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Analyzing the Application Effect of Abrasion Painting Technique in Lacquer Painting Art Creation Based on Three-Dimensional Modeling Technology

Meijian Wu[1,*]
[1] Academy of Fine Arts, Zhaoqing University, Zhaoqing, Guangdong, 526061, China
Corresponding authors: (e-mail: zquart@163.com).

Abstract The systematic analysis and reconstruction of the grinding painting technique promotes the digital development of lacquer painting art. This paper analyzes the structural characteristics of the mill painting technique, combines the modeling needs of regular and irregular structures, and chooses the stacking modeling method to complete the construction of the lacquer painting model. Key elements such as the superposition of lacquer layers are constructed in layers, and the visual realism of the lacquer painting model is enhanced by lighting, material and rendering techniques. For the point cloud data generated by high-precision scanning, KD tree denoising and octree downsampling algorithms are used to optimize the data quality and ensure the accurate reproduction of model details. The results show that the parameter combination of sampling points, ρ and γ is (123,500,1.2,0.10), and the deviation rate is only 4.3% while the coverage area reaches 5.597. In this paper, the stacked modeling method takes only 0.52 days to complete the 3D modeling of lacquer paintings. The modeling fidelity in all four structural features of the abrasive painting technique exceeds 95%, and the cost reduction is greater than 40% in all of them. Eight volunteers gave a score of 80 or more for the application of the 3D lacquer painting technique.

Index Terms mill painting technique, stacked modeling, KD tree; octree, lacquer painting creation

I. Introduction

Chinese lacquer painting has a long history and is an indispensable part of the history of Chinese civilization. China has long used the lacquer production process and completed the transformation of the artistic language of lacquer painting from practicality to aesthetics. How to make further breakthroughs in material, language and technique is of positive significance to the innovation and development of lacquer painting.

Technique has an irreplaceable role for a kind of painting, which constitutes a unique language system of an independent kind of painting [1]. What techniques are used in the creation of paintings, how to use the techniques, to what extent, there are studies to be explored. In the development process of modern lacquer painting, the basic technical language has become an unavoidable issue. Abrasive painting technique is a very characteristic technique of lacquer painting, which is characterized by doing "subtraction" after "addition" [2]. Abrasive painting technique is a collective term for several techniques with similar production principles. Grinding is the meaning of grinding and polishing, and painting is the meaning of adding and painting.

The focus of grinding and painting is grinding, which is a technique of using water sandpaper or other tools to polish the picture that has already been stacked with lacquer [3], [4]. The process of grinding is the process of creation, and grinding is painting, so it is named "grinding painting" [5]. The raw materials used in this technique are various colors of lacquer and various metal materials, such as gold powder, gold foil, silver powder, silver foil, aluminum powder, aluminum foil, etc., to make uneven traces on the tire plate, and then repeatedly painted lacquer, various colors of lacquer echo each other, overlap, and thus become fuzzy and chaotic, and then finally, after the grinding of the brilliant decorative effect can be formed, with a kind of implicit and condensed aesthetics, and at the same time the surface of the lacquer is also nearly flat [6]-[9]. Although the appropriate use of grinding painting techniques can greatly enhance the effect of the picture, but if indiscriminate abuse of techniques, stacking techniques will only destroy the effect of the picture [10], [11]. For this reason, three-dimensional modeling technology can be used to give lacquer painting deeper connotations, so that the lacquer painting in the pure art of the road farther and farther, the paintability is more and more intense, so that it has a more unique language system and charm [12], [13].

In this paper, through the construction of three-dimensional lacquer painting model and the processing of point cloud data, we quantify the process and simulate the effect of the application of abrasive painting technique in the creation of lacquer painting. We analyze the structural characteristics of the lacquer painting technique, and adopt the stacking modeling method to transfer the characteristics of different lacquer painting techniques to 3Dmax software. Handle the lighting, material and rendering processes of lacquer painting modeling to enhance the realism of the model's grinding and filling. In the processing of point cloud data obtained from scanning lacquer paintings, the KD tree is selected for data noise filtering, and at the same time, the octree is combined to extract the point cloud data features and downsample the data, so as to improve the denoising efficiency of the KD tree.

