Interactive Virtual Fruit Tree Pruning Simulation

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*Abstract--***This paper proposed an interactive virtual pruning method for fruit tree. In this method, Unity3D – a common game development platform – was used as the implementation tool for the interactive virtual pruning simulation of fruit tree, including integrating 3D fruit tree and scissor into a virtual orchard scene, processing human-computer interaction and providing real-time feedback. Citrus tree was used as an example to test the proposed method. We simulated the pruning in small fruit stage and fruit picking in matured stage respectively. Experiment results show that this method can vividly simulate the pruning process and render the morphologic changes in the 3D tree model after pruning immediately. Combining with pruning rules, Unity3D should be a convenient and easy to implement tool for demonstrating fruit tree pruning techniques, training famers and so on.**

Keywords-virtual reality; modeling; fruit trees pruning; simulation

I INTRODUCTION

Studies have shown that tree structure plays an important role to both the yield and quality of fruit tree. Pruning is one of the most important management measures in orchard production for cultivating high yield fruit trees. Fruit tree pruning is also a very technical operation skill. For instance, staff could change flowering and vegetative growth by shaping and pruning [1], or balance the vegetative growth and reproductive growth [2].However, currently methods for teaching and demonstrating fruit tree pruning skills are still mostly limited in on-site training, this means need use a real fruit tree for demonstrating how to prune, and we also must do this in the right season. The drawbacks of on-site training are very obvious, including destructive (hard to test different pruning strategies in a same tree in the same time) and high cost [3].

With the rapid development of information technology, especially virtual reality, virtual plant was proposed and expected to provide information services and technical support for modeling, simulating and visualizing in plant research and agricultural production [4]. Consequently, how to use information technology to improve and update the training means of fruit tree pruning techniques becomes a hot research topic. Virtual reality should provide a comprehensive solution for this kind application by combing computer graphics techniques, multimedia techniques, the human-computer interaction techniques, network techniques and stereo display techniques.

In recent years, virtual fruit tree pruning has been studied by many researches. For example, some researchers used walnut tree as example, designed a SIMWAL function structure model, to study the relationship between climate changing and pruning [5]. L-peach presented an example of virtual pruning experiment, where the number and type of buds that break after pruning follows certain statically distribution [6]. Li proposed a virtual pruning fruit trees shaping method [7]. However, the pruning process in all of above methods is not natural. Some modeling software, such as Xfrog, also provide interactive pruning functions, but this kind functions still show a large gap to real pruning skills.

II TECHNOLOGIES AND METHODS

Here we give a brief introduction of key technologies and methods linked to our targeted system.

A. Virtual Reality Technology And Unity3d

Virtual reality tries to create a 3D virtual world in computer and gives the users an interactive immersion experience. Unity3D is a professional virtual reality development engine, which can be used to create such as 3D video game, real-time 3D animation and other types of interactive content [8]. Unity3D also has a strong physics engine [9], which can simulate the physical phenomena in the real world, such as collision and the gravity effect, and provides particle systems such as fire, fog and waterfall. For developers, they can use Unity3D to build virtual immersive environment and delight players on any platform.

In brief, good compatibility, cross-platform, and short development cycle make Unity 3D become a good development platform for virtual fruit tree pruning application.

B. 3D Modeling Technique

There are primarily three ways for people to create models [10]: the first is to create by using the three-dimensional

scanner device; second is to construct by modeling software (such as 3DMAX, Maya and so on); third is to reconstruct from images. The 3D model of fruit tree was created by using a method which is detailed in [11].While other models were created by common modeling software.

We should pay attention to the following steps before the model was exported to Unity3D [12]: (1) the Norma of model and UV are correct; (2) the materials and objects are standard; (3) the local coordinate's direction of object is right. We also need to adjust the size of model to have a better sense of vision. Finally, don't forget to add physical attributes of collision components for models in case that the mouse cannot execute picking operation.

C. Fruit Trees Pruning Principles

Pruning of fruit leaves or branches are very common management measurements in orchard production. The timing and policy of pruning is generally based on the knowledge and experience of the grower [13]. It is important to understand the principles of pruning. The main goal of pruning is to correct major defects while maintaining the natural shape of the tree.

