Simulation of Pear Tree Growth Geometry Based on CAD 3D Modeling and Visualization Technology

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Abstract. This study employs virtual plants as a bridge between them to achieve the goal of merging the ongoing development of computer technology with modern agriculture. Virtual plants are a new study subject that has emerged in recent years as information technology and computer technology have advanced rapidly. It is a multidisciplinary field that combines computer graphics, botany, mathematics, and virtual reality technologies. This work proposes a method for visualizing fruit tree branches and stems using morphological feature information and the parameter L system. The relevant morphological and structural characteristics, as well as ecological and physiological characteristics, were extracted from the pear tree's tree structure; the L-system modeling method was used to create a model of the pear tree, which included details such as branch thickness, bifurcation angle, and so on; The geometric information of pear tree growth is turned into intuitive three-dimensional visual graphic information using three-dimensional modeling technology, laying the groundwork for the construction of a pear tree shape and pruning computer simulation system. Furthermore, the yield per unit area of an open center tree is 73.93 percent, the weight of a single fruit is 84.22 percent, and the rate of high-quality fruit is 76.15 percent, all of which are less than 85 percent, according to the real test. Only the soluble sugar content, soluble solid content, and fruit hardness relative values are greater than 90%.

Keywords: Pear branches and stems; 3D modeling; Visualization; CAD L system.

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1 INTRODUCTION

According to the statistics of the United Nations Food and Agriculture Organization (FAO), there are 76 countries planting and producing pears in the world, with a total cultivation area of about 1669700 hectares and a total output of about 19539500 tons. Pear cultivation has a history of more than 3000 years. It is one of the three origin centers of pear cultivation in the world. According to the statistics of the Ministry of agriculture of China, the cultivated area of pear trees has reached 10.73 million hectares, accounting for 10.2% and 57.9% of the total fruit area in China and the total pear harvest area in the world respectively. The output has reached 142.63 million tons, accounting for 2.2% and 63% of the total fruit output and the total pear output in the world respectively. The total output ranks first in the world, which can be called the largest country in pear production in the world [1]. Pear production is limited to temperate climate zones worldwide. Pears, particularly Asian cultivars, are more popular in China than apples [2, 3].

China currently produces more Asian pears than any other country in the world, with an annual production of around 8 million tons and 0.94 million hectares under Asian pear cultivation. The fruit is the third most important fruit in China, behind the apple and the orange [4, 5]. In general, the pear tree thrives in cold, wet climates with cool summers and freezing winters. To develop correctly, popular pear varieties are claimed to require 400-800 hours of cold exposure (temperatures below 45 °F or 7 °C) [6, 7].

Since the reform and opening up, pear production has developed rapidly, especially after the 1990s. Pear production has become a branch industry in the main pear producing areas, and pear production has changed from yield benefit type to quality type. Especially after China's entry into WTO, in order to meet the needs of the fruit consumption market, while optimizing the production layout and variety structure, each pear producing area actively adopts advanced cultivation and management technologies such as artificial pollination, bagging and yield restriction, and the fruit quality has been significantly improved.

In general, the pear tree flourishes in a cold and damp area with chilly winters and cool summers. Temperate fruit trees come from a variety of locales with four distinct seasons, including a very cold winter and a warm spring–summer period for hibernation and growth, respectively. The pear tree is a medium-sized tree that can reach a height of 10 to 16 meters. This fruit is mostly cultivated in India from 2000 to 2400 meters above sea level. The high-quality fruit rate has reached about 35%, the high-quality fruit rate in some high-quality demonstration parks has even reached about 80%, and the high-grade fruit rate reaching the export standard is about 5% [8]. However, compared with the fruit quality power, China still has a considerable gap.

For example, the high-quality fruit rate of the United States, New Zealand, Japan and other countries is more than 70%, and the high-grade fruit rate available for export is also about 50%. Chinese pear yields per unit are also significantly lower than those of the United States, France, Japan, and other nations. The reason for this is that pear production in China is now somewhat tiny, owing to decentralized administration and the family as the basic unit. Fruit farmers lack the change of supply and demand in the fruit market and the knowledge of the quality standard of green fruits. They only focus on the pursuit of output and ignore the quality of fruits in production, resulting in failure to meet the needs of the market. As a result, although the output of pear has been improved, the economic benefit is not very obvious. On the other hand, farmers attach importance to development and despise management. The overall output ranks first in the globe, making it the largest pear-producing country on the planet.