II. Analysis of three-dimensional modeling of lacquer painting art

II. A.Application of Abrasive Painting Technique in Chinese Lacquer Painting

Lacquer art was born out of ware, starting with large bowls of vermilion lacquer unearthed in the Stone Age, then exquisite lacquer coffins unearthed during the Qin and Han Dynasties, followed by delicate reddish lacquerware during the Ming and Qing Dynasties. The evolution of lacquer art is closely related to our lives. Lacquer art in the grinding and painting techniques also came into being, tracing the history, we can find that before the Qin and Han Dynasties, most of the lacquer is used to carry out direct lacquer painting. In the Qin-Han period, it was a direct inheritance of the Chu lacquer decoration, using painted lines as the main means of decoration, while a small amount of use to the “grinding and painting” in the grinding of this technique, mostly just for smoothing and polishing, and did not rise to the level of aesthetics, but more of a purely technical requirements. However, influenced by the social culture at that time, the lacquer art of the Qin and Han Dynasties as a whole formed a unique charm and majestic and solemn beauty. For example, during the Han Dynasty, two exquisite lacquer coffins were unearthed in Mawangdui, the surface of the lacquer coffins were decorated with vivid and realistic images interspersed with all kinds of immortals and exotic beasts, the lines of the brush running in the clouds and flowing water, both strong and soft, respectively, the use of red, black, white, yellow and other rich colors to depict the clouds and gas. To the Tang Dynasty when a large number of use to the grinding of this technique, and the Tang Dynasty in the traditional technique above a large number of innovations, adding the studded gold and silver, etc.. For example, the Tang Dynasty unearthed gold and silver Pingde feather people flying phoenix pattern lacquer backed bronze mirror, bronze mirror back beautifully decorated, its fine pattern is the first gold and silver piece of carving, carved out of the hollowed out pattern pasted on the back of the bronze mirror and then lacquer, through the polishing so that the lacquer surface lost the original floating light, and finally push the light, lacquer layer contained within the light to reveal the fine light. Due to the influence of the social environment and historical conditions at that time, the Tang Dynasty lacquer art as a whole presented a flowery style and elegant beauty. In the Song Dynasty, the rise of the literati, the aesthetic interest of the literati and aesthetic ideals occupied the mainstream of society, the pursuit of the bland beauty of Yi Shangyun as well as the natural sense of returning to simplicity and truth. It is also in this period of grinding and painting techniques gradually from the initial simple technical requirements, gradually rising to the stage of aesthetics, began to show a unique aesthetic meaning, the pursuit of natural simplicity. And really have a clear process recorded in the Ming Dynasty, refers to the use of push light lacquer, gold and silver, inlays and other materials on the base tire for pre-buried flowers, and then repeatedly painted color lacquer, to be dry after the grinding of the formation of beautiful decorative effect, is a kind of texture and quality of the craft techniques.

II. B.3D Virtual Lacquer Painting Modeling Design

II. B. 1) Structural characterization

The structural characterization of lacquer painting grinding technique is the basis of 3D virtual lacquer painting modeling, and its structural characteristics are usually divided into two kinds: regular structure and irregular structure. The modeling of regular structure is relatively simple, while the modeling of irregular structure is relatively demanding.

II. B. 2) Modeling methods

3Dmax software usually uses mesh modeling, face sheet modeling and stacked modeling in the process of constructing 3D models. Starting from the detail modeling, the modeling method that combines different detail models into a whole model is the stacking modeling method. The modeling process of this modeling method is similar to the process of building a house, i.e., the foundation is built as the basis, the parts of the overall structure are built, and the parts are unified to get the whole house. Before the ontology model of the milling technique is built, the structure of the objective milling technique needs to be categorized and described, if the milling technique contains the following elements, they will be described as:

$$P = \left\{X, T, J^c, \mathrm{Re}l, S^o, S_{tri}\right\} \tag{1}$$

where, X and T denote different elements within the virtual environment and relational operators between different elements, respectively; J^c and $\mathrm{Re}l$ denote conceptual hierarchies and non-clustering relations between different elements, respectively; S^o and S_{tri} denote ontological prototypes and elemental intrinsic correlations in existence, respectively. Where $X_1, X_2, \cdots, X_n \in X$, describes the full range of elements within the structure of the mill painting technique.

