Ice and Snow Culture Animation Character Design Based on Virtual Reality Technology and 3D Design

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Abstract. This study delves into the application and innovation of ice and snow culture character modeling based on virtual reality technology and 3D design in the field of 3D virtual animation design. The study first outlined the characteristics of ice and snow culture and its expression in animation character design, followed by a detailed introduction to the methodology of character painting and modeling, including multi primary color analysis of character painting and the process of character modeling based on virtual reality technology. Through simulation experiments and modeling effect analysis, this article evaluates the accuracy and effectiveness of design implementation, and proposes specific optimization strategies for identifying problems. The research results indicate that virtual reality technology has significant effects on improving the realism, interactivity, and immersion of 3D animation character design, and is of great significance for promoting the innovative dissemination of ice and snow culture and the development of virtual animation technology.

Keywords: Virtual reality technology; 3D design; Ice and snow animation; Character design

1. Introduction (Heading 1)

The ice and snow culture originates from the interaction between the natural environment in cold regions and human society, demonstrating a profound philosophy of harmonious coexistence between humans and nature. Its uniqueness is not only rooted in regional natural conditions, but also deeply influenced by the local social and historical development, thus giving birth to a rich and diverse cultural form. The core characteristics of ice and snow culture are reflected in its unique artistic expression, festival celebrations, folk activities, etc. At the same time, this cultural form has uniqueness in aesthetic emotions, spiritual sustenance, and social memory. Ice and snow, as a material form in nature, are transformed into symbols carrying profound cultural significance and social value in ice and snow culture. In the field of animation character design, the introduction and innovative application of ice and snow cultural elements not only enriches the expressive techniques of visual art, but also brings a unique aesthetic experience to global audiences. By finely capturing the delicate emotions and deep meanings of ice and snow culture, animation creation can transcend cultural and regional boundaries and resonate with the audience. The combination of this culture and modern technology not only promotes the dissemination and

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international exchange of ice and snow culture, but also gives it new vitality, demonstrating the possibility of cultural innovation and inheritance[1].

The embodiment of ice and snow culture in animation character design showcases a unique visual and emotional charm, creating character images with profound cultural connotations and artistic value by integrating ice and snow elements into character shapes, personalities, story backgrounds, and other aspects. These characters often draw inspiration from myths, historical stories, and natural landscapes in ice and snow culture, showcasing the purity, resilience, and mysterious beauty of ice and snow, while also embodying people's reverence and love for nature. In terms of personality shaping, animated characters from ice and snow culture often possess decisiveness, courage, and perseverance, reflecting the ways people living in ice and snow environments respond to natural challenges. In addition, the storyline of these characters often involves exploration, survival, and adventure in ice and snow environments, which not only enriches the storytelling of the animation, but also provides viewers with a way to experience the charm of polar culture through artistic works[2].

2. Data modeling

2.1 Structure of Character Painting and Modeling System

In 3D virtual animation design, the system structure of character painting and modeling reflects the integration of digital information technology and virtual reality technology, promoting a qualitative leap in 3D animation design technology. As shown in Figure 1, the system focuses on motion capture, virtual animation character painting, and 3D model design, achieving a high degree of integration between animation character painting and modeling. Through the combination of VR virtual technology and 3D design technology, viewers can experience real and vivid animated characters, enhancing the three-dimensional sense and vividness of animation design, and enhancing the user's sense of participation and real experience[3].

