Research Article

Jewelry Art Modeling Design Method Based on Computer-Aided Technology

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In order to improve the effect of jewelry art modeling design, this paper applies computer-aided technology to jewelry art modeling design. Moreover, in order to solve the situation that the given data points do not form a topological rectangular grid, an interpolation algorithm based on triangular BB surfaces is specially studied in this paper. The algorithm automatically triangulates the given scattered data points to establish the topological relationship between the data points, and modified and optimized the triangulation algorithm according to the requirements of jewelry art modeling design. In addition, the improved algorithm can handle the triangulation problem of spatial data points well, and the triangulation speed is fast. The experimental verification shows that the jewelry art modeling design method based on computer-aided technology proposed in this paper can effectively improve the effect of jewelry art modeling design.

1. Introduction

With the development of modern art, modern jewelry design has also undergone a revolution in shape and quality, and the connotation and shape of jewelry have undergone earth-shaking changes. The application of new materials and new technologies has a huge impact on jewelry design and expands sufficient space for the expression language of jewelry. Moreover, people’s concept of modern jewelry has begun to change, and making jewelry pays attention to the meaning in the representation, the ideology in the expression, and the pursuit of diversity and synthesis in the technique. Because modern jewelry abandons the limitations of traditional jewelry making techniques, the jewelry making methods choose to use different materials due to different materials and creativity, such as lacquer art, pottery art, glass art, wood art, screen printing technology, alloy high-tech, and other means. Moreover, it has pioneered the use of more expressive means and production methods to create modern jewelry. As an independent visual art, modern jewelry has become a symbol for interpreting personalized language. At the same time, personalized jewelry design is the embodiment of humanization, which is not only the personal aesthetic and expression of the designer, but also the expression of the individual needs of consumers. The designer’s personal experience and cultural literacy are different, and he will use different design languages. The wearer has different needs for jewelry due to factors such as different ages, personalities, accomplishments, occupations, and wearing occasions. In personalized jewelry design, wearing jewelry is not only a symbol of status and wealth, the low cost and randomness of materials have gradually become a trend, and people are trying different visual experiences created by nonprecious materials.

From ancient times to the present, jewelry works, as a way of expression of decorative art, are inseparably related to the development of human civilization. In the Paleolithic age, humans used the limbs, bones, feathers, and other materials of hunted animals to decorate their bodies, praying for the blessings and power of nature. Human beings’ demands for jewelry are getting higher and higher, but no matter what kind of jewelry, it all reflects human’s admiration for nature and the good desire to avoid disasters and pray for good luck [1]. With the progress of human beings and the development of society, people’s awareness about nature has gradually improved, and technical means have
gradually developed. Jewelry works have gradually become a label for human beings to indicate their own personality and bear the symbol of human communication. Jewelry works not only play the role of decoration and beautification, but more importantly, it expresses the designer and the wearer’s understanding and pursuit of beautiful things. It is a carrier of the spiritual world and shows the harmonious coexistence between the man and the nature [2]. For the development of jewelry, from ancient research to the present, whether it is style or craftsmanship, it is inseparable from an important carrier—material. Material is the most direct form of product expression. In jewelry product design, the choice and performance of materials also directly affect the aesthetic feeling of wearing jewelry [3]. The morphological performance of materials can often attract the attention of wearers and admirers in an instant. Not only that, the different forms of materials in jewelry products can also bring people different feelings. The performance of materials in different forms in jewelry products directly promotes the entire development process of jewelry design [4]. The texture, characteristics, color, and other aspects of the material itself affect the design concept and information transmission of jewelry works. Different environments and cultures are closely related to the degree of human cognition of the material form, and the human wearing jewelry itself and the material form play a role in promoting and restricting each other [5].