China still has a significant disadvantage in terms of fruit quality power. The reason for this is that pear production in China is now somewhat tiny, owing to decentralized administration and the family as the basic unit. Fruit growers lack awareness of the green fruit quality criteria and the changing supply and demand in the market. They are solely concerned with increasing output while ignoring the quality of the fruits produced, resulting in a failure to fulfill market demands. Some are over densely planted. In some places, there is no fruit thinning or bagging. In this way, although premature and high yield can be achieved, the pear produced is very small, the color cannot keep up, the taste is light and the price is low. In addition, the cultural quality and technical level of fruit farmers are generally low, and the backward technology restricts the further development of pear industry to a high level [9]. Virtual plant is a new research field rising with the rapid development of information technology and computer technology in recent years. It is an interdisciplinary subject based on computer graphics, botany, mathematics and virtual reality technology. This paper presents a visualization method of fruit tree branches and stems based on the combination of morphological feature information and parameter L system. Taking the tree structure of pear tree as the research object, the relevant morphological and structural characteristics and ecological and physiological characteristics were extracted.

2 LITERATURE REVIEW

Pear cultivation is a continuous production process with long production cycle and high technical requirements. Pruning technology for pears is an important technical tool for pear cultivation and management. Plastic pruning allows for a low dry and low crown on fruit trees, as well as a neat and consistent tree shape and the implementation of various orchard management techniques. Cutting off undesirable branches helps save insecticides and fertilizers while also improving their effectiveness. Pruning can improve the ventilation and light transmission conditions and reduce the occurrence of diseases and pests, which can also reduce the production cost of orchard. Pruning is an essential measure to improve fruit quality and regulate fruit yield. Pruning can cultivate and maintain high-yield tree structure, and adjust the balance between pear growth and fruit, so that pear trees can have high quality and high yield year after year. Therefore, popularizing advanced and practical fruit tree shaping and frying technology plays an important role in improving fruit quality and stabilizing fruit yield. However, for a large fruit tree planting country like China [10], there are two unavoidable problems in the production practice and scientific and technological promotion in the vast fruit areas: on the one hand, there is a lack of scientific and technological personnel who master the fruit tree pruning technology, on the other hand, it is quite difficult to popularize the correct pruning technology in rural areas. Offering fresh things while retaining quality is a challenge that pays off in the long run.

Numerous advances in postharvest technology aid in the preservation and quality assurance of fruits and vegetables along the production chain [11, 12]. Postharvest innovations and evolving technologies currently comprise a vast scientific endeavor that gives information to enhance the supply chain, nondestructive quality evaluation, postharvest loss reduction, and increased quality and shelf life [13, 14]. An incorrect pruning of fruit trees often brings irreparable losses, which is irreversible. Therefore, it is urgent to improve the problem of fruit tree pruning [15].

The traditional pruning technology of fruit trees can only be popularized through the technical training of fruit farmers by traditional technicians. This method is not only inefficient, but also involves the wrong pruning of fruit trees in the learning process of fruit farmers, resulting in economic losses. Under the background of the Internet changing life, build models of pear trees on the relevant CAD platform to monitor the whole growth process of pear trees. It can also simulate the pruning operation, find the best pruning method for production, improve the income of fruit farmers and promote the healthy development of pear related industries [16]. Papers [17-19] investigated how to extract the production rules and axiom for a basic L-system in order to replicate a specific 2D plant structure. The chromosomal encoding and genetic operation forms were kept basic since the simulated target is a simple 2D plant shape. A major issue is determining how to evaluate an individual's fitness in the system automatically. A fitness function for two-dimensional simulation models was developed by Bian et al. [20]. However, they did not explore analyzing the individual fitness of a three-dimensional simulated plant in their research.

Venter and Hardy [21] suggested a genetic programming-based 3D plant simulation model. The concept starts with a "genotype," which is defined by an L-system and describes certain plant morphology.

Temperature, moisture, wind, and competition are all elements that influence seedling establishment, development, and mortality in tree line habitats, and they vary by location and species. Many individuals become concerned with minor tree limitations while ignoring huge life-altering consequences. Soil compaction is one of the key issues that causes substantial tree stress and strain, and whose consequences are often attributed to other factors.

Virtual reality is a computer-generated human-computer interaction system that can create and experience the virtual world. It provides a real-time and three-dimensional virtual environment by using the integration technology of computer hardware and software resources. At present, virtual reality technology has also been widely used and developed in the field of agriculture, such as virtual animals, virtual plants, virtual design and development of agricultural machinery products, virtual instruments, agricultural test simulation research, etc., and its position is becoming more and more important, forming an important branch of virtual reality - "virtual agriculture" [22]. Using virtual training, you can enhance your response to this challenge. This form of training is significantly less costly. Modern technology is not cheap. Virtual training assists you in avoiding scenarios in which unskilled individuals create a malfunction or an accident.

