IEEE Access
Multidisciplinary : Rapid Review : Open Access Journal

Received November 19, 2020, accepted December 3, 2020, date of publication December 7, 2020, date of current version December 29, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.3043010

Research on Optimization of Portrait Sculpture Data Based on 3D Image and Mobile Edge Computing

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This work was supported in part by the ''Red Century'' Series of Inner Mongolia Large Scale Sculpture Creation Project.

ABSTRACT The traditional method of making portrait sculptures is hand-carving. The quality of sculpture is unstable, which mainly depends on the technical level of the sculptor. With the development of multi-coordinate numerical control processing technology and computer three-dimensional modeling technology, a new method of designing and making portrait sculptures has emerged. In order to improve the quality of sculpture and overcome the shortcomings of the existing scheme, a new optimization method for portrait sculpture data is proposed by combining mobile edge computing and 3D images. The paper first analyzes the existing portrait data collection methods based on 3D scanning and image reconstruction, and draws out the blind spots in the application of the existing data collection methods to the collection of portrait sculpture data. A method for data collection of portrait sculpture based on feature description is proposed. After determining the data optimization method, a portrait sculpture data optimization architecture is constructed through mobile edge computing technology. In order to verify the applicability of the method, the multi-angle and multi-dimensional simulation training test results show the efficiency and scalability of the realized sculpture data optimization method.

INDEX TERMS Portrait sculpture, edge computing, three-dimensional image, data optimization.

I. INTRODUCTION

Traditional portrait sculpture products mainly include wood carvings, stone carvings, clay sculptures and other sculpture products, as well as handmade soft pottery dolls, dolls and other craft products [1], [2]. The production needs to be hand-carved or kneaded, which has higher requirements for the artist's artistic cultivation and practical experience [3]. Moreover, the product is not easy to form, and its repairability after forming is also poor. It is precisely because of these limitations that the product has a long production cycle and high cost, which is not suitable for mass consumption [4].

Three-dimensional digital design is one of many digital art design methods. In the 1960s, the American pop artist Robert Rauschenberg had already established a special institution for the study of digital graphics and digital art in cooperation with the design master George Capes [5], [6]. With the rapid development of computer technology and its outstanding performance in the field of art design, artists attach great importance to digital art [7]. The industries with the most application of 3D digital technology are the development of film and television special effects, 3D animation, and computer-aided design and manufacturing technology, which has promoted the development of the design and manufacturing of portrait products [8], [9]. The forms of personalized portrait products are extremely diverse, ranging from traditional handmade stone sculptures, clay sculptures, soft pottery dolls, etc., to machine-processed metal portrait products such as tin, copper, and gold, or machine-processed and hand-made portraits. Objects in the natural world are all three-dimensional [10]. How to obtain the digital information of the physical objects in the three-dimensional world according to the existing technical means and use computers for processing has become an urgent problem to be solved.

With the advent of the 3D digital era and the rapid development of modern information acquisition technology, 3D shape digital technology has been widely used in the field of product design and inspection [11], [12]. Three-dimensional digital technology involves many industries such as aerospace, automobiles, home appliances,

The associate editor coordinating the review of this manuscript and approving it for publication was Lu Liu.

toys, clothing, handicrafts, cultural relics restoration, medical restoration, etc. Nowadays, digital art has integrated or even replaced some traditional art design techniques [13]. Digital expression techniques are widely used in music, film, television, photography, animation, games, industrial design, visual communication design, advertising design, web design, clothing design, architectural design, environmental art design and other fields and professions. Among them, the application of three-dimensional modeling design in three-dimensional film and television special effects, three-dimensional games and animation shows a wealth of artistic expression and brings opportunities for sculpture art to move into virtual space [14], [15]. The three-dimensional virtual modeling design expands the creation methods of sculpture to the computer three-dimensional virtual space. The creation process of sculpture art and even sculpture works are free from the limitation of material materials [16], [17].

How to design a data optimization method with excellent performance has an important influence on the development of portrait sculpture. This article analyzes the existing 3D portrait sculpture technology and its research status, and proposes a portrait sculpture data collection method based on feature description. In addition, a portrait sculpture data optimization architecture was constructed through mobile edge computing technology. We conducted multi-angle and multi-dimensional simulation training tests, and the test results proved the effectiveness and scalability of the implemented portrait sculpture data optimization method. This model will provide a certain reference and reference for the research on the optimization method of 3D portrait sculpture data.

The rest of the paper is organized as follow. Second II reviews the related work and describes the characteristics of 3D image feature extraction technology and an overview of edge computing. And the portrait sculpture data collection based on 3D image features and the portrait sculpture architecture based on edge computing are presented in Section III. Section IV provides the optimization test results of portrait sculpture data to verify the validity of the proposed scheme. And Section V concludes the work.