Appearance design not only affects consumers’ choices according to their literatures but also affects consumers’ evaluation of product quality, safety, and after-sales. In the field of products with increasing the same functions, such as household appliances, enterprises need to maintain the attractiveness of products to consumers, so they need to design according to consumers’ psychology and aesthetic styling literatures at the beginning of product development [6]. So, from a rational point of view, how should we research and quantify consumers’ styling literatures? In the actual design process and design scheme evaluation, we can often hear the narrow opinion or perceptual understanding of many designers or decision makers [7]. Misreading, misinterpreting other people’s designs, taking the literal meaning, and not asking for further explanations have sometimes become a common ethos of designers. For example: “this feels good,” “the line shape has a strong foundation,” and “this style is too charming”. These evaluations have no systematic basis at all [8]. There is a big difference between designers and artists. Artists often affect others by expressing their emotions; while designers are more like a service industry, and no one hires you to express emotions blindly. Every design project needs to have a certain purpose, or to increase the added value of the brand, or to increase the sales of products, etc. What designers need to do is to integrate their own understanding of design into the enterprise within the design purpose. In this process, designers often need to balance the relationship between the scheme and the interests of the enterprise [9]. A quantifiable evaluation tool will greatly improve the work efficiency of designers. In terms of rational evaluation, some designers and researchers at home and abroad have carried out in-depth research [10]. In terms of consumer styling literatures, there are already some more feasible evaluation methods. Internationally, a series of tools have been developed for research in the fields of product semantics, product form literature, etc. These research studies enable enterprises to rationally evaluate product design and product positioning from the perspective of consumer psychological structure [11]. The research in [12] further confirms that the form and style of products and consumer literatures can be quantitatively measured and analyzed. Literature [13] fully shows that the two-dimensional lines representing jewelry still contain rich visual information, which is sufficient to express the aesthetic characteristics of products.

Literature [14] explores people’s understanding of product design by decomposing the lines of the product. The study found that the apex of the line is the most important for people to understand the product accurately. When the apex is lowered, it is often difficult for the subjects to understand the product, and when some lines in the middle are removed, the subjects do not encounter such difficulties. Literature [15] explores the difference between a product’s contour line and a line containing details. In the experiment, the subjects were shown pictures of the edge of the product and the inside of the product. Literature [16] devised a method to decompose the product design into different aesthetic elements, evaluated and defined them separately, and combined this method with consumer research to explore the effect of aesthetic elements on consumer brand perception. Influence.

In the research of multisensory symbol design of the product image, Yu studied the classification and characteristics of sensory symbols, using questionnaires, principal component analysis, cluster analysis, linear regression analysis, and other analytical methods, as well as the classification of different senses and the interaction of multisensory symbols. Form discussion constructs a set of methods to establish a multisensory product image [17].

This paper combines computer-aided technology and research on the performance jewelry art modeling design method to analyze the intelligent jewelry art modeling design concept to improve the effect of jewelry art modeling design.

2. Modeling Construction Algorithms

2.1. Interpolation Surface of Scattered Data Points Based on the Triangular B–B Surface. The bicubic B-spline surface interpolation algorithm has good interpolation effect, and it can effectively solve the problem of constructing free-form surface of spatial structure.

One of the prerequisites for constructing a bicubic B-spline interpolated surface is that data points in a topologically rectangular grid must be provided. The so-called topological rectangular data points, that is, the data points constitute a topological rectangular grid. Figure 1 shows a $7 \times 7$ topology data point grid. As can be seen from Figure 1, all data points constitute a topological $7 \times 7$ rectangular grid, and each data point corresponds to a node of the grid.
When the data points cannot form a topological rectangular grid, the bicubic B-spline interpolation surface cannot be directly constructed. At this point, the data points are called scattered data points, as shown in Figure 2. The topological relationships between scattered data points are intricate and irregular. However, in most cases, a given data point is a scattered data point. Therefore, the surface interpolation algorithm based on scattered data points has great application value.

The full name of the triangular B–B surface is the triangular Bernstein–Bézier surface. It is a generalization of Bézier’s method on surfaces. However, unlike the tensor product Bézier surface, the triangular B–B surface is defined on the triangular domain.

