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Design of an Interactive Cultural Heritage Platform for the Hulusi Based on Virtual Reality Technology and Its Application in Traditional Chinese Music and Art Culture

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SUMMARY: *This study analyzes the impact of haptic interaction on the dissemination of cultural information and investigates the feasibility of virtual reality technology for cultural dissemination. Additionally, based on SMPL interaction technology, a dynamic character model was designed for virtual scenes. Additionally, a virtual reality-based interactive cultural heritage platform for the Hulusi instrument was developed, with interactive functions designed across four key areas: virtual exploration, model interaction, message interaction, and panoramic image interaction. The platform was applied to the dissemination of traditional Chinese music and cultural arts, with an analysis of the impact of virtual reality technology on its dissemination. Respondents rated the openness, timeliness, social nature, and anonymity of virtual reality technology above 4 points, indicating its high feasibility in cultural dissemination. When the key point accuracy threshold was set to 0.2, the average accuracy rate of user labeling for dynamic characters generated by the SMPL method reached 95.36%, indicating good character generation effects at this threshold. The platform's interactive modules significantly influence users' emotional experiences, and users expressed high satisfaction with the platform's effectiveness in promoting traditional music and art culture. Only 5.91% to 18.90% of respondents indicated dissatisfaction or strong dissatisfaction with the survey dimensions. Users reported the highest satisfaction with the platform's interactivity, and most users expressed willingness to recommend the platform to friends for use.*

KEYWORDS: *virtual reality technology; SMPL technology; dynamic character design; interactive platform; traditional music culture*

1 Introduction

Virtual reality (VR) technology refers to a computer-generated technology that directly imparts visual, auditory, and tactile sensations to participants and allows them to interactively observe and manipulate a virtual world [1]. In recent years, VR technology has gradually entered fields such as education and training, cultural entertainment, and various museum and exhibition displays, and is now widely influencing our lives [2]. Music culture is an important component of traditional Chinese culture and an indispensable part of its inheritance and development.

Currently, integrating traditional music art culture with VR technology has become a new trend in the “creative transformation and innovative development of Chinese civilization” [3]. By utilizing VR technology to innovate the expression forms of traditional music art culture and infuse them with new contemporary significance, this not only facilitates the inheritance

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and development of traditional music art culture itself, revitalizing it with new vitality, but also promotes the dissemination of traditional music art culture, inspiring the public to engage with, understand, and embrace China's outstanding traditional music art culture [4-6].

Currently, the application of VR technology in China remains relatively limited, particularly in the field of integrating this technology with traditional art forms, where there is a lack of relevant research. However, a review of the literature on this technology reveals that research on VR technology and Chinese traditional art and culture does exist. For example, Hu, X, et al. proposed a method for creating a virtual ceramic cultural space model based on VRML, which combines traditional ceramic culture with virtual reality and explores its interactivity and performance in network applications [7]. Way, D, and Wei, Y developed a cloud-based VR system for multi-user applications in Chinese puppet theater performances, aiming to enhance the aesthetic appeal of traditional art, provide an entertaining experience for audiences, and protect and preserve traditional intangible cultural heritage [8]. Wang, Y, and Hu, X conducted research that deeply explored the application of VR technology in Wu Opera art culture and creative product development, with a focus on visual imagery and interactive elements to enhance people's understanding and appreciation of Wu Opera art culture [9]. Through the application of VR technology and its integration with traditional cultural arts, Chinese traditional culture is combined with advanced social technology, driving the continuous development of Chinese traditional culture [10].

Traditional art and culture are widely disseminated through VR technology and the internet, completely breaking free from the geographical and spatial constraints that traditionally bound them, allowing an increasing number of people to immerse themselves in the charm of traditional cultural arts [11, 12]. Zhang, L, and others addressed the issue of disseminating Dongyang bamboo weaving art by proposing and evaluating a virtual reality experience system for Dongyang bamboo weaving based on VR technology. They demonstrated the system's effectiveness in creating an immersive and interactive learning environment that promotes the widespread dissemination and sustainable development of traditional art and culture [13]. On the other hand, Ch'ng, E., et al. delved into the impact of VR technology on intangible cultural heritage in their special topic, finding that the technology's key value lies in its ability to provide people with interactive experiences of past cultures, which holds significant importance for the sustainable protection of traditional culture [14]. By integrating various cultures with VR technology and internet technology, the efficiency of dissemination has been enhanced, breaking through the limitations of traditional dissemination methods and speeds [15, 16]. It has also enhanced the aesthetic appeal of traditional art and culture, making Chinese culture more widely appreciated by the general public [17].

This paper is based on virtual reality technology and SMPL interactive technology, designing an interactive cultural heritage platform information framework for the Hulusi and dynamic character models, and further constructing the platform's content, visual, and interactive sections. In the interaction module, a guide function has been added to improve the platform's operability and assist users in virtual exploration. Using software such as 3DMax, the platform achieves Hulusi model modeling, material selection, and model rendering to enhance the authenticity of the interaction experience. The platform's dissemination effectiveness in traditional Chinese music and art culture is evaluated through literature review, field investigation, questionnaire survey, and data statistical analysis methods.

2 Research Methods

(1) Literature Review Method

The literature review method involves collecting and reading relevant literature to understand the latest developments in related research, thereby gaining a specific and clear understanding of the research subject. This study collected and reviewed domestic and international literature on cultural dissemination under virtual reality technology, summarized and evaluated the current state of cultural dissemination, and laid the foundation for research on the application of music art.

(2) Field Research Method

This study spans two major fields: traditional music and film culture, and virtual reality technology. Through field research, we gained an in-depth understanding of the cognitive and emotional attitudes of audiences for traditional music and virtual reality, directly interacting with interviewees to obtain firsthand data on the current state of traditional music culture dissemination. During the investigation, we learned about the application of virtual reality technology, visited virtual reality experience rooms, and experienced virtual reality user interactions.

(3) Questionnaire Survey Method

A questionnaire is a form of questions used for surveys and statistics. This study adopted a combination of interviews and questionnaires to analyze the dissemination effects of virtual reality technology in traditional music culture. The study primarily measured the characteristics of traditional music audiences and their attitudes toward traditional music, using gender, occupation, and age as variables for sampling, and conducted descriptive statistical analysis of virtual reality's intervention in traditional music dissemination.