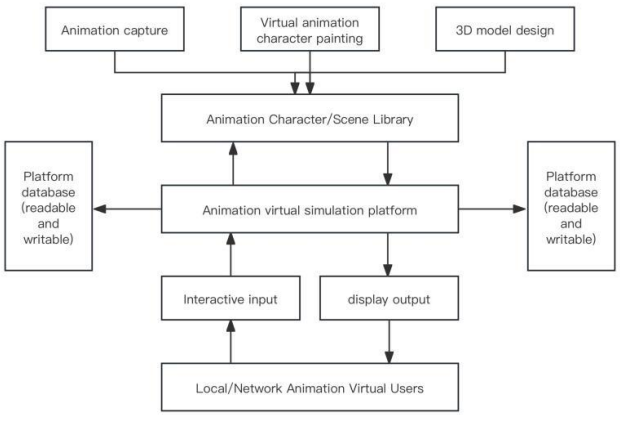

Figure 1 Structure of 3D Virtual Animation Characters and Modeling System

2.2 Analysis of Multiple Primary Colors in Animation Character Painting

The basic structure of animated characters describes their main motion framework and serves as the starting point for their effective action performance. Taking a character as an example, the drawing of its basic structure not only requires precise capture of the character's dynamic form, endowing it with rich emotions and diverse actions, but also requires detailed depiction of facial features such as eyebrows, eyes, and mouth, as well as dynamic capture of body, arms, legs and other limbs, to reflect the character's personality traits and emotional state. In addition, the design of the basic structure also needs to consider the positioning and motion trajectory of the character in three-dimensional space, ensuring the natural smoothness and realism of its actions, and providing a solid foundation for subsequent color filling and detail rendering[4].

The selection and application of colors, through careful blending, can silently tell the story and guide the audience's emotional flow. For animated characters, color is not only a part of their visual expression, but also an intuitive reflection of deep cultural connotations and personality traits. When designing colors, it is crucial to consider the coordination between the overall color of the character and the key characters[5]. This not only requires a profound understanding of color theory, but also the ability to flexibly apply color psychology to construct the emotional atmosphere and personality characteristics of the character through elements such as color temperature, saturation, and brightness. In addition, the application of color also needs to consider the depth and spatial sense of the three-dimensional image. Through color contrast and transition, the three-dimensional and dynamic beauty of animation can be enhanced, making the characters more vivid, thereby enhancing the visual experience and deepening the audience's emotional investment in the characters[6].

The action drawing process not only requires precise capture and representation of the character's action form, but also requires a high degree of coherence and natural fluency in the animation. This stage uses motion capture technology to obtain accurate data on various dynamic forms of the character, so that every action of the animated character can be presented in a way that is as close to reality as possible. In the process of action painting, animators need to comprehensively consider the physical characteristics, action logic, and emotional expression of characters to ensure that their actions are not only visually attractive but also emotionally resonant with the audience. Special attention should be paid to the transitions between actions to ensure the smoothness and consistency of the animation, thus avoiding any unnatural or fragmented movements that the audience may experience during the viewing process[7].

2.3 Structural feature analysis

In 3D virtual animation design, the structural feature analysis of ice and snow culture character modeling based on virtual reality technology and 3D design is the cornerstone of the modeling process. This analysis process involves a deep understanding of the rules and irregular structural features of animated characters. The role modeling of rule structures is relatively straightforward, with clear logic in its design and implementation process, making it easy to quickly and accurately complete modeling tasks[8]. In contrast, modeling roles with irregular structures requires higher technical accuracy and creativity to ensure the accuracy and vividness of the model. This process not only requires designers to have solid 3D modeling skills, but also requires them to have a deep understanding of the characteristics of characters in ice and snow culture, integrate these cultural elements into character design, and make the final animated

characters not only visually attractive, but also resonate with the audience at the cultural level. In addition, structural feature analysis provides important references for character action design and environmental interaction, ensuring the naturalness and rationality of character behavior, further enhancing the immersion and expressiveness of 3D virtual animation.

2.4 Modeling methods and processes

In the document "Character Painting and Modeling in 3D Virtual Animation Design", the calculation formula for animation character modeling is used as the basis to provide a quantitative understanding of the complexity in the process of animation character painting and modeling. Firstly, the structure of animated characters is defined and expressed as a set

$$P = \left\{ X, T, Jc, \mathrm{Rel},\ \mathrm{So},\ , S_{tri} \right\}$$

Among them, X and T represent different elements in the virtual environment and the relationship operators between elements, and represent the conceptual hierarchy and non clustering relationships between different elements, and represent the existing ontology prototypes and intrinsic correlations of elements, respectively. In addition, a calculation method for sensitivity index was proposed to evaluate the sensitivity of model feature elements, with the formula:

$$\mathrm{Sensitivetime} = \left\{ \mathrm{attribute\_of}\left(\mathrm{X}_1, \mathrm{X}_2\right), \mathrm{compose\_of}\left(\mathrm{X}_1, \mathrm{X}_2\right), \mathrm{effect\_of}\left(\mathrm{X}_1, \mathrm{X}_2\right) \right\}$$

