Proceedings of the 4th International Conference on Art, Design and Social Sciences
DOI: 10.54254/2753-7064/2025.27238

Research on the Design and Development of Cultural Heritage VR System

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Abstract. Chinese excellent traditional culture is the root and soul of the nation and an important embodiment of the soft power of Chinese culture. VR technology has gradually become an important means of cultural heritage (HLA) education because of its immersion and interactivity. In recent years, the Ministry of education has promoted the VR application in education to break through the limitations of time and space, which provides students with a more vivid and interactive cultural experience. The purpose of this study is to design and develop a HLA display system based on VR technology. Taking "Yu Garden" as a research case, this study explores the realization of digital display and interactive communication of HLA through VR technology, and provides students with immersive historical and cultural experience through the development of VR system. In the cultural heritage digital display (CHDD) system , the design of host and client virtual user role (UR) is the core of information interaction. This paper designs the interaction mechanism between the host and client by defining the interaction coefficient, information accumulation and other parameters of the host virtual UR. The experimental data show that the "Yu Garden" display model based on VR technology provides users with an immersive cultural experience, and the combination of audio and video makes the history and culture of murals more vivid.

Keywords: Cultural heritage, VR system, System design, System development.

1. Introduction

Culture is the soul of a country and a nation. At the 20th National Congress of the Communist Party of China, General Secretary Xi Jinping pointed out that "to achieve the great rejuvenation of the Chinese nation, we need the prosperity of Chinese culture, and we should inherit and carry forward the excellent traditional Chinese culture in combination with the new conditions of the times." the excellent traditional Chinese culture is the root and soul of the Chinese nation and the most profound cultural soft power. In the context of the new era, its inheritance and development has great strategic significance [1]. However, the current traditional culture education still faces some practical problems, such as the low degree of informatization, the lack of teaching resources, and the single teaching method, which are difficult to stimulate students' interest in learning and cultural identity [2]. Classical gardens are a unique HLA of China, carrying rich historical and artistic value, such as Suzhou Gardens, the Summer Palace, Chengde Mountain Resort, the Old Summer Palace,

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the Sun Yat-sen Mausoleum in Nanjing, and the Dali Erhai Garden. However, existing preservation methods mainly rely on traditional techniques such as tape measurement and hand-drawn sketches, which fail to accurately represent the shifting scenery, spatial changes, and deeper cultural connotations of the gardens. At the same time, these methods hinder effective data sharing, affecting the protection of garden heritage. With the continuous maturity of computer vision, artificial intelligence, VR, AR and metauniverse technologies, VR technology has gradually become an important means to promote the modernization of education because of its immersion, interactivity, imagination and other advantages. In recent years, the Ministry of education has continuously promoted the "deep integration of education and technology", and explicitly proposed to support the application of VR technology in teaching in policies such as "2035 of China's education modernization" and "key points of education informatization and network security", which emphasizes the use of modern information technology to innovate teaching mode and enrich educational resources [3].

VR technology, through 3D modeling and virtual tours, can intuitively recreate the spatial structure and landscape effects of gardens, solving the problem that traditional methods cannot dynamically record and display the complex spatial features of gardens. VR technology can accurately present the physical structure of garden heritage and dynamically showcase the evolution of garden landscapes, allowing researchers to analyze the historical, cultural, and artistic value of gardens from multiple perspectives. The VR system, through an interactive digital platform, presents the cultural context inside and outside the garden, helping the public better understand and experience the history and culture of the garden, while also providing an innovative approach for the preservation of garden heritage. The application of VR technology in HLA teaching conforms to the development strategy of national education informatization, and also responds to the urgent need for high-quality digital resources in traditional cultural education [4].

