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A COMPARATIVE ANALYSIS OF THE MALE PATTERN PROTOTYPES

АЛГОРИТМ СРАВНИТЕЛЬНОГО АНАЛИЗА БАЗОВЫХ ЧЕРТЕЖЕЙ КОНСТРУКЦИЙ ДЛЯ МУЖСКОЙ ОДЕЖДЫ*

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Исследование направлено на выявление оптимального прототипа среди базовых конструкций мужской одежды, используемых в Китае, с применением 3D-технологии. На базе классических российских методов разработаны линейные и угловые показатели и выбраны критериальные значения для оценки посадки 3D-стана одежды. Проведен сравнительный анализ чертежей и виртуальной одежды для определения прототипа, который наилучшим образом соответствует морфологическим особенностям китайских мужских фигур в диапазоне размеров 88…104 с позиций качества посадки одежды. Посредством сравнительного анализа виртуальной и реальной одежды подтверждены валидность и практическая применимость критериев. Установлено, что наиболее универсальным прототипом является базовая конструкция, разработанная Университетом Донхуа (Шанхай), с показателем удовлетворенности 78%. Результаты использованы для создания новых видов одежды путем моделирования выбранной базовой конструкции.

The aim of the research is to identify the optimal prototype among the basic Chinese patterns of men's apparel using 3D technology. The use of Style 3D software, the virtual avatars of Y, A, B, and C body types, adopted in China, have been created. By integrating the classical Russian methods for evaluating garment fit, the indicators and their criteria values have been developed to assess the fit of a 3D virtual apparel. A comparative analysis of patterns and virtual apparel was carried out to determine the prototype that best corresponds to the morphological features of bodies in the size range 88-104 in terms of apparel fit. Additionally, through a comparative analysis of virtual and real garment fittings validity and feasibility of the criteria were verified. It was found that the most versatile prototype was designed in Donghua University (Shanghai) with a 78% satisfaction rate. The results will be used to model the prototype and to design new types of clothing.

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Ключевые слова: чертежи, базовая конструкция, трехмерное проектирование, посадка, мужская одежда.

Keywords: patterns, prototype, 3D design, fit, men's apparel.

1. Introduction

The prototype is a fundamental component in garment pattern design, providing the essential framework for pattern-making, aimed at creating clothing patterns that accurately reflect the typical or individual body characteristics [1]. The pattern quality is primarily evaluated through the garment fit [2]. Achieving optimal fit is a core objective in apparel design, driving extensive research into objective methods for evaluating fit [3-5].

The construction of the pattern evaluation system has always revolved around two major principles: ergonomic adaptability and structural balance [6]. Early theoretical foundations in this domain were laid by the Russian school of apparel engineering. For example, Koblyakova E.B.'s static-dynamic adaptability assessment method emphasizes evaluating garment fit in the both states [7]. Martynova A.I etc. angular parameter system assesses fit through precise angle measurements [8]. Additionally, Romanov V.E.'s gravity balance principle further refines the quantitative framework for garment-body interaction, emphasizing the need to incorporate biomechanical dynamics (such as joint mobility and fabric deformation) and gravity balance (such as weight distribution and center of gravity alignment) into pattern design [9]. These concepts remain the cornerstone of modern garment engineering, providing an essential theoretical support for subsequent research.

Despite the availability of these established evaluation frameworks, many modern basic pattern designs have not fully incorporated such detailed morphological considerations. For instance, existing Chinese garment prototypes are often developed based on uniform standards and simplified sizing data [10], lacking adaptive adjustments for different body types such as shoulder sloping, chest circumference variations, or posture differences [11,12]. Furthermore, Chinese pattern blocks are typically drafted using consistent rules and grading principles, ignoring significant morphological differences between individuals, failing to accommodate the diversity of individual body shapes [13-15]. This limitation results in garments that struggle to meet the demands of diverse body types in practical applications, affecting consumer satisfaction and wearing experience.