And using maximum mean square error to determine the threshold of sensitivity index $Threshold_{sensitivetime}$, This provides a quantitative analysis tool for 3D virtual animation design, enhancing the scientificity and accuracy of the design process.
In the determination stage of the modeling method, the analysis of the Poisson distribution sorting waiting phenomenon based on the flicker frame rate is adopted, which helps to optimize the load distribution and processing efficiency of the model during the transfer of animated characters to 3D modeling software[9].

During animation transmission or rendering, if events (such as frame display) occur randomly at a certain average rate, then this situation can be described by Poisson distribution. The mathematical expression for a Poisson distribution is usually:

$$P(k;\lambda) = \frac{e^{-\lambda}\lambda^{k}}{k!}$$

Among them, P is the probability of observing K events within a given time interval, γ It is the average occurrence rate (i.e. expected value), e is the base of natural logarithms (approximately equal to 2.71828), K! Represents the factorial of K.Through this method, while ensuring the efficiency of model construction, it also ensures the high-quality and high-definition performance of the model.

In terms of optimizing animation effects, especially when dealing with the sensitivity index of animated characters, the following calculation is used for public display[10]:

$$\mathrm{Sensitivetime} = \left\{ \mathrm{attribute\_of}\left(\mathrm{X}_1, \mathrm{X}_2\right), \mathrm{compose\_of}\left(\mathrm{X}_1, \mathrm{X}_2\right), \mathrm{effect\_of}\left(\mathrm{X}_1, \mathrm{X}_2\right) \right\}$$

This algorithm helps to finely adjust the performance of animated character models based on their specific attributes, combinations, and effects, in order to achieve the best visual effect. The threshold of sensitivity index is determined through the maximum mean square error algorithm, which further enhIn the process of modeling ice and snow cultural characters through the integration of virtual reality technology and 3D design, the calculation formulas and algorithm optimization of key links play a core role. Especially in structural feature analysis and sensitivity index calculation, precise mathematical models and algorithms are used to guide and optimize the design process[11].

3. Design of Virtual Simulation Platform

The design of a virtual simulation platform, as the ultimate stage of 3D virtual animation design, not only reflects the cutting-edge application of virtual reality technology, but also marks a comprehensive upgrade of 3D animation design from concept to implementation. The virtual simulation platform constructed using virtual reality technology (VR) provides users with an unprecedented visual experience through its high interactivity and immersion, perfectly combining the artistic creativity and technological innovation ability of modeling ice and snow cultural characters.

As shown in Figure 2, the platform mainly consists of cluster simulation and network communication modules, simulation core working modules, 3D max modeling output modules, etc. Among them, the simulation core work module serves as the heart of the platform, responsible for handling complex data operations and image rendering, ensuring that animated characters in the virtual environment can be presented with high realism and fluency. With the support of cluster simulation and network communication modules, the platform can achieve efficient data processing and transmission, ensuring stable operation and high-speed response of large-scale virtual scenes.

In addition, the virtual simulation platform also provides users with the possibility of interacting with three-dimensional virtual characters. Through highly realistic visual, auditory, and even tactile feedback, users can communicate and interact with characters as if they were in a real world of ice and snow. This unique experience not only enhances the dissemination effect of ice and snow culture, but also opens up new paths for the application of virtual reality technology in art creation and cultural inheritance. Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you[12].