(4) Data Statistical Analysis Method

This method can effectively explore the quantitative relationships between research objects, thereby better understanding their interactions, patterns of change, and development trends, and more accurately explaining and predicting them. This study aims to analyze the valid sample data collected from the survey and use SPSS software to conduct a systematic analysis of the collected questionnaire data, scientifically and accurately evaluating the validity and reliability of the questionnaire items.

3 Research on the impact of sensory interaction on communication effectiveness

3.1 Mechanisms of Cultural Information Dissemination Promoted by Sensory Interaction

Gesture-based interaction technology influences audience cognition in the following ways, thereby affecting the effectiveness of information dissemination:

1) In the process of cultural information dissemination, the use of gesture-based interaction methods enables natural interaction, aligning user behavior and awareness, challenging skills to a certain level, and creating an immersive experience. Natural interaction also helps reduce cognitive load, enabling users to concentrate their attention, which in turn facilitates information transmission and understanding.

2) Cognition stems from sensory experiences, which are the result of the interaction between the body and the environment. Gesture-based interaction technology enables audiences to interact with the environment. On one hand, the perceptual experiences generated through interaction can help users understand abstract concepts. On the other hand, abstract concepts can be understood through the concrete concepts corresponding to the perceptual experiences generated by interaction, using metaphorical methods.

3) The senses involved in information reception are multidimensional. The stronger the

relevance between information received by different senses, the higher the quality of the information transmitted. Conversely, the weaker the relevance between information received by different senses, the lower the quality of the information transmitted.

3.2 Feasibility Analysis of Cultural Communication Under Virtual Reality Technology

Virtual reality platforms leverage new internet technologies to serve as emerging media for cultural development, offering features such as openness, timeliness, interactivity, social connectivity, and anonymity compared to traditional media. These characteristics can also be leveraged as advantages in cultural dissemination. Therefore, this study employs a questionnaire survey to analyze the feasibility of art and cultural dissemination under virtual reality technology. A survey was conducted with 50 participants, including experts in cultural communication research, university faculty and students, as well as members of the general public. The Likert five-point scale method was used to measure participants' recognition of the openness, timeliness, interactivity, social nature, and anonymity of virtual reality technology in cultural communication. Higher scores indicate higher levels of recognition.

The results of the survey on the recognition of various dimensions are shown in Figure 1. The data in the figure indicates that the scores for all dimensions exceed 3 points. Specifically, the average recognition scores for the openness, timeliness, interactivity, sociality, and anonymity of virtual reality technology in cultural dissemination are 4.83, 4.42, 4.69, 4.12, and 4.26, respectively. Among these, openness and interactivity received higher recognition from the respondents. Openness can be considered the foundation of virtual reality technology, manifesting in two aspects: the openness of the communication framework and the openness of the communication process. Compared to traditional methods, virtual reality can leverage the convenience of network technology to update information on the cutting edge of art and culture in real time. Interactivity can be considered the most important feature of cultural communication under virtual reality. Traditional mass communication is a highly one-way communication activity. Although feedback can be provided through hotlines, messages, etc., during the communication process, such feedback is often not timely and has low interactivity. Through virtual reality technology, users can immerse themselves in the journey and development of culture, send feedback to communicators in real-time via online messages, and fulfill their information-sharing needs through functions like sharing, commenting, and liking. Comprehensive analysis shows that cultural dissemination under virtual reality technology has good recognition across various survey dimensions, indicating its feasibility for cultural dissemination.

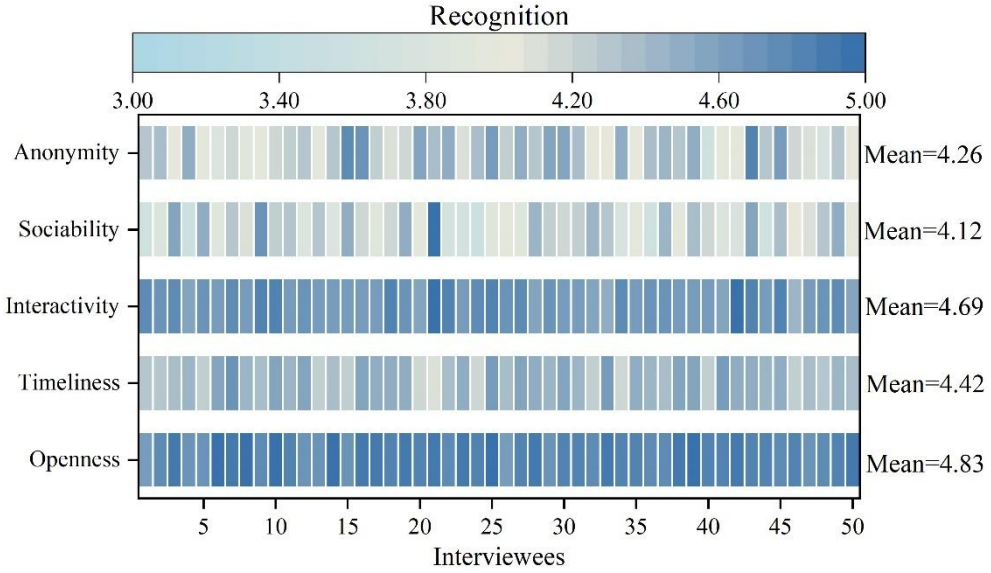

Figure 1: The results of each dimensional recognition survey

4 Three-dimensional reconstruction and interaction technology for dynamic human targets

4.1 SMPL

The Skinned Multi-Person Linear Model (SMPL) is a vertex-based skinned character model. Its goal is to create highly realistic animated human models that can represent different body shapes, deform naturally with posture, exhibit soft tissue changes like real humans, and be compatible with existing rendering engines [18-20]. The specific processing steps for the SMPL model are shown in the formula:

$$M(\beta,\theta) = W(T_P(\beta,\theta), J(\beta), \theta, W) \tag{1}$$

$$T_P(\beta,\theta) = T + B_S(\beta) + B_P(\theta) \tag{2}$$

The entire model includes the average template state in the standard T-pose represented by a mesh consisting of $N \in \mathbb{R}^{3N}$ vertex given in the initial state, skinning weights $\mathcal{W} \in \mathbb{R}^{N\times K}$, shape mixing functions $B_s(\beta): \mathbb{R}^{|\beta|} \mapsto \mathbb{R}^{3N}$, input shape parameter vectors, and output mixed shapes that shape the target body. Function for predicting joint positions: $J(\beta): \mathbb{R}^{|\beta|} \mapsto \mathbb{R}^{3K}$. Pose mixing deformation function $B_p(\theta): \mathbb{R}^{|\theta|} \mapsto \mathbb{R}^{3N}$, which takes pose parameters as input, explains the effect of pose on the model shape.

