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DEVELOPMENT OF METHODS FOR PREDICTING THE APPEARANCE OF WOMEN'S BLOUSES

05.19.04 – Technology of sewing garments

Brief of Dissertation
for the degree of Candidate of Technical Sciences

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The work was carried out at the Department of Garments Design, Institute of Textile Industry and Fashion, Ivanovo State Polytechnic University.

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The dissertation can be found in the library and on the website of the Ivanovo State Polytechnic University: ivgpu.ru.

The abstract will be sent out ___ ___ 2022.

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GENERAL DESCRIPTION OF RESEARCH

The relevance of the work. Patterns of structures are the basis for the production of clothing and the first stage of design according to the 2D → 3D scheme. Despite the large number of manuals on the construction of patterns of basic structures, not all of them can be used to customize clothing in virtual reality (VR). In VR, there are structural problems that arise during the fitting of seemingly successful patterns due to a difficult formalized procedure for coordinating the spatial interposition of anthropometric and constructive points and lines of the same name. The fact is that the search for such analogues on the surface of the figure and drawings of details of model clothing designs that combine into a single "body - clothing" system with a complex nature of the distribution of air gaps is a very serious and multivariate scientific and practical task. Due to its unresolved nature in virtual clothing models, there is often leveling of fit defects, unplanned distribution of increments and other phenomena that lead to significant differences between virtual and material prototypes and a decrease in the level of emotional perception by the user.

The level of problem development. The issues of three-dimensional design of clothing for mass production and individual consumption are actively engaged in many countries of the world, primarily in those in which the digitalization of the economy has become a determining factor. The most active are Pascal Brunio (France), Susan P. Ashdown (USA), Hwa Kyung Song (Republic of Korea), E.G. Andreeva, I.Y. Petrosova, N.A.Korobtseva (A.N.Kosygin Russian State University), A.Y. Moskvin, M.V. Moskvin (St. Petersburg State University University of Industrial Technology and Design). The research results are being commercialized to improve the virtual fitting software (CLO3D, Vidya, Assyst, Lectra, Marvelousdesigner, LookStailor, etc.), which look more and more realistic. However, the constructive component cannot yet cover all variants of various three-dimensional silhouette forms of women's clothing.

These situations make it necessary to study and predict the causes of defects in the appearance of virtual clothing, especially if there are obvious differences between real clothing and its analogues in VR. Often, virtual fitting does not allow to identify all design errors in patterns that are responsible for the appearance of landing defects, for a number of reasons: insufficient training samples and neural networks formed in virtual reality programs; lack of formalized dependencies between morphological features and techniques for modifying patterns. Therefore, in order to improve the virtual simulation and obtain realistic-looking renderings of clothing, it is necessary to develop an algorithm for the qualimetry of structural drawings and determine the numerical values of the criteria.

The work was carried out at the Department of Garment Products Design of Ivanovo State Polytechnic University in 2017-2022. Within the framework of the scientific direction "Analysis and synthesis of material and virtual systems 'body-clothing' ", within the framework of the state task "Software development for the virtual design of static and dynamic systems 'body-clothing' and the virtual fitting

of clothing Fashion Net" (No. 2.2425.2017/ПЧ) and the grant of the РФФИ and the Ivanovo region "Fundamental fundamentals of virtual design of digital systems 'human body - clothing' using neuropsychological technologies and reverse engineering", No. 20-47-370006.

The work corresponds to paragraph 5 of the passport of the scientific specialty 05.19.04 - Technology of sewing garments: Improvement of quality evaluation methods and design of clothing with specified consumer and technical and economic indicators.

The aim of the dissertation is to improve the process quality of virtual fitting women's blouses.

To achieve this aim in the dissertation work, it is necessary to solve the following tasks:

1. To form a database of design parameters of pattern blocks of women's blouses with different silhouettes and 3D models and to group them.
2. To develop graphic models based on mathematical processing of pattern blocks for women's blouses with different silhouettes and degree of fit.
3. Conduct anthropometric studies of female figures to form a set of dimensional features that can be used to check the proportionality of pattern blocks to the dimensional version of the digital twin of human body.
4. To develop a methodology for checking the pattern blocks before a virtual fitting, including the analysis of the lines of the armhole, neckline, shoulder lines and constructive addition to the dimension feature "Back to waist length" as fundamental for positioning clothing parts on the digital twin of human body.
5. To develop a method for parametrizing the pattern blocks based on flattened scans of the surface of the torso of a women body.
6. To develop an algorithm and indicators for an objective contactless assessment of the quality of virtual women's clothing.
7. Identify areas of audience interest in various areas of virtual women's blouses.
8. Develop a database on the structural causes of pattern defects and criteria for their evaluation.
9. Conduct an experimental test of the developed scenario technology for customizable virtual design of women blouse.

The objects of research - pattern blocks of women blouse, 3D to 2D pattern block flattening technology, criteria of checking blouse pattern blocks, method of checking blouse pattern blocks, real and virtual systems "digital twin - women blouse", algorithm of virtual try-on for individual bodies.

The subject of the study - the preparation of the pattern for a virtual fitting.