The emergence of 3D virtual fitting technologies (Style3D, Clo3D) enables advanced simulations of garment-body interaction using digital avatars and parametric modeling. These simulations include static fitting (pressure distribution, symmetry), dynamic fitting (fabric stretch, movement constraints), and gravity balance of which align with classical ergonomic theories [16, 17]. However, in China, the application of such technologies remains superficial, focusing on aesthetic validation rather than quantitative assessment.

To address these issues, this study proposes an innovative method that combines 3D virtual technology with classical Russian evaluation frameworks. By leveraging digital tools, the qualitative principles of traditional garment fit assessment were transformed into quantifiable indicators, expanding their application scope and achieving more precise and comprehensive analyses. Specifically, four quantitative parameters were introduced:

(1) Static fit parameter. Inspired by static-dynamic evaluation approach [7], this parameter utilizes 3D virtual try-on to assess fit across various body types. The folds (parameter ***c***) serve as an indicator for fabric deformation, thus updating this classical method with modern technology.

(2) Angular and balance parameters. Drawing from gravitational balance criteria [9], fit was assessed through precise angular measurements. Parameters ***a*** and ***b*** representing the angles between the front/back center line and the hemline, are directly informed by the angular parameters methodology.

(3) Vertical displacement parameter: The parameter ***d***, which measures the vertical deviation of the front hemline from a horizontal reference, serves as a practical application of gravitational balance principles.

Applying these criteria, this study conducts a comparative analysis of three major Chinese male pattern prototypes (Donghua University, Beijing Institute of Fashion Technology, and the Xiong method). Based on the national sizing standard [18], virtual avatars were generated by Style 3D software, representing Y,A,B and C body types and virtual fit evaluations were perform using our proposed criteria- angular deviation(***a,b***), fold count (***c***), and hem displacement (***d***), to identify the prototype that most suitable for Chinese male body types.

The goal of this study is to provide valuable insights for future pattern design and optimization through comparative analysis, thereby enhancing the precision and applicability of Chi-nese pattern-making. By combining classical theories with modern digital technologies, the limitations of current pattern design are addressed. Meanwhile, the more scientific and efficient methods are provided for the apparel industry.

2. Objects of research

Three basic prototypes, which are popular now in China, were chosen for complex analysis: prototype *1* (*P1*) of Donghua University [1]; prototype *2* (*P2*) of Beijing Institute of Fashion Technology [19], and prototype *3* (*P3*) of X. Xiong[20].

Fig.1 shows the schemes of prototypes chosen.

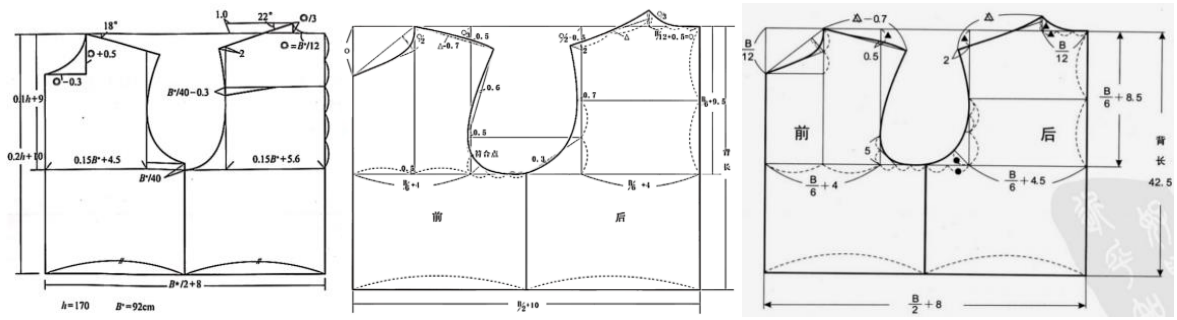


Fig. 1

The selected methods are classified as ratio-based computational approaches due to the limited number of dimensional measurements they require. The popularity of this approach in pattern construction in China can be attributed to several factors.

