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A NPR System for Generating Floral Patterns based on L-System

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Abstract—**in history, the decorative pattern represents the design of art. The styles of decorative patterns are unique according to different countries and cultures. Because of the decorative floral pattern giving human an elegant and abundance impression, it is applied to many fields including product packaging, advertising or multimedia materials design.**

In this paper, we simulate the plant growth to create the decorative floral patterns. One of plant growth simulation approach is L-System (Lindenmayer System). Due to plant growth information can be stored in the L-system grammar formats, the styles of decorative patterns can be controlled by production rules which users define. However, defining a complex L-system grammar structure by non-professional users is clearly a very difficult task. It requires expert with both botanic and programming knowledge to manipulate. Therefore, we propose a user-friendly CAD system for generating L-grammar based on a sketch-based interface. Users can draw arbitrary lines or curves on the canvas for automatically creating decorative floral patterns. In addition, we integrate the Simeco system with CUDA (Compute Unified Device Architecture) for improving the inefficiency of modeling and simulating plants.

Keywords-component; L-system; computer graphics; NPR; decorative pattern

I. INTRODUCTION

In the current society, there are many kind of the decorative patterns which are applied to the product packaging, advertising or multimedia materials. The decorative patterns can be traced back to the Neolithic era. These patterns have various appearances in different countries, and cultures. Because the decorative floral pattern gives an elegant impression, most people are able to accept it. It is normal to be designed for any theme.

In plant growth simulation, L-System has always been a mainstream approach that uses a stored plant information, L-grammar and iterative manner simulation of plant growth process. By adopting the L-system, plant information can be stored in the L-grammar format. By iteratively rewriting the sequence of strings using production rules, the self-similar growth process of plants can be simulated.

This research is divided to the two parts. One is improving the grammar generation system, and another one is applied the principles of aesthetics to creating the decorative floral patterns. Because the grammar structure of parametric L-system is very complicated, it is difficult and non-intuitive for us to generate L-grammar. Therefore, we refer the L-system engine [4][5][6], and developed a sketch-based grammar generation systems which allows users to arbitrarily draw lines on a virtual canvas. These lines are automatically transformed into decorative patterns later by using the L-System for plant growth simulation. Due to creating plant as the decorative floral patterns, we attempt to synthesize several rules from the principles of aesthetics. Then, the plant may conform of human perception that for accept it.

The rest of this paper is organized as follows. Section II introduces the related work. Section III and IV show the system architecture and current result. Finally, Section V gives our conclusions and potential future research directions

II. RELATED WORK

A. Lindenmayer-system

L-system is a parallel rewriting system. It consists of various formal grammars that can be used to make string for creating growth processes of plant development, which was proposed in 1968 by the Hungarian theoretical biologist and botanist from Aristid Lindenmayer. L-system is similar to normal language. The rules of the L-system grammar are applied simultaneously to the iterative starting from the initial state. Due to represent the branch structure, the L-grammar uses five symbols "{[,]}" for distinguishing them. The symbols which between "[" and "]" are the same group of branch structure. The symbols may contain the sub branch structure. In order to represent the curve features of plant, the conception of parameter is included. The parametric L-system means it can store more detail of structure. However, high detail may cause the formal language more complex and reduce the performance.

B. Aesthetics

Aesthetics is a branch of philosophy which concerns esthetic psychology. Aesthetics is defined as critical reflection on art, nature, society [1]. People who have different experience of life or mentation may affect the aesthetic feeling. In other words, because of various countries, and cultures, there is no standard for aesthetics. Fortunately, scholar generalize a conclusion from a collection of rules according to human common experience such as social values, ethics and education,

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and named it “principles of aesthetics”. These principles are repetition, gradation, symmetry, harmony, balance, contrast, proportion, rhythm, unity and simplicity. Generally speaking, repetition may gives people an orderly feeling; symmetry may gives people a peaceful or solemn feeling.