Methods and means of research. Various sources of information were used to create databases. The CLO 3D software was used as a technological measuring tool for virtual objects. To conduct research, a hardware and software complex was formed under the conditional name "Virtual fitting of women's blouses", which provides generation and transmission of digital information obtained at each stage of research, which included six components: (1) VITUS Smart XXL laser contactless 3D bodiscanner for obtaining digital twin of the body according to ISO

20685-2010 (E) standard; (2) Anthroscan program (Human Solutions, Germany) for processing anthropometric information; (3) CAD (BUYI Technology, China) for digitizing PMCs; (4) Rhinoceros and CLO 3D computer programs, version 5.0.156.38765 (CLO Virtual Fashion, Republic of Korea) and for generating virtual objects; (5) a measuring kit including tools for fixing eye movement TobiiPro Nano and TobiiPro Glasses 2 Wireless; (6) TobiiPro Lab software for studying visual reaction (Tobii, Sweden). Methods of mathematical statistics, correlation and regression analysis using the SPSS program (IBM, USA) were used to process the measurement results.

Scientific novelty of the thesis consists in the development of a methodological apparatus for checking the constructive defects of pattern blocks of women's blouses in accordance with the anthropomorphic features of avatars of human bodies. The following scientific results were obtained for the first time:

1. Algorithm for checking structures of patterns from the position of anthropomorphic correspondence to the avatar of a female body.
2. Criteria of pattern blocks for predicting the appearance of defects.
3. The method of checking the visual perception of defects in the fit of virtual clothing.
4. Methods of parameterization of pattern blocks of women's blouses in different silhouettes.

The theoretical significance of the research lies in the formalization of professional knowledge related to the design and visualization of women's blouses, taking into account the morphological features of bodies and patterns blocks.

The practical significance of the work consists in the creation of data and rules necessary for the preparation of pattern blocks for virtual fitting to exclude the appearance of fit defects. Data in the form of pattern blocks, established patterns and algorithms can be used in the development of software modules. The possibility of using the CLO 3D program as a means of technological research and modeling of clothing shaping processes in the "avatar-clothing" system is shown. The results obtained can be used in the educational process, the work of practicing clothing designers and the improvement of three-dimensional design systems.

The degree of reliability of the results and conclusions is ensured by a combination of the actual results of theoretical research and experimental results, the statistical sufficiency of the equations obtained, the use of modern measuring instruments, wide approbation of the results obtained in periodicals and at conferences.

Evaluation of the results. The main abbreviations are evaluated and evaluated at the following conferences: 17th World Textile Sonference AUTEX 2017- "Textiles – Shaping the Future", January 21-23, 2017 (**Corfu, Greece**); Aegean International Textileand Advanced epdipeegipd sonference aitae (**Mytilene, lesvos, Greece,** 2018); XXIV International Scientific and Technical Conference "Information Environment University", November 22-23, 2017, (**IVGPU, Ivanovo**); XIII International Scientific and Practical Forum "Physics of fibrous materials", 2020 (**IVGPU, Ivanovo**); All-Russian (with international

participation) Youth Scientific and Technical Conference “Young Students - a Developing National Technological Initiative” (ПОИСК - 2019, 2020) (**IVGPU, Ivanovo**); International Conference on Consecrated Materials, Electronic and Mechanical Devices (**Xiamen, China,** 2020); International conference on Tests, technologies and education ICTE (**Yambol, Bulgaria,** 2020); the fourth All-Russian Young International Competition Legpromnauka 2021 of the Smartex-2021 International Scientific and Practical Forum (**Ivanovo**).

Publications. According to the results of the dissertation research, 13 printed works have been published, including six articles in publications included in the “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”, seven materials of conferences and forums of various levels should be published.

The structure of the dissertation. The dissertation consists of an introduction, five chapters, a conclusion, a list of 121 references used and 10 appendices. The content of the work is presented on 291 pages of typewritten text, including 70 figures and 54 tables.

CONTENT

The **introduction** substantiates the relevance and degree of scientific and theoretical elaboration of the problem of obtaining realistic virtual twins of clothing with shape indicators projected in the pattern blocks; the goals and objectives of the study are formulated, the characteristics of the methods and means of research are given, the provisions to be defended are formulated, the scientific novelty, theoretical and practical significance of the dissertation are disclosed, its structure is presented.

First chapter analyzes the following aspects of the current state of technologies for obtaining digital twins of bodies and clothing:

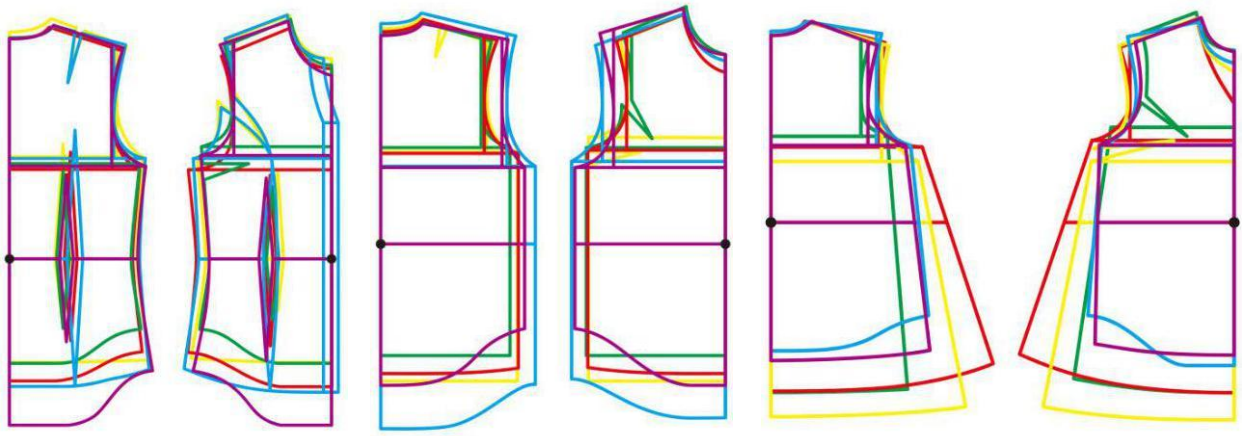
- the capabilities of modern 3D CAD in obtaining realistic virtual twins of clothing with shape indicators projected in the design patterns;
- the main problems that arise during a virtual fitting;
- design features from the position of the databases used, algorithms, shaping techniques and causes of defects;
- criteria for evaluating clothing in VR.

