Automatic Optimization Algorithm of Jewelry Design based on Machine Vision

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Abstract. In this article, an automatic optimization algorithm of jewelry design based on Computer-aided design (CAD) and machine vision is proposed in order to realize the automatic, efficient, and high-quality optimization of jewelry design. In this article, an optimization method based on a Genetic algorithm (GA) is adopted to adjust and optimize jewelry design cases automatically. In the experiment, a variety of jewelry cases with different types and design requirements are selected, and the traditional design methods and the optimization algorithm in this article are applied to the design, respectively. The effectiveness and performance of the proposed algorithm in jewelry design automation optimization are verified by experiments. The algorithm can automatically adjust and optimize the design case according to the set optimization objectives and constraints and output the optimized results. At the same time, the results show that the optimized algorithm in this article has good adaptability in jewelry cases with different types and design requirements, and the design results are competitive in aesthetics, practicality, and innovation compared with traditional methods. In addition, the efficiency and stability of the algorithm have also been verified. This optimization method provides strong support for the automation and intelligence of jewelry design, helps to improve design efficiency and quality, and promotes the innovation and development of the jewelry industry.

Keywords: Computer-Aided Design; Machine Vision; Jewelry Design; Genetic Algorithm; Optimization Algorithm
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1 INTRODUCTION

With the progress of science and technology and the diversification of consumer demand, the jewelry design industry faces great challenges and opportunities. At the same time, the jewelry market is also affected by the trend of globalization. Automation systems have been widely applied in many fields. In the field of jewelry manufacturing, achieving automated insertion of earrings has become an important issue. Baek et al. [1] proposed a template matching based hole recognition method for automated ear nail insertion systems to improve production efficiency and reduce costs. Template matching is an image processing technique that compares target images with template images to find similarities between them. In the automation system for ear nail insertion, we can use template matching technology to identify the position and size of the ear nail hole, in order to accurately insert the ear nail into the ear nail hole. It is necessary to collect images of earrings and earring holes. This can be achieved through high-resolution cameras and appropriate light sources. Then, we use image processing software to process the collected images to extract the position and size of the ear nail holes. This can be achieved through template matching technology. Next, we use a robotic arm to insert the ear nails into the ear nail holes. The control of the robotic arm can be achieved through programming, enabling it to accurately move to the position of the ear nail hole. A series of experiments were conducted to verify the effectiveness of the hole recognition method based on template matching in the automated system for ear nail insertion. The experimental results show that this method can accurately identify the position and size of the ear nail hole and can accurately insert the ear nail into the ear nail hole. Compared with traditional methods, this method greatly improves production efficiency and reduces costs. Globalization has promoted competition in the jewelry market, and consumers can more conveniently come into contact with design styles and trends worldwide.

Banfi and Mandelli [2] explored the process of expanding from Building Information Modeling (BIM) to Reality (AR) projects, as well as the decorative complexity it faces. BIM is a three-dimensional modeling technique used in architectural design and construction processes. We can understand and analyze building models from different perspectives and dimensions through computer vision and image processing technology. For example, by using deep learning algorithms, we can automatically identify and extract building elements, thereby further optimizing the design process. The Arco della Pace in Milan is a typical architectural and urban planning project aimed at achieving a perfect integration of historical and modern architecture. By using UAS PhotoGrametric data integration technology to obtain 3D models, we can create augmented reality (AR) models to understand and analyze this complex project from a new perspective. Therefore, jewelry designers need to constantly innovate and quickly adapt to market changes to meet the needs of consumers. Traditional jewelry design methods often rely on designers' experience and skills. Although this method can produce unique designs, it is inefficient and difficult to produce on a large scale. Powder Bed Metal Additive Manufacturing (PBMAM) is a revolutionary manufacturing technology that constructs complex three-dimensional components by adding metal powder layer by layer.

Due to its high flexibility and adaptability, PBMAM has been widely used in many industries, including aerospace, medical, and automotive. However, the quality and control of this technology still face many challenges, including differences in powder quality, defects in the construction process, and complex process parameters. Cataldo et al. [3] explored the key challenges and future research directions for optimizing PBMAM quality detection and control. The process parameters of PBMAM include laser power, scanning speed, powder layer thickness, etc. These parameters have a significant impact on the manufacturing process and the quality of the final components. Therefore, understanding and optimizing these parameters is crucial for improving the quality and control of PBMAM. Standardization and control of powder quality: It is necessary to research and develop new methods to stabilize and control the quality of metal powders. This may involve improving the manufacturing process, developing new powder processing technologies, and establishing powder quality standards. Further understand and optimize the construction process of PBMAM to reduce defects and improve manufacturing efficiency. This may involve finer process control, advanced scanning strategies, and real-time monitoring and feedback systems. Develop new detection techniques to more accurately and effectively evaluate the quality of PBMAM components. This may include non-destructive testing techniques, X-ray imaging, computer vision, etc. Therefore, how to combine modern science and technology to improve the efficiency and quality of jewelry design has become an urgent problem for the industry.

In recent years, CAD technology has been widely used in jewelry design, which greatly improves the accuracy and efficiency of design. At the same time, as a hot direction in the field of artificial intelligence, machine vision has also begun to show its potential in jewelry design. In today's high-tech manufacturing industry, metal printing is a highly concerned technical field. It covers a range of applications, from jewelry and aviation manufacturing to medical and microelectronic equipment manufacturing. In the journal Nature Review Materials, a latest research paper delves into the integration of metallurgy, mechanical modeling, and machine learning in metal printing, revealing the future development trends in this field. Metallurgy is a crucial aspect in metal printing.