An nth triangular B–B surface patch is defined by \((n + 1)(n + 2)/2\) control vertices \(b_{i,j,k}(i + j + k = n)(i,j,k \geq 0)\) constituting a triangular array, and its expression is

\[
p(u,v,w) = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{i,j,k} B_{i,j,k}^{n}(u,v,w), \quad 0 \leq u, v, w \leq 1. \tag{1}
\]

Among them, the parameters \(u, v, w\) are the barycentric coordinates of the triangular field, \(u + v + w = 1\), and only two of the three barycentric coordinates of a point in the triangular domain are independent. \(B_{i,j,k}^{n}(u,v,w)\) is the nth Bernstein basis on the triangular field, which is the expansion term of \((u + v + w)^n\)

\[
B_{i,j,k}^{n}(u,v,w) = \frac{n!}{i!j!k!} u^i v^j w^k. \tag{2}
\]

It can be seen that the nth Bernstein basis on the triangular field contains \((n + 1)(n + 2)/2\) basis functions. The triangular domain is correspondingly divided into subtriangular domains according to Bernstein’s triangular array. Corresponding to the subtriangle domain, each control vertex \(b_{i,j,k}\) is connected with straight line segments with 6 control vertices \(b_{i-1,j,k}, b_{i+1,j,k}, b_{i,j-1,k}, b_{i,j+1,k}, b_{i-1,j,k}, b_{i+1,j,k}\), and \(b_{i-1,j,k}\) whose subscripts are not negative, then a mesh composed of triangles is obtained, which is called the Bézier grid or control grid (Figure 3).

The properties of the triangular B–B surface and the Bernstein basis on the triangular domain of the de Casteljau recursive algorithm have the following properties:

1. This nonnegativity is when \(u, v, w \geq 0\), there is \(B_{i,j,k}^{n}(u,v,w) \geq 0\).
2. This norm is \(\sum B_{i,j,k}^{n}(u,v,w) = 1\).
3. This symmetry is \(B_{i,j,k}^{n}(u,v,w) = B_{j,i,k}^{n}(v,u,w)\).
4. This recurrence is \(B_{i,j,k}^{n}(u,v,w) = B_{i,j,k}^{n-1}(u,v,w) + B_{i-1,j,k}^{n-1}(u,v,w) + B_{i,j-1,k}^{n-1}(u,v,w)\).

Among them, there are

\[
\begin{align*}
b_{i,j,k}^{0} & = b_{i,j,k}, \\
b_{i,j,k}^{l} & = u b_{i-1,j,k}^{l-1} + v b_{i,j+1,k}^{l-1} + w b_{i,j,k+1}^{l-1},
\end{align*}
\]

\(l = 1, 2, \ldots, n. \tag{3}
\]

Among them, there are

\(i + j + k = n - l, i, j, k \geq 0\).

The formula for a step-up is as follows: for simplicity, \(\tau = (u,v,w)\) is established

\[
p(\tau) = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{i,j,k} B_{i,j,k}^{n}(\tau) = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{i,j,k}^{n}(\tau). \tag{4}
\]

In the formula, \(b_{i,j,k}(i + j + k = n)\) is the original control mesh vertex.

\[
\begin{align*}
b_{i,j,k}^{(1)} & = \frac{i}{n+1} b_{i-1,j,k} + \frac{j}{n+1} b_{i,j-1,k} + \frac{k}{n+1} b_{i,j,k-1},
\end{align*}
\]

\(i + j + k = n + 1, \tag{5}
\]

\(b_{i,j,k}^{(1)}(i + j + k = n + 1)\) constitutes the Bézier mesh after the surface patch is upgraded.

The geometric meaning of the ascending formula (4) is that the new control vertex after the surface is upgraded and is the point whose barycentric coordinates are \((i/(n + 1), j/(n + 1), k/(n + 1))\) in the corresponding control
triangle in the original control mesh (the control vertex on the boundary is also calculated in the same way).

If a surface is defined on two domain triangles, each domain triangle corresponds to a triangular patch on the surface. If the domain triangle is divided into three non-overlapping subdomain triangles by a point \( T \) within it, then each subdomain triangle corresponds to a subtriangular surface patch. The three subtriangular patches do not overlap each other, and there is a common boundary between them. After splicing, a triangular surface patch corresponding to the domain triangle is formed (Figure 4). Therefore, the segmentation of the domain triangle corresponds to a segmentation of the triangular surface patch on the domain, and this segmentation of the triangular B–B surface is called Clough–Tocher segmentation, or C–T segmentation in short.

