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Virtual Simulation Teaching System for the Entire Process of Tree Trunk Analysis

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Abstract: *This paper constructs a virtual simulation teaching system for the entire process of tree trunk analysis. By simulating the real forest farm and laboratory environment, it comprehensively simulates the field and indoor operations, enabling students to master the entire process of tree trunk analysis in a virtual environment. The main work includes: (1) Simulation of the experimental environment: Through 3D modeling and environment scene construction, it simulates the real forest farm and laboratory environment, allowing users to understand the actual working environment; (2) Simulation of experimental operations: It virtually reproduces the operation steps of field and indoor work in detail, ensuring that students can deepen their understanding through practical operations in a safe and risk-free condition; (3) Teaching guidance: Through various guidance methods such as videos and pictures, it provides students with detailed theoretical teaching content, enhancing the teaching nature of the system and improving the operation experience. In addition, the system also monitors the learning process of students in real time through a scoring mechanism, accurately positioning their knowledge mastery level. This work has important reference significance for the application of virtual simulation technology in forestry education.*

Keywords: *Trunk Analysis, Virtual Simulation, Teaching System, Forestry Education*

1. Overall System Design

1.1. Overview of Virtual Simulation System

In recent years, with the rapid development of cutting-edge technologies such as computer graphics, sensor technology, and artificial intelligence, virtual reality technology has experienced explosive growth and has been deeply applied in a wide range of fields, including industrial manufacturing, medical surgical simulation, cultural entertainment, etc. In the field of education and training, virtual simulation technology has also shown great value, and many disciplines have successfully integrated it into teaching scenarios.

For example, in the experimental teaching of psychology, by developing a psychological virtual simulation experimental teaching system, integrating multiple psychology professional courses, and designing multiple experimental projects, it can meet the needs of different users[1]. In the teaching of the subway emergency ventilation system, a virtual simulation experimental platform is constructed to help students majoring in safety engineering get familiar with the subway ventilation system and emergency operations[2]. In the teaching of laparoscopic surgery in pediatric surgery, a virtual simulation system is used to improve the teaching effect[3]. In the teaching of chemistry experiments, a chemistry simulation teaching system based on virtual reality and gesture interaction is developed[4]. In the teaching of intelligent manufacturing majors, a virtual simulation teaching platform is built, covering multiple virtual simulation modules such as electrical and electronic and PLC control, and typical intelligent manufacturing production lines, to meet teaching needs at different levels[5]. In the teaching of electrical and electronic technology courses, virtual simulation teaching resources are developed for the teaching content of "safe electricity use" to address the shortcomings of traditional teaching, stimulate students' interest in learning, and improve the learning effect[6]. In the teaching of vocal music courses, the virtual simulation teaching mode is also applied[7].

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The "Virtual Simulation System for the Whole Process of Stem Analysis" developed in this paper takes virtual simulation technology as the core and constructs a highly realistic virtual simulation teaching system for stem analysis. Through computer-generated 3D models, users can experience realistic visual and auditory effects in a common computer environment and interact with the virtual environment in a natural way with the help of devices such as keyboards and mice, thus obtaining an operating experience similar to the real world.

In the development of this system, we used Unity 3D as the development engine to build a virtual experimental environment for stem analysis. By simulating the environment and conditions of forest farms and laboratories, the system makes students feel as if they are in real forest areas and laboratories. At the same time, the system focuses on the display of details. By simulating various links such as tree felling, measurement, and analysis, students can comprehensively understand and master the whole process of stem analysis. In addition, the system also provides a variety of operation objects, including trees of different species and different growth stages, as well as different environmental conditions, helping students to more comprehensively master the stem analysis methods under different conditions.

1.2. Main Modules of the System

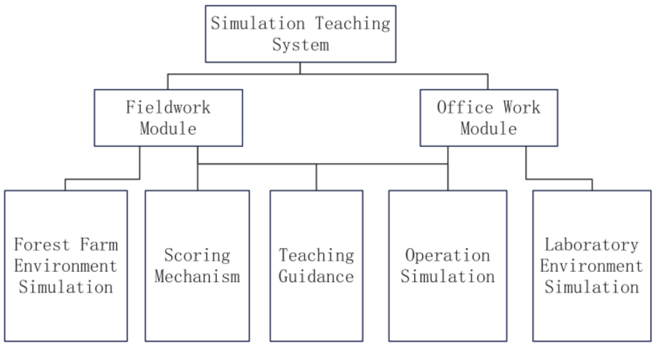

Figure 1: Diagram of Main Functional Modules of the System.