II. RELATED WORK

A. MOBILE EDGE COMPUTING

Mobile edge computing enables mobile users to perform services provided by IT or cloud computing within the range of wireless networks. The main goal is to reduce the transmission delay caused by data transmission through the core network. Mobile edge computing can be defined as a business-oriented cloud computing platform that provides mobile users with wireless access to nearby networks to receive services for delay-sensitive and context-aware applications [18], [19]. As a popular technology, edge computing has been widely used in the business field. Among them, Internet companies hope to extend their existing cloud service capabilities to edge networks with the help of their own relevant advantages in the service industry. Microsoft has released edge products such as ''Azure IoT Edge'' and enhanced streaming data analysis capabilities for Azure cloud services [20]. Amazon released the ''AWS Greengrass'' edge software to seamlessly extend AWS cloud services to devices.

Edge computing schemes process and analyze data at the edge nodes of the network. The network edge node refers to the node with computing and network resources between the cloud computing center and the source of the data. For example, the mobile phone is the edge node between cloud computing and people, and the gateway is the edge node between cloud computing and smart home [21], [22].

The composition of edge computing consists of two parts. Extend the centralized resources, including the marginal distribution of resources such as computing, storage, cache, bandwidth, and services. Bring the edge computing center closer to the demand side to provide a user experience with high efficiency, high reliability and low latency. As the edge of the resource pool, not as the center to provide users with all resources [23]. However, edge computing integrates centralized computing models, such as cloud computing, supercomputing, etc., to unify the collaboration between the central cloud and the edge cloud to achieve complementary advantages [24].

B. THREE-DIMENSIONAL IMAGE FEATURE EXTRACTION TECHNOLOGY

Image-based 3D reconstruction can be divided into two categories according to the number of images: one is based on a single image, and the other is based on multiple images. Data content framework of 3D portrait sculpture is shown in Figure 1.

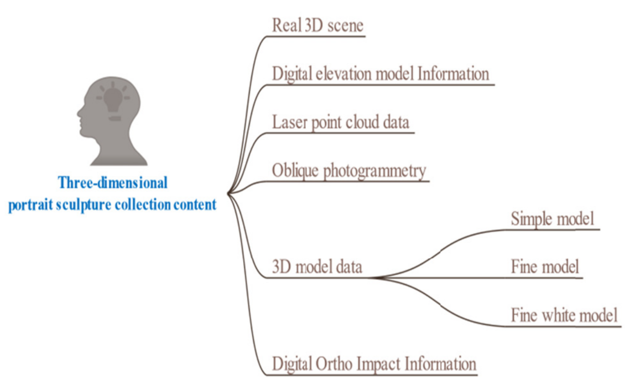

FIGURE 1. Data content framework of 3D portrait sculpture.

Because there is too little information in a single image, a large amount of human-computer interaction is needed to construct a three-dimensional model of a scene or object [25], [26]. The three-dimensional reconstruction based on multiple images mainly uses a large amount of visual information implicit in the image, such as contours, feature points, textures, brightness, etc., and combines the camera parameters to perform the inverse transformation operation of the optical projection to restore the scene or the three-dimensional model of the object. In recent decades, different researchers have conducted a lot of in-depth research on the characteristics and difficulties of 3D reconstruction of multiple images, and proposed many 3D reconstruction strategies, mainly including the following two methods: contour method and motion method [27], [28]. How to obtain the digital information of physical objects in the three-dimensional world according to the existing technical means and use a computer for processing has become an urgent problem to be solved.

The contour method is to restore the structure from the contour, which is to restore the three-dimensional shape through the contour line constraint of the multi-view image. In this method, the target scene is regarded as a cone in space, and the contour map of the target scene in multiple images is extracted through a calibrated camera, and the spatial position information of the cone is calculated [29], [30]. When the same target acquires multiple images in different orientations, multiple contour information can be acquired in the three-dimensional space, thereby generating the geometric topology of the target scene. If the number of images taken of the target scene is larger, the accuracy of the generated 3D model will be higher.

The motion method is to recover the structure from the motion. It takes multiple uncalibrated images as input, calculates the feature points of the same name in the image to derive the geometric constraint relationship between the images, and then calculates the three-dimensional coordinates of the matching points, and performs the point cloud surface Reconstruction, the method to finally obtain a three-dimensional surface model. The six steps of the motion method are summarized, including feature point extraction and matching, calculation of multi-view geometric constraint relations, layered stepwise camera calibration, depth estimation, point cloud surface repetition, and texture mapping [38], [39].