SMPL quantifies the transformation of different-shaped human models relative to the average template model as three-dimensional offsets of the model surface mesh vertices. The three-dimensional offsets can be obtained through the shape blend deformation function B_S and input shape parameters $\vec{\beta}$. B_S is a linear function of $\vec{\beta}$:

$$B_S(\vec{\beta}; S) = \sum_{n=1}^{|\vec{\beta}|} \beta_n S_n \tag{3}$$

where $\vec{\beta} = [\beta_1, \ldots, \beta_{|\vec{\beta}|}]^t$ and $|\vec{\beta}|$ represent the number of linear shape coefficients, and S_n denotes the orthogonal principal components of shape displacement. Let $S = [S_1, \ldots, S_{|\vec{\beta}|}] \in \mathbb{R}^{3N \times |\vec{\beta}|}$ be the matrix of all shape displacements. $B_S(\vec{\beta}; S)$ is entirely dependent on matrix S, which is trained during the subsequent learning process.

Define $R: \mathbb{R}^{|\vec{\theta}|} \mapsto \mathbb{R}^{9K}$ as the mapping of rotation angle $\vec{\theta}$ to rotation matrix $\exp(\vec{\omega})$. The SMPL skeleton framework has 24 joints, 23 joints, and the vector length of $\mathbb{R}^{|\vec{\theta}|}$ is 23×9=207. SMPL defines pose blending deformation as a linear relationship with $R_n(\vec{\theta}) - R_n(\vec{\theta}^*)$, where $\vec{\theta}^*$ represents the static pose parameters. $R_n(\vec{\theta})$ represents the nth element of $R(\vec{\theta})$, which is the offset relative to the vertices of the static template:

$$B_P(\vec{\theta}; \mathcal{P}) = \sum_{n=1}^{9K} (R_n(\vec{\theta}) - R_n(\vec{\theta}^*)) P_n \tag{4}$$

Hybrid deformation $P_n \in \mathbb{R}^{3N}$ is another vector of vertex displacement. $\mathcal{P} = [P_1, ..., P_{9K}] \in \mathbb{R}^{3N \times 9K}$ is all attitude hybrid deformation. $B_P(\vec{\theta}; \mathcal{P})$ is uniquely determined by $\mathcal{P}$.

Different human body shapes have different joint positions. Each joint can be represented as three-dimensional coordinates in a static attitude. SMPL defines joints as functions of shape parameters:

$$J(\vec{\beta}; \mathcal{J}, \overline{T}, S) = \mathcal{J}(\overline{T} + B_S(\vec{\beta}; S)) \tag{5}$$

Among these, $\mathcal{J}$ is the matrix that converts the vertices of the mesh in the resting pose to the joint positions in the resting pose.

The pose of the model can be defined by a standard skeleton, and the skeleton tree can be quantitatively described as the axis angle representation of the relative rotation angle of the joint node relative to its parent node. The SMPL skeleton tree contains 24 nodes, each with 3 values, and the pose parameters consist of 72 parameters. Let $\overline{\omega} = \frac{\vec{\omega}_j}{\| \vec{\omega}_j \|}$ represent the unit rotation axis. The axis angle representation of each joint node is converted to a rotation matrix using the Rodrigues formula:

$$\exp(\vec{\omega}_j) = I + \hat{\omega}_j sin(\| \vec{\omega}_j \|) + \hat{\overline{\omega}}_j^2 cos(\| \vec{\omega}_j \|) \tag{6}$$

In the above equation, $\hat{\omega}$ is the antisymmetric matrix of the three-dimensional vector $\overline{\omega}$, and I is the 3×3 identity matrix. The standard linear skinning function $W(\overline{T}, J, \vec{\theta}, \mathcal{W}): \mathbb{R}^{3N \times 3K \times |\vec{\theta}| \times |\mathcal{W}|} \mapsto \mathbb{R}^{3N}$ takes the mesh vertices $\overline{T}$, joint positions J, pose parameters $\vec{\theta}$, and skinning weights W at rest as input and returns the vertex information for a specific pose for each vertex $\overline{t}_i$ in $\overline{T}$:

$$\overline{t}_i^{'} = \sum_{k=1}^{K} w_{k,i} G_k^{'}(\vec{\theta}, J) \overline{t}_i \tag{7}$$

$$G_k'(\vec{\theta}, J) = G_k(\vec{\theta}, J) G_k(\vec{\theta}^*, J)^{-1} \tag{8}$$

$$G_k(\vec{\theta}, J) = \prod_{j \in A(k)} \begin{bmatrix} \exp(\vec{\omega}_j) & j_j \\ \vec{0} & 1 \end{bmatrix} \tag{9}$$

Among these, $w_{k,i}$ is an element of the mixed weight matrix $\mathcal{W}$, representing the extent to which the rotation of skeleton k affects vertex i. $\exp(\vec{\omega}_j)$ is the local 3×3 rotation matrix corresponding to joint j, $G_k(\vec{\theta}, J)$ is the world transformation of joint k, and $G_k'(\vec{\theta}, J)$ is the world transformation after eliminating the transformation caused by the static pose. Each 3-dimensional vector corresponding to the center of a single joint j in J is represented as j_j. $A(k)$ denotes the ordered set of joint ancestors of joint k. To ensure compatibility with existing rendering engines, SMPL assumes that $\mathcal{W}$ is sparse, allowing a maximum of four joints to influence a vertex.