The branch structure of decorative floral patterns would be affected by principles of aesthetics. We select some of them and conclusion as follow:

- Symmetry

  Symmetry is a well-defined concept of balance or aesthetically pleasing proportionality in branches of plant. Branches will grow on both sides of main stem or parent-branch evenly. The main purpose is to emphasize the self-similarity.

- Rhythm

  Rhythm reflects lively and colorful. Through arranging the branches with sequence and make them individual differences, will represent rhythm effect. However, branches containing rhythm may cause the screen disorderly. Therefore, we attempt to arrange the branches with rhythm only on the parent-branched, not on main stem.

- Balance

  Different from symmetry, balance reflects the sense of coordination. It prevents a discordant sense. We attempt to adjust the relative position of branches. Generally speaking, the main stem curve to the left, the branches would grow to the right. In color assignment, deep color will makes people feel the heavy weight. Arranging color evenly to whole image may create an effect of balance.

- Proportion

  The relationship of proportion to aesthetics is sense of distance. The branches length is based on connected position of the main stem. While the branch connection is near to the root, it will cause length longer. It represents a stairs structure.

C. *Decorative pattern*

People use decorative pattern can be traced back to the Neolithic era. They are different in various countries and cultures [2][3]. For example, pottery decorative patterns in the Neolithic age, Egypt Tombs carved and painted, Chinese traditional carved patterns, and so on. Decorative floral patterns around the world and applied to the product packaging, advertising or multimedia materials design.

D. *Non-photorealistic rendering*

In contrast to photorealistic rendering emphasizing the realistic, NPR (non-photorealistic rendering) has focused on artistic styles such as painting, technical illustration, and cartoons. Just like hand-drawn picture, NPR can simulate the ink and wash painting for illustrating mountain and river, or simulate the watercolor for drawing a portrait. NPR techniques are important for developing in digital art.

E. *CUDA*

Compute Unified Device Architecture (CUDA) is a parallel computing architecture. CUDA gives user access the memory on the graphic card for calculating the similar instruction. Due to the graphic card include many cores then CPU, computing the parallel processing is more effective.

III. IMPLEMENTATION

In this section, we introduce the plant growth status with drawing lines, and branches applied the principles of aesthetics. The following diagram is the system architecture.

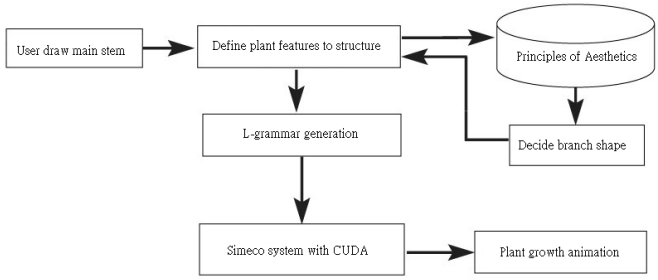

Figure 1. System architecture.

A. *User-friendly CAD system for generating L-grammar based on a sketch-based interface*

In order to improve the non-intuitive input data system, we propose a user-friendly CAD system for generating L-grammar based on a sketch-based interface. Although users do not know the formal language, they can use the system easily for generating the L-grammar. When user draws on the canvas, the system will store the sequence locus of line and distinguish the lines into segments. The segments data include length, position, parent, and child. A segment only has a parent to refer the structure.

As shown in Fig. 2, the arrow indicates the growth direction. In this case, user draw a curved line along the node a, b, c and d. Then, the system stores the data of segment 1 to segment 3, and automatically generates the segment 4 on the node c. The segment 4 means the branch. Every segment has a parent to inherit information. For example, the parent of segment 3 and segment 4 is segment 2. They inherit the features from segment 2. The drawn main stem and generated branches have been translated into L-grammar. Finally, through the Simeco system with CUDA, user can create the desired shape of plant efficiently.

