



Digital Automatic of Clothing Design Cad Based on Intelligent Sensing Technology

Hai Liu^{1,3,*}, Lei Hu^{2,4}

¹College of Big Date Science, Jiangxi Institute of Fashion Technology, Nanchang 330201, Jiangxi, China

²Operation and Maintenance Section of Assets Department, Jiangxi Institute of Fashion Technology, Nanchang 330201, Jiangxi, China

³Clothing big data research center, Intelligent Research and Innovation Team for Clothing (Jiangxi Institute of Fashion Technology), Nanchang, 330201, Jiangxi, China

⁴Information Technology Integration Innovation Center, Intelligent Research and Innovation Team for Clothing (Jiangxi Institute of Fashion Technology), Nanchang, 330201, Jiangxi, China

Emails: Hai_Li22@outlook.com; LeiHu@outlook.com

Abstract

Clothing design plays an important role in personal image expression and social and cultural transmission. The traditional fashion design method has many problems, such as low efficiency and large design error, and it is difficult to bring users better wearing experience. In order to meet different users' Design needs, reduce design errors, and improve users' satisfaction with design results, this paper combined with intelligent sensing technology, conducted in-depth research on digital automation analysis of clothing design CAD (Computer Aided Design). Aiming at the clothing design process, this paper first constructed a brand-new clothing design CAD system, using the depth transducer to solve the 3D information of the relevant feature points, and realized the accurate acquisition of the human body feature size information. Through the registration of adjacent frame point data, the 3D human body modeling was carried out. Then, according to the user's physical characteristics and related information collected by the sensor, the paper compared the user's characteristic information to filter out the user's preferences, and used the recommendation algorithm to calculate the corresponding parameters to realize the intelligent choice of clothing styles. Finally, through the measurement of each index by the sensor, the size adjustment of the garment and the specific design of the garment were realized. In order to verify the effect of clothing design CAD system based on intelligent sensing technology, this paper conducted system tests. The results showed that in terms of clothing comfort, clothing quality and clothing functionality, the number of users satisfied and very satisfied reached 50.4%, 47.9% and 51.3%, respectively. From the overall survey results, the system has a high degree of user satisfaction. The research conclusion of this paper shows that the digital automatic analysis of clothing design CAD based on intelligent sensing technology can effectively meet the needs of users, improve their wearing experience, and promote the intelligent development of clothing design.

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1. Introduction

With the maturity of intelligent manufacturing technology, the CAD digital automation of clothing design has been applied more and more widely in the field of clothing, and has greatly improved the intelligence and design efficiency of clothing design. Fashion design is a complex and tedious process, which requires designers to consider many factors such as material selection, size adjustment, and human movements. The traditional fashion CAD digital automation technology still has some limitations in design quality and design effect, and there may be design errors, which have a great impact on the user's wearing experience. The emergence of intelligent sensing technology has brought new opportunities for clothing design, which has the characteristics of high precision and

low cost. This paper takes intelligent sensing technology as the core. The digital and automatic analysis of clothing design CAD can effectively reduce design errors, improve design efficiency and the accuracy of design data collection and analysis, improve the comfort level of clothing design, and optimize users' wearing experience.

Garment design CAD digital automation technology plays an important role in simplifying design process and improving design efficiency. Petrak, Slavenka applied CAD systems and software packages to textile and fashion design in order to improve the efficiency of fashion design. Through the three-dimensional visualization of clothing design models, it greatly accelerates the development of new fashion collections, thus realizing the true presentation of designers' ideas [1]. Guo, Huijie has solidified his knowledge of clothing layout design through plate making to meet the needs of personalized clothing customization, and takes the clothing CAD system as an example. He analyzed and refined the knowledge of garment plate-making process, established a model design model by using directed graphs, and improved the digital automation efficiency of garment design CAD [2]. In order to efficiently design 3D (Three-dimensional) clothing and 2D (Two-dimensional) samples, Jankoska, Maja used CAD to assist the design of men's shirt models based on the developed 2D sample sketches. He unfolded 2D samples and 3D surface layers together, and then formed 3D finite external units directly based on the stitching information and coordination relationship between 3D surfaces and 2D samples, simplifying the pattern and parameter adjustment process in the design process [3]. In order to improve the efficiency of clothing design, Slavinskaya, Alla studied the relationship between the grading coefficient of size standard and the estimated size of shoulder structure, and determined the grading coefficient of design development and finished product size control through CAD regression analysis, reducing the design time and steps [4]. Garment design CAD digital automation technology plays an important role in simplifying the design process, but with the improvement of consumer demand, its design quality also needs to be improved and optimized. The current research does not consider the design rationality and comfort.

The development of intelligent sensing technology provides more possibilities for improving the quality and comfort of garment design CAD digital automation design. In order to improve clothing comfort and realize 3D mannequin reconstruction and human size measurement, Li Xihang proposed an information acquisition system based on multi-sensor information fusion. He collected 11 key size data of the human body, which provided convenience for clothing design and customization, and improved the comfort of design results to a certain extent [5]. In order to design a casual intelligent clothing with high comfort, Wei Ding used a relaxed skin sensor in the clothing design to conduct real-time temperature monitoring of the sample object. The results show that the design results can improve the wearing comfort of clothing to a certain extent [6]. Intelligent sensing technology provides more comprehensive design evaluation data, which helps to optimize the design effect of the digital automation of clothing design CAD. Most of the researches still have some limitations in the aspects of design data meeting user needs and design information collection accuracy.

In order to enhance user satisfaction and improve the efficiency and quality of clothing design, this paper combined with intelligent sensing technology to carry out in-depth research on the digital automatic analysis of clothing design CAD. With the support of intelligent sensing technology, the CAD system for clothing design can effectively control the error of height, shoulder width and hip circumference design information below 1%. In terms of design efficiency, this system can realize the fast processing of design data, ensure the effective realization of system functions, and design tasks. Compared with the traditional clothing design CAD system, the system redesign in this paper has significant advantages in terms of cost and user satisfaction, and can effectively meet user needs based on reasonable cost control. The innovation point of this paper is that the digital automatic analysis of clothing design CAD based on intelligent sensing technology can effectively realize the high-precision collection of design data. It brings more possibilities and advantages to clothing design in terms of user wearing experience, and improves the level of intelligence and individuation of clothing design.

