



Application of Virtual Reality Technology in Sculpture Art

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Abstract. With the rapid development and application of digital technology, it has become a normal phenomenon to use different types of new media and emerging technologies to create sculptures. The rapid development of today's sculpture art is closely related to the vigorous technological innovation behind it. Therefore, the integration of modern technology and sculpture art is an inevitable trend. How to apply virtual reality technology to sculpture art performance has also attracted the attention and attention of many artists. Based on this, this paper introduces the advantages of applying virtual reality technology in sculpture creation, analyzes the influence of virtual reality characteristics on sculpture, and puts forward a concrete application method of interactive sculpting modeling with mesh deformation in virtual space, hoping to provide reference and help for the combination of virtual reality and sculpture art.

Keywords: virtual reality · sculpture art · sculpture modeling

1 Introduction

The emergence of virtual reality technology and its popularization and application in many fields have had a great impact on the existing art forms, and promoted the innovation of various art forms from the outside to the inside. As a kind of art, sculpture is bound to be affected. Virtual reality technology was originally a computer technology developed by the US military. It was gradually popularized in the 1960s and used as military simulation. It was not until the end of the 20th century that it became a relatively sound system that people paid attention to. Virtual reality has different influences on different kinds of art. Compared with other kinds of art, sculpture is characterized by its rich disciplines, easy reproduction, three-dimensional, spatial and open interpretation, which makes the virtual reality technology have a deeper influence on it, involving the definition of sculpture's own concept, formal language and communication efficiency. Virtual reality technology is directly involved in other disciplines related to sculpture in terms of technology, and has different influences on the creation, material processing and expression of sculpture. Therefore, how to reasonably apply virtual reality technology in sculpture art has become the focus of many creators' exploration and research [1].

2 Advantages of Applying Virtual Reality Technology in Sculpture Creation

2.1 Extension of Digital Sculpture Creation

Virtual reality technology can link up with the current creation situation of digital technology. The technical method of “digital sculpture” was first put forward in 1990, and it has been more than 30 years since then, and it has been widely used in sculpture production. However, nowadays, the application of digital sculpture is limited to the production of traditional sculpture and body enlargement, or independent creation still needs to rely on 3D printing technology for printing, and the spatial structure design needs to adapt to the characteristics of realistic sculpture. Digital sculptor Zhang Sheng’s work “The Myth of Hades and Persephone” is completed by digital modeling software, and then presented by 3D printing. Virtual reality glasses or augmented reality devices enable viewers to enjoy works directly in the virtual space, and the specifications of works in the virtual space are not restricted. At the same time, the application of virtual space technology can effectively link up the works in the production stage, and the development of virtual technology is also linking up the modeling software [2]. For example, AnnaZhilYaeva, a virtual reality artist, uses virtual reality glasses and other equipment to paint directly in the virtual space and display it directly in virtual reality, without using 3D printing or CNC engraving, breaking many restrictions and constraints. Virtual reality exists not to simulate reality, but to surpass it. This feature is also applicable to sculpture. That is, sculpture art realizes the freedom of creation through virtual reality technology.

2.2 Expansion of Traditional Sculpture Creation Methods

Virtual reality can effectively combine with the physical sculpture creation mode and expand the physical sculpture, but this application mode needs to be discussed in the



Fig. 1. The combination of virtual reality and sculpture art

light of the current development situation. Physical sculpture creation usually cooperates with virtual reality, showing the effect of semi-virtual and semi-physical. For example, in the work “Companion’s Journey”, based on the giant Buddha in Bamiyan, Afghanistan, which was destroyed by the Taliban, the author used high-power laser projection equipment to restore the state of the giant Buddha before it was destroyed (as shown in Fig. 1). If we don’t consider the influence of other factors, add digital modeling, and then use the stereoscopic image projected by virtual reality, the real effect will be better and more ideal [3].

