



Research on 3D Digital Ink Art

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Abstract. Ink painting belongs to the foundation of Chinese traditional art works, and in the development history of thousands of years, oriental techniques based on ink painting techniques have gradually formed. Ink painting relies on its own boldness and softness, refinement and sprinkling to draw objects and express emotions. As a unique art form in China, ink painting art is well-known at home and abroad. With the development of digital technology and science and technology, the application of 3D digital in ink painting art creation technology is becoming more and more frequent. Based on this, this paper briefly introduces ink painting art, and discusses the application of 3D digital technology in ink painting art from the aspects of contour rendering and internal rendering, so as to provide corresponding reference for the development of ink painting art in China.

Keywords: 3D digital technology; Ink painting art; Rendering technology

1 Introduction

Ink painting art is a typical representative of oriental art, and the traditional and complicated 3D digital ink painting art production technology is very unfavorable to the spread of Chinese traditional culture. If we can use the existing ink and wash works to render the works and enrich the number of ink and wash works, it will effectively solve this problem and promote the further development of 3D digital ink painting art in China. Therefore, how to apply 3D digital technology to the creation of ink painting art works has been recognized and valued by many scholars.

2 Overview of the ink painting art

2.1 Characteristics of ink painting techniques

Chinese ink painting techniques initially show the gap in the style of works. The style of ink painting works is determined by the different painting skills of painters to some extent. Chinese ink painting techniques can be basically divided into six kinds, including boneless, texturing, splash-ink, eighteen line drawings, line drawing and double hook. The specific features are as follows: Double hook, line drawing and eighteen line drawing all require only two strokes, either up and down, or left and right, to

outline the outline, or no painting is done in the middle, or no color is added, or a little light ink is added to render it; The texturing method usually needs to outline the outline and add a certain texture in the middle; Boneless and splash-ink, you don't need to use ink lines to outline the outline, just use colored brush strokes to paint, or splash ink on paper to build many full brush strokes, giving people a magnificent feeling and then forming a picture.

The differences between the above different types of techniques can be summarized as two types: sketching the outline or not sketching the outline. Based on the differences between the two types in the external and internal rendering techniques of objects, they have evolved into more diversified painting techniques, thus forming a completely different style and charm of ink painting art. Therefore, the description of the style of objects in ink painting can be expressed through the combination of outline characteristics and internal characteristics, and the internal characteristics can be further subdivided into two types, namely, splashing ink and texturing. [1]

2.2 The characteristics of ink painting brushwork

The brushwork is the skill of using a pen, which includes three parts: writing, running, and ending. It is very important and complicated in the overall ink painting art system. The brushwork used in calligraphy can be summarized into many types, such as center, slant, forward, and reverse strokes. Among them, there are three kinds of ink painting art, that is, center, slant and side. The center stroke lines are smooth, as if they have been cut by a knife, or give people a rough feeling. Slant stroke refers to the feeling that the strokes on one side of the pen tip are very smooth and flat, while the strokes on the belly side are personally uneven. Side stroke refers to a skill between the center and the slant stroke, and the final effect of stroke is also between the two. The essence of ink painting brushwork is to use lines, and lines are mainly embodied in slender strokes. The brushwork is reflected in the effect of this stroke, and its characteristics can be displayed by changing the width and texture of the stroke.

2.3 Ink color characteristics of ink painting art

China's ink painting art forms different effects through the application of ink shades, and it is the love for this simple color that constitutes the unique artistic characteristics of China's ink painting. Ink painting does not use color or less coloring, which highlights the rich performance effect of mutual penetration between ink and wash, and shows the natural interest. Ink itself recognizes color, and the change of color level can be reflected through the shade of ink color. At the same time, the ancient Chinese ink painting art thought that ink was divided into five colors, and ink was further subdivided into five levels: focus, thick, heavy, light and clear, and the colors were from deep to shallow. Therefore, from the perspective of ink effect, the change of ink color shade can be reflected by the change of stroke gray level. [2]

3 Integration of 3D Technology and Ink Style

The creation method of computer 3D ink animation is different from traditional ink animation, but the creation is still based on the style characteristics of traditional Chinese ink painting. First of all, 3D technology is applied to simulate the effect of ink painting art, and the picture emphasizes the paintability of ink, showing the characteristics of ink in the picture, such as thick, light, dry, wet and burnt, which has a very significant ink smudge effect. At the same time, 3D ink painting art also emphasizes the aesthetic feeling of artistic conception, showing a kind of meaning through abstract elements, and conveying the reality and charm of objects. As far as narrative content is concerned, ink animation often integrates Chinese traditional culture, especially the unique national spirit, and fully displays the elegant and profound temperament in Chinese classical art. 3D ink painting art is realized by computer programming, so it can form the same realistic texture and effect as a high-definition camera. The contingency of pen and ink in China and the use of computer programs are contradictions in themselves, and whether 3D ink and wash art can be realized has also attracted the attention of many scholars. When applying 3D technology to ink painting, we should pay attention to the following three contents:

First, the composition of Chinese works of art emphasizes "multi-point perspective, counting white as black", and ink painting generally adopts the way of scattered perspective, which not only has the screen space and blank for accepting the truth, but also breaks the space and blank for balancing the truth according to the composition requirements. In this regard, in the process of modeling, it is necessary to reserve enough blank space, instead of using all the pictures like ordinary 3D modeling.

Secondly, ink painting art emphasizes "modeling with lines, vivid with form", and the outline, texture and volume are satisfied by lines. Using programming to design material plug-ins compatible with MAYA. At present, the development of this type of plug-in has also produced many new uses, ensuring that the lines and color blocks of the picture have the same effect as ink painting art. [3]

Thirdly, the ink painting art emphasizes color matching and color harmony. Ink painting art does not pay attention to the limitation of cold and warm colors of light source, but pays more attention to the inherent color of the object itself, rather than the conditional color under special light, and realizes the harmony between color and object, color and line. The application of this color rule is easy to realize with 3D technology.

4 Application of ink rendering technology based on 3D digital technology

4.1 Outline rendering

Contour can effectively show the morphological characteristics of objects, which is one of the characteristics that must be drawn in most painting art creation, and plays a very key role in 3D unreal rendering. In the creation of ink painting art, it is often necessary

to outline the model, but whether it is necessary to outline the model needs to be determined according to the style of the ink painting art. If the object of interest drawn in the work does have an outline area, it is necessary to outline the 3D model based on the outline characteristics in the work, otherwise it is not necessary to render it. The specific operation process is as follows:

4.1.1 The confirmation of contour lines.

Contour refers to the set of all points whose contour is defined as the vertical relationship between the surface normal vector and the apparent vector. Take Figure 1 as an example, where the normal vector of the position of contour point X_i should be \vec{n}_i and the visual point is set to C , so the visual vector can be expressed as \vec{cX}_i .

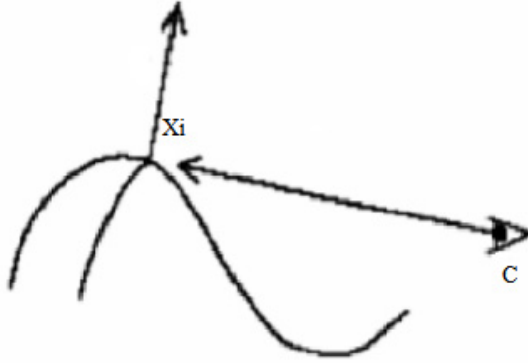


Fig. 1. Definition of contour on smooth surface

So available: $\vec{cX}_i \cdot \vec{n}_i = 0$.

For polygonal surface fragment mesh, contour refers to the set of continuous forward and backward surface edges. If the surface normal vector of the polygon is set to \vec{N} and the apparent vector is set to \vec{V} , if $\vec{N} \cdot \vec{V}$ is not greater than 0, it can be judged as a forward surface, and if it is greater than 0, it can be proved as a backward surface.

The contour search algorithm can be basically divided into two types, namely, image space detection method and object space detection method. The former is the discontinuity detection contour of the depth value of adjacent pixels. Usually, only the contour of the outside of objects, that is, the boundary between objects or between objects and background, can be detected, and the contour line of detecting the inside of no group can not be obtained. If the depth values of adjacent objects are similar, the boundary between objects may not be obtained. [4] The latter detection method actually combines the input model vertex data to confirm the contour, and then completely removes the hidden lines to obtain the final reflected contour. Because the result of image space detection method is relatively one-sided, some characteristic information data may be lost, so it is suggested to use object space detection method

to directly set the definition of contour on polygon patch grid to confirm the contour edges and put them into the set of contour edges. The specific calculation method is as follows:

Calculate the normal vectors of all patches in the model. Now let's assume that three vertices of a certain surface include $P1(x1,y1,z1)$, $P2(x2,y2,z2)$ and $P3(x3,y3,z3)$, so that the formula for calculating the normal vector $\vec{N}(xn,yn,zn)$ of this surface can be obtained:

$$\vec{N} = \overrightarrow{P_1P_2} \cdot \overrightarrow{P_1P_3} = (xn, yn, zn)$$

Where $xn = (y2 - y1) \cdot (z3 - z1) - (z2 - z1) \cdot (y3 - y1)$;

$yn = (z2 - z1) \cdot (x3 - x1) - (x2 - x1) \cdot (z3 - z1)$;

$zn = (x2 - x1) \cdot (y3 - y1) - (y2 - y1) \cdot (x3 - x1)$.

