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# Tree Modeling and Dynamics Simulation

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**Abstract**

This paper introduces the theory about tree modeling and dynamic movements simulation in computer graphics. By comparing many methods we choose Geometry-based rendering as our method. The tree is decomposed into branches and leaves, under the rotation and quaternion methods we realize the tree animation and avoid the Gimbals Lock in Euler rotation. We take Orge 3D as render engine, which has good graphics programming ability. By the end we realize the tree modeling and dynamic movements simulation, achieve realistic visual quality with little computation cost.



Keywords:tree modeling; dynamic tree movements simulation; Orge; quaternion

## 1.Introduction

Real-time simulation of natural scenes is a main area in Computer Graphics, especially for the dynamic tree movement simulation. The technology of tree modeling is mature, such as fractal processing method, particle system method and so on. Today the keystones of study modeling have transformed into how to achieve realistic visual quality with little computation cost. At earlier time, people have present the method that solve the tree's dynamic movement simulation by using non-linear dynamic equations and wave equation [1], but this simulation achieves realistic visual quality with little computation cost. And people used wind field simulation to simulate tree's swing [2], wind speed and wind field mechanics can be simulated, but environment of wind field is complicated. If we consider more factors such as vortex, it will be a very complicated field.

This paper chooses Image-based rendering methods through comparing with many methods, such as fractal processing method, particle system method. And we get the tree modeling, which is realistic visual quality with little computation cost. Tree animation synthesized from trunk motion, branch motion and leaves motion. Branches are divided into many sub-nodes. We can get the branches motion through

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superposing the rotated sub-nodes. The leaves motion use leaf cluster swinging to complete. So, we can simulate the tree animation. Rotation algorithm chooses quaternion. Quaternion can avoid the Gimbals Lock in Euler rotation.

We take advantage of 3D engine in scene management with programming. Orge 3D engine has many advantages, such as better rendering ability.

## 2.Tree modeling and rendering theory

The tree has larger difference in the type and structure, so the modeling of different kind of trees is also different. People have finished a lot of work about tree modeling. According to different researches, we can build modeling by different methods.

### *2.1.Fractal processing method*

Fractal processing method describes the self-similarity mathematical function to represent topology and morphological structure of plant's growth, such as L system [3]. This model usually include as much as tens of thousands or even hundreds of thousands of triangular face, so it is well realistic. But it sacrifices the computation to achieve realistic visual quality, so the system runs slowly or even can not run. It is not suitable for the simulation of real-time roaming system.

### *2.2.Particle system method*

In this way, object is considered as innumerable small particles, every particle has its own property, and particles caused random changes over time [4]. Nowadays, this method has been widely used in large 3D games. Particle system can fully manifested dynamics and the randomness of objects. But it is suitable for smoke, fog, forest and a wide range of modeling; it is not suitable for single plant modeling. If someone observes carefully, individual model is not very realistic.

### *2.3.Image-based rendering methods*

This method represents object through extracting information from the image [5].The advantages are as follows: Realistic, High-speed rendering, having no connection with scene complexity. Image can be rendered toward the viewpoint on the polygon's surface, and then it can get many special effects.

- *Billboard technique*

The technique that is used to determine the polygon direction according to the observe direction, called billboard technology, and the polygon is called billboard [6]. The direction of billboard is changing with the view changing. For every form of the billboard, surface vector and upward vector determine the bulletin board generally so as to determine the direction of image oriented, as in figure 1 shown, $n$ is the given surface vector, and $u$ is the approximate upward direction vector, the main purpose is establishing a set of three orthogonal vectors to determine the direction of the billboard. But this method has an obviously disadvantage –parallax.