3 The Historical Background of the Combination of Virtual Reality and Sculpture Art

3.1 The Continuous Development of Art in the Computer Age

At the end of the 20th century, with the development of art, science and technology media began to be widely used in the field of art practice, and the boundary between science and art became increasingly blurred, and the integration of the two was also widely valued by people. Under the background of the information age, digital integration is a new stage of artistic thinking. Digital technology serves as a media mechanism to realize the integration of art, and it has infinite development potential, even beyond people’s imagination. Digital technology can summarize all existing new media technologies, including movies, videos and videos. The possibility of digital travel processing is also endless. In computers, images are transformed into information, and information can be processed and manipulated in computers. Therefore, after any graphic is converted into information, it becomes the information unit of the database, which is the potential resource of art. The artist experimented with this technique to process and modify his works. Not only has the update and popularization of computer technology created a refreshing computer art for people, but the rapid development of Internet technology has also set up a new exhibition platform for art. With the development of network technology, the field of artists’ activities has further expanded, even from real life to virtual reality. The entertainment factors of interactive art in the Internet have been further strengthened, and its popularity has also developed, because anyone can get involved in art in some way. The emergence of virtual reality technology provides a brand-new creative space and way for sculpture artists [4].

3.2 The Objective Needs of the Audience

With the popularization of computer technology, the forms of artistic creation and presentation are more abundant, and the intangible digital virtual reality expands the scope of visual experience. Virtual reality not only expands the scope of human experience, but also causes great impact on consumers’ vision. Nowadays, photography, television and other mass media are beginning to permeate our daily life, and human beings have higher requirements for art figuration. The integration of painting, architecture, handicrafts and other artistic methods with virtual reality has become an inevitable trend, and sculpture art is naturally among them. With the development of science and technology, the traditional artistic language has shown signs of weakening, and new aesthetic standards

have been established. Consumers of digital sculpture art in the era can no longer satisfy the traditional sculpture art, and they tend to browse all kinds of works of art at home. Therefore, the integration of sculpture art and virtual reality is not only the demand of art development, but also the demand of consumers. In virtual reality, sculpture works are no longer “dead things” in a static state, but “living things” that can be operated, such as shrinking, enlarging, rotating, or even separating and merging, which makes the interaction between consumers and artists’ papers more sufficient [5]. The sculpture art in virtual reality is an open art, which provides people with more space for imagination and negotiation. In addition, consumers not only seek visual stimulation, but also may want to add other sensory stimulation such as taste and hearing, which can also be met through virtual reality.

3.3 The Artist’s Active Exploration

In the artistic practice of various high-tech media, works full of vitality are works that combine technical strength with artists’ creative wisdom, which proves that artists have enough ability and wisdom to apply this new media, and technical language can accurately express artists’ thoughts. In sculpture, a traditional media art, artists choose and transform the display media independently, and their ideas and creativity occupy a dominant value. In this relationship, artists are usually in a passive position, but this does not affect artists’ view of constantly innovating technology as a language for expressing art. They can try to show their thoughts more freely and fully and show the spirit of the times through the integration of advanced technology and art forms. Although they always think and practice traditional artistic expression, art and other things must have the times.

Virtual reality has contributed to the image age, and at the same time increased the research content of sculpture art. Before the application of virtual reality technology, the artist’s creative focus was on how to fully show the author’s thinking connotation in a specific environment through traditional three-dimensional entities, but there was little understanding about the integration of virtual reality technology and sculpture art. Nowadays, however, the research on the integration of virtual reality and sculpture art has attracted the attention and attention of many creators, such as whether artists can integrate hearing and vision in the process of sculpture creation, what are the characteristics of image world composition in virtual reality, and what is the relationship between the space established in virtual reality and real space [6]. Because of the complex three-dimensional structure of the real sculpture art itself, artists need to provide ideas and help for the further development of virtual reality technology.

4 The Influence of the Characteristics of Virtual Reality on Sculpture

4.1 Immersion Builds the Relationship Between Sculpture Creation Space, Experience and Time

One of the most obvious characteristics of virtual reality technology is immersion, and the most obvious feeling of immersion is the expansion of space and the difference of

experience. Audiences are more inclined to the specific spatial structure in the real space. In the spatial structure, audiences can get feelings by contacting sculptures, for example, touching the physical objects in the real space-walls, which can't be circumvented, but can be circumvented in the virtual space. Although the wall surface is information data derived from computer simulation, the immersion of virtual reality simulates the real environment, and the contents felt by sight, hearing and touch seem to be real. Because the brain doesn't care whether what it sees and hears is real or not, thinking can't be separated from virtual reality.