A new employee may practice certain scenarios in the game mode, train their talents to automatism, and then begin working with genuine technology [23, 24]. Machine learning is a hot issue right now. We are dealing with self-learning systems. Currently, there are various creative surgical options accessible, such as surgical glove prototypes. Technologies are being developed that will allow you to interact with objects in mixed (VR+AR) reality [25, 26]. Virtual plant (also known as plant visualization) is an important and rapidly developing part of virtual agriculture. It is an emerging research field with the rapid development of information technology and computer technology in recent years. It is an interdisciplinary subject based on botany, computer graphics, mathematics and virtual reality technology.

Virtual plant modeling refers to taking the morphological structure of plant individuals or groups as the research object and applying virtual reality technology to reproduce the growth process of plants in three-dimensional space on the computer. It can simulate the whole life cycle of the whole plant or even the whole group of plants in a few seconds. It does not need to plant crops in the field for a long time, which saves time, manpower and cost [27, 28]. The research of virtual plant technology is one of the core contents of virtual agriculture research. It is an indispensable part of agricultural informatization and has extensive practical significance. In this paper, by using virtual reality technology and modeling the pear tree, a realistic pear tree branch model can be made on the computer, which provides a platform for the simulation of pear tree pruning [29].

The research of virtual fruit tree branch model is of great significance. Virtual reality technology is an advanced technology widely used in long cycle, high cost and irreversible operation. A computer-generated human interface system that can construct and explore the digital universe is known as virtual reality. Virtual reality technology is now widely utilised and developed in the field of agriculture, including virtual animals, plants, agricultural machinery product design and development, virtual instruments, and agricultural test simulation research. Virtual plant technology research is one of the most important aspects of virtual agricultural research. It is an essential component of agricultural information technology and has a wide range of applications. Introducing it into the agricultural field and applying it to the popularization of fruit tree pruning technology will improve the current situation of low yield, low quality and lack of technicians.

By mastering the theory, method and related computer technology of virtual plant, this paper studies the algorithm of plant growth model and Its Simulation on computer, realizes the branch model of fruit tree, and establishes a virtual fruit tree platform. Through the next step of the platform, we can study the internal law of branch growth, and carry out experiments such as virtual pruning operation of fruit trees on this basis, so as to provide a new way for fruit farmers to design for many times, practice repeatedly and finally master advanced fruit tree pruning technology [30].

3 RESEARCH METHODS

3.1 Virtual Plant Computer Model

There are two main directions in the research of virtual plants: one is to simulate plants realistically in shape; another direction is to simulate the natural growth process of real plants from the perspective of physiology and ecology. At present, there are many computer models used to construct virtual plants. Different model classifications will be obtained according to their different application fields, problem-solving strategies and construction algorithms. Generally, according to different modeling methods and purposes, it can be divided into pure graphics model, dynamic structure model and static structure model.

3.1.1 Pure graphics model

The research purpose of pure graphics model is to generate simple plant graphics with the least botanical knowledge, only pay attention to achieving realistic visual effects, and focus on computer graphics. This kind of model does not need complex plant growth mechanism model, and is generally not suitable for simulating the process of plant growth and development. It is mainly used in landscape planning, landscape design and other aspects. The typical methods of this kind of model include fractal, generation function system, branching matrix, particle system and so on.

3.1.2 Dynamic structure model

The dynamic structure model is based on the study of the actual growth and development process of plants, such as the evolution of topological structure and the change law of geometric form in the growth process. According to a large number of measured plant information data, the plant growth rules are extracted, and the plant growth model is established to simulate the real growth process of plant growth. For a specific plant, various morphological structures of the plant can be obtained by changing the model parameters. This kind of model is generally a general model. At present, the most famous dynamic structure models include L system, automata model, GOSSYM model and cotton plus model. The dynamic pattern of the ratio of accessible biomass to demand produces changes in the plant structure that are frequently found in trees over growing plants in the model. A temporal unit for architectural growth and Eco physiological function has been established. It enables the derivation of the discrete dynamic system of development, and its state variables are adequate to determine the whole-plant design.

3.1.3 Static structure model

Static structure model is a model of plant morphological structure that directly uses the measured data after measuring its morphological structure by three-dimensional digital method [31, 32]. Static models may be used to investigate the importance of plant structure in areas such as canopy light distribution, gas exchange, remote sensing, pesticide spraying research, and plant-biotic agent interactions. Static structural models depict the structure of a 3D plant or plant canopy and can be created by scanning an existing structure, analyzing the data, and faithfully reconstructing the real-life structure in silica.

