3D Visualization Method of Folk Museum Collection Information Based on Virtual Reality

He Wang[1](✉) and Zi Yang[2]

[1] Changchun Humanities and Sciences College, Changchun 130051, China
wh15091@163.com
[2] Hubei Institute of Fine Arts, Wuhan 430060, China

Abstract. Aiming at the lack of real-time simulation rendering of Folk Museum collection information, a three-dimensional visualization method of Folk Museum collection information based on virtual reality is proposed. According to the collection information classification of Folk Museum, the exhibition space of museum is divided. The museum is structured, the rendering scene of collection information is constructed by using parametric scene description language, and these data are uniformly managed by means of spatial projection. According to the attribute value of the rendered scene, a three-dimensional visualization model of the collection information of the Folk Museum is established based on virtual reality. The role agent communicates with the outside rather than directly accessing the role, which can enhance the encapsulation of data and the reusability of code, so as to reduce the response delay. The test results show that the 3D visualization method of Folk Museum collection information based on virtual reality can shorten the information response time and optimize the real-time rendering process.

Keywords: Virtual reality · Folklore Museum · Collection information · 3D visualization · Parametric scenario · Interaction design

1 Introduction

The museum collects and preserves historical relics in order to display cultural heritage in various ways. It is a place for human beings to understand history and master science and technology. In the museum, people can appreciate the beauty of history and culture through personal experience and improve their personal cultural literacy and national spirit. Folk Museum can protect the inheritance of folk culture and bring positive social significance. Through various exhibitions and activities in the Folk Museum, the public can experience the infinite value of folk culture in a specific space. As an educational place to promote people's informal learning, with the development and reform of science and technology, the construction of digital museum and virtual museum not only expands the educational function of the museum, but also provides new ideas and methods for museum learning. With the development of the times, the understanding of museum collection resources in the field of museum research is constantly refreshed

W. Fu and L. Yun (Eds.): ADHIP 2022, LNICST 468, pp. 14–27, 2023.
https://doi.org/10.1007/978-3-031-28787-9_2

in its depth and breadth. In addition to the exquisite collections of large-scale comprehensive museums, the traditional customs activities closely related to people's life and established conventions, as well as the artifacts, artists and solar terms reflecting customs activities, as well as the related cultural space should also be included in the scope of museum collection resources research. With the rapid development of science and technology and the accelerating process of social informatization, digital resources have penetrated into our daily work, study and life. In the field of culture, the application of network technology and virtual reality technology in museum education has become a new communication development trend, Relying on computer network technology and virtual reality technology, digital museum and virtual museum have gradually become new development fields [1]. The information guidance function of museum collection is an indispensable auxiliary function of museum. The museum collection information is for visitors to uniformly plan and sort out the seemingly clueless venue zoning and browsing order according to the age, society, class, plot, function and other information, so as to guide tourists to a regular and orderly browsing scheme, and prompt and guide them in key places. Digital museum digitizes the collection resources, displays the collection with the help of network media, disseminates cultural knowledge and expands the audience area of the museum. The artifacts in the collection of Folk Museum are one of the construction of customs and habits. The performance of folk artists is the transmitter of people's beautiful demands in folk activities. Folk activities are the life wisdom extracted by ancestors according to the law of natural development. They are the most essential behavioral expression of regional culture and aborigines. The museum collection information guide makes people's tour experience in the museum clear, unified and distinctive. Because the space size, information classification and plot setting of the traditional museum cannot be reconciled, the design of the guidance system of the traditional museum has to cut off and reorganize the inherent relationship between some exhibits, so that some of the connections between exhibits can not be displayed intuitively. The application of virtual reality technology and three-dimensional modeling technology in digital museum shows the cultural relics collection or historical real scene through virtual system [2]. The collection information of Folk Museum is guided by three-dimensional visualization method, which makes the traditional museum change from the site built of reinforced concrete to the Virtual Museum of data transmitted on the Internet under the new media platform. The ideas and influencing factors in the design have also changed: it is no longer limited by the size of the site and the number of exhibits The exhibits can be classified and guided from various dimensions, and the guiding forms can be diversified.

Based on virtual reality, this paper proposes a three-dimensional visualization method of collection information of Folk Museum. Based on the classification of the collection information of Folk Museum, the parametric scene description language is selected. Based on virtual reality, a three-dimensional visualization model of Folk Museum collection information is established, and the three-dimensional visualization of Folk Museum collection information is realized. This method broadens the development scope for economy and culture through the development of derivative design, broaden the development caliber for economy and culture, so as to meet the people's various needs for local culture.

