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The Application of Virtual Reality Technology in the Digital Preservation of Cultural Heritage

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Abstract: Virtual reality technology involves computer graphics, artificial intelligence, network, sensor technology and many other aspects. It can use the powerful computing and graphics processing capabilities of computers to provide alternatives to the original and express its visual, tactile, and auditory technical means. According to archaeological research data And documentary records, virtual reconstruction and simulated display of the cultural heritage that has been wiped out. "Digital protection" of cultural heritage is a new way of protection, relying on computer technology, and the use of digital equipment to collect, save, process, output and disseminate the required information, including databases established on computer systems, So as to achieve the purpose of information sharing and dissemination. This article mainly studies the application research of virtual reality technology in the digital preservation of cultural heritage. Create an immersive environment for users, display the objects realistically in the virtual reality system, thereby digitizing the technical protection of cultural heritage; secondly, use the virtual environment model of material cultural protection to build and use the terrain to generate and edit The device imitates the terrain of the natural world to achieve its position and the effect of being in it. Finally, the radial basis function is used to calculate the value in the virtual environment, so that the digital preservation of cultural heritage is more accurate. Experimental data shows that 35.54% and 64.46% of users are more likely to use the handle to interact with three-dimensional objects. They believe that the speed of the handle has changed and the control is more precise. Experimental results show that: The virtual environment reality technology specification is more efficient than the original technology in the process of digitizing cultural heritage.

Keywords: Virtual Reality Technology, Digitization of Cultural Heritage, Virtual Interaction, Virtual Environment Model, Radial Basis Function

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1. Introduction

1.1. Background and Significance

Virtual reality technology is a technology that uses a variety of interface devices such as a computer drawing system and reality control to provide a sense of engagement in a three-dimensional conversational environment generated in a computer [1]. Urban planning, interior decoration design, simulation industry, restoration monument design, bridge and road design, real estate sales, tourism education, water resources protection, electricity, geological disasters, etc. have been widely used to provide practical solutions [2]. Cultural heritage is a precious and non-renewable resource. The trend of economic globalization and accelerating the pace of modernization have brought great changes to China's cultural ecology, and its cultural heritage and living environment are seriously threatened. Many historical and cultural cities (blocks, villages and villages), ancient buildings, ruins and scenery have been destroyed. Due to excessive exploitation and unreasonable use, many important cultural heritages have disappeared or disappeared. In areas where ethnic minorities live in a relatively rich cultural heritage, due to changes in people's living environment and conditions, national or regional cultural characteristics have accelerated their disappearance. Therefore, it is urgent to strengthen the protection of cultural heritage.

The technology that cannot be achieved with existing protection methods provides a better method with the development of virtual reality technology [3]. Among the gradually disappearing cultures, some cultures can continue to live through virtual reality technology. In the virtual space, keep as many special treasures as possible, greatly reducing the number of tourists visiting and reducing the damage to murals and sculptures [4-5]. Some cultural heritage that has disappeared can be used to get a new life. Using virtual reality technology not only can better organize archaeological excavation and research work, but also can use virtual technology to present today's museums without affecting the original cultural heritage institutions. In order to let the audience understand the content of cultural heritage, important trends have also appeared in recent years [6-7].

1.2. Related Work

Maples-Keller J L believes that VR can control the transmission of sensory stimulation by the therapist, which is a convenient and cost-effective treatment method. Sensory information is transmitted through the head-mounted display and dedicated interface devices [8]. These devices track head movements so as to naturally change motion and images with head movements, thereby making people immersive. His discussion focuses on the existing literature on the effectiveness of incorporating VR into the treatment of various psychiatric disorders, especially for exposure interventions based on anxiety disorders. In order to determine the research on the treatment of anxiety or other mental diseases based on VR, a systematic literature search was conducted [9]. Sang Y introduced an interactive truck crane simulation platform based on virtual reality technology, on which the simulation experiment of crane movement can be completed [10]. He discussed the framework and working principle of the interactive truck crane simulation platform, taking the lifting feet and hooks as examples to illustrate the motion control mechanism of truck crane components. Interactive truck crane simulation platform utilizes browser-based structure, Java3D, virtual reality and Java Applet to develop Web3D virtual reality learning environment, which has good advantages [11]. In the past few years, Coburn J Q believes that consumer virtual reality (VR) devices have made some significant advances. Immersive VR experiences have also entered consumer homes, and their cost and space requirements are much lower than the previous generation of VR hardware. These new devices also lower the entry barrier for VR engineering applications. Past research has shown that there are great opportunities for using VR during design tasks, which can improve results and reduce development time. His work reviewed the latest generation of VR hardware and reviewed the research on VR during the design process. In addition, this work extracts the main topics from the comments and discusses how the latest technology and research affect the engineering design process. They concluded that these new devices have the potential to significantly improve some parts of the design process [12].

