Simulation of Rural Digital Landscape Design Based on Virtual Reality

Qing Zhou[1] and Shi Zhang[2]

[1]Faculty of Urban Design, Shanghai Art & Design Academy, Shanghai 201808, China, zhouqing@sada.edu.cn
[2]School of Media and Animation, LuXun Academy of Fine Arts, Liaoning 116650, China, zhangshichenfeng@163.com

Corresponding author: Qing Zhou, zhouqing@sada.edu.cn

Abstract. As a part of digital city construction, rural digital landscape design is the core platform of rural digital construction plans. The optimization of digital landscape simulation results can effectively improve the quality of landscape design and planning. This article first takes rural digital landscape design as the prototype and uses 3D simulation technology to establish a rural 3D model based on virtual reality technology. Then, using the VR Platform development platform and SQL server backend database connection, as well as the combination of virtual architecture and real scene shooting, a real-time 3D virtual rural digital landscape was designed and achieved functions such as autonomous roaming, automatic path roaming, eagle eye bird's-eye view, and building query. Finally, by updating the pheromone matrix to calculate the threshold of fuzzy details on each scale of landscape design, and the detected image has complete and prominent blurry details. The accuracy of region annotation is high, and the improved scene optimization technology improves the system operation efficiency. Real time operation on a regular PC is also stable and smooth.

Keywords: Rural Digitization; Landscape Design; Simulation Design; Virtual Reality
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1 INTRODUCTION

Since the formal introduction of the concept of virtual reality in the 1980s, computer simulation of virtual worlds has been used to provide users with immersive visual, auditory, and tactile sensory simulation technology. Due to its characteristics of perception, immersion, interactivity, and conceptualization. Rural digital landscape design has emerged with the development of the Internet, virtual reality technology, network virtual communities, etc. It is a product of simulating three-dimensional landscapes and rural digitization based on real landscapes. As a part of the digital city construction, the rural digital landscape virtual roaming system is the core platform of the digital campus construction plan. In the absence of noise interference in 3D images, conventional 3D image detection methods provide ideal blurry details. However, in general, actual 3D images are mixed with noise, and both noise and blurry details of 3D images exhibit gradient mutation in the spatial domain. In this case, classical operators are difficult to accurately extract blurry details of 3D images. Therefore, it is necessary to filter out noise in 3D images, label blurry areas, and improve landscape simulation and visual effects. This process increases computational complexity while also smoothing out blurry details of low signal-to-noise ratio images. Blutea [1] analyzed the observations of digital immersive landscape design. How to carry out digital landscape design has always been a controversial point. It advocates for data quality collection and digital site improvement in a virtual environment. The network construction of the project was completed through the use of digital technology. Chang [2] adopted theory as the conceptual framework for his research and developed a cutting-edge CAD monitoring system. This system analyzes the existing rural resource management and land use policies. CAD can be used to create site planning drawings, including floor plans, elevations, sections, etc. in landscape design schemes. The drawings drawn through CAD can more intuitively display the design scheme, facilitating communication and discussion with customers. Du [3] explored the application of CAD in landscape design. In landscape design schemes, it is often necessary to deepen the design scheme, add details and local effects. CAD can help designers better express their design intentions and quickly produce detailed drawings such as floor plans, elevations, and sections.

The innovation of this article lies in the fact that the development of most virtual simulation systems only achieves the basic functions of 3D space tourism and human-computer interaction, without the disadvantage of real physical environment changes. This article innovatively uses the VR Platform development engine to achieve changes in the real physical environment. Each core module is relatively independent and can work together, with good flexibility. Developers can change the components of any module or add new components to the module at any time without disrupting the overall structure of the system.

The main structure of this article is as follows: Chapter 1 Research Background. Explain the research background and significance of this topic, as well as the main research content of the paper. Chapter 2 provides an overview of the current research status of this article, mainly involving virtual reality technology and its application in landscape design. Chapter 3 Relevant Technical Analysis. Introduced the development platform and technology related to the research in this article, including the introduction and characteristics of the development platform, the general process of mobile platform development, and the development environment of the VR platform. And introduced the tools involved in 3D virtual landscape production, including modeling tools, vegetation creation tools, script programming tools, etc. Chapter 4 System Testing and Simulation. Firstly, the testing method was described, and then the testing process and results of the system were introduced. The simulation design results were analyzed and summarized. The research results indicate that applying virtual reality interfaces to rural digital landscape design can change the traditional landscape design based solely on text and graphics, making it more convenient to query and access information through computer networks.