2. Research methods

2.1. Virtual UR design

In CHDD system , the design of virtual UR includes two parts: host virtual UR and client virtual UR. As the starting point of information interaction, the host virtual UR has strong data scalability l. The host can divide a data object into several associated parameters through VR technology [5]. Suppose $\boldsymbol{\beta}$ is the interaction coefficien, $\overline{\boldsymbol{E}}$ is the accumulation of HLA information, $\boldsymbol{\lambda}$ is the virtual UR composition on the host side, and $w_1, w_2, \ldots, w_n$ represent the virtual characteristics of n different host side UR. According to these physical quantities, the definition of host virtual UR can be expressed by the following formula:

$$e_1 = \frac{\beta \times \left|\overline{\boldsymbol{E}}\right|^2}{\sqrt{\boldsymbol{\lambda}\left(\boldsymbol{w}_1^2+\boldsymbol{w}_2^2+\ldots+\boldsymbol{w}_n^2\right)}} \tag{1}$$

As the target of information interaction, the client virtual UR has strong transmission adaptability. The design of client role can integrate and process data parameters according to VR and interactive technology. Suppose $\boldsymbol{R}_1$ and $\boldsymbol{R}_2$ are two different virtual information, $\widehat{\boldsymbol{k}}$ is the HLA cumulative characteristics, j is the client information interaction, $\overrightarrow{x}$ represents the transmission vector, and h

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is the information coefficient [6]. The definition of the client virtual UR can be expressed by the following formula:

$$e_2 = \frac{\left| j \bullet \widehat{k}^2 \left(\boldsymbol{R}_1 + \boldsymbol{R}_2 \right) \right|}{h \bullet \overrightarrow{x}} \tag{2}$$

2.2. Human computer interaction mode

The human-computer interaction mode is built based on VR, which is mainly used for the transmission and interaction of data information. Without considering the external interference factors, In CHDD system of HLA, the virtual signal definition item ($\boldsymbol{\alpha}$) is usually located in the physical interval of (0,1], and its value is low. The node interaction parameter ($\boldsymbol{\varepsilon}$) is also located in the physical interval of (0,1], but it is less than the virtual signal definition item $\boldsymbol{\alpha}$ with the support of VR technology. Combined with the above physical quantities, we can get the discriminant expression of the application ability. The expression is:

$$L_{\boldsymbol{\alpha}-\boldsymbol{\varepsilon}} = f\left(\frac{\left| \boldsymbol{\alpha} \bullet e_1 + \boldsymbol{\varepsilon} \bullet e_2 \right|^2}{\sqrt{d^2 + g^2}} \right) \tag{3}$$

Where, f is the data interaction strength, and d and g respectively represent the indicators of two virtual behavior items.

2.3. User based collaborative filtering

Similarity to predict user interest, the similarity formula is as follows:

$$\mathrm{sim}\left(\mathrm{u_i}, \mathrm{u_j} \right) = \frac{\sum_{\mathrm{k}} \mathrm{R_{ik}} \bullet \mathrm{R_{jk}}}{\sqrt{\sum_{\mathrm{k}} \mathrm{R_{ik}}^2} \sqrt{\sum_{\mathrm{k}} \mathrm{R_{jk}}^2}}$$

Wherein, $\mathrm{sim}(\mathrm{u_i}, \mathrm{u_j})$ is the similarity between $\mathrm{u_i}$ and $\mathrm{u_j}$, $\mathrm{R_{ik}}$ and $\mathrm{R_{jk}}$ represents the score or interaction value of users $\mathrm{u_i}$ and $\mathrm{u_j}$ on items ik respectively.

2.4. Tightness between host and client

The connection closeness of "Yu Garden" is directly affected by two physical indicators, the host input intensity (e_1) and the client information output intensity (e_2), ΔC is the HLA .unit change.

$$\widetilde{w} = \frac{\theta_1 \bullet \theta_2}{\Delta C}$$

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3. Research results

3.1. Display model of "Yu Garden" based on VR

The VR based "Yu Garden" display model provides an immersive cultural experience through VR technology. Users can enjoy the details of murals in all directions through VR, while augmented reality technology allows users to interact with murals in a real environment.VR system can combine audio and video multimedia and interactive elements to vividly present the history and culture of murals, which can stimulate the emotional resonance of users. At the same time, the system adjusts the display content according to users' interests and needs to ensure that users at different levels can get the appropriate experience. This paper statistics the display model of "Yu Garden" based on VR, as shown in Figure 1.