D. Interactive Picking In 3d Scene

There are two common ways for people to pick 3D object in the virtual scene. The first one makes use of a special OpenGL feature in which you render your scene in a "selection mode". The second approach is the ray picking which is independent from OpenGL [14].It is the process of shooting a line (ray) from the camera through the 2D view screen (where 3D scene is projected on) into the scene until it hits an object. In this paper, we adopt the second method (ray picking) to pick object [15]. We have a 2D point on the view screen (x, y) and now want to map this point into world coordinates. One way would be to make use of the inverted viewing matrix, but we follow a more geometrical approach: We compute the position of the plane of the view screen in world space and map the 2D point on this plane and from there into world space. The principle of the ray picking is showed in fig. 1.
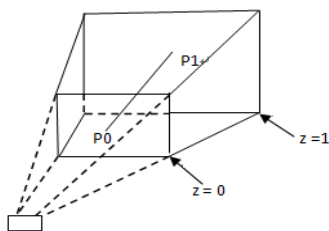

FIGURE I.   THE PRINCIPLE OF THE RAY PICKING.

$Z = 0$ is the nearly clipping of the vertebral and $z = 1$ is the far clipping plane. Concrete implementation algorithm is as follows：

1): Get the point on the screen and find the point of its window on the corresponding projection;

2): Compute the position of the plane of the view screen in world space;

3): Map the 2D point on this plane and from there into world space;

4): Determine whether the object and the ray are intersected, and get the object which is picked.

However, there are scenarios where ray picking is simply inferior or impractical considering a scene with a lot of small objects.

E. Collision Detection Technology

Many applications in Computer Graphics require fast and robust 3D collision detection algorithms. There algorithms can be divided into four approaches: space-time volume intersection, swept volume interference, multiple interference detection and trajectory parameterization [16]. Collision detection is an important research of visual simulation in virtual immersive environment, which allows users interact with scene objects in a more natural way [17]. In this paper, we divided OBBs (Oriented Bounding Box) in the scene graph by Octree, then implement collision detection effectively by the hierarchical structure of Octree. By this method can improve the accuracy of the collision detection availably and meet the requirements of real-time virtual environment for complex model.

III   IMPLEMENTATION OF VIRTUAL PRUNING SYSTEM

Our system is implemented in object-oriented style and using c# programming language.

A. System Introduction

In this system, we define several pruning points with different colors on the fruit tree model, which are visible in the whole process of pruning. However, not all of them are correct. Warning interface will visible if users picked the wrong pruning points. Users can rotate, move and scale the fruit tree model and pick pruning points at any time. Once an object is picked, the virtual scissor will appear to indicate the selection. Then, it prunes the objects when detected the collision and disappears after pruning. The morphologic changes in the 3D tree model with different pruning strategies immediately render.

B. Case Study

We use the citrus trees with different stages as an example to test the proposed method. They were reconstructed and imported to Unity3D for pruning study. For instance, a citrus tree model in small fruit stage is showed in fig.2. We pre-process citrus trees model with some pruning points combining with pruning rules. Some small models (appertaining Unity3D) are set in the citrus branches to stand for different pruning rules. We define them as pruning points by three colors: green, red and blue. To select the pruning point, users can click these small models (called pruning points) with different colors. As is shown in the fig.3a, green represents internodes including some apical bud and sub-branches; red stands for the flower; and blue represents the fruit. We will see in this section an application of the system to get different age pruning strategy of a zooming sample branch of citrus tree. The pruning in small fruit stage and fruit picking in matured stage are simulated respectively.

FIGURE II. THE CITRUS TREE MODEL IN UNITY3D.

1) Pruning in small fruit stage: Removal of early fruit is a common strategy in pruning management, which can help to improve fruit quality and ensure robust [18]. Three pruning strategies were tested on the same branch of virtual citrus tree. The first one served for comparison without any pruning (fig.3a); in the second case, fruit (blue pruning point in the below) was pruned (fig.3b-c); in the third case, internodes (green pruning point in the top) were removed (fig.4).