2 STATE OF THE ART

Virtual reality technology has a significant impact on the process of landscape architecture design and designer decision-making, enhancing designers' imagination and creativity, and improving design quality and efficiency. The design scheme can be presented in a virtual space, allowing customers or other stakeholders to have a more intuitive understanding of the design scheme. It can simulate real scenes and environments to immerse customers or other stakeholders more. George et al. [4] attempted to quantify the spatial impact of virtual reality on tree distribution in planting design tasks. It uses traditional analog hand drawing technology as well as VR digital technology. Teaching structure refers to various links and steps in the teaching process, including teaching objectives, teaching content, teaching methods, teaching evaluation, and other aspects. In traditional teaching structures, teaching content and methods are fixed, and teachers teach based on these content and methods. CAD design refers to the use of computer-aided design software for architectural design and drawing. Hsu and Ou [5] attempted to combine teaching structures with learning models based on CAD design. It has actually realized the innovative practice of parameterized auxiliary design and application in sustainable landscape architecture education. 3D geographic visualization in landscape design can be used to evaluate efforts to reduce carbon dioxide emissions. CAD3D can be used for farmland planning, including farmland regional planning, crop planting planning, etc. Through the visualization function of CAD3D, designers can better express their design intentions and integrate them with agricultural production. The integration of augmented reality and drones enables the visualization of past and future landscapes from an aerial perspective. Kikuchi et al. [6] constructed a 3D model of urban sustainable development. A 3D virtual model of outdoor augmented reality has been developed through the digital twin of visualized cities. This system can measure the occlusion processing of the original system. It has developed an internet-based architecture to integrate reality and drone systems. Lin et al. [7] used virtual reality technology to simulate different restoration landscape design schemes, such as landscape vegetation restoration, mountain restoration, water restoration, etc., and evaluated their impact on visual aesthetics. By utilizing virtual reality technology, visual evaluation of restored landscapes can be conducted, including analysis and evaluation of the colors, textures, forms, and other aspects of the landscape. Lin et al. [8] used virtual reality technology to visually compare different restoration landscape schemes. These assessments can help designers better understand the effectiveness of landscape restoration, thereby enabling better design and improvement. Mao and Wenyan [9] proposed specific design ideas for rural revitalization and leisure agricultural tourism with rich ecological resources and agricultural culture. Paul et al. [10] analyzed the ecosystem governance function of cultural landscapes. In order to better analyze the landscape scale analysis of drainage ditches, it analyzed the results of digital elevation model, and adopted a unique method to backfill ditches in the current digital elevation model to reproduce the prehistoric landscape. The results indicate that the use of CAD virtual landscapes in ecosystem management can help planners make more informed decisions. Tzima et al. [11] proposed a hybrid image recognition technology for AR applications and its evaluation in outdoor environments. Against the backdrop of rural revitalization in China. Wang et al. [12] conducted aesthetic processing of visualization frameworks and utilized computer color mapping for data processing. Wu et al. [13] developed a landscape architecture protection virtual system based on vision, sound, and smell using immersive virtual reality technology based on multi-sensory spherical videos. The use of immersive virtual reality technology based on multi-sensory spherical videos in landscape architecture protection courses can effectively improve students' academic performance. Wu et al. [14] constructed a landscape architecture learning system using an easily accessible interactive video immersion virtual reality method. And its effectiveness was tested and analyzed. The results showed that the experimental group had good effects in learning attitude and self-regulation. Yu et al. [15] analyzed the integrated planning of three-dimensional rural geographic information. Through the development of 3D participatory GIS of virtual globe, it analyzes the spatial planning process of public participation. It discussed landscape design under rural planning and interacted with different data management. Zhang and Deng [16] created more realistic and detailed 3D modeling and rendering models, and presented them in virtual reality to better showcase design solutions. This model performs collision detection between geometric objects in drawings to assist in discovering and solving design problems, while supporting multi person collaboration to achieve team design and discussion.