III. OPTIMIZATION METHODS FOR PORTRAIT SCULPTURE DATA

A. PORTRAIT SCULPTURE DATA COLLECTION BASED ON 3D IMAGE FEATURES

The human face is a very complex whole, and the shape of each part has its particularity, such as the complex structure of the eyes and the relatively smooth forehead [40]. While summing up the work of the predecessors, we found that most of the human faces are considered as a whole to build models [41]. The light section method is the basic principle of the grating projection type three-dimensional measurement method. The application of three-dimensional modeling design in three-dimensional film and television special effects, three-dimensional games and animation shows rich artistic expression, and brings opportunities for sculpture art to enter the virtual space. And Portrait sculpture collection process in distributed edge computing scenarios is shown in Figure 2.

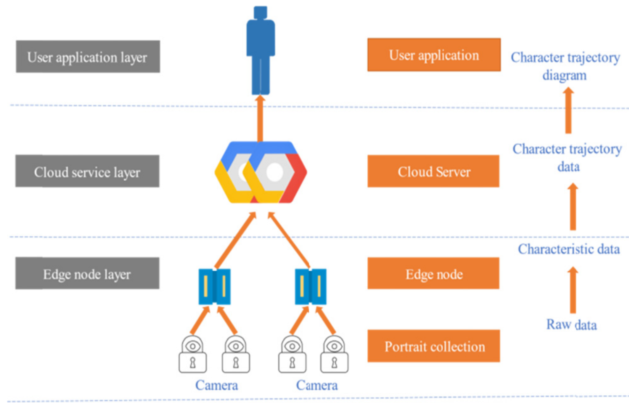

FIGURE 2. Portrait sculpture collection process in distributed edge computing scenarios.

The 3D virtual modeling design extends the creation method of sculpture to the computer 3D virtual space. Sculpture art and even the creation process of sculpture works are not limited by materials. A light beam emitted by a laser light source passes through a cylindrical mirror to form a laser plane. The laser plane is projected onto the surface of the object to be measured, forming a tuned spatial curve that carries three-dimensional information on the surface of the object. In this case, it would be more difficult to deal with a certain organ or part of the face (such as eyes, nose, mouth, cheeks, etc.) alone. Because it is difficult for the computer to determine whether a certain three-dimensional point belongs to the eye part or the forehead part in the entire model, the application of this model has certain limitations. After that, a fixed position CCD camera is used to shoot the image of the space curve at a certain angle, and then according to the geometric imaging relationship between the exit point, the projection point, and the imaging point, the three-dimensional data of each point on the space curve can be calculated, It also gets the three-dimensional information of a contour curve on the surface of the measured object. A sample of the original model of a three-dimensional portrait sculpture is shown in Figure 3.

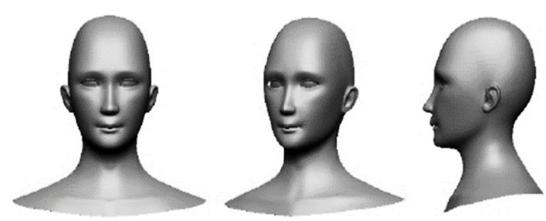

FIGURE 3. A sample of the original model of a three-dimensional portrait sculpture.

In order to solve this problem, this article establishes a three-dimensional face geometry model with blocks. In this model, the entire face is decomposed into multiple parts, and each part can be modeled and processed separately, and each part can be combined to form a complete face. The forms of personalized portrait products are extremely diverse, from traditional handmade stone carvings, clay sculptures, pottery, etc. to machine-processed metal portrait products, or machine-processed and hand-made portraits. Objects in nature are all three-dimensional. The three-dimensional reconstruction based on multiple images mainly uses a large amount of visual information implicit in the image, such as contours, feature points, textures, brightness, etc., and combines the camera parameters to perform the inverse transformation operation of the optical projection to restore the scene or the three-dimensional model of the object.

In recent decades, different researchers have conducted a lot of in-depth research on the characteristics and difficulties of 3D reconstruction of multiple images, and proposed many 3D reconstruction strategies, mainly including the following two methods: contour method and motion method. Blocking will not destroy the integrity and proportional relationship of the face (for example, the relative position of various organs or parts will not change after blocking). For the reconstruction of a three-dimensional portrait image, the data received by the detector is mainly used to obtain the pixels in the image matrix, thereby obtaining the corresponding image. First, simplify the unknown medium in the question to a thin slice without thickness. The industries with the most applications of 3D digital technology are film and television special effects, 3D animation and the development of computer-aided design and manufacturing technology, which has promoted the development of portrait product design and manufacturing.