To see clearly a virtual scissor will appear to indicate the selection, when users picked the right pruning point (blue pruning point in the below and green pruning point in the top showed in fig.3b and fig.4a). Contrary, warning interface will visible if they selected the wrong pruning point, for example, the top of blue point (fig.3c). Then, the scissor removes the selected object (including pruning point) and disappears in the end. The morphologic changes after pruning immediately render (fig.3c and fig. 4b). Comparing to the paper [19],[20], this method can simulate fruit tree pruning in a more natural way by using virtual scissor and has a better sense of realistic.
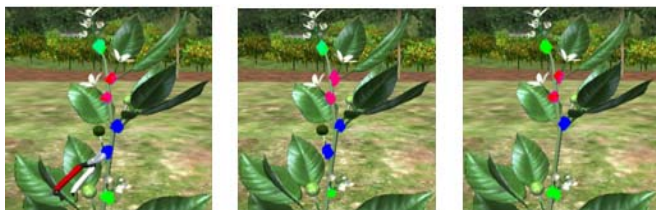
a.Without any pruning   b. Virtual scissor appears   c .After pruning

FIGURE III. REMOVE FRUIT (BLUE PRUNING POINT IN THE BELOW).
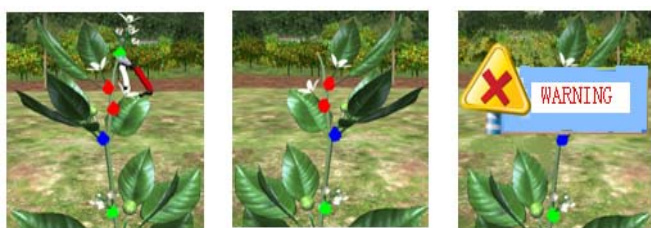
a. Virtual scissor appears   b .After pruning   c Warning interface

FIGURE IV.REMOVE INTERNODES (GREEN PRUNING POINT IN THE TOP).

2) Fruit picking in matured stage: Maturity is the most important factor that determines storage-life and final fruit quality. Fruits picked at the proper maturity in their season are less susceptible to postharvest physiological disorders than picked too early or too late. There are two steps for us to simulate the citrus fruit picking, which are as follows:

The first step is to choose the way with forehand and backhand of scissor by GUI interaction. A virtual scissor will appear when users drag the forehand button to fruit tree model and prepare to prune after detecting the collision (fruit and scissor), as is shown in fig.5a-b. We can see fruit drop in a container after that. The second step is to prune the handle of fruit by the way of backhand of scissor (fig. 5c). The whole process of fruit picking simulation will finish after above two steps.

a. Drag the forehand button to model b. The first step of pruning c .The second step

FIGURE V. FRUIT PICKING IN MATURED STAGE.

IV APPLICATIONS

The simulation of pruning fruit tree can substitute for the labor and time-consuming field experiments to test the effects of different pruning measures. One important application of simulation fruit tree pruning is on fruit production estimation. Another application is on simulation of pruning activity in an orchard scene for training and education.

A. Production estimation

In order to give users greater convenience in production management and reduce the blindness of production, the system can apply to production estimation. We can evaluate the yield with different pruning measures for the same tree, and also assess with the same pruning measures for the different tree. The Mathematical formula of production based on pruning knowledge is defined in the first place. In brief, different pruning measures have different yield. By computing production to obtain optimal pruning strategies for best quality and quality, can give reference for the management on real tree pruning.

B. Training and education

As is known to us all, the conventional fruit tree pruning training and education, has the following drawbacks: irreversible, high cost, and difficult to fast rendering of pruning. Using of plant modeling technology, virtual 3D interactive technology and simulation technology to build virtual interactive fruit tree pruning by visualization orchard scene, which can address this bad condition. It can demonstrate the whole growing process of citrus tree pruning from seedling to adult tree with fruit, and the virtual growing effect of various level models from organs to branches to the whole tree. Thus, for a new-hand, quick and cheap experiments can be desirable to learn quickly how to master the pruning strategies.

V CONCLUSIONS AND DISCUSSION

We established an interactive system for fruit tree pruning based on Unity3D. As illustrated in the section 3, the virtual pruning simulations are both botanically and visually realistic under different pruning strategies. Using a virtual scissor is beneficial to enhance reality and improve the enthusiasm of teaching and training. This system should be a convenient and

easy to implement tool for demonstrating fruit tree pruning techniques, training famers and so on.

However, there are several questions if the aim is to simulate faithfully the behavior of a real fruit tree. Owing to the complexity of the tree structure, simulating physiological development after pruning has yet to be further studied [21].

In recent years, a large number of virtual interactive equipments for more natural, faster and accurate virtual experience have emerged, such as data gloves and helmets, as well as kinect, leap motion and other equipments of somatosensory. If these virtual interactive products can be applied for training fruit trees pruning skills, they are bound to enhance the immersion, interactivity and interest.

ACKNOWLEDGEMENTS

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