На правах рукописи

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РАЗРАБОТКА МЕТОДИКИ ПРОГНОЗИРОВАНИЯ ВНЕШНЕГО ВИДА ЖЕНСКИХ БЛУЗОК

Development of method of women blouses outlook predicting

05.19.04 - Технологии легкой промышленности

Диссертация на соискание ученой степени

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CONTENT

GENERAL DESCRIPTION OF RESEARCH

The relevance of research. Pattern drafting is the basis for the production of clothing and the first stage of 2D → 3D design. There are many manuals of sewing pattern blocks making and some of them aren't good for the customization in virtual reality (VR). Well-known methods of virtual try-on technologies are CLO3D, Marvelous Designer, Optitex, DC Suite, etc. which are showing own structural problems related to misfit, unreasonable distribution of ease allowance of pattern blocks, and so on. The fact is that the search for such analogs on the surface of body and drawings of details of model designs of clothing, combined in a single "body - clothing" system with a complex distribution of air gaps, is a very serious and multivariate scientific and practical task. Due to its lack of resolution in virtual clothing models, there is a leveling of fit defects, an undesigned distribution of increments, and other phenomena that lead to significant differences between virtual and material prototypes.

Depth of topic development. The issues of three-dimensional design of clothes for mass production and individual consumption are actively dealt with in many countries of the world, primarily in those in which the digitalization of the economy has become a determining factor. The most active is Pascal Bruniaux (France), Susan P. Ashdown (USA), Hwa Kyung Song(Republic of Korea). In Russia, E.G. Andreeva, I.Y. Petrosova (Russian State University named after A.N. Kosygin) and A.Y. Moskvin, M.V. Moskvina (Saint-Peterburg State University of Industrial Technologies and Design). The research results are commercialized to improve software for virtual fitting (CLO3D, Vidya, Assyst, Lectra, Marvelous designer, LookStailor), which look more and more realistic. However, the constructive component can not yet cover all the options for the diverse volumetric-silhouette forms of women's clothing.

These situations make it necessary to study and predict the causes of defects, especially when there are obvious differences between real clothes and their analogues in VR. Often, a virtual fitting does not allow to identify all design errors in drawings, especially those that are responsible for the occurrence of pattern blocks defects, for a number of reasons: insufficient training samples formed in virtual reality programs; the absence of formalized dependencies between morphological features and techniques for modifying pattern blocks. Therefore, to improve virtual simulation and obtain realistic-looking clothing renders, it is necessary to develop an algorithm for qualimetry of structural drawings and determine the numerical values of the criteria.

The work was performed at the Department of Design of Garments of the Ivanovo State Polytechnic University in 2018-2020. as part of the scientific direction of the department **“Analysis and synthesis of material and virtual systems ‘body-clothing’”**, as part of the state task “**Development of software for the virtual design of static and dynamic systems ‘body-clothing’ and virtual fitting of Fashionnet clothes”** (No. 2.2425. 2017 / HR) and grant of the Russian Foundation for Basic Research and the Ivanovo region "Fundamentals of virtual design of digital systems "human figure - clothing" with the use of neuropsychological technologies and reverse engineering technologies", No. 20-47-370006.

The work corresponds to the following points of the passport of the scientific specialty 05.19.04 – Sewing technology: 5 – Improvement of quality assessment methods and design of clothing with specified consumer and technical and economic indicators.

The aim of research is to develop scenario technology for customized virtual women blouse.

To achieve this goal 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’s blouse.

The objects of study - 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 study - preparation of pattern blocks for virtual try-on.

Methods and means of research. In theoretical research, we collected various books and magazines to create database of pattern blocks for women's blouse. Methods of mathematical statistics, correlation and regression analysis (Excel, SPSS) were used to process the measurement results. For experimental research, a hardware and software complex was formed under the code name “Virtual fitting of women’s blouses”, which generates and transmits digital information obtained at each stage of research, which included six components: (1) laser contactless 3D body scanner VITUS Smart XXL for obtaining scanatars of female bodies according to the ISO 20685-2010 (E) standard; (2) Anthroscan program (Human Solutions, Germany) for processing anthropometric information; (3) CAD (BUYI Technology, China) for digitizing pattern blocks of women blouse; (4) CLO3D computer program, version 5.2 (CLO Virtual Fashion, Republic of Korea), for generating static and dynamic virtual objects; (5) measuring kit including Tobii Pro Nano and Tobii Pro Glasses2 Wireless eye tracking instruments; (6) Tobii Pro Lab software for studying visual data (Tobii, Sweden). Statistical processing of the measurement results was carried out using the SPSS software (IBM, USA).

Provisions for defense:

1. Methods of parameterization of pattern blocks of women's blouses using a prototype of the basic pattern blocks and a scan of the torso of a virtual female body.

2. Graphic-mathematical models of women's blouses pattern blocks with different silhouettes and three-dimensional female bodies.

3. Methods and criteria for checking the structure lines of virtual women blouses relative to similar anthropometric lines of a virtual female body.

4. Regularities of neuropsychological perception of areas of location of defects in virtual clothing.

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.

Theoretical significance of the research lies in the formalization of professional knowledge of designing women's blouses, taking into account the morphological features of human bodies and structural features of pattern blocks.

Practical significance of the research consists in the creation of data and rules necessary for the preparation of pattern blocks of women blouse for virtual fitting to exclude the appearance of fit defects. Data in the form of pattern blocks of graphic-model structures, 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.

Reliability degree of the results of the thesis 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.

Approbation of the results. The main results of the study were reported and discussed at the following conferences: 17th World Textile Conference AUTEX 2017- “Textiles–Shaping the Future”, June 21-23, 2017 (**Corfu, Greece**); Aegean International Textile and Advanced Engineering Conference AITAE (**Mytilene, Lesvos, Greece,** 2018); XXIV International Scientific and Technical Conference "University Information Environment", 22-23 November 2017, (**IVGPU, Ivanovo**); XII International Scientific and Practical Forum

"Physics of Fibrous Materials", 2020 (**IVGPU, Ivanovo**); All-Russian (with international participation) Youth Scientific and Technical Conference "Young Scientists - Development of the National Technological Initiative" (SEARCH-2019, 2020) (**IVGPU, Ivanovo**); International Conference on Advanced Materials, Electronical and Mechanical Engineering (**Xiamen, China,** 2020); International Conference on Technics, Technologies and education ICTTE (**Yambol, Bulgaria,** 2020); the fourth All-Russian Youth International The LIGHT INDUSTRY SCIENCE 2021 competition of the international scientific and practical forum Smartex 2021 (**Ivanovo**).

Publications. According to the results of the dissertation research, 13 printed works have been published, including four 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" should be published and in international publications indexed in the citation-analytical databases of Web of Science and Scopus, seven materials of conferences and forums of various levels.

Structure and volume of the dissertation. The dissertation consists of an introduction, five chapters, a conclusion, a list of references and appendixes. The content of the work is presented on 348 pages of typewritten text, including 70 figures and 54 tables. The dissertation consists of an introduction, 5 chapters, a conclusion, a list of 121 sources used and 10 appendices.

INTRODUCTION

Digital technologies are the main instsrument for design of clothes and processes of its production within the Industry 4.0. The first achievements of such technologies in clothing industry show that their potential is huge for disclosure of creative opportunities of designers and considerable economy of material and human resources. The game industry shows their obvious creative opportunities. However, transfer of all cogitative and physical actions in virtual reality faces certain problems when forming virtual twins of real prototypes: patterns, textile materials, clothes, "body-clothes" system.

The final result of design correctness of all system elements is the virtual fitting of parts and components of clothes on a avatar. There are two schemes of virtual fitting: the first scheme is based on the use of the basic pattern blocks created by the known rules, and the second scheme operates with modified pattern blocks created by unknown techniques and which are in fact "a black box". Results of the first scheme of virtual fitting are predictable, but the second scheme does not allow predict a fit. The importance of fit improvement of the second scheme "modified pattern block + avatar of human body" is following by the fact that in the fashion industry there are a huge number of such pattern blocks which correct application can exempt the designers and the pattern makers from repetition and copying.

Therefore, in the thesis exactly earlier created modified pattern blocks are chosen for a research and a development of rules of carrying out virtual fittings and achievement of the predicted level on an avatar. The purpose of dissertation work is an improvement of carrying out virtual fittings of the women's blouses generated on avatars.