2 3D Visualization Method of Collection Information of Folk Museum Based on Virtual Reality

2.1 Classification of Collection Information of Folk Museum

Based on the characteristics of traditional art forms, the three-dimensional visualization of collection information of Folk Museum also has the characteristics of interactivity, entertainment, networking and so on. It is not limited by time and space, and can interact with the audience in three-dimensional space. It is an art born in the digital information age. The collection information of folk museum can be divided into two categories: Folk images and folk portraits. Its resource structure is shown in Fig. 1.

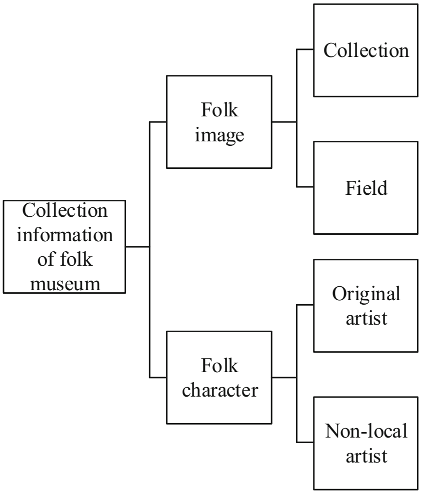

Fig. 1. Framework of collection resources

Three dimensional visualization makes the dominant static mode in the guidance system gradually change to dynamic mode. The dynamic mentioned here is not only the dynamic of visual elements, but also the dynamic of guidance data, guidance thinking and guidance path. The collection part of the Folk Museum includes artifacts, words and video, the field part includes the field area and region, the folk artist part includes native artists and non-native artists, and the group people include native people and non-native people. In this frame structure, “utensils” refer to the objects in the collection, which are used in folk activities, used by folk artists or have specific reference. Facing the full room of collections, the audience has the right to browse, choose, approach and stare, while the collections can only wait for the discovery and appreciation of the audience. Because the collection is not arranged in a narrative way, the dialogue between different collections is also quite limited. There may be an interesting story behind each collection, but there is no complete story that can be used to explain the collection of the whole room. Therefore, the display space at this time is fragmented and fragmented. The close relationship between Folk Museum and electronic equipment has laid the foundation for the dynamic display of collection information. More and more visual element symbols of virtual museum guidance system begin to transmit guidance content through dynamic images and data. The dynamic design of guidance system enriches its forms of expression and provides an opportunity for its diversified development. "Writing" refers to the written historical materials or written images with special meanings recording folk activities. "Shadow and sound" refers to the historical materials recorded in the form of video or audio or the scenes of current folk performances, practical operations and other activities. "Site area" refers to the space category of folk museum or limited local area. When the museum space is divided according to the function, it can be divided into service area, exhibition area, transition area, etc. other division methods include division according to time stage or display mode. "Region" refers to the regional spatial category divided by administrative regions. The difference between "native artist" and "non local artist" is whether the artist's folk performance or folk behavior is native. After determining the starting point and the ending point, the first-class guide moving line is formed for users according to time, material, region and other classifications. This moving line improves the visiting efficiency of visitors who are confused about the tour route and have low initiative. Considering that users with clear needs have interspersed the second-class moving lines of different paths in the first-class guide moving line, Without cutting off the connection between various lines, it is convenient for users with high initiative to visit more purposefully.