1.3. Innovation in this Article

The main innovative work of this paper includes the following aspects: (1) This paper proposes a method based on VR three-dimensional scenes to obtain projection presentation data sets in the form of three-dimensional space coordinate transformation and multi-view sampling to solve the problem of model feature construction. (2) Propose and implement a method for interactively acquiring 3D models in VR 3D scenes, and specifically improve the output of traditional 3D models. View output and 3D model output have been improved to dynamically load models in 3D scenes.

2. Virtual Technology Algorithm of Cultural Relics

2.1. Three-Dimensional Construction of Cultural Relics Buildings Based on Virtual Interaction

Conceptual model of virtual reality

The three-dimensional virtual interactive system is a computer-generated virtual environment that gives a variety of sensory stimuli and is an advanced human-computer interactive system [13-14]. According to the definition, virtual reality consists of two parts: one part is the created virtual world (environment), and the other part is the intervene (person). The core of virtual reality is to emphasize the interaction between the two, that is, to reflect the human experience in the virtual world (environment) [15]. In this way, we can get the conceptual model of virtual reality as shown in Figure 1.

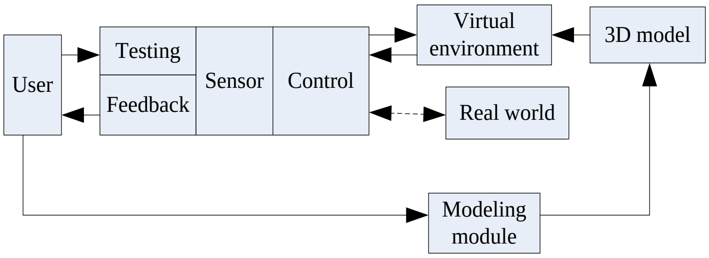

Fig. 1. Conceptual model of virtual reality

A successful three-dimensional virtual interactive system will inevitably create an environment for users to feel immersive [16]. To achieve this effect, it is necessary to realistically display the objects represented in the virtual reality system [17-18]. Not only does it resemble real objects in appearance, but it also requires good performance in terms of form, light and shadow, and texture. To achieve this requirement, the technical implementation can be divided into four steps: the first step is geometric modeling, which mainly establishes the geometric model of the three-dimensional scene; the second step is image modeling, which mainly focuses on the results of geometric modeling Perform material, lighting, color and other processing [19]; the third step is behavior modeling, which mainly deals with the behavior and motion description of objects [20-21]. As shown in Fig. 2.

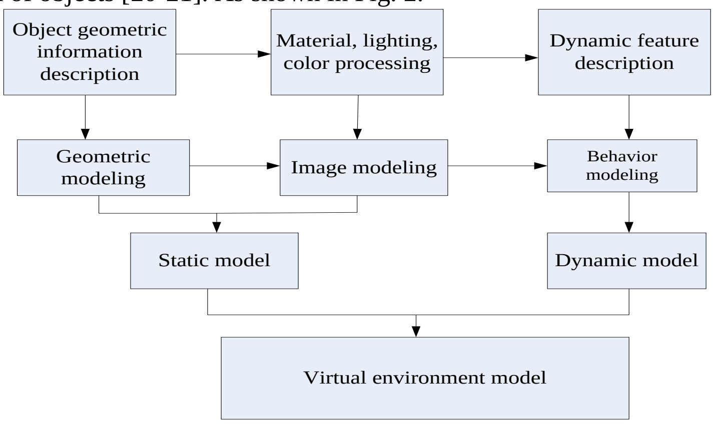

Fig. 2. Flowchart of virtual environment model

Characteristics of cultural relics building and its environment modeling

As an important field of virtual reality research, the virtual realization of architectural heritage protection has aroused great interest of researchers in recent years [22]. Compared with other graphical modeling, cultural relics architecture and its environment modeling have their own characteristics, mainly manifested in the following four aspects:

1) There can be many objects in cultural relic buildings and their environments, and it is often necessary to construct a large number of completely different types of models.