It involves the selection, processing, and conversion of materials, directly affecting the quality and performance of printed products. In recent years, scientists have developed various new materials with excellent properties, such as high-strength aluminum alloys, stainless steel, and titanium alloys, which exhibit good printability and mechanical properties during the manufacturing process. In addition, the metallurgical process also directly affects the particle size and distribution of metal powders, both of which are key factors in the quality of metal printing. By precisely controlling the metallurgical process, metal powders with consistent characteristics can be generated, resulting in higher quality and more efficient metal printing. DebRoy et al. [4] analyzed the mechanical model metal printing process and predicted its results. By establishing detailed physical models, scientists can simulate various phenomena during the printing process, such as the formation of molten pools, powder flow, and solidification process. These models can not only be used to optimize printing parameters, but also to predict the performance of new materials. The traditional jewelry design and production process often involves a lot of manual operation and waste of raw materials, which is contrary to the concept of sustainable development. By introducing CAD and machine vision technology, we can achieve more accurate design and production, reduce waste of raw materials, and optimize the supply chain, thus reducing the environmental burden. In today's digital age, shape analysis has important application value in many fields, such as machine vision, image processing, and computer graphics. Especially for complex geometric shapes such as buildings and terrain, two-dimensional shape analysis is particularly important. Đurić et al. [5] explored how to use complex geometric two-dimensional shape analysis methods based on imaging photogrammetry models to achieve high-precision measurement and analysis of complex geometric shapes. The imaging photogrammetric model is a method of reconstructing the shape of three-dimensional objects through image acquisition and processing. This method mainly relies on steps such as camera calibration, image feature extraction and matching, and 3D reconstruction. Through this method, we can obtain shape information of objects from images and perform precise measurements and analysis. In order to verify the feasibility and accuracy of a complex geometric two-dimensional shape analysis method based on imaging photogrammetry models, we conducted a series of experiments. The experimental results show that this method can achieve high-precision measurement and analysis of complex geometric shapes, with measurement errors at the sub pixel level. In addition, this method also has high robustness and adaptability, and can adapt to different complex scenarios and environments.

In addition, traditional handicraft skills need to be studied and practiced for a long time, and with the retirement of experienced designers, these skills may face the risk of being lost. Laser scanning technology has demonstrated its strong potential in various fields. In terms of 3D model generation, laser scanning technology provides an efficient and accurate method for obtaining and transforming object shapes from the real world. Jadhav et al. [6] explored the design and development process of generating virtual 3D models of real objects using laser scanning technology. Laser scanning technology is a technique that determines the shape of an object by measuring the distance between the laser beam and the target object. It typically consists of a laser emitter, receiver, and one or more rotating or translational mirrors. When the laser beam hits the target object, the reflected light is received by the receiver, which calculates the distance between the laser beam and the target object. Through this process, we can obtain a large number of data points on the surface of an object, which are called point clouds. In the design phase, we need to determine the objects to be scanned, as well as the accuracy and resolution of the scanning. This usually involves selecting appropriate laser scanning equipment, determining the scanning area and angle, and software tools for processing and parsing point cloud data. At the same time, we also need to consider how to clean and optimize the obtained data to reduce noise and erroneous data points. However, through the application of CAD and machine vision technology, this skill shortage can be partially compensated. Designers can use these advanced technologies to assist design, improve design efficiency, and reduce the dependence on their craft skills.

With the popularization and maturity of 3D printing technology, creating 3D objects from 2D images has become an important research direction. Among them, reconstructing 3D facial relief through RGBD images is of great significance. It can be applied in many fields, such as personalized souvenirs, film and television production, game development, etc. Jung et al. [7] proposed a template-based 3D facial relief creation method that can generate relief models for 3D printing from RGBD images. RGBD images are images that contain both color and depth information. There are many methods to obtain this type of image, such as using structured light scanning equipment, laser scanners, etc. In this article, we use a common RGBD camera to obtain facial images. This camera can simultaneously obtain high-resolution color images and depth information, providing necessary data for our subsequent 3D reconstruction.

Based on the matching results, we use Boolean operations and texture mapping methods to generate the final 3D facial relief model. For areas larger than the facial model in the template, we fill them as entities; For areas smaller than the facial model, we will empty them out. At the same time, we can also map texture information to the relief model to increase the details and realism of the model. Machine learning technology can be used to recognize and classify images of architectural heritage. By training and learning a large amount of image data, machine learning models can automatically recognize various elements in the image, such as building features, material types, damage situations, etc. This helps to enhance awareness and understanding of architectural heritage, providing a basis for protection and restoration work. Machine learning can also be used to predict and evaluate the damage situation of architectural heritage. By learning and analyzing historical data, machine learning models can predict the future damage trend of building structures and take corresponding protective measures in advance. In addition, machine learning can also be used to evaluate the effectiveness of repair work and provide reference for subsequent protection decisions. By utilizing machine learning technology, architectural heritage can be transformed into digital information for long-term preservation and dissemination. For example, through 3D scanning and reconstruction technology, the structure and details of buildings can be digitally preserved, providing convenience for subsequent research and display. Karadag [8] establishes a data-driven decision support system by combining big data and machine learning technology, providing comprehensive decision support for the protection of architectural heritage. Network Intrusion Detection System (NIDS) is an important tool for protecting the security of IoMT systems, but traditional NIDS has problems such as high false alarm rates and slow detection speed. To address these issues, Li et al. [9] proposed a NIDS based on Butterfly Optimization Algorithm (BOA) to improve its accuracy in medical IoMT systems. The butterfly optimization algorithm is an optimization algorithm that simulates natural selection and genetic processes, inspired by the flight behavior of butterfly populations. It built an experimental environment to simulate the medical IoMT system and conducted comparative experiments between the proposed NIDS and traditional NIDS. The experimental results show that NIDS based on butterfly optimization algorithm outperforms traditional NIDS in terms of false alarm rate, detection speed, and accuracy.

In this context, this study aims to explore the optimization algorithm of jewelry design automation based on CAD and machine vision, so as to improve the efficiency and quality of jewelry design and meet the diverse needs of consumers. Its innovations are as follows:

(1) This article applies GA to the optimization of jewelry design, which is a novel method. By using the algorithm to automatically adjust and optimize the design scheme, the design efficiency and quality can be improved.

(2) This article not only shows the results of the optimization algorithm, but also compares it with the traditional design method. This setting can intuitively show the differences between the two methods and verify the effectiveness and superiority of the optimization algorithm.

(3) By applying the optimization algorithm to jewelry cases with different types and design requirements, this article verifies the robustness and universality of the algorithm. This verification

helps to prove the feasibility of the algorithm in practical application and provides a basis for its application in a wider range of design problems.

