# L-Systems

Eleanor Chlan
Ph.D. candidate, UMBC (CADIP, GAVL)
Faculty, JHU/WSE/PTE

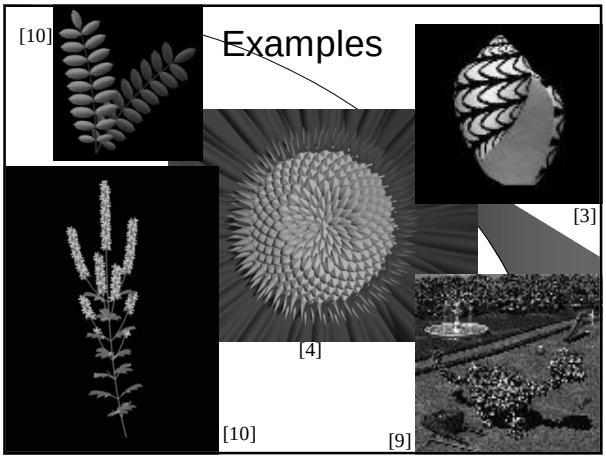
# Topics

- Background and Examples
- L-systems at UMBC
- Demo
- References

# Background

- Developed by biologist Aristid Lindenmayer (1969) [11]
- Modeling biological systems
- Formalized the self-similarity characteristics of biological entities

# Examples




# Background

Spectrum of L-systems applications

- Simple multi-cellular organisms [5]
- Fractals [10]
- Trees, shrubs, herbaceous plants [10]
- Stomach model [2]
- Genetic Algorithms [6]
- Modeling of Cities [8]

# Background

- Uses parallel string rewriting
- Turtle graphics
  - All motion relative
  - With respect to current position and orientation
  - LOGO uses turtle graphics

## Background – Notation

A small subset to show syntax

F – move forward one unit (pen down)
f – move forward one unit (pen up)
[, ] – push and pop from stack (branching)
+, -, &, ^, \, / Rotations around the axes
; - change color
! – change line width
e.g. !(5) changes line width to 5

## Examples

Sierpinski Gasket created with following L-system

n = 6, d = 60 degrees
$F_r$
$F_l \rightarrow F_r + F_l + F_r$
$F_r \rightarrow F_l - F_r - F_l$

Check out this applet:
http://www.arcytech.org/java/fractals/lsystems.shtml

## Background

Id : LC < rule > RC : { α } cond { β } → newrule : prob

When rule occurs in the context of left context **LC** and right context **RC** and the condition **cond** is true, then rule is replaced by **newrule** with probability **prob**. The statements α and β are performed before and after the condition is evaluated.

## Background

- Rule and newrule are the only mandatory components.
- Alpha can affect the condition.
- Alpha and Beta can include the execution of "C" style coding statements
- It is common to have multiple instances of the same rules with minor variations which can be executed with appropriate probability.
- Highly recursive

## Background

Parametric L-systems:

rule(a,b,c,…) → newrule (a',b',c',…)
where a' = f(a), etc.

e.g.
A(w,a,l) : * → A(.7*w, a, .95*l)

## Background

- This example only shows use of parameters.
- It is common to adjust parameters every time the rule is applied. For instance, if you are "growing" a tree then it would make sense to reduce the length and width of each branch as you get further from root.

## Background

Open L-systems [7]

- A variation that permits communication with the environment
- Used to model plant growth affected by external factors,
  - A tree growing next to a wall
  - A tree overshadowed by a larger tree.

## L-systems at UMBC

- ***cpfg*** (UNIX) and L-Studio (Windows)
- ***cpfg*** installed on **/data/gavl2/lsys/vlab-4.0**
- Developed by P. Prusinkiewicz, et. al. (University of Calgary) – currently the leading researcher in L-systems

## L-systems at UMBC

- L-systems support the use of predefined Bicubic patches to add leaves or other surfaces to plant models
- E.g. Draw one basic leaf and attach at any desired point with stochastic or predefined variation in angle or orientation or color to get realistic effect.
- ***cpfg*** has Bezier curve editor to support development of predefined surfaces
- L-systems can also generate the Bezier curves directly.

## Demos

Using L-Studio

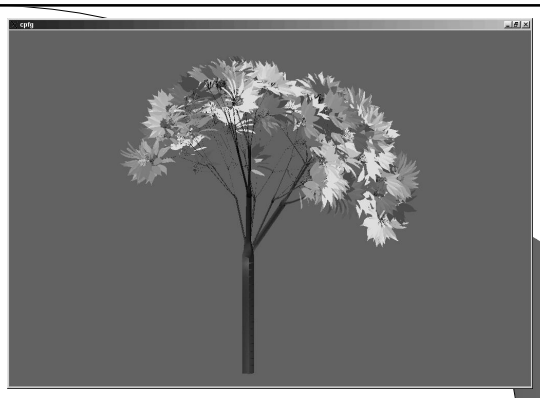
Interesting url:

http://www.cpsc.ucalgary.ca/Research/bmv/vmm-deluxe/TitlePage.html

## L-systems at UMBC: E. Chlan

Visualization of large, hierarchically clustered data sets [1]