The relation operator described by T can be expressed as:

$$\begin{cases} attribute\_o\left(X_1, X_2\right) \\ compose\_of\left(X_1, X_2\right) \\ effect\_of\left(X_1, X_2\right) \end{cases} \tag{2}$$

Eq. describes the (combined, dependent and weakly influenced) correlations between X_1 and X_2, respectively. During the transmission of lacquer paintings in picture form with different abrasion techniques to the 3D modeling software, the number of strobe frames of different videos exhibits a Poisson distribution ordering waiting phenomenon. In order to highlight the difference of ontology features, the 3Dmax software operating system uses ontology element features and operation behaviors as the sensitivity index to improve the modeling efficiency. For the sensitivity index, the feature elements within Eq. (2) can be described by Eq. (3):

$$\begin{aligned} Sensitive_{time} = \{ & attribute\_of\left(X_1, X_2\right) \\ & compose\_of\left(X_1, X_2\right), effect\_of\left(X_1, X_2\right)\} \end{aligned} \tag{3}$$

In accordance with the maximum mean square error it is possible to determine the threshold value of the sensitivity index, described by the formula:

$$Threshold\_Sensitive_{time} = \frac{1}{3E}\left[\int_{t=0}^{E}\{attribute\_of\left(X_1(e), X_n(e)\right)d(e)\}\right] \tag{4}$$

where E denotes the time of video animation playback.

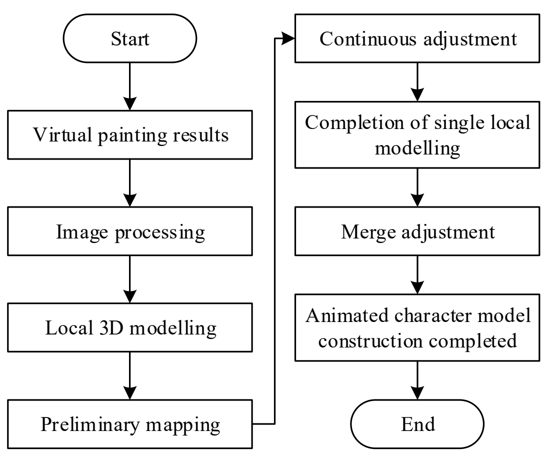

Figure 1: shows the modeling process of 3D virtual lacquer painting

II. B. 3) Modeling process

After analyzing the structural characteristics of the lacquer painting technique, the corresponding modeling method is selected to produce a three-dimensional virtual model of lacquer painting. Lacquer painting modeling includes three aspects: lighting, material and rendering, using different types of light and shadow to simulate the light and shadow effect of the light, enhancing the realism of the model through the material, and realizing the characteristics of the abrasive painting technique described by the lighting and material through rendering. A better modeling effect can be obtained by dealing with these three aspects. When constructing the 3D virtual lacquer painting model, we first construct a 3D virtual model with a single structural feature of the abrasive painting technique, and map the model with lights, materials and rendering, and continuously optimize the mapping position until it meets the actual demand, so that the single structural model of the abrasive painting technique is successfully constructed. One by one, we process different single structure models of the lacquer painting technique, merge all the local structure 3D models of the single lacquer painting technique, and at the same time, incorporate other elements such as the surrounding environment into the merger. Figure 1 shows the process of building a 3D virtual lacquer painting model.

II. C.Noise Reduction Analysis of 3D Point Cloud Data

II. C. 1) Lacquer painting point cloud denoising based on KD tree

A certain degree of noise usually exists in the 3D point cloud data of lacquer paintings, which is mainly caused by the measurement error of scanning equipment, environmental interference and data processing. Point cloud denoising is an important step in point cloud preprocessing, which can remove useless information while retaining useful structural features of the lacquer painting technique. After removing the noise, the point cloud data become more simplified and regular, which can improve the operation speed and accuracy of the subsequent processing algorithms. In addition, the denoising process can make the storage space of the point cloud data greatly reduced, saving the storage cost, making the useful features in the point cloud data more prominent, and facilitating the subsequent analysis and processing.

