THE RESEARCH ON SIMULATION OF 3-D TREES

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ABSTRACT:

This paper introduces the L-system, affined manipulation and particle system. And discussed the different methods is used for the different parts of the tree. Currently, mainly simulations of trees carry on in 2D according to the papers in China, which only use one method to simulate trees. Aimed at this problem, this paper carries on the thorough research according to the theories of L-systems, affined manipulation and particle system; the trees are drawn using APIs of OpenGL in ArcGIS. We carried on the 3-D overlay display of the tree in the Poyanghu area geographic information system, obtaining ideal result of the stereoscopic and true feeling.

Along with the development of the geographic information system and Computer Graphics, people always inquiry into various methods of the natural and artificial features of the nature by computer simulation. Currently, mainly carry on the modeling according to the Euclidean geometry methods for the simulations of the regular objects, and generated the better simulation results. For the simulation of the culture and relief of the irregularity, then just be placed in a stage for develop, still stay around a simple mode so far up. For example on the simulation of the tree, see the report of the simulation of the 2-D tree only in China currently, for the simulation of the 3-D tree, have not yet seen mature related treatise.

Aim at this problem, this paper carry on the thorough research according to the platform independent OpenGL APIs, the industrial library that the high performance graphics and interactive applications in fact. We put forward the adoption with the L-systems carries on the trunks, branches and leaves for the framework simulation, and make them expand from the 2-D system to the 3-D system. Because the tree trunk, tree branch and leaves are each to have the characteristics on the appearance, can't adopt the one algorithm to carry on unifying the transaction. For this we adopted the different method to different part. In tree trunk handle, because the tree trunk is rougher, the trees that have grow the surface to still have the crack, so adopted the algorithm of self-squaring fractals to carry on the surface transaction of the tree trunk.

For the sake of the gnarled and contorted appearance of the simulation tree branch, we can apply twisting functions as well as scaling to create the random, self-similar branches. For the leaf, mainly adopted to use random scaling parameters and branching directions for modeling of the vein patterns in leafs, and joined the random number to draw the boundary of the leafs out of the leaf vein edge. Moreover because of the discrepancy of the tree trunk, tree branch and the leaf appearance, on the foundation of the Statistically self-similar fractals, adopted the above algorithm to create to them respectively homologous mathematics model, then the tree that carry on the overlay to become an integrity. Because some tree crowns contain buds and random distribution of floral shape in crown of tree on, so we adopted the particle system to carry on the simulation.

1. L-SYSTEM, THE SIMULATIONS OF TRUNK AND BRANCHES

L-systems are a mathematical theory of rewriting, which was proposed by Lindenmayer firstly. In general, rewriting is a technique for defining complex objects by successively replacing parts of a simple initial object using a serial of rewriting rules.

This discussion starts with an example of the DOL-system to introduce the main idea.

Consider strings (words) built of two letters a and b, which may occur many times in a string. Each letter is associated with a rewriting rule. The rule a->ab means that the letter a is to be replaced by the string ab, and the rule b->a means that the letter b is to be replaced by a. the rewriting process starts from a simplest string, which called seed or axiom. In the first step of rewriting the seed b is replaced by a using rule b. In the second step a is replaced by ab using rule a. then the word ab consists of two letters, both of them are simultaneously replaced in the next derivation rule. Thus, a is replaced by ab, and b is replaced by a, as a result, we can get the string aba. In this way, the string aba produces abaab, which yields abaababa, and so on.

Formal definitions describing DOL-systems and their operation are given below.

Let V denote an alphabet, V* the set of all words over V, and V+ the set of all nonempty words over V. A string OL-system is an ordered triplet G=<V,w,P> where V is the alphabet of the system, w $\omega \in V+$ is a nonempty word called the seeds or axiom and $P \subset V \times V*$ is a finite set of productions. A production $(a, \chi) \in P$ is written as $a \rightarrow \chi$. The letter a and the word χ is called the predecessor and the successor of this production, respectively. It is assumed that for any letter $a \in V$, there is at least on word $\chi \in V*$ such that $a \rightarrow \chi$. If no production is specified for a given predecessor a $a \in V$, the only production a->a is assumed to belong to the set of productions P. an OL-system is

deterministic if for each $a \in V$ there is exactly one $\chi \in V*$ such that $a \to \chi$.

