Research on Fast Reconstruction of Virtual Plant Leaves

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Abstract—**Based on the original image of plants leaves, the edge detection method will be used to extract the geometrical morphology of leaves. The characteristic points of the contour can be calculated by Harris method. The characteristic points will be used to construct the cubic Bezier curve fitting of contours of leaves, the leaf vein is generated by L system. Finally, the simulation drawing of plant leaves is realized by using the OpenGL and rendering technology.**

Keywords- ***plant leaves; contour; L system; cubic Bezier curve; edge detection, leaf modeling***

1. INTRODUCTION

The growth simulation of the virtual plant is that the process of growth and growth of structure of plant in the three-dimensional space will be simulated by combining computer-related techniques with visualization technology. The plant growth simulation is a hot topic of research in the agriculture information technology and virtual reality [1].The plant leaves as a vital part of the plant, it is the main organ of plant. The plants mainly obtain energy by leaves. The physiological and ecological functions of Leaves and is closely related to its external morphology. The plant leaf modeling is constructed by using stem skeleton [2]. In Literature [3], the surface data points of leaf are obtained by laser sensor, the data points will be used to construct accurate leaf modeling by linear triangulation and CT technology. A large number of spatial data in leaf were obtained using the Loch method [4], in combination with CT (lough-Tocher) and RBF (Radial basis function) method, Oqielat reconstruct a more realistic modeling of leaf. But in above method, requires higher accurate equipment and a large amount of human interaction, so that the efficiency is low. Use of multiple images, in combination with two dimensional image and three-dimensional data, Quan[5] reconstructed leaf modeling. An efficient leaf image extraction method was proposed by combining active contours with cellular neural networks [6], this approach could be used for effectively extracting leaf vein. Mundermann[7]extracted the leaf contour using single leaf image, and reconstructed leaf modeling by calculating the leaf frame and other steps Remolar obtain its shape bya series of decomposition and merging operations for leaf leaves[8]. In[9], the leaf veins will be constructed using the relevant rules.

In this paper, based on the original image of plants leaves, the geometrical morphology will be extracted. The leaf contour will be constructed by cubic Bezier curve. The leaf vein will be is generated by L system. Finally, the simulation drawing of plant leaves is realized using the OpenGL and rendering technology.

2. RECONSTRUCTION OF VIRTUAL PLANT LEAVES

In this paper, the leaves of citrus as example, illustrate the virtual plant leaf reconstruction ideas. Using edge detection method extract the Contour of citrus leaves and distribution characteristics of leaf vein distribution, Harris method compute the characteristic points of the contour. Finally, the leaf morphological reconstruction realized using the L system and Bezier curve fitting. The design idea of plant leaves reconstruction as shown in figure 1.

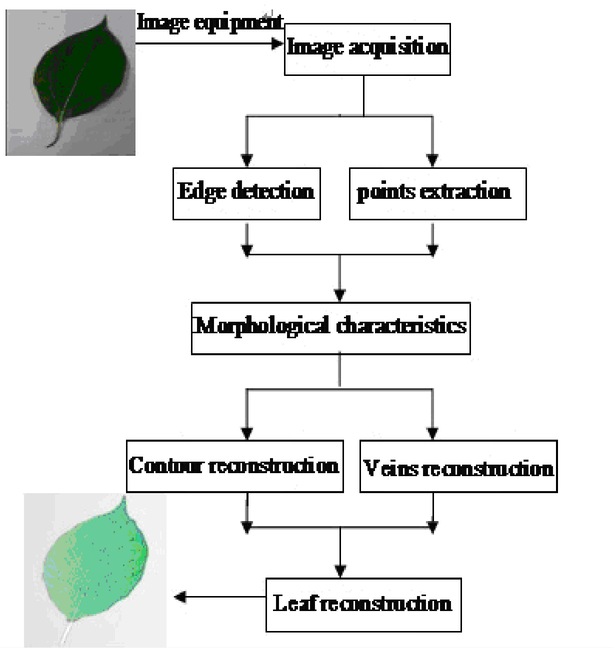


Fig 1 the design idea of plant leaves reconstruction

3. METHOD OF FAST RECONSTRUCTION FOR VIRTUAL PLANT LEAVES

3.1 The original image collection

The basics of plant leaf simulation are based on the real leaf image. I n good light condition, using image acquisition equipment (as a digital camera) collects high-definition plant leaf image, and stored in the computer by format bmp. Figure 2 is a real citrus leaves collected from the front and back.

