Manuscript rights

万斯达

Wan Sida

Development of fit evaluation and prediction system of digital twins for women's classic jacket sleeves

05.19.04 - Technology of garments

Brief of Dissertation
for the degree of candidate of sciences

Ivanovo – 2022

The work was carried out at the Federal State Budget Educational lnstitution of Higher Education "Ivanovo State Polytechnic University"? Institute of Textile Industry and Fashion, the Department of Garment Design.

Science leader	**KuzmichevVictorEugenievich,** Dr.Sc., Prof., Head of Garment Design Department, Federal State Budget Educational lnstitution of Higher Education «Ivanovo State Politechnical University», Ivanovo
Official reviewers	**Cherunova Irina Viktorovna,** Dr.Sc., Prof., Prof. of Design, Pattern making and Technology of Clothing Department, Institute of service and management (branch) Federal State Budget Educational Institution of Higher Education «Don State Technical University» in Shachty Rostov-on-Don Region
	Korobtseva Nadezhda Alekseevna, Dr.Sc., Prof., Professor of the Department of Information Technology and Computer Design, Federal State Budget Educational Institution of Higher Education "A.N. Kosygin Russian State University (Art. Design. Technologies)", Moscow
Leading organization	Federal State budget Educational Institution of Higher Education “Vladivostok State University of Economics and Service”, Vladivostok

The dissertation defense is scheduled for 06.10.2022 at 11-00 a.m. at a meeting of the Dissertation Council D 212.355.02 at the Ivanovo State Polytechnic University: 153000 Ivanovo, Sheremetevsky pr., 21.

The dissertation will be available in the library of Ivanovo State Polytechnic University and on the official website of the university: ivgpu.ru.

The abstract was sent out «___» __________ 2022

Scientific Secretary of dissertation council E.N. Nikiforova

INTRODUCTION

Actuality. The digitization process of clothing construction has become a reality in the fashion industry, allowing us to fill the content of many traditional processes with new digital information. Virtual "stitching" of clothes patterns takes place with two lines, which can be divided into several groups: open or closed, straight or curve, stacked on the plane or not stacked on the plane. Connecting the two closed curved lines occurs at sewing the sleeve assembled into the armhole. It is the most difficult from the aspect of designing and achieving the desired fit appearance. The "armhole-sleeve" not only is the quality indicator of design and but also the source of misfit appearance of several classic clothing (jacket, coat, outwear etc.).

The virtual process of sleeve-armhole assembly involves many factors. Under the influence of these factors, the necessary volume and position of the sleeve can be provided.

The flat pattern of sleeve cap and armhole are initially projected and overlapped. The configuration can be described by measurable parameters and Cartesian coordinates of feature points. After transfer from Cartesian coordinates to 3D space, the assembly lines of sleeve cap and armhole change their configuration and acquire approximately same shape under the complex-directed force field. For the mathematical modelling of armhole, many parametric factors are required: the sleeve cap and armhole shape; the ease-allowance of bust girth, the armhole plane direction; the stiffness and thickness of the materials; curvature of the original lines; anisotropy of material properties, because along the armhole seam are following possible combinations: weft + weft (in the widest point of the sleeve), basis + basis (under the armhole), basis + weft (in the highest point of the shoulder seam). Obviously, the complete model involves multi-factors. 3D CAD software includes factors related to thickness and stiffness of materials, parameters of flat pattern, peculiarities of body morphology, methods of shaping, etc.

Depth of problem development. Currently the research on the "armhole - sleeve" was carried out by researchers from IVGPU (M.R. Smirnova, Chen Zhe, Lo Yun, N.M. Kochanova), Russian State University named after A.N. Kosygin (E.G. Andreeva, I.A. Petrosova, V.V. Getmantseva, N.A. Korobtseva, I.N. Tyurin), DSTU (I.V.Cherunova), Hyunsuk Han, Lee, YeJin Do, Wol-Hi (Japan) and other scientists.

However, the successful development of this direction requires further formalization of professional knowledge in the areas of pattern construction and virtual objective qualimetry. Unfortunately, complete databases, knowledge, and rules are not yet formed due to the lack of a unified approach to the pattern and three-dimensional design processes. The existing CAD systems do not have enough functions to check sleeves and armholes and do not allow identifying the causes of defects appearance. Therefore, from the standpoint of further development and improvement of digital design, it is crucial to develop new design technologies in the virtual environment.

The work was performed in 2017-2022 at the Department of garment design, IVGPU, in the framework of the main scientific direction "**Analysis and synthesis of real and virtual systems 'body-clothing**", under the grants of the Heyuan Polytechnic Institute Research Fund No. 2017kj06 (China), and the Russian Foundation for Basic Research (RFBR) and Ivanovo region "**Development of the fundamentals of virtual design of digital twin systems 'human figure-apparel'" using neuropsychological technologies and reversible engineering**" No. 20-47-370006.

The research has been performed in accordance with the ВАКscientific specialty 05.19.04 Technology of sewing garments (technical sciences): point 3 "Development of mathematical and information support systems of automated clothing design", point 5 "Improving the methods of quality assessment and design of clothing with given consumer and technical-economic parameters".

Aim of this research is to develop databases, knowledge, and rules to transfer the design process of the "armhole-sleeve" with given appearance parameter from the real to the virtual environment.