2) Most building components in cultural relics buildings must express the texture of the material surface through elaborate material texture.

3) The three-dimensional construction of the three-dimensional virtual interactive system Chinese building and its environment must be based on accurately reflecting the true spatial scale relationship of the architectural heritage and the texture characteristics of the building materials.

4) Some architectural components in the heritage buildings need to respond to the observer. When the observer interacts with the object, the object must react in some appropriate way and cannot ignore the observer's actions.

These modeling features put special requirements on the virtual environment modeling technology:

1) Reusability. There are many kinds of building components in the virtual environment, and building a model of building components often takes a lot of energy, so it is very necessary to build a standard model library that can be reused.

2) Authenticity and accuracy. The three-dimensional construction of cultural relic buildings and their environments must be based on various surveying and mapping data and historical archives.

3) When modeling, the texture mapping features of the model must be considered, and the form of its mapping coordinate mapping must be considered.

4) During the interaction, the model should provide corresponding prompts so that the interaction can proceed as intended.

Main technical indicators of virtual environment modeling

3D virtual environment modeling is one of the key technologies in virtual reality technology. Whether the model is built or not will directly affect the quality of the entire 3D virtual interactive system [23-24]. Some researchers even say that building a perfect three-dimensional model is more important than a thousand facts [25-26]. At present, many mature computer software can be used to establish virtual environment models, such as: CAD, 3DSMAX, Maya, VRML, etc[27-28]. To establish a good virtual environment should have a detailed understanding of the main technical indicators of modeling. The main technical indicators for evaluating virtual environment modeling are:

1) Precision. It is an index to measure the accuracy of the model to represent real objects.

2) Display speed. Many applications have large restrictions on the display time. In interactive applications, we hope that the shorter the response time, the better. If the response time is too long, it will greatly affect the availability of the system.

3) Manipulation efficiency. In the actual application process, the display of the model, the behavior of the motion model, and the collision detection in the virtual environment with multiple moving objects are all high-frequency operations that must be efficiently implemented.

4) Ease of use. Creating an effective model is a very complicated task. The modeler must represent the geometric and behavioral model of the object as accurately as possible. The modeling technology should construct and develop a good model as easily as possible.

5) Extensiveness. The broadness of modeling technology refers to the range of objects it can represent. Good modeling technology can provide a wide range of geometric modeling and behavior modeling of objects.

6) Real-time display. In a virtual environment, the display of the model must be above a certain limit frame rate, which often requires fast display algorithms and model reduction algorithms.

2.2. Construction of Virtual Environment Model in the Protection of Material Culture

The use of the terrain generation editor has a great advantage in imitating natural terrain, but it also has specific disadvantages [29]. Such restrictions occur in modern cities, small towns, underground palaces, etc. whose scales are beginning to appear, when relatively regular terrain prompts. When using the terrain editor to create terrain, the number of ground maps cannot be large [30-31]. The greater the number of maps selected, the lower the performance of the server. Two to three images are the best choice. In addition, the ground in the city needs a lot of textures. There are more than three highways, pedestrian crossings, lawns, etc. The streets of the city are very neat, and it is not impossible for the terrain generation editor [32-33]. Another important issue is that the ground constructed in this way is particularly space-saving. Necessary skills: The operation of 3ds max software requires proficiency. Of course, you also need to learn some specific lighting and render applications, and the function of making environment maps.