2. Clothing Design CAD System

Clothing design CAD is computer-aided clothing design [7]. The CAD system of clothing design based on intelligent sensing technology in this paper is based on traditional style design, and follows traditional design rules from design ideas to design procedures. For the design process, the overall framework of the garment design CAD system in this paper is shown in Figure 1:

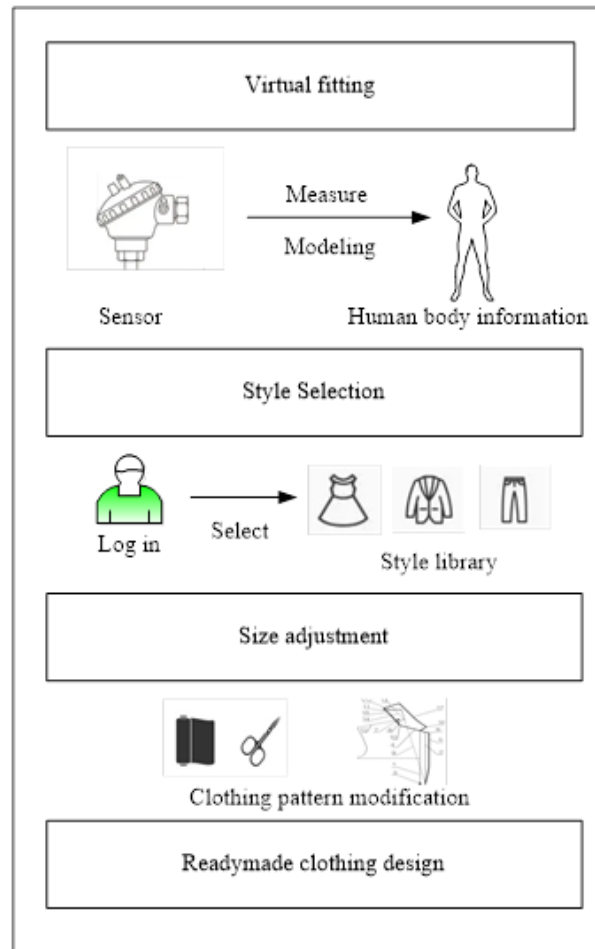


Figure 1. Clothing design CAD system

According to the overall framework, the functions of the garment design CAD system are divided into virtual fitting module, style selection module, size adjustment module and garment design module.

In the virtual fitting module, the system can use the sensor to collect and measure the body circumference information at a ratio of 1:1. The human body model is built according to the dimensional feature points, so that the overall dimensional information needed for clothing design can be obtained at a faster speed.

In the style selection module, users can log in to the system through the terminal or on the webpage on the computer, and select suitable clothing styles and color patterns according to the system recommendations.

After the work of the first two modules, the clothing would enter the trial board, that is, the user order information and its size data would be analyzed through the size adjustment module. Combined with user needs, it uses intelligent sensing technology to adjust clothing samples. After adjustment, the garment CAD system would automatically arrange the material according to the template, and generate independent paper patterns and layout drawings. The paper pattern data is then passed into the virtual fitting module for 3D conversion and cutting operations, and fitting is performed on the constructed 3D model. After fitting, if the final effect meets the needs of the user, then the paper pattern would be transmitted to the garment design module. The garment design module organically combines sensors and process systems to enable flexible design. It can not only greatly reduce the inventory of products and the cost of enterprises, but also allow direct communication between users and enterprises to improve user satisfaction.

2.1 Virtual Fitting

The so-called virtual fitting is to match a garment shape with a human body model, and then simulate the shape of the garment according to the movement of the human body, to judge whether the size of the garment fits, and the shape and characteristics of different materials of clothing in the natural overhanging state [8].

2.1.1 Body Measurement

In the CAD system of clothing design, the key to the realization of virtual fitting function is to build the human model of clothing. The measurement of human body circumference information is the first step to build the model. It is a very important supporting work in fashion design to obtain the information of human outline size through accurate measurement technology and means [9]. It is not only the prerequisite for the construction of clothing mannequin, but also the basis for the establishment of specifications and technical standards. However, due to the large difference of human profile size information, the measurement work is more complicated, and it is difficult to accurately obtain the complete and fine human characteristics parameters in practice.

In order to realize the accurate measurement of human body circumference information, this paper realizes the unity of human body measurement method with the support of intelligent sensing technology. The advantages of depth transducers are low cost, small size and strong flexibility [10]. It has high adaptability in clothing design CAD system. In this paper, the depth transducer combined with the depth information of the human body is used to extract the corresponding three-dimensional spatial information of the feature points, to achieve the accurate extraction of the circumference information of the human body. The depth transducer consists of a wire, a pinhole camera, a light-emitting diode, a 3-volt button battery, a switching metal, an insulating board, and a silicone carrier containing an integrated circuit. The usage parameters are shown in Table 1:

Table 1: Usage parameters of the depth transducer

SEQUENCE	PARAMETER	SPECIFICATIONS
1	SERVICE LIFE	MORE THAN 300000 TIMES
2	STATIC RESISTANCE	1-8 MEGAOHMS
3	HYSTERESIS	LESS THAN 10%
4	RESPONSE TIME	5 TO 10 MILLISECONDS
5	WORKING VOLTAGE	1-8 VOLTS
6	NUMERICAL STABILITY TIME	0-5 SECONDS

In this paper, the human bone node is used as the feature point to measure the depth information of the human body. In the selection of measurement benchmarks, the bone nodes constructed in this paper mainly include 15 parts such as trunk, shoulder and head, which cover the main bone node parts of the human body. Then, the pinhole camera is used to reverse position each node, and the position information of each node is obtained. The calculation formula is as follows [11]:

$$d_v = \begin{Bmatrix} a \\ b \\ 1 \end{Bmatrix} = \begin{bmatrix} f_x/l_x & 0 & a_0 \\ 0 & f_y/l_y & b_0 \\ 0 & 0 & 1 \end{bmatrix} [M, t] \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \quad (1)$$

The explanation of variables in the formula is shown in Table 2:

Table 2: Interpretation of formula variables

SEQUENCE	VARIABLE	MEANING
1	D_v	DEPTH VALUE
2	A	COORDINATE
3	B	
4	A_0	ORIGIN OF COORDINATE SYSTEM
5	B_0	
6	F_x	FOCAL LENGTH IN THE X DIRECTIONS
7	F_y	FOCAL LENGTH IN THE Y DIRECTIONS
8	L_x	THE LENGTH OF A UNIT PIXEL IN THE X DIRECTIONS