2.2 Select Parametric Scene Description Language

Folk Museum has certain particularity. The external architectural scenes and internal booths of the museum are relatively fixed, but the number of exhibits in the exhibition hall is large and scattered, the placement position of exhibits is changeable, and the information carried by exhibits is complex (including text information, audio information, video information, etc.). The variety and location of exhibits vary greatly. This requires to increase its variability and scalability when building virtual scenes. The realization of virtual scene is based on the three-dimensional simulation of the scene. Integrate the resources of the whole museum before building a virtual museum. In the three-dimensional visual management of the collection information of Folk Museum, most operations need to operate the graphics, and these operations on the graphics are based on the spatial database, so a large amount of spatial data will be used in the system. Because spatial data has a large number of spatial attributes, it is very important to manage these spatial data reasonably and effectively [3]. There are mainly two kinds of data for the collection information of Folk Museum: one is the data stored when building the system, including scene model, page and so on. The second is the data obtained in real time. For example, the location coordinate information of the first person needs to be transmitted in real time in the museum system. When a click event occurs, the click coordinates should be obtained and the corresponding text and audio data should be loaded. Due to the efficient accessibility, spatial database can store a large amount of data in a data set, can store seamless and continuous geographic data, and does not need to store geographic data in blocks [4]. Therefore, spatial database can store massive spatial data, which greatly enhances the ability of things processing. Due to the wide scope of the museum as a whole and the large amount of total model resources, there are more than ten exhibits in a theme museum, which occupy a large amount of resources after simulation. If all model resources of the whole museum are rendered when the system is loaded for the first time, the pressure on the server and memory will be great, which is bound to affect the efficiency of rendering and user experience [5]. In order to improve the efficiency of browser rendering, it is necessary to structure the museum and reduce the rendering range as much as possible. To sum up, this paper selects a parametric scene description language to build a virtual scene. XML based parametric scene description language has a good reputation for its proven architecture, its reliability, data integrity, powerful function set, scalability and the contribution of the active open source community behind its software, and has been providing users with high-performance and innovative solutions [6]. When constructing the scenario, it is implemented by XML parametric language. Considering the rendering efficiency of the whole system, the collision detection rate and the convenience of subsequent scene interaction, the scene is organized in a tree structure. For the motion model, the bounding box after motion is calculated, and the projection points in three axes are recorded. In the state of linear motion, it can be considered that the projection coordinates on the Z axis remain unchanged, so as long as the relationship between the Y axis and the X axis is considered. The projection points in motion satisfy the following relationships:

$$\begin{cases} \beta_{\min} = \varphi\alpha_{\min} + \gamma \\ \beta_{\max} = \beta_{\min} + \delta \\ \alpha_{\max} = \alpha_{\min} + \delta \end{cases} \tag{1}$$

In formula (1), $\beta_{\min}$ and $\beta_{\max}$ are the minimum and maximum values of the projection of the motion model on the Y axis respectively; $\alpha_{\min}$ and $\alpha_{\max}$ are the minimum and maximum values of the projection of the motion model on the X axis respectively; δ represents the side length of the moving bounding box; φ and γ are linear motion parameters respectively. Parameters φ and γ can be obtained according to the linear formula, and the calculation formula is as follows:

$$\begin{cases} \varphi = \dfrac{(\eta - \beta_{\min}) - \left(\eta' - \beta_{\min}\right)}{(\eta - \alpha_{\min}) - (\eta' - \alpha_{\min})} \\ \gamma = \eta - \beta_{\min} - \varphi\left(\eta' - \alpha_{\min}\right) \end{cases} \tag{2}$$

In formula (2), η and η' respectively represent the coordinates of the projection points of the bounding box before and after the movement. Thus, the interactive management of attribute data, graphic image data and spatial relationship data is realized. These data are managed uniformly by means of spatial projection. XML based parametric scene description language has small volume and less space; The structure is simple, the scene can be built intuitively, and it is easy to modify; Strong cross platform and scalability; It is more flexible than data and has high access efficiency. It is suitable for 3D programs with high real-time requirements.