To achieve this aim, it is necessary to complete the **following tasks:**

1. A graphical analysis study of the pattern of women's jackets with different quality parameters was carried out, in order to build a database of the design parameters' influence on the appearance of virtual sleeves.

2. Develop geometric models of the "armhole-sleeve", in order to build the feature points database of the coordinates for armhole and sleeve assembly.

3. Develop a method and criteria for objectively evaluating the virtual sleeve appearance fit in women's jackets.

4. Investigate the reasons for virtual sleeve defects under the designed pattern parameters.

5. Develop the algorithm to design the "armhole-sleeve" of women's jackets in the virtual environment and predict fit defects in the sleeve appearance.

6. Develop modules in Python environment for sleeve assembly fit evaluation and automatic selection of parameter combinations to prevent sleeve defects appearance.

7. Develop the comprehensive fit criteria and correlations for the whole sleeve.

8. Study the fit evaluation and defect recognition from grayscale.

9. Study the pressure and constructive ease-allowance for "body- jacket" system.

10. Test the results in real for validation.

Object of research - women's body, jackets and its' sleeve with different spatial shapes, the coordinate and grayscale fit evaluation process.

Subject of research - the design parameters of flat pattern and 3D models of the "armhole-sleeve" assembly, whole sleeve, and sleeve grayscale.

Research field – the process of designing women's jacket sleeve.

Methods and tools of research. To study separate elements and the integrated system “women’s jacket sleeve” we used the following methods:

method of measuring pressure of clothes on the human body, method of pattern parametric configuration, method of coordinate location, method of image recognition by grayscale.

We used the following experimental studies: CAD software ET (BUYI Technology, China) to digitize pattern construction; computer program CLO 3D, version 5.0.156.38765, (CLO Virtual Fashion, Republic of Korea) for generating virtual objects; ImageJ program to analyze grayscale images; The 3D modeling software MAYA (Autodesk, USA) was used for feature points coordinate measuring; FlexiForce sensor to measure pressure of clothes on soft tissues of human bodies.

Statistical processing of the measurement results was performed using SPSS software (IBM, USA), PASS15 (NCSS LLC, USA) was used for sample size calculation, Python language was used to write the models for feature point fit evaluation criteria and sleeve parametric combination. Graphpad (Graphpad software, USA) were used for plotting.

Scientific novelty of the research consists in the development of a scheme for coordinating the parameters of flat pattern of structures and three-dimensional sleeve for predicting its appearance and spatial position. The following scientific results have been obtained for the first time:

1. Designed databases of women's classic jackets.
2. Geometric model of the "armhole-sleeve".
3. Five basic principles for the whole sleeve fit prediction, including: Selected Avatar for sleeve fit prediction; the similar indexes are used to parametrize the 2D pattern and 3D simulation, and the interrelationship between them is found according on the established criteria; Application the same conditions for creating virtual and real sleeves; Combination of subjective and objective fitting evaluation methods; linear regression to predict simulated sleeve appearance.
4. Grayscale criteria for sleeve fit evaluation and defect identification.

The theoretical significance of this research is to establish the theoretical and experimental foundation for the fit evaluation and prediction of simulated women's jacket sleeve.

Practical significance of this research is to develop a system of virtual design of women's jacket sleeve with predictable indexes for fit evaluation. The technology and methods can be used in traditional design practice, CAD software modules development, and virtual twins of women's jacket sleeve generation. The results were implemented in undergraduate training of Heyuan Polytechnic Institute (Heyuan, China).

Reliability degree of the results of the thesis is provided by the consistency of the results of experimental studies of the initial elements (material, women's body, parameterized indexes of pattern and simulated sleeve, and grayscale values) and the used research tools (3D CAD for technological research, image analysis for grayscale research).

Evaluation of the results. The main results of the work were reported at conferences: Proceedings of the international scientific and technical conference “Modern science-intensive technologies and advanced materials for textile and light industry (progress)” 2013 **(Ivanovo)**; Information environment of universities: materials of XXIV international scientific and technical conference, November 22th-23th, 2017 **(Ivanovo)**; International conference on advanced materials, Electronical and Mechanical Engineering AMEME, 2020, September 27th-28th, 2020 **(Xiamen, China)**; Scientific and Technical Inter-university Conference of Postgraduates and Students (with international participation) “Young Scientists - the development of national technology initiative” (SEARCH), 2020 **(Ivanovo)**; International Scientific and Technical Conference on innovative development of textile and light industry, March 29th-31th, 2021 **(St. Petersburg)**; XXIV International Scientific and Practical Forum SMARTEX-2021, October 12th-14th, 2021 **(Ivanovo)**, International Conference on Techniques, Technologies and Education ICTTE 2021, November 3th - 5th, 2021 **(Yambol, Bulgaria)**; In the educational curriculum "Digital looks: artistic and industrial design of 3D clothing in virtual reality" of national project "Education" 2020 **(Ivanovo, IVGPU).**

The computer program "remote clothing customization system (abbreviated: clothing customization)" is registered by the national copyright administration of the PRC, No.: 03006712 dated 14.09.2018, registration number 2018SR745971. The database "drawings of designs and design parameters of women's classic jackets: application" is registered in Russia Federation (database No:2022621167).