X-rays pass through an unknown medium with an absorption rate in parallel, according to the principle of X-ray projection:

$$\int_{I0}^{I} \frac{dI}{I} = -\mu \int_0^x dx \tag{1}$$

$$\ln \frac{I}{I_0} = -\mu x \tag{2}$$

The projection equation of X-ray on the plane of the detector is:

$$P(x,y) = \int\int \mu(x,y)dxdy = -\ln(x,y) \tag{3}$$

In the formula, I_0 is the X-ray output intensity, and I is the X-ray intensity received by the detector. According to the X-ray projection equation, the projection value $p(x,y)$ is the two-dimensional distribution of the absorption rate $\mu(x,y)$ on the plane.

Calculate the error term of each output node in the output layer:

$$\delta_k = o_k' (t_k - o_k) = o_k (1 - o_k) (t_k - o_k) \tag{4}$$

Calculate the error term of each hidden node in the hidden layer:

$$\delta_k = o_k' \sum_{k \in outputs} w_{kh}\delta_k = o_k (1 - o_k) \sum_{k \in outputs} w_{kh}\delta_k \tag{5}$$

Calculate the correction value of each connection weight. The smaller one can ensure more stable.

$$h_\theta (x) = [1 + exp(-\theta^T x)]^{-1} \tag{6}$$

The three-dimensional portrait system in the problem is that the parallel incident X-rays irradiate the detector vertically, and the relative position of the X-ray emitter and the detector will never change. The entire transmitting-receiving system rotates 180 times around the center of rotation with one degree as the standard, so the projection The value $p(x,y)$ is related to the position of the ray after each rotation, so a new coordinate system is established to represent the corresponding different positions of the X-ray rotation at different angles, which can be expressed as: It can be expressed as such a structure.

$$xcos\theta + ysin\theta = R \tag{7}$$

Select $\mu(x,y)\sigma(t)$ as the screening factor of the function, then $\mu(x,y)\sigma(t)$ is the absorption rate of one of the X-rays passing through one of the paths of an unknown medium, so it is possible The corresponding projection to any angle:

$$P_\theta (R,\theta) = \int\int \mu(x,y)(xcos\theta + ysin\theta - R)dxdy \tag{8}$$

In order to eliminate the edge de-sharpening effect, the filter function is used to filter to form a filtered back projection signal, that is, the filter function is combined with any angle the projection function of the convolution operation:

$$\mu(x,y) = \int_0^\pi B_\theta (x,y)\, d\theta = \int d\theta \int P_\theta(R',\theta)\varphi(t-R')dR' \tag{9}$$

Then we can get back projections at different angles:

$$B_\theta(x,y) = \int Q_\theta(R',\theta)\delta(t-R')dR' \tag{10}$$

All the filtered projections of each point are accumulated in the angle of 0π, and the absorption rate of each fixed point is obtained:

$$Q_0 (R,\theta) = P(R) * \varphi(R) = \int P(t)\varphi(R-t)dt \tag{11}$$

According to the filter back-projection equation, all the filtered projections of each point are accumulated in the $0 \sim \pi$ angle to obtain the pixel value and absorption rate of the fixed point. Three-dimensional reconstruction based on multiple images mainly uses a large amount of visual information implicit in the image, such as contours, feature points, textures, brightness, etc., and combines camera parameters to perform optical inverse transformation operations.

B. DESIGN OF PORTRAIT SCULPTURE DATA ARCHITECTURE BASED ON MOBILE EDGE COMPUTING

A hierarchical storage and application model are proposed for massive data. And the structure design of the edge node layer of the portrait sculpture is shown in Figure 4. The model is divided into edge node layer, cloud service layer and user application layer. Their respective main components and realized functions can be summarized as follows. The edge node layer is mainly composed of a large number of

