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GPU Accelerated Method for Constructing and Rendering Trees

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Abstract

This project aims to convert and extend the Lindenmayer-system based tree construction method presented by (Prusinkiewicz et al., 1996) to be used as an independent OpenGL module. The module should allow the addition of trees to a real-time environment with minimal user interaction, avoiding the difficulties and expenses of manually producing tree models.

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1 Introduction

In this section a context will be provided for the

1.1 Context

Creating and rendering realistic models of trees manually requires advanced expertise with modelling software packages. This limits the ability to produce convincing 3D scenes for small developers with restricted resources.

The purpose of including trees in a natural environment is to provide realism. Trees are common natural structures present in even simple environments throughout the history of computer graphics and have seen many iterations as technology has advanced allowing for more detailed and realistic results.

The aim of this project is to provide a method for creating and rendering trees to be used in a real-time graphics application. This method should be simple to use and implement into an existing OpenGL project.

1.2 Related Work

In this subsection various related works will be discussed with respect to how they contribute to the main knowledge required for this project, ordered chronologically. These areas of main knowledge are the branching structure, branch thickness and leaf placement of the constructed trees.

A paper by Lindenmayer (1968) proposes a theory for the development of organisms using a cells current state and being combined with input that the cell receives from its neighbour. Two new cells are produced from this development to replace the existing cell and the cycle repeats for the two new cells.

This process of generating new outputs recursively to produce larger structures became “Lindenmayer systems” or the abbreviated “L-systems” which became important tools in pattern generation for future applications. L-systems became a common approach for the generation of branching patterns in flora which is where the aim of this project is concerned.

Another early paper that is referenced by many later studies of the subject is by Honda (1971) where he presented one of the earliest algorithmic methods for creating a branching structure. This was done by starting with a parent branch which then bifurcates into

two child branches and rotating them by given angles about the termination point of the parent branch, an example of which can be seen in Figure 1. By continuing this method he treated each child branch as another parent and bifuracted them to expand the branching structure which would be continued until a desired result is reached.

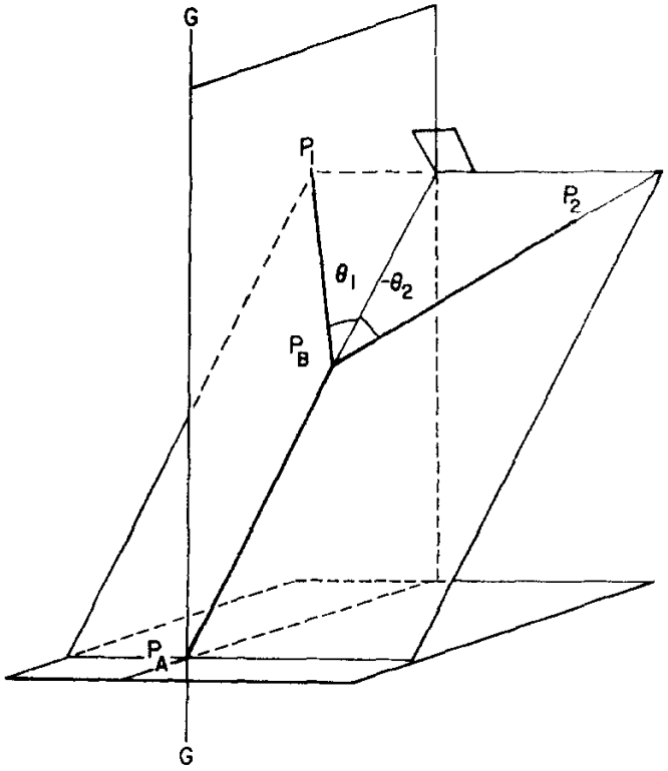

Figure 1: Example diagram of parent branch P_AP_B bifurcating into child branches P_BP_1 with a rotation of θ_1 and P_BP_2 with a rotation of $-\theta_2$

This paper does not include any information relating to branch thickness or leaf placement as its focus was only on the branching structure. However, this paper provides a groundwork for many later studies that will be discussed in this project.

Bloomenthal (1985) presents his own tree generation process, specifically for a maple tree. For the construction of the branches and trunk he uses splines to create a tree skeleton, the use of splines rather than straight lines is chosen to produce a more natural structure. He then uses generalised cylinders with varying radii across the splines to create thickness. He also describes the use of ramiforms, shown in Figure 2, to make

branch bifurcations realisticly curve rather than have an acute separation.

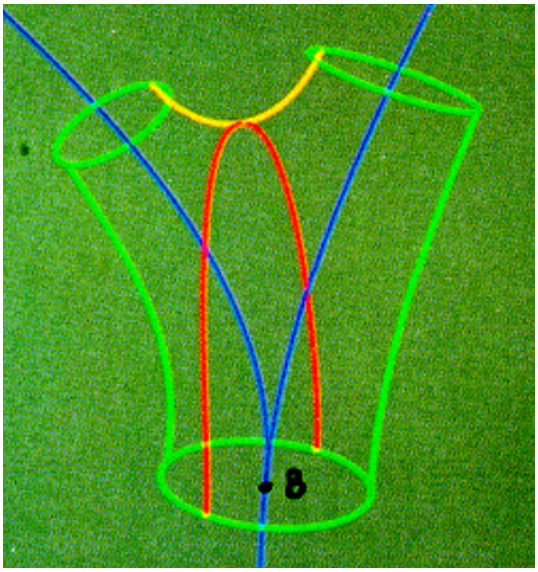

Figure 2: A ramiform used to create a realistic bifurcation

The method he describes for leaf placement uses polygon structures to which he applies a leaf texture, these polygons are then brought together in clusters that he calls "configurations" and for each limb that does not exceed a given diameter and that has no outgoing limbs, a leaf configuration is chosen at random, scaled randomly and placed at the limb tip. The interior lines of each polygon correspond to hinge points of the leaves that could be manipulated to show leaf distortion from wind.