(4) The method proposed in this article is helpful to realize the intelligence and automation of jewelry design. Through the automatic optimization of the algorithm, manual participation can be reduced, design efficiency can be improved, and designers can be provided with more innovative possibilities.

This article is divided into six sections. The first section is the introduction, which introduces the research background, significance, present situation, content, and methods. The second section will introduce the application of CAD technology in jewelry design in detail. The third section will discuss the application of machine vision in jewelry design. The fourth section will propose an automatic optimization algorithm for jewelry design based on CAD and machine vision. The fifth section will simulate the proposed algorithm. The last section, the sixth section, will summarize the whole research work and look forward to the future research direction.

2 RELATED WORK

The murals from Tang tombs in China are an important carrier of ancient culture, and clothing images reflect ancient social life, aesthetic taste, and craftsmanship. However, these precious cultural heritage faces the threat of natural erosion and human destruction, and there is an urgent need for effective protection and restoration. Liu et al. [10] explored how to use reverse engineering and human-computer interaction technology to achieve precise restoration of Tang tomb mural costumes, in order to promote the sustainable development of cultural relics. In cultural relic restoration, reverse engineering is used to reconstruct lost or damaged parts to restore the original appearance of the cultural relic. For the restoration of Tang tomb mural costumes, reverse engineering can help us understand the design principles and production techniques of mural costumes, and then repair damaged or blurred parts. Human computer interaction technology is a technology that enables computers and humans to communicate and collaborate with each other. In the restoration of cultural relics, human-computer interaction technology can be used to assist experts in more accurate restoration work. For example, experts can use human-computer interaction technology to establish a digital model of Tang tomb mural costumes, and then predict the restoration effect through computer simulation to more accurately restore cultural relics. Gold processing control is a key link in the resource extraction process, which is of great significance for improving production efficiency and reducing operating costs. In recent years, with the rapid development of artificial intelligence and machine learning technology, the application of these technologies in gold processing control has gradually become a research hotspot. Discrete event simulation, as an effective method for controlling gold production, can realistically simulate various events in the gold processing process, providing sufficient data support for machine learning. Pe ñ a et al. [11] explored how to use discrete event simulation methods to model the gold processing process and introduced its application in gold processing. In specific application scenarios such as gold processing, discrete event simulation plays an important role in optimizing process flow, evaluating equipment performance, and quality control. With the further development of artificial intelligence and machine learning technology, the application of discrete event simulation in gold processing control will have broader prospects and potential. The traditional clothing culture in South Korea is profound and unique, and the batik technique is one of its unique forms of artistic expression. The diversity and uniqueness of batik patterns provide a rich source of inspiration for fashion jewelry design. Tsolmonchimeg and Ahn [12] explored how to integrate batik patterns from traditional Korean clothing into fashion jewelry design, showcasing the charm of Korean traditional culture and innovation in modern design. Traditional Korean clothing, also known as Hanfu, has unique styles and color combinations. Among them, the batik pattern is a common decoration of Hanfu, and its history can be traced back to the Silla period. These patterns typically depict natural landscapes, flora, fauna, and abstract shapes such as cloud patterns, flower and bird patterns, wave patterns, etc. They have become representatives of traditional Korean culture with their exquisite craftsmanship and symbolic significance. In fashion jewelry design, one can directly draw on the batik patterns of traditional Korean clothing. Designers can transform these patterns into jewelry works, such as necklaces, earrings, bracelets, etc., to showcase the unique charm of traditional Korean culture. Designers can also draw on the color matching and composition techniques of batik patterns to integrate these elements into jewelry design. For example, using gradient colors, symmetrical or asymmetric composition methods, etc.

Designers can innovate their designs by combining modern design concepts and techniques while preserving the essence of traditional Korean culture. For example, using modern inlay techniques or 3D printing techniques to present batik patterns in a more modern way. The application of machine learning technology in the field of clothing design has gradually emerged. By training and learning a large amount of clothing design data, machine learning models can automatically identify the relationships between various design elements, providing valuable references for designers. For example, by learning historical design data and market data, machine learning can predict which combination of design elements is more popular, thereby improving the success rate of new designs. How to achieve sustainability in clothing design while satisfying personalization is an important issue. Wang et al. [13] proposed a machine learning enhanced 3D reverse design method to achieve sustainable personalized clothing design. Specifically, we first use machine learning technology to learn and analyze historical design data to obtain more sustainable design elements and structural information; Then, use 3D reverse design technology to obtain design elements and structural information from actual samples; Finally, the design scheme is evaluated and optimized through machine learning technology to achieve more sustainable personalized clothing design. This method combines the advantages of machine learning and 3D reverse design technology, and can obtain more sustainable design elements and structural information from historical design data, as well as design elements and structural information from actual samples. At the same time, machine learning technology is used to evaluate and optimize design solutions to achieve more sustainable personalized clothing design. Additive manufacturing (AM) has become an important component of modern production processes. Additive manufacturing is a process of building objects by adding materials layer by layer, which can achieve rapid and efficient production of complex structures. However, its operational process involves many variables, including material type, physical properties, thermal parameters, etc., which have a significant impact on the manufacturing process and results.

In recent years, the application of machine learning (ML) in additive manufacturing has gradually become a research hotspot. Machine learning can process a large amount of data and automatically learn patterns and relationships in the data through algorithms. Xames et al. [14] conducted a systematic literature review on the latest trends in the application of machine learning in additive manufacturing in recent years. After the completion of additive manufacturing, machine learning can be used to detect defects in the manufacturing process. By training defective and flawless samples, machine learning can learn to distinguish between normal and abnormal manufacturing results. Machine learning can also be used to optimize material selection. By learning and analyzing the properties of different materials, machine learning can identify the most suitable materials for a specific additive manufacturing process, thereby improving product quality and production efficiency. Hakka cardigan is a traditional Hakka clothing with unique historical and cultural value. However, due to the long history and limited storage conditions, many Hakka cardigan styles and details are no longer fully preserved. Meanwhile, the traditional cardigan production process often relies on manual labor, which cannot meet the needs of large-scale and efficient production. Therefore, the restoration and display of Hakka cardigans through digital technology and virtual reality technology is of great significance for protecting and inheriting Hakka culture. Yu and Zhu [15] use high-definition cameras and other devices to take multi-angle, high-resolution photos of the original cardigan and obtain image data. By using computer vision technology and image processing algorithms, features such as texture, style, and color of cardigans are extracted. Based on the obtained feature data, a digital model of Hakka cardigan is established using 3D modeling technology. In terms of numerical algorithm optimization, we adopted an optimization method based on a gradient descent algorithm. The model achieves optimal maintenance of details and overall structure by setting appropriate loss functions and constraint conditions. At the same time, we have also introduced artificial intelligence technologies such as deep learning to improve the automation of feature extraction and model building [16].