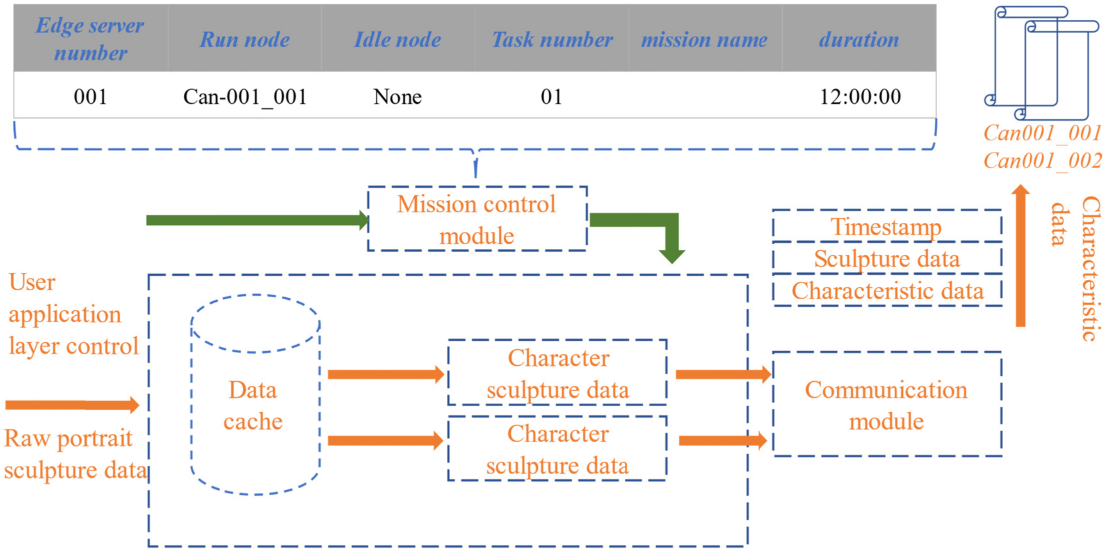

FIGURE 4. The structure design of the edge node layer of the portrait sculpture.

distributed sensors existing in the physical environment and edge servers serving the sensors. An edge server can serve several or even dozens of sensor nodes. The cloud service layer is composed of cloud servers. These servers can use hosts from different operators based on cost and performance considerations.

They are mainly responsible for data analysis of the massively collected structured data and complete the computing tasks required by users. The user application layer belongs to the control role in the entire data layering model. It can be composed of one or more users and has a complete set of applications. On the one hand, the user can control the computing tasks running at the edge node layer and the cloud service layer. On the other hand, the user can receive the application computing results from the cloud service layer after processing. In this model, the entire face is decomposed into multiple parts, and each part can be modeled and processed separately, and each part can be combined to form a complete face. The composition of edge computing consists of two parts. Extend the centralized resources, including the marginal distribution of resources such as computing, storage, cache, bandwidth, and services. Bring the edge computing center closer to the demand side to provide a user experience with high efficiency, high reliability, and low latency. As the edge of the resource pool, not as the center to provide users with all resources.

However, edge computing integrates centralized computing models, such as cloud computing, supercomputing, etc., to unify the collaboration between the central cloud and the edge cloud to achieve complementary advantages. The three-dimensional reconstruction based on multiple images mainly uses a large amount of visual information implicit in the image, such as contours, feature points, textures, brightness, etc., and combines the camera parameters to perform the inverse transformation operation of the optical projection to restore the scene or the three-dimensional model of the object.

As people's demand for mobile devices increases, mobile devices in the future will show a growing trend. Although the energy consumption of a single mobile device is small, because of the large amount, if a small energy saving on a single mobile device is extended to the total energy consumption of other mobile devices can be reduced a lot, so energy saving is also a very important criterion in the calculation of unloading decisions.

IV. EXPERIMENT RESULTS

In order to verify the effectiveness of the proposed scheme, the difficult points of the model and the areas that are not obvious are obtained. The three-dimensional portrait system irradiates the parallel incident X-rays vertically to the detector, and the relative position of the X-ray emitter and the detector will never change. The entire transmitting-receiving system rotates 180 times around the center of rotation with one degree as the standard, so the projection value is the position of the ray after each rotation is related. After obtaining the basic model, the detailed features of the model are carved by carving technology. Then the aesthetics of the model was improved.

After the optimization of the aesthetics-enhancing model, it can be found that the appearance of the model has been improved, and the similarity has been improved through model calibration based on favorite photos. A new coordinate system is established to represent the corresponding different positions of the X-ray rotation at different angles. Then the optimization of the model for numerical control processing was carried out, and the processing difficulty was reduced to a certain extent, and the product effect after processing was improved without changing the appearance. We adjusted the overall size of the model, modified the position of the facial features and the proportions of each part to make it conform to the proportions of the customer's photo head profile. In addition, we will appropriately add facial muscle structure according to the apparent degree of muscles in the corresponding part of the face in the photo. After the established 3D model has passed the internal and customer review, subsequent processing can be carried out. In this model, the entire face is decomposed into multiple parts, and each part can be modeled and processed separately, and each part can be combined to form a complete face. The specific test results are shown in Figure 5 to Figure 11.

