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Interactive Fractal Tree Generation Method having Multiple Clipping Volumes

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Abstract

The Environmentally sensitive L-system expresses the shapes of topiary by "Query module". This L-system is hard to model the tree that have multilevel growth domain, because this system confine limited the growth using a unit volume. We extended environmentally sensitive L-system for multilevel and multimodal topiary and added the rule of main-branch and growth-area-variable in this paper. If the main-branch moves into another domain in the growing process, it is branched with the new domain as its growth-limitation area. Growth-area variable is used for checking area. We also designed new L-system for leaves. This designed L-system generated various shaped leaves from same rule by changing parameter value. The proposed tree modelling technique is possible to model various sort of garden tree. The proposed tree modelling technique is possible to model multilevel and multimodal tree.

Keywords: *Fractal Tree Modeling, Leaf Modeling, L-system*

1. Introduction

One of the main research themes in computer graphics is modeling of natural objects. To model the natural phenomenon, fractal modeling, the particle system and grammar based modeling technique are commonly used [2-4]. Among them, grammar-based modeling technique is used to simulate the plant shape and its growth process. The most popular grammar based modeling method is L-system [7-9]. On the assumption that the plants interacts their environment, dynamic tree modeling method called environmentally sensitive L-system, has been designed to model the tree [5]. In this system, growth point (branching point) of the trees is assigned as a parameter to Query Module in each iteration step. These parameters are used to control the growth area dynamically. However, Environmentally-Sensitive L-system is limited to model the tree that has a multi-modal or multi-level growth area.

We added main-branch production rules and growth-area-variables to previous L-system for interactive tree modeling system. In proposed L-system, when the main-branch moves from initial domain to another domain in the process of tree growth, main-branch production rule for other domain is initiated in concurrent with the branching rule for initial domain. Both rules are applied for each domain simultaneously. Growth-area-variable is used to prune the branches of tree. We could generate multi-level tree and multi-modal tree. We also propose the L-system for modeling the various leaf shapes. By combining the two L-system for the branch and leaf, we can model the final tree having multiple clipping volumes.

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2. Previous Work

L-system and Turtle interpreter: The L-system is called “grammar based modelling” because it produces the model by converting the string by the production rules defined in the initial step. The L-system [9] can further be subdivided into context-free L-system, context-sensitive L-system, stochastic L-system and the parametric L-system. Others include non-propagation L-system, L-system with cut symbol and environmentally sensitive L-system. The environmentally sensitive L-system uses a query module, which stores the branching position that occurs during the growth process. These stored positions are used to control tree growth.

Stochastic tree model: Many simple models of branching structures produce an exponentially increasing number of branch segments. Borchert and Slade showed that in reality this exponential increase is not sustained beyond the early stages of tree development [6]. As soon as a tree surpasses a certain, relatively small size, the rate of branching decreases.

Environmentally sensitive L-system: In conventional L-system, the turtle interpreter interprets the string after the production rule has been applied and converts its static model into 3D data without affecting the L-system. However, in environmentally sensitive L-system, the generated string is interpreted after each derivation step and turtle attributes found during the interpretation are returned as parameters to reserved query modules in the string [5].

We extend our previous research [10] and enhanced the L-system that can modify and edit the clipping volume more interactively and also design the L-system in order to model the leaf.

3. Fractal Tree with Multiple Clipping Volume

3.1. Concepts for modeling with multiple clipping volumes

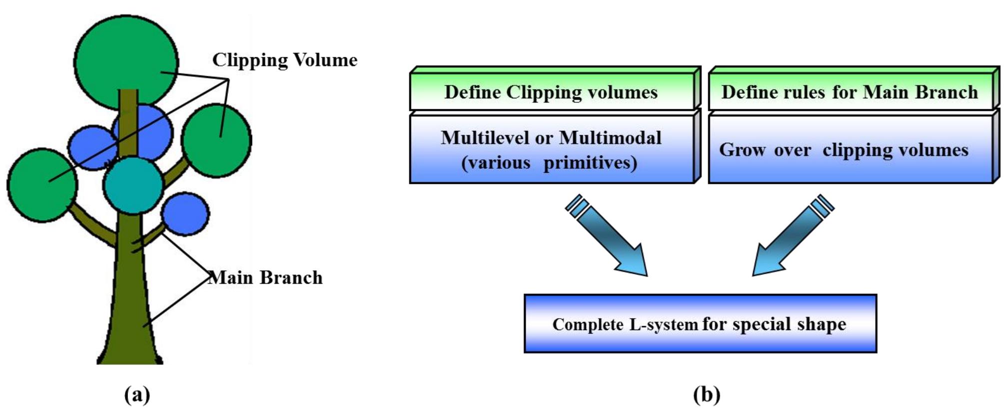


Figure 1. Preprocess for modeling the special shaped tree

A garden tree shown in Figure 1-(a) is among the trees that can be observed in the garden. It is not so easy to represent various topiary shapes using existing modeling procedures. For the multilevel or multimodal topiary shape, we add the production rule for main-branch that grows through each clipping volume and creates growth-area-variables that differentiate each clipping volume. When a main-branch grows over a clipping volume, it tests the boundary of its selected volume. The clipping volume is controlled by the growth-area-variable. Preprocess is necessary for proposed L-system. This preprocessing involves two main areas: main-branch procedure and clipping-volume procedure as shown in Figure 1-(b). Clipping volumes are defined by various primitives in accordance with the shapes of the trees and are assigned by an area index that distinguishes each volume. Also, main branch rule of axiom is designed in order to enable the main branch to migrate to the clipping volume. Lateral branching can be simulated by stochastic tree model [6].