In the teaching of jewelry creative design, teachers will first teach students how to use CAD software for basic modeling. This includes learning basic drawing commands, view operations, and 3D modeling techniques. Through the study of basic modeling, Zheng and Chang [17] can master the basic skills of using CAD software, laying the foundation for subsequent advanced design. After students master basic modeling skills, teachers can further teach more advanced design skills. For example, teaching students how to use advanced features such as Boolean operations, surface modeling, and solid modeling to create more complex jewelry designs. These advanced design techniques can help students achieve more creative design works. Using CAD software, designers can quickly create and modify jewelry design models on a computer. Compared to traditional manual production, CAD can greatly shorten the production cycle and improve design efficiency. CAD software has high-precision modeling capabilities, which can accurately express the creativity of designers. At the same time, CAD can also perform precise dimensional measurements and data analysis, helping designers better grasp design details. Machine vision is a technology that simulates human visual functions through computer vision technology. In jewelry design, machine vision can be used to recognize and classify the shape, color, texture, and other features of jewelry. In addition, machine vision can also be used to analyze and optimize the design of jewelry, thereby improving the efficiency and accuracy of the design. The automatic optimization algorithm for jewelry design based on CAD and machine vision is a combination of CAD technology and machine vision technology. Zhou et al. [18] used CAD technology to design and model jewelry models and then used machine vision technology to extract and analyze features from the models. Based on these features and analysis results, the algorithm can automatically optimize and improve the model, thereby improving the design quality and manufacturing efficiency of jewelry.

3 APPLICATION OF MACHINE VISION IN JEWELRY DESIGN

In jewelry design, CAD technology provides a digital design environment for designers and supports designers to create, modify, analyze and optimize design schemes. In jewelry design, the main applications of CAD technology include: shape design: the shape of jewelry can be easily adjusted and modified through three-dimensional modeling tools. Material and texture simulation: CAD software is usually equipped with a material library and rendering tools, which can simulate the texture and lighting effects of different materials (such as gold, silver, and diamonds). Precision control: CAD technology can accurately control the size and proportion of jewelry and ensure design accuracy. Design visualization: Through CAD software, designers can generate high-quality renderings and animations to show the design effect more intuitively.

Jewelry design based on CAD usually follows the following process:

Demand analysis: Define the design objectives, including styles, materials, sizes, etc.

Preliminary design: Use the modeling tool of CAD software to design the preliminary shape of jewelry.

Perfect details: Add textures and adjust lighting and materials to make the design more realistic.

Accuracy check: Use the measuring tools of CAD software to check whether the designed size and proportion meet the requirements.

Rendering and visualization: Generate high-quality renderings or animations to show and assess the design.

Design modification and optimization: According to the assessment feedback, use CAD software to modify and optimize the design.

Output and manufacturing: Export CAD design data to provide accurate data basis for subsequent manufacturing and production links.

In jewelry design based on CAD, the following key technologies are involved: three-dimensional modeling technology, parametric design technology, high-precision measurement and control technology, realistic rendering technology, data exchange and format conversion technology. Mastering these key technologies can help jewelry designers to design more efficiently and accurately, and realize the seamless connection between design and manufacturing. Machine vision is a comprehensive subject, which combines the knowledge of computer science, artificial intelligence, image processing and other fields, aiming at enabling computers to understand and interpret visual information in the real world. Machine vision system obtains images through image sensors, and then uses various algorithms to perform tasks such as image processing, feature extraction and pattern recognition. The key technologies involved in the application of machine vision in jewelry design are shown in Table 1.

Web technology	*Describe*	*Example*
Image preprocessing technology	Techniques for improving image quality and extracting regions of interest	Denoising, enhancement and segmentation
Feature extraction technology	Extract meaningful information from the image and describe the characteristics and attributes of jewelry design.	Edge detection, texture analysis, shape description
Pattern recognition and classification technology	Pattern recognition and classification are carried out based on features, and classified design elements are identified and designed.	Design element identification (such as diamonds, metals, etc.) and design classification (such as rings and necklaces, etc.)
Design quality assessment algorithm	By setting assessment criteria and rules, an algorithm is constructed to automatically assess the quality of jewelry design.	Symmetry detection, proportion analysis and design specification verification
Optimization algorithm	It is used to automatically optimize jewelry design, and an efficient design optimization algorithm is developed by combining design rules and constraints and optimization objectives.	Design parameter adjustment (such as shape, size and layout optimization) and multi-objective optimization design.

Table 1: Examples of key technologies.

By using CAD and machine vision technology, the automation, intelligence, and efficiency of jewelry design can be realized, thus improving the productivity of designers, meeting the diversified needs of the market, and promoting the innovation and development of the jewelry design industry.

4 AUTOMATIC OPTIMIZATION ALGORITHM OF JEWELRY DESIGN

The automatic optimization algorithm of jewelry design is an innovative method combining CAD technology and machine vision technology, aiming to optimize jewelry design automatically, meet design requirements, and improve design efficiency. Based on mathematical optimization theory and computer science and technology, the algorithm automatically adjusts the design parameters by setting design rules, constraints, and optimization objectives, using iterative calculation and heuristic strategy, and realizes the automatic optimization of jewelry design. The identification and extraction of key features of jewelry design are shown in Figure 1.