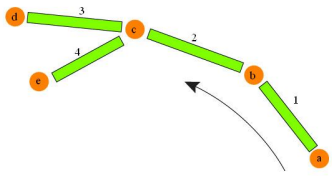

Figure 2. The plant growth is based on painting path.

B. *Applied L-grammar of the principles of aesthetics*

In addition, we attempt to integrate the branches structure with principles of aesthetics. This creation may be more easily accepted by people. However, some combinations of principles are exclusive. Such as contrast and harmony, they are almost impossible to exist in one creation. Therefore, we attempt to apply special combination of the principles that can simultaneously exist.

As shown in Fig. 3, the green line is the main stem, which is drawn by user. The pink nodes mean the points between segments, and the orange curved lines are branches. The branches are applied the golden spiral to represent the natural curve, and integrated with the principle of proportion. It is the reason that while the position of the connection is more close to the root, then the length of branch would be longer. Otherwise, the position of the connection near to the top of the main stem will cause the branch shorter.

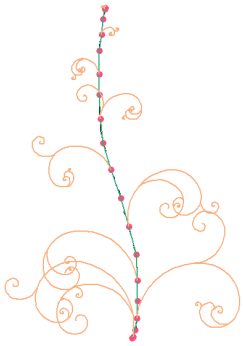

Figure 3. The simple shape of plant model.

The growth directions of branches are based on the main stem. As shown in Fig. 4, the black arrow means the growth direction of main stem. It will cause the branch growth on the node b, and the direction of branch will grow on the contrary, just as the pink arrow.

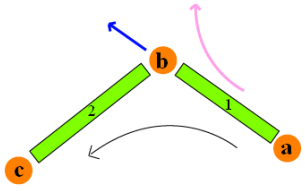

Figure 4. Painting path. Black arrow is growth direction, blue arrow is vector of segment 1, and pink arrow is branch direction.

IV. CURRENT RESULT

There is the comparison between the original system and the modified system as show in Fig. 5. The original system emphasizes the realistic simulation of plants. By loading two plant pictures which are orthogonal to each other, the system constructs the plant model based on the appearance of real plant. However, this original system is non-intuitive for general user. In addition, if the simulation of plant is very realistic and complex, the performance may be low. Therefore, we attempt to create the simple plant shape as the decorative floral patterns. This is the reason to modify the input method. User can only use the mouse or canvas with pen to draw the main stem as shown in Fig. 6. The decorative floral pattern will be created by arbitrary curve lines. This input interface improve the effect that general user may feel easy to be an artist.

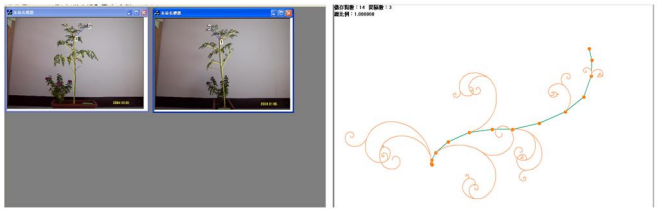

Figure 5. On the leaft is original input interface. On the right is current interface system which can draw directly for determining plant growth path.

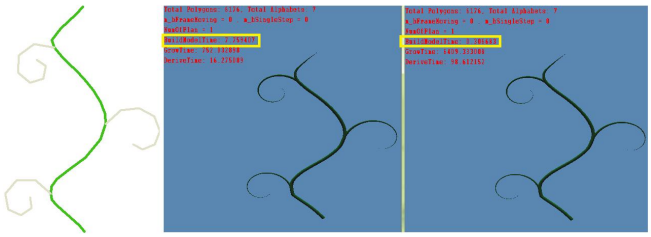

Figure 6. On the left is the current system interface for input; in the middle simulates the plant growth by Simeco without CUDA; to its right simulates plant growth by Simeco wth CUDA.