The virtual simulation experiment project of the whole process of stem analysis shows each link of the growth process of the analysis tree in a virtual way, realizing a new mode of "logging - analysis" systematization and the whole - process "stem analysis".

The simulation teaching system divides the stem analysis work into two parts successively: fieldwork and office work. Fieldwork refers to on - site operations carried out in a natural environment, usually involving direct measurement and sampling of trees. Office work refers to data processing and analysis work carried out in a laboratory.

The main functional modules the system are shown in *Figure 1*. Forest Farm Environment Simulation and Laboratory Environment Simulation mean simulating the real forestry operation environment through 3D modeling and environmental scene construction, allowing users to understand the real working environment. Teaching Guidance provides detailed theoretical teaching content by adding videos, pictures and other guiding methods before and after each operation part, including basic knowledge of analysis tree operations, collection and disk processing of analysis trees, determination of growth indicators and analysis of change laws, so as to strengthen the teaching nature of the system and improve the operation experience. Operation Simulation makes a detailed virtual reproduction of the operation steps of fieldwork and office work, ensuring that students can deepen their understanding through practical operations under safe and risk - free conditions. The Scoring Mechanism modularizes each operation and scores the user's operation skills, enabling users to have a clearer understanding of their knowledge mastery, operation correctness and accuracy, and stimulating users' learning motivation to get high scores. The following will specifically introduce the experimental environment simulation, teaching guidance, operation simulation and scoring mechanism.

2. Experimental Environment Simulation

2.1. Forest Farm Environment Simulation

To simulate the real forest area landforms, we used the Terrain tool in Unity to create the terrain. According to the different topographical features of the southern and northern regions, we constructed

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various terrain types such as mountains and plains. The southern model mainly consists of mountains, with large undulations in the terrain, providing rich three-dimensional space for the growth of trees. The northern model, on the other hand, is mainly composed of plains, with relatively flat terrain, offering vast ground space for tree growth.

The system meticulously depicts the unique natural landscapes of both the southern and northern regions. The southern environment model is characterized by a tropical rainforest, with lush vegetation and an abundant water source, as shown in *Figure 2.*

The northern environment model, however, exhibits the characteristics of a temperate continental climate, with deciduous broad-leaved forests as the main vegetation, as depicted in *Figure 3*. Based on the characteristics and distribution of tree species in the southern and northern regions, Chinese fir is selected as the tree species for the southern model, and Larix gmelinii is chosen as the tree species for the northern model.

Figure 2: Southern Forest Farm Environment Simulation.

Figure 3: Northern Forest Farm Environment Simulation.

2.2. Laboratory Environment Simulation

The laboratory is mainly used to complete the office work of analysis trees, including tasks such as determining the age and dividing the age classes. The system simulates the laboratory environment, as shown in *Figure 4*, including the experimental workbench and tools. For the convenience of selection, all the discs obtained from the fieldwork are placed on the workbench, and all the tools are put in the toolbox. Users can select the tools by clicking the tool icons on the right side and operate on the discs.

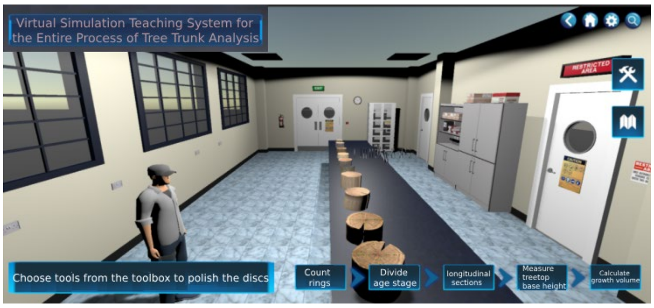

Figure 4 Laboratory Environment Simulation.

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Through simulating the above two working environments, the system makes users feel as if they are in the real forest area and laboratory. They can personally experience the experimental environment of stem analysis, understand the experimental process, and obtain a better experimental experience and more profound experimental knowledge. This virtual simulation technology can also help users better understand the differences in the natural environments between the southern and northern regions, and improve their ability to understand and apply ecological and botanical knowledge.

3. Teaching guidance

In terms of teaching guidance, this system adopts diversified guidance methods to ensure that users can comprehensively and deeply understand the theoretical knowledge and operation procedures of stem analysis.

Firstly, the system introduces video teaching guidance, as shown in *Figure 5*. The content covers the basic concepts of stem analysis, practical applications, and key points in the operation process. By shooting real experimental scenes and correct actual operations by real people, the video presents complex theoretical knowledge to students in an intuitive and understandable form.