The SMPL model cannot model detailed information such as clothing or head details. To enable SMPL to represent such details, additional bias values $D \in \mathbb{R}^{3N}$ are added to the SMPL model to represent the details:

$$T(\theta, \beta, D) = T_\mu + B_s(\beta) + B_p(\theta) + D \tag{10}$$

4.2 Virtual Character Generation Effects

To further evaluate the practicality of the dynamic character construction method proposed in this paper, 30 users were invited to participate in a survey experiment, with each user required to complete 20 sets of experiments. For each dynamic character synthesis result image, users dragged and dropped markers on the interface to indicate the positions they believed the various keypoints should occupy. The purpose of this experiment was to verify whether the dynamic character results generated by the method proposed in this paper exhibit good part recognizability, i.e., whether the character's posture and various body parts can be effectively identified.

By recording the user's marking results and comparing them with the true values, the Euclidean distance of each corresponding joint point in the image space is calculated, and the key Point accuracy rate (PCK) index is used to measure the proportion of joint points that are correctly marked. PCK calculates the percentage of joint points whose normalized distance error between the predicted joint point results and the corresponding true values is less than the set threshold. It is a commonly used joint point detection and evaluation index in human pose recognition. In this experiment, the pixel length of the person's head in the image is used as the data normalization reference, and PCK@0.2 indicates that the error does not exceed 20% of the person's head length.

The PCK evaluation results for different body parts at different thresholds are shown in Figure 2. It can be seen that when the PCK threshold is 0.2, the average accuracy of user annotations can reach 95.36%. For specific body parts, the accuracy rates are also satisfactory. Among them, for regions with clear boundaries and easy recognition, such as the head, shoulders, wrists, knees, and ankles, their accuracy rates are all above 95.0%. The hip, unlike the limbs, does not have a strong correspondence with the human silhouette, and most experimental participants lacked sufficient understanding of human skeletal structure, leading to unclear recognition of its position and resulting in lower user-labeled accuracy rates. However, overall, the results of this user survey experiment indicate that the interactive poses

of the virtual characters generated by the method proposed in this paper have high recognizability, and different limb regions can be correctly identified, thereby demonstrating that the generated results are in line with expectations.

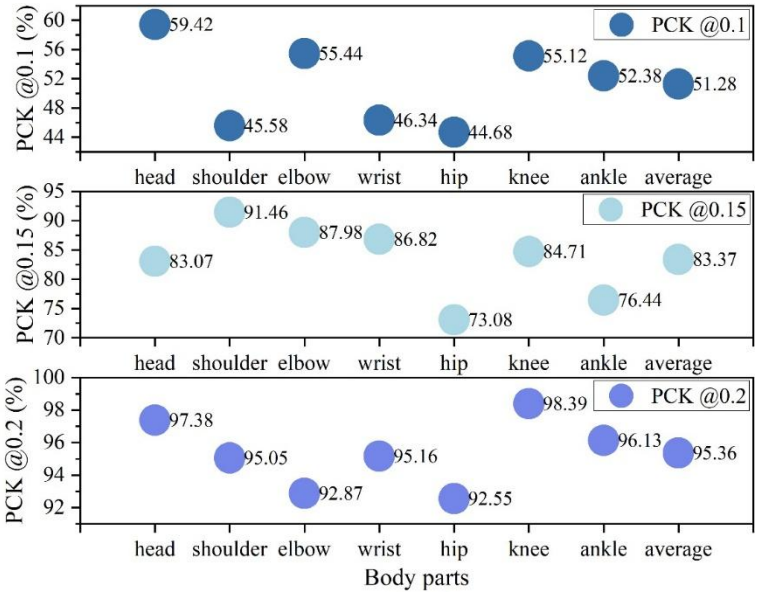

Figure 2: The PCK assessment of different body parts under different threshingvalues

5 Building a virtual reality-based interactive cultural platform for the Hulusi

5.1 Platform Information Architecture

Through research on the origin, development, craftsmanship, and performance activities of the Hulusi, as well as a survey of users' expectations for the platform, an interactive cultural heritage platform for the Hulusi was designed. The overall information architecture is shown in Figure 3.

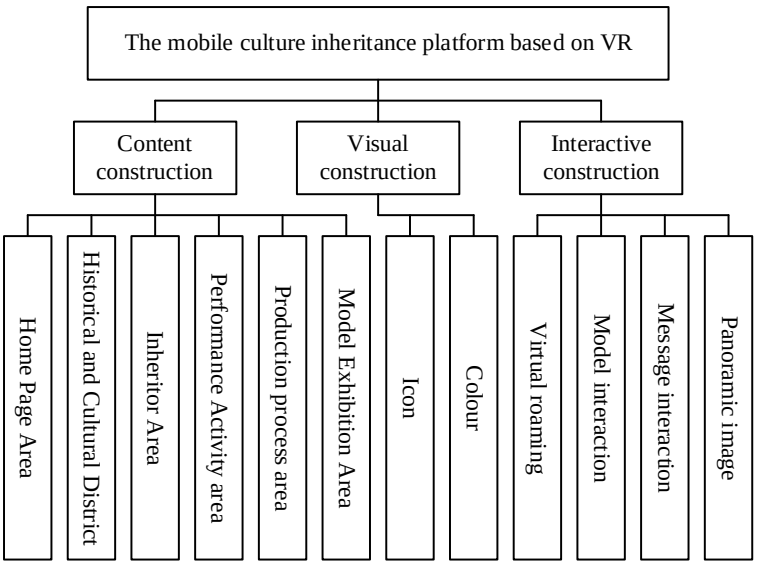

Figure 3: Platform information architecture

5.2 Content Construction

The six content dissemination zones of the Hulusi Interactive Cultural Heritage Platform (Virtual Exhibition Hall) are arranged in sequence in terms of spatial layout, starting from the homepage zone and ending at the model display zone. The spatial layout is shown in Figure 4.