The purpose and objectives of the study are formed, its algorithm is compiled.

Second chapter is devoted to the development of anthropometric data and graph-mathematical models of pattern blocks for women blouse (the results are published in three papers).

Anthropometric data include measurements of female figures and the development of virtual twins of female bodies in the CLO3D program with additional dimensional features responsible for the quality of clothing fit and designed to find anthropometric points in the upper shoulder line. 16 dimensional features were used to control the torsos of virtual twins of female bodies, including five additional ones.

A training sample of 132 blouse pattern blocks was formed. The patterns were digitized using ETCAD and divided by frontal silhouettes into X, H, A, and then by the ease allowance of bust girth into body-fitted, loose-fitted and looser-bodied. **Fig. 1** shows the diagrams of patterns demonstrating the differences between the silhouettes under study.



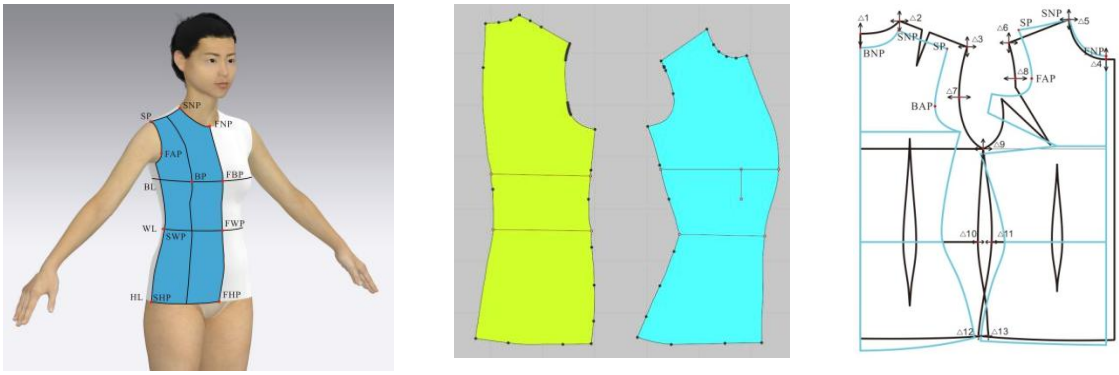
a *b* *c*

Fig. 1 - Blouse pattern blocks with different styles: a - X, b - H, c - A

Graph-mathematical models of blouse pattern blocks in X, H and A styles with three different degrees of fit were developed on the basis of prototype of women blouse pattern blocks with limited parameters of correlation and regression analysis. Graph-mathematical models include equations for the transformation of the coordinates of the external contour of the prototype of women blouse pattern blocks into the blouse pattern blocks. The graph-mathematical models include structural changes in patterns at the level of the bust and waist, shoulder line, back widths, neck, etc. With the help of the obtained equations, it is possible to parameterize patterns to obtain the necessary volume-silhouette shape.

Third chapter is devoted to the development of a methodology for preparing blouse pattern blocks for virtual fitting (the results are published in 3 articles).

Parameterization of the blouse pattern blocks by scanning the surface of the avatar. Parameterization includes combining, according to special rules, the blouse pattern blocks and the avatar surface scan and measuring the main design parameters. The coordinates of similar points of the blouse pattern blocks and virtual twin of female body, as well as the values of the design parameters, can be obtained using a torso scan and graph-mathematical models in the coordinates of the X and Y axes. **Fig. 2** shows the virtual twin of female body, the flat scan of the torso obtained in the CLO3D program using the alignment tool, and the combined flat scan of the virtual twin of female body and the graph-mathematical model of the blouse pattern blocks.

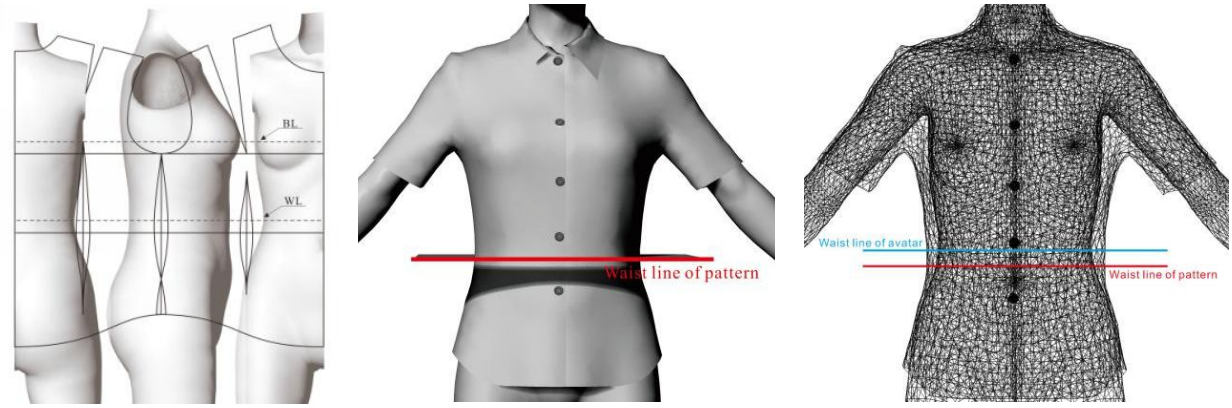


a *b* *c*

Fig. 2 - Virtual twin of female body (a), flattened 2D surface (b) and the scheme of combining the flattened 2D surface with blouse pattern blocks (c)

After combining, according to the specified scheme, the main structural ease allowances were calculated, knowing which, it is possible to ensure the positioning of virtual patterns on the avatar body.