3.2 Plant Simulation Model

From the perspective of virtual plant definition, the plant simulation model can be divided into the following levels:

3.2.1 Plant geometric structure model

Plant geometric structure model, that is, plant morphological structure model, refers to the three-dimensional information description of the composition and structure of the whole or part of plant organs. The geometric structure of plants is self-similar, that is, plants have repetitive modular structure. This is the core of fractal geometry. Therefore, although the number of modules in a plant may be large, there are not many types of modules. Therefore, we can use the perfect substitution mechanism and branching principle provided by L system and the mathematical method of fractal geometry to concisely describe plants with specific module types without describing the properties of each module in plants to build a better plant geometric structure model to simulate the growth of plant morphological structure, so as to construct plants with thousands of different geometric forms similar to nature.

The geometric structure model covers different levels of plant population, individual plant and various parts of the plant, such as flowers, leaves, nodes and roots. There are various typical applications in horticulture, plant geometry and forestry. From the research progress and actual simulation results, the simulation modeling and simulation technology of plant geometric structure has been improved day by day.

3.2.2 Structure function model

Plant geometric structure model is mainly a description of plant morphological structure, and cannot simulate the growth of plants due to the change of environmental conditions; Nor can it simulate the corresponding changes of plant biomass production and distribution after artificially changing plant structure (such as pruning and fruit thinning). By simulating the feedback relationship between plant structure and function, the above problems can be solved. Therefore, a plant structure function model is proposed, which provides a deeper understanding of plant function.

Structure function model is the combination of plant structure and function model. It is essentially based on the geometric structure model and combined with the growth mechanism of plants, such as respiration and transpiration, calculate the production of fresh substances, simulate the changes of the whole plant structure by using the relationship between organ biomass accumulation and morphogenesis, and explore the proposed plant growth hypothesis or the relationship between plant growth and its environment through plant growth simulation. For example, the transmission and distribution of carbon in roots, the transmission of water in trees, the influence of branch gravity and direction on plant branch development, and the transmission of sunlight through canopy, etc. Most of the current structural and functional models assume that other environmental factors are appropriate, and only consider the impact of some environmental factors on plant growth. Their research focuses on the functional structural model with a single physiological or biological mechanical process. Obviously, this idea has great limitations and cannot meet the actual needs of the cultivation of ideal plant type of crops, the prediction of population yield and cultivation management. Therefore, it is necessary to deeply study the relationship between the stress of environmental factors and crop growth, and establish a comprehensive structural and functional model that can simulate a variety of environmental conditions.

3.2.3 Organ and tissue model

The organ and tissue model, which is based on the growth of plant cells and organs, reflects another requirement of virtual plant modeling: through the direct analysis of the growth of cells or organs in plants. It will be able to more accurately and accurately predict the growth status and final morphological structure of the whole plant, and distinguish the main growth factors determining the surface shape. The modeling granularity of virtual plant organs and tissues is becoming smaller and smaller. The organ and tissue models are becoming more and more sophisticated. The combination degree with plant physiological mechanism is higher and higher. It can also more and more accurately simulate the real physiological process of plants.

3.2.4 Gene suppression network model

Within the specified range of geometric and artificial constraints, the plant growth pattern and morphological structure are finally determined by genes. Only by adding the gene mechanism to the research of virtual plants can we deeply understand the basic mechanism of plant growth, master the development law from the gene level to the final plant morphology, and enhance the understanding of nature through the comprehensive action of biology, computer science and art. The plant gene model is more complex than the above three models, and its research is still in the stage of conceptual exploration, which is far from the progress of other plant models. However, the plant gene model may be a real virtual plant, which is a research direction worthy of in-depth exploration [33, 34].

3.3 Plant Growth Model

The visual simulation process of plants tells us that we first need to calculate the growth process of plants, and then use computer graphics technology to show the development changes of plant morphological structure with growth [35]. Therefore, according to the functions completed by the model, the plant growth model can be divided into two categories: growth machine model and visual model, as shown in Figure 1. Plant biology and the plant structure building model are used to create a virtual simulation three-dimensional display that reflects plant structure features and shows the growing process because of the diversity of morphological traits of the same plant at different growth stages and the complexity of the morphological structure of different plants.

