

MSc Computer Games and Entertainment

Maths & Graphics Unit 2011/12

Lecturer: Gareth Edwards

Morphogenesis

A comparison between the work undertaken by **PRUSINKIEWICZ** and actual plant growth and development, review of image synthesis plant growth, development and animation and a review of in-game plant modelling and animation

Morphogenesis

- In living organisms, complex forms and patterns result from development, and their emergence is traditionally referred to as *morphogenesis*.
- Rapid progress in the modelling of biological structures and simulation of their development has occurred over the last few years.
- It has been coupled with the visualization of simulation results, which has led to a better understanding of morphogenesis and given rise to new procedural techniques for realistic **IMAGE SYNTHESIS**.

Biological Structures

- Biological structures are interesting to model and visualize for several reasons.
 - *Database amplification*, a term coined by Alvy Ray Smith [Smi1984], is the process of creating complex images using small data sets.
 - *Emergence*, a term brought into prominence by the study of Artificial Life [Tay1992], means that the system as a whole acquires complex properties through the interaction, in space and over time, among its component modules. The modules themselves are usually fairly simple.
- By studying emergent processes in a biological context, we can gain a better understanding of the world around us.

L-Systems

- An **L-system** or **Lindenmayer system** is a formal grammar (a set of rules and symbols) most famously used to model the growth processes of plant development, though able to model the morphology of a variety of organisms. L-systems can also be used to generate self-similar fractals such as iterated function systems. L-systems were introduced and developed in 1968 by the Hungarian theoretical biologist and botanist from the University of Utrecht, Aristid Lindenmayer (1925-1989).

L-Systems

- As a biologist, Lindenmayer worked with yeast and filamentous fungi and studied the growth patterns of various types of algae, such as the blue/green bacteria *Anabaena catenula*.
- Originally the L-systems were devised to provide a formal description of the development of such simple multicellular organisms, and to illustrate the neighbourhood relationships between plant cells.
- Later on, this system was extended to describe higher plants and complex branching structures.

L-Systems

- When using this model, we have to define a set of grammar rules that will be used to describe the growth of the branches of a tree. The rules that we define will later be implemented as the growth of the tree in an iterative fashion. In this system, we define these following alphabets that will be used in the production rules:

f : create branch

l : create leaf

[and] : define a set of local area/branch. The definitions of the area are put inside the [and]

+ and - : rotate the branch right/left in x-axis

^ and v : rotate the branch up/down in y-axis

<> : twist the branch left/right in z-axis

L-Systems

- By using the symbols above, we can begin to create a tree with our system. But before that, we also have to define several properties that are also important in generating the tree, which are:
 1. The number of production rules iterations, for determining the level of the branches,
 2. The angle, for determining branch curves, and
 3. The radius of the branches and the decreasing value of it, in an iterative way The length of the branches