The continuous definition of \( G' \) of a surface is similar to the continuous definition of \( G' \) of a curve, which is expressed as follows:

If two adjacent \( C \) continuous surfaces \( S_1(u, v) \) and \( S_2(r, s) \) have the same tangent plane at each point along the common boundary, and the unit normal vector of the common tangent plane is a continuous function of the position of the common boundary point, then the two surfaces \( S_1(u, v) \) and \( S_2(r, s) \) are said to be continuous.

To construct a \( G' \) continuous triangular B–B surface, the control vertices of two adjacent triangular B–B surface patches must be adjusted. As we know before, the control vertices determine the shape of the triangular B–B surface. Two triangular B–B patches \( \Gamma \) and \( \Gamma^* \) of degree \( n \) are given as follows:

\[
\Gamma: p(\tau) = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{i,j,k} B_{i,j,k}^n(\tau), \quad i + j + k = n, \quad (6a)
\]

\[
\Gamma^*: p^*(\tau^*) = \sum_{i=0}^{n} \sum_{j=0}^{n-i} b_{i,j,k}^* B_{i,j,k}^n(\tau^*), \quad i + j + k = n. \quad (6b)
\]

Its common boundary curve is \( p(0, \tau_2, \tau_3) = p^*(0, \tau_2^*, \tau_3^*) \). We assume that point \( C \) is the point on the intersection of surface patches \( \Gamma \) and \( \Gamma^* \) corresponding to coordinate \( \tau_c = (0, \tau_2, \tau_3) = (0, \tau_2^*, \tau_3^*) = \tau_c^* \), the tangent plane of surface patch \( \Gamma \) at point \( C \) is determined by the three points \( b_{001}^0(\tau_c), b_{010}^0(\tau_c), b_{100}^0(\tau_c) \), and the tangent plane of surface \( \Gamma^* \) at point \( C \) is determined by three points \( b_{001}^0(\tau_c), b_{010}^0(\tau_c), b_{100}^0(\tau_c) \) (Figure 5). The continuous condition of the two surface patches \( G' \) can be expressed as follows: for any point on the intersection, there are

1. Four points \( b_{001}^{n-1}(\tau_c), b_{010}^{n-1}(\tau_c), b_{100}^{n-1}(\tau_c), b_{111}^{n-1}(\tau_c) \) which are coplanar.

2. The two points \( b_{001}^{n-1}(\tau_c), b_{100}^{n-1}(\tau_c^*) \) lie on both sides of the straight line \( b_{001}^{n-1}(\tau_c) b_{100}^{n-1}(\tau_c) \).

Among them, the four points \( b_{001}^{n-1}(\tau_c), b_{010}^{n-1}(\tau_c), b_{100}^{n-1}(\tau_c), b_{111}^{n-1}(\tau_c) \) are the points obtained by performing the de Casteljau algorithm \( n \) times on the two surfaces relative to the point \( C \). Among the above continuous conditions, the first guarantees that there is a common tangent plane, and the second guarantees that the surface does not have singularities at the common boundary: cusps or ridges.

We assume that \( \alpha_0, \beta_1, \beta_0, \beta_1 \) are real numbers. After deduction, the \( G^1 \) continuity condition can be expressed as
Delaunay triangulation consists of tetrahedra that satisfy the interior angle maximum criterion, and a three-dimensional triangulation consists of triangles that satisfy the minimum area criterion. Different triangulations can be obtained, with the Delaunay triangulation being the best. A two-dimensional Delaunay triangulation consists of triangles that satisfy the minimum area criterion. For a given set of scattered data points, an infinite number of triangulations can be obtained, with the Delaunay triangulation being the best. In two-dimensional Delaunay triangulation, the control vertices near the vertices can be determined.

After domain segmentation of scattered data points on the plane (or in space), the triangulation formed by connecting pairs of scattered data points with common domain boundaries is called Delaunay triangulation (Figure 6). For a given set of scattered data points, an infinite number of different triangulations can be obtained, with the Delaunay triangulation being the best. A two-dimensional Delaunay triangulation consists of triangles that satisfy the minimum interior angle maximum criterion, and a three-dimensional Delaunay triangulation consists of tetrahedra that satisfy the spherical criterion.