1. CURRENT SITUATION OF GENERATING REALISTIC VIRTUAL CLOTHING

1.1. Quality of pattern blocks - definition and development

1.1.1. Definition of pattern blocks quality

The garment structure is an important part of the design, which is a mean and a way to realize the style. It is an indispensable part of design process in total. The structure design of the garment extends the design by transforming the idea of style into graphic pattern blocks, and provides the necessary data and foundation for garment production at the same time[111]. A perfect, correct pattern block is, in short, one that meets the needs of the garment style, meets requirements of the human body sizes, and can be used for garment production [119]. The clothing made with the correct and reasonable pattern blocks is not only comfortable to wear, but also can achieve the effect of modifying human body, and plays an important role in the final garment shape [4]. Nowadays, the quality of pattern block is widely regarded as an important aspect of clothing appearance and comfort, and more and more scholars pay attention to and study the quality of pattern blocks.

For instance, Chen Ming-yan proposes that, first, a good pattern block must be based on reliable specific measurements on various parts of the body to draft pattern block. Through anthropometric measurement, the specific measurements of various parts of the human body should be mastered. At the same time, before the anthropometric measurements, the key bone points of the human body structure should be understood, so accurate human values can be obtained. And Chen Ming-yan suggested that we also need pay attention to the corresponding measuring parts and dimensions of different clothing styles. Otherwise, it will affect the fit degree of pattern block and will not reach the expected design effect. Second, A good pattern block must be based on the clothing style to determine the correct ease allowance of the various parts of the pattern block, such as ease allowance of the bust line, the ease allowance of the waist line, etc. The ease design of pattern block is the key factor to affect the clothing comfort. Third, no matter what the style of the garment, the corresponding fabric is needed to express it. Therefore, the textile materials properties must be considered to make a good garment pattern block. And according to the corresponding materials properties, the parameters of the various parts of the pattern block should be adjusted, such as thepucker valuesof the sleeve, the ease allowance of bust girth, etc.[8].

Dailu suggests that the ultimate goal of garment patternmaking is to realize garment production, so the drafting of pattern block should not only consideredgarment style, but also the possibility of production. A good pattern blocks ensures not only perfect garment silhouette, but also convenient layout, cutting and sewing, which improves production efficiency[25].

Li Wenyuan, on the other hand, proposes that the structural balance of the women's dress pattern blocks directly determines and relates to the beauty of the dress shape and the comfort of the human body, which has an important influence on the overall shape of the dress. Therefore, the balance of garment bodice structure is an important component to evaluate the quality of garment pattern blocks [59].

According to Zhou Hongmei, many properties of garment fabric have an important influence on garment structure design. When making clothing pattern blocks, we should not only consider the beauty of style, but also must combine different clothing fabrics, from the fabric thickness, fluffy degree, extension length, shrinkage and other aspects to consider, in order to be able to make suitable for human structure, a pattern block of high quality in accordance with style characteristics [120]. At the same time, as the extension and perfection of clothing style design, garment pattern blocks is the premise and foundation of garment technology realization. The quality of garment pattern blocks is also influenced by the structural characteristics of human body, clothing materials and craft techniques and other factors [8].

Wang Shujing discusses that the technical data of clothing pattern making and the trial-manufacture and production of sample clothes also have an impact on the quality of pattern blocks. At the same time, before the actual pattern making work, the patternmakers need to communicate with fashion designer and exchange design details with each other, so that the pattern blocks of the clothing can show the effect that the designer wants to express. Therefore, the communication and tacit understanding between the designers and the patternmakers also have a great influence on the quality of pattern blocks. In the meantime, the technical level of the patternmaker also has a great impact on the quality of pattern blocks [93].

Liufei et al. believes that there are still different errors in the process of using garment size to grade the garment pattern blocks, which will affect the quality of clothing pattern blocks. At the same time, in the process of garment production, it is necessary not only to guarantee the production quality, but also to pursue the production efficiency, which, to a certain extent, results in the neglect of the details of garment pattern blocks in the process of garment production. Furthermore, it has a great influence on the quality of clothing pattern blocks [64].

Yue Wenxia et al. considers that clothing structure and clothing craft were complementary to each other. Clothing structure determines clothing craft, and clothing craft should reflect the characteristics of clothing structure. Therefore, in the process of clothing production, only with excellent production technology as the technical support, can we get the desired structure and style of clothing, so as to produce high-quality clothing [113].

Li Zheng, based on the characteristics of the human body's shape, summarized and studied the difficulties in the design of the curve in the structure design of the garment and the design of the dart, and discussed the effect of the difficulty in the design of the garment structure on the quality of the pattern blocks [61].

V.E. Kuzmichev points out that among the many factors that affect consumer demand, habits, and satisfaction, fit is the most important factor in determining the quality and sales of clothing. Clothing fit plays an important role in clothing design, because it significantly affects the appearance and comfort of clothing. At the same time, well-fitting clothes depend heavily on the accurate sewing patterns. A well-designed sewing pattern is the basis for making different kinds of properly fitting clothes. Therefore, in the process of making well-fitting clothes, not only the comfort and appearance of the clothes should be considered, but also the accuracy of the pattern making should be considered. And, when designing different styles of clothing, the design of appropriate values of ease allowances which are designing in sewing patterns should prevent clothing from being misfit [50].

Yang Qi thinks that pattern block is one of the soul elements of clothing brand culture. Pattern block and garment style, fashion and comfort restrict each other and cooperate with each other. A comprehensive understanding of the characteristics of garment shape with different silhouettes is the basis for making perfect pattern blocks. At the same time, fashion has an impact on the pattern block, which serves the fashion and is restricted by the fashion. The pattern block develops according to the change of the fashion. Pattern-makers need to have a fashion vision, according to the changing characteristics of fashion to draw the pattern blocks that conforms to the fashion shape [106].

Liu Liqun summarized and discussed the mutual relationship between clothing structure design and formal beauty principle on the basis of the existing formal beauty principle of design theory. She pointed out that the clothing structure design starts from the shape of clothing style, to the internal structure change of the pattern blocks, coordinates the part and the whole to carry on the design. The garment structure design first simulates the outer contour structure of clothing, then analyzes the proportion, segmentation, darts and folds of the inner structure of clothing, finally coordinates the part and the whole, and then returns to the unification of the final clothing design effect. In this complete structural design process, no matter what method of making pattern blocks, can not do without the guidance of the formal beauty principle [68].

Derya T. proposes that in order to provide clothing fit, it is necessary to associate garment pattern making with body shapes. Body shape is the major factor that has an influence on fit and satisfaction with clothing. Ideal body shapes have always been used by the apparel industry, from which technicians take dimensions for pattern making and fitting and designers create their new designs. At the same time, she also found that the pattern making systems are not suitable for each body shape. For this reason during making the sewing patterns, pattern making systems should be revised in terms of the characteristics of each body shape [27].

In general, the quality of pattern blocks is widely considered to have a very important impact on garment production and improving garment comfort. The latest researchers propose that a good pattern block must be based on reliable body measurements, the style of the garment, the properties of garment fabric.

1.1.2. Development of quality of pattern blocks

Nowadays, the theme of world fashion industry is developing towards individuation and comfort. It is generally accepted that the garment must be comfortable and beautiful when they wear it, and they hope that the style, material, color, accessories and other aspects of the garment can embody the personalized characteristics. And then clothing fit has been widely considered to be an important aspect affecting clothing appearance and clothing comfort, and it is even considered to be one of the most important factors affecting clothing sales. In the meantime, the production mode of customer-oriented customization and mass customization for customers can meet people's requirements for personalized and fit clothing. However, the traditional pattern making method has been unable to meet the needs of people. In this context, with the development of 3D human body scanning technology, clothing virtual try-on technologyand other information technology, these technologies are constantly used to improve the quality of pattern blocks, and promote the development of pattern making methods for customization and mass customization [53].

In the development of 3D human body scanning technology to promote the quality of the pattern blocks, for example, the research team lead by Yang Yunchu developed a new method to customize individual pattern block using 3D human body scanning technology and surface flattening technology. Figure 1.1 shows the progress of individual pattern customization by using 3D human body scanning technology.