3 METHODOLOGY

3.1 Principles of Landscape Image Visual Effect Optimization System

To optimize the visual effect of digital landscape images, it is first necessary to label the blurred areas in the landscape image. The following describes the labeling principle. The annotation of blurry areas in the image requires wavelet transform on the digital landscape image, setting a small threshold to obtain the 3D coarse blurry details of the landscape image. 3D Facet fitting is performed one by one for the 3D coarse blurry details of the landscape image, obtaining the actual blurry fine nodes of the landscape image, and accurately locating the blurry details of the landscape image. The coarse positioning process of wavelet transform reduces the number of voxel points for 3D Facet fitting of the landscape image, Accelerated the speed of labeling blurry areas in images. Using the 3D neighborhood restoration of the current voxel in the landscape image to fit the ternary cubic polynomial for the current image gradient, i.e

$$f(x,y,z)=k_1+k_2x+k_3y+k_4z+... \tag{1}$$

Among them, x, y, and z respectively describe the coordinates of landscape image voxels in the length, width, and height directions. Based on their neighboring volume data, the least squares method is used to fit the above equation, and the undetermined coefficients k0, k1,..., k20 are obtained by solving. In three-dimensional indoor spaces, the direction of the vector can be determined by angles a and β Describe and use the following equation to represent the voxel coordinates of the landscape space

$$\begin{cases} x = p\sin\beta\cos\alpha \\ y = p\sin\beta\sin\alpha \\ z = p\cos\beta \end{cases} \tag{2}$$

Among them, P represents the length of the landscape image vector, which is the distance from the neighboring voxel points of the landscape image to the current center point. Taking equation (2) into equation (1) for differentiation can obtain the gradient modulus and gradient direction

$$f'_{\alpha,\beta}=\sqrt{k_2^2+k_3^2+k_4^2} \tag{3}$$

Based on the derivative calculated from the above equation, the following judgment criteria are used to determine whether the current landscape image point is a fuzzy fine node:

1) Calculate the gradient modulus value f 'a. of digital landscape images, (When f 'ɑ . B≤ T, it is considered as image noise.

2) When f'aB<0 is less than zero, it indicates that the second derivative of the defined landscape image fuzzy minutiae along the gradient direction is a negative slope at the zero intersection.

3) When f '..s-0, the estimated value lpeof pe obtained by solving should be less than the half voxel of the image.

Assuming that the current processing of 3D landscape image voxels meets the above conditions, it can be determined as fuzzy detail voxels, and its accurate position can be determined using the following equation

$$\begin{cases} x_e = x_i + p_e\sin\beta\cos\alpha \\ y_e = y_i + p_e\sin\beta\sin\alpha \\ z_e = z_i + p_e\cos\beta \end{cases} \tag{4}$$

Among them, x, y, and z represent the estimated coordinates of fuzzy fine nodes in 3D landscape images, while x, y, and z represent the voxel integer coordinates of fuzzy fine nodes in 3D landscape images, respectively. The wavelet transform modulus maxima method can be used to extract the fuzzy details of the coarser 3D landscape image, define the partial derivative of the three direction wavelet functions p (x, y, z) to x, y, z, and use Gaussian function as the smooth function, that is

$$\theta(x,y,z)=\exp\left(-\left(x^2+y^2+z^2\right)/2\right) \tag{5}$$

Using the following equation to represent the 3D wavelet transform of 3D landscape images

$$W_k f(x,y,z)=f(x,y,z)*\varphi_k(x,y,z) \tag{6}$$

Among them, * represents the convolutional form of landscape images, k represents wavelet transform coefficients, f (x, y, z) represents discrete wavelet transform, y (x, y, z) represents three directional wavelets, and the landscape image wavelet transform modulus is represented by the following equation

$$\mathrm{M}f\left(x,y,z\right)=\sqrt{\sum_{k}^{3}\left(W_{k}f\left(x,y,z\right)\right)^{2}} \tag{7}$$

