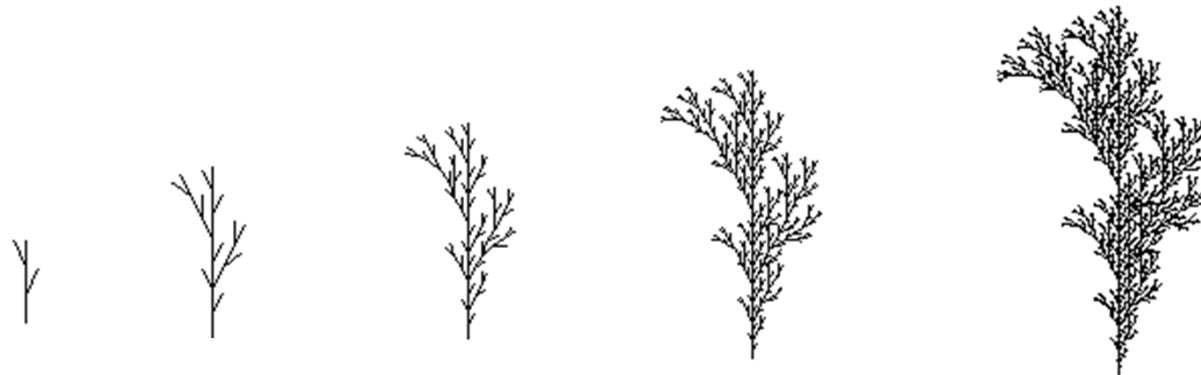
- "Quadratic Koch Island"
 - Ângulo: 90
 - Axioma: $F + F + F + F$
 - Regra: $F \rightarrow F + F - F - F F + F + F - F$





L-Systems

- Uma planta
 - Ângulo: 30
 - Axioma: F
 - Regra F \rightarrow F [-F] F [+F] F





L-Systems Paramétricos

- As regras podem receber parâmetros.
- Os parâmetros podem ser utilizados na selecção das regras.
- Os parâmetros podem ainda assumir significado gráfico.
 - Axioma: $A(4,4)$
 - Regras:
 - $A(x,y) : y \leq 3 \rightarrow A(x*2, x+y)$
 - $A(x,y) : y > 3 \rightarrow A(x/y, 0)$

$A(4,4)$
$A(1,0)$
$A(2,1)$
$A(4,3)$
...



L-Systems Estocásticos

- Permite introduzir irregularidade através da especificação de várias alternativas para a mesma regra
 - Axioma: F
 - Regras:
 - $F \rightarrow (0.5) FF$
 - $F \rightarrow (0.5) F[+F][-F]$



L-Systems e Contexto

- Context-Sensitive L-Systems
 - A regra a ser invocada para um símbolo está dependente do contexto, ou seja, dos símbolos que precedem e/ou sucedem o símbolo
 - regra dependente de contexto: $A^* \langle s \rangle A^* \rightarrow A^+$
 - $xy \langle a \rangle z \rightarrow ab$
 - $x \langle a \rangle yz \rightarrow aa$
 - $xyzabyxayzab \Rightarrow xyabzabyxaayzab$



L-Systems e Contexto

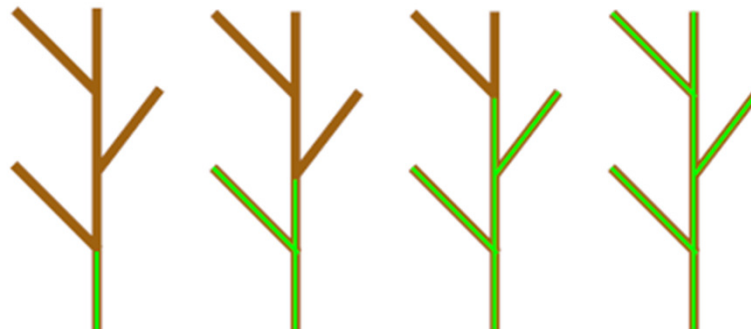
- Simulação de propagação de sinais
 - Axioma: baaaaaa
 - Regras $b \rightarrow a$
 - $a \rightarrow b$