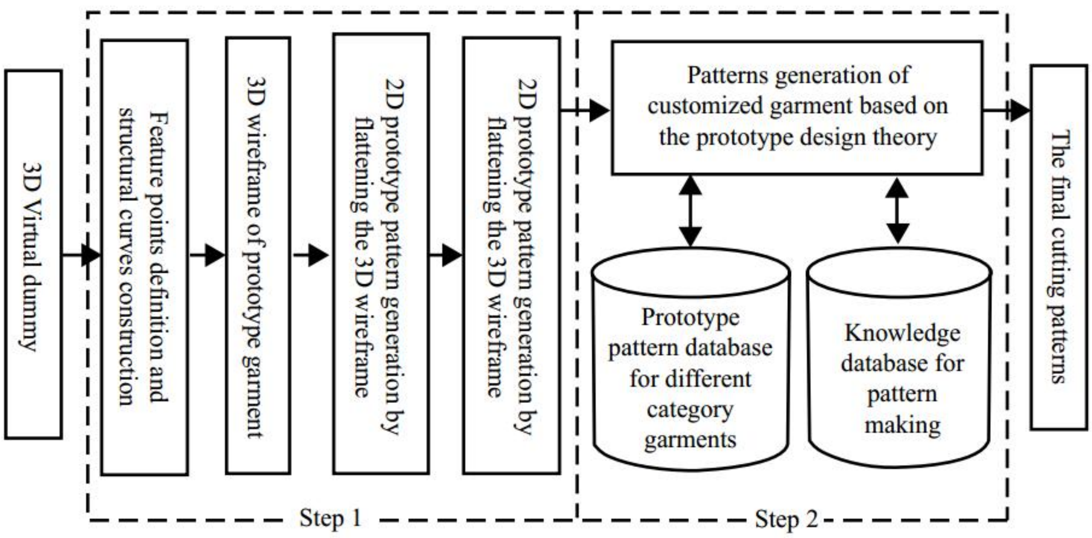


Figure 1.1 - The progress of individual pattern customization by using 3D human body scanning technology [107]

As shown in Figure 1.1, firstly, they created a virtual dummy by scanning a real dress like dummy. Then they constructed a 3D prototype wireframe based on the virtual dummy, and flattening 3D surface of the prototype garment to 2D pattern block. Finally, they obtained the 2D pattern blocks based on the 3D virtual dummy. In the meantime, by comparing the newly created 2D prototype with conventional prototype, they found that the new 2D pattern blocks of prototype are precise and have good quality. Therefore, the new method of customizing individual pattern can help people to create prototype in terms of individual bodies features, and improve the quality of pattern blocks [107].

Kaixuan Liu et al. proposed a new method to optimize and improve the quality of pattern blocks for cycling clothing in terms of the static and dynamic clothing pressure by using virtual try-on technology, as shown in Figure 4. Firstly, they assembled the pattern blocks of cycling clothing together by using virtual try-on technology. Then, they respectively measured the clothing pressures under static and dynamic conditions. And then, they analyzed the difference of static-to-dynamic clothing pressure, and found the correct pattern blocks to modify according the analyzed results. Finally, the pattern blocks of cycling clothing were optimized and the cycling garments were made further. Results indicate that using virtual try-on technology can effectively improve the quality of pattern blocks and also improve dynamic wear comfort significantly [65].

Thus, the technologies of 3D scanning of the human body and virtual fitting can be used to optimize and create pattern blocks of clothes that meet the needs of people.

1.2. Methods of women blouse designing and adapting to bodies features

1.2.1. Pattern making methods

At present, there are two main methods for the structural design of blouse: proportion method and prototype method. In China, both the prototype method and the proportion method are widely used to make clothing pattern blocks. Because the prototype method is easy to use and easy to teach, it is widely used in clothing colleges. The proportion method is fast and convenient, and is used by more pattern-makers in garment factories [44]. Proportion method is also called the method of direct drawing. By controlling the size of the main parts of the human body, and adding appropriate amount of ease according to the style of blouse, and then according to a certain proportion formula to obtain the partial size of the garment. Such as Hu Yue et al. used proportion method. The idea of pattern making is based on the body size measurements firstly, and secondly according to thestyle of blouse by adding an ease to obtain garment size, then the structure chart of the front and back were drawn according to the specificstructural sizes and formula [44].

In the Zhou Bangzhen’s book, the method of structural design for blouse-proportion method is introduced in detail. First of all, through two ways of the measurement of human body or the calculation of proportion of human body, the body value of the important parts of the clothing requirements are obtained. Secondly, by designing the size specification of garment and the size of ease, the sizes of blouse are obtained. Finally, according to the main size specification and the formula of the blouse, the front and back pieces are respectively drawn [121].

The prototype method originated in Japan, is an indirect method of pattern making. Based on adding the length of the basic pattern block, or changing bust girth, waist girth, neck girth of the basic pattern block and another operations, and then stretching, folding. Finally the satisfactory blouse pattern block is made [6].

In the Machiko Miyoshi' book, the method of pattern making for blouse is systematically introduced, among them, the author gives an overview of women blouses and gives a detailed introduction to the concept, materials and classification methods of blouses. And according to the morphological characteristics of the human body, through certain changes to the back length, ease allowance to armhole dart, and ease allowance to back shoulder dart of the Bunka basic bodice pattern, a basic prototype for blouse drafting was made. On this basis, by a series of structural changes such as changing the length of the clothes, and increasing or eliminating ease allowance to armhole dart and ease allowance to waist dart, etc., we can further produce various kinds of women blouse patterns [72].

In the Liu Ruipu's book, the blouse is divided into worn-inside blouse and worn-outside blouse. The basic block pattern of fitting blouse is derived through basic block pattern, and the basic block pattern of X style blouse with three pieces style, X-type blouse with seven pieces style, H style blouse with three pieces style and A style blouse with three pieces style is also derived through basic block pattern, and then the method of pattern making of a style getting much patterns, a pattern getting much styles, much patterns getting much styles are achieved [69].

In the Xiong neng's book, theoretical knowledge and the method of structural design for blouse is systematically introduced. Firstly, through analyzing the structure of women's body to draw the basic block pattern, secondlythe basic block pattern of blouse is derived through the basic block pattern, and then according to the requirement of the basic structure and the ease of the various parts to adjust and amend the basic block pattern of blouse. Finally, the pattern of blouse is made [102].

In the Wu Houling's book, the basic block pattern is divided into the basic block pattern of half-length, the basic block pattern of garment body, the basic block pattern of sleeve, the basic block pattern of skirt and thebasic block pattern of trousers. At the same time, based on the actual measurement size of the human body, the basic pattern specifications of the key parts of the garment are designed according to the specific rule of fashion shape and functional requirements, and the basic block pattern of half-length is divided into the basic block pattern of body-fitting type, the basic block pattern of fitting type, the basic block pattern of loose type, the basic block pattern of loose-bodied type. And this paper explains the steps of using the prototype method to make pattern in details: analyzing the structure of clothing-choosing basic block pattern-making patternof basic block pattern-structural design-drawing outline-adding seam allowances-pattern cutting-making mark-getting a complete pattern [95].

In the Armstrong H.J.'s book of pattern making for fashion design, it introduces the basic pattern of men's blouses and women's blouses in detail on the coordinated distribution principle of each structural part when the dart of side seam changes position and the number of dart is different. And taking the Yoke blouse as an example, based on the basic pattern of men's blouses the design process and method of blouses was described in detail. At the same time, the author in the book also introduces the pattern design and production methods of casual blouses, oversized blouses and peasant blouses. Among them, in the production of casual blouse pattern making, the author uses the basis pattern of women blouse as the basis, through transfer the shoulder darts and rib darts to the armhole part, so as to achieve the effect of increasing the armhole arc, making it more relaxed and comfortable [3].

From the previous literatures, two main structural design methods for drafting blouse pattern blocks - proportion method and prototype method were surveyed. Although both the proportion method and the prototype method can draft the blouse pattern blocks quickly and conveniently, they can only been used to draft the garment pattern that conforms to the standard human body characteristics, but cannot meet the needs of the atypical human body characteristics.

1.2.2. Methods of adapting to bodies features

Although current ready-to-wear (RTW) clothing system can fully meet the needs of people for clothing, this problem is related primarily to an RTW system based on an "average" body and a standard grade between sizes [32]. However, a report from Kurt Salmon Associates showed that 50% of females and 62% of males were dissatisfied with the fit of ready-to-wear clothes. Even bodies with the same measurements may have varying distributions in the front and back, resulting in the need for a differently shaped garment to achieve good fit. At same time, with the improvement of people's living standard, people are not only satisfied with the warmth of clothing, but also pay more attention to the comfort, fit and individuation of clothing. Therefore, the individualized pattern making method is the key to satisfy the mass customization garment production mode. The pattern design must be based on the real body features, and the fit of the garment depends on the detail and quality of the generated pattern blocks [5]. The individualized patterns could not only meet the body feature well, but also beautify the human body. Women blouse were the necessary clothes during the work and social environments, and the fit of the suits could directly affect the appearances of the wearers [2]. Therefore, pattern design for women blouse should be implemented adapting to the human body features.