After the scattered data points are triangulated, there are \( m \) points \( P_i (i = 1, 2, \ldots, m) \) adjacent to the point \( P_0 \) around it, and each plane where the \( m \) triangles are located has \( m \) normal vectors \( n_1, n_2, \ldots, n_m \) (Figure 7). The normal vector of the triangle formed by \( P_0, P_i, P_{i+1} \) is \( n_i \), as follows:

\[
\mathbf{n}_i = \frac{(P_i - P_0) \times (P_{i+1} - P_0)}{\| (P_i - P_0) \times (P_{i+1} - P_0) \|} \quad i = 1, 2, \ldots, m.
\]

The improved Cline–Renka algorithm is suitable for scattered data points on surfaces with general smoothness requirements, and the segmentation effect is good.

2.2. Jewelry Network Structure Design. After the triangulation of spatially scattered data points is completed, a triangular mesh is obtained with each data point as the vertex. When constructing a triangular B–B surface patch on each triangle of the mesh, the normal vector on each vertex and the tangent vector along the surface boundary at the vertex must be given in advance. The normal vector and the tangent vector are unknown quantities, which can only be given by an estimation method and then adjusted when necessary.

The vertex normal is usually calculated as the weighted average of several triangle normals around the vertex. In this paper, the area of each triangle is used as a weight factor to estimate the normal vector as follows:

\[
\mathbf{n}_i = \frac{\mathbf{b}_1^* (\tau') \mathbf{P} (\tau) \mathbf{n} \mathbf{b}_1^* (\tau')} {\| \mathbf{b}_1^* (\tau') \mathbf{P} (\tau) \mathbf{n} \mathbf{b}_1^* (\tau') \|}, \quad i = 1, 2, \ldots, n - 1.
\]
By performing the above three steps on all the space triangles in the mesh, an initial cubic B–B surface with values at each data point is constructed, but the G⁰continuity requirements between the surface patches cannot be met. In order to solve the continuous compatibility problem at the page points, the Bézier grid points near the vertices can be obtained and the normal vector of the tangent plane can be calculated according to the following formula:

\[ n_{P_i} = \frac{\sum_{j=1}^{m} S_j n_j}{\sum_{j=1}^{m} S_j} \]  

(11)

Knowing the normal vector \( n_i \) at the vertex, a tangent plane can be determined there. Vertices \( P_i, P_{i+1}, P_{i+2} \) are given, and the normal vector of the tangent plane corresponding to point \( P_i \) is \( n_i \), as shown in Figure 8. Then, the tangent vector along the boundary \( P_i P_{i+1} \) and \( P_i P_{i+2} \) at point \( P_i \) can be calculated according to the following formula:

\[
\begin{align*}
D_{i,i+1} &= (P_{i+1} - P_i) - [(P_{i+1} - P_i) \cdot n_i] n_i, \\
D_{i,i+2} &= (P_{i+2} - P_i) - [(P_{i+2} - P_i) \cdot n_i] n_i.
\end{align*}
\]

(12)

Similarly, the tangent vector along the boundary curve direction at other vertices can be obtained. After weighted average, the normal vector at point \( P_0 \) is

\[ n_{P_0} = \frac{\sum_{i=1}^{m} S_i n_i}{\sum_{i=1}^{m} S_i} \]  

(13)

This paper adopts the following method to determine the control vertices of the cubic triangular B–B surface:

(1) the algorithm takes the three corner points of the space triangle as control vertices \( b_{003}, b_{030}, \) and \( b_{300} \), respectively.

(2) The algorithm determines other control vertices on the boundary.