The virtual reality technology of 3D building model is generally realized by adjusting the texture granularity through the fixed geometric modeling of the scale conclusion viewpoint. For complex models, especially large experimental instruments and special laboratory buildings, significant distortion can occur at large scales. For this reason, this paper designs a method for dynamic adjustment of both geometric modeling and texture detail, which dynamically changes the geometric modeling according to the viewpoint distance and scale. At the same time, it implements multi-level of detail loading and rendering of texture based on quadtree index, and realizes the consistent expression of geometric modeling hierarchy and texture hierarchy. Its principle is shown in Figure 1.

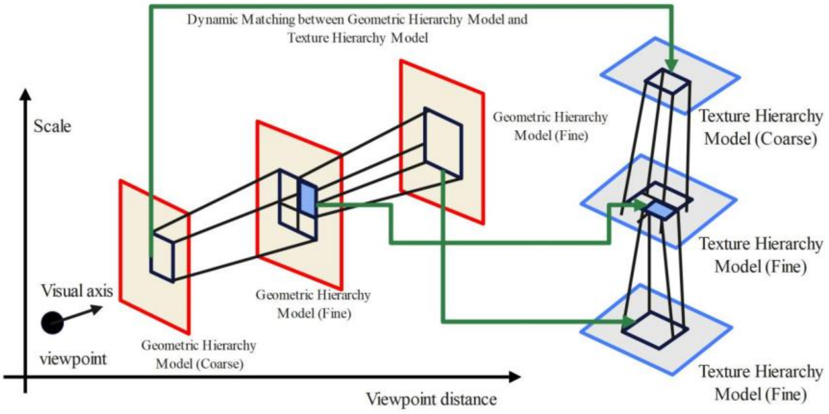

Figure 1: Dynamic matching principle of geometric modeling and texture granularity.

3.2 Obtaining Blurry Details at Various Scales of Landscape Images

The exponential smoothing filter with linear minimum mean square error is used to detect blurry details in digital landscape images. In the case of 1-dimensional images, the filter expression is as follows

$$\mu(\varepsilon)=A\exp[-\delta(\varepsilon)] \tag{8}$$

Where s=1, N. N represents the length of the landscape image signal, 8 (6) is used to describe the filtering coefficient, A represents the normalization coefficient, and its corresponding discrete form can be described using the following equation

$$\mu(\varepsilon)=1/(1+b)\mu_{1}(\varepsilon)+b/(1+b)\mu_{2}(\varepsilon-1) \tag{9}$$

In the equation, u (é) represents a causal filter, uz (E) represents a non-causal filter, and a and b represent the coefficients in the filter.

Perform ROEWA filtering on the digital landscape image R (x, y, z), use a one-dimensional smoothing filter u (y) to filter the elements of each row in the three-dimensional landscape image, and then use L (s) and uz (s) to further filter each row of the image to obtain the intensity of blurred details in the horizontal direction of the image. It can be divided into causal part T and non-causal part:

$$\begin{cases} \hat{\eta}_{\varepsilon 1}(x,y,z) = \mu_1(\varepsilon) * \mu(y).R(x,y,z) \\ \hat{\eta}_{\varepsilon 2}(x,y,z) = \mu_2(\varepsilon) * \mu(y).R(x,y,z) \end{cases} \tag{10}$$

In the formula, · represents the convolution in the vertical direction of the image, which can obtain the blurry detail intensity r xmar (x, y, z) in the horizontal direction of the landscape image. Similarly, the intensity r, ma (x, y, z) in the vertical direction of the landscape image can be obtained. Combining the above information, the blurry detail intensity amplitude of the entire digital landscape image can be obtained:

$$|r_{\max}(x,y,x)| = \sqrt{r_{x\max}^2(x,y,z) + r_{y\max}^2(x,y,z)} \tag{11}$$

Once the blurred detail direction of the landscape 3D image is determined. The gradient directions of blurry details in landscape 3D images can be divided into four types, namely horizontal, vertical, and diagonal directions.