Commonly used denoising methods include bilateral filtering, Gaussian filtering, KD tree denoising, conditional filtering, voxel filtering and other methods. In this paper, KD tree denoising method is mainly used to realize the noise filtering of paint painting point cloud data. The main process of denoising is as follows:

1) Construct KD tree: construct the point cloud data into the structure of KD tree and establish the topological relationship of point cloud.

2) Neighborhood search: For each point, search its neighboring points in the KD tree through the nearest neighbor search algorithm to find out its K nearest neighbor.

3) Noise point judgment: for each point and its neighboring points, evaluate its noise level by calculating its distance average, and judge whether the point is a noise point according to the given threshold.

4) Noisy point removal: the point judged as noise is removed from the point cloud, and the paint point cloud data is used for experimental testing, and the denoised point cloud data becomes concise and regular.

II. C. 2) Octree-based point cloud downsampling for lacquer painting

Since the original data is too dense, there is a lot of redundant information, if the original data is directly processed, there are greater difficulties and lower efficiency, so it is necessary to downsample the point cloud to meet the needs of subsequent processing. Point cloud downsampling refers to reduce the number of point cloud data by selecting a portion of representative points, which can be realized by different downsampling algorithms, such as random sampling, spatial uniform sampling, octree sampling, etc. Downsampling processing can reduce the complexity of the point cloud data, reduce the cost of storage and computation, and keep the shape and characteristics of the point cloud unchanged.

In this paper, the octree sampling method is used to downsample the point cloud of lacquer painting, and this algorithm can effectively reduce the amount of point cloud data and keep the feature extraction of the original data, while keeping the shape and structural characteristics of the point cloud data. According to the point cloud features set the detail level threshold for sampling and simplification of point cloud data, the process is as follows:

1) Construct octree: the point cloud data is partitioned into eight sub-regions according to certain rules, each sub-region corresponds to a sub-node of the octree, and initially, the whole point cloud is taken as the root node.

2) Calculate node attributes: for each node, calculate its center of mass, enclosing box or other attributes.

3) Determine whether the node needs to be subdivided: based on the number of points inside the node, determine whether the current node needs to be subdivided into eight children.

4) Recursively subdivide the node: if the node needs to be subdivided, divide the current node into eight equal-sized child nodes and assign the point cloud data to the corresponding child nodes.

5) Layer-by-layer subdivision: recursively judge and subdivide the nodes from the root node until the termination condition is reached, for example, the depth of the tree reaches a certain number of layers or meets certain subdivision conditions.

6) Sampling point cloud data: In the leaf nodes of the octree, select representative points as sampling points.

7) Reconstructing point cloud data: according to the sampling points and the structure of the octree in which they are located, an approximate representation of the point cloud data can be reconstructed. The data volume of the point cloud data after downsampling is reduced, but the shape and structural features remain unchanged.

III. Practice of applying abrasive painting techniques based on 3D lacquer painting modeling

III. A. Point cloud data processing effect analysis

III. A. 1) Sampling point coverage tests

In order to verify the validity of sampling lacquer paintings with HD scanning, ensure the effectiveness of the subsequent KD tree point cloud data denoising and octree point cloud downsampling, and establish a more realistic 3D model of lacquer paintings, this section determines the combination of sampling point setups for obtaining the optimal coverage rate through multiple sets of tests. Table 1 shows the coverage test results of the sampling points. The table shows several sets of test data to calculate the coverage of sampling points obtained using different combinations of the parameters of the number of sampling points, ρ, and γ in the scanning scene of a certain structural feature of the abrasive painting technique. Only the combinations of sampling points, ρ, and γ of (123,500,1.2,0.10) and (123,500,1.2,0.20), the coverage areas of the sampled points are larger than that of the baseline of 5.350, which reaches 5.597 and 5.653, and the bias rates are around 4.3% and 4.6%, which provide a good coverage effect. Therefore, for the modeling effect of the paint painting, the number of sampling points is set to 123,500, and the parameters ρ=1.2 and γ=0.10, which ensures the sampling coverage and reduces the deviation rate at the same time.