Knowledge points for constructing environment model: The visual area is the area of the scene that the audience can see in the interactive experience with virtual reality [34]. The visual area changes constantly according to the listener's movements, and the scene is divided according to this level [35]. The division of the scene area shows that no matter where the field of view is in the interactive area, the direction of the field of view sometimes only displays hundreds of scenes. If we put the whole scene together, we can interactively get the model of the whole scene to render together. Therefore, the number of models in the scene cannot be too large. Too many models will seriously affect the efficiency and execution speed of the interaction. When this happens, you can use block swapping to change work efficiency. When the scene is enlarged in the block, only the model within the display angle is rendered, and the model that is not completely displayed is not rendered. The optimization of the overall modeling scene can be obtained by transforming it into a square-like area. HDRI high dynamic range images can cover buildings and roads in the environment with a lighting information layer. The size of the HDRI high dynamic image has a decisive influence on the sharpness of the eye shadows in the scene and the atmosphere of the entire scene. In addition, HDRI high dynamic images can not only generate shadows, but also draw conclusions from the perspective of the overlay model. The new inherent color formed by the color of amber and light. The size of a bright HDRI high dynamic image needs to be adjusted according to each model. HDRI high dynamic images cannot exceed 1024 * 1024. The render can be used to render HDRI high dynamic images. With 3ds max, what kind of effect can actually be produced, what kind of result can be obtained in the virtual interactive scene. The rendering time and quality of various renders are completely different, and it takes time to achieve a better rendering effect. The role of optics is to illuminate the scene and give it an atmosphere. The generation of lighting effects is very important for the atmosphere of the scene. In the absence of lighting effects, HDRI high dynamic images are not required. No shadow can be formed, there is no atmosphere, and the entire environment loses the depth of the three-dimensional space. The seamless texture is represented by four azimuth boundaries for each texture. Seamless texture means that even if the random side of this texture is completely merged with the other three sides, no trace of convergence can be seen.

2.3. Radial Basis Point Interpolation Method in Virtual Environment

The radial basis function (RBF) calculates the distance between the node x and the node xi. The radial basis function has a simple structural form, good stability, and has an isotropic point. In numerical calculation and surface it has been widely used in fitting. In particular, it can help numerical calculation in a virtual environment. For two-dimensional plane problems, the stress, strain, and displacement components can be expressed as follows, where L is a differential operator:

$$\varepsilon = Lu \quad (1)$$

For a two-dimensional elastic solid, the law can be used to express its constitutive relationship. Its matrix is as follows

$$\sigma = D\varepsilon \quad (2)$$

In the formula (2), σ and ε are the components of stress and strain, respectively, and D is expressed as the constant matrix of the material. In order to make the weak form of the balance equation easy to operate and solve, we need to describe the problem defined in the problem domain, number the nodes, first solve the interpolation coefficients in the radial basis point interpolation shape function, and then form the population through mathematical derivation. Then, calculate the overall body force vector of all nodes, and finally form the overall governing equation. Through mathematical derivation and transformation, you can get

$$Ku = F \quad (3)$$

In the formula (3), K is the overall stiffness matrix; F is the overall physical force vector. For the overall physical force vector, it can be further expressed as:

$$F = F^b + F^t = \int_{\Omega} \varphi_i b d\Omega + \int_{\Gamma_t} \varphi_i t d\Gamma \quad (4)$$

By solving the system of equations, the displacement of the node can be obtained first, and then the stress and strain of the node can be further obtained by the formula.

3. Virtual Interactive Eye Tracking Experiment

3.1. Experimental Environment Configuration

In this experiment, we used HTC Vive combined with a Glass DK II eye movement module to record the eye movement data of the subjects. The HTC Vive virtual reality helmet integrates the tracking technology and positioning guidance system of the Steam VR platform [36], with a binocular resolution of 1980 * 1080 (monocular 1080 * 1200 resolution), its refresh frequency is 80Hz, and the tracking accuracy reaches 0.08 degree. Computer hardware and software platform: a desktop computer equipped with a GTX1080Ti graphics card, an Intel Core i7-8700K processor, and a DELL LCD monitor. The test procedures for this study were edited by Unity3D software.

3.2. Experimental Procedure

Because each person's eye feature structure is different, in order to ensure the accuracy of the eye movement data, eye movement calibration is required for all subjects before the experiment starts. There is no time limit for the operation of this experiment. According to the needs of the experiment, several indicators as shown in Table 1 were selected to analyze the cognitive state of the subjects.

Table 1. Experimental data analysis indicators

Experimental sequence	Evaluation index	Remarks
Experiment 1, 3, 4	FT (Finish time, s)	Time taken to complete the task
	TtFF (Time to first fixation, s)	The time from the start of the experiment to the first time you are watched
	ACC (Average time needed for a correct click, s)	The average time to complete the task correctly
	AC (Accuracy)	The correct rate selected by all subjects
	VR (Visit ratio, count)	Proportion of points at which objects are fixed

The calculation method of the data analysis indicators in Table 1 is as follows:

(1) Time to complete the task (FT). This parameter is the time required for the subjects to enter the experimental test task and complete all the experimental tasks:

$$FT = t_{end} - t_{begin} \quad (5)$$

In formula (5), t_{end} represents the time stamp of task completion and t_{begin} represents the time stamp of task start.