Checking the positions of the anthropometric and pattern waist levels. The technique is designed to find the waistline by specifying two eases along the midline of the back length - ease allowance to BNP and ease allowance to back length - by coordinating the rendering of the blouse and the virtual twin of female body relative to each other with orientation to two waist levels – anthropometric and constructive. **Fig.3** illustrates the scheme of finding waist levels of the both objects.



a *b* *c*

Fig. 3 - Scheme of calculating the ease allowance to back length: a - digital twin with the patterns, b - render of blouse with waist line at narrowest waist place, c - shearing render of blouse with the both waist lines

At the blouse pattern blocks, the anthropometric waist line of the patterns was determined by using the measurement "Distance from FNP to waist line through protruding bust points located on BL" and the position of narrowest width of waist WL (**Fig.3, a**). The blouse render was generated from the patterns on digital twin in CLO3D (**Fig. 3, b**), and in the form of a transparent the triangulation grid after exporting the file to Rhinoceros (**Fig. 3, c**). The anthropometric waist line of the digital twin was defined as the narrowest place of torso through a transparent mesh.

The ease allowance to the dimension feature “Back length to waist” is equal to the distance between the anthropometric and constructive waist levels.

Checking the neck line and shoulder lines. The technique includes the analysis of the same structural and anthropometric – shoulder lines and neck – digital twin and pattern blocks of blouse. The technique is based on finding the coordinates of points on the neck girth line, shoulder slope lines and their alignment with similar points and lines of patterns. The analysis of the neck line includes its assessment relative to the neck and neck girth line and checking their compliance with each other.

During the inspection, the front and the back of patterns were coincided in such a way as to obtain a closed neck line, and inside to arrange the neck section in compliance with the previously calculated ease allowance to the constructive segment “ease allowance to BNP”. The cross section of the neck and the shoulder lines of the digital twin deployed on the plane can be positioned differently depending on the size of this ease allowance. Therefore, the absence or appearance of pattern defects will depend on the relative position of two closed lines - cross-section of neck girth of digital twin and neck line of pattern blocks, as well as on the angular difference between the shoulder lines of the pattern blocks and the digital twin. **Fig. 4** shows possible variations for the mutual arrangement of identical lines of the digital twin and the patterns responsible for fit, and their impact on the occurrence of patterns defects in virtual environment.

