Planning Procedural Architecture in Tree-like Geometry

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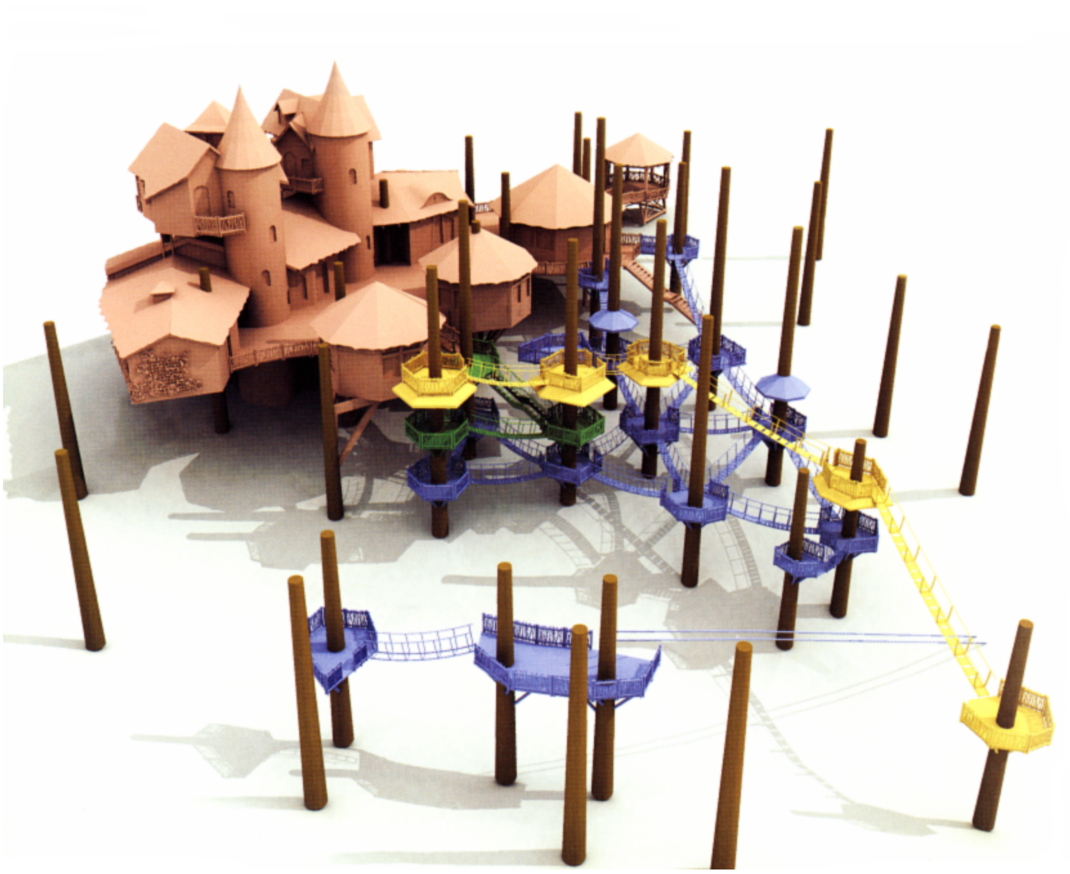

Abstract

my abstract

Contents

Chapter 1

Introduction

Procedural content generation (pcg) lately received a lot of attention from various players in the field. It is believed that PCG will eventually play a major role in virtual worlds of simulations and games, replacing a significant amount of conventional man-made content, and thereby reducing costs and improving time efficiency.

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.

Visual modeling of plant development is a field which started in 1962, when Ulam applied cellular automata to simulate the development of branching patterns [6]. 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 [6]:

> 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 [6] 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 [9]. 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 [5] (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. A precise statement of the problem and why it's an interesting problem to solve will follow in section 3.

In section 4 I will present the conceptual system model. The method for the generation of the forest layout and the generation of the tree geometry is presented in section 5.

With the forest geometry in place we are ready to review the planning method which is responsible for the construction of a connected graph representing a tree community. I will conclude the method description with a look at the final stage of the pipeline, translating the symbols from the nodes and edges of the graph to the geometrical architectural elements. Section 7 discusses user interactivity and usability of the proposed system. The last two sections present results and conclusions respectively.

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Chapter 2

State of the Art

2.1 plants and trees

Algorithmic Beauty of Plants by Lindenmayer and Przemyslaw [7] 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 [6] [3]). Visual editing of procedural plants models is discussed in **(author?)** [1].

2.2 road networks

The foundation for procedural city and building modeling was provided by Parish and Muller **(author?)** [10] 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. **(author?)** [2].

2.3 architecture

An attempt was made to use L-systems for the creation of buildings **(author?)** [10], 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 **(author?)** [9] 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 **(author?)** [5] 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. **(author?)** [4] introduce a visual method for the editing of the CGA Shape grammar for procedural architecture to simplify the rule building process.

Chapter 3

Problem Statement

The purpose of this thesis is to tackle a specific instance of the problem of planning connected architectural geometric elements into an environment with existing geometry which has to be used as the supporting structure for the architectural elements. We handle the specific case in which the pre-existing geometry is a virtual forest, using the trunks and branches of the trees as supporting structures for architectural elements such as platforms, bridges, stairs and buildings. We propose several heuristics for the generation of a connected 'tree house community' and using these heuristics we construct a procedural algorithm. The architectural elements need a large degree of adjustibility to be able to incorporate them into the irregular environment, therefore we present procedural methods for the generation of these elements.

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Chapter 4

Concept

This section discusses the system design of the proposed procedural modeling method with special attention to the planning algorithm for architectural objects. Figure 4.1 shows a diagram of the proposed system.

Figure 4.1: diagram of the conceptual model

The pipeline is presented in figure 4.2.

Figure 4.2: pipeline of procedural generation method

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Chapter 5

Procedural Forest Generation

5.1 Scattering Techniques for Tree Positions

(author?) [6]

]

(author?) [8]

5.2 Ecosystem Modeling

5.3 Simple Tree Structures

Procedurally generating trees by means of l-systems has had a great amount of succes since the original proposal by Lindenmayer. The L-system formalism is widely applied in academic work and is also succesfully used within commercial applications. This thesis does not focus on the l-system formalism in particular, since it is already a well established theory **(author?)** [7]. However, the following section will describe the basics of l-systems to establish some basic understanding wich will be needed in following sections.

I am interested in the structure of trees and the possibilities and restrictions it poses for placement of architectural shapes. For the purpose of this thesis the generated trees do not have to be visually convincing, however the basic shape should still be identified as a tree. The geometric properties of a tree model that are to interest of us are those that have effect on the possibilities with respect to the incorporation of architectural man-made structures. The tree geometry functions as the support structure for the building blocks I define in detail in section 6.

In this section we will identify geometric configurations within tree geometry that allow for the construction of the proposed set of architectural elements.

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Chapter 6

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Appendix A: Implementation

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