baaaaa
abaaaa
aabaaa
aaabaa
aaaaba
aaaaab



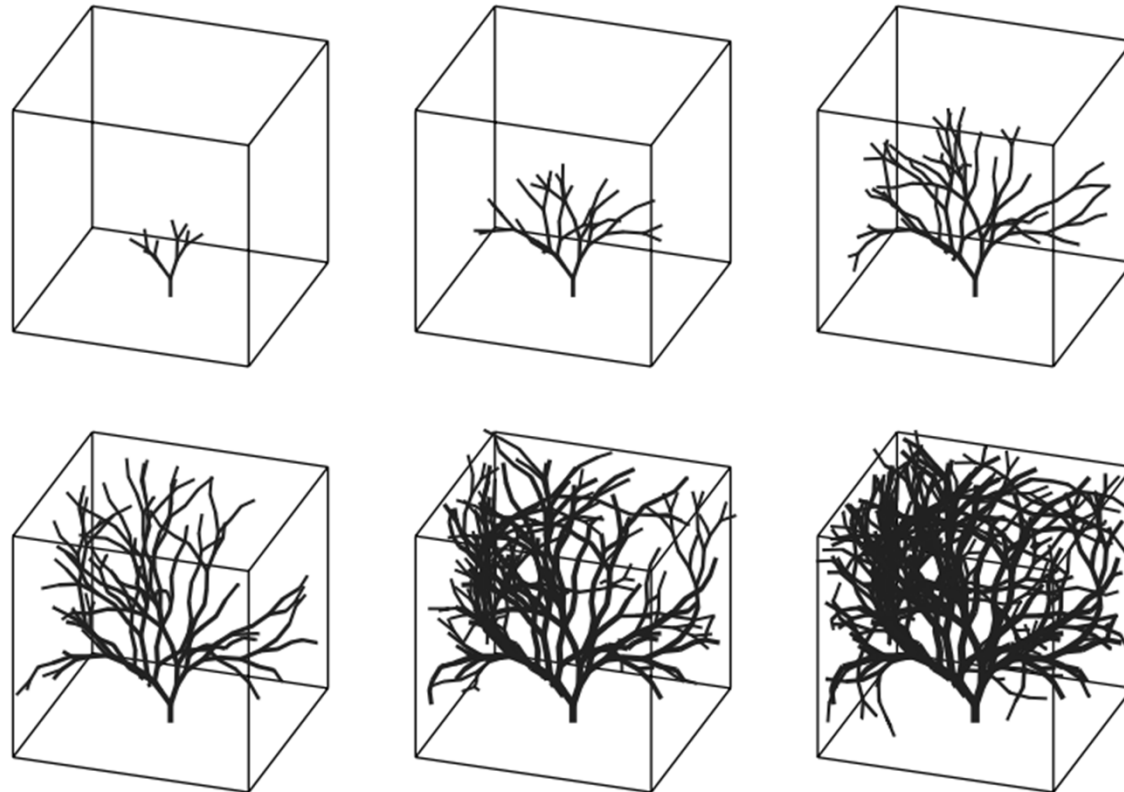
L-Systems e Contexto

- Axioma: $B [+A] A [-A] A[+A]$
 A
- Regra: $B < A \rightarrow B$





L-Systems - Pruning





Arquitectura

Single Generation Turtle Graphics

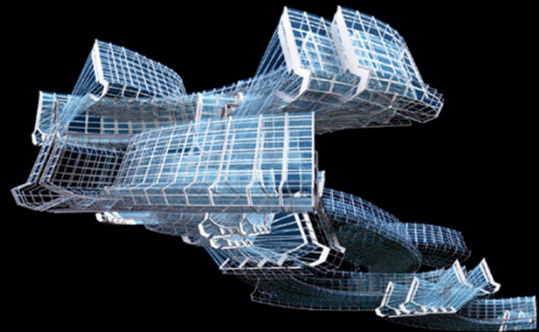
By expanding the grammar of turtle graphics, high flexibility can be achieved with only a single generation of string. While the string and thereby the system may grow from generation to generation, each single generation of string comprises its own proper form.