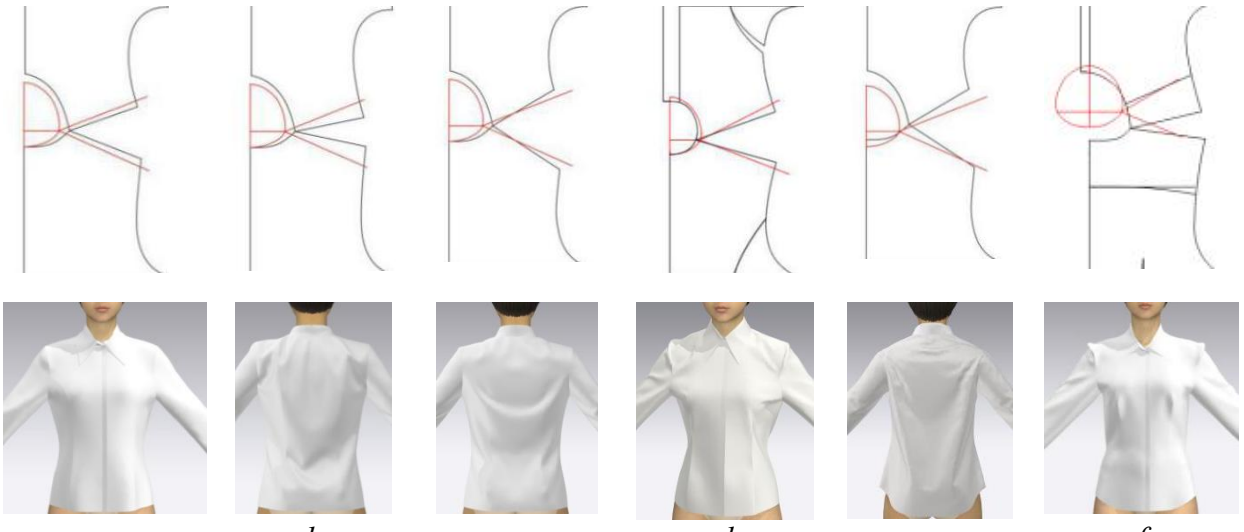


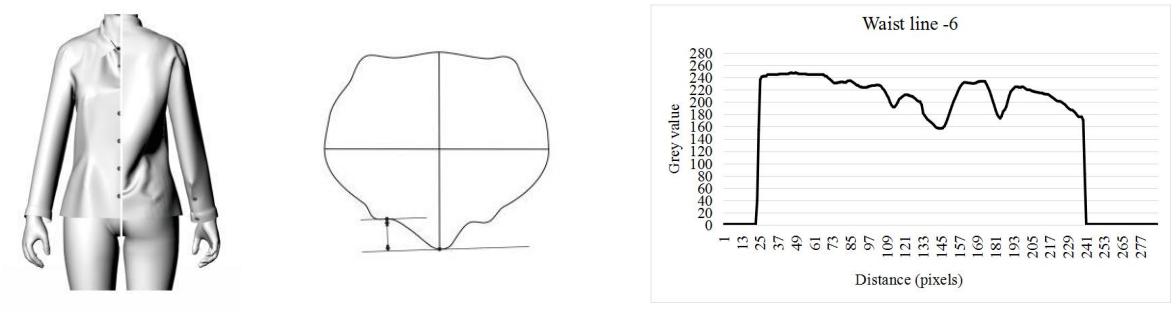
Fig.4 - Possible variations for the mutual arrangement of identical lines of the digital twin and patterns and the corresponding appearance of virtual try-on: a - good fit variation, b,c,d,e,f - incorrect angles of inclination of the shoulder lines, d- insufficient length of the neck line, e - insufficient ease allowance to BNP, e - excessively large ease allowance to BNP

Checking the armhole line is based on using the anterior and posterior points of the armpit as the key points. The constructive ease allowance in armhole line can be calculated by virtual overlap of the armhole lines of the blouse pattern blocks and the line of body prototype of the digital twin.

Thus, the conditions for matching similar constructive and anthropometric lines and points for the unambiguous location of virtual clothing on the digital twin were determined.

Fourth chapter is devoted to the development of methods for detecting pattern defects using the gray-scale and the use of neuropsychological eye-tracking technology for analyzing virtual clothing (the results of the work are published in three articles).

The method of measuring the parameters of folds on the surface is based on measuring the intensity of gray color on the surface of virtual models at the locations of folds and patterns between the depths of folds measured on horizontal sections. The parameters of the folds were selected as indicators of the quality of the fit of virtual blouses. The technique is implemented using the programs CLO 3D, Rhinoceros, ImageJ. **Fig. 5** shows the render of a blouse and schemes for parameterizing folds on horizontal sections and the surface of a virtual blouse using gray-scale technology.



a *b* *c*

Fig.5 - Blouse render (a), horizontal cross-section for measuring fold depth of blouse (b) and a diagram of the gray color of the blouse surface at the locations of the folds in the coordinate axes “Gray intensity (Gray value) - distance (distance) in pixels” (c)

The average values of the width and depth of the folds were calculated using the following formulas:

$$V_D = \frac{\sum_i \left| V_{Di} - \overline{V}_D \right|}{\overline{V}_D} 100 \quad (1)$$

$$V_H = \frac{\sum_i \left| V_{Hi} - \overline{V}_H \right|}{\overline{V}_H} 100 \quad (2)$$

where V_{Di}, V_{Hi} are, respectively, the width and depth of the i-th fold; V_D, V_H are, respectively, the average value of width and depth.

A database has been formed that combines linear parameters of folds and surface irregularities on a gray scale.

The technique of parametrization of visual interest using neuropsychological eye-tracking technology was developed to study the degree of people's attention to defects on various parts of clothing. 20 material and virtual women's blouses with different fit quality from perfect to bad were studied with the help of sensory eye-

tracking technology. The studies were carried out in areas where folds appeared as indicators of defects (**Fig.6**).