3.3 Fuzzy Region Labeling of Landscape Images Based on Chaotic Ant Colony Algorithm

Chaotic ant colony algorithm is an optimization algorithm based on swarm intelligence, which can be used to label fuzzy regions in images. It randomly generates some initial solutions as the population of the chaotic ant colony algorithm. The solution in each population is evaluated for fitness, and the solution with high fitness is selected as the optimal solution. According to the requirements of the problem, the concentration and update frequency of pheromone are determined. The structure of the rural landscape 3D digital platform designed in this article is shown in Figure 2.

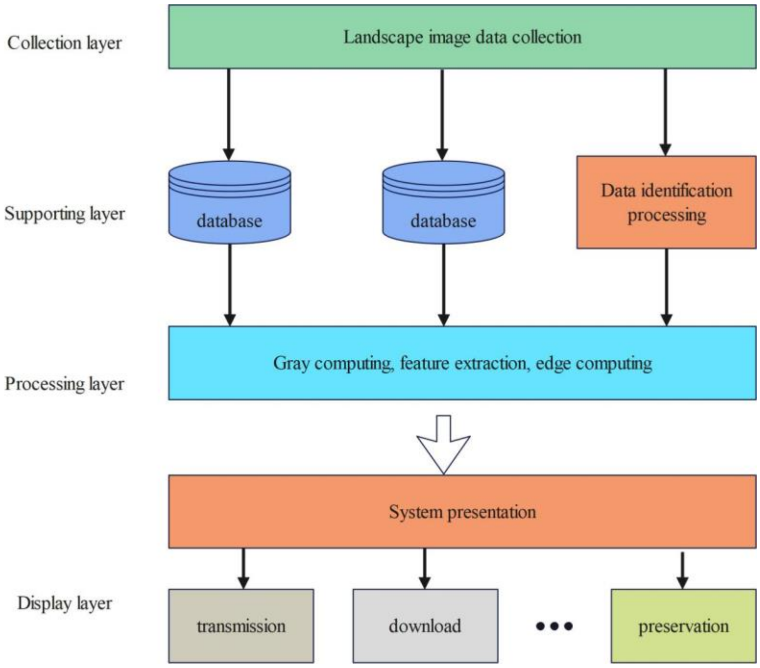

Figure 2: Schematic diagram of the three-dimensional digital platform structure for landscape architecture.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Comparison of Effects of Different Image Visual Optimization Methods

Using VC++6.0 as the experimental platform. As shown in Figure 3, adding Gaussian noise with a per capita value of 0 and a variance of 0.010 to the original digital landscape image constitutes the corresponding noise image. Now, a comparative experiment is conducted on the visual optimization of digital landscape images using the traditional Sobel operator and the fuzzy region annotation method using Roberts operator, as well as the method proposed in this paper, on an image containing Gaussian noise.

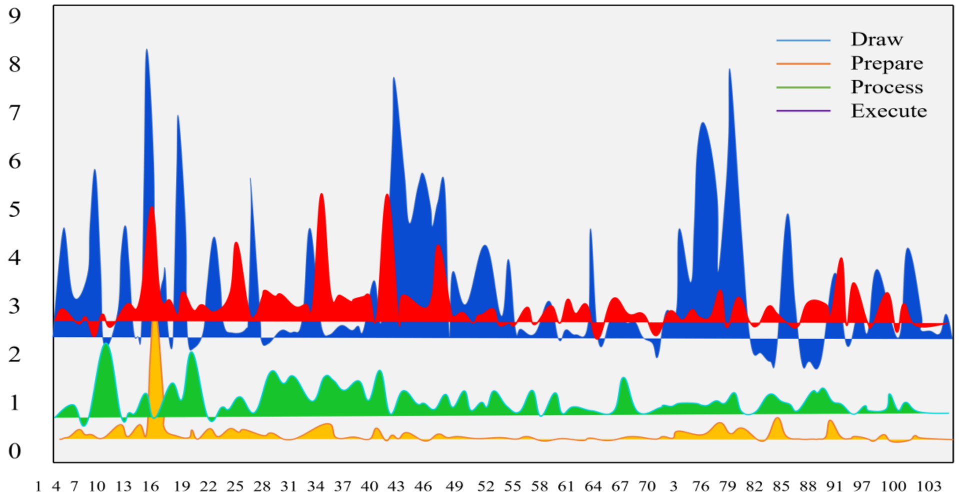

Figure 3: Experimental results of image frame loss rate.