Publications. Based on the results of the dissertation research, 10 publications were published, 2 of them in publications indexed in the international citation and analytical databases of VAK, one database and seven in the proceedings of conferences at various levels. The total volume is 2.625 p.l. (personal contribution 1.4688 p.l.)

Structure of the dissertation. The dissertation consists of an introduction, 6 chapters, conclusion, list of 163 references and 12 appendixes. The content is set out on 226 pp., including 66 figures, 62 tables.

CONTENT

The **introduction** substantiates the relevance and degree of scientific and theoretical elaboration of the problem; the goals and objectives of the study are formulated, the characteristics of the methods and means of research are given, the provisions for defense are formulated, the scientific novelty, theoretical significance, practical significance, and structure of the dissertation are express.

In **First chapter**, the analysis of all the components of the scientific problem of generating virtual clothing and predicting its fit quality are carried out: methods of design women's jackets, types and causes of fit defects are analyzed; the CLO3D work with digital twins and women's jackets is justified;

- the application of the Bunka technique (Japan) for the pattern construction in women's jackets is justified,
- selected research objects,
- the methods and means of research are substantiated,
- the purpose and objectives are formulated.

It is shown that with the help of digital twins, it is possible to reproduce many situations when modeling the "armhole-sleeve". The stages of the technology for generating virtual twins of women's jackets with the possibility of predicting some defects by improving the quality of pattern are formed in the dissertation work **(Fig. 1).**

In **Second chapter**, the graph-analytic description and study of the pattern of women's jackets were carried out and the scale for sleeves fit evaluation was developed (the result were published in one article).

The samples were formed from 82 patterns of women's classic jackets from year 2006-2018, which were parameterized by ETCAD. The drawings were developed for a typical female figure, cm: P = 160; $O_{г3}$= 84, $O_{т}$= 68; $O_{б}$ = 90, $Д_{рук}$= 50.5; $O_{п}$ = 25.8; $O_{лок}$= 22.1; $O_{зап}$= 15. The bodice and sleeve parameterization were performed according to the published methodology of the Department of Garment Design ISPU. The parameterization was separately for the bodice, sleeve and sleeve assembly at the armhole.

Possible combinations of armhole and sleeve parameters for sleeve fit defects are investigated. All jackets were performed for qualimetry in the virtual environment based on the requirements of the upper and lower parts of the sleeve appearance. **Fig. 2** shows the projection of virtual women's jacket with the identification areas of defects occurrence.

Fig.2 - Areas of fit defects

Depending on the number of defects and the impact on the overall subjective fit evaluation. 21 jackets with a perfect fit, 25 with a good fit, 18 with a appropriate fit, 7 with a fair fit and 6 with a poor fit were selected as training samples. **Fig.2** shows the areas of defects by the quality of pattern construction.