9	L_y	THE LENGTH OF A UNIT PIXEL IN THE Y DIRECTIONS
10	M	ROTATION MATRIX
11	T	TRANSLATION VECTOR

The camera coordinate system of the depth transducer is consistent with the absolute coordinate system(X, Y, Z), so M can be used as an identity matrix, t can be used as a zero vector; depth value d_v and the absolute coordinate system overlap each other, so Formula 1 can be simplified as:

$$d_v = \begin{Bmatrix} a \\ b \\ 1 \end{Bmatrix} = \begin{bmatrix} f_x/l_x & 0 & a_0 \\ 0 & f_y/l_y & b_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ d_v \\ 1 \end{bmatrix} \quad (2)$$

According to Formula 2, the three-dimensional coordinates of the human body model can be calculated as [12] :

$$\begin{cases} X = (a - a_0) \cdot d_v \cdot l_x/f_x \\ Y = (b - b_0) \cdot d_v \cdot l_y/f_y \\ Z = d_v \end{cases} \quad (3)$$

It can be seen from the formula that the depth information of human bones collected by intelligent sensing technology is converted into three-dimensional coordinates. The circumference of key feature points of the human body can be accurately measured, and the final measurement effect is shown in Figure 2.

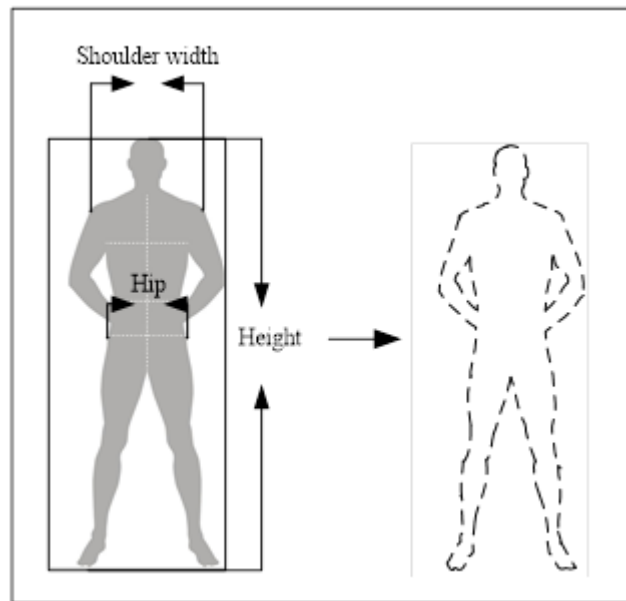


Figure 2. Measurement effect of intelligent sensing technology

2.1.2 Human Body Modeling

3D human modeling is the key of virtual fitting in CAD system of clothing design. In order to build the human body model, the existing anthropometric data must be applied to the 3D model. Starting from the requirements of virtual fitting, this paper establishes a set of human body modeling system by using sensors and rotating platform. The main process of the system is shown in Figure 3.

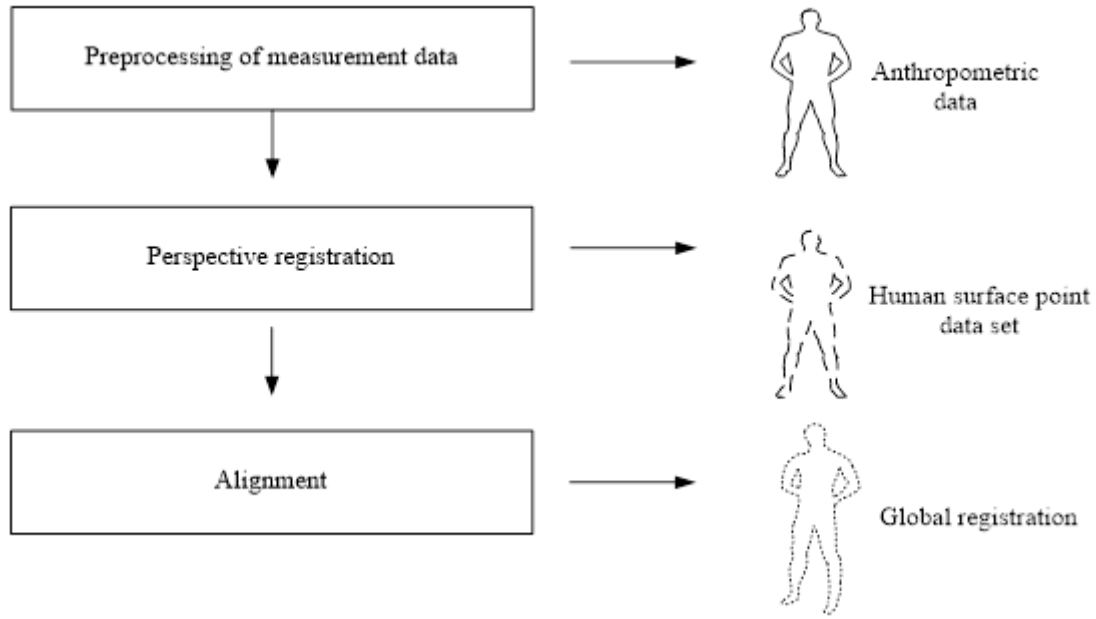


Figure 3. Process of 3D human modeling system

First, all points on the ground plane are defined as inner points, and points other than inner points are defined as outer points. Thirty points were randomly assigned from the inner points and then divided into three groups of 10 points each: $p_1, p_2, \dots, p_{10}, p_{11}, p_{12}, \dots, p_{20}, p_{21}, p_{22}, \dots, p_{30}$. In this paper, the mean values of 10 points in each group are calculated [13]:

$$p = (\bar{X}, \bar{Y}, \bar{Z}) \quad (4)$$

Among them:

$$\begin{cases} \bar{X} = \frac{1}{10} \sum_i X_i \\ \bar{Y} = \frac{1}{10} \sum_i Y_i \\ \bar{Z} = \frac{1}{10} \sum_i Z_i \end{cases} \quad (5)$$

Three points are obtained for calculating the plane equation:

$$\begin{cases} \bar{p}_1 = (\bar{X}_1, \bar{Y}_1, \bar{Z}_1) \\ \bar{p}_2 = (\bar{X}_2, \bar{Y}_2, \bar{Z}_2) \\ \bar{p}_3 = (\bar{X}_3, \bar{Y}_3, \bar{Z}_3) \end{cases} \quad (6)$$

Suppose that the ground plane equation is [14]:

$$AX + BY + CZ + D = 0 \quad (7)$$

Then calculate the distance from the point to the surface according to the formula:

$$\text{distance} = \frac{|AX_i + BY_i + CZ_i + D|}{\sqrt{A^2 + B^2 + C^2}} \quad (8)$$

By registering the point data of adjacent frames, the point data set of the global surface, that is, the 3D model of the completely human body can be obtained. In the registration process, the conversion matrix T_i between adjacent frames is calculated first, which is used to represent the transformation relationship from the $i + 1$ point data p_{i+1} to the i point data p_i . The transformation matrix consists of a matrix of $4 * 4$, including a rotation matrix and a shift matrix.