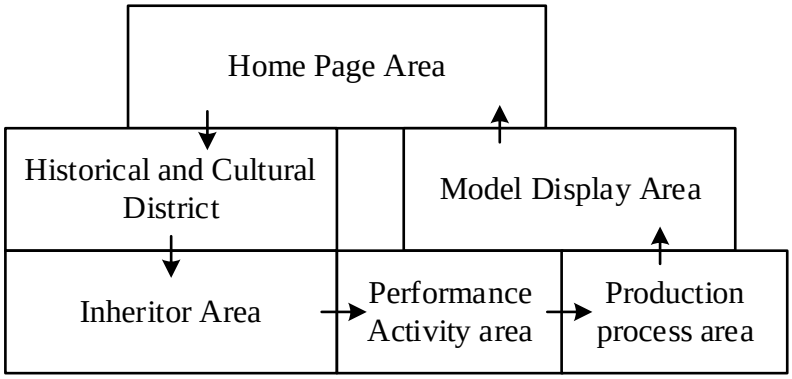

Figure 4: Spatial layout of the exhibition area for the communication platform

(1) Home Page Area

The home page area serves as the gateway to the Hulusi Interactive Cultural Heritage Platform. When users access the platform via a mobile device or PC by clicking on the link or scanning the QR code, they are greeted with an icon design reflecting the unique characteristics of Hulusi culture, accompanied by an introductory animation. After familiarizing themselves with the specific operations, users can enter free exploration mode by operating the virtual keyboard on the mobile device.

(2) Historical and Cultural Zone

Based on field research and data analysis, the historical and cultural exhibition zone is divided into multiple content modules to showcase historical and cultural elements according to the cultural characteristics of the Hulusi.

(3) Heritage Bearers Zone

The Heritage Bearers Zone uses VR interaction and digital information resources to allow users to gain a deeper and more detailed understanding of how heritage bearers protect and promote the Hulusi, thereby enhancing users' immersion and sense of presence while browsing the platform.

(4) Performance Activity Zone

In the dissemination platform, the Performance Activity Zone primarily presents digital information about Hulusi performances. When users open the VR panoramic video for each performance, they can not only enjoy the performance up close but also view it from all angles and perspectives.

(5) Manufacturing Process Zone

The Manufacturing Process Zone primarily showcases the rolling techniques used in Hulusi production. Each technique is introduced with detailed digital information, including text, images, audio, and video.

(6) Model Exhibition Area

The Model Exhibition Area is dedicated to showcasing 3D models of the Hulusi. The 3D models in this area were created using image materials provided by the Hulusi Heritage Center and three-dimensional scanning software to obtain the physical object's three-dimensional data, ensuring the highest level of realism and alignment between the virtual model and reality.

5.3 Visual Construction

(1) Use of Color

In terms of color selection, certain colors from the Hulusi were extracted, and the colors most closely aligned with the Hulusi's visual appearance were selected as the primary color scheme for the platform. The Hulusi's colors are primarily red and yellow, with black and gold as accent colors. Colors have emotional connotations, and different colors evoke different psychological associations and emotional responses.

(2) Icon Design

Icons are the first visual symbols users encounter on the Hulusi digital platform, so they must align with the platform's overall design style. Therefore, the Hulusi dissemination platform icon design uses red as the background color and yellow as the primary color tone.

5.4 Platform Interaction Functionality Construction

The core of the interactive implementation of the Hulusi Interactive Cultural Heritage Platform is to build a virtual scene on a PC platform and design functions within the scene that enable physical sensory interaction with users. The design flowchart for the interactive functions of the Hulusi Interactive Cultural Heritage Platform is shown in Figure 5.

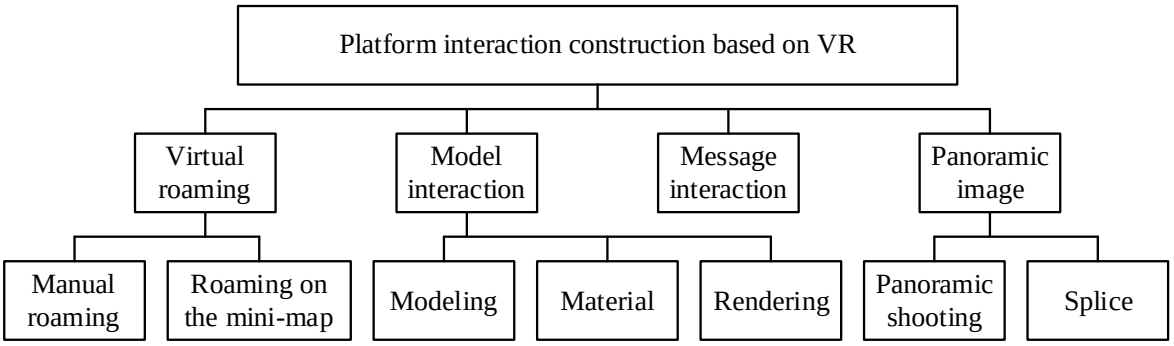

Figure 5: Flowchart of Interactive Function construction

5.4.1 Virtual Roaming

The VR-based Hulusi Interactive Cultural Heritage Platform is designed based on a guided navigation concept, integrating user needs to create a manual control exploration feature. Manual exploration allows users to independently explore the content displayed and disseminated within the platform's 3D scenes or its interesting designs after initially familiarizing themselves with the entire digital platform through the mini-map and operation guidelines. During the development of manual exploration, a guided navigation function was incorporated to enhance the platform's user experience. In the Hulusi Interactive Cultural Heritage Platform, the guide function uses arrow prompts to guide users' actions, enabling them to comprehensively browse the platform's content and engage in interactive behaviors with the content.

5.4.2 Model Interaction

The virtual space users enter is created using modeling software. The steps for creating the Hulusi model are as follows:

(1) Modeling: First, collect the three-dimensional data of the Hulusi object and draw a plan view and three-view diagrams to establish the preliminary design plan for the model. Then, create the model according to the design requirements. This is done in the three-view interface

of 3DMax software, where rotation and scaling operations are performed to further inspect the modeling results.

(2) Materials: After completing the construction of the Hulusi model in 3DS MAX, material selection and texture mapping must be applied to the model. Open the material editor in 3DS MAX software and select the material spheres corresponding to the Hulusi model. Then, based on the different properties of various parts of the Hulusi, process some textures in Photoshop software to enhance the realism of the Hulusi model.