In fact, the technical application of sculpture art is the author's understanding and grasp of the real space. It is very important for the sculptor to sensitively grasp and design the distance, angle and position between the audience and the sculpture, and to make clear the size and state of the space occupied by the sculpture and the emotional feelings that the audience will have. In virtual reality, people know that all scenes and sculptures are the result of computer rendering, but this immersive reality can still deceive the brain and various senses. Some scholars believe that digital media can not only simulate the visual experience of human eyes, but also simulate the high-risk perspective that breaks the visual experience of reality by combining with the accuracy of digital algorithms. Using the high-risk perspective, we can do behaviors that can't be done in reality, such as folding, enlarging and penetrating, etc. The author can sculpt some objects that don't exist in reality in the virtual space, or arbitrarily switch the environment, so that time and space show disorder and randomness. In this way, we can infinitely expand the thinking of sculpture creators, change their traditional creative experience, and improve their new understanding and knowledge of sculpture art. At the same time, it also means that the composition medium of sculpture creation has undergone a qualitative change, and this influence will be sustained in the future creation.

4.2 Imagination Enriches the Imaginative Thinking of Sculpture Creation

The emergence of virtual technology is the key node of the extension of human imagination. The research and development of virtual technology provides a new way for human beings to know things, which makes human beings break the boundary between time and space, go through the events that have occurred or have not yet happened in the world, and make human beings enter the macro or micro world to conduct research, or accomplish some realities that cannot be accomplished due to the constraints of reality. Through the above-mentioned scheme, we can expand and deepen the imaginable space of human beings and stimulate more creative thinking, and artistic creation needs rich imagination as support. Sculpture usually makes use of materials such as soil, steel or wood to make the image of people's inner thoughts abstract or artistic, while the shape in the creator's mind is produced by different people combined with personal aesthetic experience, with different shapes, which is invisible and fictitious. However, it can be displayed through imagination by the way of sculpting. The concept and thinking mode of sculpture creation are very important. In other words, artistic works are an important embodiment of the author's world outlook and outlook on life. The works displayed by different artists with the same materials are different, so sculpture is actually a reflection of the author's imagination. Virtual reality has a deepening effect on human imagination,

so the author can improve his creative ability of sculpture to create more idealized sculptures. The application of virtual technology makes the creation and display of sculpture have more unique and rich effects than the traditional sculpture [7].

5 Interactive Sculpt Modeling of Mesh Deformation in Virtual Space

5.1 Introduction of Interactive Sculpting Modeling System of Mesh Deformation in Virtual Space

Nowadays, some digital carving softwares may be able to form three-dimensional details and basic sculptures on the basis of rough models, but the two-dimensional realistic space restricts the author's feeling of the depth of sculptures and his creative ability to some extent. Based on this, this paper combined with the virtual reality environment, using the iterative process of the initial basic model to influence the region search, weighted deformation and local topology, etc., to complete the generation of sculpture images. The system takes HTC Vive helmet as the test hardware platform, uses the glasses users of the helmet and the established three-dimensional model to be in the same three-dimensional space, and uses its matching handle as input. The left hand handle is used to change the grid position and rotation as a whole, and the right hand handle represents the current position and shape of the input brush. At the beginning of the system, a total of 642 vertices and 1280 patches of spherical mesh were set up. Users can modify the surface of the initial mesh with a brush, and then form the branches and details of the model. The sculpture can be completed by several iterations.

5.2 Retrieval of Brush Affected Area Based on Space Partition

During the engraving of the existing model, that is, aiming at the area affected by the retrieval brush on the model M and iteratively deforming it, the user uses the brush to input a spherical area S , so that the center of the sphere is located at the center of the sphere $C(x_0, x_0, z_0)$ and the radius R . In order to clarify the vertex set V of the surface of M in the sphere S , it is necessary to traverse all vertices v_i above M , and calculate the distance D between v_i and point C in detail. If the value of D is less than the value of R , it is proved that v_i .

In order to speed up the timely retrieval of the vertex set V that meets the requirements, the Vive activity space can be subdivided into several subspaces U_k by using the equal space partition method, and all the grid vertices are guaranteed to be located in this subspace set U , so it is only necessary to retrieve v_i from the U_k whose center point and C distance meet the requirements. Specifically, the following methods are adopted:

First, equal space partition and grid vertex loading. If the user activity space is specified in $(x, y, z) \in [-A, A; -A, A; -A, A]$, the space grid interval is a , and the number of divided space grids is $m = 2a/a$. Divide along the three coordinate axes at equal distances to form m^3 subspace grids, $S_{i, j, k} = (x, y, z)$. In which $x \in [-A + ia; -A + (1 + i)a]$, $y \in [-A + ja; -A + (1 + j)a]$, $z \in [-A + ka; -A + (1 + k)a]$, $i, j, k = 0, 1, 2, \dots, m-1$. If the vertex of the grid contained in $S_{i, j, k}$ is $PtInGrid(i, J, K)$, for

any vertex $p(x_p, y_p, z_p)$ in the grid M , the subscript i_p, j_p, k_p of the subspace S_i, J, K to which it belongs is defined in combination with its coordinate values, and P is inserted into the corresponding $PtInGrid(i_p, j_p, k_p)$, where $i_p = \lfloor (x_p + A)/a \rfloor$, $j_p = \lfloor (y_p + A)/a \rfloor$, $k_p = \lfloor (z_p + A)/a \rfloor$ can be obtained.