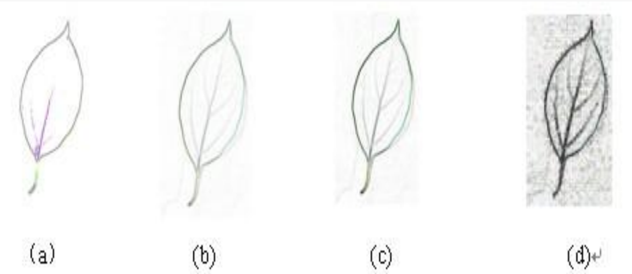
Fig 2 the original citrus leaves image collected from the front and back

3.2 The original image processing and feature extraction

The morphological reconstruction of the citrus leaves: based on original leaf image, extract the contour of the leaves、veins and other main features. The edge detection、the Harris corner detection and other image processing technology will be used to this section.

① Edge Detection

In image processing, the commonly used edge detection methods include differential operator method, Gauss - Laplasse operator method, Canny operator method and zero-crossing edge detection method. Because of the particularity of citrus leaves, this paper uses the differential operator method, compare the differential operator in differential operator method, the experimental results show that the Robert operator to detect the effect of good. The results as shown in figure 3.



(a) Prewitt (b) Sobel (c) Robert (d) Kirsch

Fig 3 the results of edge detection based on different operator

The Roberts edge detection operator[10] is an approximate detection method, in the diagonal direction, the difference between adjacent pixels will be used to detect leaf edge. The algorithm has the characteristics of high positioning accuracy, good results in vertical and horizontal directions. During the growth process, by the influence of the external condition, citrus leaves may occur the Leaf roll phenomenon，so this paper uses the Roberts edge detection operator.

②Extract of Leaf Characteristic Points

In the plant leaf morphological reconstruction， leaf characteristic points must be extracted by edge detection methods. In the graphics and images, Harris corner detection algorithm is simple in computation， the extracted corner feature has the advantages of uniform rational [12]. In figure2.2, the leaf characteristic points are extracted by Harris algorithm, its results as shown in Figure 4.

Fig 4 Extraction results of feature point

Structure of stored Contour is defined as follows：

```
{
    CPoint startPoint; //The starting point of the region
    Int *linkcode; // Contour chain code table
    Int muncode; //The number of Characteristic points
    Long perimeter; // Contour perimeter
    Long area; // Contour area
    Long form factor; // Area shape
}
```

4. THE 3D RECONSTRUCTION OF PLANT LEAVES

In order to effectively simulate the structural characteristics of citrus leaves and its morphological reconstruction, it is necessary to plant leaf margin and veins were reconstructed, to quickly generate the plant leaf model with three-dimensional information.

4.1 The Reconstruction of Contour

The leaf characteristic points will be extracted by the Harris corner detection algorithm, Piecewise cubic Bezier interpolating curve of leaf contour will be constructed using the characteristic points. Specific methods are as follows:

In the section, because the characteristic points of leaf is the symmetrical distribution, so the leaf contour is divided into left and right contour. Suppose that the tip of leaf is Q_j, the characteristic points in left contour are $Q_1, Q_2, \cdots, Q_j$, the characteristic points in right contour are $Q_j, Q_{j+1}, \cdots, Q_{2j-1}$.