Analyzing the results of Figure 3, it can be concluded that the three-dimensional digital platform for landscape architecture designed in this article has a low frame loss rate and can effectively maintain the clarity of three-dimensional images; Analyzing the results of Figure 3, it is found that the designed three-dimensional digital platform system for landscape architecture has a lower packet loss rate, indicating that the three-dimensional images displayed on the platform designed in this article are more stable. From Figure 3, it can be seen that the Roberts operator used to detect landscape images is prone to missed fuzzy details, and its suppression effect on noise is not significant. As the Roberts operator is not sensitive to landscape image noise, many of the noise is mistakenly labeled as fuzzy areas, resulting in too many pseudo fuzzy details. From Figure 3, it can be seen that using the Sobel operator to detect blurry details in landscape images is not continuous enough, but it can suppress noise in landscape images. Compared to what can be seen, in Figure 3, the image blurry details detected using the method proposed in this paper are continuous and complete, and the detail information is preserved.

Finally, 80 noisy landscape images were selected for the experiment and visually optimized using both traditional and proposed methods. The experimental results are shown in Figure 4. During the experiment, the optimization accuracy of traditional methods remained low as the number of images increased. The highest point was in the 10th image, with a labeling accuracy of 39%. In contrast, the region labeling accuracy of the proposed method remained between 80% and 90%, The accuracy meets the practical application requirements, indicating that the method has good performance in use.

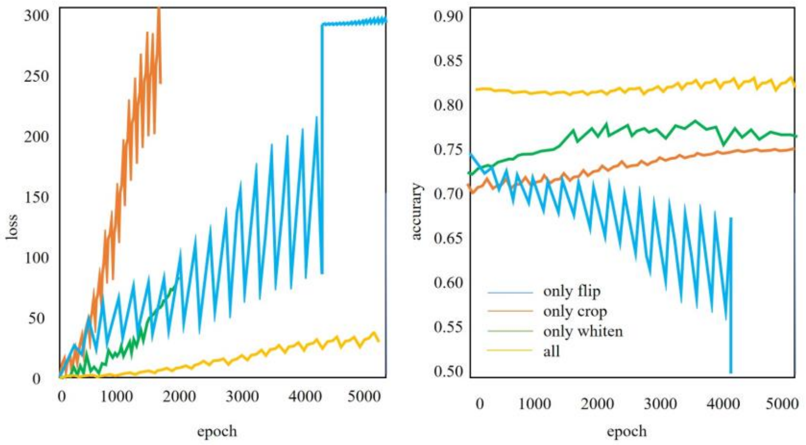

Figure 4: Comparison of image visual optimization accuracy by different methods.

To verify the overall effectiveness of landscape prediction methods based on virtual reality technology, an experiment is required. The experimental platform was built on Mat Lab2017, and the experimental data was sourced from rural landscapes. Utilize key steps such as soil layer merging, mapping, and transformation to obtain relevant data for landscape transformation, in order to verify the effectiveness of the proposed method. The experiment verifies the proposed method in terms of prediction accuracy and prediction efficiency. The experimental results are shown in Figure 5.