Traverse the $PiPj$ of all edges. If this edge is associated with only one patch, it can be marked as an outline edge. If there is an association between this edge and two patches, the normal vectors are set to \vec{N}_1 and \vec{N}_2 respectively, the calculation formula of visual vector \vec{V} is $\overrightarrow{CP_i}$, and C is set to visual point, so if $(\vec{N}_1 \cdot \vec{V}) \cdot (\vec{N}_2 \cdot \vec{V})$ is not greater than 0, this edge is regarded as an outline edge.

The connection between contour edges is the contour line. Define the temporary contour as deque, save the adjacent contour changes, construct the temporary contour for the first contour edge, and add the temporary contour set S . Traverse the remaining E_i . If E_i meets any contour edge at both ends of a temporary contour line in S , the E_i chain can be classified as a temporary contour line; otherwise, a new temporary contour line is established for E_i and added to S at the same time. Finally, the adjacent contour lines in S are merged, so that the summary of contour lines can be obtained. Because this algorithm directly completes the model contour rendering in 3D space, it is not necessary to test the visibility of all contours. The purpose of checking contours here is to provide corresponding reference for the process of rendering texture coordinates.

4.1.2 The generation of contour mapping texture.

It is suggested that the rendering method of two-dimensional texture mapping can be applied, and the defined mapping texture map is mapped into the three-dimensional model to produce the outline of ink painting effect. Mapping texture map requires designers to refine the texture composition of contour rules, and the mapping rules are formulated based on the concise model contour lines defined by contour points of smooth surfaces:

First, define the specifications of the mapping texture. Set the regular textures in the texture library as $T1, T2, \dots, Tn$, and the peak value of the texture height is H_{max} , and the peak value of the texture width is W_{max} . Based on this, the width of the mapped texture can be calculated, that is, $W = W_{max}$. The formula for calculating the height of the mapped texture is $H = (H_{max}/\alpha) \cdot n$, where α represents the control factor of the contour stroke width. After adjusting α , it can affect all contour textures. In the

contour drawing result, the overall width is too large, and the contour stroke width in the final drawing result will increase. If α is too large, a large area of black spots will be produced.

Secondly, the Width W_i of different types of contour textures in the contour texture library is adjusted to W by combining the mapping texture width w to obtain a brand-new contour texture T_i' , and at the same Time, the last column of pixels is engraved in the final $(W-W_i)$ column of T_i' , that is, the texture t_i is extended until it is unified with the height W . After all the contour textures are adjusted above, brand-new contour textures T_1', T_2', \dots, T_n' can be obtained.

Thirdly, an image T with a width of W and a height of H is for, and all pixels are set to white.

Fourthly, align T $[(2i-1) h/2n]-1$ from bottom to top, and T_i' s $H_i/2-1$ from bottom to top, and duplicate different pixels in T_i' to corresponding pixels in T .

4.1.3 The design of contour mapping rules.

During the design of mapping rules, the activity of defining its texture coordinates is combined with the fixed-point information on the model. For contour rendering, the texture coordinates of a fixed point are defined by using the product of the confirmed contour line with all vertices' normal vectors and visual vectors on the model. [5] The calculation method is as follows:

Firstly, the texture coordinates of the model fixed points in each contour line are defined. For the contour line S_i , a random number R is formed in $[1,n]$ to randomly select the sample texture T_r to be mapped for S_i . The corresponding texture ordinate of each point P_{ij} ($j = 0, 1, \dots, N_i$) in S_i can be determined by the following methods:

$$T(P_{ij}) = \frac{\vec{V} \cdot \vec{n}_{p_{ij}} + 1}{2n} + (r-1) \cdot 1/n$$

Where $n_{p_{ij}}$ represents the fixed-point P_{ij} normal vector, and $(\vec{V} \cdot \vec{n}_{p_{ij}} + 1)/2$ normalizes the dot product of the visual vector and the fixed-point P_{ij} normal vector. Where n represents the total amount of sample textures contained in the contour mapping texture coating, and the ordinate range of the r -th sample texture in the reflection texture map is $[(r-1)/n, r/n]$, and $t(P_{ij})$ actually maps the P_{ij} point to a certain texture unit in the r -th sample texture range, and $t(P_{ij})$ represents the width of the contour stroke that maintains a vertical relationship with the contour line. [6]