The following example provides an illustration of the operation of DOL-systems.

```
W:b                    ;;as seed
p1:a->ab               ;;rule a
p2:b->a                ;;rule b
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Starts from a single cell b, also called from the axiom, the following is the words produced:

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b
a
ab
aba
abaab
abaababa
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in order to model the plants, the more sophisticated graphical interpretation of the L-system is needed. The key concept is to represent the current orientation in space by three vectors $\vec{X}, \vec{Y}, \vec{Z}$, which indicating the direction to the ground. From ground we can assume that Z presents go higher. And X and Y present horizontal plane or parallel with the surface of the ground. These three vectors have unit length, are perpendicular to each other, and satisfy the equation $\vec{Z} = \vec{X} \times \vec{Y}$. Rotations are then expressed by the equation

$$\begin{bmatrix} \vec{X'} & \vec{Y'} & \vec{Z'} \end{bmatrix} = \begin{bmatrix} \vec{X} & \vec{Y} & \vec{Z} \end{bmatrix} R$$

Where R is a 3*3 rotation matrix by angle α about the vectors are represented by the matrices:

$$R_{Z(\alpha)} = \begin{bmatrix} \cos a & \sin a & 0 \\ -\sin a & \cos a & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R_{Y(a)} = \begin{bmatrix} \cos a & 0 & -\sin a \\ 0 & 1 & 0 \\ \sin a & 0 & \cos a \end{bmatrix}$$

$$R_{X(a)} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos a & -\sin a \\ 0 & \sin a & \cos a \end{bmatrix}$$

Turn left by angle a, using +a, turn right by angle a, using –a. As rules of physics that tree only grow up and cannot grow down, so the direction of Z only goes up as a trunk. But as a branch this is not true. According this, in each derivation step, the straight apex issues a lateral apex of the next order at angle

a or –a with respect to the mother axis. Two productions are used to create lateral apices alternately to the left and right. So that the vector $\vec{Y}$ pointing to the left is bring to a horizontal position. Consequently, the branch plane is "closest to a horizontal plane". From a technical point of view, the branch modifies the orientation in space according to the formulas as below:

$$\vec{Y} = \frac{\vec{V} \times \vec{X}}{\left| \vec{V} \times \vec{X} \right|} \quad \text{and} \quad \vec{Z} = \vec{X} \times \vec{Y}$$

Where vectors $\vec{X}, \vec{Y}$ and $\vec{Z}$ are described as above: $\vec{V}$ is the direction opposite to gravity, and $\left| \vec{A} \right|$ denotes the length of vector $\vec{A}$.

In order to express the texture of trunk, we use self-squaring fractals method to get this effect.

This method for generating fractal objects is to repeatedly apply a transformation function to points in complex space. In 2D, a complex number can be represented as z=x+iy, where x and y are real numbers, and i^2 =-1. In 3D, points are represented with quaternion. A complex squaring function f (z) is one that involves the calculation of z^2, and we can use some self-squaring functions to generate fractal shapes.

The squaring transformation formula is following:

$$z' = f(z) = \lambda z(1 - z)$$

Where λ is assigned any constant complex value. Variables x, y, and λ is with $|\lambda| = 1$. And the normalized λ values plotted as the vertical axis.

2. SIMULATION OF LEAVES WITH AFFINE MANIPULATION

We cannot use the L-system, as some user to simulate the leaves in the tree because the tree we simulated is too much to use up our computer sources. So we have to choose other methods simulate the leaves.

Self-similative carries on using self-similar translation, which achieved using affine manipulation.

Self-similar translation is the translation in all direction using the same ratio. And affine manipulation is the conversion of the different directions using the different ratio. So the latter

manipulation can result the distortion, and the frontal is the special example of the latter.

The mathematic expression of the affine manipulation is following:

$$x^{'} = ax + by + e$$
$$y' = cx + dy + f$$

Where x,y = coordinate before changed

x' ,y'= coordinate after changed

a, b, c, d, e ,f = coefficient which can be got by using 3 fixed points we computed.

We can add z to this formula, which change 2D into 3D.then the formula is below:

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = w\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a & b & c \\ d & e & f \\ g & h & k \end{pmatrix}\begin{pmatrix} x \\ y \\ z \end{pmatrix} + \begin{pmatrix} m_1 \\ m_2 \\ m_3 \end{pmatrix}$$

We can use different affine conversions for a complicated graphic simulation and different trees.

3. SIMULATE FLOWERS WITH PARTICLE SYSTEM

The used method for modeling natural objects, or other irregularly shaped objects, that exhibit fluid-like properties is particle systems. This method is particularly good for describing objects that change over time. The system formula is:

$$p_i = (x_i, y_i, z_i)$$
$$v_i = \frac{dp_i}{dt} = p_i^{'} = \left(\frac{dx_i}{dt}, \frac{dy_i}{dt}, \frac{dz_i}{dt} \right)$$

Where p = position of particle in special time.

Random processes are used to generate objects within some defined region of space and to vary their parameters over time. At some random time, each object is deleted. During the lifetime of a particle, its path and surface characteristics may be color-coded and displayed. The particles shapes can be small ellipsoids, or other shapes. The size and shape of the particles may vary randomly over time. And also other properties such as color all can vary randomly.

In this simulation, we control the path of particles in the tree surface and branches, and the changes of colors and sizes with time over long time to simulate the blossom in all lifetime of flowers, which bring good effect and decrease much computing time.

4. SIMPLE PROGRAM WITH THE APIS OF OPENGL

The OpenGL is a software interface to graphics hardware. The interface consists of a set of several hundred procedures and functions that allow a programmer to specify the objects and operations involved in producing high-quality graphical images in 2D or 3D. For the most part, OpenGL provides an immediate-mode interface, meaning that specifying an object causes it to be drawn.

Using OpenGL, We can use a series of operation methods such as rendering, lighting, multi-views, antialiasing, which release us much time on these programming.

According to the above algorithm, we carried on the 3-D overlay display of the tree in the Poyanghu area geographic information system, obtaining ideal result of the stereoscopic and true feeling. This research fruit can also expand the 3-D display of the geography earth thing of other geographic information systems.

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