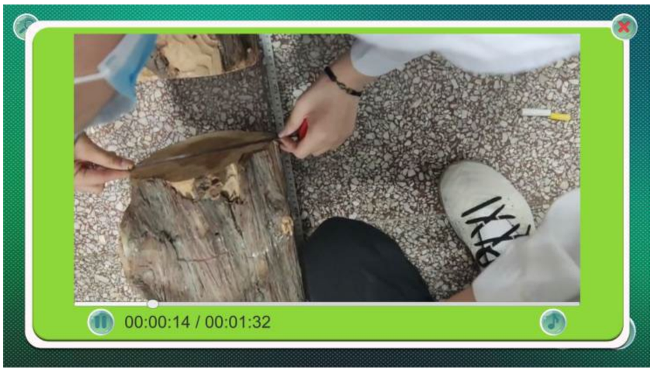

Figure 5: Teaching Guidance Video.

Secondly, we have also added teaching pictures to the key operation steps section, as shown in *Figure 6*. During the process of stem analysis, there are many key steps and details that students need to pay special attention to, such as the usage method of measuring tools before felling trees, the annual ring characteristics of different tree species, etc. The system has collected on-site experimental pictures and schematic diagrams, and these pictures are ingeniously embedded in the corresponding operation links. When students reach a specific step, the system will automatically pop up relevant pictures accompanied by detailed text descriptions, helping students to understand the essentials of the operation more intuitively. This enables students to have a clear understanding of the actual operation before the virtual operation, thus improving the accuracy and safety of the operation.

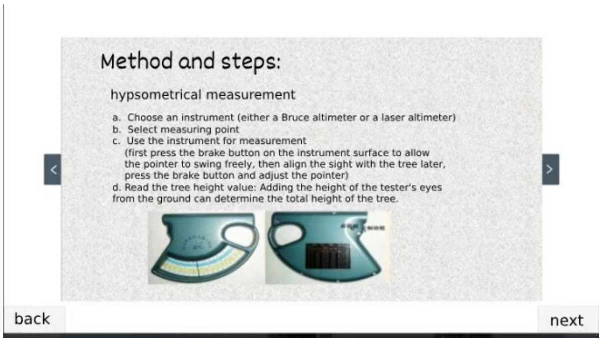

Figure 6: Teaching Guidance Picture.

4. Operation Simulation

The fieldwork part is an important link in the stem analysis experiment, mainly involving operations such as the selection of standard trees, the measurement of pre-felling indexes of sample trees, and the felling of analysis trees. In this system, the real forest farm environment is simulated through virtual

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reality technology, enabling students to complete the whole process of fieldwork operations in a virtual environment.

Based on the field forest farm, in order to create a better sense of immersion, we have created a character model. The main camera follows the target, and the character's movement can be controlled via the keyboard.

After the user selects the analysis tree, they can trigger the felling operation through the interactive interface. The system will simulate the process of the tree being felled and display the process of the tree falling through animation effects. During the felling process, the system will monitor the user's operation behavior in real-time to ensure that the user operates according to the correct steps.

After the tree is felled, the user needs to perform the operation of cutting discs. The system will provide detailed step-by-step prompts to guide the user on how to cut the discs correctly. The user needs to select the appropriate tools according to the prompts and perform the cutting operation on the tree. The system will provide real-time feedback on each step of the user's operation to ensure that the user can complete the disc cutting operation correctly.

The office work part is a crucial link in the stem analysis experiment, mainly involving laboratory operations on the analysis trees, including determining the age of the analysis trees, dividing the age classes, measuring the diameter of each age class, determining the tree height of each age class, determining the bottom height of the treetop, calculating the volume and various growth amounts, etc. In the office work part of the system, we have simulated the real laboratory environment through virtual reality technology, allowing students to complete the whole process of office work operations in a virtual environment. The following will introduce in detail each link and its functions of the design and implementation of the office work.

Age determination is the first step of office work operations, aiming to determine the age of the analysis tree and provide basic data for subsequent growth amount analysis. After the user enters the office work operation module, they first need to select a polishing tool to polish the disc. The system will pop up a toolbar, and the user needs to select the correct polishing tool from the toolbar. If the user makes a wrong selection, the system will prompt that the selection is wrong and no points will be awarded until the user selects the correct tool to proceed to the next operation. After the user selects the correct polishing tool, the system will play a polishing animation effect to simulate the polishing process in actual operation. After the polishing is completed, the annual rings of the disc are clearly visible, preparing for the subsequent age determination. Next, the system will pop up an annual ring number input box, and the user needs to enter the counted number of annual rings in the input box. The system will make a judgment based on the number of annual rings entered by the user. If the user enters the correct number for the first time, 2 points will be awarded; otherwise, the system will directly display the correct answer and no points will be awarded. The operation training interface for age determination is shown in *Figure 7*.