Secondly, the abscissa of P_{ij} texture at different fixed points on the contour line S_i is defined, and the change of the original pen width along the center line of the sample texture T_r is reflected in the extension direction of the contour line S_i . Accordingly, the two end points of S_i , i.e. P_{i0} and P_{iN_i} , are set, so that the abscissa of P_{ij} texture can be obtained and the following formula can be obtained:

$$S(P_{ij}) = \begin{cases} 0 \\ s(P_{ij-1}) + \frac{\|P_{ij-1}P_{ij}\|}{\sum_{k=1}^{N_1} \|P_{ik-1}P_{ik}\|} \end{cases}$$

In the above formula, $\|P_1P_2\|$ represents the Euclidean distance between P_1 and P_2 .

Thirdly, the texture coordinates of other fixed points on the model are clear. The texture coordinates of any fixed point in the model are determined by combining the texture coordinates of the contour points closest to it. Assuming that there is any point P in the model and the contour point P_{ij} with the shortest distance, the point P is mapped with the sample texture corresponding to the contour line where P_{ij} is located, and the texture coordinate is controlled by the dot product of the visual vector and the normal vector of the point, so that the texture abscissa of P_{ij} can be obtained, and $s(P)=s(P_{ij})$ can be obtained.

4.2 Rendering of internal areas

The rendering of the inner area corresponds to the painting style of the non-sketching technique in the inner target of the ink painting. In the process of painting an object, ink painting art not only needs to sketch the outline of the object to show its external physical characteristics, but also outline the internal characteristic lines to show its detailed characteristics. In order to show the texture, lighting conditions and sense of space on the surface of the object, it also needs to bridge a large area of ink, dots and dyes, so that the ink painting target has very rich ink color changes and texture distribution characteristics. Because of its obvious variability, it is impossible to simulate different types of techniques in a unified way. We can refine the features of the internal rendering method which mainly focuses on ink color change, and use the refined ink color scale factor k to render the internal region of the model according to the pixel gray information data of the model projected on the two-dimensional screen in Gouraud lighting environment.

Gouraud shading solution is carried out for the model, and the two-dimensional projection image is obtained by traditional rendering pipeline, and the internal area is rendered by the following process:

Firstly, calculate the gray histogram of the projected image, and set the obtained gray histogram as $h'=\{h'(C) = N'c|C = 0,1 \dots 255\}$, where $N'c$ represents the total number of pixels with the gray level of C . [7]

Secondly, the ink color demarcation points existing in the image, that is, the representative gray values $C1'$, $C2'$, $C3'$ and $C4'$, are calculated in combination with the ink color scale factor k_j extracted in the internal non-slender image, so as to satisfy the following formula:

$$h'(C)/\sum_{C=0} h'(C)=k_j$$

And further add two ink color dividing points, namely C0'=0 and C5'=255. Confirm that Cj' algorithm adopts the following pseudo code, that is, the total number of pixels in the image, as follows:

```
proc ComputeCj(H',kj,Cj1')
    float k=0.f;
    for(int C=Cj1';C<=255;C++)
        if(k>=k)
            break;
        k=k+h'(C)/N;
    end for
    return C;
end proc
```

Third, the ink is printed. Combined with the internal characteristics, the ink color boundary point in the calculation result and the ink color boundary point in the picture are mapped to the corresponding ink color for each pixel gray level, as shown in Table 1. [8]

Table 1. corresponds to the mapping content between ink colors

Focus	Thick	Heavy	Light	Clear
C0-C1	C1-C2	C2-C3	C3-C4	C4-C5
C0'-C1'	C1'-C2'	C2'-C3'	C3'-C4'	C4'-C5'

Fourth, filtering analysis. In order to add the hazy feeling of ink infiltration in the rendering effect, the 5*5 weighted average filtering mask shown in Table 2 is applied to perform average filtering processing on the images that have accepted ink color mapping.

Table 2. 5*5 weighted mean filter mask

1	2	3	2	1
2	4	6	4	2
3	6	9	6	3
2	4	6	4	2
1	2	3	2	1

5 Conclusions

The application of 3D digital model rendering technology in ink painting works is of positive significance for promoting the development of Chinese traditional culture. Therefore, designers should be clear about the application of 3D digital model rendering technology in ink painting art, so as to effectively improve the artistic effect of

ink painting works and promote the development and inheritance of Chinese traditional art.

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