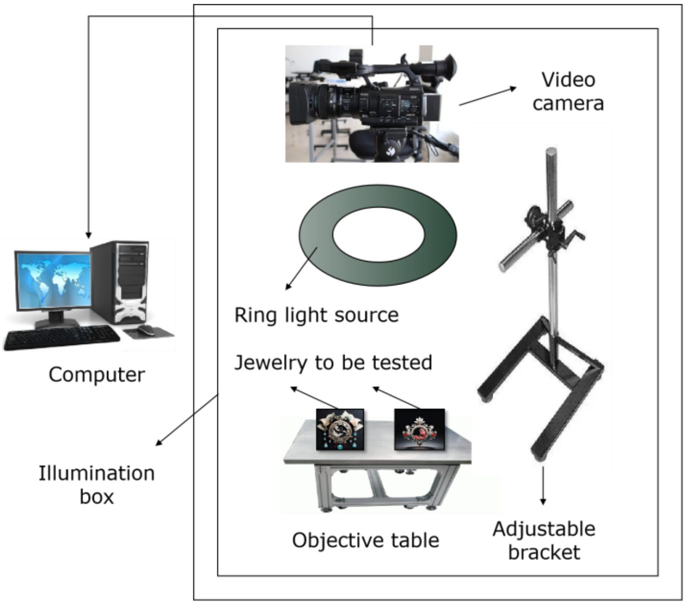

Figure 1: Identification and extraction of key features in jewelry design.

The flow of the jewelry design automation optimization algorithm constructed in this article is as follows:

(1) Determine the optimization objectives and constraints

The optimization goal is defined according to the demand and market trend of jewelry design. The optimization goals in jewelry design in this article include minimizing material cost and maximizing aesthetic feeling. Material cost optimization is helpful in realizing economical and efficient design, while aesthetic degree optimization can pursue the artistry and attractiveness of the design. At the same time, design rules and constraints need to be determined. These rules and conditions are derived from the actual demand and production restrictions, which are set as size restrictions and symmetry requirements in this article. Size limitation can ensure that the designed jewelry is suitable for wearing, and symmetry requirement comes from people's general recognition of symmetrical beauty.

(2) Generation of initial design scheme

Using CAD technology or based on the designer's experience, one or more initial design schemes are generated. These schemes serve as the starting point of the algorithm and are optimized in the following steps.

(3) Feature extraction and expression

Using machine vision technology, the initial design scheme is processed and analyzed, and key features, such as shape and texture, are extracted, which are the key elements to describe a design scheme. These features will be quantified and used for subsequent assessment function calculation.

(4) Construction of assessment function

Firstly, an assessment function is constructed according to the optimization objectives and constraints. This function can map the design scheme into a numerical score to measure the quality of the scheme. In this article, the assessment function considers many factors, such as material cost, aesthetic feeling, and size limitation. The processing of distance feature data is as follows: The distance feature data of samples and newly acquired images are used for cross-correlation processing, and the expressions of discrete autocorrelation and cross correlation functions used in this article are shown in the following formulas respectively:

$$R_{SS}\ n\ =\sum_{m=1}^{k}S\ \ m\,S\ \ m+n \tag{1}$$

$$D_{NS}\ n\ =\sum_{m=1}^{k}N\ \ m\,S\ \ m+n \tag{2}$$

Where S represents the sample image data, N represents the newly acquired image data, and m represents the m-th number from the starting position in the k distance arrays; n represents the number of intervals between the sample and the starting position of the newly sampled data. $S\ \ m+n$ represents the number $m+n$ in the sample array from the starting position; $N\ \ m$ represents the m number from the starting position in the distance array of the newly acquired image. The k distance values of newly collected jewelry and k distance values of sample jewelry are processed by discrete cross correlation, and the maximum value of discrete cross correlation is obtained.

(5) Design adjustment and optimization algorithm application

Optimization algorithm, such as GA or particle swarm optimization (PSO), is used to adjust and optimize the design scheme. Among them, GA is an optimization algorithm based on the theory of biological evolution, which searches for the optimal solution in the solution space by simulating natural selection and genetic mechanism. Jewelry design involves a large number of parameters and constraints, which is a complex optimization problem. GA is suitable for dealing with this complex, multidimensional and nonlinear optimization problem, so it is very suitable for automatic optimization of jewelry design. Therefore, this article adopts GA as the automatic optimization algorithm of jewelry design in this article. In the process of jewelry design automation optimization, GA is introduced to construct the objective function of jewelry design material collocation, and the function expression is:

$$f=\sum_{i>1}^{i}x_i y_i \tag{3}$$

Where f is the objective function expression of jewelry design material collocation based on GA; i stands for the category of matching materials for jewelry design. Different optimization objectives can be selected according to the actual needs of the project. Make clear that the parameter of different jewelry material dosage is x_i, and carry out boundary constraint on x_i to form a constraint condition formed by double boundaries. The formula is as follows:

$$x_i\in\left[a_i,b_i\right] \tag{4}$$

In the formula, a and b are respectively expressed as the boundary constraints of x_i, and the value of i is set according to the kind of jewelry materials. In combination with the actual situation, the values of a and b are set as constants.

Firstly, this article transforms the jewelry design scheme into a coding form that GA can handle. Each design parameter is encoded as a gene, and a complete design scheme is a chromosome composed of these genes. Then, a certain number of initial design schemes are randomly generated to form an initial group. The size of this group will affect the search efficiency and diversity of the algorithm. At the same time, an adaptive function is designed based on the assessment function mentioned above. This function is used to assess the fitness of each design scheme, that is, how close it is to the optimization goal. According to the value of the fitness function, the design scheme with higher fitness is selected to enter the next generation. Finding the maximum sum of design variables under constraints belongs to the optimization problem, and the general form of the optimization problem is:

$$\min f(x) \quad x \in \Omega$$
$$s.t \quad S_i(x) \geq 0 \quad i = 1,2,3,\cdots \tag{5}$$
$$h_j(x) = 0 \quad j = 1,2,3,\cdots \tag{6}$$

Where $S_i(x)$ is an inequality constraint; $h_j(x)$ is an equality constraint; $f(x)$ is the objective function. The optimization problem of the objective function can be expressed by the following formula:

$$\max f(X_i), X_i \in R \quad R \subseteq U \tag{7}$$

$$X_i = [x_1, x_2, x_3, \cdots, x_n] \tag{8}$$

Where $f(X_i)$ is the objective function of the optimization problem, X_i is the decision variable, the set of solutions satisfying the constraint conditions is denoted as R, and the basic space is denoted as U.