First, cultural and moral norms restrict the measurement of certain subordinate body dimensions. For instance, full-body scanners are not used for passenger screening in Chinese airports for this reason.

Second, this approach to calculating structural parameters is rooted in tradition and time-tested practices. In China, only 52 typical male bodies are defined across four fullness groups. In contrast, Russian standards (e.g., GOST R 52774-2007 Classification of Typical Male Figures by Height, Size, and Fullness) define 356 typical body types across five fullness groups. Thus, the number of typical male figures in China is nearly seven times fewer than in Russia.

Third, Russian standards utilize 48 body measurements to describe male figures, including 20 torso-related measurements. In comparison, the Chinese national standard GB 100000-2023 Dimensional Characteristics of Men includes 52 measurements in total, but only five are related to the torso. This means the number of torso dimensions used in Chinese construction practices is four times fewer than in Russia.

As a result, ratio-based computational methods continue to be used, improved, and published in practical manuals. However, no systematic comparative analysis of these methods has been conducted to date, which highlights the significance and relevance of this study.

Table 1 shows the parameters of each prototype.

Table 1

No	Parameter	Parameters of prototype		
		prototype 1	prototype 2	prototype 3
1	Chest girth CG, cm	88-104		
2	The ease to chest girth, cm	16	20	16
3	Distribution of the ease to chest girth, %, between front - armhole - back	9:70:21	18:55:27	23:50:27
4	Shoulder sloping, angle (front + back),degree	40	54	42
5	Location of back seam (front: back), %	50:50		
6	Upper balance (difference between back and front lengths from waist to shoulder- neck point),cm	2.4...2.8	2.6...3.0	2.4...2.8

3. Methods of research

Figure 2 shows the flowchart of the research.

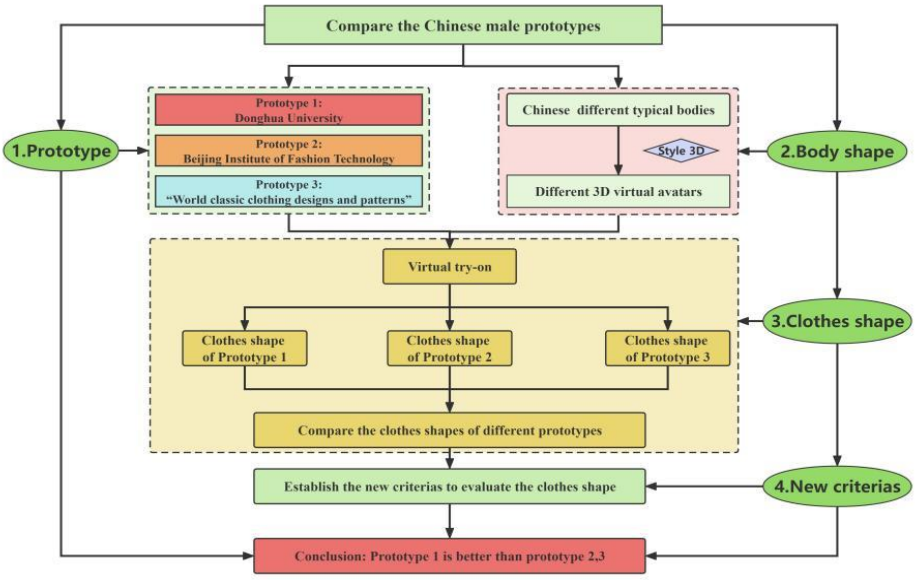


Fig. 2

The primary steps are as follows.

1. Selection of menswear prototypes.

2. Drawing the pattern employing 2D Richpeace 7.0 CAD [21].

3. Creation of human body avatars based on real Chinese typical bodies utilizing Style 3D [22].

4. The establishment of a criterion to define the contour of garments.

5. The validation of the evaluation criteria.

Finally, a comparative analysis of the three prototypes is conducted through the data comparison analysis method.