Next, we construct respectively the left contour and right leaf contour, the contour interpolates characteristic points of leaf.

In the interpolation point $Q_i (i = 1, 2, \cdots, j)$, the tangent of left contour is defined as follows

$$\mathbf{m}_i = \alpha_i (Q_i - Q_{i-1}) + \alpha_{i+1} (Q_{i+1} - Q_i), i = 2, 3, \cdots, j$$

$$\mathbf{m}_1 = \alpha_1 (Q_j - Q_1)$$

where $0 < \alpha_i < 1 \ (i = 2, 3, \cdots, j)$ are the tangent adjustment parameters.

In the interpolation point $Q_j, Q_{j+1}, \cdots, Q_{2j-1}$, the tangent of right contour is defined as follows

$$\mathbf{n}_i = \beta_i (Q_i - Q_{i-1}) + \beta_{i+1}(Q_{i+1} - Q_i), i = 1, 2, \cdots, j-1$$

$$\mathbf{n}_j = \beta_j (Q_{2j-1} - Q_j)$$

where $0 < \beta_i < 1 (i = 1, 2, \cdots j-1)$ are the tangent adjustment parameters.

In the tip Q_j of leaf, leaf contour is a cusp. At Q_j, because the left and right contour has tangents $\mathbf{m}_j$ and $\mathbf{n}_j$ with different directions, just the leaf contour formed a cusp, as shown in figure 4 and 5 below.

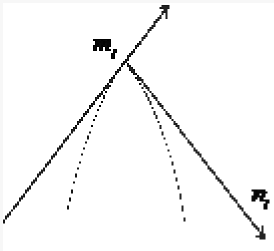


Fig 4 $\mathbf{m}_j$ and $\mathbf{n}_j$ with the different direction

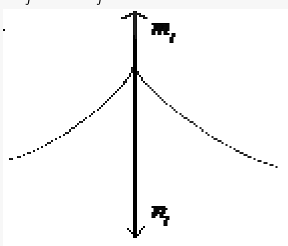


Fig 5 $\mathbf{m}_j$ and $\mathbf{n}_j$ in opposite directions

For the left contour, construct a cubic Bezier curve between two adjacent feature points, its Bezier points are as follows

$$b_i = Q_i, \quad b_{i+1} = Q_i + \|Q_{i+1} - Q_i\| \mathbf{m}_i / 3$$

$$b_{i+3} = Q_{i+1}, \quad b_{i+2} = Q_{i+1} - \|Q_{i+1} - Q_i\| \mathbf{m}_{i+1} / 3$$

Where $i = 1, 2, \cdots, j-1$.

The piecewise cubic Bezier interpolating curve of left contour is expressed as [13]

$$\mathbf{r}_i(u) = \sum_{i=0}^{3} b_i C_3^i u^i (1-u)^{3-i} (0 \le u \le 1), \quad i = 1, 2, \cdots, 2j-1$$

By the properties of endpoints of the cubic Bezier curve, has

$$\mathbf{r}_i(0) = b_i - Q_i, \ \mathbf{r}_i(1) = b_{i+3} = Q_{i+1}, \quad i = 1, 2, \cdots, j-1$$

$$\mathbf{r}_i'(0) = 3(b_{i+1} - b_i), \quad \mathbf{r}_i'(1) = 3(b_{i+2} - b_{i+1})$$

That is, the left contour interpolated characteristic points $Q_1, Q_2, \cdots, Q_j$.

Similarly, for the right contour, construct a cubic Bezier curve between two adjacent feature points, Its Bezier points are as follows

$$\bar{b}_i = Q_{i+j-1}, \quad \bar{b}_{i+1} = Q_{i+j-1} + \|Q_{i+j} - Q_{i+j-1}\| \mathbf{n}_i / 3$$

$$\bar{b}_{i+3} = Q_{i+j}, \quad \bar{b}_{i+2} = Q_{i+j} - \|Q_{i+j} - Q_{i+j-1}\| \mathbf{n}_{i+1} / 3$$

Where $i = 1, 2, \cdots, j-1$.