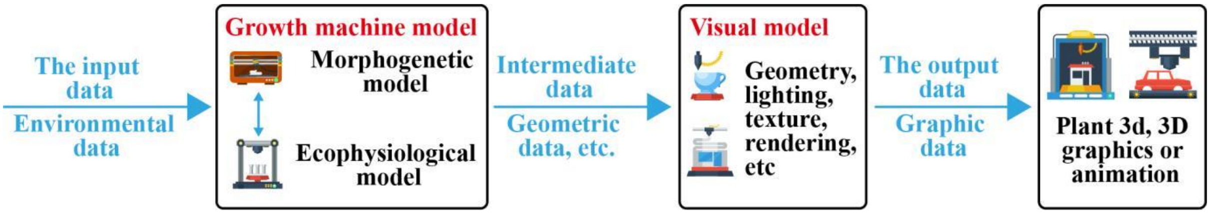

Figure 1: Visualization of plant growth model.

3.3.1 Growth machine model

The growth machine model is composed of morphogenetic model and ecological physiological model. It calculates the dynamic growth process of plants according to the known initial information of plants such as preset environmental parameters and model parameters. Morphogenetic model provides morphological information of plants, including topological structure model and geometric structure model. Topology model is often used to describe the connection relationship between discrete structural units of plants. It is the most basic model in plant modeling. Eco physiological models include many specific growth mechanism models, such as respiration and transpiration, plant soil, water and fertilizer, photosynthesis, nutrient generation and distribution and so on.

3.3.2 Visual model

The visualization of plant growth is processed by using geometric graphics or three-dimensional graphics, including computer graphics. The main function of these sub models is the data information calculated according to the growth machine model. Some graphic symbols are transformed by scaling, rotation and distortion to represent the composition of plant organs. With the help of visual model, plant growth problems such as light intensity distribution in plant canopy, deformation, bending and lodging of plant body can be studied. On the other hand, the simulation of plant growth process under artificial interference in plant production process, such as artificial pruning, shaping and other cultivation operations, also involves three-dimensional visual simulation [36].

4 RESULT ANALYSIS

4.1 System Implementation

Differential L-system theory is to enable the model to be simulated in a continuous form and separate the model developed in a continuous time period from the observations obtained at discrete time points. It is a well-developed L-system method. It is a process of replacing a series of discrete transformations by introducing continuous time flow information on the basis of parametric L-system. It is an extension of parametric L-system. Its main basic idea is to introduce a mathematical model that can simulate the smooth animation in the process of plant growth. This model uses a unified form to express the discrete or continuous behavior in the process of plant growth [37]. In this system, the production formula is used to express the change in the number of models such as plants producing new branches, and the differential equation is used to express the continuity of the plant growth process such as the gradual elongation of plant stems. Such a series of discrete language steps can be replaced by continuous time flow, so that the model can realize smooth "continuous" growth and enhance the sense of reality. Define a module a (x) x as a parameter, and its value range is B. This module grows in a continuous way. Once the value of the parameter W reaches the boundary D of the value range B, it will trigger a production to generate discrete changes. The module a (x) will be replaced by future generations according to the rules. The adopted rules are determined by the crossed boundary d [38]. For example, the running track simulation of module m in its parameter space is shown in Figure 2:

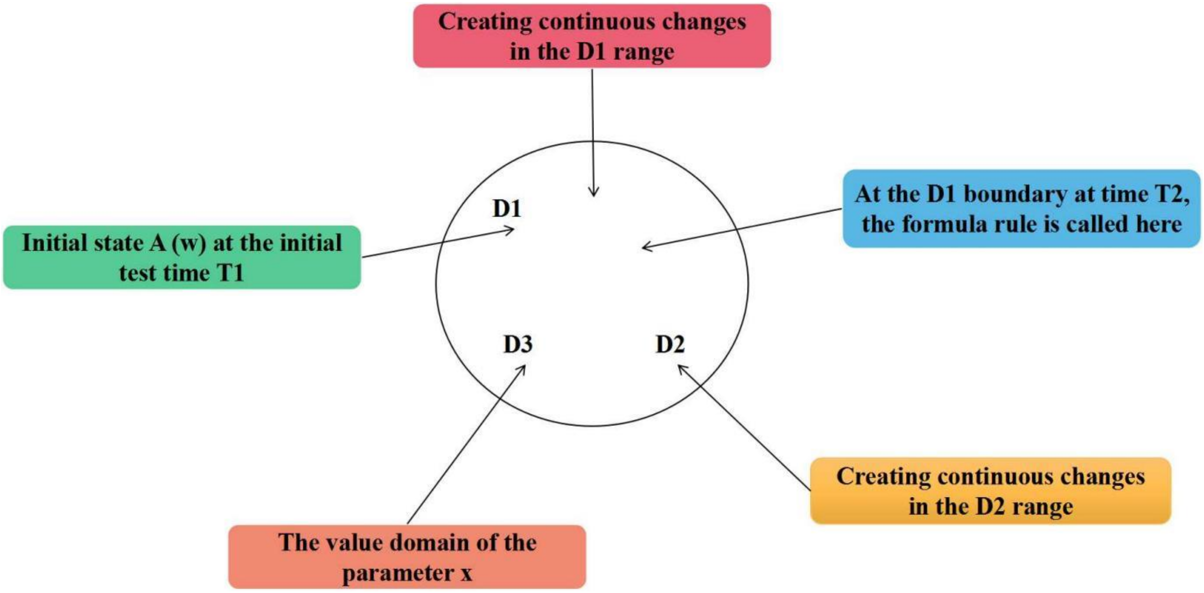

Figure 2: Simulation diagram of operation track of module m in its parameter space.

Taking windows as the platform, using the good user interface development function of Visual C + + and the powerful graphic display and processing ability of OpenGL, this course develops a visualization platform for simulating and generating three-dimensional plants and trees based on L system. Then realize the three-dimensional modeling of pear branch model on this platform [39].

4.2 Pear Tree Shape and Structure

Tree shape refers to the overall structure mode of the tree body. A good tree shape is an important means to achieve early fruit, high yield, high quality and high efficiency. As long as the amount of branches is moderate, the distribution is reasonable, the skeleton is firm and the space utilization rate is high, it is conducive to three-dimensional results. Based on the literature of pear trees and the knowledge provided by relevant agricultural experts, the main tree forms suitable for pear cultivation are as follows.

4.2.1 Natural open center shape

There is no obvious central trunk in this tree shape. Three main branches are divided on the main branch, and secondary main branches arranged in layers are divided on each main branch. Side branches are distributed on each secondary main branch, and the center of the crown is transparent. The base angle of the three main branches is 45-50 degrees, and the angle beyond 1m of the main branches should be gradually reduced, that is, the waist angle should be 30 degrees. The angle of the apex of the main branch, that is, the tip angle, should be close to upright, and the plant is about 4 meters high. This tree shape has the advantages of good ventilation and light transmission, firm skeleton, suitable for dry and dense planting, small main branch angle and slow aging. It is suitable for varieties with strong growth potential and non-opening main branches.

4.2.2 Trunk sparse

This is based on the obvious layered characteristics of the branch distribution of arborization trees. There is an obvious central trunk in the crown. The whole tree has 8 ~ 10 main branches, which are arranged on the central trunk in layers. There are 3 ~ 4 main branches in the first layer, 2 ~ 3 main branches in the second layer and 3 ~ 4 main branches in the third layer, which can also be divided into the fourth and fifth layers. The main branches of the first layer shall be evenly distributed in 3 or 4 directions. The layer spacing of the main branches from the first layer to the second layer is 80~100 cm, and that from the second layer to the third layer is 50~60 cm. The spacing of the fourth and fifth layers gradually shrinks. The distribution of the main branches in the adjacent two layers is staggered and does not overlap each other. This tree shape has the advantages of natural shaping, less pruning, fast forming, firm backbone, large load and high and stable yield.

4.2.3 Small crown sparse layer

The small crown is in the form of sparse layer tree, which is in the form of central stem tree. Its trunk is about 50cm high and the tree is about 2.5m high. The whole tree has 5 ~ 7 main branches, divided into 2 ~ 3 layers. The first layer has 3 ~ 4 main branches, and the second layer has two main branches. Sometimes the last main branch forms a third layer. The inner distance of the first layer is 20 ~ 30cm, and the inner distance of the second layer is 30 ~ 40cm. The layer spacing between the first layer and the second layer is 80 ~ 100 cm. The main branches of each layer are evenly distributed around the central trunk, and there is no heavy curtain between the upper and lower main branches. The base angle of the main branch is about 60 ° and the waist angle is about 80 °. Small crown sparse layer shape is suitable for low density planting garden. Its advantages are firm skeleton, high output, long service life and good light transmittance [40, 41].