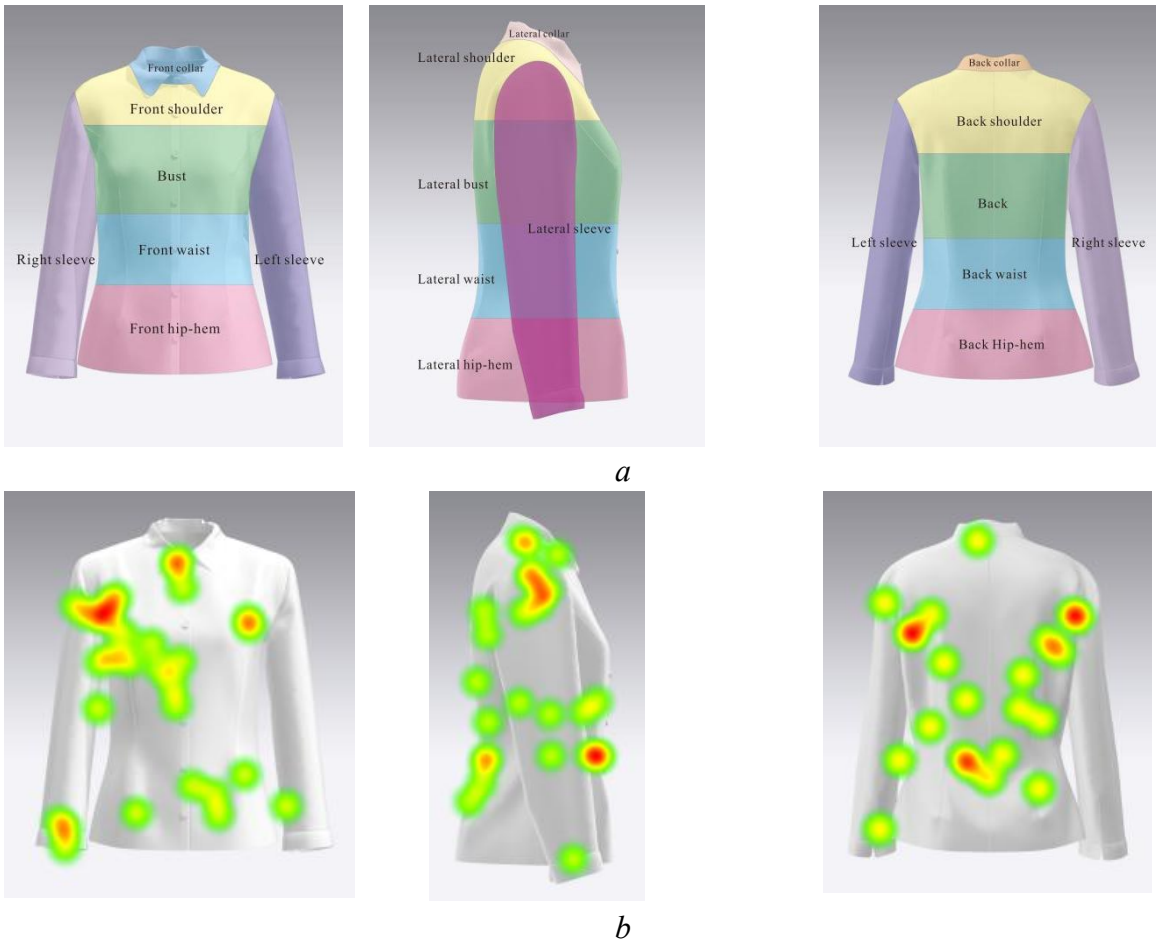


Fig. 6 - Areas of Interest (AOIs) in different views (a) and examples of heat map for X- style women blouse (b)

Quantitative characteristics were obtained: total duration of fixation in AOI and fixation count, the comparison of average values for the objects of the same name was carried out and a multidimensional analysis of the variance of eye-tracking data was performed. Areas of increased attention have been identified where the appearance of defects is extremely undesirable.

The duration and count of fixations to the front of the bust are the highest, followed by the sleeve and waist area. The greatest weight of these sections indicates the correctness of the approach chosen in **Chapter 3** on the anthropometric parameterization of the upper surface of the blouse pattern blocks, on which the occurrence of defects depends on these areas.

Fifth chapter is devoted to the development of technology for virtual fitting and pattern quality (the results of the work are published in three articles).

The developed scenario technology of virtual fitting of women's clothing includes the following stages:

– generating a virtual twin of a female body using basic and additional dimensional features;

– generating a torso scan;

– graphoanalytic analysis of the torso scan and patterns of parts to coordinate the mutual position of anthropometric and structural points and levels;

– formation of the primary virtual system “avatar - blouse” to clarify constructive ease allowances;

– checking and correcting design parameters responsible for the occurrence of pattern defects;

– formation of the final virtual system “avatar - blouse”;

– quantitative evaluation of the surface condition of the “avatar - blouse” system by measuring the surface unevenness.

The blouse fit evaluation included the identification of defects, the features of their location and the determination of the design parameters responsible for their appearance. The causes of defects are selected as the constructive basis of the technology:

1) distribution of ease allowance for the bust line between three parts: front bust width, armhole width and back bust width;

2) longitudinal balances;

3) neck and neck girth parameters;

4) transverse balance along the hip line.

By checking all the blouse pattern blocks from the training sample, the numerical values of the criteria that lead to the appearance of defects were determined. **Table 1** shows the numerical values of the criteria for two variants of blouses - real and virtual.

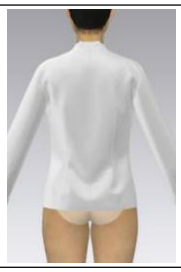
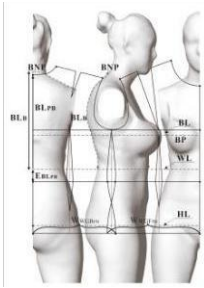
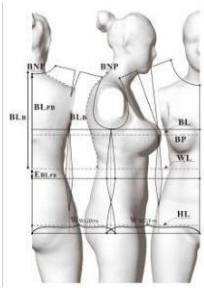
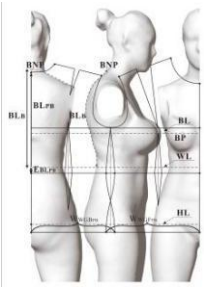
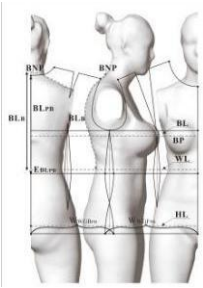
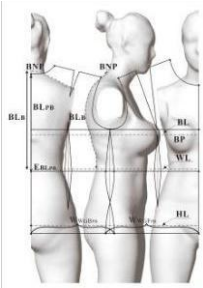
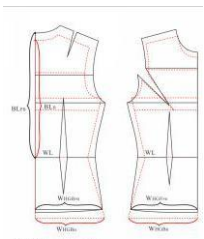
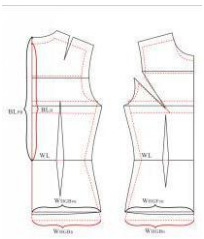
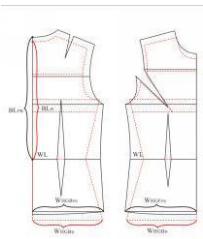
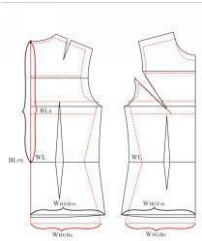
Table 1 - Numerical values of criteria for real and virtual blouses