Second, vertex retrieval. During the interaction, the subspace S_i, j, k that should be traversed can be found by combining the spherical center C and radius R entered by the user. The relational expression can be obtained: $i_{min} \leq i \leq i_{max}, j_{min} \leq j \leq j_{max}, k_{min} \leq k \leq k_{max}$, where I should meet the following requirements, $i_{min} = \lfloor (x_0 - R + A)/a \rfloor$, $i_{max} = \lfloor (x_0 + R + A)/a \rfloor + 1$. The following formula can be obtained by inserting a point p that meets the following conditions into $PtList(i, j, k)$:

$$p \in PtInGrid(i, j, k) \ \& \ |p - C| \leq R$$

Then the set of all points with a distance less than r from the brush is:

$$PtList = U_{i,j,k} PtList(i, j, k)$$

5.3 Local Iterative Subdivision

In order to be close to the shape of the brush input by the user, if the mesh patch is too large, it will lead to the deviation of the approximation effect of the brush. It is necessary to divide the mesh in detail according to the size of the brush to ensure a more approximation effect of the brush. Specifically, the following methods are adopted:

Firstly, a local mesh subdivision scheme based on half-edge structure. The adjacent vertices of a half of the structure are subdivided into two halves, the directions of which are completely opposite, which are the left and right planes of the side, respectively. The first-order domain process of accessing one of the vertices is shown in Fig. 2.

Assume that two halves of a certain side are H_1 and H_2 , respectively. If the threshold of network subdivision, that is, the maximum allowable side length is L_m , subdivide H_1 : let H_1 start point P_{from} , end point P_{to} and H_1 belong to the third vertex P_{tri} of the triangle. Then, the edge is deleted, and a new point V_{new} is inserted at the key position of the edge. At this moment, H_1 and H_2 and their two faces have been deleted, forming a brand-new four halves. Then, $P_{from}P_{new}P_{tri}$ and $P_{new}P_{to}P_{tri}$ are connected in sequence to form two new faces to replace the triangle to which H_1 belongs. Finally, at the same time as H_1 , do the same for H_2 . In this way, the original two larger faces are subdivided into four smaller faces, as shown in Fig. 3.

Secondly, edge length is used to constrain the iterative subdivision of unspent local grids. In order to get close to the shape of the brush, the moving speed v frame by frame



Fig. 2. One-ring field based on half-edge structure

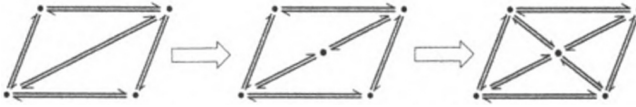


Fig. 3. Subdivision based on the longest edge mesh

is defined by combining the distance between the grid vertex p and the center point C of the brush. If the distance between p and C is d , the moving speed v is expressed as $v = (R - d)$.

Where, represents the speed adjustment factor, which can be adjusted by the user independently. The iterative subdivision process is as follows:

First, for $p \in PtList$, traverse all the relevant edges L of p , and insert all the convenience L that accords with L not lower than $L_{max} \& L \notin eList$ into $eList$, then $eList$ represents all the edges that need to be subdivided during this modification. Secondly, the $eLists$ are sorted according to the length of sides. If the $eList$ set is empty, it means that this modification is finished. Otherwise, take the longest side L_{max} , carry out a subdivision and obtain the P_{new} . If $|P_{new} - C|$ is not higher than R , traverse all sides L_{new} of the P_{new} , and insert all sides that meet $L_{new} > L_m$ into the $eList$.

This system can meet the needs of sculptors as non-professional users for the generation and editing of sculpture 3D models in the virtual environment. It places the operator and the sculpture model in the same virtual 3D space, which increases the interactivity of modeling, reduces the difficulty of manipulation, and enables artists to quickly construct complex 3D models.