To achieve individually-fitted products for different consumers adapting to the human body characteristics, three-dimensional human body scanning technology, garment virtual try-on technology, automatic, intelligent clothing pattern block generation technology and other information technology are widely used in pattern block design. It greatly promotes the development of pattern making methods adapting to human body characteristics and mass customization.

For instance, the research team lead by Bingfei Gu used body measurements taken from two-dimensional (2D) front and side images of a subject and developed an approach that could automatically generate the customized patterns for women’s suits in 2016. At the same time, this design method fully considers the relationship between human features and each element in the garment prototype, so the pattern block generated by this design method can meet the needs of individuation and comfort [38]. Figure 1.2 shows the relationship between pattern blocks and body features.

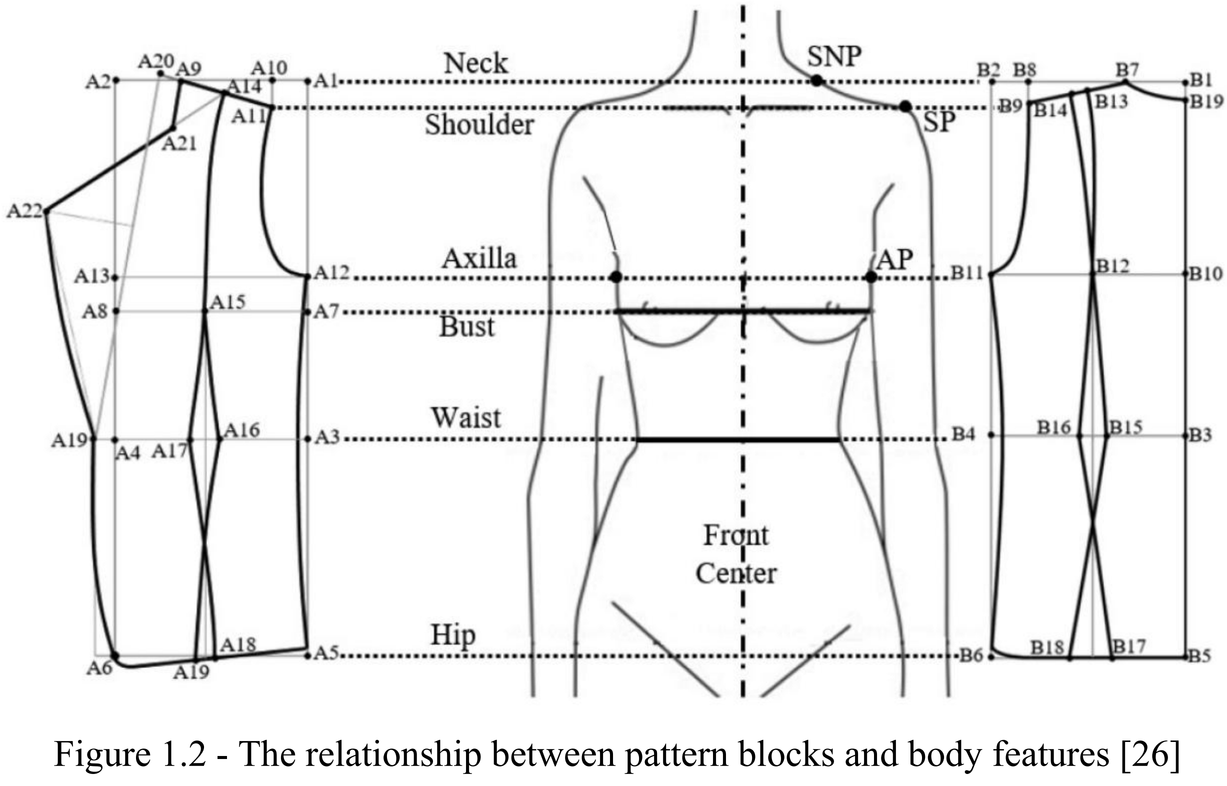


Figure 1.2 - The relationship between pattern blocks and body features [26]

As shown in Figure 1.2, Bingfei Gu et al. proposed an approach to calculate the pattern dimensions according to the body measurements from 3D point-cloud images, and to generate individually customized patterns for women's suits automatically. The feature data of female upper body were obtained from female body to establish the height rules and girth rules, and then the necessary height and girth measurements could be predicted for pattern generation. The experiment also demonstrated that the customized suit using this method could fit the subject's body well at each characteristic landmark (i.e. shoulder, bust and armhole). Since this pattern-making method is originated from the relationship between the features of a human body and the elements of a pattern prototype, the generated patterns are individualized by unique body shapes to attain a good fit [39].

Yang Yunchu et al. created a new method to generate prototype pattern based on individual three-dimensional (3D) virtual dummy for further study on apparel customization. In this research, the process of customizing individual pattern was separated into two steps: the mapping process from 3D body model to 2D prototype and the altering process from prototype to the final cutting patterns [107].

Cynthia, L.Istook outlined the activities involved in setting up CAD systems to automatically customize garments for fit, and explored the technologies that enable the customized fit of previously created garment designs [24].

Youngsook Cho et al. developed an interactive 3D body model suitable for pattern making. And they presented a cross-sectional line method for body model construction. Also they assigned each SCL which can be altered independently for suitable to accurately real body shapes. Established interactive body model system enables easy and accurate model adjustments. Moreover, from result of investigation of the adaptability and potential usefulness of the virtual body model, there was over93 percent agreement ratio between the cross section areas and perimeters. It is capable for customers during the buying process to not only modify the body model to match their own body shape, using this system on the internet or catalogs, but also for apparel manufactures to communicate with their customers by describing the body model to fit on the screen while in the ordering process [112].

H.Q. Huang et al. created a method for generating2D block patterns from 3D scanned body. A parameterization process is first conducted on a scanned body to create a parameterized model, represented by horizontal B-spline curves. A basic wire-frame aligned with body features is then established based on the parameterized model. Proper clothing ease is carefully incorporated into the model by scaling the wireframe to accomplish the desired fit. Based on the deformed wireframe, a 3D flattenable garment is modeled by boundary triangulation. The main contribution of the proposed method is that the created 3D garment blocks are geometrically flattenable to produce accurate 2D patterns with optimized ease distribution to ensure garment fit. The proposed method is validated and compared to two conventional block pattern-making methods. The experimental results indicate that the proposed method is easy to implement and can generate patterns with satisfactory fit. Furthermore, the method can be used to create fit-ensured mass-customized apparel product [46].

Choong Hyo Kim et al. proposed a 3D pattern generation method, which is an innovative method by which optimum-fitting patterns can be obtained easily without trial-and-error-based traditional grading methods. And they developed an automatic pattern generation system. With this method, a surface model with a regular mesh structure could be generated, and its topological information could be used for efficient flat-pattern development. In this method, changes made on the garment model such as dart insertion are instantaneously reflected on the resulting patterns, so designers can make customer-oriented MTM garments easily [15].

Yunchu Yang developed an individual prototype garment pattern based on3D body scanning data.In this study, each cross-section of body scan data was re-sampled to ensure the same common topological structure. A dress-like virtual dummy were employed to create and the corresponding feature lines were defined on the models through calculating the intersection curves of the body surface and local planes. The 3D models were subdivided using different cutting methods and the advancing front triangulation method. Corresponding 2D prototype patterns were generated using the surface flattening method based on the energy model.The area error and length error between the 3D surface and 2D pattern were analyzed. Finally, the prototype garment pattern developed in the paper will be applied in future research to customise the pattern of other garment styles through the 2Dpattern design system [108].

On the basis of analyzing and comparing Donghua prototype, proportional method and three-dimensional cut-out method, Ning guanhua proposed a new pattern design method-mapping method based on human body shape features. They carried on the detailed research and analysis to the position of human body features and the generation of the human body curve, and established the parametric relation model of the female blouse based on the human body features. In addition, they studied and analyzed the automatic generation rule of blouse pattern block, and further established the automatic generating rule of blouse pattern block. Finally, based on the establishment of automatic generation rules, the customization development of automatic generation system was completed by using C programming language. The validity of the parametric relationship model of blouse pattern block based on body features was verified by sample fitting and evaluation of the amount of void space for automatically generated pattern blocks [77].

In conclusion, although the proportion method and the prototype method can quickly and conveniently make the pattern blocks of garment that conforms to the conventional human body size, it can not comprehensively characterize human body characteristics very well. With the three-dimensional human body scanning technology, garment virtual try-on technology, automatic, intelligent clothing pattern block generation technology and other information technology widely using in pattern-making, it greatly promotes the development of pattern making methods adapting to human body characteristics and mass customization.