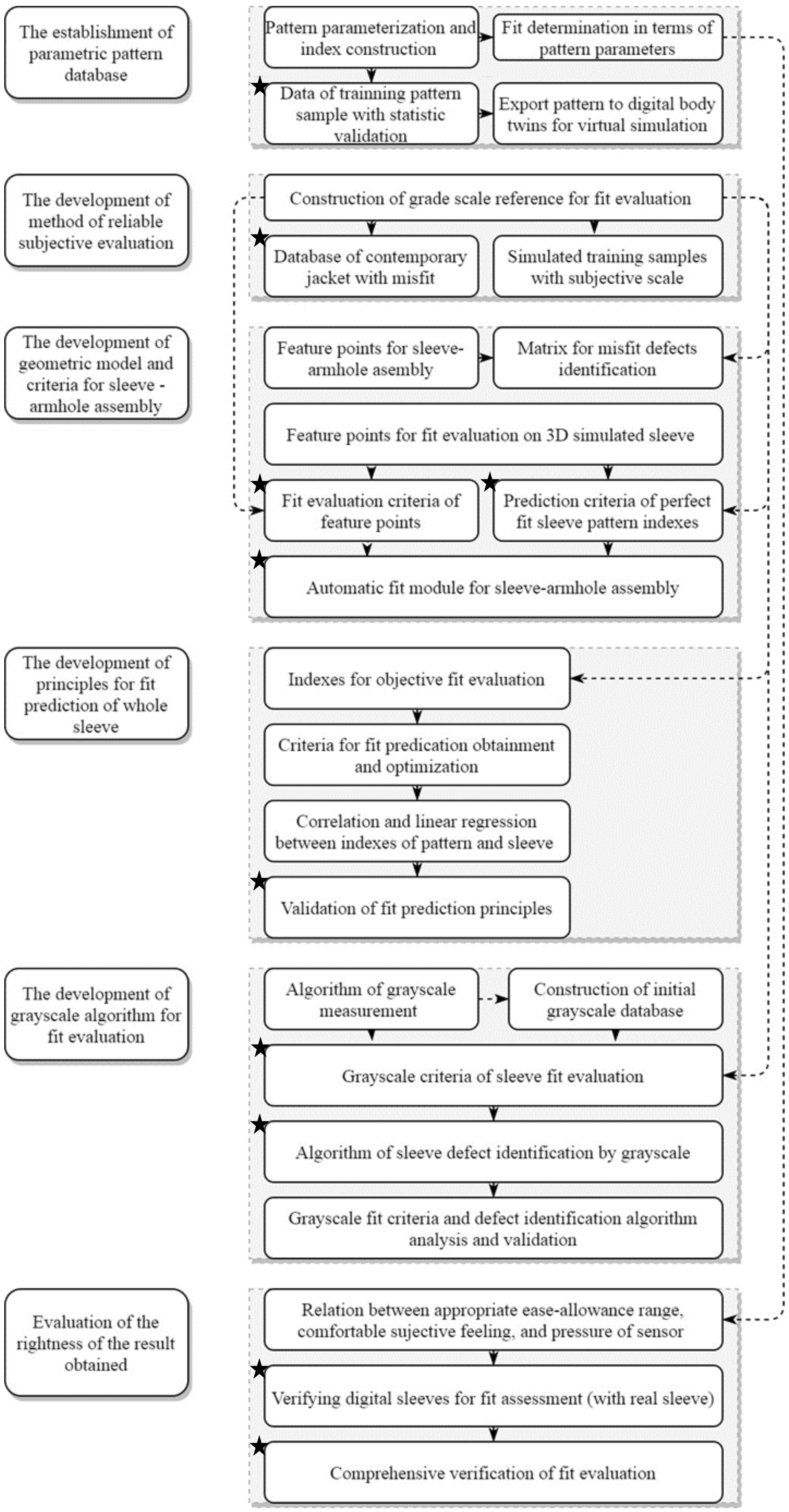


Fig.1 - Framework of developing fit evaluation and prediction system for women jackets sleeve

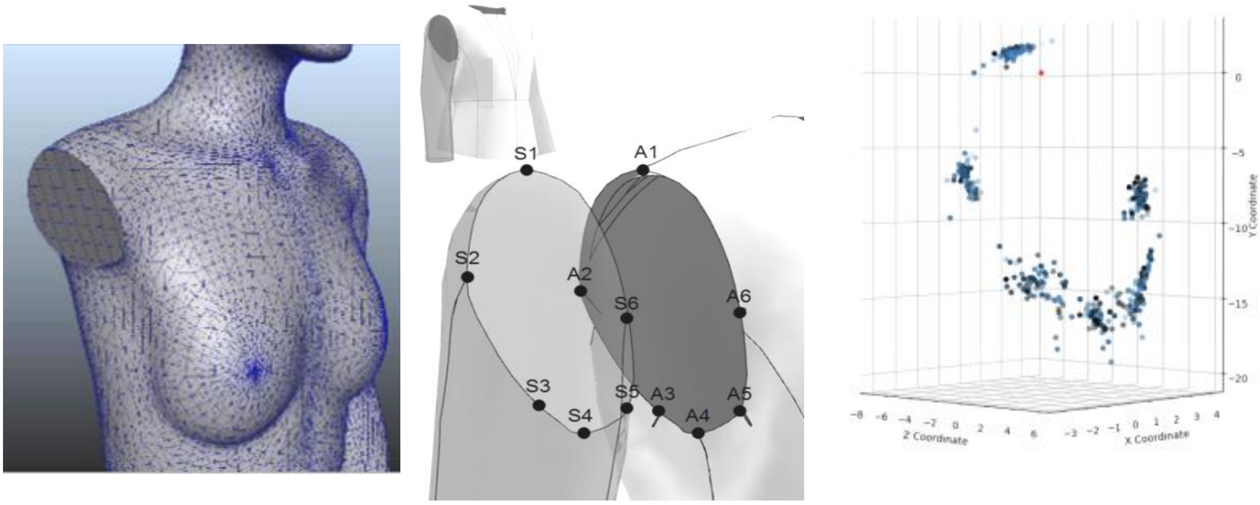
Combinations of design parameters have been established, such parameters can assessment the sleeve. The main design parameter is the armhole length, as the indicator of the three-dimensional shape of the jacket.

In **Third chapter**, geometric models of the flat and spatial armhole-sleeve are developed (the results were published in two papers).

The sleeve assembly permissible boundaries of the feature points of the armhole-sleeve were established after the alignment of the two lines on the flat. The development of geometric models included the following stages.

1. Parameterization of the armhole line of the bodice.
2. Parameterization of the sleeve cap line of the sleeve.
3. Parameterization of the combination lines of the armhole-sleeve.
4. Virtual "stitching" for jackets.
5. Visual analysis and selection of sleeves with a high-quality fit.
6. Development the parameterization of the virtual armhole-sleeve seam.
7. Database formation.