(3) Rendering: After applying textures to the Hulusi model, rendering is required. Rendering enables the model to achieve a realistic visual effect.

5.4.3 Message Interaction

The specific method of interactive messaging is as follows: when users are browsing Hulusi content, they can click on the flashing area of the content, and a message button will pop up at the top of the page. Users can then post messages according to their own needs and wait for others to reply.

5.4.4 Panoramic Image Interaction

The digital virtual exhibition hall for the Hulusi features panoramic images in some of its photo and video displays, enabling a 360-degree surround view of the videos and images. The creation of panoramic images involves the following three steps:

(1) Shooting panoramic images

Panoramic photos and videos are captured using specialized VR panoramic cameras. When selecting equipment, the Insta360 camera is recommended. During the panoramic shooting process, choose a relatively open shooting environment and set up shooting markers to avoid interruptions caused by the movement of unrelated personnel during the shooting process.

(2) Panoramic image stitching

Panoramic images differ from traditional flat images in that they break the dimensionality of flat space and produce “three-dimensional” images. After shooting, the footage must be stitched together. For stitching software, Adobe's Premiere Pro CC is recommended. Its advantages include good compatibility with shooting materials and user-friendly operation.

(3) Interactive elements in panoramic images

Add interactive trigger points to panoramic images. Panoramic images offer a comprehensive, visual, and intuitive experience. Interactive hotspots enhance and amplify this experience, breaking the limitations of pure playback and viewing.

6 Research on the effectiveness of traditional music art culture dissemination

6.1 Analysis of the impact of interactive experiences on the emotional experiences of user groups

This section explores the interactive emotional experiences provided by virtual reality platforms for their user communities. During the questionnaire survey, five projects were selected: “I feel the atmosphere of traditional music and art culture,” “I believe it helps me understand related traditional music and art culture knowledge,” “As a descendant of the Chinese nation, I feel very proud,” “I feel as though I am attending a live traditional music art performance in person,” and “I believe that an online cultural exhibition hall can replace a physical exhibition hall” (designated as N1-N5, respectively) to investigate users' emotional experiences regarding the

interactive cultural heritage of the Hulusi on virtual reality platforms. A chi-square test (cross-analysis) was conducted on the emotional experiences of respondents based on their interactive participation. The results indicated that whether respondents participated in the interaction had a significant effect on these five emotional experiences ($p<0.05$), revealing a significant difference.

The analysis results for non-interactive user groups and emotional experiences are shown in Figure 6. The analysis results for interactive user groups and emotional experiences are shown in Figure 7. It can be seen that whether respondents participated in interactions had a significant effect ($p<0.05$) on these five emotional experiences, indicating a significant difference. For items N1-N4, by comparing the percentage differences, it can be seen that after interacting, the proportions of respondents who selected "strongly agree" were 70.48%, 38.43%, 26.37%, and 9.86%, respectively, which were significantly higher than the proportions of those who did not participate in interaction (15.06%, 12.00%, 26.37%, and 9.86%), all showing statistical significance at the 0.01 level ($p = 0.000 < 0.01$). For item N5, statistical significance was also observed at the 0.01 level ($p = 0.000 < 0.01$). Through percentage comparison, it was found that the proportion of respondents who selected "strongly disagree" after interacting was 48.16%, significantly higher than the proportion of those who did not participate in the interaction (28.88%).

Overall, it can be concluded that the interactive modules in virtual reality platforms have a significant impact on users' emotional experiences. Interactive respondents reported stronger emotional experiences than non-interactive respondents. However, it is worth noting that while respondents felt their emotional experiences were enhanced after engaging in interactive activities, and they felt immersed in the atmosphere of traditional music art and culture, as well as experiencing the sensation of participating in traditional music performances offline, they still believed that "online traditional music art and culture exhibition halls cannot replace offline exhibition halls."