1.3. Evaluation of clothing fit and methods of its achieving

1.3.1. Evaluation of clothing fit

Nowadays, under the condition of industrial mass production of clothes, ready to wear clothes are more likely to adopt the garment size series to meet people's requirements for the suitability and comfort of clothes. However, the clothing size of garment industry is derived from human body size, but it is not equivalent to specific and personalized body size. At the same time, it is very difficult for people to find the true fit clothing in many kinds of clothing size on the market [47]. The evaluation of clothing fit can only provide a technical reference for consumers to select clothing with good fit, and the result of clothing fit evaluation can directly affect the design, processing and specification determination of clothing and other production links [28]. Therefore, the study for evaluation of clothing fit has important research value and wide application prospect for garment industry.

Chin-Man Chen defined clothing fit as the relationship between the size and contour of the garment and those of the human body. He thought that the clothing fit depends on four aspects: ease, line, balance, and folds. Ease is the dimensional difference between the garment and the individual wearing the garment, so that it is the first criteria to evaluate clothing fit. The second criteria is the lines that form the pattern block. After a well-fitting pattern block being made into a garment, the side seams, the front and back midline of the garment should present vertical perpendicular to the floor and parallel to the body center when it is worn on the human body. The third criteria is balance, and the structure balance of garment is an important part of the quality evaluation system of clothing fit, which is defined that after wearing, the front and back garment can keep fit and smooth, and there are no wrinkles on the surface of the garment. The last criteria is folds, which refers to if the presence of folds on garments [7].

Xu Yi-chao believed that the fit information of clothing is perceived through the sense of vision and touch. The evaluation of clothing fit is a complicated process, which relates to whether the human body and clothing meet a series of requirements [104]. The research lead by Erwin M summed up the requirements of clothing fit into five points: comfort, line sense, roughness, balance and fixation [33]. Nowadays, Cheng Xiaoling thought that the evaluation methods of clothing fit are divided into two categories: one is subjective evaluation method based on clothing fit, the other is objective evaluation method based on physical fit of clothing itself [11].

In this section, the importance of clothing fit evaluation, the method of clothing fit evaluation and the evaluation criteria of clothing fit were surveyed.

1.3.2. Subjective evaluation method of clothing fit

Subjective evaluation method refers to the evaluation method that the person or others will judge whether the clothing looks fit or not after wearing the clothes. When conducting subjective evaluation of clothing fit, clothing experts or observers who have received certain training will be organized to carry out subjective evaluation. And the expert meeting method, the expert investigation method, etc. are used to evaluate clothing fit. At the same time, the expert evaluation results are summarized and analyzed, and the final evaluation results are obtained [55]. However, Chen Xiaoling and others thought that the cognitive and psychological characteristics of the evaluation subject, the scale adopted and the difference of the evaluation methods all will affect the correctness and reliability of the evaluation results [12].

According to the different clothing types, Marina Alexander selected the corresponding body parts as the rating factors to evaluate the fit of clothing. For example, when evaluating the fit of trousers, they selected the waist, hip, abdomen, crotch length, thigh length, hip girth and other control parts as evaluation factors. They also divided the degree of fit into three grades: fit, basic fit and misfit. The fit degree of different parts of clothing were evaluated by the way of visual measurement, and the evaluation results were statistically analyzed by chi-square statistical method. Finally, the fit degree of clothing in the key parts of the body were analyzed synthetically, and the final evaluation results of clothing fit for different body types were obtained. However, due to the inevitable human factors, the evaluation results were not accurate enough [73].

Dai Wei et al. studied the fuzzy mathematics method for evaluating the fit of clothing bodice by quantifying the fit of clothing as a fuzzy concept. They regarded the ease amount of clothing as an important factor to affect the fit of clothing, and obtained the theoretical value of the degree of membership for fit corresponding to different ease allowance. At the same time, they classified the clothing types as fitted, semi-fitted, semi-loose fitted, loose fitted. And then the range of membership degree of fit for the four clothing types was obtained respectively. They also used Delphi method, expert survey method to modify membership function, and obtained function expression of membership degree of fit with ease allowance as the study object [26].

Dong Xiaoying et al. have studied the pattern block making method of jacket-type vocational smock based on the features of body shape. Then they used the new pattern block making method to make three jacket-type vocational smock samples with different ease allowance. The subjective evaluation method of clothing fit was used to evaluate the fit of three samples. They divided the subjective evaluation experiment into two aspects: one is the fitting evaluation of the sample clothes from the aspect of clothing comfort according to their own wearing feeling. The other part is that according to the effect of the wearer, the expert group evaluated the fit of the sample from the aspect of the beauty of the sample. At the same time, the authors also gave different evaluation indexes based on different subjective evaluation experiments. Among them, according to the wearing effect, the subjective evaluation indexes of the wearer were divided into five evaluation grades: very tight, slightly tight, fit, slightly loose and very loose. The subjective evaluation indexes of the expert group were also divided into five evaluation grades according to the wearing effect from good to bad. The optimum ease allowance of jacket-type vocational smock were obtained through the evaluation experiments on the compatibility of the sample garments, and a new method was provided for making pattern blocks of jacket-type vocational smock at the same time [29].

From the above literatures, a preliminary cognition about subjective evaluation method of clothing fit could be reached: the subjective evaluation method of clothing fit is mainly to evaluate the clothing fit based on the appearance of the garment and the feelings of the wearer. However, the evaluation subject, the scale adopted and the difference of the evaluation methods that will affect the accuracy and reliability of the subjective evaluation results should be comprehensively considered.

1.3.3. Objective evaluation method of clothing fit

Objective evaluation method refers to the use of image processing, mathematical modeling and other objective methods to evaluate the fit of clothing. Although objective evaluation methods are more reliable than subjective ones, objective evaluation methods are relatively more complex. And the standard of clothing fit has always been a complex and controversial topic. Nowadays, there are five kinds of objective evaluation methods for clothing fit: 3D anthropometry, mathematical analysis, waveform evaluation, pressure evaluation and computer simulation evaluation [80]. Because this research mainly studies the virtual try-on technology, this paper mainly introduces two evaluation methods: the method of three-dimensional anthropometry and the method of virtual try-on technology.

（1） The method of three-dimensional anthropometry

3D body scanner is widely used in the research of clothing fit evaluation because of its advantages of short scanning time, lots of measuring positions and high measuring accuracy [85]. In the meantime, we also can create 3D virtual body model by using 3D body scanning system [71]. And according to the requirements of scientific research and garment production, the 3D virtual body model can be divided into different parts at any time, as shown in Figure 1.3. On the basis of the measurement results, the relationship between clothing and human body can be analyzed, so as to evaluate the fit and comfort of clothing, as shown in Figure 1.4.

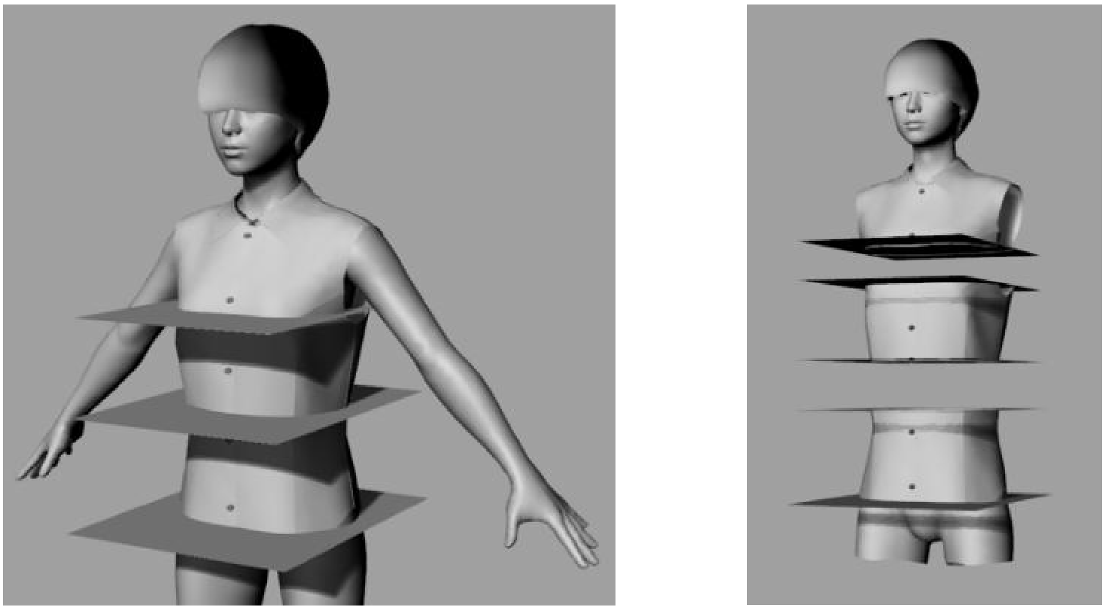
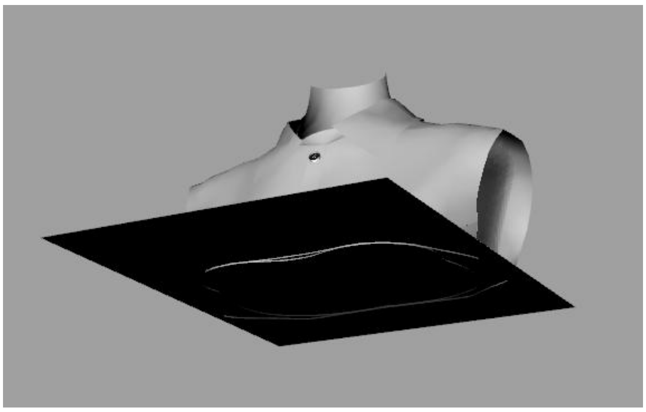


