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Study on Size Recommendation of H-Silhouette Men's Shirt

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Abstract: Based on the pattern-matching database of field body fitting records, this paper analyzes the male body data and matched shirt size. The Vervaeck index, which comprehensively reflects the body shape, is used to modify the feature parts, and the weight contribution rate of each featuring part is determined by using BP neural network. The fit evaluation function with high adaptability to various body types is established to recommend shapes. The specification recommendation result is quick and accurate and has certain practical significance.

1. Introduction

In the current trend, people are gradually turning to new models such as contactless online consumption and live broadcasting, which has further expanded the scale of e-commerce in clothing. At the same time, however, the return rate of clothing remains high, resulting in a tremendous waste of resources. According to a research study, the main reason for consumer feedback is the wrong size choice [1]. The recommended methods for garment size designation are mainly divided into two categories: one is Qualitative Analysis and the other is Quantitative Analysis. The qualitative method refers to the use of the Delphi method (expert investigation method), the Analytic Hierarchy Process, etc. [2] to screen key factors and use the methods of multi-factor comprehensive appraisal. Prior to this, Yu Xiaokun [3] divided the human body into 9 body types depending on the different types of the chest (2B/h), waist (2W/h), and hip (2H/h). After comparing the chest, waist, and hip types of the human body with the corresponding type of clothing, a suitable garment size designation can be recommended. Another type of method is Quantitative Analysis. Zhang Heng [4] divides the specifications and proposes to use the sum of squares of the error between the size of the human body and the size of the finished product specifications as the fit index. Recommended by Hao Kunrong [5], the fuzzy algorithm is combined with a neural network, which has both learning ability and fuzzy reasoning, and the weight coefficients of 10 characteristic parameters are obtained iteratively through neural network training. Zheng Aihua [6] predicts the garment size designation based on the BP neural network, inputs the main parts of the human body, and obtains the corresponding garment size designation. Ren Zhe [7] defined the specification with a Minimum difference between the specifications data of each specification of clothing and the corresponding parts of the human body as the most suitable specification and created a mobile garment size designation recommendation system. The shortcomings of its research are that the weight of the feature site is determined, the calculation of the recommended method is large and complex, and there are few samples to verify the accuracy of the method. Based on the specifications matching library recorded by on-site body measurement and try-on. We analyze the human body data and the matching specifications to determine the characteristic parts and correct the values of the characteristic parts.

2. Method

Shirts are a major part of men's garments. The silhouette of classic shirts is predominantly H-shaped, and they are typically worn directly near the body. Therefore, the requirements for the fit of the shirt are relatively high. In this paper, the classic shirt with H-profile and non-elastic lightweight fabric is used as an experimental example to match the garment size designation and establish a specification-matching library.

2.1. Measuring Objects and Methods

2.1.1. Determine the Subject Population

The research group was men between the ages of 18 and 45 in North China, including people in different occupations and college students.

2.1.2. Measurement Method

Anthropometric methods are mainly divided into contact measurement methods and non-contact measurement methods [8]. The contact measurement method mainly adopts the hand anthropometric measurement method. The main non-contact measurement methods are the three-dimensional human body measurement method, the cross-section measurement method, and the two-dimensional image measurement method. Through traditional manual measurement methods, we use measuring tools such as a Martin-type Anthropolometer, altimeter, ruler, and tape measure. This article refers to GB/T 16160-2017 clothing to collect measurement data using the definition and method of human measurement.

The measurement parts follow the requirements of ready-to-wear garment size designation, combined with the national standard and practical applications, to measure height, weight, neck circumference, total shoulder width, upper arm circumference, bust, waist circumference, hips, wrist circumference, and arm length.

2.2. Sample Data Processing and Inspection

First of all, according to the national standard GB/T22187-2008 [9], the general requirements for establishing an anthropometric database calculate the value of the sample size N to determine whether the sample size is sufficient. The maximum value of the data coefficient of variation is 10.795, and the minimum amount is N=116. The collected data is 230, which meets the standards.

Special body shape or inaccurate measurement data will affect the accuracy of data analysis. Based on the results of the stem and leaf diagram and the box diagram, the singular values were checked, and the final valid samples were 217. The normal P-P diagram of the difference between each part is shown in the Figure 1: P-P diagram of the sample bust, it can be seen that it conforms to the normal distribution.