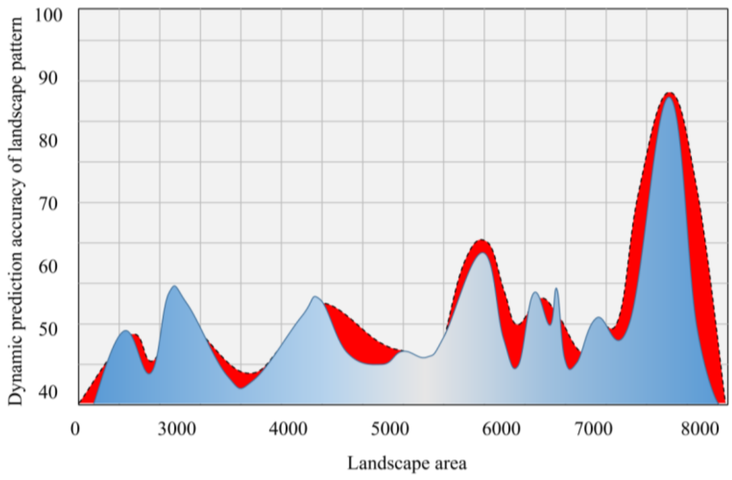

Figure 5: Prediction accuracy of landscape area based on moving spline method.

Analyzing Figure 5, the prediction accuracy of the landscape area prediction method based on the moving spline method is in an extremely unstable state, with significant overall fluctuations. The overall prediction accuracy of the dynamic degree and plane center of gravity landscape area prediction method is relatively low, with a maximum of no more than 63%. The prediction accuracy curve of rural landscape prediction method based on virtual reality is stable, although there are slight fluctuations, the minimum prediction accuracy is not less than 90%. According to the comparison of the three methods, it can be seen that the rural landscape area prediction method based on virtual reality technology is more feasible. The landscape area prediction method based on the number of virtual reality transfers shows a clear upward trend in the prediction time curve, with an average time consumption of 9.6 hours. The rural landscape area prediction method based on virtual reality takes an average of 3.2 hours to predict. The main reason for this result is that the rural landscape area prediction method based on virtual reality introduces an acceleration factor in the prediction process, which can improve the overall efficiency of the prediction.

4.2 Experimental Simulation and Analysis

The algorithm in this article runs on a 3.10 GHz quad core CPU and 4 GB memory environment. Figure 6 shows the simulation results and final rendering of the rural digital landscape model under the control of simple and complex geometric contours. Figure 6 shows the rendering of the plant contour model under the control of simple and complex geometric contours, respectively. Among them, generating the model in Figure 6 takes 3 minutes and 19 seconds. Figure 6 shows the effect of the tree model generated by applying the fractal algorithm, which is generated by manually adjusting the branches represented by the curve for the user. It is the effect of the tree model obtained by applying the algorithm in this paper and controlling the crown contour. The difference between this algorithm and the literature is that it focuses on the simulation method of rural landscape under fixed conditions, while the main difference between this algorithm and the literature is that the computer automatically generates the landscape structure, which saves the workload of user interaction and saves time and cost. Comparing the real landscape effect with the simulation effect generated by applying the algorithm in this article, it can be seen that the two have a significant degree of similarity. The experimental results indicate that the algorithm proposed in this paper is effective in simulating garden landscape plants.

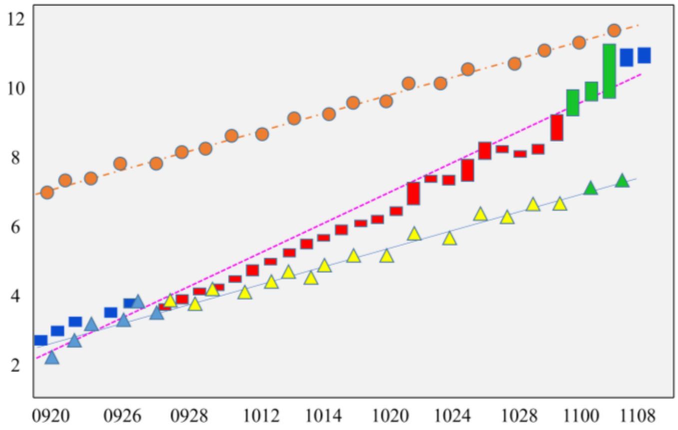

Figure 6: Comparison of Simulation Results.

As shown in Figure 6, for the interactive response settings of virtual campuses, a GUI window is usually created in the advanced interface of the VRP editor first, and then attributes such as style and size are set according to the actual situation. Next, import the radio box into the window, set its display content, mouse color, and distribute the structure layout. Finally, write script triggering functions for each mouse event in the radio box.

