The Application of Computer Virtual Reality Technology in the Cultivation of Dendrobium Officinale of High Efficiency

Que Caixia, Shi Lin, Li Dongmei*

Department of Design,
Shunde Polytechnic,
Guangdong, 528300, China

Abstract — Cultivation of Dendrobium officinale of high efficiency needs real-time monitoring of plant growth status, also needs preliminary stage of virtual plant research to find the D. officinale optimum growth conditions. Shape visualization technique is one of the key technologies of virtual plant research. This study used D. officinale crop as the object. On the basis of D. officinale morphology visualization framework, first of all, 3D geometric modeling technology of different organs of D. officinale was researched, and the geometric model based on organ morphology parameters was constructed, including geometric model of leaf and stem. Then based on the platform of OpenGL, the 3D morphology of the organs of D. officinale was rendered, and realistic graphics display technology such as color rendering, texture mapping, light processing was put forward. Finally, D. officinale visualization forms from three levels of organ-individual-group was realized through coupling D. officinale plant topological structure model and D. officinale individual relationships between each other, which laid the technical foundation for building visual growth of D. officinale system.

Keywords - dendrobium officinale; visualization; geometric modeling; rendering; openGL

I. INTRODUCTION

Virtual reality technology was used to simulate the growth and development of plants in three dimensional space by virtual reality technology [1], in order to simulate the change of plant morphology and structure in a visual way. This was to further deepen and expand the simulation of plant growth, in the field of plant growth design and management regulation has a wide range of application prospects [2]. Plant morphology and visualization was one of the key technologies of virtual plant research, it was refers to the use of computer graphics technology, with 2D or 3D graphics display the growth and morphology of plant built, including geometry, light, texture, rendering and modeling technology. Abroad in this area has been a lot of research [3], developed a number of virtual plant software, the establishment of a number of basic plant graphics library. But the software only simple appearance of plant simulation tool to generate visually realistic plant (organ), focus on computer graphics, containing a few of Botany mechanism cannot be objectively and effectively simulation real plant growth process. In China, the research on the modeling and visual simulation of the organ modeling and individual growth of corn, wheat and other crops was carried out. Liu using NURBS was established in leaves of maize and wheat in the geometry model [4], Deng put forward based on the cardinal spline interpolation and triangular blade static modeling method [5], Zheng cubic B sample to fitting of maize leaf shaped 3-D state [6]. However, the morphological data required by these methods were not easy to obtain, and it was difficult to describe the process of organ building. Chen and other forms based on the simulation model, the initial realization of the wheat organs and individuals of the virtual growth of, but the wheat organs and individual plot of real sense was not strong, and has not yet involved in the virtual display of wheat groups.

The morphological structure of Dendrobium officinale was more complex, from D. officinale morphology visualization can be for D. officinale growth visualization system was designed to provide technical basis. Therefore, this study using D. officinale crop as the object, on the basis of D. officinale morphology visualization framework construct organ shape characteristic parameter based geometric model [7]; and based on the platform of OpenGL, rendering the 3D morphology of the organs of D. officinale and at the same time, a color, texture, light photos and other graphics realistic display sub model; through further coupled D. officinale individual relationships, D. officinale from three levels of organ - individual group shape visualization.

II. THE TECHNICAL FRAMEWORK OF D. OFFICINALE MORPHOLOGY VISUALIZATION

The technical framework of visual form of D. officinale in the form of D. officinale built simulation model based on, combined with computer graphics technology to build the formation.

On the whole, D. officinale morphology visualization framework including construction of organ geometric model, color rendering, texture mapping, light according to processing, the process can divided into two stages: Modeling and rendering. Modeling was a three-dimensional geometric model of the organs of D. officinale; rendering was refers to the use of realistic computer graphics display technology (such as color, texture mapping, light illumination, etc.) three-dimensional geometric model of the...
organs of D. officinale to generate realistic image of the organs graph, the specific implementation process as shown in Fig. 1. The simulation model can simulate the morphology of morphogenesis of plants changed with the growth and development of the law and the dynamic relationship between the environment[8] geometry parameters and topology of the output index including leaf and stem; organ 3D geometric modeling module according to the three-dimensional geometric model of morphology parameters of organ after establishment; the color, texture, light and realistic organ geometry model technology processing and display, generate lifelike graphics so as to realize the visualization of organs, organ growth; in addition, according to the morphogenesis of plant topological structure simulation model output, can be organized into individual organs; and further according to plant spacing [9].