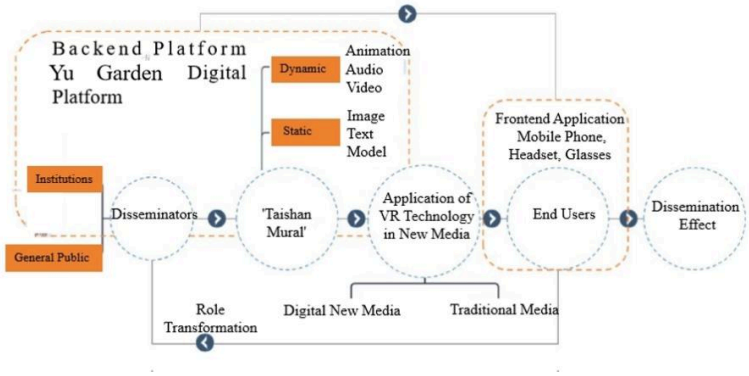

Figure 1. The propagation model of "Yu Garden" based on VR

3.2. Task flow

Task process is the core of platform operation, which aims to ensure that every step can be carried out smoothly to achieve efficient task management and execution. When the system user initiates a task on the platform, it will automatically generate the corresponding workflow according to the task type and requirements. The preliminary stage of the task includes the setting of task objectives and the allocation of resources, which can ensure that every detail is confirmed before the task starts. The platform will monitor the progress in real time, provide feedback information, and adjust relevant parameters according to the actual situation. Finally, after the task is completed, the platform will generate a task report for users to view and evaluate the task results. This paper formulates the task flow chart of the HLA VR system, as shown in Figure 2.

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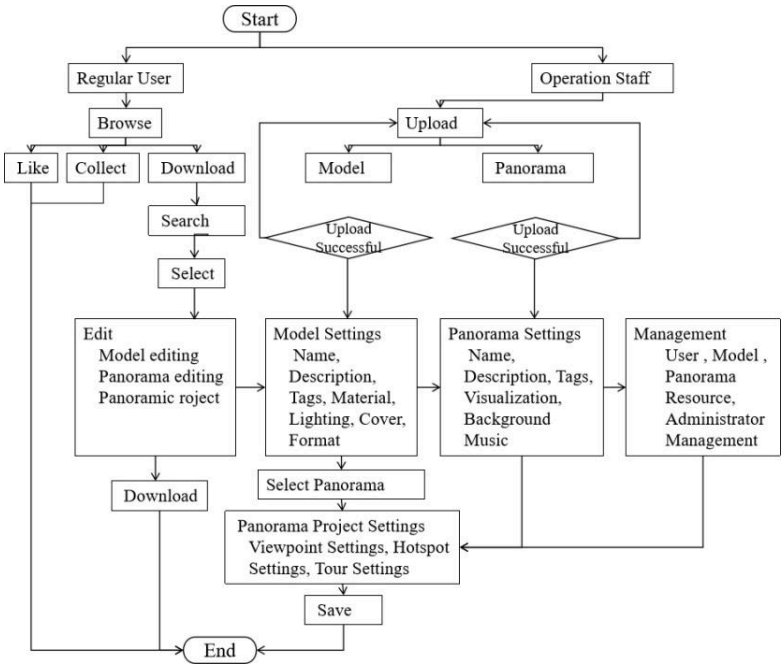


Figure 2. Task flow chart of HLA VR system

3.3. VR system user interaction process

The user interaction process of "Yu Garden" VR system aims to provide users with an immersive virtual experience, and display and disseminate Yu Garden, an important HLA, through VR technology. Users enter the system by wearing VR devices. The "Yu Garden" VR system has designed multiple interactive interfaces. Users can trigger different functional modules through simple actions, such as switching mural display perspectives. The user interaction process of AR system is shown in Figure 3.