Figure 1.3 - The scheme of dividing the 3D virtual model into three parts in terms of bust line, waist line and hip line



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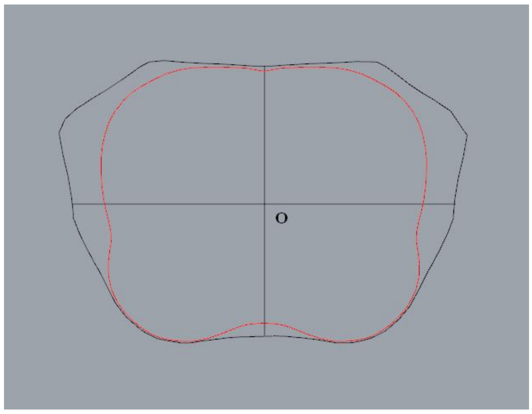

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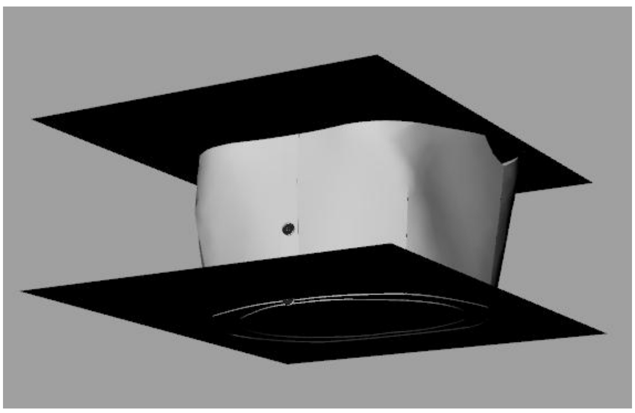

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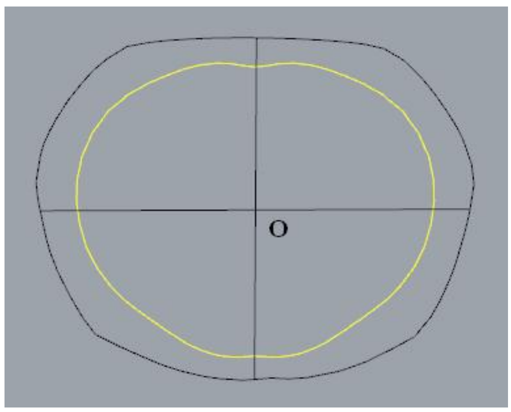

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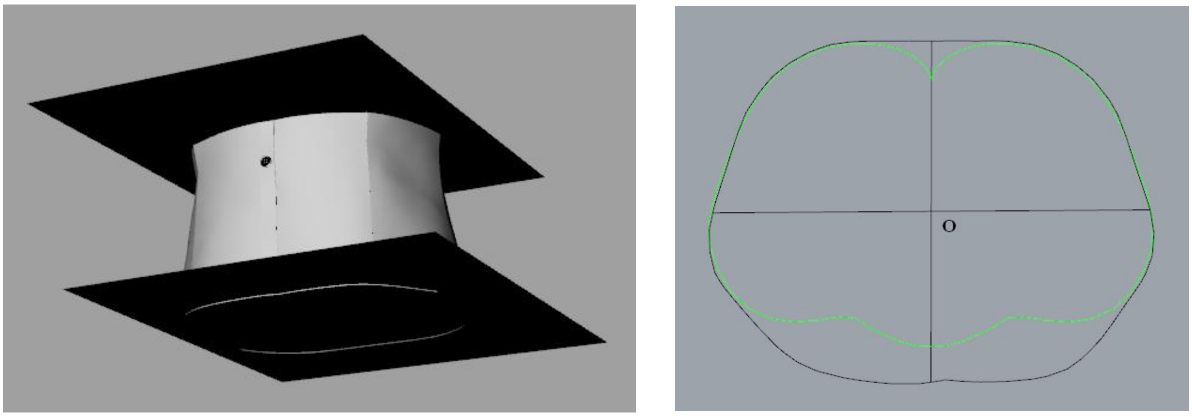


e f

Figure 1.4 - The scheme of analyzing the relationship between clothing and human body in terms of the measurements of human body and clothing: a - section part of upper bust level, b - cross-section lines of bust girth of human body and clothing, c - section part of upper waist level, d - cross-section lines of waist girth of human body and clothing, e - section part of upper hip level, f - cross-section lines of hip girth of human body and clothing

Figure 1.3 shows that by using Rhino 3D software, the scanning body was cut into three sections in terms of bust line, waist line and hip line, then the circumference and length on the obtained sections can be measured [85]. While, Figure 1.4 shows that after dividing the 3D virtual model into three parts in terms of bust line, waist line and hip line, the cross-section of the three parts and corresponding cross-section curve were obtained respectively, then the relationship between clothing and human body can be analyzed effectively in terms of the measurements of human body and clothing.

Nowadays, three-dimensional anthropometry has become the mainstream method to evaluate clothing fit. For example, the research lead by Yehu Lu presented a novel method of systematic exploration on fit analysis of thermal protective clothing using a 3D body scanning technology. At first, they scanned the naked dummy, and then the dressed dummy was scanned with the same posture.Secondly, they used the Rapid form XOR software to process the scanned data, and obtained data that the scanner did not capture, such as the top of the shoulder and head, and the area under the arms, the crotch. Thirdly, they respectively input the naked dummy and the dressed dummy into the Rapid form XOR software to measure, and then they obtained the average air gap and air gap distribution of the fit clothing. The experimental results can help clothing engineers to improve thermal performance and fit of thermal protective clothing [71].

At first, Suzanne Loker used a three-dimensional human scanner to scan participants twice. Once time the participants worn with the scanning suit for capturing the minimally clothed body and the second time they worn with the test pants. And then they got three-dimensional human models of the participants. Secondly, they imported the scanned 3D human models into the Polyworks software for measurement, data processing, and 3D presentation of the measurements. Finally, they used cluster analysis to analyze the measured data, and evaluated the fit of clothing according to the results [90].

Tannie Mah investigated the effect of garment style and fit on thermal performance for women's protective clothing compared to garments designed for men.At first, they scanned the naked mannequin with cylindrical nodules which were placed on the sensor locations using a 3D body scanner, and then the mannequin dressed in the test garments were also scanned. Secondly, they aligned and merged the naked and dressed mannequins, and used the Bersoft Image Measurement Professional software to process the scanned 3D human body models, and then the air gap size at each sensor was measured. At last, according to this method, they studied the differences of air gap sizes between women's and men's thermal protective clothing. The results indicated that the fit of clothing has an important effect on the thermal insulation of female thermal protective clothing [92].

(2) The method of virtual try-on technology

At the same time, because the 3D try-on software can quickly simulate the pressure value of clothing on the human body, and can directly observe the effect of clothing design after simulation. Thus, many research efforts have been taken in the area of evaluation of clothing fit using virtual try-on technology, as shown in Figure 1.5.

For example, in 2016, Kaixuan Liu et al. developed a new method to evaluate the fit of cycling clothing based on clothing pressures. For this purpose, they used the 3D-2D flattening technology to obtain pattern blocks of upper cycling clothing, and the cycling clothing were simulated by using 3D virtual try-on technology. And then the clothing pressure under static and dynamic in the virtual environment were measured to evaluate the upper cycling clothing [66]. In the next year, they proposed a machine-learning-based model to predict garment fit, and they collected digital clothing pressure data by virtual try-on and garment real fit respectively.And then the proposed model can predict garment fit rapidly and automatically without any real try-on in accordance with these collected data [67], as shown in Figure 1.5.