III. THREE-DIMENSIONAL GEOMETRIC MODELING ORGANS OF D. OFFICINALE

To realize the visualization of D. officinale morphology, three-dimensional geometric model of the organs had to be established. Through observation and study of the appearance of organs of D. officinale, based on morphogenesis simulation model output of leaves, stems, flowers and other organs of the morphological parameters, establish the geometry model in different organs of D. Officinale[10].

A. Leaf Geometry Modeling

D. officinale leaf consists of leaf and sheath, leaf sheath below sheath, an opening cylindrical, completely surrounded by internode. The study on the leaf sheath and leaf unified use NURBS (non-uniform rational B spline surface non uniform rational B-spline) to modeling.

A k * NURBS I surface can be expressed as follows:

\[
p(u,v) = \sum_{i=0}^{m} \sum_{j=0}^{n} W_{i,j} N(i,m) N(j,n) \]

\[
W_{i,j} = \prod_{k=0}^{K} \frac{d_l^k}{d_l^k-1} \prod_{l=0}^{L} \frac{d_l^l}{d_l^l+1}
\]

Where, \(d_l^k\) was the weight factor associated with vertex \(N_{i,j}(i = 0,\ldots,m; j = 0,\ldots,n)\) was respectively \(u\) to \(k\) times and \(v\) to \(l\) times the standard B spline basis, and determined by the formula of Boolean recursion through the node vector in \(U = (u_0,u_1,\ldots,u_{m+1})\) direction and \(V = (v_0,v_1,\ldots,v_{n+1})\) direction.

How to determine the control point of the leaf was the key of NURBS surface modeling. The morphological structure of D. officinale built simulation model and describe the model of leaf morphological characters of leaf length, leaf (different strengths of leaves and leaf width), leaf curve and leaf sheath morphology of sub model. In this study, the morphological structure built simulation model output parameters (such as leaf length, leaf width, leaf angle and leaf sheath length, etc.) to determine the control points of the NURBS surface, so as to establish the geometric model of leaf.

Each leaf formed by a NURBS surface, each NURBS surface has 10 rows of control points, the leaf sheaths and blades each row 5, each row has 7 control points. Leaf sheaths ranked first by the seven control points formed a square, which defined a circle with its tangent square, by the SR roughness of leaf sheath decided seven control points coordinates (Fig. 2A).

If leaf sheath of the first row of control points to define the coordinates of the center circle to (0,0,0), leaf sheath 2, 3, 4 rows of control points of the Y coordinate with the row number increases, X and Z coordinate unchanged. The 5th row of control points defines a non-closed curve (Fig. 2B), X and Z coordinates of the seven control points was determined by leaf crude Sr, y coordinates by the leaf sheath length SL decided (Fig. 2C).

For leaves and leaf curve model to simulate leaf air stretching, leaf curvature equation determine the control points in the middle of the main vein, leaf blade margin controls the control points of the point with a row of main vein of X and Y coordinates, but Z coordinates by the leaf length and leaf shape model to determine. In edge control...
point and main vein between the control points set 2 columns and main veins parallel control point (Fig. 2C) and leaves of the control point also has 5 rows, each row of seven, the 1st platoon control point y and Ye 5 rows of control points of the Y coordinates, this can better enable leaf and leaf sheath smooth connection.

The OpenGL utility function library (GLU) was a set of functions that can be used to draw a NURBS surface, so that the input control point array and the node sequence can be used to complete the drawing process of NURBS surface. The main process using NURBS surface OpenGL generation of D. officinale leaves were as follows:

Step1: calculate the control points of the leaf, set the U, V to the node value;

Step2: creates a pointer to the NURBS object:

GLUnurbsObj*theNurbs=gluNewNurbsRenderer( );

Step3: call gluNurbsProperty () function to set the various properties of the NURBS object;

Step4: in the glBeginSurface () function and gluEndSurface() function between the call gluNurbsSurface () function to generate and draw NURBS surface, as follows:

```
gluBeginSurface(theNurbs);
```

```
&ctrPoints[0][0][0],4,4,GL_MAP2_VERTEX_3);
```

```
gluEndSurface(theNurbs);
```

```
```

```
cpwas an array of colors, sknot1 and sknot2 were respectively stored u and v to the node value of the array, thus completing the leaves of D. officinale NURBS surface rendering. The effect was shown in Fig. 2D.

B. Geometric Modeling of Stem

D. officinale stems from many nodes and internodes, internodes cylindrical. The shape and structure of the structure was relatively simple, so it was used to simulate the structure of the. From D. officinale stem built to output sub model [11] internode length Th and internode thickness Tw respectively, to determine the length and the diameter of the cylinder, by calling the OpenGL using quadric surface technology drawing geometry as a function of gluCylinder () to draw the cylinder, to establish the geometrical model of sheet iron, the stem of D. officinale, as shown in Fig. 2E.

Specific call procedure was as follows:

Step1: to create and initialize the two surface:

```
GLUquadricObj *obj=gluNewQuadric( );
```

Step2: call gluQuadricDrawStyle () function to set the type of the two curved surface:

```
gluQuadricDrawStyle(obj,GLU_FILL);
```

Step3: call gluCylinder () function drawing cylinder:

```
gluCylinder(obj,Tw/2,Tw/2,Th,10,10);
```

Th and Tw were the length of the nodes and the length of the nodes.

IV. THE SENSE OF REALITY SHOW THE MORPHOLOGY OF D. OFFICINALE

The visualization of D. officinale morphology should not only ensure the accuracy of the geometry, but also has more realistic visual appearance. Therefore, after building a three-dimensional geometric model of the various organs of D. officinale, still need to geometric model to generate color, texture rendering and illumination processing realistic display technology of processing, to generate more realistic graphics.

A. Color Rendering

This study uses the RGB model in OpenGL to realize the color rendering. In the stem and leaf color rendering, call the function glColor (type R, type G, type b) to set up organ color, three color parameters of function values of R, G, B were respectively set the color red, green and blue components value, from which the form was built simulation model of color sub model. Leaf color rendering was achieved. This study using an array of colors to put leaves the control of color component value, in tune with gluNurbsSurface () function to generate and NURBS surface was drawn upon to add the following statement, the leaf color rendering:

```
gluNurbsSurface(theNurbs,11,sknot1,14,sknot2,10*3,3,c p,4,4,GL_MAP2_COLOR_4);
```