4.2.4 Spindle shape

The tree structure is characterized by: the height of the tree is 25 ~ 3m, the middle trunk is strong and upright, the height of the trunk is 50 ~ 60cm, there is no lateral branches and no stratification, 10 ~ 15 small main branches are evenly planted directly on the middle trunk, the lower part is large and the upper part is small, and the waist angle of the main branch is 70 ° ~ 90 °. Key points of plastic surgery and pruning: cultivating strong and upright central leaders is the key to plastic surgery. After planting, the stem is about 80cm long, and the middle stem is short to promote branching and support its power. Every year, 2 ~ 4 small main branches are selected on the central trunk and leveled when the new shoots stop growing. When the small main branches are selected enough, they will fall and be happy, and the tree height of 25 ~ 3m shall be controlled. For varieties with weak growth potential such as Japanese pear, in order to effectively control the tree height and maintain the growth power of the tree body, the fixed stem height can be 20 ~ 40cm, the tree height can be controlled at 1.5 ~ 2m, and the ability to resist wind disasters can be effectively enhanced. The tree shape is characterized by simple and easy pruning, small pruning amount in young tree stage and early production, which is suitable for dense planting [42].

4.3 3D Modeling of Pear Branches

The branching pattern of pear tree belongs to the axial branching pattern. The apical bud of the tree with axial branching develops to a certain extent and dies, which is replaced by several lateral buds under it to form strong lateral branches connected to the main shaft. There is no obvious trunk, forming multiple main shafts, and the crown is in an open state. Combined with the knowledge of the morphological structure of pear tree, the thickness of branches is. When the detailed information such as bifurcation angle is introduced into the rules as its parameter control, we can establish a rule model suitable for different tree shapes of pear trees.

In this paper, the parameter L system is used to introduce the information of trunk, branch thickness, length and bifurcation angle in the process of tree growth, add the detail control of trunk color information, and expand the detail control process to three-dimensional space to realize the three-dimensional modeling of branch model. Figure 3 shows the modeling and visualization process of pear branches.

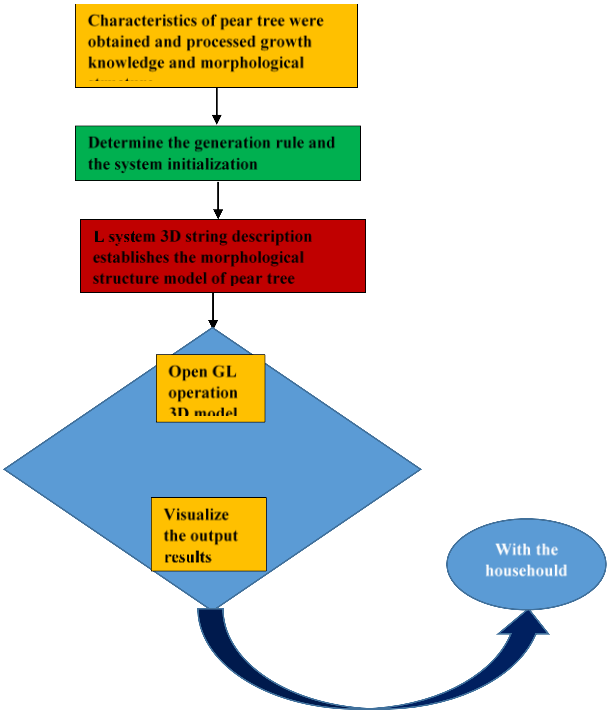

Figure 3: Three-dimensional visualization flow of pear branches.

4.4 Pear Branch Model

The L-system rules corresponding to each tree shape of pear tree are stored as txt files as input, and finally the three-dimensional effect models of pear tree trunk sparse layer shape, small crown sparse layer shape, natural open center shape and spindle branch model are obtained [43]. Because the L-system principles are recursive, they result in self-similarity, making fractal-like structures simple to define. Plant models and natural-looking organic shapes are simple to define, as the form gradually 'grows' and gets more complicated as the recursion level is increased.

4.5 Influence of Pear Branch Shape on Fruit Trees

Under the same growth environment, the open center shape (natural open center shape) and open center shape (trunk sparse layer shape) of pear trees were selected for comparison. The investigation results of tree condition and branch volume of the two tree forms are shown in Table 1. The total branch volume and short branch volume of the open form are significantly higher than those of the open form, and the branch spread in the east-west direction is also much higher than that of the open form; Although there are obvious bare bands at the base of the two tree forms, and most of the fruiting branch groups grow in the middle and upper part of the tree body, the number of branches in the open form is significantly more concentrated than that in the open form.