Randomly select two design schemes in the group, and perform crossover operation to generate a new design scheme. Cross operation can exchange some genes of the two schemes, thus combining the advantages of both. The newly generated design scheme is randomly modified to increase the diversity of the population and prevent the algorithm from falling into local optimization prematurely. For a certain sample (WT, p), when the output y is not equal to the expected output p, there is an output error:

$$E = \frac{1}{2}(y - p)^2 \tag{9}$$

The convergence of GA mainly depends on crossover operator, which ensures the global search ability of GA. In this article, GA is coded by floating point number, and crossover operator adopts non-uniform linear crossover, and the formula is as follows:

$$\begin{cases} x_1' = r_1 x_1 + (1 - r_1) x_2 \\ x_2' = r_2 x_2 + (1 - r_2) x_1 \end{cases} \tag{10}$$

Among them, $r_1 \in (0,1), r_2 \in (0,1)$ is randomly generated.

(6) Determination of termination conditions

After each iteration, check whether the termination condition is met. The termination conditions can be that the preset maximum number of iterations is reached, and the design scheme meets the set optimization goal. Once the termination condition is met, the algorithm will stop iteration.

(7) Optimal design scheme output

When the algorithm is terminated, the optimal design scheme is output. The scheme can be a design drawing in CAD file format for designers to further process and improve, or it can be directly output to manufacturing equipment for practical production. Using CAD polygon modeling to design jewelry is very convenient and fast, and the characteristics of jewelry can be reflected in fewer steps, which is especially important for modern commercial design process. Designers need to get the customer's confirmation of the design draft in the shortest time. Therefore, using 3D software can effectively shorten the design process. By implementing the above process, the automatic optimization of jewelry design can be realized, and the design efficiency and quality can be improved.

5 SIMULATION STUDY

5.1 Simulation Environment and Methods

In order to verify the effectiveness and performance of the automatic optimization algorithm of jewelry design based on CAD and machine vision, this section carries out simulation research. The simulation environment adopts high-performance computer cluster, and professional CAD software and machine vision library are used to simulate the jewelry design process. In the simulation method, a large number of random design cases are generated and input into the automatic optimization algorithm, and then the optimization results of the algorithm are observed and recorded. At the same time, the automatic optimization algorithm is compared with traditional design methods and other optimization algorithms, and its performance in design quality, efficiency and stability is analyzed. Through the simulation and optimization of a large number of design cases, this article obtains a wealth of experimental results and data. These data are statistically analyzed and visually displayed to assess the performance and effect of the algorithm.

5.2 Simulation of Automatic Optimization Algorithm for Jewelry Design Based on CAD and Machine Vision

In the simulation process, firstly, a variety of jewelry design cases with different styles, shapes and materials are generated by using CAD software. Then, the features of these design cases are extracted and assessed by machine vision technology. Through the methods of image processing and pattern recognition, this article successfully extracts the key features of jewelry design and establishes the corresponding assessment model. In order to extract the characteristics of design cases, this article uses high-resolution image acquisition equipment to take multi-angle and high-definition images of each design case. Image processing techniques, such as denoising, enhancement and segmentation, are used to preprocess these images to make their features more obvious. At the same time, the features of these preprocessed images are extracted by pattern recognition technology. The key features of jewelry design are extracted as shown in Figure 2.

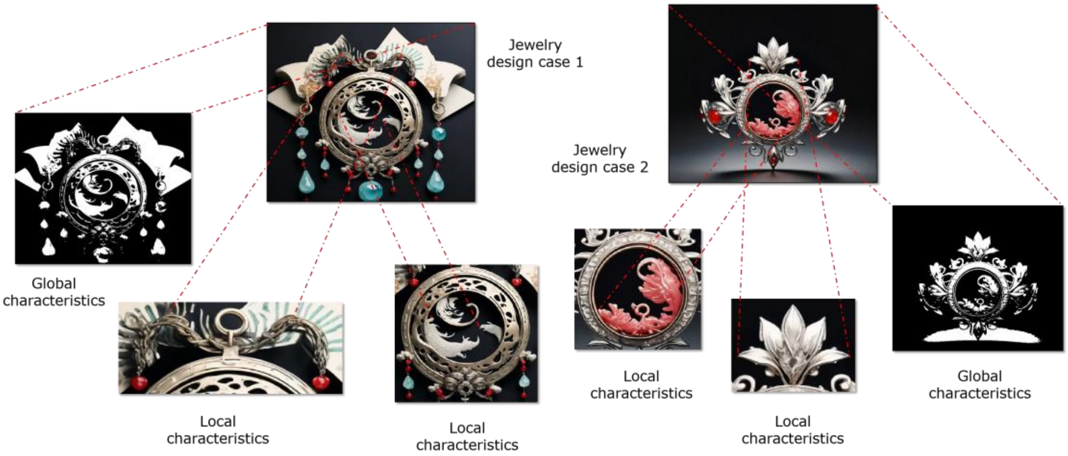

Figure 2: Extraction results of key features of jewelry design.

As shown in Figure 2, this article successfully extracted several key features of jewelry design. These features include the overall shape of jewelry, the way of cutting gems, the surface texture of metal and so on. Every feature is closely related to the aesthetic appearance, manufacturing difficulty and market acceptance of jewelry. Through this experiment, the feasibility of extracting key features from jewelry design generated by CAD by machine vision technology is verified. This provides strong data support for the subsequent optimization algorithm, which enables the algorithm to assess the advantages and disadvantages of each design scheme more accurately, and then make targeted optimization.