2.3 Establishment of 3D Visualization Model of Collection Information of Folk Museum Based on Virtual Reality

Virtual reality is generated through the interaction between learners and things in the situation, but there are no real things in the virtual situation. Therefore, interactive behavior should be set in the situation of the built virtual museum system. When learners trigger an instruction in the situation, the Folk Museum will give some feedback information, so as to achieve better experience effect [7]. In order to adapt to the complex and changeable Museum application scenarios, the three-dimensional visualization model of Folk Museum collection information needs to support dynamic application. Based on the idea of "model instance", this paper proposes a general role model (model algorithm attribute message) to form a configurable management mechanism, that is, the role algorithm and role attribute unit are granulated, and the role algorithm and attribute are dynamically bound around the specific three-dimensional application to form a role instance. The three-dimensional visualization model of Folk Museum collection information based on virtual reality should pay attention to interactive experience in the design and development, which is embodied in the model size, mapping, materials and information presentation. The design principles of these two functions correspond to the immersion, authenticity and multi perception of virtual reality technology. After exporting the 3D model in SketchUp and saving it in the "SKP" file format, it is necessary to import the exported model into lumion for real-time rendering. If you import the model directly, you may not see the effect directly after importing, which will affect the control of the overall scene. Through data-driven, enrich and improve role examples, and solve the problems of reusability and coupling of roles. Actor is the base class of the role class and has the general (basic) attributes of the role, such as role ID identification, role name, spatial location, association model, bounding box, selected status and other attributes. Therefore, make some preparations before importing, adjust lumion to the best state, and then import the model, so that there will be no phenomenon that the operation is not smooth after the model is imported or the imported model needs to be readjusted after the terrain is modified. Role agent is an encapsulation of a role and maintains all attribute and method information of the role. Communicating with the outside world through the role agent instead of directly accessing the role can enhance the encapsulation of data and the reusability of code. In the three-dimensional visual modeling of Folk Museum collection information, it is necessary to obtain the attribute value of each scene. For the data points in each relatively small area, the spatial difference method is used to solve the problem of sparse and irregular discrete distribution of museum information spatial data. After adjusting the position of the three-dimensional visualization model of the collection information of the Folk Museum and the positional relationship with the coordinate origin, the visualization models are separated and classified one by one. The core idea of spatial difference method is that the closer to the target, the greater the similarity and the greater the weight. Its weight is mainly weighted by the distance between the interpolation point and the known point. The difference point of Folk Museum collection information can be expressed as:

$$p(a,b) = \frac{\sum_{j=1}^{n} p_j \varpi_j}{\sum_{j=1}^{n} \varpi_j} \tag{3}$$

In formula (3), $p(a, b)$ represents the value of interpolation point p; p_j is the third of the sampling points j Values of points; ϖ_j is the second j The weight of a sample point in interpolation. The weight is calculated as follows:

$$\varpi_j = \left(\frac{1}{h_j}\right)^{\kappa} \tag{4}$$

In formula (4), h_j represents the distance from the j sampling point to the interpolation point; κ is the index, which significantly affects the interpolation results. The value in this paper is 2. Through the distribution of known points, data characteristics, accuracy requirements of desired results, etc., select appropriate search patterns and search ranges, as well as the number of known points to be searched, to control the way and number of their use, so as to achieve the required data modeling requirements. Import the three-dimensional models into lumion from large to small. Their positions are adjusted one by one in lumion, so that the models are rearranged and combined, thus completing the construction of the collection information scene of the Folk Museum. Virtual reality technology enables the audience to enter a newly created cultural time and space. At this time, the museum will introduce the curatorial narrative into the audience role-playing (selection), making the audience a part of the visiting situation. The three-dimensional visualization of some exhibits in the museum enables the audience to enter the original cultural time and space of the exhibits or the imagination space of artists in the virtual world, so as to further experience the objects. Considering the multi terminal application mode, the load balancer adopts a dynamic load balancing strategy based on ant colony algorithm. The load of service nodes is measured according to the load balancing factor, so as to iterate the ant colony algorithm and dynamically update the load strategy. Pheromone concentration after a task is:

$$\vartheta_t = \vartheta_{t-1}(1-\varepsilon) + \sum_{i=1}^{N} \Delta\vartheta_i \tag{5}$$

In formula (5), t represents the number of iterations; ϑ_t and ϑ_{t-1} represent the pheromone concentration after the t th and $t-1$ th iteration, respectively; ε represents Volatilization Coefficient; N represents the number of ants passing through the node; $\Delta\vartheta_i$ is the pheromone left by the i th ant at the node in this task assignment. The adaptive method is adopted to adjust the heuristic probability according to the setting threshold and the completion time of each iterative task. Therefore, the probability model of service node selection in an iteration process is obtained:

$$w_z = \frac{\mu_t \vartheta_t \sigma}{\sum_{t=1}^{m} \mu_t \vartheta_t \sigma} \tag{6}$$