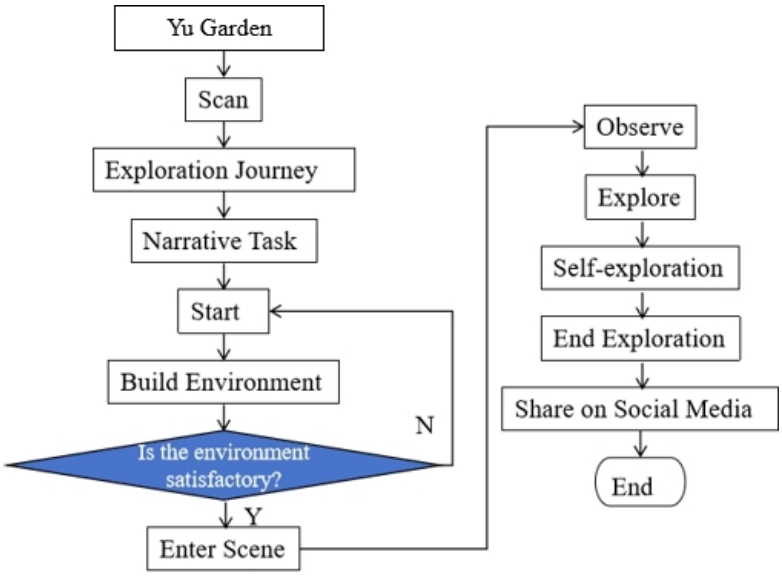


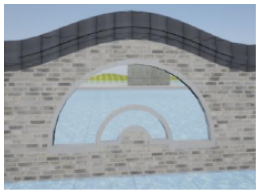
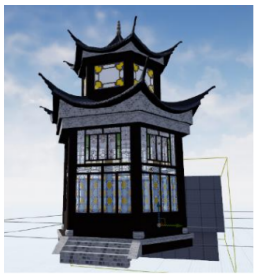
Figure 3. AR system user interaction process

DOI: 10.54254/2753-7064/2025.27238

3.4. Model creation

The key to the model creation for the landscape garden VR system lies in transforming real garden landscapes into interactive models in virtual space. To ensure the authenticity and cultural continuity of the VR system's landscapes, the model creation referred to several culturally symbolic landscapes within the Yu Yin Mountain House. For example, the architectural style of Yuyuan.The research team utilized 3D modeling technology to convert these details into virtual models, enabling the VR system to vividly reproduce the architectural features and garden layout of the Yu Yin Mountain House. This paper organizes the situation of 3D model creation, as shown in Table 1.

Table 1. 3D model creation for VR system

	Reference Objects	3D Model	Rendering Effects
Wall			
Pavilion			

3.5. Experimental results

This paper formulates the experimental value, as shown in Table 2.

Table 2. The experimental values of client information output intensity

Input amount of material HLA information (× 10^7 MB)	Host side information input intensity (θ_1)	
	Experimental	Control
1.5	6.7	4.8
3	6.7	4.8
4.5	6.8	4.8
6	6.7	5.0
7.5	6.6	5.0
9	6.9	5.0
10.5	6.7	5.0
12	6.7	5.2
13.5	6.8	5.2
15	6.7	5.3

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According to the experimental results, with the increase of the input of material HLA information, the relationship between the host and the client shows different trends. The e_1 index of the experimental group increased first and then stabilized, while the e_1 index of the control group increased first, then stabilized, and then continued to rise. This shows that the experimental group is more stable in information output, while the control group has a certain volatility.

4. Conclusion

Through the experimental research on the VR system of the HLA of "Yu Garden", this paper discusses the impact of the amount of material HLA information input on the information transmission between the host and the client. The experimental results show that with the increase of the amount of material HLA information input, the experimental group and the control group show significantly different trends in the intensity of information output(e_1). Firstly, the host side information input intensity (θ_1) of the experimental group remained relatively stable, while the control group showed greater volatility. The e_1 index of the experimental group increased first and then tended to be stable in the process of increasing the input, indicating that the experimental group can effectively adapt to the increased amount of data and maintain a high stability when processing information. The experimental results verify the stability and efficiency of the "Yu Garden" VR system under the large amount of data input, especially in the aspect of information interaction and output, the experimental group system shows better stability and performance.

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