Next, these design cases and assessment models are input into the jewelry design automation optimization algorithm. The algorithm automatically adjusts and optimizes these design cases according to the set optimization objectives and constraints. Through continuous iterative calculation, the algorithm gradually improves the design scheme and outputs the optimized results. For GA, key parameters such as population size, crossover probability and mutation probability are set in this section to control the search efficiency and diversity of the algorithm. The termination condition of the algorithm-the threshold to meet the optimization goal is set. By running the algorithm, the automatic optimization results of jewelry design are obtained, and the corresponding Figures 3 and 4 are generated to show the efficiency and stability of the algorithm.

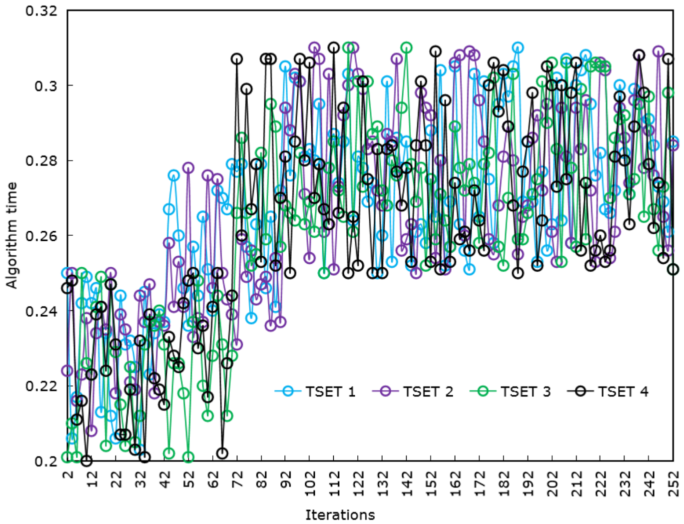

Figure 3: Efficiency of the algorithm.

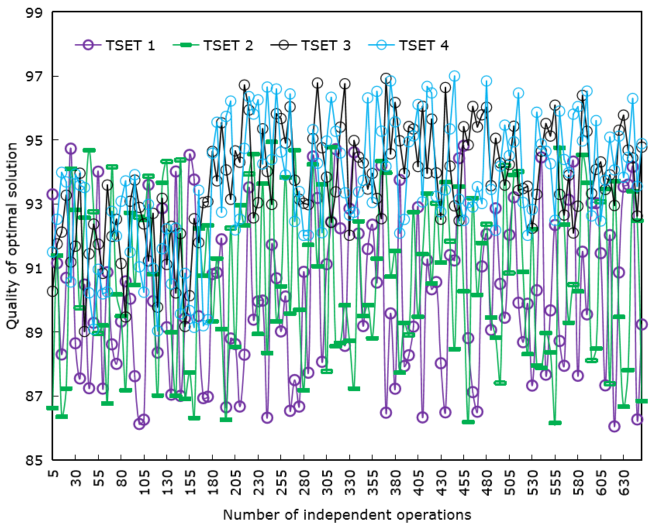

Figure 4: Stability of the algorithm.

Figure 3 shows the efficiency of the algorithm. It can be seen that with the increase of iterations, the algorithm is constantly approaching the optimal solution, and converges to a more stable result after a certain number of iterations. This verifies the convergence and efficiency of GA in jewelry design automation optimization.

Figure 4 shows the stability of the algorithm. By running the algorithm independently for many times and counting the optimal solution obtained from each run, it can be observed that the fluctuation of the algorithm is small between different runs, which shows that the algorithm has good stability. This means that the algorithm can consistently find high-quality design schemes under different design cases and random initialization. To sum up, through experiments, the effectiveness and performance of GA in jewelry design automation optimization are verified. The algorithm can automatically adjust and optimize the design case according to the set optimization objectives and constraints, and output the optimized results. At the same time, the efficiency and stability of the algorithm are verified, which provides reliable support for the subsequent practical application.

In the following experiment, a set of weight allocation strategy is formulated for the key elements of jewelry design, such as creativity, aesthetics, practicality and material cost. Each element has a quantitative scoring range, and it is scored according to the performance of the design scheme. Run the algorithm and record the quality score of each design scheme, as shown in Figure 5.

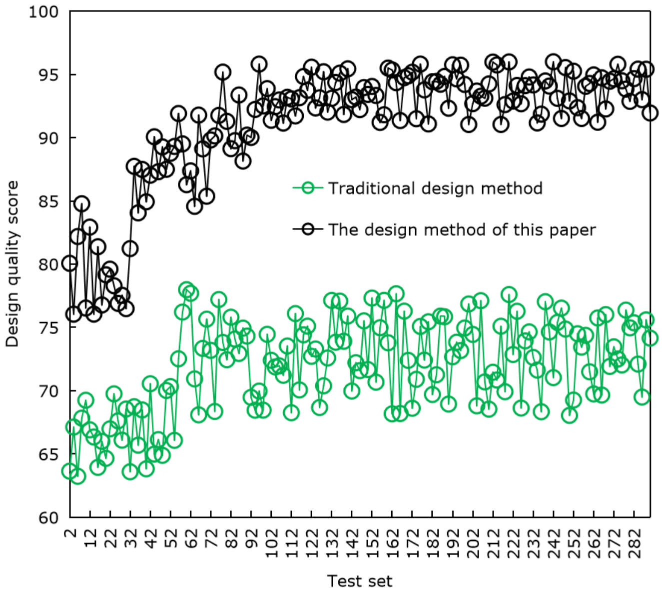

Figure 5: Algorithm design quality score.

Figure 5 shows the quality performance of the algorithm in jewelry design. It can be seen that the overall curve shows an upward trend, and finally converges to a higher score, which shows that the algorithm is effective in jewelry design optimization and can continuously improve the quality of design.

Other commonly used optimization algorithms, such as PSO algorithm and simulated annealing algorithm, are selected as comparison algorithms. In order to make a fair comparison, ensure that all algorithms run in the same computing environment and use the same computing resources. All comparison algorithms are applied to the same set of jewelry design cases to ensure that the optimization objectives and constraints are consistent. In addition, in order to ensure that each algorithm can show its best performance, this section pre-tunes the key parameters of each algorithm. The design efficiency comparison of different algorithms is shown in Figure 6.