In formula (6), z represents the serial number of the server node; w_z represents the probability of selecting the z th service node; μ_t represents the heuristic probability of ant routing during the t second task assignment; σ represents the load balancing measurement factor. Lumion can output still frame pictures and video animations. At this time, according to actual needs, local perspective views and lens scenes roaming from different perspectives are used to set them respectively. At the same time, in order to make the picture more vivid, the scene is given special effects such as near and far scene virtualization, time and lighting changes and transition lens, so as to enrich the display content of the lens. Make the display content of the lens richer. A complete scene role model is formed through model resource management, registration model, defining scene roles, associating role models, configuring role attributes and related behaviors (algorithms); 3D application configuration management provides scene production function, and uses role model resources to build specific 3D application scenes. By adding environment to the equation of embodied experience, the three-dimensional visualization model shifts attention to how the experience of screen and network media transcends the visual experience. Based on the understanding of place as a relationship environment, in this environment, local and global are composed of each other, which makes the Internet a potential kinship field. There are certain differences between the preview effect in lumion and the final exported image and video effect. The most obvious difference is that the final exported image and video, especially the video effect will be brighter than the preview effect, and the color scale will be whiter. In addition, once the picture is overexposed, it is difficult to adjust it in the post-processing software. If the picture is slightly dark, it can be adjusted to a certain extent in the post-processing software. Therefore, before exporting, adjust the exposure value a little smaller and the contrast slightly larger. Start the 3D application running service, load the visual application scenario and necessary data at runtime, and provide runtime services; 3D application visualization provides a three-dimensional and virtual simulation rendering environment. Users can complete specific 3D applications through human-computer interaction through the operation interface. So far, the design of 3D visualization method of collection information of Folk Museum Based on virtual reality has been completed.

3 Experimental Study

3.1 Experimental Preparation

The three-dimensional visualization of Folk Museum collection information is an important part of digital museum. As a media resource for visitors and learners to browse independently and experience learning, and also as a virtual environment for experience learning, its application and evaluation is a way to test the effectiveness and function of the system. Through surveying and mapping the site, the size parameters required for modeling are obtained, and the corresponding position data are collected by dynamic GPS. Then use CAD technology to carry out the overall plane planning and design of the Folk Museum, and then build the three-dimensional model on the basis of the plan. Based on the three-dimensional model, the real-time simulation rendering of the building scene is carried out. In the early stage, some map textures are obtained through digital cameras to facilitate the material map rendering of the building in the later stage. Finally, a three-dimensional visual dynamic display effect is output. The relevant configuration of this experiment is shown in Table 1.

Table 1. Experimental configuration

Configuration name		Parameter
Hardware configuration	CPU	i3-4160
	Main frequency	3.6 GHz
	Memory	4GB
	Graphics card	NVIDIA GeForce 9600 GT
	Video memory type	64-bit DDR3
Software environment	Windows 7 ultimate	64 bit operating system
	Visual Studio 2013	C++ language
	OSG	3.4
	OpenGL	4.3
	NVIDIA driver	174.16

3.2 Results and Analysis

In order to verify the application effect of the three-dimensional visualization method of Folk Museum collection information based on virtual reality, the response time of three-dimensional visualization of information data is selected as the test index to test the performance of the design method. The three-dimensional visualization methods of collection information of Folk Museum Based on Web GIS and data mining are compared. The response time of each three-dimensional visualization method is compared and analyzed under the condition that the collection information data of Folk Museum is 50G, 100G, 150G and 200G. The test results are shown in Tables 2, 3, 4 and 5 respectively. In order to more clearly compare the response time trends of different methods, the results in Tables 2, 3, 4 and 5 are graphically processed. As shown in Figs. 2, 3, 4 and 5. In order to more clearly compare the response time trends of different methods, the results in Tables 2, 3, 4 and 5 are graphically processed. As shown in Figs. 2, 3, 4 and 5.

Table 2. Response time of 50G collection information data (s)

Number of tests	Virtual reality	Web GIS	Data mining
1	**1.91**	2.56	2.84
2	1.84	2.63	**2.96**
3	1.65	2.86	2.53
4	1.56	2.59	2.82
5	1.63	2.65	2.75
6	1.72	2.73	2.49
7	1.65	2.44	2.85
8	1.52	**2.88**	2.65
9	1.61	2.62	2.82
10	1.82	2.51	2.86