We assume that the normal on vertices \( b_{003}, b_{030}, \) and \( b_{300} \) are \( n_{003}, n_{030}, \) and \( n_{300} \), respectively. In order to make the boundary Bezier curve smooth, without turning, cusp or too flat, the boundary tangent vector and modulus length can be taken according to the standard introduced in Section 1; that is, the tangent vector takes the direction of the normal projection of the chord vector of the boundary curve on the tangent plane, and the modulus length is the chord length. Such a value not only simplifies the calculation but also makes the grid points evenly distributed. After calculation, the 9 control vertices at the boundary are

\[
\begin{align*}
\begin{bmatrix} b_{210} = b_{300} + f(b_{300}, n_{300}) \\
b_{120} = b_{030} + f(-b_{030}, n_{030}) \\
b_{212} = b_{030} + f(-b_{030}, n_{030}) \\
b_{102} = b_{003} + f(-b_{003}, n_{003}) \\
b_{201} = b_{300} + f(b_{300}, n_{300}) \\
033 = b_{030} - b_{300}, n_{033} = b_{030} - b_{300}, n_{303} = b_{030} - b_{300}, n_{30} = b_{003} - b_{030}.
\end{bmatrix}
\end{align*}
\]

(14)

In the formula, the function \( f(b, n) \) is

\[ f(b, n) = \frac{|b - (b \cdot n)n|}{3|b - (b \cdot n)n|} |b|. \]  

(15)

(3) The algorithm determines the control vertex \( b_{111} \)

\[ b_{111} = \frac{b_{201} + b_{102} + b_{021} + b_{120} + b_{220} + b_{300}}{6}. \]  

(16)

Points. The area of the triangle formed by \( P_0, P_1, P_{i+1} \) is

\[ S_i = \frac{1}{2} \| (P_0 - P_i) \times (P_{i+1} - P_0) \|, \quad i = 1, 2, \ldots, m. \]  

(11)
be calculated according to the condition of equal-area ratio. We assume that the area of triangles obtained by connecting triangular Bézier mesh points and vertices near the vertex is equal to $1/n$ of the corresponding large triangle area ($n$ can be taken as 9).

As shown in Figure 9, we assume that the triangle mesh vertices adjacent to the inner vertex $P_0$ are $P_i(i=1,2,\ldots,m)$ in order, and the Bézier points adjacent to the inner vertex $P_0$ and corresponding to $P_i$ are $Q_i$ in order. We assume that $\gamma_i$ is the angle between $P_0Q_i$ and $P_0Q_{i+1}$, then the area $s_i$ of triangle $P_0Q_iQ_{i+1}$ can be calculated according to the following formula:

$$s_i = \frac{\|Q_i - P_0\| \cdot \|Q_{i+1} - P_0\| \sin \gamma_i}{2} = \frac{S_i}{n}, \quad i = 1,2,\ldots,m,$$

(17)

In the formula, $S_i$ is the area of triangle $P_0P_iP_{i+1}$. From formula (17), we get

$$\|Q_i - P_0\| \|Q_{i+1} - P_0\| = \frac{2S_i}{n \sin \gamma_i}, \quad i = 1,2,\ldots,m,$$

(18)

$$Q_{m+1} = Q_1.$$

Among them, there are

$$\|Q_i - P_0\| = d_i, \quad i = 1,2,\ldots,m,$$

(19)

We can get

$$\begin{align*}
\frac{d_{i+1}}{d_i} = c_i, & \quad i = 1,2,\ldots,m, \\
\frac{d_{m+1}}{d_1} = 1,
\end{align*}$$

(20)

when $m$ is odd, the system of equations (20) can be solved in the order of formula

$$\begin{align*}
d_1 &= \sqrt{c_1c_3c_5\cdots c_m}, \\
d_i &= \frac{c_{i-1}}{d_{i-1}}, & \quad i = 2,3,\ldots,m.
\end{align*}$$

(21)

When $m$ is an even number, equation (20) has no solution. At this time, the continuous compatibility problem at the vertex needs to be solved; that is, the remaining $Q_i$ points are adjusted based on the $Q_1$ point. From formula (18), we get

$$d_{i+1} = \frac{2S_i}{nd_i \sin \gamma_i}, \quad i = 1,2,\ldots,m.$$

(22)

Since $m$ is an even number, we have

$$d_{m+1} = \frac{c_1c_3c_5\cdots c_m}{c_2c_4c_6\cdots c_{m-1}}d_1 = c \cdot d_1.$$

(23)