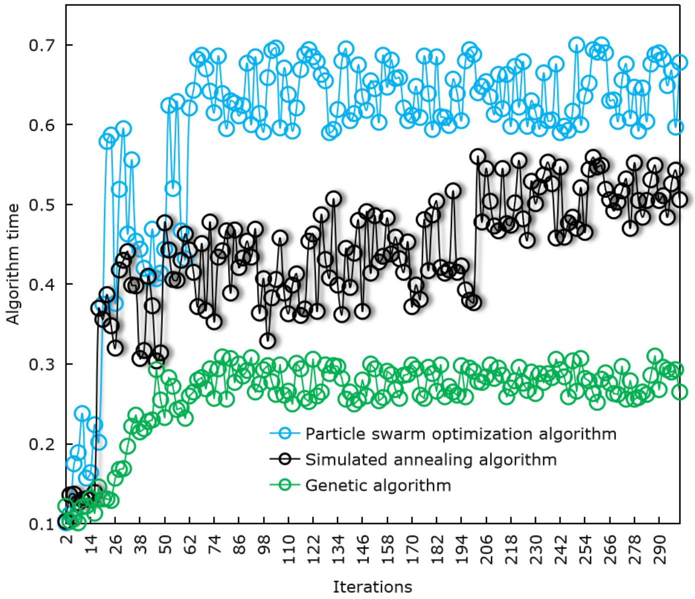

Figure 6: Comparison of design efficiency of different algorithms.

As can be seen from Figure 6, compared with PSO algorithm and simulated annealing algorithm, the automatic optimization algorithm proposed in this article shows obvious advantages in design efficiency. GA shows low calculation time and iteration times, which verifies the efficiency of GA in jewelry design optimization.

Finally, the traditional method and the optimization method in this article are used to design jewelry respectively. In order to compare the effects of the traditional method and the optimization method proposed in this article on jewelry design, the following experimental settings were carried out: the traditional method: selecting experienced jewelry designers, according to the design demand and market demand, adopting the conventional design process to design jewelry. This involves hand-drawn sketches, CAD software modeling and other steps. Designers mainly rely on their professional knowledge and experience in the design process, rather than algorithm optimization. The optimization method in this article: Using GA, according to the same design demand and market demand, the jewelry design is automatically optimized. According to the market demand and jewelry design rules, this article sets specific optimization goals: maximizing aesthetic feeling and minimizing material cost. Constraints such as size limit and weight limit are determined to ensure the feasibility of the generated design in actual manufacturing. At the same time, representative cases are selected from various types of jewelry with design requirements, including but not limited to rings, necklaces and earrings. These cases cover different materials, shapes, styles and design constraints. In order to ensure fairness, this section chooses the same design case, which is handled by the traditional method and the optimization method in this article respectively. The comparison results obtained by the experiment are shown in Figure 7 and Figure 8.

From the comparison results of Figure 7 and Figure 8, it can be seen that the optimization algorithm in this article has shown good adaptability in jewelry design cases with different types and design requirements. Specifically, no matter what kind of design case, the optimization algorithm in this article can find a high-quality design scheme stably, which proves its robustness. At the same time, the algorithm can adapt to different design requirements and constraints, showing its versatility for diverse tasks. Compared with the traditional design method, the optimization algorithm in this article shows obvious advantages and wide applicability in jewelry design, which provides a powerful tool for the automation and intelligence of jewelry design.

Figure 7: The results of traditional jewelry design.

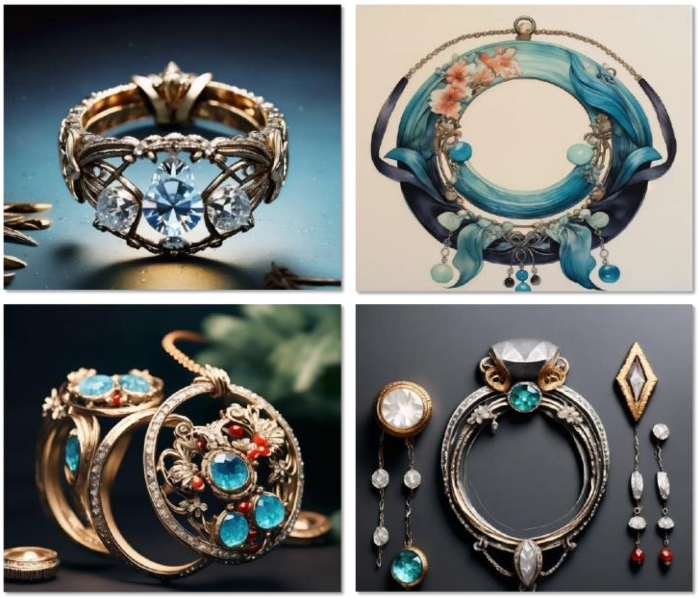

Figure 8: The jewelry design results of the optimization method in this article.

6 CONCLUSION

This study combines CAD technology and machine vision technology, proposes an automatic optimization algorithm for jewelry design, and studies and verifies its performance. In the research process, firstly, the basic principles of CAD technology and machine vision technology are introduced, and their applications in jewelry design are analyzed. Then, the principle and implementation steps of jewelry design automation optimization algorithm are described in detail, and the effectiveness and performance of the algorithm are verified by simulation research. Through simulation research, this article verifies the effectiveness and performance of the automatic optimization algorithm of jewelry design based on CAD and machine vision, and proves the advantages of the automatic optimization algorithm in design quality, efficiency and stability. The algorithm can significantly improve the efficiency and quality of jewelry design and provide designers with more powerful and efficient design tools.

On the whole, the research on the automatic optimization algorithm of jewelry design based on CAD and machine vision not only helps to improve the efficiency and quality of jewelry design, meet the diversified needs of consumers, but also meets the requirements of global competition and sustainable development of jewelry market, and is expected to solve the skill shortage problem faced by the industry. Therefore, this study has important practical significance and long-term development value. In the future work, we will further improve the algorithm, improve its performance and adaptability, and promote its practical application in jewelry design industry. Through continuous efforts and exploration, it is believed that the automatic optimization algorithm of jewelry design based on CAD and machine vision will bring more innovations and breakthroughs to the jewelry design industry and promote the progress and development of the industry.

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