Table 1. Growth of main-branch and checking clipping volume

```
w  : F[FC(1, 1)?P(x, y, z, 1)][FA(1, 1)?P(x, y, z, 1)]
              (1)                 (2)
P1 : C(k, area) > ?P(x, y, z, area) : bound(x, y, z, area) → FC(k,area+1)
                                          (3)          ÷  (4)          ≠
P2 : C(k, area) > ?P(x, y, z, area) : !bound(x, y, z, area) →
        /(ϕ)[FA(1, area+1)?P(x, y, z, area+1)][FD(k, area+1 )?P(x, y, z, area+1)]
                                                       (5)
Area check module : bound(x, y, z, area)
  if(area == 1) if(first area's inside) return TRUE;
    else if(area == 2) if(second area's inside) return TRUE;
```

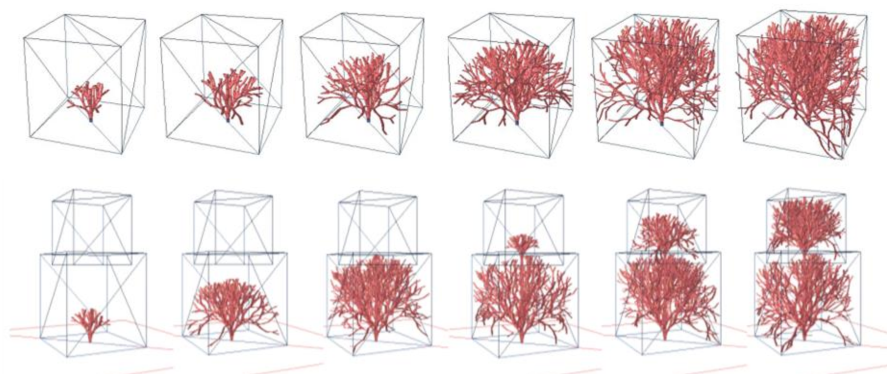


Figure 2. Tree structure using one and two cubes

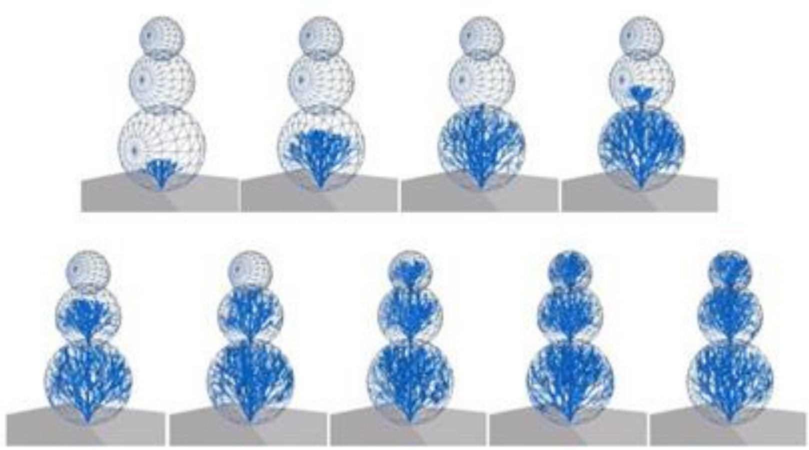


Figure 3. Tree structure using three spheres

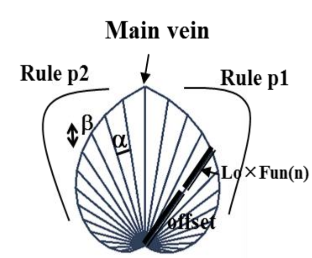
The Table 1 shows L-system simplified by extended concept. According to axiom w, the development begins with main-branch and lateral branch. (1) consists of *FC(1,1)*, which means the beginning of main-branch growth and a query module, *?P(x,y,z,1)*. The symbol *A* and query module in (2) shows branching of lateral branch using stochastic tree model [6]. The number 1 means the first clipping volume. (1) is transformed into productions *P1* or *P2*. Production *P1* is the main-branch's growth. *P2* means lateral branch and main branch growth to new volume. The area-check-module, (3) determines whether the current position is inside or outside of the current clipping volume. And (4) of production *P1* depicts the growth of the main-branch when the position of the main-branch is inside the first clipping volume. In this step, if the position of the main-branch is inside the second volume, *P2* is applied. Finally (5) changes the growth-area-variable to make the main-branch grow into the next volume. As a same approach, (3)-(5) rules can be extended for defining over two volumes. Figure 2 shows the branching pattern of the bi-m tree growing process. Figure 3 shows the shapes of trees and growth procedure using the various boundaries.