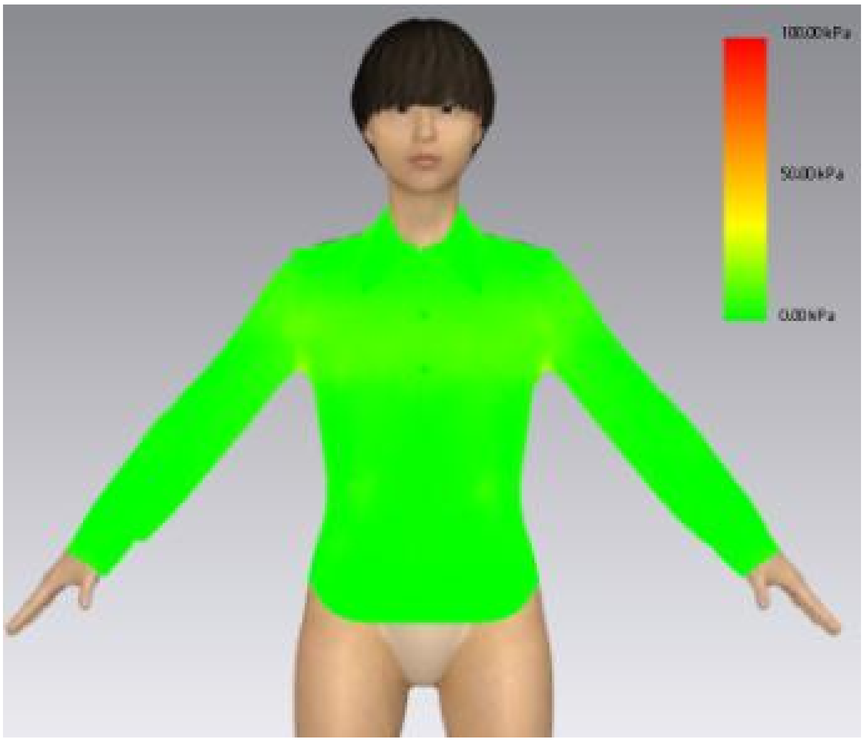


Figure 1.5 - Measurement of clothing pressures for fit analysis after virtual try-on using CLO3D

Figure 1.5 shows that after virtual try-on using CLO3D, using the clothing pressure display function, the distribution of clothing pressure in various parts of the body was shown immediately. Green represents comfortable and unstressed, and the yellow area represents there is a little pressure, but it can be accepted, and the red area represents the area of clothing pressure that is more than the body can withstand, and it is uncomfortable for human body in the area. After that, the comfort of clothing can be predict rapidly and automatically according to the digital pressure data of clothing.

Yueh-Ling Lin proposed a garment fit evaluation method on 3D digital human models using virtual try-on software. The clothing patterns were virtually tried on the six individual3D digital human models. And they compared the appearances of the virtual clothes and the actual shirts in different sizes. And then they conducted subjective fit evaluations of the clothing appearance and the objective quantitative fitting index analysis. The results generate the fitting range to achieve satisfactory fit between real body and virtual model, which can provide useful information in enhancing better garment fitting for human body [62].

Slavenka Petrak et al. analyzed the influence of male body posture and changes in human structure on suit fit by using virtual try-on technology. They respectively 3D scanned the 50 male bodies, and made a statistical analysis of the measurement results. Then, they divided the 50 male bodies into three categories according to their different body positions and body sizes. From these three categories, the most representative human body was selected for clothing simulation in order to evaluate the garment fit. At last, the pattern blocks of suit were adjusted in terms of the simulation results [84].

In this section, according to the previous literatures, the objective evaluation methods of clothing fit were preliminarily recognized, and two objective evaluation methods of clothing fit: three-dimensional anthropometry and virtual try-on technology were investigated in detail. Although the objective evaluation method is more complex, compared with the subjective evaluation method, it can avoid the influence of factors such as the evaluation subject, the difference between the evaluation methods, so that the evaluation results are more reliable.

1.3.4. Methods of improving clothing fit

Clothing, as the second skin of the human being, provides people with protection, comfort and the others [10]. The fit of clothing which is influenced by trends, styles and other factors is considered to be an important element affecting the quality of clothing, and it is the decisive factor to decide whether the customer buys the garment or not [105]. However, under the condition of industrial mass production of clothing, clothing with ready to wear are more to adopt the standard clothing size to meet the people's requirements for the fit and comfort of clothing. At the same time, due to the difference of the specific morphological characteristics of people and the diversity of human body shape, ready to wear clothing has been unable to meet the requirements of clothing fit [81]. With the development of virtual technology, many researchers are committed to using virtual technology to study how to achieve clothing fit and improve the quality of clothing.

For instance, Suzanne Loker et al. described how they evaluates clothing fit by using 3D human body scanning technology, and adjusted ready-to-wear size to improve the fit of clothing according to the evaluation results. They presented a series of static and visual analysis methods based on body dimensions that could be used to analyze human scanning data for target market customers, and determined the important adjustment dimensions of garments. The method increases the percent of acceptable fit within each size category for a target market [90].

In the meantime, we can also use virtual try-on technology to simulate the try-on effect, so that we can observe the fit effect of the clothing in real time and check the correctness of the garment pattern blocks. Then, we can further modify the pattern blocks and improve the clothing fit in terms of checking results, as shown in Figure 1.6.

Figure 1.6 shows that the position of the SNP for the blouse pattern block was first declined to a certain size, and the position of the SP is raised in terms of the size for SNP. After virtual try-on processing, we found that there are several longitudinal folds upper shoulder part, so the angles of shoulder lines of the pattern block do not fit the morphological features of the avatar.

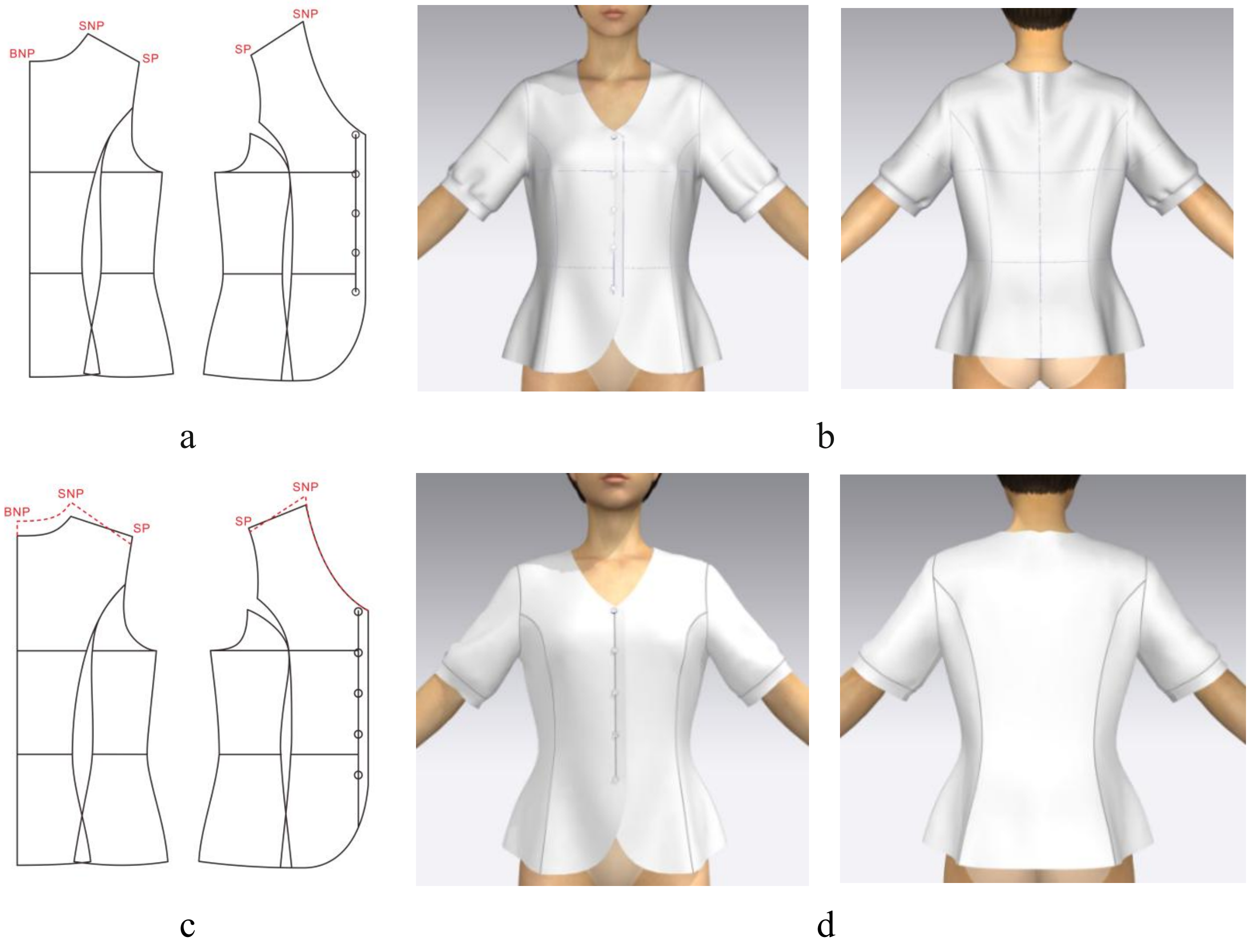


Figure 1.6 - The scheme of checking and modification of pattern blocks using virtual try-on technology: a - pattern blocks of blouse before modification, b - simulation of pattern blocks of blouse with misfit, c - pattern blocks of blouse after modification, d - simulation of pattern blocks of blouse with good fit