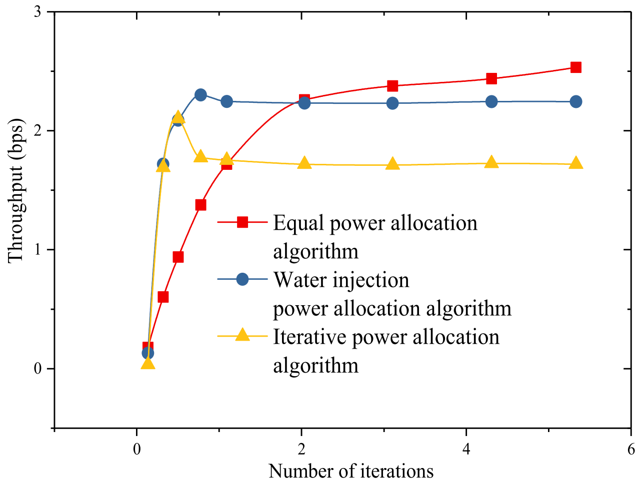

FIGURE 5. The relationship between the number of iterations and throughput under different algorithms.

Figure 5 shows the curve of system throughput with the number of iterations. This article compares three algorithms, namely the equal power allocation algorithm with fixed power, the traditional water injection power allocation algorithm and the iterative power allocation algorithm proposed in this article. It can be seen from Figure 5 that when the number of iterations reaches 4-5 times, the throughput of the three power distribution modes tends to be stable, no longer changes, and the convergence speed is faster, which is suitable for the real-time requirements of power distribution. The difference is that when using equal power allocation, due to the lack of a reasonable power allocation mechanism in the algorithm, the throughput of the system has a downward trend, but as the number of iterations runs, it will eventually become stable.

Figure 6 shows that the utility of SCBS varies with the number of SCBS when different pricing factors are used. As the number of SCBS increases, the utility of SCBS continues to increase, and the higher the set pricing factor, the lower the utility obtained by SCBS. This is because as the number of SCBS increases, the more computing power the SCBS obtains, and the more energy it saves, the more utility it obtains. However, because the higher the pricing factor, the fee charged by the edge server to SCBS will increase, so as the pricing factor increases, the utility of SCBS will decrease instead.

Figure 7 compares the solution in this article with the solution where the calculation rate is fixed and only the CPU cycle changes, and the solution where the CPU cycle is fixed

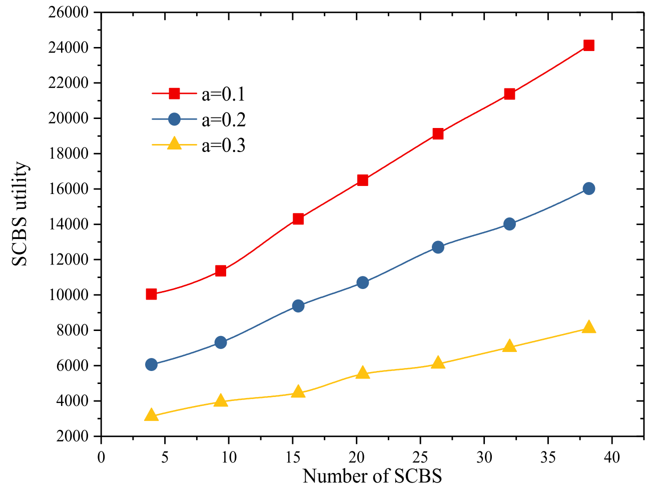

FIGURE 6. The relationship between the number of SCBS and the utility of SCBS under different price factors.

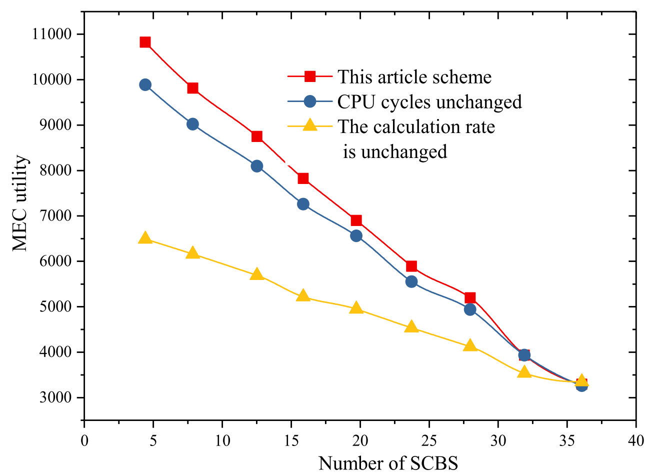

FIGURE 7. The relationship between the number of SCBS and the utility of MEC in different schemes.

and only changes the calculation rate. The results show that when the number of SCBS changes, the trend of edge server utility changes. It can be seen from the figure that as the number of SCBS increases, the utility of the edge server in the three solutions is reduced. As the number of SCBS increases, the quality of MEC service will be further improved.