The time from the beginning of the experiment to the first observation (TtFF). This parameter is the time from the beginning of the experiment to the first time the subject finds the target correctly:

$$TtFF = t_{find} - t_{begin} \quad (6)$$

In formula (6), t_{find} represents the time stamp when the target is found for the first time, and t_{begin} represents the time stamp at the start of the task.

The average time to complete the task correctly (ACC). This parameter represents the average time the subjects correctly choose:

$$ACC = \frac{\sum_{i=1}^{N} t_{rf}}{N} \quad (7)$$

In equation (7), t_{rf} represents the time to complete the task correctly, and N represents the number of subjects who completed the task correctly.

The correct rate (AC) selected by all the test subjects. This parameter represents the proportion of subjects who correctly complete the task under different color mapping schemes:

$$AC = \frac{N_r}{N_{total}} \quad (8)$$

In equation (8), N_r represents the number of subjects who completed the task correctly, and N total represents the number of all subjects.

The fixation ratio (VR). This parameter indicates the proportion of the subject's viewpoint falling on the target object:

$$VR = \frac{C_{object}}{C_{total}} \quad (9)$$

In equation (9), C_{object} represents the number of effective viewpoints falling on the surface of the target object, and C_{total} represents the number of all effective viewpoints.

3.3. Data Collection

In this experiment, a total of 20 subjects were divided into two groups, each group of 10 people, receiving the same experimental test tasks. Aged between 24 and 28 years old, in order to ensure that all the tests have the same cognitive level, the subjects have no experience of virtual reality experience, and the tests have professional knowledge related to cartography and geographic information systems. The subjects' naked eyesight and myopia were not higher than 600 degrees, without color blindness.

4. Discussion and Analysis of Experimental Results

4.1. Analysis of Virtual Reality Tracking Technology

Analysis of task settings

A total of 10 configuration tasks are set, and the object operates according to the target position through translation and rotation. The target position is given by a line frame model with the same shape as the object being operated. These 10 tasks are timed tasks. In order not to let users get too tired, the maximum time limit for each task is 65 seconds. There are three ways to enter the next task. The user will automatically match the target location and automatically enter the next task. After a period of time, the task will automatically enter the next task and choose to abort the current task. The configuration task is set with an error threshold. When the user locates the target within the error threshold range of the target position, the color of the target changes to green, indicating that the task was successful and the next task begins. In order to improve the accuracy of the configuration, the error thresholds in the three directions of x, y, and z are set to 0.003 meters. As the time of the task elapses, if the user does not locate the target at the target position, the task will fail and the position of the last second of the target will be saved. Table 2 shows the description of each task.

Each user needs to complete the testing of the two devices separately. To prevent deviations in the test sequence, half of the users first test the interaction of the control handle, and the other half of the users first test the interaction of the multi-entity tracker. In order to maintain consistency with entity interaction, when interacting with the handle, the task starts timing when the handle grabs the object, not counting the time it takes the user to grab the object. For tasks with ten matching locations, each user performs two rounds of testing for each device. Each round of tasks is always displayed in the same order, as shown in Table 2. The target position of each task is set according to the Latin matrix to distinguish between different rounds. Record the completion time of each task, the deviation of the position of the model, and calculate the success rate of the task of each type of equipment. For the additional two tasks, only do the test of the handle interaction, do two rounds, each round of 2 tasks, each task includes 2 interactions.