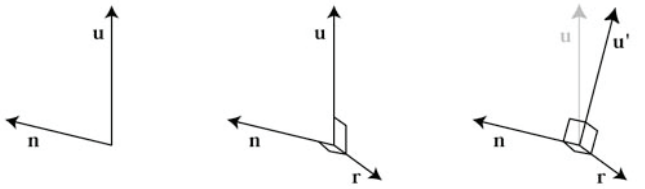


Figure 1. The direction of billboard

- *Crossing plane technology*

Billboard technique simulates the complex object by using one plane, and crossing plane technology simulates complex object by using several crossing planes. It chooses map of texture pixels by alpha test. There are several crossing planes, so it can be seen as texture plane from different angles [7]. It will show good effect through this method. This method is made possible by different crossing plane and map cooperating well with the plane. Figure 2 shows the crossing plane.

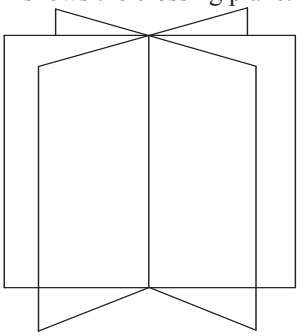

Figure 2. Crossing plane

## 3.Our Tree Modeling Method

The structure of one tree can be decomposed into three parts: trunk, branches and leaves. The relationship of these parts is called parent child relation [8]. Trunk determines the size of tree; Branches show tree's structure and external shape; Leaves' number is the largest and leaves' shapes are various.

The modeling of the branch is based on branches details, that is to say, it expresses branches by certain forks. The fork and branch are shown in figure 3.

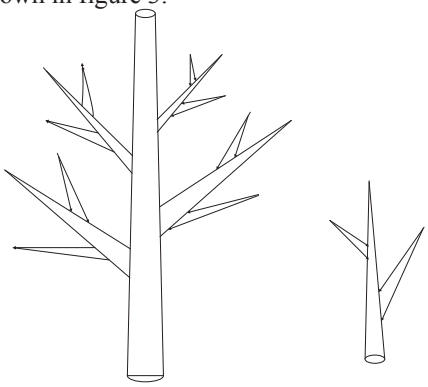

Figure 3. The branch and fork

The modeling of the leaves must avoid multifarious calculation and ensure realistic. Plane is used to express leaf cluster. A plane shows a leaf cluster. Using the full freedom of billboard can realize leaf cluster swinging with tree branch. The principle of leaf arrangement in botany is used to confirm the leaf cluster's position. We use collision detection to avoid plane cross, which is caused by the leaf arranged closely. It adopts images with alpha channel as texture of leaf cluster, and eliminates the black side of the leaves, and then we finish the modeling of leaves.

## 4.Tree Animation Theory

Trunk motion, branches motion and leaves motion mix to produce tree animation. Such a structure can be represented as a simplified hierarchy of interconnected rigid segments with the trunk as the root of the hierarchy. Trunk motion is shallow movement, and it is not evident on the vision, so this paper only considers branches motion and leaves motion.

A branch can be divided into many nodes, parent-node control sub-node [10]. As figure 4 shown, a node controls b node, b node controls c node. Branches motion is the rotation and translation of sub-nodes.

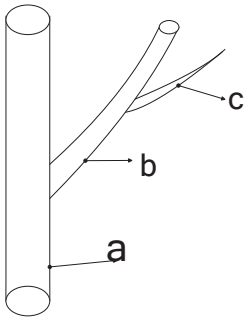


Figure 4. A branch can be divided into many sub-nodes

The branch motion can be obtained by matrix rotation. Firstly, each sub-node of branches is assigned an only index; secondly, according to the predetermined elastic parameters distribution corresponding weights; at last, according to rotation algorithm to get branch motion, bending and vibration effect as nature. Rotation algorithm as the following formula:

Rotating around X-axis:

$$R_X(\theta)=\begin{bmatrix}1 & 0 & 0 & 0\\ 0 & \cos\theta & -\sin\theta & 0\\ 0 & \sin\theta & \cos\theta & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Rotating around Y-axis:

$$R_Y(\theta)=\begin{bmatrix}\cos\theta & 0 & \sin\theta & 0\\ 0 & 1 & 0 & 0\\ -\sin\theta & 0 & \cos\theta & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Rotating around X-axis:

$$R_Z(\theta)=\begin{bmatrix}\cos\theta & -\sin\theta & 0 & 0\\ \sin\theta & \cos\theta & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{bmatrix}$$

Leaf clusters own swinging and branch motion mix to leaves motion. Leaf clusters own swinging is simple pendulum motion around pendant point on the branch [11]. We can define movement cycle and amplitude according to our requirement.