To parameterize the seam line of the armhole in 3D space, the following conditions were chosen. The shoulder point of the Avatar is selected as the original point with the coordinates x,y,z {0.0.0}. The plane through the shoulder point, the anterior and posterior corners of the armpits, let the arm and trunk separate (**Fig. 3,a**).



a *b* *c*

Fig. 3 - Avatar preparation (a), the connection diagram of the armhole and sleeve cap lines (b), the field of points for 82 virtual jackets about the sleeve assembly into the armhole (c)

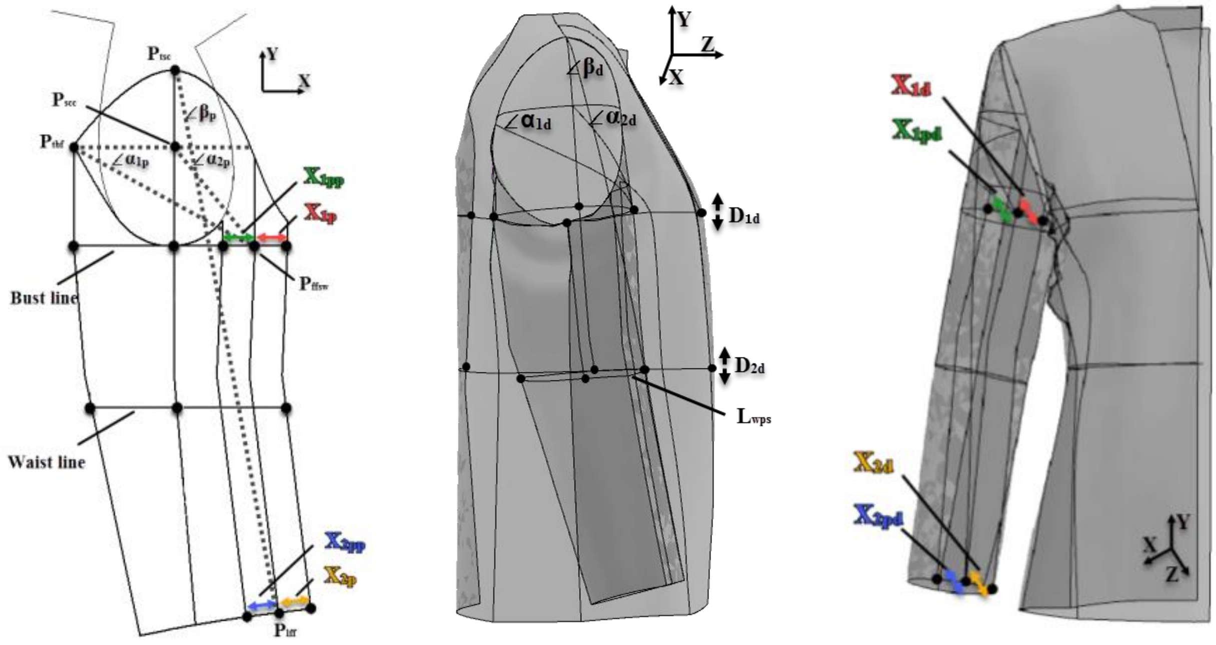
The location of the three planes belonging to the avatar (the initial one), the sleeve cap line of the sleeve (the intermediate one) and the seam line of the armhole (the final one) relative to each other is shown in **Fig.3,b**. For example, in **Fig.3,b**, the highest point of the armhole A1 is located above the shoulder point of the Avatar (the x and y coordinates have a positive increment). To coordinate the position of space, six pairs of points were used on the lines of the armhole (A) and the sleeve (S) with the following indexes: 1 – means the highest point of the armhole and the sleeve cap, 2,6 – means the top points of the elbow and front, respectively, 3,5 – means auxiliary points on the boundaries of the overlap area of the lower part of the sleeve on the armhole from the back and front, 4 – means the lowest point of the armhole and the armhole.

A matrix of parameters (armhole length and height, sleeve cap height, sleeve width and length, difference when sleeve assembly) for different forms of jackets, depending on the fit prediction has been developed.

Based on the analysis of virtual jackets, the coordinates for the selected pairs of feature points and the criteriaΔ for ensuring a high-quality fit of the sleeve are determined. A module has been developed in Python (Spyder-IDE) to automatically recommend the appropriate ranges of design parameters before virtual tailoring.

In **Fourth chapter**, the basic principles of sleeve prediction in virtual environment are developed (the results are published in two papers).

The form of a torso without arms and with hands is justified for sleeve fitting. To purposefully control the process of virtual sewing of sleeves, parameter nomenclatures of flat pattern and 3D virtual sleeves have been developed **(Fig. 4)**.



a b c

Fig.4 -Designing parameters of pattern (a) and application in 3Dsimulated sleeve (b, c)

The equation for calculating and transformation of the parameters according to the scheme are determined.

$$I_v = I_P \pm \Delta r \quad (1)$$

where I_v- the index of the virtual sleeve, I_P- the index of pattern, **Δ**r - the possible transforming range.

The values of permissible differences between parameters have been established, which guarantee the virtual sleeves with desired indicators and indexes. After statistical processing, the relations between them were established (two types of avatars - with hands and without hands) **(Table 1)**.

Table 1 - Comprehensive criteria of perfect fit sleeves

Indexes symbol, unit	Интервал значений			Ошибка	
	Pattern	Full avatar	Torso avatar	Δr pattern-full avatar	Δr pattern-torso avatar
First group "stabilization"parameters					
$\angle\beta^o$	12±0.2	10.9±0.4	11.5±0.4	1.1±0.6	0.5±0.7
D_1 , см	0	-0.1±0.2	0.1±0.2	0.1±0.2	
D_2 , см	0	0.1±0.4	0.4±0.4	0.1±0.4	0.4±0.4
Second group "changeableness"parameters					
$\angle\alpha_1^o$	28.7±0.7	37.1±1.3	34.2±1.3	8.3±2,0	5.4±2.0
$\angle\alpha_2^o$	48.9±0.9	63.3±0.8	59.1±1.1	14.5±1.7	10.2±2,0
X_1 ,X_2 ,см	3.4±0.4	1.9±0.3	2.2±0.3	1.5±0.6	1.2±0.6
$\|X_1-X_2\|$,см	0	0.3±0.1		0.3±0.1	
X_{1p} ,X_{2p} ,см	3.4±0.4	0,9±0.2	1.1±0.2	2.5±0.5	2.3±0.6
$\|X_{1p}-X2_p\|$, см	0	0.2±0.1		0.2±0.1	

Correlation analysis was carried out and regression equations were obtained to predict the quality of virtual sleeves on full avatars and torsos (**Fig. 5**).