3.1. Methodology for the establishment of fit assessment criteria

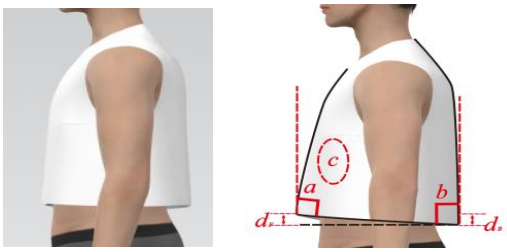
The research method combines two-dimensional computer-aided design (2D CAD) for prototype pattern drawing and 3D human body modeling in Style3D according to different human body shapes. This is followed by the virtual trying on of different prototypes on the avatars with chest girth 88-104 cm and types Y, A, B, and C. The spatial location relationship between the body and clothes is then analyzed. A new evaluation criteria is established through the shape parameters, and validated by real and virtual shape analysis, then shape quantitative analysis is carried out. Finally, fit parameters are used to objectively compare and analyze the data obtained.

Fig. 3 shows the scheme for determining indexes for fit evaluation.

The specific steps are as follows.

1. The initial step is to generate the sample in Style3D.

2. The side view was chosen as the basic contour of the sample for analyzing the front centerline, the back centerline, the hemline, and the folds. It is necessary to mark the positions of the hem, front centerline, back centerline, and side seam. Three parameters were measured: the angles between the front and the back centerlines and the hemline (*a*,*b*); the front vertical distance from the hemline to the horizontal line (*d*). Fourth parameter - the number of folds (*c*) that appear on the garment surface - was calculated.



а) б)

Fig. 3

3. The critical values of recognizable fuzzy intervals for angles and lines by the naked eye were determined by the professional evaluation method, which were 2° and 0.8 cm, respectively.

The criteria for good fit are $a,b = 88...92^\circ$, $c = 0$, $d<0.8$ cm.

Fig. 3,a shows the samples corresponding to the criteria. Fig. 3,b shows the opposite situation when the indexes of samples are bigger than the established criteria, which correspond to a bad fit.

3.2 Validation of the evaluation criteria

To verify the generalize ability, validity, and feasibility of the proposed evaluation criteria, a comparative experiment was designed. Samples fitting was conducted in both virtual and real environments, and the established parameters (a,b,c,d) were measured and analyzed. The procedure was implemented as follows:

(1) Virtual fitting. In the virtual environment using Style 3D, each prototype was tested with three different digital fabrics (F1, F2, F3), representing typical light weight, medium-weight, and heavy weight materials, respectively. The corresponding virtual shape parameters were measured. Table 2 shows three representative fabrics (100% cotton; 100% polyester; 100% wool) were utilized for the experiment, with fabric weights selected according to the Chinese National Standard GB/T 3801-1997 (“Textiles—Woven fabrics—Determination of mass per unit length and mass per unit area”) [24], corresponding to lightweight, medium-weight, and heavyweight garment categories.

Table 2

Fabrics	Fiber content	Weight, g/m2	Thickness, mm
F1	Cotton	168	0.31
F2	Polyester	259	0.74
F3	Wool	544	1.15

(2) Real fitting. Using three real fabrics corresponding to the virtual fabrics, real fitting was constructed on a mannequin with chest girth 100 cm, waist girth 84 cm, and hip girth100 cm. This mannequin corresponds to Chinese typical body with the same measurements. The real parameters were recorded.

(3) Comparative analysis. Parameter differences were compared across two perspectives to validate the scientific rationale and practicality of the evaluation criteria: 1) The differences in average parameter values among the three prototypes; 2) The differences between virtual and real parameters under the same fabric conditions for each prototype.