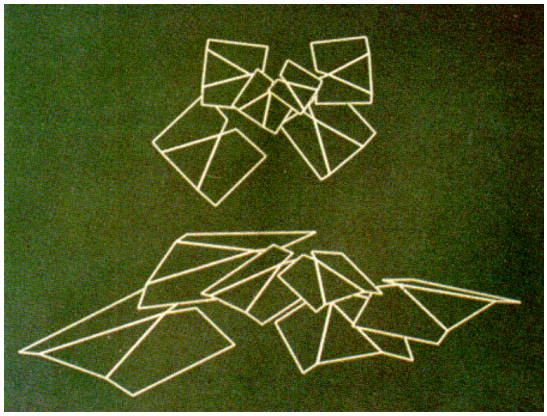

Figure 3: A leaf configuration: plan view (top) and perspective view (bottom)

Prusinkiewicz et al. (1996) presents a method of tree generation using an advanced L-system, developed from the work of Lindenmayer (1968) and applying that system to the bifurcating parent and child branch trios displayed by Honda (1971). Their chosen method for representing their models is by using turtle graphics in a 3D space and the string generated from the L-system uses symbols that correspond to controlling the turtles orientation in space.

Prusinkiewicz et al. produce a variation on a standard L-system known as a "deterministic" L-system or "D0L-system" which produces the same result every time. They demonstrate the application to turtle graphics with a simple snowflake fractal shown in Figure 4.

The D0L-system uses an Axiom string and a production rule to recursively develop a longer and more complex string. Once a chosen result is reached, the string is traversed and each character or group of characters corresponds to the movement of the turtle. For example the D0L-system below represents that of the snowflake fractal where $F(s)$ corresponds to a movement forward of distance s and $+(r)$ or $-(r)$ correspond to a rotation positively or negatively about the x axis by r degrees.

Axiom ω: $F(1)-(120)F(1)-(120)F(1)$

Production p_1: $F(s) \rightarrow F(s/3)+(60)F(s/3)-(120)F(s/3)+(60)F(s/3)$

The axiom draws an equilateral triangle with edges of unit length. Production p_1 replaces each line segment with a polygonal shape where the line segment has been given a convex triangular appendage. The Production p_1 can be visualised as so:

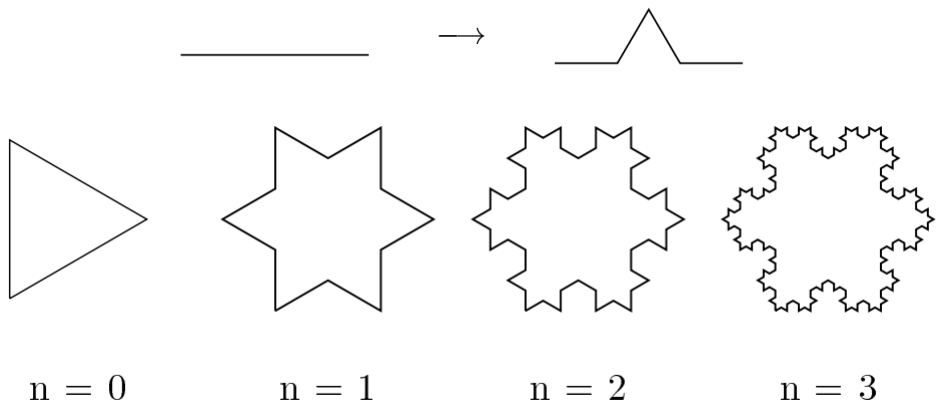

Figure 4: The visualised production rule p_1, axiom and first 3 recursions defined by the snowflake D0L-system from (Prusinkiewicz et al., 1996) pg.12

Prusinkiewicz et al. went on to present a complex D0L-system to be used for constructing tree structures by creating a Parametric L-system allowing for input to alter the axiom string producing different results along with using a conditional requirement to decide automatically when to stop recursing.

This L-system is defined below, in this context $A(s,w)$ refers to a line segment or "apex" of length s and width w. Production p_1 begins with the conditional statement to only continue if the length s of the current apex is greater than or equal to *min* which is a chosen minimum length. If the condition is met then $!(w)F(s)$ draws a line of length s and width w.

Lines a_1 and a_2 refer to the bifurcated child apices of the parent apex which are given a rotation of α_1 and α_2 radians about the x axis and a rotation of ϕ_1 and ϕ_2 radians about the y axis. The length of the child apices is calculated by multiplying the parent apex length s by the corresponding length degradation parameters r_1 and r_2 respectively.
–width description–

ω: $A(100, w_0)$

p_1: $A(s,w) : s >= min \rightarrow !(w)F(s)$

a_1 $[+(\alpha_1)/(\phi_1)A(s*r_1, w*q^e)]$

a_2 $[+(\alpha_2)/(\phi_2)A(s*r_2, w*(1-q)^e)]$

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