L-Systems

- **Tree A**

Angle : 25

Iterations: 6

Branch radius: 0.02

Branch radius reduction: 0.0015

Branch length (height): 0.15

Initial value : fffffA

Production rules : $A = f[++A][--A]>>>A$



L-System

- **Tree B**

Angle : 30

Iterations: 10

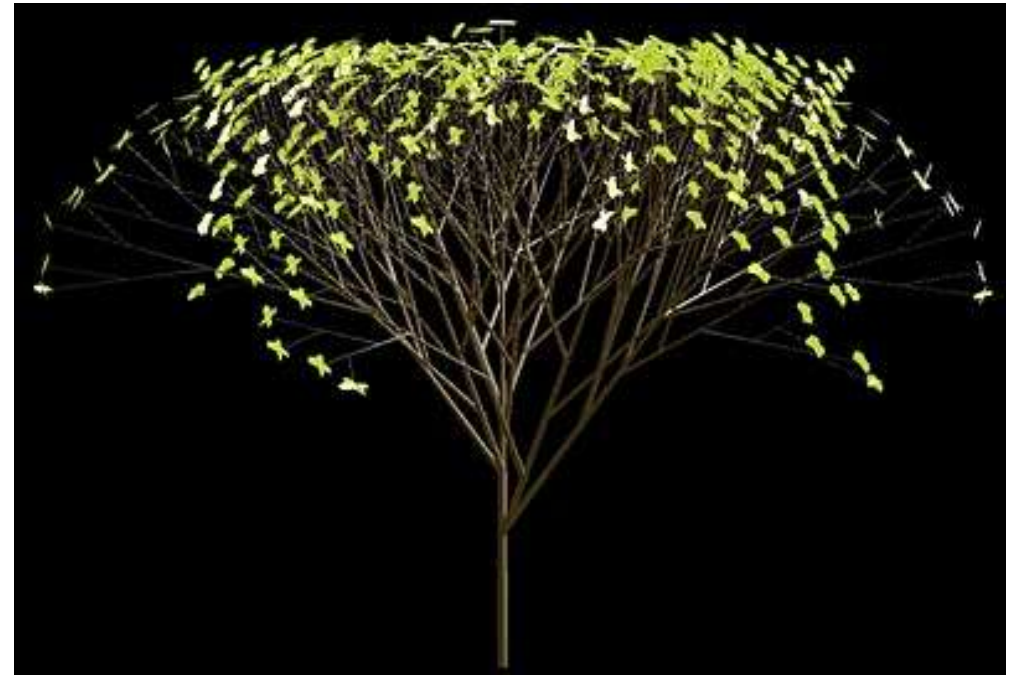
Branch radius: 0.01

Branch radius reduction: 0.001

Branch length (height): 0.16

Initial value : fA

Production rules : $A = f[\wedge BI] \gg [\wedge BI] \gg A$, $B = f[-BI]B$



L-System

- **Tree C**

Angle : 15

Iterations: 13

Branch radius: 0.02

Branch radius reduction: 0.0015

Branch length (height): 0.15

Initial value : fA

Production rules :

- $A = ^fB>>>B>>>>B,$
- $B = [^f>>>>>A]$



Reference

- There is a lot of reference material; papers, books, web sites, blogs;
- Typical web references might include:
 - [SpeedTree](#)
 - [Tree Generator](#)
 - [Greenworks Organic Software](#)
 - [Computergenerierte Pflanzen](#)
 - [Webpage of Ken Perlin](#)
 - [Open Tree](#)
 - [Arbaro](#)
 - [Tree and Leaves Generation](#)
 - [TReal](#)
 - [Virtual Terrain Project](#)

Reference

- There is a lot of reference material; papers, books, web sites, blogs;
- Further Information
 - [Definition Lindenmayer systems \(L-systems\)](#)
 - [Gamasutra - The Art & Science of Making Games](#)
 - [Virtual Terrain Project](#)

Papers

- There are thousands of papers – including:
 - [1986 - Graphical Applications of Tree Systems - Prusinkiewicz](#)
 - [1988 - Developmental Models of Herbaceous Plants - Prusinkiewicz Lindenmayer and Hanan](#)
 - [1992 - Lindenmayer Systems - Lars Larsson](#)
 - [1999 - An L-System-based plant modelling language - Prusinkiewicz Mech and Hanan](#)
 - [2005 - Approximate Image-Based Tree-Modeling using Particle Flows](#)
 - [2008 - Deciduous Coniferous Single Tree Classification - Ko , Sohn and Remmel](#)
 - [2009 - Interactive Modeling of 3D Tree with Ball B-Spline Curves – Wu, Zhou and Wang](#)

Actual Plant Growth and Development

- A comparison between the work undertaken by **PRUSINKIEWICZ** and actual plant growth and development
- Using time lapse photography:
 - 01 - [Plants Growing](#)
 - 02 - [Fern Sprouting](#)
 - 03 - [Prime Luci Sulla Laguna](#)
 - 04 - [Red Rose Blooming](#)
 - 05 - [Flower Blooming](#)
 - 06 - [Blue Oyster Mushroom](#)

Biological Simulation

- Development of a Mammary gland:
 - [Branching Morphogenesis](#)

Seasonal Plant Growth and Development

- Using time lapse photography:
 - [08 - One year in 14 seconds \(Oak Tree\)](#)
 - [09 - One year in 40 seconds \(Wood\)](#)
 - [10 - One year in two minutes \(Wood\)](#)

Seasonal Plant Growth and Development

- Image Synthesis:
 - [11 - Real-time Rendering and Animation of Trees](#)
 - [12 - Physically Guided Animation of Trees](#)
 - [13 - Tree Growth](#)

Biological Based World Creation

- Example:
 - 14 - [Spore E308 Trailer](#)
 - 15 - [The Science Behind Spore](#)

In-game plant modelling and animation

- Example:
 - 16 - [Far Cry 2](#)
 - 17 - [Crysis](#)

In-game plant modelling and animation

- Example:
 - 16 - [Far Cry 2](#)
 - 17 - [Crysis](#)
 - 18 - [Killzone 3](#)

World Modelling

- Example:
 - 19 - [WoW Cataclysm Zones Change](#)
 - 20 - [Warcraft Landscaping](#)

Required For Next Week

Required - reading and work to be undertaken for next week....

NEXT WEEKS LECTURE:

- Matrices.....

So:

- Read - Lengyl – Chapter 3 on Matrices again!
- Read - Dunn & Parberry Chapter 7 on Matrices again!

Assignment:

- 4 weeks.....

END