3.3 Prototype shape analysis based on the parameters established

For prototypes analyzing next bodies with dimensions were chosen: the height is 182 cm, the chest girth are 88, 92, 96, 100, 104 cm, the waist girths are (66,72,78,84); (70,76,82,88); (74,80,86,92); (78,84,90,96); (82,88,94,100) cm, the difference between chest and waist are 22,16, 10, 4 cm in according with Chinese standard. 20 different virtual avatars were generated in Style3D. All 20 silhouette lines were overlapped along the side seam line, serving as the basis for the superposition of the silhouettes in Illustrator 2019[23].

The total number of patterns was 54.

Following the mentioned procedure, 20 samples designed by prototypes P1, P2, P3 were conducted a virtual try-on of.

4. Results and discussion

Table 3 shows the parameter measurements (a, b, c, and d) of real and virtual sample s for three prototypes.

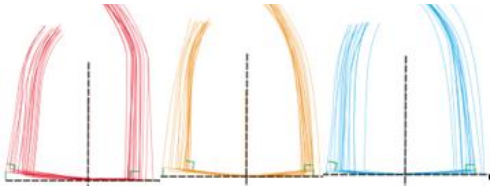
Table 3

	P1						P2						P3					
	F1		F2		F3		F1		F2		F3		F1		F2		F3	
	V	R	V	R	V	R	V	R	V	R	V	R	V	R	V	R	V	R
a	90.8	90.2	90.7	91.5	95.1	90.5	98	96.6	101	101.6	99.1	94.2	104.5	104.8	103.9	102.1	106.2	105.7
b	90	88.1	90.6	90	91	91.8	92.5	95.6	90.5	93.7	95.4	91.8	99.6	100.1	99.4	92.5	98.7	100
c	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1	0	0
(dF+dB)/2	0.6	0.7	0.6	0.6	0.7	0.7	1.5	2.1	1.7	1.9	2.5	2.3	2.3	2.4	2.8	2.8	3	2.7

Table 4 presents the average parameter values for the three prototypes. Based on the parameter values in Table 2, calculate the average value of parameters (a, b, c, and d) for three prototypes, including both real and virtual environments. All values for P1 fall within the defined evaluation thresholds and are significantly lower than those of P2 and P3.

Table 4

Prototypes	Average value of indexes, cm			
	a	b	c	(dF+dB)/2
P1	91.3	89.8	0	0.7
P2	97.9	92.9	0.33	1.8
P3	104.5	98.2	0.33	2.7



a) b) c)

Fig.4

Fig.4 shows the images of the samples after virtual try-on of three prototypes using the same approach for overlapping.

The samples were subsequently imported into Illustrator to quantify their outline lines while maintaining their original proportions. The overlapping seam lines served as the reference for this quantification process. Following the fit evaluation criterion, the exemplary shapes are distinguished by color, facilitating their identification and differentiation from one another.

By superimposing the outline lines of each prototype onto different body models and measuring them based on the novel evaluation criteria, we obtained the shape parameters.

Table 5 presents the statistical analysis of parameters, which reveals that the number of good shapes in prototypes *P1,P 2,* and *P3*is 10, 3, and 6, respectively.

Table 5

CG, cm	Comparative analysis of parameter *a*											
	Prototype											
	P1				P2				P3			
	Body type											
	Y	A	B	C	Y	A	B	C	Y	A	B	C
88	-2.5	-2	2.8	2.6	0	2	2	2	0.3	-0.3	4.4	3
92	-1.3	1.6	0.8	1	3.1	2.1	-3.2	3.1	0.4	2.6	-1.4	-1.7
96	1.2	-0.3	0	-1.2	3.6	3.1	2.5	2.7	1.5	2.2	3.2	2.5
100	2.1	-2.9	-3.5	2.6	3.2	4	2.7	0.5	2.9	2.8	-2.2	2.1
104	1.9	1.0	2.1	2.6	3.5	4.7	0.5	0.9	3.1	2.3	-1.5	1.6
Av	1.8				2.0				2.1			
Equation for calculating front length	0.2H+10 (H is height)				BL (BL is back length)				BL			

Table 6 presents the statistical data forparameter *b*. The number of good shapes in prototypes *P1,P2,P3* is 16, 12, 9 respectively.