Fig. 6 illustrates our input interface. The green curved line on the left is the drawn line which represents the main stem. The gray lines beside of the main stem are branches that automatically grown by the principles of aesthetics. The branch shape clearly represents the spiral appearance because it applied to the principle of balance. Then, the system can generate the L-grammar based on above-mentioned plant structure, and create the plant by Simeco. Due to CUDA, the execution time drops from 7.75 milliseconds to 0.30 milliseconds.

Fig. 7 shows the sequence simulation of plant growth. The animation of decorative floral patterns has been created.

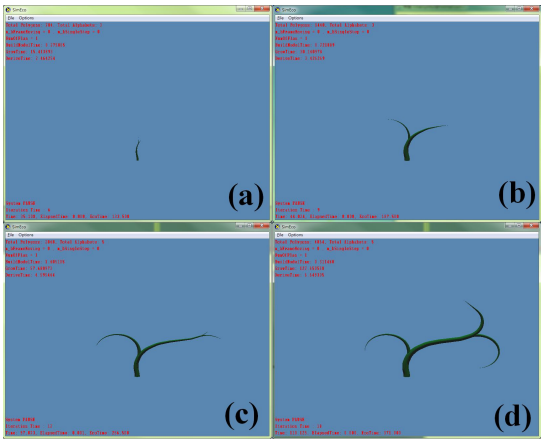

Figure 7. The plant growth status.

In addition, we attempt to apply other principles to the plant structure. Fig. 8 shows that we integrate the floral pattern with principle of symmetry and rhythm. It is clear that the branches have symmetry feature, and different forms of branches make the sense of rhythm.

Another experiment shows in Fig. 9. We integrate the principle of balance and proportion for plant shape. The principle of proportion causes the branches length according to the distance from the root.

The last experiment shows in Fig. 10. The plant color changes by the principle of balance. The yellow-green are distributed around the plant. It also makes the sense of unity.

V. CONCLUSION

We use the L-grammar generation systems for creating decorative floral patterns. The plant will be automatically created with drawn line. Branches of plant are applied to the principles of aesthetics that can embellish illustration or window lattice. The interface is very intuitive and easy to use. The system improves the producing more effectively.

Sometimes, the plant growth animation is embedded in the advertising or opening of movie. This effect can be created by video post-production software such as Adobe After Effect®. We attempt to create an interface, which can create more colorful and lively animation of decorative floral patterns by hand-drawn sketch or any method.

Our system does not contain the interactive interface for adjust details [7][8]. We do not detect each part of branches. Therefore, the intersections of each part are disorderly. We may introduce the open L-system to detect the branches and refine it. It is a way to make a painting more clearly.

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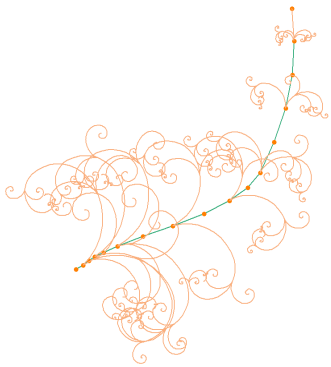

Figure 8. The plant growth structure applied the principles of "Symmetry" and "Rhythm".

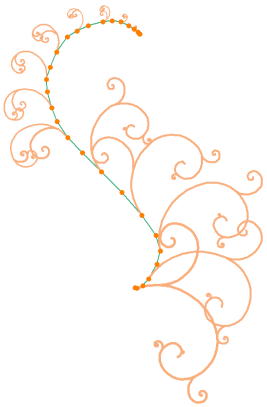

Figure 9. The plant growth structure applied the principles of "Balance" and "proportion".

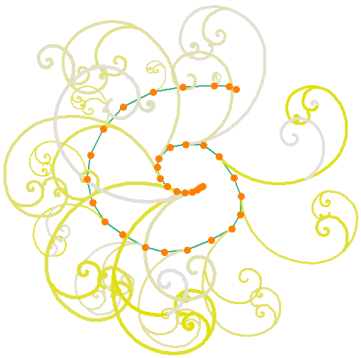

Figure 10. The plant color applied the principle of "Balance".