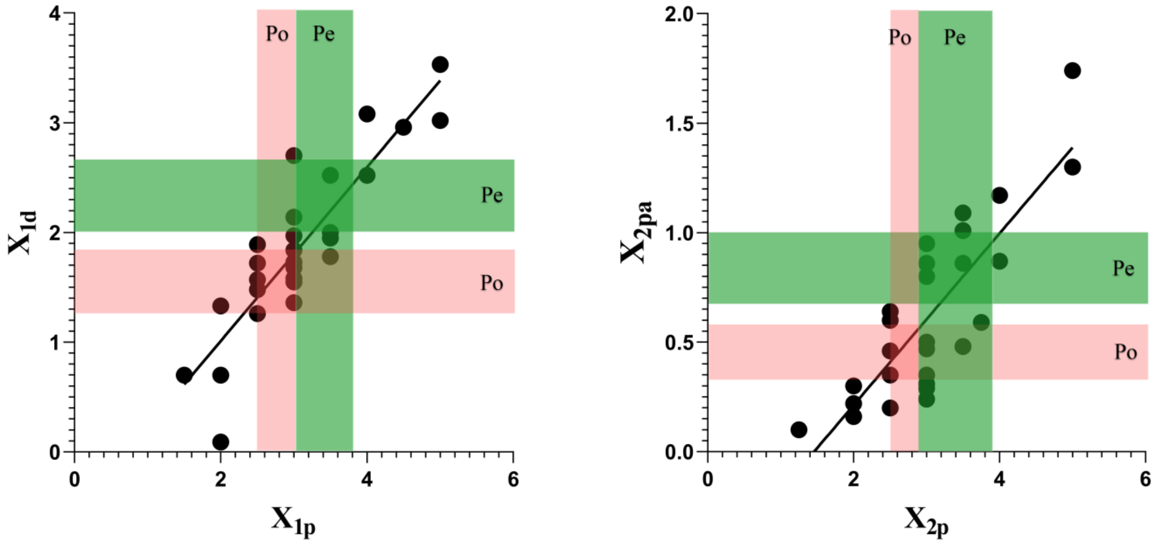
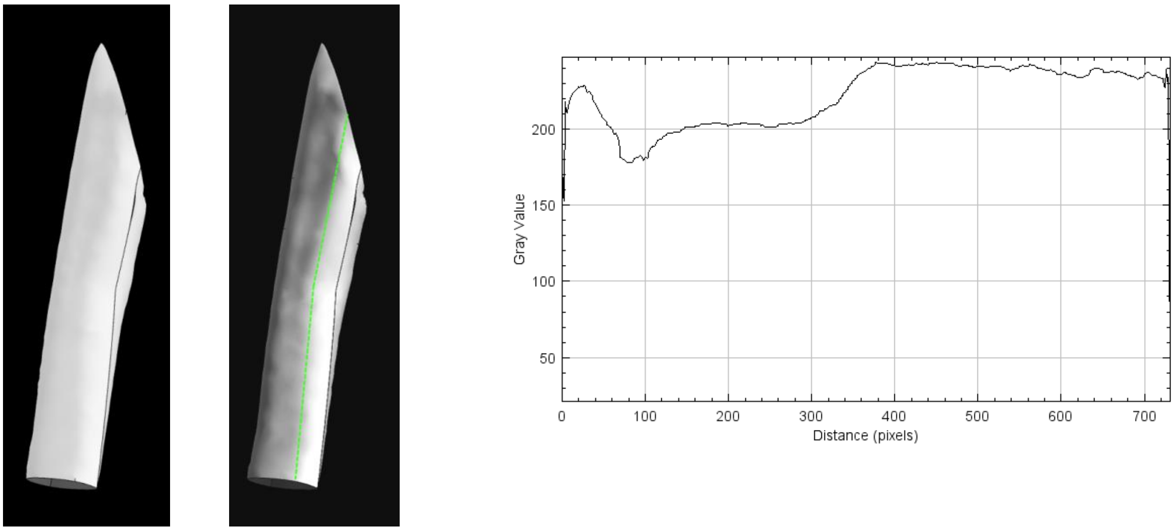


Fig. 5 -Diagrams for predicting the position of the front seam of virtual sleeves: Pe - the perfect fit area, Po - the poor fit area

Combinations of design parameters are validated by sensory analysis of virtual samples.

In **Fifth chapter**, the algorithm for objective identification of defects in virtual twins of sleeves is formed under the influence of designed features of sleeve patterns (the results are published in two papers).