Table 1: Test results of sampling point coverage rate

Parameters (points,ρ,γ)	Coverage area (unit:10^7, baseline:5.350)	Deviation rate (%)
3500,1.2,0.20	5.079	6.6
3500,1.5,0.45	5.120	7.2
3500,2.5,0.75	5.133	5.1
23500,1.2,0.20	5.245	4.8
23500,1.5,0.45	5.279	5.2
23500,2.5,0.75	5.302	4.2
123500,1.2,0.10	5.597	4.3
123500,1.2,0.20	5.653	4.6

III. A. 2) Scene data analysis

After the parameter settings are completed, data information statistics are carried out on the lacquer painting scene for virtual design, including data such as paper shape diagrams, structural characteristics diagrams, floor space diagrams and so on. Using a scanner to scan the drawings of lacquer paintings and other data, the obtained data is uploaded to the experimental platform to establish a three-dimensional scene virtual lacquer painting model, and the scene model is imported into the 3ds MAX software.

In order to better distinguish the 3D virtual lacquer painting scene under the design method of single abrasive painting technique structural features and multi-class abrasive painting technique structural features, 8 different scenes were divided, and data sampling and analysis were carried out respectively. Table 2 shows the results of the data analysis of different scenes.The number of fixed points of the eight scenes ranges from 2000-57501, the number of objects ranges from 101-357, and the number of triangular facets ranges from 305-6893. According to the included data, the three-dimensional virtual model design of lacquer painting was carried out, and the application effect of the grinding painting technique in the creation of lacquer painting art was analyzed according to the obtained model.

Table 2: Scene data analysis results

Scene sequence number	Contain fixed-point numbers	Number of objects	Number of triangular patches
A	57501	357	6893
B	40789	262	6735
C	5210	200	895
D	5784	231	934
E	5639	224	925
F	3570	189	607
G	3007	155	562
H	2000	101	305

III. B. Modeling Effect Analysis

III. B. 1) Comparison of modeling efficiency

In order to verify the modeling practicality of the stacked modeling method in this paper, the modeling efficiency of lacquer painting is taken as the experimental index, and high-definition scanning and 3D printing are chosen as the comparison methods to test the modeling efficiency of different methods. Figure 2 shows the modeling efficiency comparison results of the three methods. In this paper, after 120 iterations of the stacked modeling method, it takes only 0.52 days to complete the lacquer painting modeling. While the same after 120 iterations, the HD scanning method takes 1.23 days to complete the modeling, and the 3D printing method takes 1.39 days to complete the modeling. The stacked modeling method takes 0.71 days and 0.87 days less than HD scanning and 3D printing. The stacked modeling method used in this paper has higher modeling efficiency and can reduce the time needed for modeling lacquer paintings, thus gaining more time for the subsequent application of the grinding painting technique in lacquer paintings.

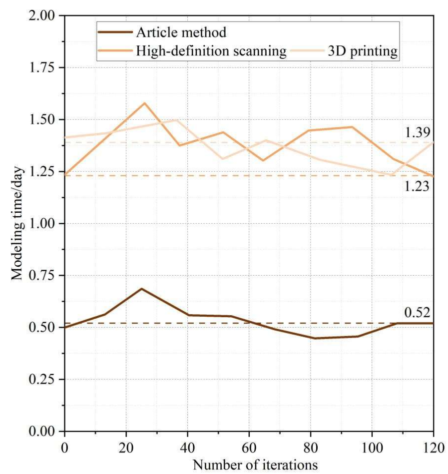

Figure 2: Comparison of modeling efficiency

III. B. 2) Modeling Performance Comparison

In order to judge the paint modeling fidelity and modeling cost of the methods in this paper, the modeling performance of the three methods is compared with the related performance data. Table 3 shows the modeling performance comparison results. The modeling fidelity of this paper's method is higher than 95% in modeling the structural features of the four abrasive painting techniques, namely, carving, lacquering, sanding, and pushing, reaching 98.3%, 97.5%, 97.3%, and 98.7%. Meanwhile, the modeling cost is reduced by more than 40%, reaching 45.9%, 47.5%, 46.3%, and 43.1%. Compared with the modeling fidelity and modeling cost reduction levels of the comparison methods, the lacquer painting model established by the stacking modeling method in this paper possesses the fidelity that is closer to the effect of the application of the abrasion painting technique in the original lacquer paintings, and at the same time, the cost of the modeling implementation is lower.