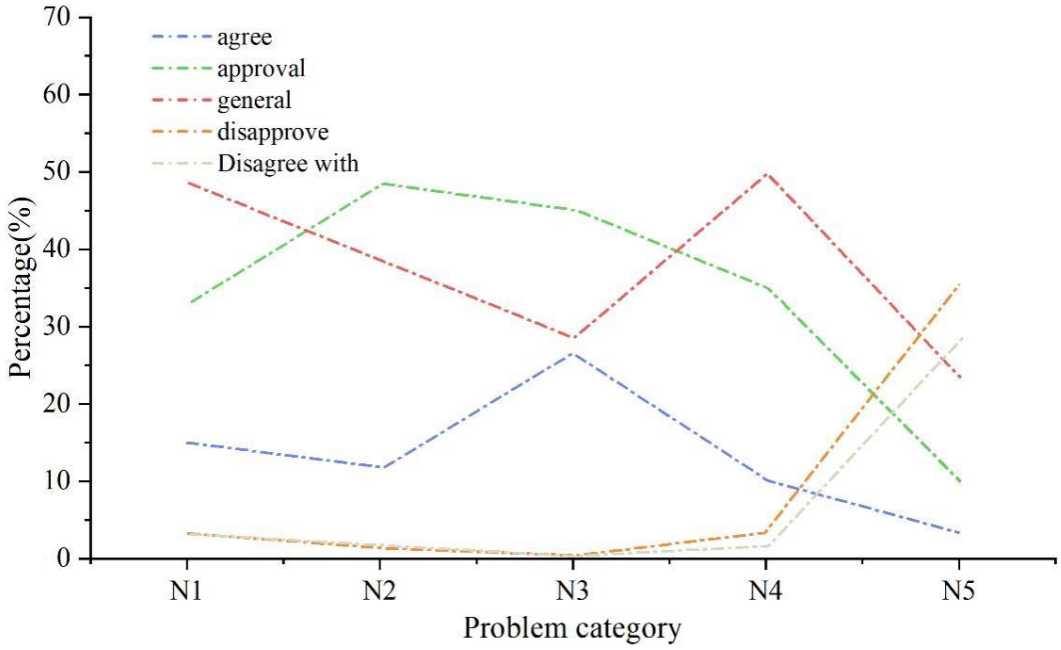

Figure 6: Analysis of non-interactive user groups and emotional experience

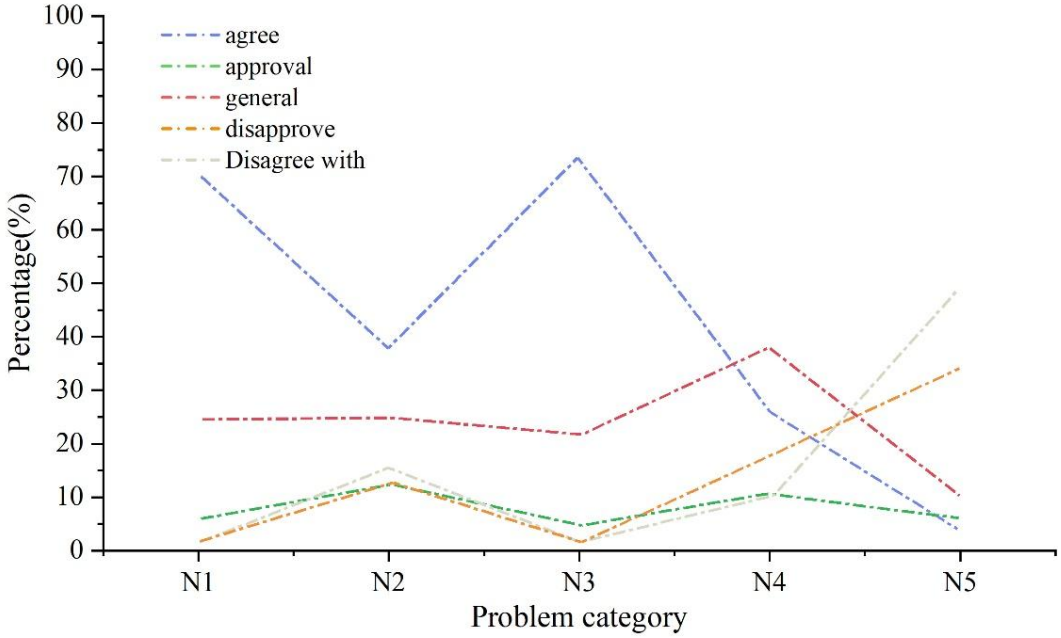

Figure 7: Analysis of interactive user group and emotional experience

6.2 Evaluation of the effectiveness of traditional music art and culture dissemination

This section investigates the dissemination effects of a virtual reality-based interactive cultural heritage platform for the Hulusi in the context of traditional Chinese music and art culture. The study includes questionnaire design and data collection and organization. After multiple revisions, the questionnaire was distributed via both online and on-site methods to assist in the investigation of traditional Chinese music and art culture dissemination. A total of 273 questionnaires were distributed, with 254 valid responses, yielding a validity rate of 93.04%. According to big data platforms, the age distribution of individuals searching for traditional music primarily ranges from 28 to 70 years old, and the age distribution of respondents in this questionnaire also falls within this range. Therefore, the survey results are based on the 28 to 70 age group. Occupational categories were divided into six groups: students, civil servants, business managers, professional technical personnel, self-employed individuals, and private business owners.

To assess the comprehensive impact of traditional Chinese art and culture dissemination, five dimensions were designed for research: exhibition zone accessibility, promotional effectiveness, content fidelity, interactive experience, and brand positioning. The aim was to understand the impressions virtual reality platforms create for traditional music art, attitudes toward digital exhibitions, whether cultural dissemination meets various needs, and audience satisfaction levels. Figure 8 shows the results of respondents' satisfaction with the cultural dissemination effects of traditional music art under virtual reality platforms. According to the data, only 33 people (12.99%) expressed strong dissatisfaction or dissatisfaction with the digital exhibition hall for traditional music, while 178 people (70.08%) expressed satisfaction or strong satisfaction. In terms of promotional effectiveness, 13.78% of respondents expressed strong dissatisfaction or dissatisfaction, while 72.44% expressed satisfaction or strong satisfaction. The highest proportion of respondents were very dissatisfied or dissatisfied with the content fidelity, at 18.90%, while the satisfaction level for this dimension was 54.72%. Over 80% of respondents were satisfied or very satisfied with the cultural interaction experience on the platform, with the highest proportion of respondents, while only 5.91% of respondents were

very dissatisfied or dissatisfied. Regarding the image positioning of traditional music and art culture, a small number of respondents expressed dissatisfaction or very dissatisfaction with the image presented by the platform, while the vast majority expressed satisfaction. Overall, respondents were generally satisfied with the experience of traditional music and art culture on the virtual reality platform, demonstrating good dissemination effects.

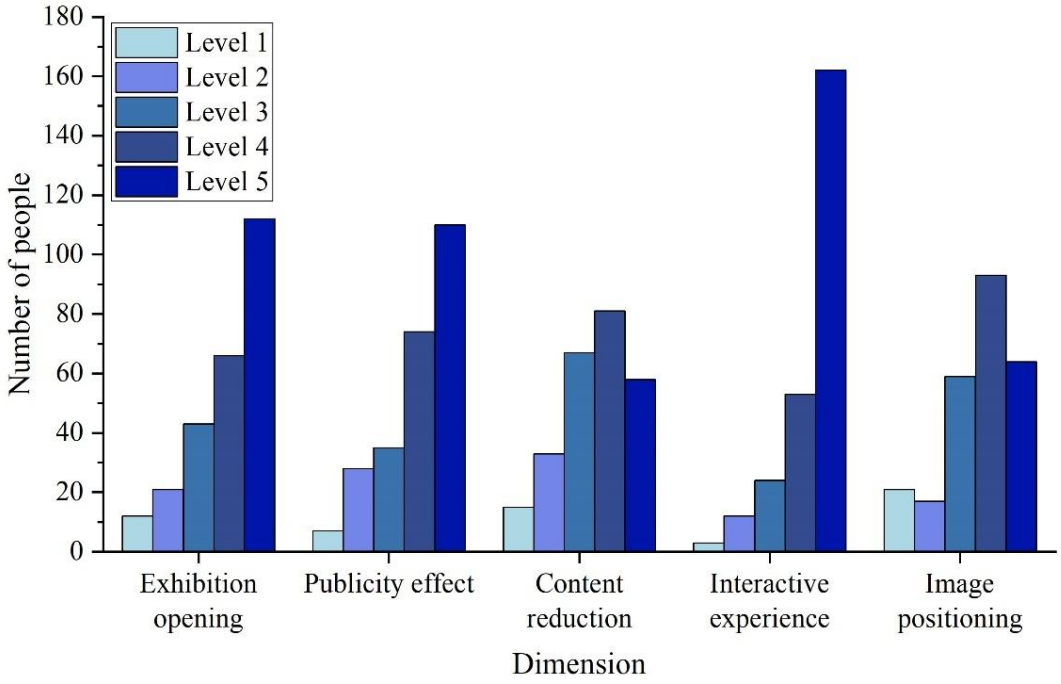

Figure 8: The satisfaction of the traditional music art culture propagation effect