Training samples were formed and the reason of the occurrence defects were studied. To reproduce surface defects, the pattern were modified by changing the sleeve cap height and the sleeve cap width, and the direction from the elbow line and whole sleeve. The sleeve surface was assessed by two ways: subjective of experts observation (sensory analysis) and measuring the grayscale intensity along the length and width of the sleeve in comparison with the reference sleeve. In order to measure the intensity of grayscale, the original virtual sleeve contrast was modified automatically in the ImageJ. **Fig. 6** shows the scheme of preparing the virtual sleeve for the grayscale intensity (along the front fold) and a diagram of the gray scale.



a *b* *c*

Fig. 6 - Steps in measuring the gray scale along the front fold of the sleeve: a-the original sleeve, b-the sleeve after contrasting, c-the grayscale diagram

The quantification of grayscale intensity differences for each sleeve was performed by comparing it to a control sleeve that had a perfect fit. The equation was described as:

$$Go = \frac{\sum_{i} | P_i - D_i |}{n} \quad (2)$$

where G_o – the grayscale offset between the control sleeve (perfect fit) and experimental sleeves in each pixel, P_i– the *i*-th pixel of perfect fit sleeve value. D_i – the *i*–th pixel value of the deformed sleeve at different views, n – number of pixels, n = 500.

The linear regression was employed to establish the relation between objective grayscale and subjective fit evaluation. The linear regression equation is:

$$Go(w) = 43{,}1 - 11{,}4\,Aws, \quad (3)$$

where *Go(w)* is the weighted grayscale offset, *Aws* is the arithmetic average score of the sensory analysis. The correlation coefficient was 0.89, which confirms the consistency of the two assessment methods.

Thus, an algorithm for qualimetry of virtual twins of sleeves of women's jackets using a gray scale was developed.

In S**ixth chapter,** jackets of the training sample were examined to validate their ergonomic fit and unproblematic use in virtual modeling, and a comprehensive test of the developed technology was carried out.

Firstly, using the pressure sensor, the occurrence of pressure under the jackets was investigated to verify the correctness of the allowance of design. The ergonomics of the jacket were evaluated twice: subjectively using the five-point scale and pressure values were measured by **FlexiForce** at the following anthropometric points: T1 - point of the back, locating on the shoulder blade area. T2 - point of back armhole, locating on the back armpit area, same height level of back armpit point, T3 - on breast point of the bust girth, T4 - on the shoulder girth. These points were chosen because at certain human movements (vertical arm raising, horizontal arm extending forward, body tilt with arms downward, car door opening) the greatest pressure is placed on them, it depends on the designed allowances. The relations between the values of design allowances and the resulting pressure are obtained. It is shown that the difference between the values of constructive allowances in real and virtual jackets is insignificant.

Secondly, the developed matrices were validated by randomly selected patterns. (1) checking the patterns of bodice and sleeve, (2) silhouette lines, (3) pattern and virtual sleeve. The virtual sleeve fit quality was evaluated by gradient of grayscale. The capability of all matrices was confirmed.

Thirdly, this stage included experimental verification by making real jackets from Melton fabric (composition: 50% wool fiber, 50% acrylic fiber; thickness 1.4 mm, surface density 490 g/m²) and creating its virtual twins. The digital fabric twin was selected from the CLO3D library. **Fig. 6** shows the two jackets with the parameter measurement scheme, the values are shown in **Table 1**. **Fig. 7** shows the sleeve has a flat surface, and **Table 2** shows there is little difference between the virtual and material sleeves.

Table 2 - Results of measuring the parameters of the virtual and real sleeves

Type of sleeve	Angle values, degrees (**Fig.7**)		
	α_1	α_2	β
real	34.6	56	11.9
virtual	33.6	58.5	11.9

Fig. 7 - The appearance of the virtual and real jackets comparison

Fourthly, in this stage, a comprehensive check of all the developed criteria and algorithms was carried out on the example of randomly selected sleeve patterns by simulation, subjective fit assessment, pattern and virtual sleeve parameterization, and grayscale evaluation. It was found that the fit of sleeves using the grayscale is: for sleeves with excellent fit 0.03-0.21, for sleeves with poor fit 17.2-38.0, which is enough to predict the fit quality based on the construction parameters.

Comprehensive verification of the obtained results showed that the developed methods, algorithms and criteria make it possible to identify the causes of fit defects and to remove them in a proper way.

Thus, the correctness and practical applicability of the developed method on the basis of the formed databases, knowledge, and rules is confirmed.

THE RESULTS OF THE PERFORMED RESEARCH

1. A database of design parameters of women's classic jackets patterns by the form of digital tables and the image library of virtual sleeve with different indicators of fit quality has been developed.

2. Two geometric models of armhole-sleeve assembly were developed by feature points at armhole and sleeve. The first model is designed to verify bodice and sleeve pattern. The second is designed to verify the coordinates in 3D space which relative with the arm/torso plane and the position of closed line of sleeve cap and armhole. The feature points allowable range are established, which do not cause fit defects when assembly (sleeve insert into armhole).

3. A unified nomenclature of indicators related to drawings and virtual sleeves has been developed, which could accommodate the spatial position and condition as viewed from the front, profile, back, and inner. In order to exclude sleeve defects. equations have been established, conditions and allowable criteria of parameters coordination have been determined.