Table 6

CG, cm	Comparative analysis of the parameter *b*											
	Prototype											
	P1				P2				P3			
	Body type											
	Y	A	B	C	Y	A	B	C	Y	A	B	C
88	0	0	0	2	-1.4	-2.7	1.4	2	0.3	-0.3	4.4	2
92	0.1	0	0.4	2.3	2.7	2.8	-1.4	2.4	0.4	2.6	-1.8	2.4
96	0	0	0.2	0	0.7	-3.2	1.0	2.8	1.5	2.2	3.2	2.5
100	0.4	0	0	0	0.7	0.5	3.1	0.4	2.9	2.8	-1.2	1.1
104	0	0	2.3	2	0.4	0.5	1.6	1.2	3.1	2.3	-1.5	1.6
Av	0.5				1.6				2			
Equation for calculating back length	0.2H+10+B/36				BL+B/36+0.2				BL+B/36			

Table 7 presents the statistical data forparameter *c*. The number of optimal shapes in the prototype is 10, 4, 9 respectively.

Table 7

CG,cm	Comparative analysis of the parameter *c*											
	Prototype											
	P1				*P2*				*P3*			
	Body type											
	Y	A	B	C	Y	A	B	C	Y	A	B	C
88	2	1	2	1	2	2	2	2	0	0	2	1
92	0	0	0	1	0	0	1	1	2	2	2	1
96	0	0	0	0	1	1	0	1	2	2	2	3
100	0	2	2	2	2	2	2	2	3	0	2	2
104	0	0	1	2	0	1	2	2	2	3	2	2
Av	0.2				0.9				1.3			

Table 8 presents the statistical data forparameters $(d_F+d_B)/2$. The number of optimal shapes in the prototypes *P1, P2, P3* is 11, 7, 10 respectively.

Table 8

CG,cm	Comparative analysis of parameter the index $(d_F+d_B)/2$											
	Prototype											
	P1				P2				P3			
	Body type											
	Y	A	B	C	Y	A	B	C	Y	A	B	C
88	0.2	0.8	1	1	0.3	0.4	0.5	0.5	0.8	0.8	0.6	0.7
92	0.7	1	1.1	1.2	0.6	0.7	0.9	0.9	0.8	0.8	1	1.1
96	0.8	0.2	0.2	0.4	1	1.3	1.3	1.1	1.2	0.8	1.8	1
100	0.7	0.8	1.2	1.3	0.8	1.1	1.4	1.8	0.6	0.7	0.9	1.3
104	0.5	0.6	1.1	2	1.8	1.8	1.9	1.6	0.6	0.9	1.1	0.9
Av	0.8				1.1				0.9			

Table 9 shows a summary plot of the number of good shapes of the three prototypes.

Table 9

Index	Amount of samples with good fit of different prototypes		
	P1	P2	P3
a	10	3	6
b	16	12	9
c	10	4	3
(dF +dB)/2	11	7	10
Total amount	47 (78 %)	26 (43 %)	26 (43 %)

Figure 5 shows the histogram with the results of shape with good parameters for three prototypes to facilitate a more intuitive comparison and analysis.

According to the analysis of histogram data, based on the newly established shape parameters, prototype *1* demonstrated superior shape modeling parameters in virtual fitting across 20 distinct body shapes. Consequently, considering the aforementioned analysis, three Chinese male prototypes can be derived; with prototype *P1* exhibiting a higher level of excellence compared to prototypes *P2* and *P3*.