When using the alloc method to create an object, the hold count is automatically set to increase when you send a retain message to an object. On the contrary, when you send a release message like an object, the hold count value will decrease. When the holding count of an object becomes 0, the object will release the memory it has occupied. The state of each object instance is saved in a different memory area. Therefore, the creation and deletion actions of an object are equivalent to the allocation and recycling of the memory it occupies. There is a testing tool specifically designed to analyze virtual reality in the UDK Unreal Engine, and this game thread analysis can also be used in conjunction with mobile devices. Including gameplay analyzer and statistical data viewer. These analysis files will be used to analyze and view potential issues with the system, as shown in Figure 7 for the test results of the UDK testing tool.

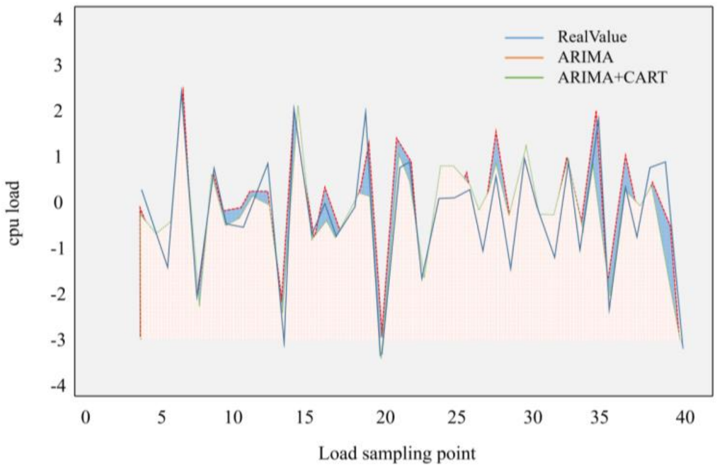

Figure 7: Comparison of CPU load prediction results.

According to the requirement analysis in Figure 7, the functions that the 3D virtual landscape system needs to achieve are: Users can use this system smoothly, and there is no obvious pause when switching between UI buttons. Users can smoothly use the roaming function in three modes. Users can view from the system's set viewpoint and operate smoothly. Users can customize the system's environment and adjust the tab parameters in the atmospheric environment and light source settings module to reflect the system's scene in real time. Users can set the overall parameters of the system based on the hardware conditions and personal preferences of their mobile devices to achieve the best usage effect. During the user's use of the system, the system can automatically control the usage rate of mobile intelligent devices such as GPU, CPU, and memory, and can self-optimize. Strengthen the stability of system operation.

5 CONCLUSION

This article focuses on the development of a rural digital landscape system based on virtual reality. Virtual simulation systems require efficient hardware support, and landscape virtual systems used on PC platforms have quite strict requirements for PC hardware configuration. Given the current hardware, CPU, and GPU conditions of mobile devices, many developers have not explored developing virtual landscape simulation systems from mobile devices. This system focuses on performance, optimization, and strict control of mobile device CPU and GPU. Explored a series of mobile device virtual landscape system development processes. Reality, interaction, and contextualization are the unique charm of virtual reality technology. This study explores, designs, and implements a virtual rural digital landscape environment based on virtual reality and 3D visualization. Users can immerse, interact, and imagine in this environment. This article designs a three-dimensional digital platform system for rural digital landscapes, which uses discrete elevation calculation to preserve the frame of images. It can obtain images with certain stability, optimize the calculation of edge correlation, ensure the stability of edge operators and grayscale gradients, and fundamentally solve the problem of 3D image shaking. The research in this article can provide a good theoretical basis for the three-dimensional digital platform of rural digital landscape. Digital landscape is a massive system engineering that fully utilizes various information such as basic geography, natural resources, social resources, and cultural resources within the landscape for digital collection and storage of data. Based on this platform, the implementation of its application support system - the construction of three-dimensional visualization virtual rural landscape based on virtual reality - still has a lot of problems to be studied urgently. Therefore, there is still a certain gap between it and the final product level digital landscape.

Qing Zhou, https://orcid.org/0009-0001-0435-4506
Shi Zhang, https://orcid.org/0000-0002-8608-3956

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