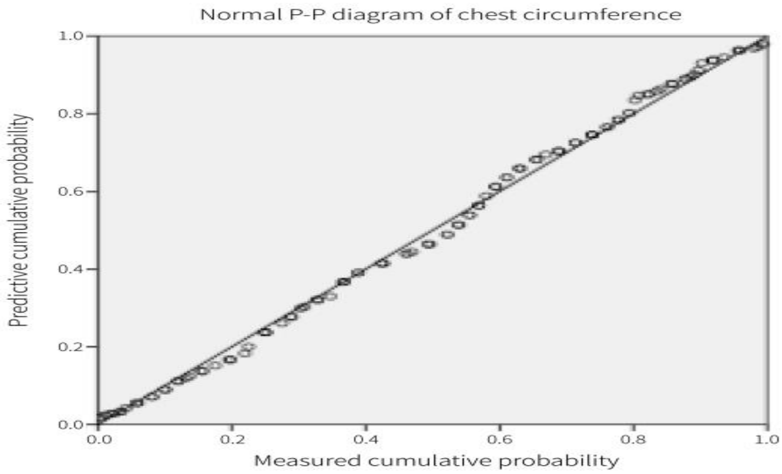

Figure 1: P-P diagram of the sample bust

2.3. Classification of Body Types by K-means Clustering Method

The K-means clustering method is a commonly used method for classifying human body shapes. It must comply with the minimum sum of squares between the data point and the center in each grouping category. The optimized objective feature is the sum of the distances between the data point and the center of the cluster. The adjustment rules for iterative operations are obtained by finding the extreme values [10]. Researchers select suitable indicators for clustering analysis, analyze the body shape characteristics of the target group, and obtain a lower body shape coincidence rate and a higher population coverage rate, which meets the principle of non-correlation and non-overlap of information [11].

2.4. Special Parts of Clothing

Chinese standard garment size designation labeling methods such as 170/92A, however, according to scholars' research, some consumers have a vague concept of sizes such as 160/84A and small sizes, and returns and exchanges are caused by incorrect size selection when purchasing online [12]. The body parts that support the clothing and the silhouette of the clothing should be considered first to determine the characteristic parts when the specification is recommended.

The chest size plays a decisive role in the structural design. It is one of the important parts that determine whether the clothing fits the human body. In this study, the shirt collar was highly fitted to the neck, so the neck circumference was used as a characteristic part for quantitative analysis. The length of the clothes is related to the length of the human body, and it is more convenient to change them. Therefore, the height of the human body is selected instead of the length of the clothes as the characteristic part for discussion. In summary, the characteristic parts are determined to be bust, neck circumference, and height.

3. Results and discussion

3.1. Principal Component Analysis

When describing the characteristics of the overall shape of the human body, in addition to the basic circumference and length values of the human body, there are also circumference differences, body mass index, height and thinness index, etc. Commonly used body indices include BMI value, Vervaeck index value, chest and waist difference, hip and waist difference, etc. The Vervaeck index is mainly used to characterize physical development and physical condition, with height, weight, and bust as variables.

First, KMO and Bartlett spherical tests are performed on the data to determine whether the measured data can be factor analysed [13]. After testing, the KMO statistic is 0.845, which is close to 1, and the Bartlett test statistic is less than 0.05, which can be used for subsequent principal component factor analysis.

The three component matrices with eigenvalues greater than 1 are rotated orthogonally. As shown in Table 1: Component matrix, the first principal component is the body circumference factor, with a contribution rate of 59.327%, including shoulder width, neck circumference, upper arm circumference, chest, waist circumference, hips, Vervaeck index, and BMI value variables. The second main component is the circumference difference factor, with a contribution rate of 14.863%, including variables such as chest-waist difference and waist-hip difference. The main component of the third category is the length factor, with a contribution rate of 12.157%, including height and arm length variables.

Table 1: Component matrix

	Factor		
	1	2	3
Neck circumference	.811	-.289	.200
Shoulder width	.795	-.166	.375
Chest	.930	-.434	.177
Waistline	.692	-.517	.189
Hip	.854	-.343	.246
Biceps circumference	.612	-.483	.484
Vervaeck value	.919	-.032	.133
BMI	.864	-.059	.041
Chest-waist difference	.100	.833	-.090
Hip-waist difference	-.198	.759	-.006
Arm length	.201	.184	.841
Length	.438	.292	.804

Bivariate correlation analysis of the first principal component factor yielded the mean correlation coefficient, and the correlation coefficient (0.6, 0.8) indicated that there was a strong correlation between the variables. Table 2: Mean correlation coefficient of the first principal component factorshows that the mean correlation coefficient of the Vervaeck value is greater than the BMI value. Comparing the mean correlation coefficient and the necessity of combining factors for body type classification, the chest, hips, and Vervaeck values with larger correlation mean are selected to characterize the morphological characteristics of the circumference direction.