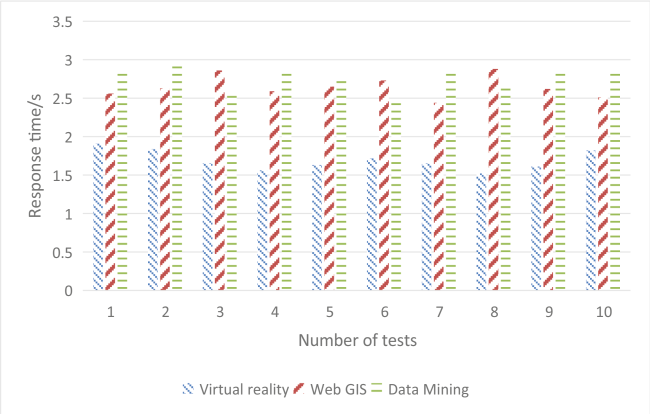

Fig. 2. Response time of 50G collection information data

In the test of 50G collection information data of Folk Museum, the response time of 3D visualization method of Folk Museum collection information based on virtual reality is 1.69 s, which is 0.95 s and 1.07 s shorter than that based on Web GIS and data mining.

In the test of 100G collection information data of Folk Museum, the response time of 3D visualization method of Folk Museum collection information based on virtual reality is 2.41 s, which is 1.00 s and 1.19 s shorter than that based on Web GIS and data mining.

Table 3. Response time of 100G collection information data (s)

Number of tests	Virtual reality	Web GIS	Data mining
1	2.23	3.16	3.57
2	2.36	3.54	3.66
3	2.47	3.48	3.25
4	**2.59**	3.66	3.42
5	2.36	3.25	3.84
6	2.55	3.32	3.51
7	2.52	3.51	3.68
8	2.43	**3.84**	3.35
9	2.31	3.25	**3.92**
10	2.25	3.12	3.83

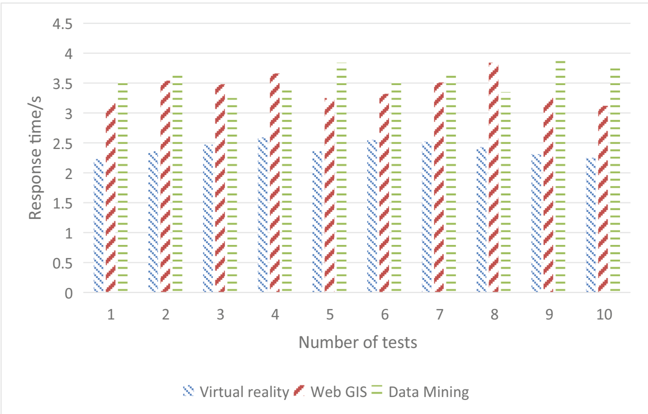

Fig. 3. Response time of 100G collection information data

In the test of 150G collection information data of Folk Museum, the response time of the three-dimensional visualization method of Folk Museum collection information based on virtual reality is 3.26 s, which is 1.43 s and 1.59 s shorter than the three-dimensional visualization method based on Web GIS and data mining.

In the test of 200G collection information data of Folk Museum, the response time of 3D visualization method of Folk Museum collection information based on virtual reality is 3.83 s, which is 2.69 s and 2.64 s shorter than that based on Web GIS and data mining. Therefore, the method proposed in this paper realizes the optimization of the real-time rendering process of the three-dimensional visualization of the collection information of the Folk Museum, and solves the problem that the collection information of the Folk

Table 4. Response time of 150G collection information data (s)

Number of tests	Virtual reality	Web GIS	Data mining
1	3.24	4.59	4.86
2	3.17	4.67	4.73
3	3.36	4.78	**4.97**
4	3.08	**4.85**	4.84
5	3.18	4.62	4.61
6	3.29	4.75	4.82
7	3.35	4.63	4.95
8	**3.42**	4.51	4.93
9	3.36	4.72	4.90
10	3.18	4.80	4.91

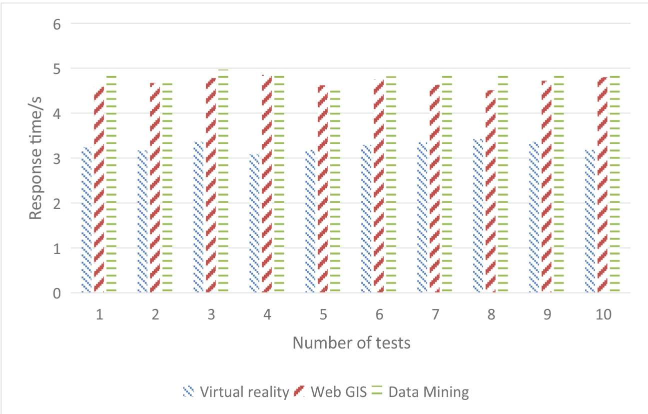

Fig. 4. Response time of 150G collection information data

Museum is difficult to respond in real time. This research provides new ideas for the construction of digital museum and has practical application value.