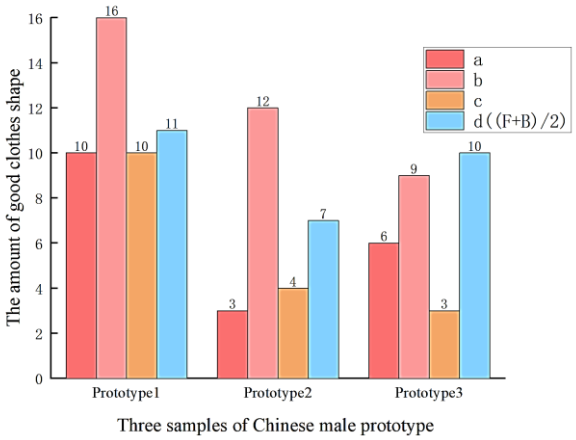


Fig. 5

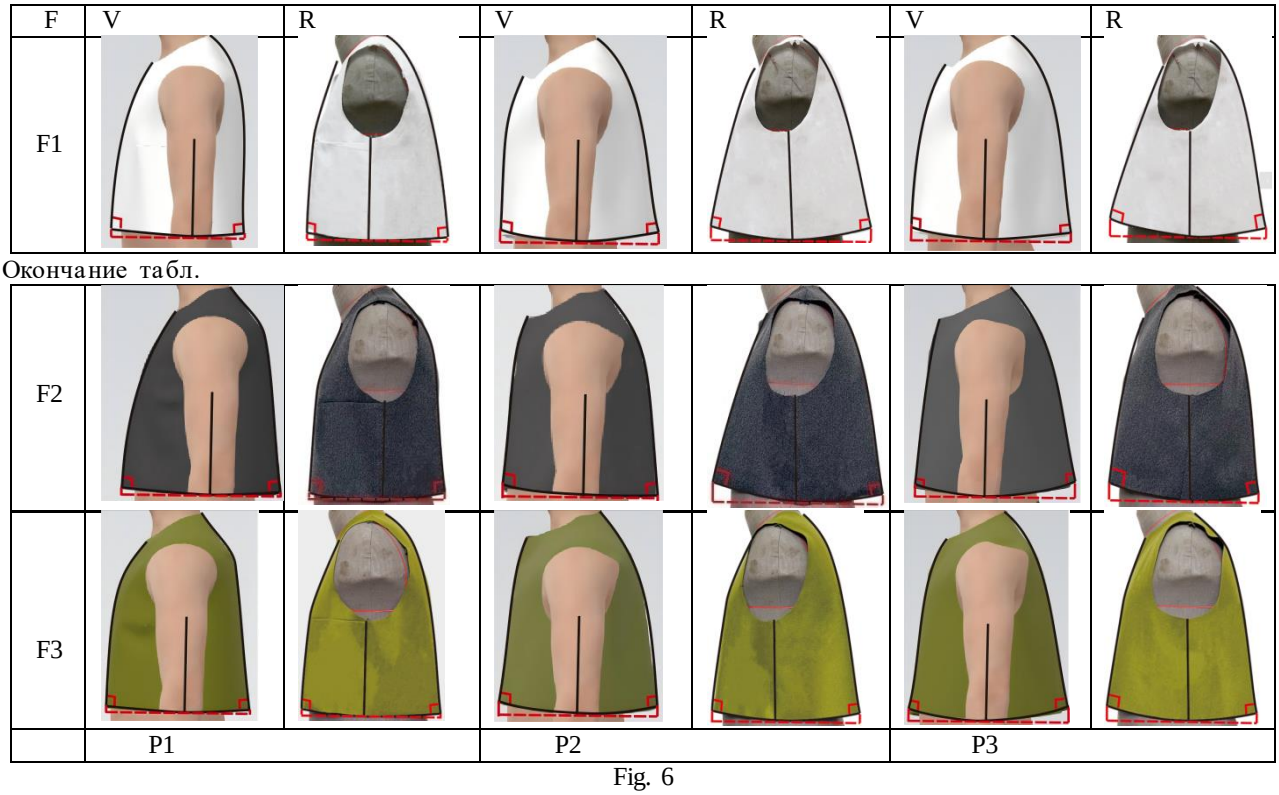


Fig. 6

The specific comparative analyses are as follows.