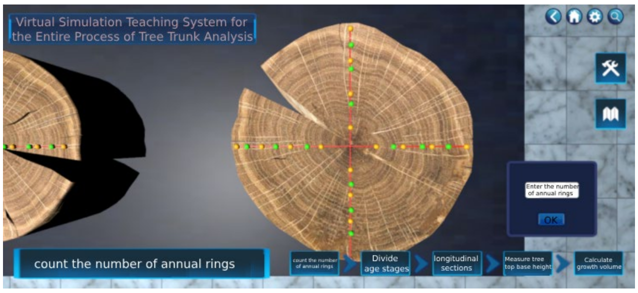

Figure 7: Determination of Age.

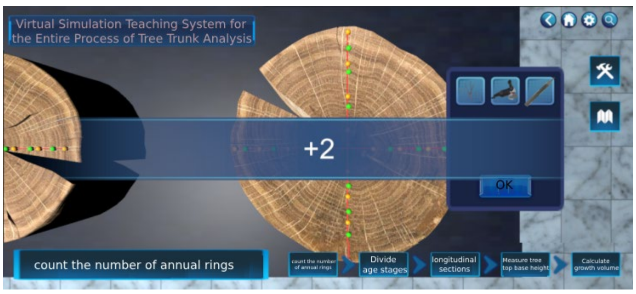

Figure 8: Division of Age Classes.

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Age class division is to divide the growth process of the tree into different age classes on the basis of determining the age of the analysis tree, so as to analyze the growth law of the tree more meticulously. After the age determination is completed, the system will prompt the user to perform age class division. The user needs to select the number of years for age class division in the popped-up selection box, such as 3 years, 5 years, 10 years, etc. Only when the user selects the correct number of years for age class division will the system award 2 points; otherwise, no points will be awarded and the answer will be automatically checked. After the user selects the correct number of years for age class division, the system will pop up a toolbar, and the user needs to select a nail from the toolbar. After selecting the correct tool, the user needs to mark a dot and place a nail at the position of every five annual rings on the disc. After all the dots are placed, the system will display "Placement completed" and award 2 points. The relevant operation training interface is shown in *Figure 8*.

Recording the height of the cross-section is an important step in determining the height of each cross-section of the analysis tree, providing data support for subsequent growth amount calculations. The user needs to determine the height of the cross-section of the disc according to the display of the coordinate axis. After selecting the disc, the user needs to fill in the corresponding height of the cross-section in the input box. After clicking the "Save" button, the data of the disc will be saved to the file. After clicking the "Display" button, the enlarged picture of the disc will be shown on the left side. The user can click the "Magnifying Glass" button and hover the mouse over the picture on the right side to zoom in and view the picture and the coordinate display, so as to input the height of the cross-section more accurately.

Calculating the volume and various growth amounts is the core link of office work operations. By calculating the volume and growth amounts of the tree, the growth law and growth potential of the tree can be analyzed. The user needs to calculate the relevant values of the tree's growth according to the given age and total growth amount. After entering the interface, the system will display a table, which contains many input boxes. The user needs to calculate the data of the corresponding column and corresponding age and fill them into the input boxes. After the user fills in the data, the system will store the data in the document and compare the filled data with the standard answer. If the score difference is within a certain range, it is considered correct. Finally, the score will be calculated by multiplying the ratio of the number of correct data to the total number of input boxes by the total score of this part.

5. Scoring Mechanism

Figure 9: Score Interface.

In the virtual simulation teaching system for stem analysis, the application of the scoring mechanism can monitor users' learning processes in real time, accurately determine their degree of knowledge mastery, and help users conduct self-assessment of their learning outcomes. The scoring mechanism quantifies the learning achievements, making users' learning goals clearer and stimulating their motivation to learn. In the virtual simulation environment, users can try multiple times, and the system will give corresponding scores according to the standardization and completion degree of their operations, urging students to continuously optimize their operations until they master the correct methods. This instant feedback and motivation can effectively enhance students' learning enthusiasm and participation, strengthen their practical abilities and problem-solving skills, and enable them to make targeted improvements. *Figure 9* shows the score results of various parts given by the system according to users' operations after the completion of the whole process of the simulation experiment.