In the same, the properties of endpoints of the cubic Bezier curve, has

$$\mathbf{r}_i(0) = \bar{b}_i = Q_{i+j-1}, \quad \mathbf{r}_i(1) = \bar{b}_{i+3} = Q_{i+j}, \quad i = 1, 2, \cdots, j-1$$

There, the right contour interpolated characteristic points $Q_j, Q_{j+1}, \cdots, Q_{2j-1}$.

The piecewise cubic Bezier interpolating curve of right contour is expressed as

$$\mathbf{r}_i(u) = \sum_{i=0}^{3} \bar{b}_i C_3^i u^i (1-u)^{3-i} (0 \le u \le 1), \quad i = 1, 2, \cdots, 2j-1$$

Based on the figure 2, the piecewise cubic Bezier interpolating curve of the contour as shown as in figure 6.

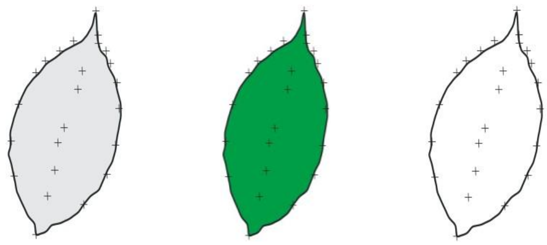


Fig6 Use Bezier curve form edge under the condition of different rendering

4.2 Reconstruction of leaf Vein

The leaf veins as the leaf frame, guarantee the stability of plant leaves. Figure 3 shows that plant leaf veins have certain levels. According to the thickness, size and other parameters of leaf vein, can be divided into major veins, lateral veins and thin vein, and the lateral veins and thin veins are opposite or alternate. According to this characteristic, in this paper, citrus leaves as a reference, we used L system to construct leaf veins. The L system is an important branch of fractal [14], this article as a reference to citrus leaves, application of L systems to achieve the structural design of the veins. Fractal Theory in the plant simulation, L system is a fractal is an important branch of the L system generated veins. By the L system definition, it consists of the number of iterations, the rotation angle, axiom, production type etc.. The construction process is as follows:

The iteration number N : (S-2)/2;

The rotation angle, δ : 180/N;

Axiom ω : [+L] V [-R];

The production type P : V->…: L->…; R->…

Where S is the number of intersecting veins and leaf border, "+" And "-" express a different direction of rotation, L is the growth rules of the left lateral in veins main, R is the growth rules of the right lateral in veins main, p is the growth rules of veins main.

The simulation drawing of plant leaves is realized by using the OpenGL and rendering technology. The citrus leaves morphological remodeling results as shown in figure7.

Fig 7 experimental results

5. CONCLUSION

In the process of leaf reconstruction, we introduced a large number of graphics and image method and mathematical thinking, and quickly realized the reconstruction of citrus leaf model. Through the experiment we know that this method can effectively describe the morphological structure characteristics of leaf and, and quickly realized the simulation of morphological structure. This method are compared with the traditional methods, the operation is simple, fast and practical. However, because of the complexity of the growth of a plant, the various factors influenced the growth of leaves, therefore, the simulation of the plant leaves is very difficult[15]. On the other hand, in the growing process of the plant leaves, the temperature, moisture and other effects may change the Leaf morphology. So, in the modeling and rendering process, no full consideration of light, shadow, transparency effects, degree of bending of the leaf vein and other factors, the generating graphics and the original graphics exist certain difference. Therefore, in future work, we need to fully consider the influence of various factors, quickly realized the simulation of in various morphology of plant leaves, provide the basis for plant leaf dynamic growth model, plant modeling and visualization.

ACKNOWLEDGMENT

This paper is supported by the "Twelfth Five-Year" national science and technology support program and Hunan Province key science and technology project (2010FJ1006).

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