From the above analysis, it can be seen that the method in this paper has a good response time under different capacities of library information data. The main reason for this result is that this method uses the two formulas in part 2.2 to obtain the scene information of the Folk Museum, and combines the formula derivation in part 2.3 to obtain the weight of the collection information at different points, which improves the response efficiency.

Table 5. Response time of 200G collection information data (s)

Number of tests	Virtual reality	Web GIS	Data mining
1	3.89	6.24	**6.59**
2	3.82	6.49	6.48
3	3.76	**6.87**	6.86
4	3.83	6.54	6.63
5	3.75	6.68	6.52
6	3.78	6.76	6.25
7	3.82	6.52	6.18
8	3.81	6.35	6.46
9	**4.02**	6.21	6.54
10	3.85	6.53	6.23

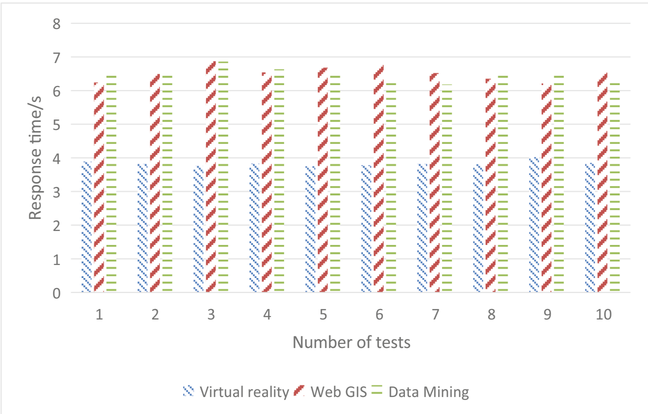

Fig. 5. Response time of 200G collection information data

4 Conclusion

The three-dimensional visualization method of Folk Museum collection information provides users with sufficient information display methods, and gives users a high sense of experience and reality. This paper mainly studies the Folk Museum in reality, and puts forward a three-dimensional visualization method of Folk Museum collection information based on virtual reality technology. According to the classification results of the collection information of Folk Museum, this paper constructs the museum. The parametric scene description language is used to construct the rendering scene of the collection information, and the virtual reality technology is used to establish the three-dimensional visualization model of the collection information of the Folk Museum. The experimental results show that this method can improve the response time of collection information and is suitable for the data transmission mode of virtual museum. Due to the limited research time and less research on caching and distribution, this paper only studies and applies it, but it also plays a certain role in improving the interaction efficiency of collection information. The functional analysis of geographic information, intelligent management of museum projects and Internet big data fusion analysis need to be improved. In the later stage, we can research and improve the data cache and distributed implementation, and constantly improve the three-dimensional visualization system of Folk Museum collection information.

Fund Project. 2022 Jilin Provincial Department of Education Scientific Research Project: Design of Interactive Picture Books for Cultural Creation of Northeast Ethnic Folk Museum in the New Media Era. Item number: JJKH20221334SK.

References

1. Zhang, S., Zhao, W., Peng, J., et al.: Augmented reality museum display system based on object 6D pose estimation. J. Northwest Univ. (Nat. Sci. Ed.) **51**(5), 816–823 (2021)
2. Li, Y.: Analysis on 3D visualization of bim in the network environment based on WebGL technology. Comput. Sci. Appl. **11**(1), 233–239 (2021)
3. Wang, Z., Peng, M., Xu, H.: Research on information visualization design of bronze ware in museums. HuNan BaoZhuang **35**(5), 57–61 (2020)
4. Yang, C.: Design of museum space multi-element interactive system based on three-dimensional representation. Mod. Electron. Tech. **44**(12), 155–158 (2021)
5. Xu, X., Tian, B.: Simulation of free handover of hybrid mobile guide information in virtual reality. Comput. Simul. **37**(1), 439–443 (2020)
6. Wang, W.: Design of 3D visualization system of geographic information based on virtual reality. J. Shenyang Inst. Eng. (Nat. Sci.) **17**(4), 74–78 (2021)
7. Shen, X., Yang, Y.: Spatial schema: immersive virtual reality promoting geospatial cognition. E-Educ. Res. **41**(5), 96–103 (2020)