Figure 8 shows the change curve of SCBS utility as the pricing factor increases. It can be seen from the figure that when the pricing factor continues to increase, the utility of SCBS continues to decrease. This is because when the pricing factor continues to increase. The more SCBS pays to the MEC server, the utility of SCBS will decrease.

Figure 9 shows the fitting curve of customer satisfaction in similar environments. Three-dimensional portrait products adopt computer-aided technology to realize modeling design and modern manufacturing technology to realize numerical control processing. This mode of operation breaks through the traditional manual production of three-dimensional portrait sculptures. First use the basic knowledge of portrait features as a reference to identify the typical features of

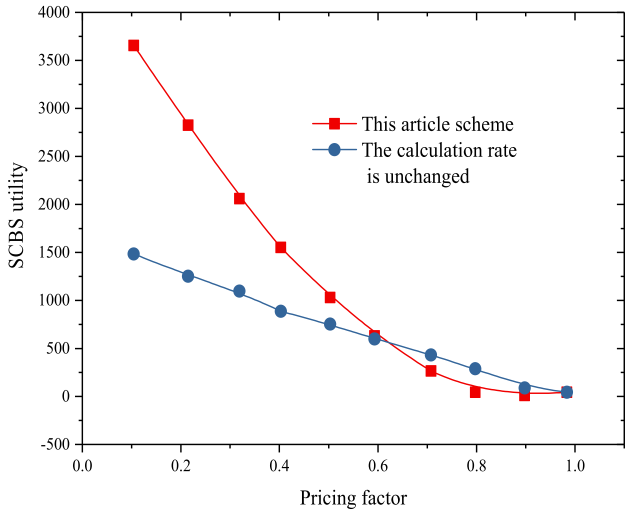

FIGURE 8. The relationship between pricing factors and SCBS utility under different scenarios.

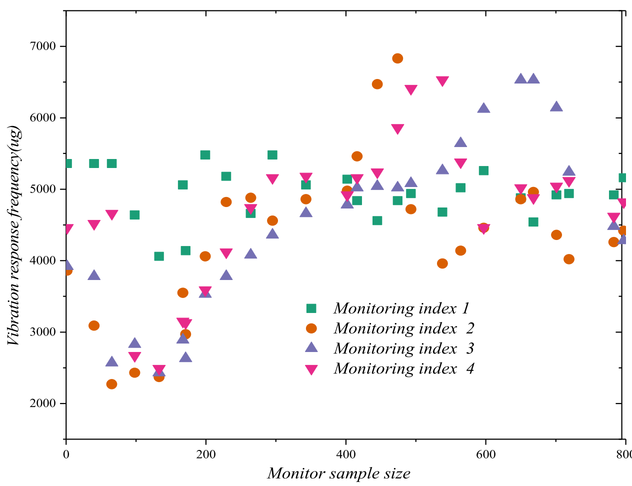

FIGURE 9. Customer satisfaction fitting curve of similarity.

customer photos. By combining the special requirements of customers to analyze the initial portrait model obtained after macro deformation, the initial model needs to be modified. We adjusted the overall size of the model, modified the position of the facial features and the proportions of each part to make it conform to the proportions of the customer's photo head profile. In addition, we will appropriately add facial muscle structure according to the apparent degree of muscles in the corresponding part of the face in the photo. After the established 3D model has passed the internal and customer review, subsequent processing can be carried out.

An example of a histogram of hue probability distribution. The box on the right represents the area to be tracked. From the picture, you can get the percentage of the number of pixels in each hue area to the total number, that is, the value of each bar. The histogram of hue probability distribution is used to represent the tracked object, that is, the tracking model. Usually, first select an area on the image that happens to contain the tracked object, and transfer the sub-pictures of the area from RGB space to HSV space to obtain the tone value of each pixel. Then, divide the hue range into 32 areas. In this sub-picture, count how many pixels belong to the area in each hue area.

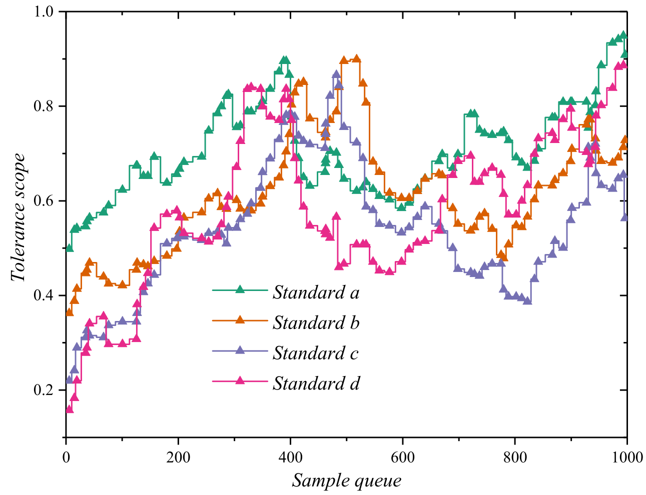

FIGURE 10. Probability distribution of portrait sculpture tone after normalization.