Tree Shape	*Tree Height (M)*	*Branch Spread (M)*		*Average Quantity Per Plant (Piece)*				*Short Branches / Total Branches (%)*
		East and West	*North and South*	*Total Branch Volume*	*Short Branch*	*Middle Branch*	*Long Branch*	
Open Center Shape	1.80a	4.52bb	4.35a	1543.6b	1643.6b	59.5a	32.9a	95.9a
Evacuation Form	3.64a	6.37aa	5.68a	1769.8a	1669.8a	57.4a	31.4a	98.6a

Table 1: Branch quantity configuration and tree condition of two tree shapes.

There was no significant difference in photosynthetic effect and internal light intensity between the two tree shapes, but the internal photosynthetic effective radiation and net photosynthetic rate of open center tree were significantly higher than that of open center tree (see Table 2). It shows that the ventilation and light transmission conditions of the tree body have been effectively improved after the cleaning and transformation of the crown tree by reducing the tree height and shrinking the branch spread. However, due to the relatively large number of branches and branches reserved in the middle, the photosynthetic effect inside the tree body is significantly lower than that of the open center tree [44].

Tree Shape	*Branch Spread (M) Average Quantity Per Plant (Piece)*			*Net Photosynthetic Rate { μ mol/ (m ². s) }*			*Light Intensity (Internal) (Lx)*
	Inside	*External*	*Whole Tree*	*Inside*	*External*	*Whole Tree*	
Open Center Shape	67.654a	248.365a	157.658a	3.652a	9.325a	6.932a	15.658a
Evacuation Form	34.356a	254.698a	146.697a	1.658b	8.693a	5.435a	14.364a

Table 2: Photosynthetic effect and light intensity of two kinds of trees.

Under the same growth environment, select the open center (natural open center) and open center (trunk sparse layer) individual plants of pear tree, and compare the yield and sugar content of pear fruit, as shown in Table 3:

Tree Shape	*Single Fruit Weight*		*Soluble Solid Content*		*Fruit Hardness*		*Titratable Acid Content*	
	Value (g)	*Relative Value (%)*	*Value (g)*	*Relative Value (%)*	*Value (kg /cm2)*	*Relative Value (%)*	*Value (g)*	*Relative Value (%)*
Open Center Shape	235.68a	104.35	11.89a	103.65	7.365a	103.65	0.268a	103.65
Evacuation Form	207.65b	87.56	11.65a	98.95	6.689a	97.65	0.264a	97.65
Tree Shape	Soluble Sugar Content		High Quality Fruit Rate		Yield Per Plant		Output Per Unit Area	
	Value (mg / g)	Relative Value (%)	Value (%)	Relative Value (%)	Value (kg)	Relative Value (%)	Value (kg/hm2)	Relative Value (%)
Open Center Shape	113.68a	100.35	74.97a	100.35	142.64a	100.35	33 215.6a	100.35
Evacuation Form	105.12b	92.32	59.64b	74.25	105.67b	74.35	27 104.8b	74.68

Table 3: Fruit yield and quality of two tree shapes.

Compared with the manual teaching of pear tree pruning method by agricultural technicians, the simulation and practice of pear tree pruning with the modeling system in this paper can greatly save learning time. After a variety of pear branch models were established in the simulation system, the plants in the orchard were pruned into the branch types in the simulation system. After the actual test, the pear fruit was collected and counted. In terms of single fruit weight, soluble sugar content, high-quality fruit rate, single plant yield, and yield per unit area, the open center branch plant outperforms the open branch plant. The natural open center branch type is the most suited branch type for pear planting.

5 CONCLUSION

Virtual fruit tree branch model research is very important. In a matter of seconds, virtual technology can replicate the whole life cycle of a plant or a group of plants. This work investigates the algorithm of plant growth model and its computer simulation in order to develop a fruit tree branch model platform based on the L system by mastering the theory, technique, and associated computer technology of virtual plants. This paper's objective is to: (1) This paper delves into the fundamental theory of virtual plant, classifies and summarizes the computer model of virtual plant based on the method and purpose of virtual plant modeling, the definition of virtual plant, and the model's function, and provides a simple summary of existing virtual plant software implementation.
(2) A visualization platform based on Windows was built for simulating and producing three-dimensional models of fruit tree branches and stems using the L system.
(3) Gain a thorough understanding of the pear tree's growth and morphological structure characteristics, extract the corresponding morphological rules, establish the corresponding L-system rules based on the morphological structure knowledge of various tree shapes, and then conduct three-dimensional visual simulation on the established fruit tree branch model simulation platform.

(4) In comparison to an open center branch plant, the former has a considerable increase in single fruit weight, soluble sugar content, high-quality fruit rate, single plant yield, and yield per unit area, according to practical trials. The natural open center branch type is the most suited branch type for pear planting.

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