Evaluation area	N.	Indicators	Test conditions	Quality of fit criteria	
				Renders in Rhinoceros 3D	Real blouse
Shoulder angle	1	$\Delta_1 = \Sigma\alpha_B - \Sigma\alpha_{PB}$	$\Sigma\alpha_B > \Sigma\alpha_{PB}$	$\leq 22^o$	$\leq 14...16^o$
			$\Sigma\alpha_B < \Sigma\alpha_{PB}$	$\leq 20^o$	$\leq 10...12^o$
Neck	2	$\Delta_2 = NL - NG$	$NG<NL$	≤5,5см	≤ 2..2,5 см
	3	$\Delta_3 = BL_{PB} - BL_B$	$BL_B<BL_{PB}$	≤2,5см	≤ 0,9...1,2 см
	4	$\Delta_4 = FL_{PB} - FL_B$	$FL_B<FL_{PB}$	≤3,5см	≤ 1,5...1,8 см
Bust line	5	$E_{FBW} : E_{AHW} : E_{BBW}$	$E_{FBW} >40,5>E_{AHW}<90,$	(5...35) :(15...85) :(10...50)	(5...35) :(15...85) :(10...50)

It can be seen that the established values of the criteria for virtual renderers exceed by 1.4...2.3 times those that are confirmed by the practice of real design. This difference indicates the insufficiency of programs that simulate the behavior of textile materials as triangulation shells on the surface of the figure. Existing software ignores small differences and does not identify them as defects.

Table 2 shows a fragment of a matrix for evaluating the back of blouse (1 - quality level, 2 - criteria, 3 - real image, 4 - virtual image, 5 - virtual fitting, 6 - blouse pattern blocks, 7 - design criteria).

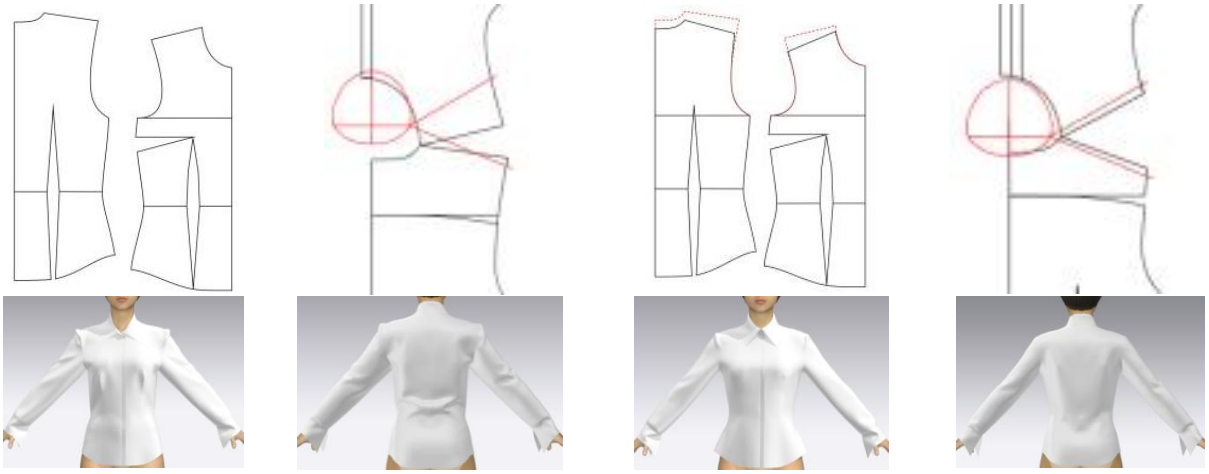
Table 2 - Criteria for fit evaluation of the blouse from the back

Quality fit levels of women blouses					
1	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
2	Too much horizontal wrinkles upper hip level; non-predictable location of the	Several sloping folds.	Few soft vertical folds.	The back is completely smooth; the hem is in normal position.	The back is completely smooth; the hem is in normal position.
3					
4					
5					
6					
7	The first criteria is ease allowance to back length E, cm				
	E≥4.8±0.3	E≤3.8±0.3	E≤2.8±0.3	E≤1.8±0.3	E ≤ 0.8±0.3
	The second criteria is the transverse balance along the hip line Δ, cm				
	Δ≤ -2.2±0.4	Δ≤ 1±0.4	Δ≤ 0.2±0.4	Δ≤ 1.4±0.4	Δ≤ 2.6±0.4

The technology was tested on randomly selected patterns. **Fig. 7** shows the pattern blocks of the blouse, in which, after combining with several sections of the digital twin of scan, the following features are revealed:

- the shoulder lines of the avatar and the pattern blocks are not parallel, $\Sigma\alpha_B > \Sigma\alpha_{PB}$;
- the neck point in front is located below the neck line;
- the ease allowances to the BNP and the front are not coordinated with each other.