5.4 Improvement of Local Grid

In order to ensure the mesh quality after subdivision and the robustness of subsequent mesh deformation, the subdivision mesh should be optimized. In this paper, the neighborhood plane fitting based on fixed point is used to optimize the newly inserted fixed point area. Specifically, the following methods are adopted:

First, the fitting of tangent plane. For all the first-order domain points $P_i(x_i, y_i, z_i)$ of point $v, i = 1, 2, \dots, n-1$, find the plane f , and get the formula: $z = a_0x + a_1y + a_2$. Is that the distance from n points to this plane has the smallest comprehensive S value, $S = \sum_{n=0}^{n-1} (a_0x + a_1y + a_2 - z)^2$, and at the same time, $\frac{\partial S}{\partial a_k} = 0, k = 0, 1, 2$ can be obtained.

The relationship can be obtained as follows: $\sum_{n=0}^{n-1} 2(a_0x_i + a_1y_i + a_2 - z_i) x_i = 0;$
 $\sum_{n=0}^{n-1} 2(a_0x_i + a_1y_i + a_2 - z_i) y_i = 0;$ $\sum_{n=0}^{n-1} 2(a_0x_i + a_1y_i + a_2 - z_i) = 0.$

The parameters of plane equation can be obtained as follows:

$$\begin{pmatrix} a_0 \\ a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} \sum x_i^2 \cdots \sum x_i y_i \cdots \sum x_i \\ \sum x_i y_i \cdots \sum y_i^2 \cdots \sum y_i \\ \sum x_i \cdots \sum y_i \cdots n \end{pmatrix}^{-1} \begin{pmatrix} \sum x_i z_i \\ \sum y_i z_i \\ \sum z_i \end{pmatrix}$$

Second, the fixed-point optimization based on the projected mean of the method. The projection of the fixed point $p(x_p, y_p, z_p)$ on the grid on the fitting plane F is $q(x_q, y_q, z_q)$, which needs to meet the following requirements:

$$z_q = a_0x_q + a_1y_q + a_2$$

In this way, the projection vector pq can be expressed as $(x_q - x_p, y_q - y_p, z_q - z_p)$, and the normal vector N of the plane F is expressed as $(a_0, a_1, -1)$. pq needs to be parallel to N , so the formula can be obtained:

$$\frac{x_q - x_p}{a_0} = \frac{y_q - y_p}{a_1} = \frac{z_q - z_p}{-1} = k$$

The data is available by calculating: $k = -(a_0x_p + a_1y_p - z_p + a_2)/(a_0^2 + a_1^2 + 1)$.

Therefore, the coordinates of the point Q can be expressed as $(x_p + ka_0, y_p + ka_1, z_p - 1)$. For the n th point, $p_i(x_i, y_i, z_i)$, $i = 1, 2, \dots, n-1$, which fits the plane, calculate its projected position $p_i'(x_i', y_i', z_i')$. At the same time, $\sum_{i=0}^{n-1} (x_i', y_i', z_i')/n$ can be obtained by calculating the average point. For the point $u(x_u, y_u, z_u)$ that needs to be smoothed at present, the projection point position $p_u'(x_u', y_u', z_u')$ can be calculated in detail, so that the projection amount: $u_u'(x_u' - x_u, y_u' - y_u, z_u' - z_u)$. Move M to the area of M' , and the smoothing of this point can be realized.

Interactive modeling system has strict requirements for the immediacy of interaction. In order to significantly improve the efficiency of the system, the acceleration effect of spatial grid division is reasonably designed, so that the larger the model drawn by the system, the smaller the brush and the larger the acceleration ratio [8]. Therefore, this system is suitable for making details of carving models. This system can meet the needs of sculptors as non-professional users for the generation and editing of sculpture 3D models in the virtual environment. It places the operator and the sculpture model in the same virtual 3D space, which increases the interactivity of modeling, reduces the difficulty of manipulation, and enables artists to quickly construct complex 3D models.

6 Conclusion

Nowadays, virtual reality technology has been widely used in various fields of sculpture art. With the development of science and technology, virtual reality technology has provided more innovative ideas in technology and thought for the development of sculpture, making the creation and presentation of sculpture have changed obviously. Based on this, creators should be clear about the advantages and functions of applying virtual reality technology in sculpture art, and enrich the creative forms and expressions of sculpture art through rational application of virtual reality technology, so as to provide new ideas for creators and continuously promote the development of sculpture art.

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