3.2. L-system for Leaf

The type of leaf is also various. We also introduce the parametric L-system for modeling the leaf in this paper. We make a hypothesis that the structure of leaf is symmetric by m vein of leaf and then design the L-system. Table 2 is show the proposed L-system for leaf. . According to axiom w, the leaf is modelled with both sides, *L(n)* and *R(n)*. *L(n)* represents the left veins with main vein as its center. *R(n)* has an opposite direction with *L(n)*. *α* means rotation angle of vein and *β* represent bending angle of each vein and offset means minimum length of vein that disturb abnormal growth of vein. *Fun()* can be general mathematical linear functions and control the length of each vein by function value according to the parameter, n. Figure 4 shows the various leaf shape by proposed L-system.

Table 2. Parametric L-system for leaf and its description

n **: number of data point**
lo : ratio change of length vein
α : rotation angle of vein β : angle of bending
k : b / 2 offset : minimum length of vein
w : { L(1) [G(lo*Fun(1)).] R(1) }
P1 : L(n) : n < k → [+(α *n)<(β *n)G(offset+lo*Fun(n)).]L(n+1)
P2 : R(n) : n < k → [-(α *n)<(β *n)G(offset+lo*Fun(n)).]R(n+1)
Fun() : functional module for controlling the length of vein



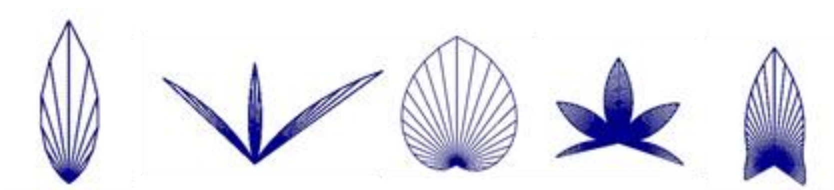


Figure 4. Leaf structure by proposed L-system

4. Conclusions and Future work

We propose the extended environmentally sensitive L-system, which represents tree branches with multilevel and multimodal clipping volume. In order to model the garden tree structures, we proposed the rule of main-branch and growth-area-variable in our L-system. If the main-branch moves one clipping volume into another in the growing process, branching in both volumes take place simultaneously. Growth-area-variable is used to control the volume checking. We also designed new parametric L-system for leaves. This designed L-system generated various shaped leaves from same rule by changing parameter value. Our modeling system provides the UI to organize the clipping volumes interactively. The proposed tree modeling technique makes it is possible to model multilevel and multimodal topiary. Figure 5 shows images that are developed by proposed L-system. In our system, the final data is stored as polygonal model. We used the ray-tracing algorithm to render the final image [1]. Our works lead to the development of interactive application program with user-input of main branch and clipping volume. We can generate the leaf type by changing the parameters of L-system for leaf modeling as well.

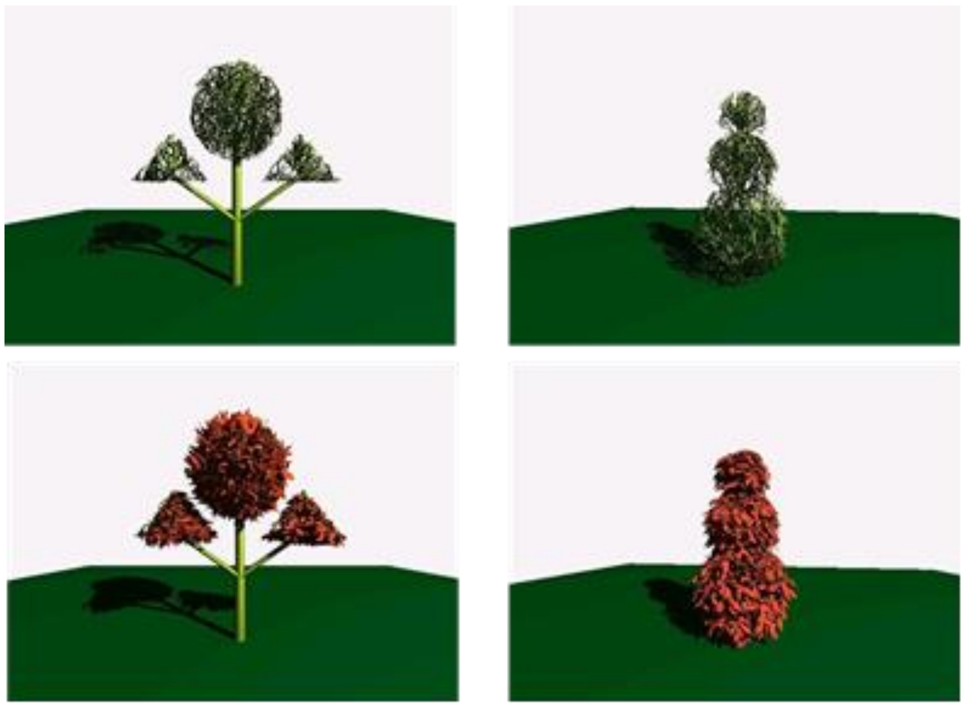


Figure 5. Trees using various clipping volumes

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