1) To design the prototypes, each algorithm uses a different number of equations: prototype *P1* based on 10 equations, prototype *P2* - 5, and prototype *P3* - 6. So, the algorithm of prototype *P1* drawing is based on augmented calculations, which are more accurate.

2) To determine the increment, the dimensional characteristic "chest width" from the

current national standard GB 100000-2023 *Human Dimensions of Chinese Men* was used. As the Chinese standard does not include the measurement of "back width," this parameter was obtained by measuring a representative avatar in the Style3D. The increment was calculated as the difference between the corresponding garment width on the pattern and the body width of the virtual model.

The distribution of the chest ease between front, armhole, and back is 9:70:21 (prototype *P1*), 18:55:27 (prototype *P2*), and 23:50:27 (prototype *P3*). The main focus is given to the armholes. In the case of prototype *P1*, the ease value is the biggest, which allows the sample to be adopted more easily in terms of the morphological features of male bodies.

3) The shoulder slope, which is stable from size 88 to size 104 also different for prototypes: 40° for prototype *P1*, 54° for prototype *P2*, and 42° for prototype *P3*. Values 40-42° are more suitable for different male bodies.

4) Additionally, prototype *P1* has front and back darts, which are changing from size 88 to size 104 and allowing to get a better fit. The front dart extends from the lower point of the armhole line parallel to the chest line and is designated as *B*/40. The width of the shoulder dart is equal to *B*/40 - 0.3. So, the 78% level of satisfaction belongs to prototype *P1*.Parameters a, b, c, d were measured based on the red reference lines in virtual and real environment. Table 10 presents the analysis of the parameter difference between virtual and real environments.

Table 10

Prototypes	Environment	Average values of parameters for three prototypes			
		a	b	c	$(d_F+d_B)/2$
P1	V	92.2	90.3	0	0.6
	R	92.4	89.7	0	0.7
P2	V	95.4	92.3	0	1.9
	R	100.5	93.5	0.7	2.1
P3	V	104.8	97	0	2.6
	R	104.2	99.3	0.7	2.7

For each prototype, the absolute differences in parameters between virtual (V) and real (R) environments were calculated and averaged. All resulting differences were less than 0.2 cm, indicating a high level of consistency between virtual and real shape.

The results confirm that the proposed evaluation criteria are applicable across different types of fabrics. Moreover, the strong consistency between virtual and real shapes validates the use of virtual fitting as a reliable substitute for real fitting. Therefore, subsequent comparative analyses of prototypes will be conducted based on the virtual shape.

Conclusion

This study validates the integration of classical Russian garment fit evaluation principles with modern 3D virtual fitting technology for the assessment and comparison of garment prototypes. By introducing quantitative parameters derived from classical methods. A scientifically rigorous and practically applicable fit evaluation criterion was established. Experimental validation confirmed the reliability of these criteria, with results from virtual and real environments showing a high degree of consistency. Among the tested prototypes, the Donghua prototype demonstrated superior fit, making it suitable for Chinese male body types.

The findings hold significant implications for the apparel industry, particularly in enhancing the precision and efficiency of pattern design. By leveraging 3D virtual technology, designers can simulate and optimize garment fit more accurately and rapidly, thereby reducing reliance on physical prototypes and minimizing material waste. Additionally, the incorporation of classical evaluation principles ensures that the design process is grounded in scientific methods, further improving the reliability and validity of the outcomes.

Nevertheless, the study has certain limitations. Experiments were conducted under controlled conditions, which may not fully capture the complexity of real-life wearing scenarios,

such as posture variation, dynamic movement, or environmental influences. Future research should expand to include a wider range of body types, fabric behaviors, and dynamic fitting conditions. Furthermore, integrating advanced simulation technologies, such as biomechanical modeling or AI-based optimization, may enhance the predictive accuracy of virtual fitting systems.

Overall, this research represents an important step forward in garment pattern design. By experimentally validating the proposed evaluation criteria, the study lays a solid foundation for future advancements in apparel development, ultimately contributing to greater consumer satisfaction and sustainable industry practices.

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