In general, the constant $c \neq 1$; that is, $d_{m+1} \neq d_1$. Therefore, it is necessary to make appropriate corrections to $Q_i$, so that $Q_1, Q_2,\ldots,Q_m$ satisfy the condition that the area ratios are equal. The purpose of the correction is to make $c = 1$. In this paper, the angle $\theta$ between $Q_1$ and $Q_2$ and the angle $\beta - \theta$ between $Q_1$ and $Q_m$ are adjusted, so that the following formula is established:

$$\begin{align*}
d_1d_m \sin (\beta - \theta) &= \frac{2}{n}S_m, \\
d_1d_2 \sin \theta &= \frac{2}{n}S_1.
\end{align*}$$

(24)

that is, the adjustment looks like this

$$\begin{align*}
d_1 &= \frac{2}{nd_2d_m \sin \beta} \sqrt{(d_mS_1)^2 + 2d_2d_mS_1S_m \cos \beta + (d_2S_m)^2}, \\
\theta &= \arcsin \left( \frac{2S_1}{nd_1d_2} \right) \pi - \arcsin \left( \frac{2S_1}{nd_1d_2} \right).
\end{align*}$$

(25)

The choice of $\theta$ in formula (25) should satisfy two conditions: (1) $\theta$ should be selected so that $\beta$ is within the range of angle $Q_1$; (2) the point $Q_1$ adjusted according to $\theta$ is the closest to the original $Q_1$.

If the $P_0$ point is the boundary point on the surface, there is no compatibility problem, and $Q_1, Q_2,\ldots,Q_m$ can be calculated directly according to formula (18) without correction.

The continuity adjustment between subsurface patches is divided into two stages. The algorithm firstly adjusts the control vertices of each child patch to ensure that its parent patch is continuous along the boundary $G^1$. Then, the algorithm adjusts the control vertices of the three subsurface patches belonging to the same parent surface patch to make them $G^1$ continuous along the boundary.

(1) After the compatibility adjustment at the vertices, the six control vertices on each large-diagonal surface patch (finally upgraded and divided) obtained by the equal-area mapping method ensure the compatibility at the vertices. Therefore, after upgrading and dividing, the three points $R_0, S_0, T_0$ and $R_3, S_4, T_3$...
near the vertex of the original triangle mesh do not need to be adjusted.

\[
\begin{align*}
T_0 &= k_1 S_0 + k_2 S_1 + k_3 R_0, k_1 + k_2 + k_3 = 1 \\
T_3 &= k_4 S_3 + k_5 S_4 + k_6 R_3, k_4 + k_5 + k_6 = 1
\end{align*}
\]  

(26)

\(k_1, k_2, k_3, k_4, k_5\) and \(k_6\) can be solved by the above formula. After equal-area mapping, \(k_3 = k_6\).

To make a large triangular surface patch \(G_1\) continuous across boundaries, the following formula must be satisfied:

\[
\begin{align*}
T_i &= \frac{n-i}{n} (k_1 S_i + k_2 S_{i+1} + k_3 R_i) \\
+ \frac{i}{n} (k_4 S_i + k_5 S_{i+1} + k_6 R_i), i = 1, 2.
\end{align*}
\]

(27)

The choice of \(R_i\) and \(T_i\) satisfying formula (27) is not unique, and an optimization condition needs to be added. That is, under the condition that \(R_i\) and \(T_i\) satisfy formula (27), the distance from the corresponding control vertices obtained from the original large triangular surface sheet after the step-up and C–T division satisfies the least squares condition. In this way, the convexity of the original patch and the shape of the patch can be maintained as much as possible.

We assume that the adjustments of \(R_i\) and \(T_i\) are \(\varepsilon_i\) and \(\varepsilon_i'\), respectively, that is, \(T_i = T_i' + \varepsilon_i, R_i = R_i' + \varepsilon_i'\).

\[
\begin{align*}
T_i' + \varepsilon_i &= \frac{n-i}{n} (k_1 S_i + k_2 S_{i+1} + k_3 (R_i' + \varepsilon_i')) \\
+ \frac{i}{n} (k_4 S_i + k_5 S_{i+1} + k_6 (R_i' + \varepsilon_i')), i = 1, 2.
\end{align*}
\]

(28)