After the pair-to-pair registration of all adjacent frames is completed, it is only necessary to convert the obtained adjacent frame conversion matrix into the conversion matrix $T_{i \rightarrow 0}$ of the T_i frame to the first frame for convenience of subsequent processing and analysis. $T_{i \rightarrow 0}$ is expressed as:

$$T_{i \rightarrow 0} = (T_0 * T_1 * T_2 * \dots * T_i)^{-1} \quad (9)$$

By converting the point data of each frame to the coordinate system of the point data of the first frame, the 3D human body modeling shown in Figure 3 can be obtained.

2.2 Style Selection

In the fashion design CAD system, the style selection module is mainly based on the analysis and collection of the user's body data, related information and the historical behavior data that the user has browsed. It can calculate the clothing styles that users are likely to be interested in and recommend them. The logical structure of the module is shown in Figure 4:

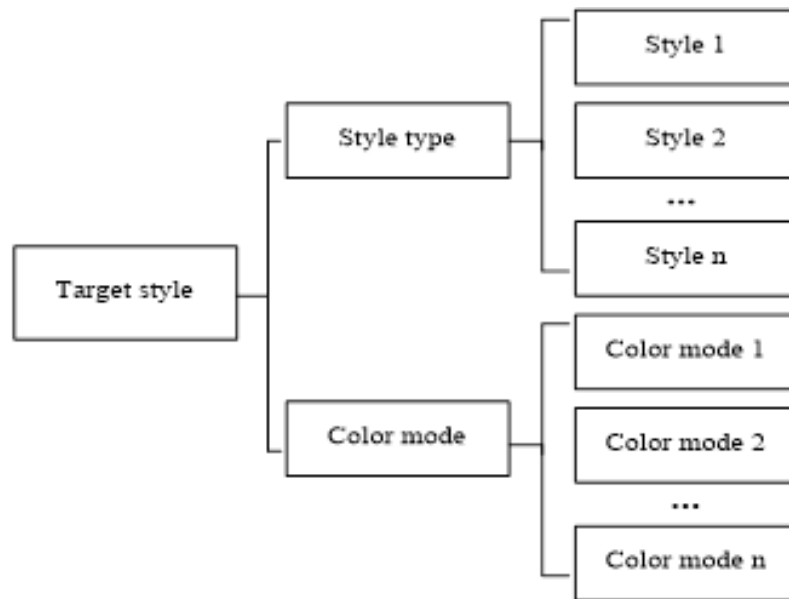


Figure 4. Logical structure of style selection module

The target user is input into the system module along with various information, and the module analyzes the user's body data, related information and behavioral data obtained by the sensor. The recommendation algorithm can calculate the corresponding parameters, and the descriptive model of the user's clothing style can be established.

Before establishing the final description model of the user is clothing style, it needs to build the user's feature model. The description model is constructed on the premise of parameter calculation; while the feature model is extracted from, the user has completed personal data through a pre-set of key words. The system would implement the construction of each user feature model by assigning weights to each keyword.

After establishing the user feature model, it also needs to perform cluster analysis. The K-means algorithm has a small amount of computation and can process a large amount of data quickly [15]. The clustering of user feature model is realized based on K-means algorithm and its specific steps are as follows: a data set is assumed to have n targets and the number of clusters k . On this basis, k data objects are randomly selected from n objects, and each data object represents the initial average of a cluster. The remaining data objects are assigned to the most similar clusters by Euclidean distance. After the assignment, the average number of clusters needs to be recalculated until the assignment result is stable [16].

If the vector of the i object in the remaining data objects is represented as $(v_{i1}, v_{i2}, \dots, v_{in})$, and the vector of the j object in the center of the cluster is represented as $(u_{j1}, u_{j2}, \dots, u_{jn})$, then the Euclidean distance of i and j can be expressed as [17]:

$$o_{ij} = \sqrt{\sum_{k=1}^n (v_{ik} - u_{jk})^2} \quad (10)$$

In order to evaluate the effect of clustering, it can use the error sum of squares criterion function to judge whether the final grouping assignment result is stable. In particular, suppose that it has completed the clustering and obtained several clusters, each containing some objects. Suppose the clusters are c_1, c_2, \dots, c_k and the number of objects in each cluster is h_1, h_2, \dots, h_k . The mean points of each cluster are m_1, m_2, \dots, m_k . Then, the error sum of squares criterion function E can be defined as [18]:

$$E = \sum_{i=1}^k \sum_{h \in c_i} \|h - m_i\|^2 \quad (11)$$

After the cluster analysis of the user feature model, the Euclidean distance between the model and the center point of the cluster needs to be calculated, which formula 10 can achieve. After the calculation is complete, the results need to be filtered. Euclidean distance can be used to measure the similarity between the center points of different clusters and the user clusters.

The clothing style type and color pattern selected by all users in the user cluster can be obtained, and the descriptive model of the user cluster is calculated as \vec{R}_a by using the Term frequency-inverse document frequency method, and the descriptive model of the target user is calculated as \vec{R}_b .

According to \vec{R}_a and \vec{R}_b , the final description model \vec{R}_e of the target user is generated. Set description model $\vec{R}_a = (R_{1a}, R_{2a}, \dots, R_{\gamma a})$ and description model $\vec{R}_b = (R_{1b}, R_{2b}, \dots, R_{\gamma b})$, then the final description model \vec{R}_e of the target user is [19]:

$$\vec{R}_e = \vec{R}_a + \frac{1}{s^q} \vec{R}_b \quad (12)$$

s is a constant; γ is the total number of keywords in the description model, and q is the number of styles and color patterns that the target user has selected.

Based on the user's physical characteristics and related information collected by the sensor, this paper compares with the user's characteristic information to screen out the user's preferences. Finally, it recommends suitable clothing styles to users, and displays the recommended clothing styles on the clothing design CAD system interface. The test interface of the system is shown in Figure 5. Users can choose the style and color they want in the interface according to their actual needs. Compared with the traditional offline fitting, the style selection module in the clothing CAD system can effectively realize the digital automation of clothing design. This not only brings great convenience to the user, but also reduces the user's time and energy costs.