After generating the primary render of the blouse, folds were diagnosed: vertical on the front under the protruding points of the busts and horizontal on the back in the waist area (**Fig. 7, a**).



a *b*

Fig.7 - Correction of structural patterns after virtual fitting:
a - initial blouse pattern blocks and render, b - corrected blouse pattern blocks and render

To eliminate these defects, changes have been made to the design patterns (see **Tables 1** and **2**): the slope of the shoulder lines has been reduced to achieve equality $\Sigma\alpha_B = \Sigma\alpha_{PB}$; the armhole line has been lengthened; the neck line has been redesigned by shortening the middle line of the back and ease allowance to the BNP. As can be seen from **Fig. 7, b**, after such changes, the blouse render no longer has any fit defects, and its appearance has become of high quality.

The developed technology was tested by manufacturing women's blouses, which confirmed the correctness of all stages of the technology.

RESULTS OF THE PERFORMED RESEARCH

1. A scenario technology has been developed for carrying out virtual fitting of women's clothing, including the development of patterns, generation of a scan of the torso surface, coordination of anthropometric and structural points and levels, and the location of patterns of the relative female body according to calculated structural ease allowances.

2. An anthropometric database has been formed containing additional dimensional features necessary for generating virtual twins of typical female bodies and checking the proportionality of virtual clothing.

3. Graphic-mathematical models of patterns of women blouses in X, H and A styles with different degrees of fit have been developed based on the prototype of women blouse pattern blocks, the range of variability of design parameters and correlation and regression analysis.

4. Methods and algorithms for implementing the stages of scenario technology for anthropometric parameterization of patterns on the supporting surface of the avatar, as well as methods for preparing patterns of model structures for virtual fitting, have been developed.

5. A method of quantitative objective evaluation of the appearance and surface condition of virtual twins of women clothing on avatars using gray-scales has been developed. Mathematical expressions for calculating the parameters of folds appearing on the surface of virtual clothing were defined.

6. An algorithm has been developed for evaluating the surface condition of virtual twins of women's clothing on avatars using instrumental sensory neuropsychological technology of fixing the gaze on various parts of virtual blouses. The AOIs of increased visual interest affecting the evaluation of the quality of clothing fit have been identified.

7. A design framework and criteria have been developed for predicting the quality of the fit of virtual women blouses in X, H and A styles with different degrees of fit, with the help of which it is possible to predict the appearance of folds as indicators of the quality of the design of drawings and fit on the female body.

RECCOMENDATIONS, PERSPECTIVE OF FUTURE DEVELOPMENT

1. The work can be continued in the direction of expanding the range of textile materials and types of women's clothing and supplementing the developed scenario technology with new databases.

2. The nomenclature and causes of defects can be expanded by studying the design features of sleeves and collars and identifying criteria for matching the design parameters of the bodice, sleeve and collar for different volumetric silhouette shapes.

3. The results of the work are recommended to be used to improve 3D CAD software using artificial intelligence.

4. The results of the work are recommended to be used in secondary and higher educational institutions for the training of clothing designers, as well as in the system of additional professional education.

The main results of the work are published:

In the publications included in the "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. Ся, П. Прогнозирование качества чертежей на виртуальных двойниках женских фигур / П. Ся, В.Е. Кузьмичев // Известия вузов. Технология текстильной промышленности. – 2019. - № 4. - С. 121-127 (0,438/ 0,225 п.л.).

2. Ся, П. Исследование влияния типа фигуры и объемно-силуэтной формы на качество посадки одежды в виртуальной реальности / П.Ся, В.Е. Кузьмичев // Известия вузов. Технология текстильной промышленности. - 2022. - № 2. – С.178-183 (0,375/ 0,188 п.л.).

3. Xia P. Virtual method of predicting the accuracy of pattern blocks // X. Peng, V. E. Kuzmichev: IOP Conf. Series: Materials Science and Engineering, 459 (2019) 012084IOP Publishing doi:10.1088/1757-899X/459/1/012084//Aegean International Textile and Advanced Engineering Conference (AITAE 2018), (0,25/0,125 п.л.)

4. Xia, P. Improvement of virtual simulation by means of sewing patterns// P.Xia, V. E. Kuzmichev// 2020 International Conference on Advanced Materials, Electronical and Mechanical Engineering, Xiamen, China, Sept 2020, p. 10-19 (0,625/0,313 п.л.)

5. Xia, P. Evaluation of fit criterias by means of eye-tracking technology// P.Xia, V. E. Kuzmichev // 2020International Conference on Advanced Materials, Electronical and Mechanical Engineering, Xiamen, China, 2020, p.43-54 (0,75/0,375 п.л.)

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7. Ся П. Исследование процесса автоматизированного проектирования женских блузок /П. Ся, Кузьмичев В.Е., Ли Юэ, Ван Сяоган // Молодые ученые - развитию текстильно-промышленного кластера (ПОИСК-2017): сб. материалов науч.-техн. конф. аспирантов и студентов (с межд. участием). Ч. 1.- Иваново: ИВГПУ, 2017, с.120-122 (0,188/ 0,09 п.л.).

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9. Ся, П. Технология оцифровывания чертежей модельных конструкций для виртуальных примерок / П. Ся, В.Е.Кузьмичев, Ю. Ли // Информационная среда вуза: материалы XXIV межд. научн.-техн. конф. 22-23 ноября 2017 года. Иваново, ИВГПУ, с.133-137 (0,3125/ 0,16 п.л.).

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11. Xia, P. New method of armhole line analyzing by using virtual reality technology / P. Xia, V. Kuzmichev. Молодые ученые- развитию национальной технологической инициативы, (ПОИСК- 2019): Сборник материалов, Часть 1. Иваново 2019, с.226-231 (0,375/ 0,19 п.л.).

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