The second main component is the circumference difference factor, which includes variables such as chest-waist difference and waist-hip difference. Arrange the chest-waist difference of the samples in ascending order and take 50 samples, and compare the line chart with the corresponding hip-waist difference (Figure 2: Comparison of trends of hip-waist difference and chest-waist difference) It can be seen that the difference between the hip-waist difference and the chest-waist difference in the sample is large and the trend is different. The hip-waist difference polyline is generally higher than the chest-waist difference polyline. Using only the chest-waist difference to divide the body size of the sample cannot accurately reflect the body size difference, and two variables need to be retained for subsequent analysis.

Table 2: Mean correlation coefficient of the first principal component factor

Part	Mean correlation coefficient
Shoulder width	0.709
Neck circumference	0.758
Biceps circumference	0.634
Chest	0.840
Waistline	0.801
Hip	0.829
Vervaeck value	0.822
BMI	0.784

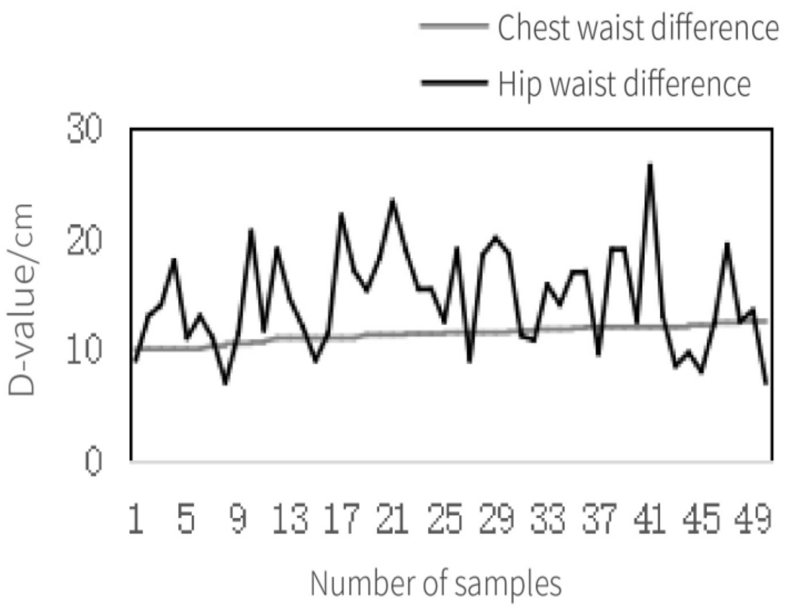

Figure 2: Comparison of trends of hip-waist difference and chest-waist difference

The third main component is the length factor, which contains height and arm length. It is easier for consumers to grasp height data and choose it as a variable of length factor.

Principal component factor analysis was used to analyze seven eigenvalues as data points, and the classification results under the number of clusters were compared. Comparing the mean square value and F value between classes, the clustering effect is relatively best when the number of clusters is 5.

To analyze the body surface characteristics of each body type sample more intuitively, we adjusted the values of each part to the mean of the collected data through the CLO 3D-Virtual Model Editor (Figure 3: Front view of various body types of male samples, Figure 4: Side view of various body types of male samples).