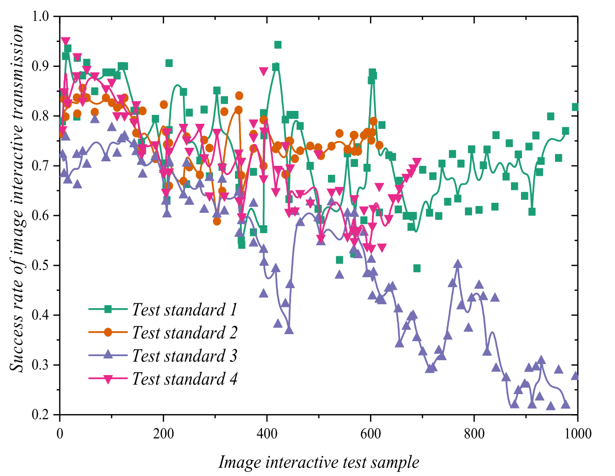

FIGURE 11. Recognition efficiency of portrait sculptures under different test standards.

Figure 11 shows the recognition efficiency of portrait sculptures under different test standards. Through the two-dimensional tracking process experiment of the feature points, the tracking effect of the feature points using the Camshaft method is verified. From the result, in the continuous frame, each feature point is tracked accurately without loss. Through the experiment of the 3D reconstruction process of the characteristic points, it is verified that the tracking and 3D reconstruction results in each binocular vision system are accurate. We found that the conversion process of the three-dimensional coordinates of each feature point to a unified three-dimensional coordinate system is correct. Through the early-warning capability experiment with the application of peripolar constraints, the DIS values of a certain feature point under normal tracking conditions and the DIS values under artificial disturbance (simulated tracking loss) are calculated. The comparison shows that in the latter case, the DIS value is much larger than the DIS values in the former case. Selecting an appropriate threshold for the DIS can trigger an alarm.

Similarly, compared with the fixed calculation rate allocation scheme, the utility of this scheme is still higher than other schemes. Through the above cases, it is found that the first analysis of multi-mode data collection is the data collection method based on three-dimensional scanning, and the obtained portrait model is of higher quality. Three-dimensional portrait products adopt computer-aided technology to realize modeling design and modern manufacturing technology to realize numerical control processing. This mode of operation breaks through the traditional manual production of three-dimensional portrait sculptures. First use the basic knowledge of portrait features as a reference to identify the typical features of customer photos. At the same time, the customer provided favorite photos for later model optimization. After obtaining the basic model, the detailed features of the model are carved by carving technology. Then the aesthetics of the model was improved. After the optimization of the aesthetics-enhancing model, it can be found that the appearance of the model has been improved, and the similarity has been improved through model calibration based on favorite photos.

V. CONCLUSION

In this article, 3D digital modeling technology and its application in sculpture are presented to improve the quality of sculpture. Through a dialectical analysis of technology and art in sculpture creation, it is concluded that sculpture art should fully absorb, accept and utilize three-dimensional digital modeling technology, instead of treating it in an opposing attitude. In this era of rapid changes in both technical means and ideological concepts, we should face changes with a positive attitude, regard changes as opportunities, make full use of the factors that are conducive to the development of sculpture art, and treat the impact of changes with correct concepts.

In order to solve the existing problems in the digitalization of portrait sculptures, this article analyzes the shortcomings of the existing methods, and on this basis, combines three-dimensional images and mobile edge computing technology to develop a new optimization method for portrait sculpture data. We carried out multi-angle and multi-dimensional simulation training tests, and the test results proved the efficiency and scalability of the realized data optimization method for portrait sculpture. The application case shows that the method researched in this article and the customer satisfaction evaluation application model established in this article have good application effects, and better improve the modeling efficiency and model similarity. In this article, a certain degree of exploration and research on the similarity improvement technology of portrait product 3D modeling and customer satisfaction evaluation methods have been made, and some phased results have been obtained. There is still a lot of work that needs to be further studied. In the future, we will continue to devote ourselves to the technical exploration and application of achievements in the field of portrait sculpture, hoping to provide a certain boost to the development of the field of portrait sculpture.

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