- A tree model automatically reflects the hierarchical organization
- Supplemented with glyphs
  - Cross-section of the tree branch (reflects subscluster characteristics as tree rings)
  - Arbitrary high-dimensional glyph (future)



Census data set with 30K records in 212 clusters (138 leaves)

## L-systems at UMBC: E. Chlan

- The tree view also functions as a glyph
- Branching reflects clustering
- Branch size reflects cluster size
- Branching angle reflects subcluster similarity
- Leaf color reflects attribute value for record or terminal cluster

## L-systems at UMBC: E. Chlan

- Uses parametric, stochastic L-systems
- Open L-systems (???)
- Skeleton form:

  A( ) → B( ) A( ) : prob

  (general case - 2 instances with equal probability)

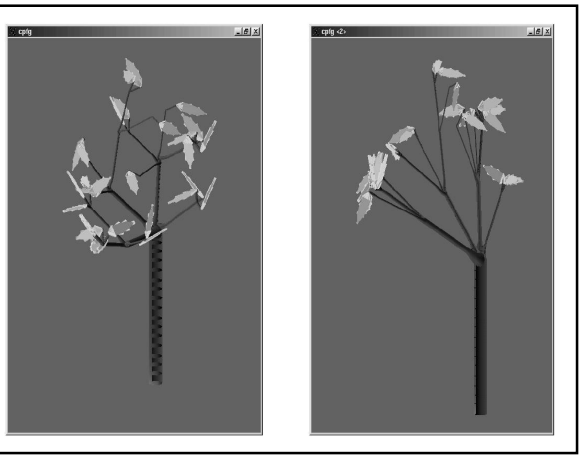
  A( ) → B2( ) A2( ) (terminal clusters)

  A2 ( ) → L (L is the rule which applies leaf)

  (B2 is a simple rule that corrects the branch count)

## L-systems at UMBC: E. Chlan

- Next slide shows a variation which maps cluster similarity to the angle between adjacent clusters
- On left – No similarity mapping ( a fixed angle is used)
- On right – Similarity factor of parent controls angle between the child clusters



## Selected References


[1] Eleanor Boyle Chlan and Penny Rheingans. A Botanically Inspired High-Dimensional Visualization with Multivariate Glyphs. April 2003. (under review).

[2] Roman Durikovic, Kazufumi Kaneda and Hideo Yamashita. Visual Modeling of Stomach Growth on the Basis of {L}-systems. *Proceedings of the Shape Modeling International*, pages 121-128. Aizu-Wakamatsu, Fukushima, Japan. March 1997.

[3] Deborah R. Fowler, Hans Meinhardt and Przemyslaw Prusinkiewicz. Modeling Seashells. In *Proceeedings of the ACM Conference on Computer Graphics*, 26(2):379-387, July, 1992.

[4] Deborah R. Fowler, Przemyslaw Prusinkiewicz and Johannes Battjes. A Collision Based Model of Spiral Phyllotaxis. In *Proceeedings of the ACM Conference on Computer Graphics*,26(2):361-368, July, 1992.

[5] F. David Fracchia and Neil W. Ashton. A Visualization Tool for Studying the Development of the Moss Physcomitrella patens. In *Proceedings IEEE Conference on Visualization*.364-367.1995.


## Selected References (continued)


[6]Christian Jacob. Genetic {L}-system Programming. In *Parallel Problem Solving from Nature III*. pages 334-343. Springer-Verlag, October, 1994.

[7] Radomir Mech and Przemyslaw Prusinkiewicz. Visual Models of Plants Interacting with Their Environment. In *Proceeedings of the ACM Conference on ACM Computer Graphics*, pages 397- 410. August, 1996.

[8] Yoav I. H. Parish and Pascal Muller. Procedural Modeling of Cities. In *Proceeedings of the ACM Conference on Computer Graphics*. 2001. pages 301-308. August, 2001.

[9] Przemyslaw Prusinkiewicz, Mark James and Radomir Mech. Synthetic Topiary , In *Proceeedings of the ACM Conference on Computer Graphics*. pages 351-358. 1994.

[10] Przemyslaw Prusinkiewicz, Aristid Lindenmayer, James S. Hanan, F. David Fracchia, Deborah R. Fowler, Martin J. M. de Boer and Lynn Mercer. *The Algorithmic Beauty of Plants*. Springer-Verlag. 1990. 150 ill., 48 in color.

[11] Grzegorz Rozenberg and Arto Salomaa. *The Book of L*. Springer-Verlag. 1986. dedicated to A. Lindenmayer and containing a list of his published papers to 1984.