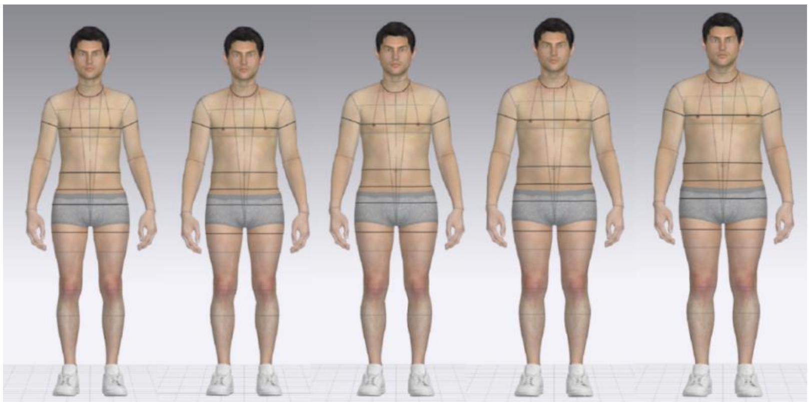

Figure 3: Front view of various body types of male samples

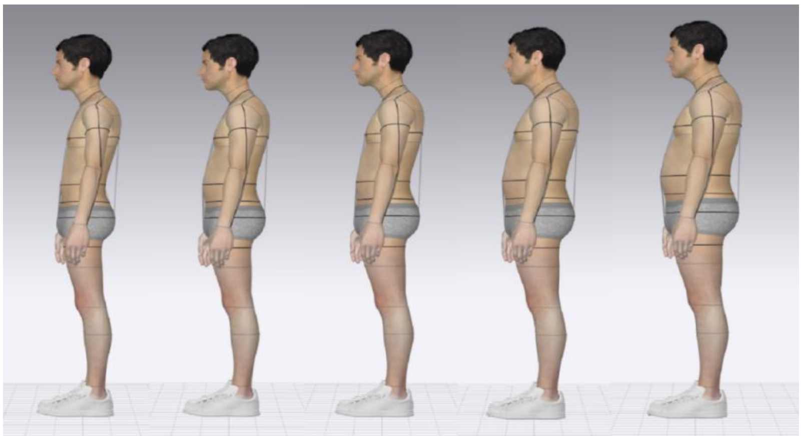

Figure 4: Side view of various body types of male samples

3.2. Correction of the Height Based on the Vervaeck Index

R^2 is an important index to determine the goodness of fit of linear regression linear lines (1).

$$R^2 = \frac{\sum (\hat{y}_i - \bar{y})^2}{\sum (y_i - \bar{y})^2} \quad (1)$$

$R^2=0$, this means that there is no linear relationship between the independent variable and the dependent variable. The closer R2 is to 1, the better the fit. Regression analysis of the sample height and the number worn obtained R2 = 0.0432, the fitting effect is poor, and it can be seen that the selection of the corresponding specification according to the height is inaccurate. When choosing garment size designation in life, there will also be differences in specification. Thin people usually choose a size smaller than their actual height, and fatter people choose a larger size than their actual height. The Vervaeck value includes three variables: human height, chest circumference, and weight, which can better judge the fat and thinness of the human body and can also distinguish between different chest circumferences. We analyze the actual Vervaeck value of each type of body type, determine and round the Vervaeck value range of each type of body type according to the actual demand, and obtain that the Vervaeck value ranges of the first, second, third, fourth, and fifth types of body types are (75,87], (87,93], (93,102], (102,112], (112,120), respectively.

The height is corrected based on the Vervaeck value. The corrected height and the number of the corresponding specification are analyzed for linear regression, and the linear regression equation is obtained as follows: $y_1 = 0.589x_1 + 71.492$ (2).

R2 = 0.890, It shows that there is a very significant linear relationship between the corrected height and the corresponding number, which is of a certain value to improve the matching of the specifications.

3.3. Establish a Regression Equation for Feature Parts and Models

The linear regression equation is obtained by linear regression analysis of human chest and clothing chest values: $y_2 = 0.589x_2+71.492$ (3), $R^2=0.8962$.

The linear regression equation is obtained by linear regression analysis of human neck circumference value and clothing: $y_3 = 0.755x_3+11.629$ (4), $R^2=0.890$.

3.4. Analysis of the Importance of Each Featuring Part

Based on the collected human body data and the specification obtained by the try-on evaluation, the BP neural network can be used for parameter tuning training and testing. The neural network is composed of nodes similar to human brain neurons, and through the machine learning of the test data, understand the characteristics and internal connections of the data, and judge and identify the data. The main steps are: establishing a network, training the network, testing the network, and evaluating the effect [14].

In the study of garment size designation, most people use a multi-layer reverse BP network. The biggest feature of BP neural networks is that they can handle nonlinear problems. The essence of training is that each layer of the neural network contains a large number of neurons, and the neurons are connected by a directed arc of variable specific gravity. After a large number of samples are input, the weights W and bias b are constantly adjusted to minimize the mean square error of the network output and the target vector and keep the output results consistent.