```
cpwas an array of colors, sknot1 and sknot2 were respectively stored u and v to the node value of the array.
```

B. Light Treatment

Light was very important for the simulation of 3D realistic graphics, if there was no light, there was no three-dimensional graphics rendering three-dimensional. In this study, a OpenGL model was used to simulate the illumination effect of the real world. The light equation of OpenGL was an approximate algorithm, but it was very close to the actual situation, and the calculation speed was relatively fast. The natural growth of D. officinale when the light comes from the sun, so this study adopts parallel light source, using the OpenGL light according to the main steps were as follows:

Step1: uses glLightfv () function to define the light source, and sets the various attributes of the light source, such as the color intensity of the light, the position of the light source, the attenuation characteristic of the light source and the light gathering effect of the light source;

Step2: before using the light source, using glEnable () function to open the light source, so that the light source was effective;

Step3: using glLightModelfv () function to set the OpenGL light model of the three parts: the global ambient light, the position of the observation point and the front, back light;

Step4: (glMaterialfv) function specifies the material properties of organs of D. officinale.

C. Texture Mapping

Due to the existence of a rich texture details and the true surface of organs of D. officinale and computer drawing of D. officinale, in order to make the generated organs graph with sense of reality, in addition to the establishment of color model, light illumination model outside, still need to simulate the surface texture details of organs, namely texture mapping. Color texture was used for texture mapping, and color texture belongs to 2D texture. It was a texture mapping method that can be used to stick a predefined texture image...
to the surface of an object. On the basis of field test, we used
digital camera shot pictures of different organs at different
growth stages, through the picture processing to obtain a
variety of organs of D. officinale texture data. Finally, in
order to 2D texture images were mapped to the three-
dimensional surface of the organ, still need to establish a
correspondence between organ space coordinates (x, y, z)
and texture space (u, v) coordinates, the texture mapping to
the organ surface. In OpenGL provides a series of texture
operation function, can realize the texture mapping, the
specific implementation method was as follows:
Step1: acquisition of texture data
Call the function auxDIBImageLoad (), the texture data
read from a digital camera to shoot organs of D. officinale
organs in the picture.
Step2: texture control
Call function glTexParameter*() to illustrate the texture
mapping to the three-dimensional model on the surface of
the mapping method.
Step3: description of the texture mapping method
Call the function glTexEnv*(), with the value of the
texture to adjust the color of the three-dimensional model of
the organ or the texture and three-dimensional model of the
original color.
Step4: define the texture coordinates
The function call glTexCoord*() defining 3D organ
models vertex texture coordinates and geometry, coordinate
graph, coordinate geometry determines the vertices on the screen plotting
position, texture coordinates determined texture image in
which a texture to give the vertex. For the leaf of the
NURBS surface model, drawing NURBS surface, you can
call the function glTexCoord*() automatically generated
surface texture coordinates.

V. THE VISUALIZATION OF D. OFFICINALE
ORGANS, INDIVIDUALS AND GROUPS

A. Application Examples
In D. officinale as materials, the 2014-2015
meteorological data growth at the Sichuan Agricultural
University field station of D. officinale process based on
(including the daily maximum temperature, daily minimum
temperature, sunshine hours and precipitation), soil
characteristics, varieties and cultivation measures parameters
of basic data, driving D. officinale morphogenesis model of
plant topology the structure and morphological
characteristics of each organ parameters, and morphogenesis
of part of the output results of the model, such as leaf length,
leaf angle, leaf sheath, Ye Kuan length, internode length,
internode thickness and other organs morphology description
parameters as D. officinale organ geometric model input, to
drive the organs of D. officinale geometric model the
operation, a geometric model of D. officinale organ.

B. The Visual Organs of D. officinale
After the establishment of the three-dimensional
geometric model of the organs of D. officinale, the use of
realistic graphics display technology (such as color, texture
mapping, light illumination, etc.) three-dimensional
geometric model of the organs of D. officinale to generate
realistic image of the organs graph (Fig. 3A and 3B), and
further to achieve D. officinale morphogenesis process
visualization (Fig. 3C).

C. The Visualization of D. officinale Individuals
D. officinale individual contains a main stem and tiller
number. Stems of D. officinale by many nodes and
internodes, of D. officinale in other organs (leaves, flowers
and roots were born in the festival, so D. officinale plant the
same internode, and its leaves can as a growth unit. Since the
sections were generally very small, can’t be considered in
the virtual display. Leaves grew alternately on both sides of the
main stem (Fig. 4).
individual, you can build a D. officinale plant of three-dimensional shape (Fig. 5A) further combined with the morphological built simulation model output of each organ morphology parameters and growth and development of time sequence, to realize the virtual growth of individual plants.

![Figure 5. Virtual realization of individual and population D. officinale plant on computer.](image)

**D. Visualization of D. officinale Group**

The morphology and structure of populations of D. officinale was extremely complex and differences between individual groups of D. officinale mainly for tiller number, main stem leaf number and organ geometrical properties (with a leaf a leaf length, leaf width, leaf angle, etc.) etc. different aspects. This paper on the basis of individual visualization implementation, from the optimization calculation in consumption, enhance the sense of reality, such as speed and reduce the memory of, using a kind of both speed and versatility of the method and realizing visualization of groups (Fig. 5B). First according to the statistical characteristics of D. officinale between individuals, most individuals from the population of consistent rendering, just individual around the stem rotation angle random processing, and then draw some distinct individuals in the sample, and in drawing group, random selection of the sample, the drawing of such groups has obvious mutual opposite sex. In order to solve the visualization and display the contradiction between speed, draw the populations of D. officinale by LOD (level of detail), with different levels of model rendering individual; model based on different levels of the grid number was not the same, closer to the point of view, the model more fine, the farther away from the point of view, the model was simple and rough.

![Figure 6. The photos in the cultivation of D. officinale.](image)

VI. CONCLUSION

Cultivation of D. officinale of high efficiency needs real-time monitoring of plant growth status, also needs preliminary stage of virtual plant research to find the D. officinale optimum growth conditions. Shape visualization technique is one of the key technologies of virtual plant research. Using D. officinale plants as the object, parametric geometry modeling method was used in D. officinale organ shape modeling, and D. officinale organ geometrical model was constructed based on the organ shape characteristic parameters. It was good for describing organ morphology of D. officinale built process through design for the basic parameters of the geometric model of the organs of D. officinale from the leaf length and width, stem leaf angle, sheath length of flag leaf and internode length and internode diameter. Virtual display effect showed that there was strong sense of reality for the reconstruction of D. officinale which could simulate the D. officinale different scales of spatial shape change process. This laid the technical foundation for constructing the visualization of the D. officinale growth system. At the same time, the visualization of other crops expression also got very good reference.

ACKNOWLEDGEMENTS

This work was supported by the efficient cultivation technology research of Dendrobium officinale (No. 2013B020422001).

REFERENCES