Table 3: Performance comparison results

Method	Structure of the grinding and painting technique	Fidelity (%)	Cost reduction (%)
Article method	Engraving	98.3	45.9
	Painting	97.5	47.5
	Polishing	97.3	46.3
	Shine	98.7	43.1
High-definition scanning	Engraving	89.3	25.1
	Painting	87.0	26.4
	Polishing	86.1	27.0
	Shine	85.7	23.5
3D printing	Engraving	80.4	19.6
	Painting	80.5	20.4
	Polishing	81.7	23.1
	Shine	82.3	19.8

III. C. SUS scale scores

After the modeling of the lacquer paintings was completed, nine volunteers were invited to participate in the creation and application of the grinding and painting techniques in the 3D models of the lacquer paintings. By wearing VR virtual glasses, the nine volunteers completed the steps of realizing the digitized lacquer painting technique and finally created their own digital lacquer paintings. After the production was completed, through the set SUS scale containing five questions related to the application effect of lacquer painting, the experience satisfaction of the nine volunteers was collected and analyzed to provide reference for the subsequent modeling optimization. Figure 3 shows the statistical results of the SUS scale scores of the 9 volunteers (taking the average score of the 5 questions). Three volunteers rated the effect of the application of the lacquer painting grinding technique at 90 or more, with the highest being volunteer #9, who gave an average score of 96.55. There were 5 volunteers who gave an average score greater than 80 and less than 90, the highest being 89.35. Only 1 volunteer gave an average score of 78.71. With the scoring results, it can be judged that most of the volunteers are more satisfied with the application effect of the lacquer painting grinding and drawing technique, but it is also necessary to continue to optimize and improve the modeling effect and the application experience of digital creation on a continuous basis.

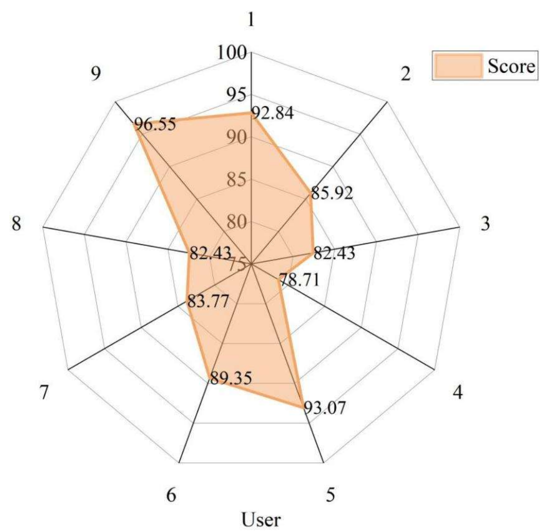

Figure 3: Statistics of SUS scale scores

IV. Conclusion

In this paper, the 3D modeling of lacquer paintings is completed through the stacking modeling method, and the application effect of the grinding painting technique in the creation of lacquer paintings is analyzed by combining the digital method. After the sampling point coverage test, the number of sampling points is determined to be 123,500, and the parameters ρ and γ are set to 1.2 and 0.10, respectively, to achieve an area coverage of 5.597 and a sampling deviation rate of 4.3%. In this paper, the stacked modeling method takes only 0.52 days to complete the lacquer painting modeling, which is 0.71 and 0.87 days less than the comparison method. At the same time, the modeling fidelity is higher than 95%, and the modeling cost is reduced by more than 40%. 3 volunteers give an average score of more than 90 points for the digital application effect of the abrasion technique in lacquer painting models, and 4 volunteers give an average score of more than 80 points, which is a high degree of satisfaction with the application effect of the abrasion technique. In the future, we should focus on the shortcomings of the digital application of the abrasive painting technique in lacquer painting models to improve the sense of realism in creation.

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