Planning Procedural Architecture in Tree-like Geometry

Ruud op den Kelder

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Abstract

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Contents

1 Introduction

This thesis adresses the problem of procedural architecture in the special case of restrictions and possibilities enforced by the geometric properties of pre-existing objects, trees, in the scene. A side goal for this research was to develop methods for intuitive interactive control over the objects wich were to be generated. Regarding user control and procedural techniques it is important to strike a balance which allows for a fast and intuitive building process, and meanwhile the user should have just the right amount of control to make the scene to its liking.

This thesis combines research from the fields of procedural architecture and procedural plant generation.

Visual modeling of plant development is a field which started in 1962, when Ulam applied cellular automata to simulate the development of branching patterns [**?**]. A formalism for modeling plants was proposed by Lindenmayer in 1968, this formalism was called L-systems since. The following definition of an L-system is given by Przemyslaw [**?**]:

> An L-system is a parallel rewriting system operating on branching structures represented as bracketed strings of symbols with associated parameters, called modules. Matching pairs of square brackets enclose branches. Simulation begins with an initial string called the axiom, and proceeds in a sequence of discrete deriviation steps. In each step, rewriting rules or productions replace all modules on the predeccesor string by succesor modules.

Przemyslaw [**?**] has employed and extended the l-system formalism for realistic visualisation of entire plant ecosystems. Within a ecosystem organisms interact with each other and this interaction determines many properties for individual organisms; such as growth rate. Since the original L-system formalism does not account for communication between two processes, Przemyslaw proposed *open l-systems* which incorporates *communication modules*.

Since 2001 L-systems also proved to be useful in the field of urban procedural generation [**?**]. It was then that Muller proposed the use of L-systems for the generation of road networks and building generation.

Techniques for tree generation in this thesis are based on L-systems, however these techniques are simplified to a certain degree since the modeling of plants is not the maintopic of this thesis. We have used the l-system formalism to generate simple branching tree structures. We did not strive to generate visually realistic models of trees since this has already been achieved by many people before me with impressive results. Instead our simplified method generates the main structure of a tree which is then used as input in our method for the generation of treehouse architecture.

It is often the case that traditional general purpose modeling software is hard to master as a result of the freedom which is given to the user. Special purpose modeling tools such as cityEngine [?] (in the case of urban modeling) and speedTree (in the case of modeling plants and trees) provide procedural methods to generate objects within a certain class with very high time effiency. However the human touch still remains a very important part of the modeling procedure. Eastatics are very hard to turn into a set of formal rules on which an algorithm can operate.

The special purpose modeling tool for the generation of organic geometry and treehouse architecture that was developed for this thesis provides the user with intuitive interaction tools to allow easy manipulation.

1.1 Overview

This thesis is structured as follows. In the next section I will discuss related work. In the related work section I will bring my thesis into context with regard to procedural modeling of trees and architecture. In section ¡¿ I will present the conceptual system model. After this I will be discussing the method for the generation of forest geometry. With the forest geometry in place we are ready to review the planning method which is responsible for positioning the architectural shapes. I will conclude the method description with a look at the final stage of the pipeline, which is the procedural generation of the actual geometric objects representing the man-made architectural objects. Section ¡¿ discusses user interactivity and usability of the proposed system. The last two sections present results and conclusions respectively.

2 Related Work in the fields of Procedural Modeling of Trees and Architecture

The famous book Algorithmic Beauty of Plants by Lindenmayer and Przemyslaw [?] is the first complete work discussing the generation of plant geometry using procedural methods such as L-systems and fractals. To model and visualise realistic ecosystems, Przemyslaw extended the l-systems concept to a system which allowed communication between systems (open l-systems [?] [?]). Visual editing of procedural plants models is discussed in [?].

The foundation for procedural city and building modeling was provided by Parish and Muller [?] in their paper *"Procedural Modeling of Cities"*. The main contribution of this paper is the use of extended L-systems for the generation of city roadmaps. They also propose a method for the texturing of facades. An intuitive editing approach for road networks with the use of tensor fields and bush techniques is presented by Chen et al. [?].

An attempt was made to use L-systems for the creation of buildings [**?**], however this did not prove to be effective. L-systems are designed to handle growth-like processes, it has been acknowledged that the construction process of a building is not a growth like process. Instead, building construction is better expressed by series of partitioning steps. These partitioning steps can be described by another kind of rewriting grammar called *set grammar*. In [**?**] Wonka presents a method for the automatic creation of building using such grammar systems. In this work Wonka introduces the idea of a specialized type of set grammar called *split grammar* which operates on shapes. In [**?**] the split rules from the split grammar concept are defined in a grammar system called *CGA Shape*, which was the first procedural system for the creation of detailed buildings with consistent mass models. The process of creating a ruleset in CGA shape for a specific type of building is not straightforward and requires a trained expert. Lipp et al. [**?**] introduce a visual method for the editing of the CGA Shape grammar for procedural architecture to simplify the rule building process.

3 Concept

This section discusses the system design of the proposed procedural modeling method with special attention to the planning algorithm for architectural objects. Figure **??** shows a diagram of the proposed system.

Figure 1: diagram of the conceptual model

The pipeline is presented in figure **??**.

Figure 2: pipeline of procedural generation method

4 Procedural Forest Generation

4.1 Scattering Techniques for Tree Positions

Algorithm 1 this is the pseudocode for the spatial layout of the trees

if $i \geq maxval$ **then**
  $i \leftarrow 0$
else
  if $i + k \leq maxval$ **then**
    $i \leftarrow i + k$
  end if
end if

4.2 Ecosystem Modeling -¿ selfthinning

4.3 Procedural Generation of Simple Tree Structures

5 Tree House Architecture

5.1 Architectural Elements

5.1.1 Platforms

5.1.2 Buildings

5.1.3 Bridges

5.1.4 Stairs

5.2 The Planning Algorithm

Algorithm 2 The planning algorithm

```
if i ≥ maxval then
  i ← 0
else
  if i + k ≤ maxval then
    i ← i + k
  end if
end if
```

6 User Interaction Tools

6.1 Growing Surfaces

5op de andere en vica versa. Ook bespreken op wat voor manier een vector field (en andere tools

A definition of land: "The part of Earth which is not covered by oceans or other bodies of water".(bron: http://en.wiktionary.org/wiki/land ...jaja ik vind nog wel een betere bron) In reality land obviously does not grow, so first we must ask ourselves whether growing land in our virtual world can be made useful and intuitive to use. There are no real rules for the bounding shape of a piece of land, the bounds can be configured in any way. However due to this fact almost any random configuration of the shape of land looks realistic. The question is, as with other growth models with a minimum amount of rules, whether generating land by means of a growth model, thereby having less control over the result compared to conventional methods, is something which we want.

When you want maximum control over the resulting geometry of a piece of land, using a growth model is not a very attractive method.However there are some situations in which this method is quite helpful.

Land provides the underlying surface of many of the growth models discussed in this paper.

6.2 Vector and tensor fields

7 Fully automated design process

8 Results

9 Conclusion

Appendix A: Implementation

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