## 5.Simulation of tree animation

### *5.1.About Orge*

Nowadays, the developing of 3D engine rapidly increases. There are Orge, Irrlicht, Nebula, KlayGE and so on. Most game businessman prefer Orge 3D engine, because Orge engine has many advantages: Firstly, Orge engine support Direct3D and OpenGL, and it can support many computer operating system, such as windows, Linux, Mac oc x. Secondly, Orge 3D engine has a powerful particle system, and it is good at produce atomizing results. Thirdly, Orge 3D engine excel at graphics programming; it has visual programming tools; it builds scripting language; and then it can modify external data and debug built-in programming. To sum up, it can finish graphics programming quaintly and efficiently, support many kinds of graphics algorithm. Orge 3D engine apply to tree animation, bone animation etc, which need many textures and vertex [12].

### *5.2.Rotation in Orge*

Computer graphics often uses Euler rotation. There is fixed API for Euler rotation in Orge 3D engine. But Euler rotation has the Gimbals Lock problem. Gimbals Lock can be descript as following: It rotate X axis, Y axis and Z axis around objects coordinate. When the Y axis rotates 90 degrees, the Z axis will point to the original X axis. But we only rotate around the X axis and Y axis in fact. Obviously, the degree of freedom of the third axis is lost.

In order to avoid Gimbals Lock, we choose quaternion in Orge 3D engine. The quaternion class will be used for quaternion processing in Orge 3D engine. The quaternion class consists of four parts: X axis, Y axis and Z axis and rotation component W, the formula is listed as following:

$$Q = \cos(angle/2) + i(x * \sin(a/2)) + j(y * \sin(a/2)) + k(z * \sin(a/2))$$

Code：

```
Q.w = cos (angle / 2)
Q.x = axis.x * sin (angle / 2)
Q.y = axis.y * sin (angle / 2)
Q.z = axis.z * sin (angle / 2)
```

Then we construct a quaternion to rotate: Quaternion q (Degree (-90), Vector3::UNIT_X); where, the first parameter definite rotation angle, the second parameter define the axis of revolution. The above code shows that it rotate -90 degrees around the X axis. The quaternion is used for Scene Node rotation: SceneNode->rotate (q); and then it can realize this node around X axis rotation -90 degrees.

### *5.3.Tree animation*

Rotation of sub-node and mutual control of sub-nodes with each other realize branches motion. Besides leaf clusters own swinging, there are leaf clusters motion with branch motion. These two parts mix to leaf motion. Tree animation includes branch motion and leaf motion. We synthesize realistic tree animation from combining branch motion and leaf motion [13].

## 6.Simulation results

Hardware environment as following: System Memory is 2GB；CPU Clock is 2.0GHz；Display card is NVIDIA GeForce 7300GT, Graphic Memory is 128MB. Algorithm completed in windows 7 system and visual studio2008. We choose poplar tree as model. The number of triangular face is 12058. Figure 5 is some key frames in simulation.

Figure 5. Some key frames in simulation

## 7.Conclusion and future work

In this paper, we achieve realistic visual quality with little computation in tree modeling based on Geometry-based rendering. Branch and leaf motions are simulated respectively, and then we synthesize tree animation. Computational complexity can be greatly decreased through this method. By the use of quaternion we avoid the Gimbals Lock problem in Euler rotation. The future work is to simulate animation forest. And we can use LOD technology which is greatly efficiency to decrease faces number and details for those trees in distance.

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