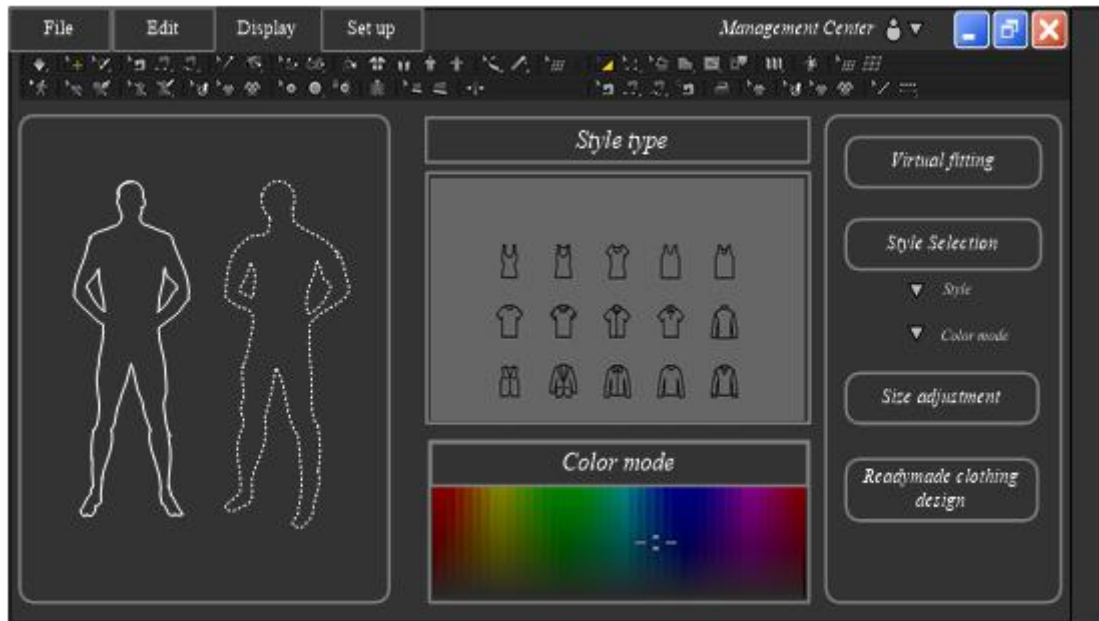


Figure 5. Garment design CAD system test interface

2.3 Size Adjustment

Clothing design in the new era pays more attention to the wearing experience of clothing. Therefore, in the process of technology adoption, clothing design CAD not only has a good effect in style selection, but also needs to have intelligence in size adjustment [20-21]. The function of the size adjustment module is mainly reflected in the comfort of clothing. Clothing comfort refers to the clothing performance that can have a favorable impact on human movement and daily life and work in a specific human clothing environment, which can satisfy the basic wearing experience of users. This kind of satisfaction comes from both physiological and psychological levels, which is the result of multiple factors [22]. Generally, when judging whether the material selection and structure of clothing are reasonable, the surface topography of clothing can be detected according to the pressure, temperature, and humidity of the clothing to improve the comfort of the clothing. The size adjustment module of the system in this paper mainly adjusts the size of clothing according to the difference of users, and uses sensors to measure the clothing pressure, temperature and humidity of the human body at rest or in motion. By accurately measuring these indicators, the module can ensure the comfort and fit of the garment, thus intuitively and in real time meeting the users comfort needs for the garment. The working principle of the module is shown in Figure 6:

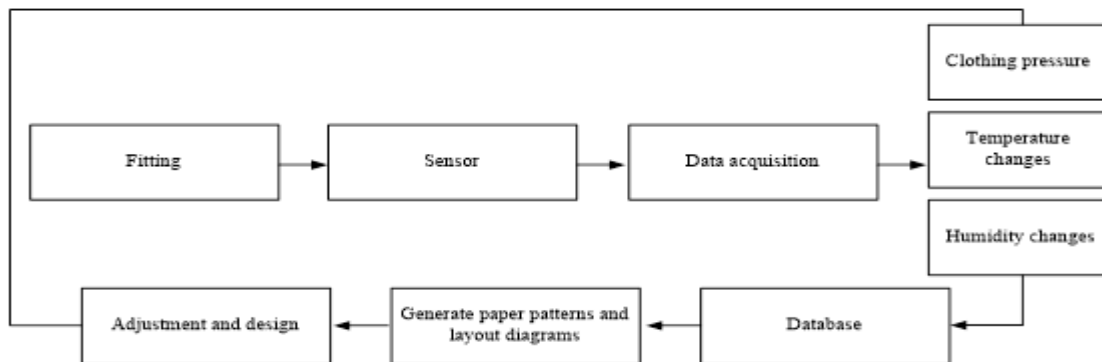


Figure 6. Working principle of the size adjustment module

In Figure 6, the size adjustment module of the garment design CAD system mainly uses the sensor to convert the measured physical quantity into an electrical signal, and then transmits, analyzes and processes the data through the database. It calculates and displays the indicators in the system, takes the final analysis result as the reference, carries on the automatic discharge, generates the paper pattern and the discharge diagram. Ready-to-wear can be tried on a model for final costume adjustment and design. In the size adjustment module, the measurement of each index by the sensor provides a reliable data basis for the satisfaction of clothing comfort requirements.