Table 2. Task settings

Serial No.	Task	Description
1	x-axis translation	translate the object in the x-axis direction to match the target position
2	y-axis translation	translate the object in the y-axis direction to match the target position
3	z-axis translation	translate the object in the z-axis direction to match the target position
4	x- / y- / z-axis translation	translate the object in the xyz axis direction to match the target position
5	x-axis rotation	rotate the object around the x axis to match the target position
6	y-axis rotation	rotate the object around the y axis to match the target position
7	z-axis rotation	rotate the object around the z axis to match the target position
8	x- / y- / z-axis rotation	rotate the object around the xyz axis to match the target position
9	rotate around the z axis and translate along the xy axis	match the object to the target position
10	six full degrees of freedom	match the object to the target position

Analysis of test results

The time to complete the interaction of the handle starts when the user grabs the object using the handle and starts counting, and stops when the user releases the handle to place the object within the allowable error of the target position. The completion time of the physical tracker interaction starts when the user uses the tracker to collide with the object, and stops counting when the collision detection trigger calculates that the object has reached the allowable error of the target position. The results of experiments that did not successfully complete the task were not included in the final results. For the translation task, the rotation task and the average completion time of the tasks with 6 degrees of freedom to complete the operation are shown in the Fig. 3.

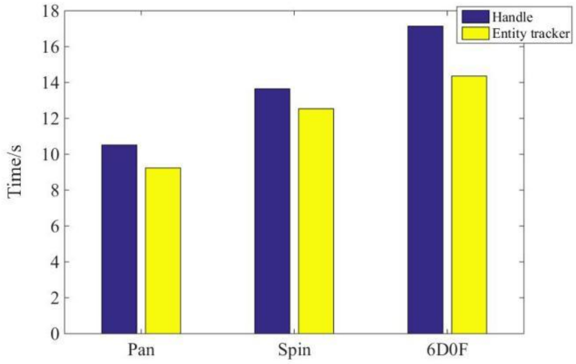

Fig. 3. Average task completion time

The needle diagram of the time taken by the entity tracker and the handle to interact with each task is shown in Fig. 4. The task completion time is in seconds. The table shows the median, upper quartile, and lower quartile, with the minimum and maximum time to complete (the length of the vertical bar).

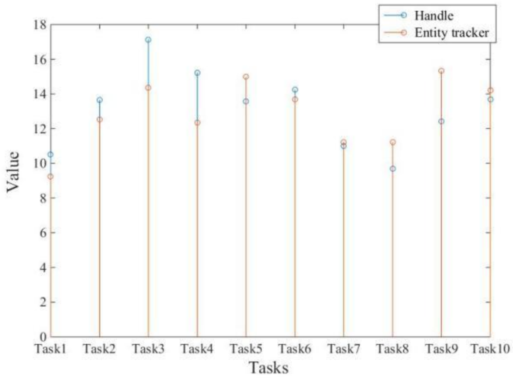

Fig. 4. Time taken by the physical tracker to interact with the handle

4.2. Experimental Analysis of Illumination-Three-Dimensional Model Attribute Mapping

This part of the experiment includes 1 test: the qualitative test of the city 3D model attribute value under the synergy of color and light visual variables, transparency = 1. According to the attribute data, it can be known that the building model id 52, 33, 48, 36, 55 is the first 10% of the attribute value is smaller. As shown in Fig. 5, under the condition of light intensity of 0.4, the test results expressed by the isometric color mapping are relatively uniform, followed by linear color mapping, circular color mapping and divergent color mapping. The lower the value, the darker the entire test scene, giving the subject a visually low feeling, which affects the subject's judgment. It can be seen from Fig.. 6 that the result of the test scene based on iso-illuminance color mapping is still uniform, while linear color mapping is next.

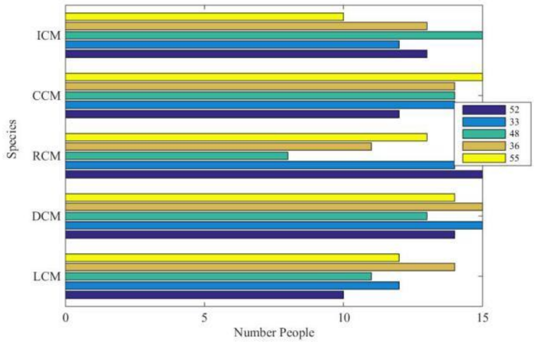

Fig. 5. Statistics of subject selection results under light intensity of 0.4

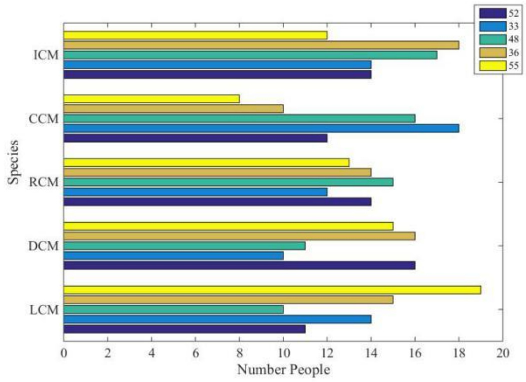

Fig. 6. Statistics of the results of subject selection under the condition of light intensity 1.0