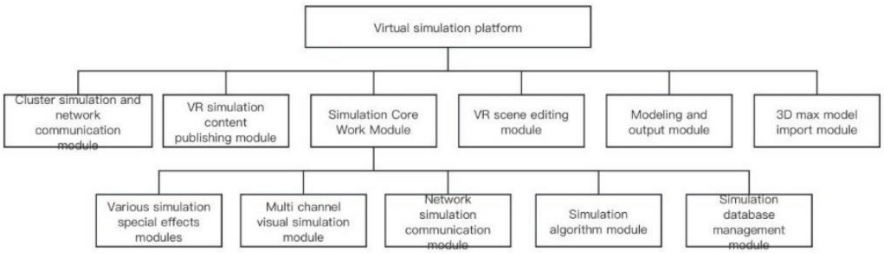

Figure 2 Design Block Diagram of Virtual Simulation Platform

4. Simulation

4.1 Painting and Model Building Testing

In the experimental verification stage of 3D virtual animation design, a series of refined methodologies were adopted for painting and model construction testing, aiming to ensure that the model construction of animated characters achieves optimal accuracy and realism through quantitative and qualitative comprehensive evaluation. In this process, advanced numerical analysis techniques were used to determine the geometric accuracy. By comparing with the original design parameters, the deviation value of the model was accurately calculated to ensure a high degree of consistency between the shape of the model and the design intention. In terms of accuracy evaluation of textures and textures, image processing algorithms have been introduced to analyze the resolution and color reproduction of textures, thereby ensuring the detailed expressiveness of character skin and clothing. In the dynamic simulation stage, a physics engine and motion capture data are used to simulate the dynamic behavior of the character. By comparing the simulation results with actual physical behavior, the naturalness and realism of the actions are evaluated. The testing of lighting and shadow effects relies on ray tracing technology, simulating the impact of different environmental light sources on character modeling, to ensure the realism and artistry of lighting and shadow effects. Finally, through user experience testing, collect feedback from the target audience on the interactivity and immersion of the character model, further optimize the character design from a user centered perspective, and ensure that the final outcome can meet or even exceed expected standards in artistic expression and technical implementation. This comprehensive testing methodology not only reflects the scientific and innovative nature of 3D virtual animation design, but also provides valuable theoretical and practical references for subsequent research.

4.2 Analysis of modeling effect

A three-dimensional animated character design project with the theme of ice and snow culture was conducted to analyze the modeling effect. The specific numerical values and analysis results of the test are as follows:

Table 1 Descriptive Statistical Analysis Table

Evaluation dimension	design goal	experimental result	deviation	Optimization suggestions
Geometric accuracy	≤ 2%	2.5%	0.50%	Adjust modeling parameters and refine detail processing flow
Texture Resolution	4096x4096 pixels	2048x2048 pixels	Resolution decrease	Update texture resources and adopt higher resolution images
Fluency of movements	30fps	25fps	-5fps	Optimize animation algorithms to reduce the computational complexity of complex actions
Lighting effect	Natural lighting simulation	Partially too bright or too dark	Uneven distribution of light	Adjust light source settings and increase ambient light compensation
User Experience	90%	80%	-10%	Enhance interactive design and improve user interface

This set of simulation data reflects the common problems and challenges that may be encountered in 3D animation character design projects with ice and snow culture themes. By comparing the design objectives and experimental results, specific optimization directions can be identified, such as fine-tuning geometric accuracy, improving texture resolution, optimizing motion fluency, adjusting lighting effects, and improving user experience. Each optimization suggestion aims to address specific issues identified during the testing process to ensure that the final animation product can achieve or exceed design goals, meeting the audience's expectations for high-quality 3D virtual animation.

5. Conclusions

Exploring the modeling of ice and snow culture characters based on virtual reality technology and 3D design reveals the infinite potential of technology and art integration, while highlighting the innovative regeneration of ice and snow culture in the field of digital media art. This study not only improves the accuracy and interactivity of animation design through meticulous modeling and simulation experiments, but also provides a new platform for the global dissemination of traditional culture, endowing it with cross generational value。

Acknowledgment: This study emphasizes the complementary relationship between technological innovation and cultural heritage. The application of virtual reality technology not only greatly enriches the expressive power of 3D animation design, but also opens up new avenues for the modern dissemination and innovation of traditional culture, such as ice and snow culture. With the continuous progress of technology and its deepening in innovative applications, it is expected that 3D virtual animation design will further promote the display of cultural diversity and international cultural exchange.

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