2.4 Garment Design

The garment design module is mainly designed for users' virtual fitting, style selection and size adjustment structure. When designing garments, modules would be selected from men or women's clothing according to the user's gender, and then determine the final design style according to the user's requirements. After determining the design style, the specific structure design of the garment can be carried out. In general, modules follow traditional design steps and sequences to automate design. Its main process is shown in Figure 7:

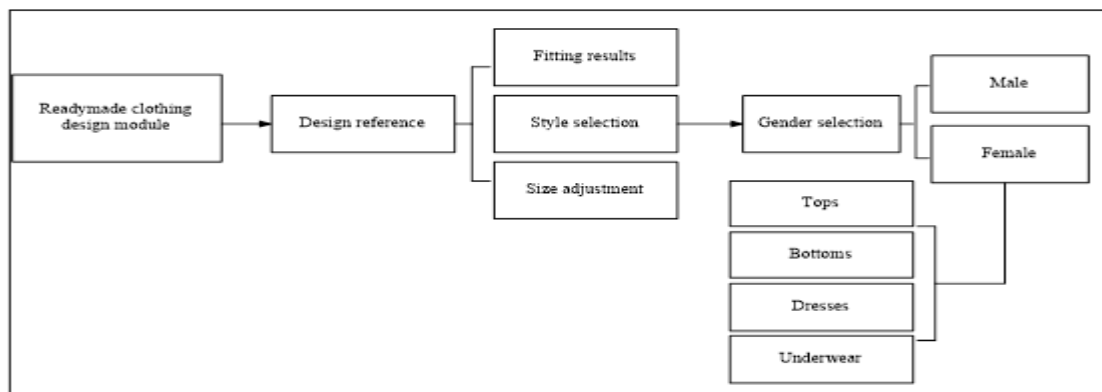


Figure 7. Main process of garment design module

3. Garment Design CAD System Test

In order to verify the effectiveness of digital automatic analysis of clothing design CAD based on intelligent sensing technology, the paper tested the clothing design CAD system from the aspects of design information collection accuracy, design efficiency, design cost and user satisfaction. In order to highlight the effect of fashion design CAD system, this paper compares it with the traditional fashion design system in the market. The test environment of the two systems is shown in Table 3:

Table 3: System test environment

ATTRIBUTE	ITEM	SPECIFICATIONS
HARDWARE	CENTRAL PROCESSING UNIT	PENTIUM 630 2.7GIGAHERTZ
	OPERATING SYSTEM	WINDOWS 2019 SERVER
	MEMORY	4GIGABYTES
	HARD DISK	1TERABYTE
SOFTWARE	BROWSER	INTERNET EXPLORER 11.0
	NETWORK PROTOCOL	TRANSMISSION CONTROL PROTOCOL/INTERNET PROTOCOL

3.1 Design Information Collection Accuracy

Design information mainly refers to the user's circumference information. In fashion design, the collection of body circumference information has a key impact on the user's wearing experience. Therefore, the system needs to ensure the accuracy of information collection and determine the structure and size of the clothing, to meet the purpose of the human body and functional requirements. In this paper, the height, shoulder width and length measured by the two systems are compared with the real circumference value of the hip circumference tester. After extracting the dimensional feature points of the subjects, the important dimensions of the tested objects are obtained, and on this basis, the real circumference information of the subjects is collected, as shown in Table 4. The relative error results collected by the two systems are shown in Figure 8:

Table 4: Real circumference information of subjects

SEQUENCE	HEIGHT (CENTIMETER, CM)	SHOULDER WIDTH LENGTH (CM)	HIP CIRCUMFERENCE LENGTH (CM)
SUBJECT 1	177	41.6	89.2
SUBJECT 2	169	39.2	84.5
SUBJECT 3	173	37.3	85.1
SUBJECT 4	180	39.5	92.3
SUBJECT 5	172	41.2	86.7
SUBJECT 6	163	38.1	82.4
SUBJECT 7	179	39.3	89.6
SUBJECT 8	185	43.9	93.3
SUBJECT 9	176	38.4	89.5
SUBJECT 10	182	39.2	90.8

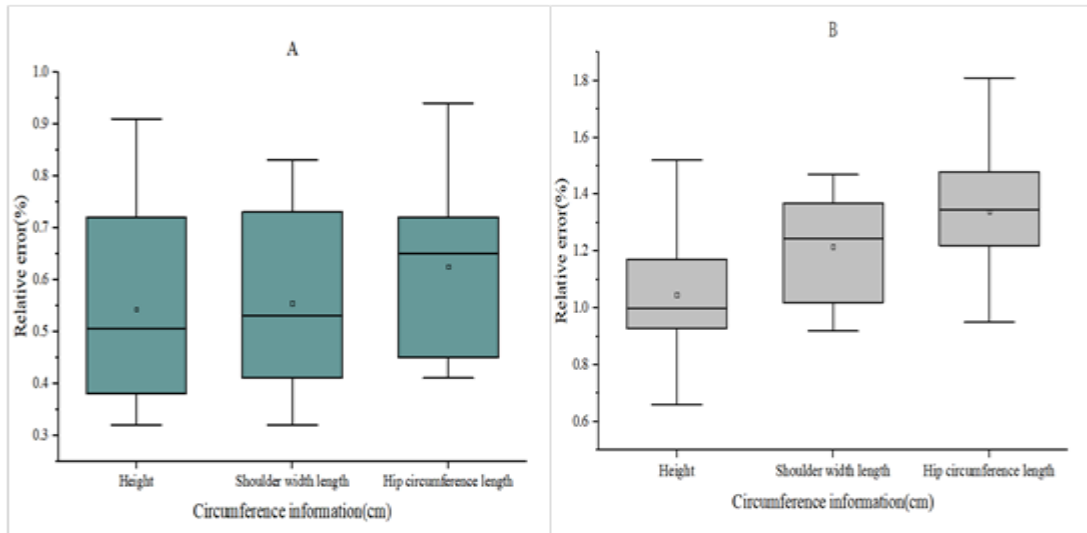


Figure 8. Results of information collection accuracy: Figure 8A shows the accuracy of the system information collection in this paper; Figure 8B shows the accuracy of information acquisition in traditional systems

In Figure 8, the horizontal axis represents the subject's height, shoulder width, and hip length information, and the vertical axis represents the relative error of the system's measurement results. As can be seen from Figure 8A, the mean relative error of the measured results of the system in this paper was about 0.54% in terms of height, and about 0.56% in terms of shoulder width. In terms of hip circumference, the mean relative error of the measured results was about 0.63%. As can be seen from Figure 8B, the mean relative errors of measurement results of height, shoulder width and hip circumference in the traditional system were about 1.05%, 1.22% and 1.34%, respectively.