According to the analysis of Tables 3 and 4, it is found that under the condition of light intensity of 0.4, the task completion time is longer than that of natural light, but under the condition of light intensity of 0.4, the accuracy of the corresponding illumination mapping scheme is improved, and the first attention The time is also shortened. Combined with the intuitive analysis of the statistical chart, it can be concluded that the iso-illuminance mapping scheme is effective for dark lighting conditions; in addition, when the lighting condition is 1.0, the overall task completion time becomes longer, but in the isometric color. Under the mapped scene, the choices made by the subjects are more accurate, and the time of the first attention is earlier than the natural environment. This shows that when the illumination variable changes, the isometric color mapping is the most effective.

Table 3. The average value of eye movement index of qualitative test scene with light intensity of 0.4

	LCM	DCM	RCM	CCM	ICM
FT(s)	5.32	5.43	5.62	5.64	5.21
TtFF(s)	0.52	0.63	0.51	0.34	0.45
ACC(s)	0.08	0.35	0.24	0.15	0.07
AC	0.65	0.35	0.24	0.62	0.54
VR	0.63	0.25	0.34	0.36	0.42

Table 4. The average value of eye movement index of qualitative test scene with light intensity of 1.0

	LCM	DCM	RCM	CCM	ICM
FT(s)	6.32	6.35	6.59	6.32	6.24
TtFF(s)	0.75	0.74	0.76	1.02	0.36
ACC(s)	0.08	0.23	0.14	0.25	0.22
AC	0.75	0.65	0.55	0.61	0.45
VR	0.66	0.35	0.31	0.25	0.66

The light-three-dimensional model attribute mapping experiment conducts extensive research on the visual variables of the three-dimensional model in the form of user cognition experiments. Through the cross combination of visual variable conditions such as color, transparency, and lighting, the user cognition experiment is designed. The indicator calculates the average value from the data generated by the experiment, and combines it with the statistical chart analysis of the results of the subject's answer selection to find the most suitable color mapping under each condition. According to the user's cognitive experiment results, combined with the process determination method, a three-dimensional model symbol visual variable mapping model is constructed, and appropriate model evaluation indicators are selected to evaluate the rationality of the constructed model through cognitive experiments.

5. Conclusions

Based on the development of the three-dimensional virtual simulation of cultural heritage protection, this paper has studied and researched most of the three-dimensional virtual interactive technology and the three-dimensional virtual interactive development tool platform at home and abroad, and determined the realization method and technical route of the research object. According to the actual situation and technical conditions, the virtools platform uses the interactive functions of the system to implement the virtools behavior interaction module and establish a virtual interactive program. This greatly shortens the development cycle of the cultural heritage protection 3D virtual simulation system and optimizes the system development process.

Aiming at the digital protection of architectural models of cultural heritage monuments, this paper uses VR-based 3D scenes as research tools and VR-based 3D feature extraction and search as research goals to realize the cultural heritage digital application. This article overcomes the differences in the user's interpretation of the model. It directly searches the 3D 3D model with the 3D space shape manually drawn in the VR environment, avoids the overall route of the large building complex, and loads the searched consistent pattern into a monument dynamically with the VR scene model. Realize the virtual interaction of the digitization of historical monuments. The visual and historical information of cultural heritage is recorded and preserved in digital form, and the shape data is reproduced and stored in the form of three-dimensional digital model. With the help of virtual reality and human-computer interaction technology, it provides an intuitive and vivid visual image and modern media platform.

The rapid development of digital technology has brought unprecedented opportunities for the development and protection of China's cultural heritage. It is promoting the full realization of the sharing and inheritance of cultural heritage in an unprecedented manner and speed. The digital system of cultural landscape heritage relies on the network platform and uses a variety of digital technologies to create virtual cultural heritage scenarios. It integrates text, pictures, audio, video, animation and virtual interactive experience to establish a cultural resource protection and sharing system.

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