The chest, neck circumference, and height corrected data in the sample data are used as the input layer, and the chest, neck circumference, and height values of the corresponding specifications are used as the output layer. Use the mapminmax function to normalize the data, convert all data to numbers between (0,1), and eliminate the magnitude of each variable. The formula for data standardization is $x' = \frac{x-x_{min}}{x_{max}-x_{min}}$ (5). The specific gravity contribution rate analysis method is a method used to analyze the weight distribution of the output layer and the input neurons. The weight matrix obtained after neural network training is analyzed, and then the contribution rate of each input layer feature to the output value prediction process is obtained, and the importance of each input feature is determined. The traditional weight design is very subjective, and the weight contribution rate analysis based on neural network theory is used to determine the weight of each featuring part, which is relatively objective. The calculation formula for the weight contribution rate of the input feature [15], $W_i = \sum_{j=1}^{11} |w_{ij}| \left(|v_j| \frac{\ln|w_{ij}|}{\ln \sum_{i=1}^{3} w_{ij}} \right)$(6). Calculate the proportion of the influence of each input feature on the output value. The greater the contribution rate, the stronger the ability to interpret the output, and then obtain the weight of each featuring part on the output specifications. For men, the weight of the corrected height = 0.22, the weight of the corrected bust = 0.43, and the weight of the corrected neck circumference = 0.35.

3.5. Establish a Number of Recommendation Function

After determining the weight of each characteristic part, the difference between the human body size data and the corresponding data of each garment size designation is obtained:

$$\Delta h=|H-h^*| \ (7),\ \Delta b=|B-b^*| \ (8),\ \Delta n=|N-n^*| \ (9)$$

(H: Number, h*: Corrected height value; B: Clothing bust value, b*: Corrected bust value; N:

Clothing collar circumference value, n*: Corrected neck circumference value)

Establish a fit number evaluation function: $F = W_h \times \Delta h + W_b \times \Delta b + W_n \times \Delta n$ (10).

Sort the specifications of the comprehensive matching value F of the human body size and the candidate specifications, and the smallest F value is the recommended fit specifications.

3.6. Instance Verification

Analysis and verification randomly selected 1 sample instance, as shown in the Table 3: Sample data.

Table 3: Sample data

Height	Weight	Chest	Neck circumference	Actual try-on model
176.0	68.6	92.0	40.0	170/88A

Based on height, weight, and chest, as is shown in the Table 4: The difference between the sample and the data of each model, the Vervaeck index value of the sample was 91.25, and the corrected height was 171.0. According to formula (3), the bust is corrected to 108.2, and the neck circumference is corrected to 41.8 according to formula (4). Calculate the F value of each specification. The value is the smallest, $F_{170/88A}$= 0.761, and the final recommended specification is 170/88A, which is consistent with the fit specification obtained from the experiment.

Table 4: The difference between the sample and the data of each model

Model	Height	Chest	Neck circumference
165/80A	6	8.2	3.3
170/84A	1	4.2	2.3
170/88A	1	0.2	1.3
175/92A	4	3.8	0.3
175/96A	4	7.8	0.7
180/100A	9	11.8	1.7
180/104A	9	15.8	2.7
185/116A	14	19.8	3.7

To further verify the accuracy of the specifications recommendation method, 20 new volunteers with obvious differences in body shape between the ages of 18 and 45 were selected for trial-on experiments. They are used to compare whether the tried-out optimal norm is consistent with the norm computed by the fit norm evaluation function. The fit specifications of 20 volunteers were calculated through the fit specifications evaluation function. After comparison, the specifications recommended by 19 male volunteers were correct and 1 was wrong, and the recommendation accuracy was high.

4. Conclusions

In this paper, the current situation of garment size designation recommendation is analyzed, the human body size cluster analysis is analyzed and the height value correction method of different body types is obtained, and the correction equation is obtained by linear regression of the human chest circumference value, neck circumference value, clothing chest circumference value, and collar circumference value. By recommending the specification, corrected item data can prevent the situation that the size of the garment is smaller than the size of the human body. The weight contribution rate in the BP neural network was used to determine the weights of each featuring part, and volunteers with obvious differences in body size were selected for try-on experiments, and the accuracy of specifications recommendation was verified by example. When consumers purchase men's shirts, they can recommend a more appropriate garment size designation based on this type of recommendation method to increase consumer confidence.

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