The least squares solution can be found by the Lagrange multiplier method as follows:

\[
\begin{align*}
\varepsilon_i &= \frac{\zeta_i}{1 + k_3^2} \\
\varepsilon_i' &= \frac{k_3 \zeta_i}{1 + k_3^2}, i = 1, 2.
\end{align*}
\]

(29)

In the formula, there are

\[
\begin{align*}
\zeta_i &= \frac{n-i}{n} (k_1 S_i + k_2 S_{i+1} + k_3 R_i) \\
+ \frac{i}{n} (k_4 S_i + k_5 S_{i+1} + k_6 R_i) - T_i.
\end{align*}
\]

(30)
The adjusted $R_i$ and $T_i$ are calculated by the following formula:

$$
T_i = T'_i + \epsilon_i,
$$

$$
R_i = R'_i + \epsilon_i.
$$

(31)

So far, there are still two points $X$ and $Y$ that have not yet been determined. Since they have no effect on the cross-boundary $G^1$ continuity, they can theoretically take any value.

(2) In order to ensure that the interior of the three subsurface pieces of the large triangular surface piece divided by C–T is $G^1$ continuous, as long as $E_1, E_2, E_3, F_1, F_2, F_3,$ and $O$ are all the centers of gravity of the three surrounding control vertices.

(3) After the adjustment of the above two steps, the $G^1$ continuity has been achieved between each surface piece and the surface. So far, the $G^1$ continuous quartic B–B surface interpolated to the scattered data points has been constructed.

### 3. Jewelry Art Modeling Design Method Based on Computer-Aided Technology

The second part verifies the jewelry art modeling design method and carries out the jewelry art modeling design according to the actual needs.

What shape the product is, what color it is, and what materials it seems to use are the first observations that users observe when they come into contact with the product. These perceptions originate from cognitive behaviors at the instinctive level. Moreover, cognitive behavior is the way to know the world and understand the external form of material things, and it is also the first and most basic link in the entire experience process. The user’s sensory organs will receive external sensory stimuli, and through nerve conduction, they will form cognition of things in the brain. At the same time, the brain will give feedback similar to conditioned reflex to the cognition formed. In the process of growing up, people will form their own unique ways of knowing things and understanding things. For direct sensory stimulation, people will instinctively give relatively shallow emotional feedback. In addition, cognitive ability is the basis of behavioral ability and emotional ability, and cognition during product use has a great impact on subsequent behavioral and emotional feedback. According to experimental research, when users appreciate the visual design, MRI shows that other senses are also involved in the experience. When the stimulation of other senses is generally enhanced, the subjects appear more pleasant, have a more profound impact on the product, and have a greater desire to buy the product. This experiment shows that the sensory designed product can stimulate the user’s perception and thinking more, which is a positive reward for the user. Therefore, in the design process of jewelry, we should not only focus on a single decorative function, but regard jewelry as a product with decorative functions and design a multifaceted sensory experience for the wearer. It enables users not only to appreciate jewelry with eyes but also to use senses such as touch and hearing to experience jewelry in an all-round way. At the same time, such an experience can bring surprises to users, even arouse users’ previous cognition and memory, and resonate and stimulate users’ deep emotional experience. Figure 10 shows an example of jewelry art design designed in this paper.

Based on the above design effects, the effect evaluation of the jewelry art modeling design method proposed in this paper is carried out, and the evaluation results are finally obtained as shown in Table 1 through the evaluation of multiple groups of jewelry art modeling designs.

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4. Conclusion

As a decorative product, jewelry is the most fundamental experience attribute, and it is also the first perception at the cognitive level. As far as jewelry is concerned, the materials used are inherently beautiful, and different gems and metals can show their unique color and luster through grinding and cutting. In addition, designers should choose suitable gemstones for combination and matching, and they should use different modeling forms to show them to achieve overall harmony and balance to reflect the beauty of jewelry itself. This paper combines computer-aided technology and research on the performance jewelry art modeling design method to analyze the intelligent jewelry art modeling design concept. The experimental verification shows that the jewelry art modeling design method based on computer-aided technology proposed in this paper can effectively improve the effect of jewelry art modeling design.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interests.

Acknowledgments

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References