3.2 Design Efficiency

The design efficiency of garment CAD system depends on the system functional integrity, data processing efficiency and task completion rate. Among them, functional integrity mainly examines whether the system design, modification, saving, export and other functions are perfect, and whether it can support a variety of clothing design requirements. Data processing efficiency is to examine the efficiency of the system in processing a large number of design data, including the speed of design data import, export, calculation and other operations. The task completion rate is the response efficiency of the system to the requests and commands issued. Within the specified test time, this paper takes 10 types of clothing design tasks of different styles as test cases to test the functional integrity, data processing efficiency and task completion rate of the two systems. The results are shown in Figure 9:

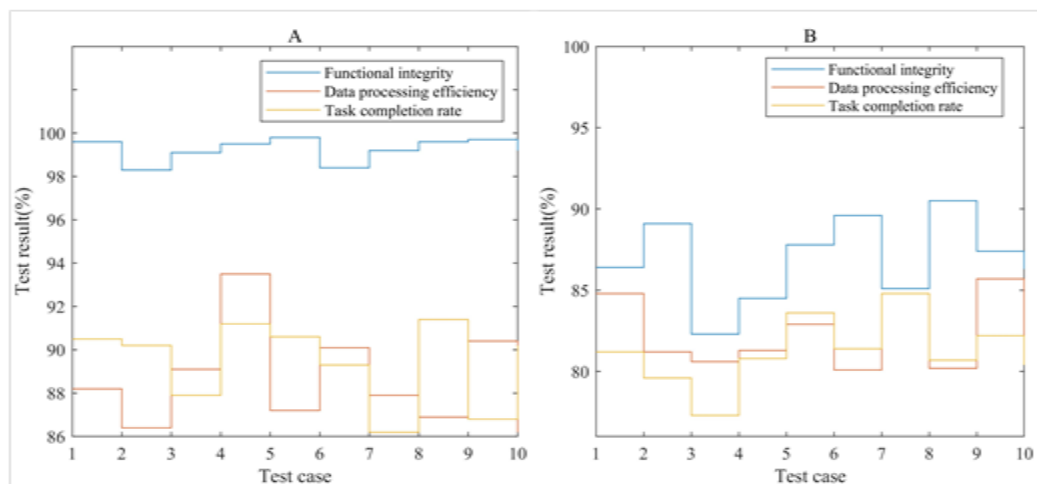


Figure 9. Design efficiency results: Figure 9A shows the design efficiency of the system in this paper; Figure 9B shows traditional system design efficiency

In Figure 9, the horizontal axis represents the test cases for design efficiency, and the vertical axis represents the test results. In Figure 9A, the average test results of functional integrity, data processing efficiency and task completion rate of the system in this paper under different test cases reached about 99.2%, 88.6% and 89.4%, respectively. In Figure 9B, the average test results of functional integrity, data processing efficiency and task completion rate of the traditional system under different test cases were about 86.9%, 82.4% and 81.2%, respectively.

3.3 Design Cost

In fashion design, sample production cost, design process cost and quality control cost often take a large proportion in the overall cost structure. This paper also takes 10 types of clothing design tasks of different styles as test cases, and compares the proportion of sample making cost, design process cost and quality control cost of the two systems in the overall cost structure. The results are shown in Figure 10:

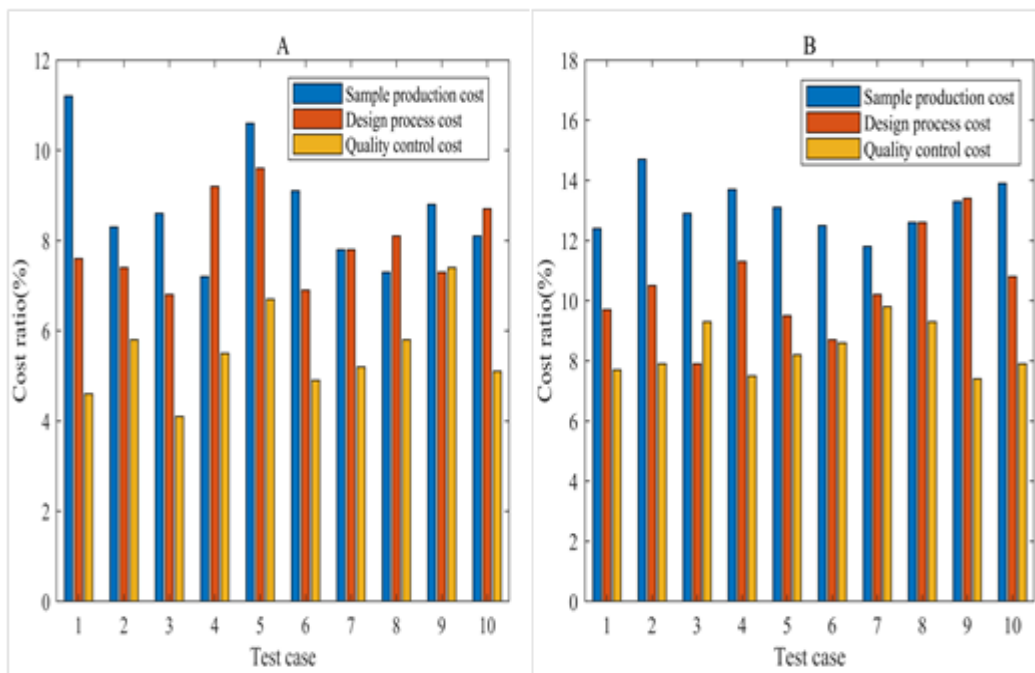


Figure 10. Design cost results: Figure 10A shows the system design cost in this paper; Figure 10B shows the cost of traditional system design

In Figure 10, the horizontal axis represents the different test cases of the design cost, and the vertical axis represents the proportion of the sample production cost, design process cost, and quality control cost of the two systems in the overall cost structure. As can be seen from Figure 10A, the average proportion of sample production cost, design process cost and quality control cost in the overall cost structure of the system under different test cases was about 8.7%, 7.9% and 5.5% respectively. In Figure 10B, the average proportion of sample production cost, design process cost and quality control cost in the total cost structure of the traditional system under different test cases was about 13.1%, 10.5% and 8.4%, respectively. From the comparison results of the design costs of the two systems, the system in this paper has achieved good cost control in sample making, design process and quality control.