6.3 Interactive Virtual Reality Platform User Satisfaction Survey

From the above application research, it can be seen that the interactive cultural heritage platform based on virtual reality technology has achieved initial success in the protection and dissemination of traditional music and art culture, and has been recognized by the interviewees. After another round of optimization measures and publicity for the platform, satisfaction questionnaires were distributed to various universities to obtain specific feedback, observing college students' satisfaction with the platform and their understanding of traditional music and art culture.

This satisfaction survey was primarily conducted at a music college in a certain city, focusing on two dimensions. A combination of paper-based and online questionnaires was used, with 200 valid questionnaires collected. Among the valid questionnaires, 97 were completed by male students and 103 by female students. Consistent with the previous section, the Likert 5-point scale was used to indicate users' level of agreement, with Level 1, Level 2, Level 3, Level 4, and Level 5 representing completely disagree, mostly disagree, unsure, mostly agree, and completely agree, respectively. The relevant information was entered into the Questionnaire Star software to obtain the following data and conclusions. The specific content and survey results for each dimension are as follows:

Dimension 1: Satisfaction with platform sections and related content

Q1: I frequently use this platform.

Q2: I really like this platform.

Q3: I find the Hulusi culture embedded in the platform very interesting.

Q4: I find the platform's interactivity very good.

Q5: I am very satisfied with the design of the various sections of the platform.

The results of Dimension 1 of the questionnaire are shown in Table 1. Based on the data proportions in the table, it can be seen that while the Hulusi interactive cultural heritage platform sections and related content based on virtual reality technology have not received complete approval, they have been recognized by the majority of platform users. Regarding the interactive experience of the platform design (Q4), 75% of users indicated full satisfaction. However, in terms of platform usage and promotion (Q1), a small number of users indicated room for improvement, with only 65 users frequently using the platform.

Table 1: Questionnaire dimension 1 answer question

	Level 1	Level 2	Level 3	Level 4	Level 5
Q1	8 (4%)	15 (7.5%)	39 (19.5%)	73 (36.5%)	65 (32.5%)
Q2	2 (1%)	4 (2%)	21 (10.5%)	64 (32%)	109 (54.5%)
Q3	0 (0%)	2 (1%)	32 (16%)	55 (27.5%)	111 (55.5%)
Q4	0 (0%)	0 (0%)	18 (9%)	32 (16%)	150 (75%)
Q5	0 (0%)	0 (0%)	7 (3.5%)	64 (32%)	129 (64.5%)

Dimension 2: Perceived Benefits of Using the Platform and Willingness to Share it with Others

Q6: This platform has given me a detailed understanding of Hulusi culture.

Q7: This platform has left me with a deeper impression of Hulusi culture and sparked my interest in it.

Q8: Through using this platform, I want to learn more about Hulusi culture.

Q9: I believe this platform plays a positive role in the protection and dissemination of traditional music and cultural arts.

Q10: I am willing to recommend this platform to my friends.

The results of Dimension Two of the questionnaire are shown in Table 2. From the data in the table, it can be seen that the Hulusi interactive cultural heritage platform based on virtual reality technology has enabled the majority of users to understand the related culture of the Hulusi, thereby deepening their impression of Hulusi culture and sparking interest in it among many users. Furthermore, over 80% of users believe that this platform has played a positive role in the protection and promotion of traditional music and cultural arts, and are willing to share this platform with more people to learn about traditional music and cultural arts together.

Table 2: Questionnaire dimension 2 answer question

	Level 1	Level 2	Level 3	Level 4	Level 5
Q6	1 (0.5%)	4 (2%)	43 (21.5%)	55 (27.5%)	97 (48.5%)
Q7	0 (0%)	0 (0%)	52 (26%)	67 (33.5%)	81 (40.5%)
Q8	0 (0%)	0 (0%)	28 (14%)	67 (33.5%)	105 (52.5%)
Q9	0 (0%)	0 (0%)	8 (4%)	31 (15.5%)	161 (80.5%)
Q10	0 (0%)	0 (0%)	19 (9.5%)	47 (23.5%)	134 (67%)

7 Conclusion

The article explores the feasibility of virtual reality technology for cultural dissemination and evaluates the effectiveness of virtual dynamic character generation based on SMPL interaction technology through research experiments. Based on this, a virtual reality interactive cultural heritage platform for the Hulusi instrument was designed. The platform's information

architecture is divided into content, visual, and interaction modules, with each module working synergistically to significantly enhance the depth, breadth, and effectiveness of cultural dissemination. A case study of the platform's application in traditional Chinese music and art culture was conducted, using methods such as questionnaire surveys to evaluate users' interaction experiences, cultural dissemination effects, and platform satisfaction. The feasibility indicators for virtual reality technology in cultural dissemination, such as openness and timeliness, scored between 4.12 and 4.83, demonstrating good application value. The dynamic characters generated by SMPL technology achieved the highest user-marked accuracy and optimal generation effects when the keypoint accuracy threshold was set to 0.2. The platform's interaction module significantly enhances users' cultural emotional experiences. Most respondents expressed satisfaction or high satisfaction with the evaluation metrics for traditional music cultural dissemination under the virtual reality platform, with only 5.91% to 18.90% of respondents indicating dissatisfaction or high dissatisfaction. 75% of users found the platform's interactivity to be very good, and over 80% believed the platform plays a positive role in cultural preservation and dissemination, resulting in high platform satisfaction.

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