4. A method of image grayscale for fit evaluation have been developed, A high correlation between the subjective indicators of sensory evaluation and the measured indicators of the gray scale intensity is confirmed.

6. A computer module in Python was developed to automatically check the design parameters of armholes and sleeves.

7. The interchangeability of sleeve design processes between real and virtual environments has been proved, which in terms of the designed pattern allowance, the acceptable pressure in the "figure - jacket" system, and the resulting of sleeve volumetric-spatial shape.

8. The developed design and control technology are combined into a new method, namely armhole-sleeve assembly in virtual environment and appearance defect prediction based on gray scale.

9. Production approbation of the results, which confirmed the correctness of the research.

RECOMMENDATIONS, PROSPECTS FOR FURTHER DEVELOPMENT TOPICS

1.The results of the study are recommended for use in the educational process of training bachelors and masters, who study CAD design skills in the field of light industry, in enterprises of women's clothing production, in CAD modernization and retraining to develop new knowledge oriented to the digital economy.

2. Extension of databases and rules to improve the accuracy and sensitivity of virtual design technology to the characteristics of figure morphology and shape of jackets.

3. Developing the technology for obtaining virtual "figure - clothing" systems by combining the processes of making patterns, virtual stitching, automatic control and automatic correction of patterns to achieve the required quality level.

The main results of the work are published:

in journals from "List of peer-reviewed scientific publications in which the main scientific results of dissertations for the degree of candidate of Sciences, the degree of Doctor of Sciences should be published":

1. Ван, С. Создание цифровых двойников узла "пройма-рукав" / С. Ван, В.Е. Кузьмичев//Известия вузов. Технология текстильной промышленности. - 2020. - № 1(385) - С.177-184 (0,5/ 0,25п.л.).

2. Ван, С. Идентификация дефектов виртуальной одежды / С. Ван, В.Е. Кузьмичев // Известия вузов. Технология текстильной промышленности. – 2022. - № 2. – С.159-168 (0,625/ 0,3125 п.л.).

Conference proceedings and other publication:

3.Ван, С. Новый подход к проектированию двух шовных рукавов / Ван Сида, В.Е. Кузьмичев // Современные наукоемкие технологии и перспективные материалы текстильной и легкой промышленности (Прогресс-2013): сборник материалов межд. науч-техн.конф. Часть 2. – Иваново: Текстильный институт ИВГПУ, 2013, с.23-25 (0,1875/0,0938 п.л.).

4. Ван, С. Сценарная технология виртуального кастомного проектирования женских жакетов / С. Ван, В.Е. Кузьмичев // Информационная среда вуза: материалы XXIV межд. научн.-техн. конф. 22-23 ноября 2017 г. Иваново, ИВГПУ, с.147-150 (0,25/0,125 п.л.).

5. Ван, С. Матрица для прогнозирования дефектов посадки рукавов в женских жакетах / С. Ван, В.Е. Кузьмичев // Молодые ученые – развитию национальной технологической инициативы (ПОИСК–2020): сб.материалов национальной молодёжной научно-технической конференции. – Иваново: ИВГПУ, 2020, с.69-72 (0,25/0,125 п.л.).

6. Ван, С. Automatic Evaluation of Sleeve Pattern for Classical Women Jacket (Автоматическаяоценкачертежейконструкцийклассическогоженскогожакета) / С. Ван, В.Е.Кузьмичев // DEStech Transactions on Materials Science and Engineering: Electronical and Mechanical Engineering AMEME, 2020, 13, с. 36-42 (0,4375/0,21875п.л.).

7. Ван, С. Прогнозирование качества проектирования рукавов в виртуальной среде / Ван Сида, В.Е. Кузьмичев //LightConf 2021 "Наука - Технологии - Производство": матер. международн. науч.-технич. конф. 29-31 марта 2021 г. / СПб.: ФГБОУВО "СПбГУПТД", 2021. - 46 с. (0,0625/0,03125 п.л.).

8. Ван Сида. Разработка метода диагностирования качества рукавов виртуальной одежды / С. Ван //Физика волокнистых материалов: структура, свойства, наукоемкие технологии и материалы: сб. материалов XXIV междунар. науч.-практ. форума «Smartex-2021», 12–14 октября 2021 года. – Иваново: ИВГПУ, 2021. Смартекс 2021, с. 187-188 (0,125/0,125 п.л.).

Database

9. База данных № 2022621167 Российская Федерация. Чертежи конструкций и конструктивных параметров женских классических жакетов: заявл. 23.05.2022/ С. Ван, Кузьмичев В.Е.

Other publication

10. Wan, S.D. Study on Application of Clothing Simulation by software Marvelous designer and ET-CAD (Chinese) / S.D.Wan // China New Technologies and Products, 2015, 8, pp.19-20. (0,1875/0,1875 п.л.).

Подписано в печать 01.07.2022.
Формат $^{1}/_{16}$ 60x84.
Бумага писчая. Плоская печать.
Усл. печ. л. 1,05. Уч.-изд. л. 1,0. Тираж 80 экз. Заказ №

ФГБОУ ВО «Ивановский государственный политехнический университет»
Редакционно-издательский отдел УИРиК
153000, г. Иваново, Шереметевский пр., 21