3.4 User Satisfaction

User satisfaction is crucial in fashion design. This paper takes the audience of the CAD system of clothing design under the intelligent sensor technology as the sample object, and conducts a questionnaire survey on the user satisfaction of the system design results. 126 questionnaires were issued and 117 valid questionnaires were collected, with an effective questionnaire recovery rate of about 92.9%. In addition to the basic information of users, the main contents of this survey are shown in Table 5:

Table 5: Main contents of questionnaire survey

INVESTIGATION CONTENT	SEQUENCE	QUESTION ITEM
CLOTHING COMFORT	1	ARE YOU SATISFIED WITH THE DESIGN STYLE OF THE SYSTEM'S CLOTHING DESIGN RESULTS?
	2	ARE YOU SATISFIED WITH THE SELECTION OF CLOTHING SIZES AND FIT DESIGNED BY THE SYSTEM?
	3	ARE YOU SATISFIED WITH THE RECOMMENDED CLOTHING STYLES AND COLORS IN THE SYSTEM?
	4	ARE YOU SATISFIED WITH THE CLOTHING DESIGN STYLE OF THE SYSTEM?
CLOTHING QUALITY	1	ARE YOU SATISFIED WITH THE PRODUCTION PROCESS AND DETAILS OF THE SYSTEM?
	2	ARE YOU SATISFIED WITH THE COST-EFFECTIVENESS OF THE SYSTEM'S CLOTHING DESIGN?
	3	ARE YOU SATISFIED WITH THE MATERIAL SELECTION AND TEXTURE OF THE SYSTEM CLOTHING DESIGN?
CLOTHING FUNCTIONALITY	1	ARE YOU SATISFIED WITH THE FUNCTIONALITY AND PRACTICALITY OF THE SYSTEM'S CLOTHING DESIGN?
	2	DO YOU THINK THE SYSTEM CLOTHING DESIGN MEETS YOUR USAGE NEEDS.

As can be seen from Table 5, the user satisfaction test in this paper is mainly conducted from three aspects: clothing comfort, clothing quality and clothing functionality. There are five choices for all questions: very satisfied, satisfied, average, dissatisfied, and very dissatisfied. This paper calculates the survey results of user satisfaction in the system, as shown in Figure 11:

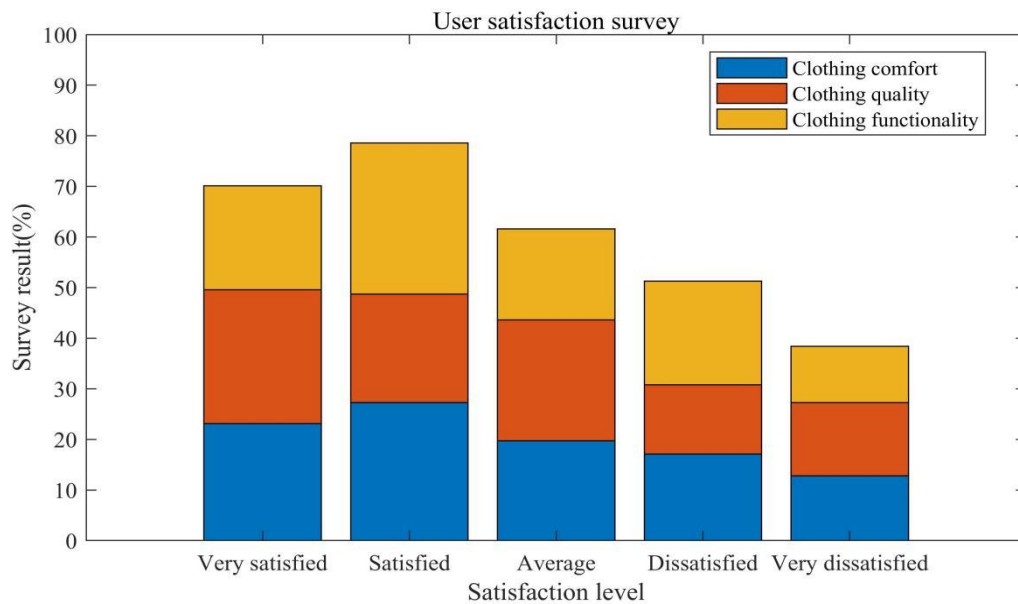


Figure 11. User satisfaction survey results

As can be seen from Figure 11, in terms of clothing comfort, the number of users who were satisfied or very satisfied reached 50.4%. In terms of clothing quality, 47.9% of users were satisfied or very satisfied with the results of digital automatic analysis and design of clothing design CAD system based on intelligent sensing technology. In terms of clothing functionality, 51.3% of respondents were satisfied or very satisfied with the design results of the system. From the overall survey results, the system has a high degree of user satisfaction.

4. Discussions

In the system test, this paper verifies the effect of the clothing design CAD system based on intelligent sensor technology from the aspects of design information collection accuracy, design efficiency, design cost and user satisfaction:

- From the test results of design information collection accuracy, compared with the traditional clothing design CAD system, the measurement error of human body circumference information can be controlled within a reasonable range. With the support of intelligent sensor, this system can effectively realize the digital automatic collection of design information based on ensuring the accuracy of information collection, to realize the subsequent dimensional adjustment function module.
- Judging from the test results of design efficiency, the CAD system of clothing design based on intelligent sensing technology can ensure the automatic realization of various functional modules of the system and simplify the process of design data processing and analysis through intelligent data information analysis. This reduces the number of design adjustments and provides real-time data feedback, effectively improving design efficiency.
- According to the test results of design cost, this system can effectively control sample production cost, design process cost and quality control cost. Based on intelligent sensing technology, the CAD system of clothing design reduces the manual operation and time cost. Through digital automation means to realize intelligent decision-making in clothing design, it significantly reduces the proportion of sample making, design process and quality control in the cost structure.
- From the perspective of user satisfaction survey structure, the clothing design CAD system based on intelligent sensing technology can effectively meet the user's clothing comfort, clothing quality and clothing functionality needs. Through digital automatic analysis, the system can realize personalized design according to the difference of user needs, to improve the user's recognition of the system's clothing design results.

5. Conclusion

With the improvement of people's living conditions and the change of consumption concept, consumers' demand for clothing comfort and personalized gradually increased. It is difficult for traditional fashion design methods to fully meet the needs of different consumers. In order to enhance the intelligence of clothing design and improve consumers' wearing experience, this paper combined with intelligent sensing technology, conducted in-depth research on the digital automatic analysis of clothing design CAD. In this paper, a new garment design CAD system was constructed, which analyzed the function realization of four modules: virtual fitting, style selection, and size adjustment mold and garment design. In this paper, the CAD system for clothing design based on intelligent sensing technology can not only effectively realize the high-precision collection of design information, but also significantly improve the efficiency of clothing design. Based on reducing the design cost, it can effectively meet the clothing design needs of different users and improve the satisfaction of users. Although the CAD digital automatic analysis of clothing design based on intelligent sensing technology in this paper can improve the effect of clothing design and optimize user experience to a certain extent, there are still some shortcomings in this paper. In the future research, in-depth research would be considered from the aspects of user habits and system function expansion, to promote the intelligent development of clothing design.

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