Essential to the expanded grammar is the introduction of letters that are not directly interpreted as commands themselves but act as placeholders for other series of commands. These placeholders can thus constitute their own shape or process, allowing for the use of modular elements.

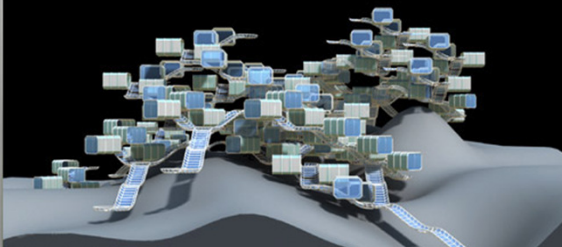
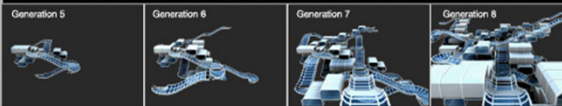
Letters can also be interpreted as branching commands. Thus one letter can save the position of the turtle in a stack, while another letter returns the turtle to the last saved position.

Environmental influences can be introduced to L-Systems turtle graphics interpretations. In a very basic system, the path of a turtle can be interrupted or substituted by an alternative if it enters a forbidden space such as the ground (see bottom image this page).

Branching system with two modules: truss and spiral

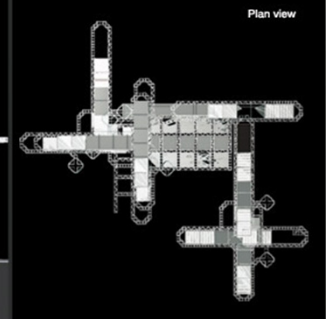
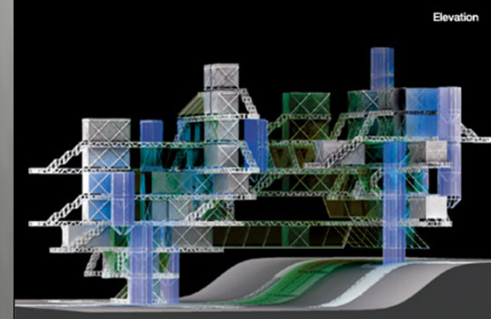
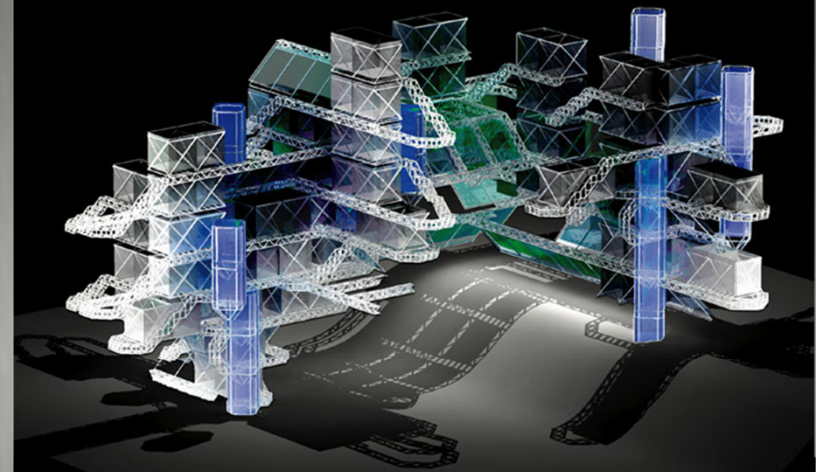


Growth of system over several generations (see disk for animation)



Modular branching system with environmental interaction

Modular branching system
8th generation, ~250,000 letters



http://www.mh-portfolio.com/Algorithms_Architecture/p13m.html