The scores obtained by users' operations are calculated by the following formula:

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$$G = G_1 + G_2 + G_3 \tag{1}$$

$$G_1 = 0.15 * \left(G_{\text{Selection and Pre-felling Work}} + G_{\text{Selection, Numbering and Processing}}\right) \tag{2}$$

$$G_2 = 0.10 * G_{\text{Felling and Measurement}} \tag{3}$$

$$G_3 = 0.40 * G_{\text{Office-based Analysis}} + 0.20 * G_{\text{Growth Pattern Analysis}} \tag{4}$$

6. Investigation Result

This system invited 57 college students to conduct a practicality test to evaluate the effectiveness of the system in the teaching of stem analysis. Since the system mainly simulates the stem analysis experiment, a sample survey was mainly conducted among students majoring in forestry and related personnel. The test mainly focused on students' mastery of knowledge and overall satisfaction with the system. We adopted the survey method of inviting the testers to use the software, and then conducting a questionnaire survey and interviews after completing the experiment. The results are shown in *Figure 10*.

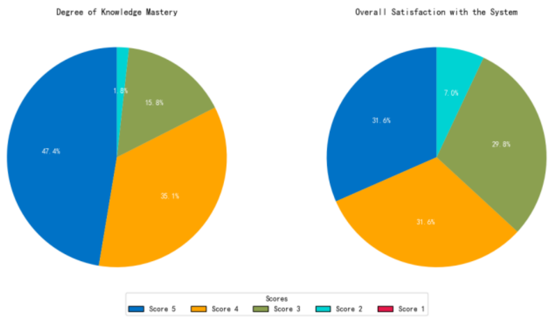

Figure 10: Investigation Result.

According to the test results, approximately 92.5% of the testers believed that by using this system, they had a good grasp of the relevant knowledge of the whole process of stem analysis, had a deep impression of the specific operations, and achieved their learning objectives. In terms of overall satisfaction with the system, about 63.2% of the testers thought that the system had a good simulation effect and smooth operation, and gave feedback with a score of more than 4. Although the remaining testers gave a rating of 3 or below, they generally believed that the system performed well in simulating the real experimental environment and providing detailed teaching guidance, but there was still room for improvement in the handling of some details and the convenience of operation.

Through an in-depth analysis of the test results, we found that most of the testers had a deeper understanding of the relevant knowledge of the stem analysis experiment and became more proficient in mastering the experimental operations after using this system. They believed that through the simulated operations of the system, they were able to conduct practical operations in a safe and risk-free environment, which deepened their understanding of the experimental principles and operation steps. At the same time, the scoring mechanism of the system also gave them a clearer understanding of their learning achievements and motivated them to strive for higher scores.

In addition, the testers also highly praised the diversified guidance methods of this system. They believed that the combination of various guidance methods such as videos, pictures, and pop-up windows made the learning process more vivid and interesting, and was more likely to attract their attention. This diversified guidance method not only helped them better understand the experimental principles and operation steps, but also improved their learning interest and participation. However, some testers also put forward some improvement suggestions, such as optimizing the user interface and increasing the richness and diversity of the experimental content.

The above tests show that this system has certain practicality in the virtual simulation teaching of stem analysis. By simulating the real experimental environment, providing detailed teaching guidance, and applying the scoring mechanism and other methods, this system has effectively enhanced students' learning interest and practical ability. Therefore, the author believes that this virtual simulation teaching method can indeed be used as an effective means for conducting stem analysis experiments.

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7. Summary and Prospect

In this paper, aiming at the problems in the teaching and training of forestry discipline, a virtual simulation teaching system for the whole process of stem analysis has been developed. By simulating the real forest farm and laboratory environments, it comprehensively mimics the field and office operations, enabling students to master the whole process of stem analysis in a virtual environment. The survey shows that the system has a good teaching effect in the teaching of stem analysis, providing strong support for the application of virtual simulation technology in forestry education. However, the system also has some shortcomings. For example, some testers have proposed issues such as the optimization of the user interface and the richness of experimental content, which need to be addressed in the subsequent system optimization. In the future, the system will be further optimized, the experimental content will be enriched, and the application scenarios will be expanded to provide more comprehensive support for forestry education.

In addition, with the continuous development of virtual reality technology, more innovative teaching models can be explored in the future. For instance, by combining augmented reality (AR) technology, seamless switching between virtual and real worlds can be achieved, allowing students to learn with the help of virtual simulation even in actual forest areas. Or mobile virtual simulation applications can be developed to facilitate students to learn and practice anytime and anywhere. It is believed that virtual simulation technology will have a broader application space in the field of forestry education in the future, providing a strong guarantee for cultivating more professionals who meet the needs of modern forestry.

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