According to problems of pattern blocks found before, the angles of shoulder lines of the pattern block were reduced to fit the morphological features of the avatar, and the modified pattern block were further virtually tried on by using the CLO3D virtual fitting software. After the modification, the redundant longitudinal folds on the back shoulder of the blouse have been eliminated, and the shoulder lines of the blouse accords with the morphological features of the avatar. Moreover, there is no excess value in the neck girth, so the accuracy of the plate is very high, which meets the requirements of the human body for garment fit.

Agne Lage et al. studied the distance ease distribution of the dress under different mechanical properties of fabrics by using virtual try-on technology. And then according to the distance ease of each structural part and different fabric properties of textile materials, the garments were adjusted to improve the fit of the garment [1].

Kaixuan Liuet al. proposed a new method to achieve the fit of cycling clothing based on the difference of static-to-dynamic clothing pressure. They respectively measured pressure values of cycling clothing in both the static and dynamic conditions by using virtual try-on technology. And the results of the measurement were analyzed and studied. According to the results of the analysis, the pattern blocks of the front and back pieces, sleeves and collars of the cycling clothing were adjusted respectively in order to achieve the purpose of optimizing the pattern blocks of cycling clothing [65].

The research team lead by Yueh-Ling Lin applied virtual technology to study a new method to evaluate clothing fit, and applied the evaluation results to improve clothing fit. At first, they used virtual try-on technology to simulate the pattern blocks on the avatar. Secondly, they evaluated a fit by visual analysis and measuring the vacant space area between the clothing and avatar.They found the fitting relations between real body and virtual model by analyzing the measured vacant space. Thirdly, they obtained the fitting range to achieve satisfactory clothing fit in terms of the fitting relations. At last, the findings can be used to enhance the clothing fit [62].

In summary, the subjective and objective evaluation of clothing fit can be conducted based on the criteria according to the exterior clothing appearance, pattern blocks, proportionality, etc. in both real and virtual environments. To conduct fit evaluation of clothing, the fit criteria should be established first, and be applied in the whole garment product procedure.

1.4. CAD for clothing design and virtual try-on

The computer aided fashion design (CAD) is the application of traditional CAD theory and technology to clothing design, production, management and other links[105]. It is a comprehensive new and high technology which integrates clothing structure design, computer graphics, database, network communication and so on. The trend of diversified development of garment CAD also makes computer science and technology widely used in garment industry [30].

With the improvement of living standards, people began to pursue personalized clothing design, and want to be able to wear clothes tailored to their own body features and aesthetic needs. According to the data of Zitex & Store—online, among consumers, 77.9 % require fit, 39.1 % require quality, and 37.1 % require individuality [42]. It can be seenthat consumers have higher and higher requirements on the individualization and fit of clothing, and personalized consumption has become a major feature of current marketing.The customization and personalized service of CAD based on the morphological features of customer has become its inevitable development trend.

1.4.1.CAD for clothing design

Nowadays, the functions of 2D garment CAD are mainly focused on two dimensional style design, pattern design, coding, layout, style design and so on, which can not meet the needs of current garment customization. Garment CAD has developed from the current graphic design to three-dimensional design. 3D garment CAD is based on 3D human body measurement. At present, 3D human body measurement system has been commercialized in the world, and its technology has been relatively mature. Generally, the commonly used 3D human body measurement system in the world is non-contact. The lights are captured on the surface of the human body through a photosensitive device. Then, computer image processing is used to describe the three-dimensional features of the human body [49]. Because the 3D human body measurement system has many advantages over traditional measurement technology, such as short measurement time, large amount of data acquisition, etc. [63]. Three-dimensional human body measurement system is widely used in the research and production of clothing customization according to morphological features of customer [78].

Olaru Sabina et al. presented an innovative method to design patterns for atypical bodies. Firstly, they used a three-dimensional human body scanner to measure the bodies with atypical characteristics. Secondly, they analyzed the anthropometric data from the 3D body scanner, and found that many women have different sizes for the two hip contours. Thirdly, this important morphological features of body was applied to the drafting of the pattern blocks of trousers. The method can also be applied to pattern making for human body with other morphological features [78].

Using three-dimensional body measurement data, Choong Hyo Kim et al. Proposed the method of the generation of basic garment pattern.At first, a dummy model was reconstructed using 3D human body data measured. With this method, a surface model with a regular mesh structure could be generated, and its topological information could be efficiently used for flattening pattern blocks. An FFD-based method was used to change the size and shape of the body model to match morphological features of bodies. Finally, the body model was projected into flattening garment pattern blocks incorporating multiple darts. In this method, changes made on the garment model such as dart insertion are instantaneously reflected on the resulting pattern blocks, so designers can make garments in accordance with morphological features of customer [15].

Ei Chaw Hlaing et al. developed reproducible construction of fashionable and functional ladies trousers on the basis of generated scalable 3D virtual female models by using 3D-CAD methods. They predefined the variable parameters and modified the pattern blocks of a trouser by changing the parameters for the variety of trouser models. Two-dimensional pattern block pieces were then automatically generated and modified. According to morphological changes, the whole process proceeds automatically up to 2D patterns and thus corresponds to a grading in 3D. Based on the results of the research, optimal clothing fit corresponding to the different morphological features for the targeted groups is possible [31].

Yang Yunchu et al. presented a new method to generate prototype pattern based on individual three-dimensional virtual dummy for further study on apparel customization in accordance with morphological features of customer. At first, the symmetrized preprocessing and convex hull method were employed to create a dress-like virtual dummy based on 3D body scanning data. The corresponding structure lines of 2D prototype pattern block were defined on the 3D dummy and 3D dummy surface was cut into ten zones. Based on the features of each surface, further subdivision was made in each zone to create 3D wireframe of garment prototype by calculating the intersection curves between the dummy surface and local planners. Pattern blocks of the prototype were obtained by using flattening geometrically 3D wireframe of each part [107].

In terms of male bodies morphology using scanning technology,V. E. Kuzmichev et al. proposed a method of improving an underwear design. At first, they found the main differences between the Russians and the Chinese by using new list of body sizes. They prepared the recommendations how to design the underwear pattern block for the Russians and the Chinese, to choose the structure of underwear with more reasonable and satisfy characteristics in accordance with morphological features of the male body. This research provides detailed and clear approach to describe men's underwear and male bodies' morphology, new way to advance mass production and individual customization with body scanning technology [52].

In conclusion, the 3D human body measurement system are much more capable in body measuring, clothing development and virtual design compared to the 2D-CAD. It brings about many new possibilities in anthropometric work and clothing design, especially for the individual body and customized clothing.

1.4.2.Modern virtual try-on CAD

Virtual try-on CAD is a software tool for the three-dimensional visualization of garments and fabric drape on a 3D human body. Using this technology, users can choose and modify garments, apply fabric properties, andtest various garment-design modifications on a 3D virtual model.

With the progress of science and technology and the need of society, more and more CAD companies have entered the field of virtual try-on CAD: CLO3D and Marvelous Designer (CLO Virtual Fashion Inc., Korea), 3D Vidya (Assyst GmbH, Germany), Modaris 3D Fit (Lectra, France), PDS (Optitex, USA), AccuMark 3D (Geber Technology LLC, USA), ASSOL (Russia), Vstitcher (Browzwear Solutions Pte Ltd., Singapore), TUKA 3D (Tukatech Inc., USA) etc.[14, 55, 97]. These software are featured at realizing the 3D virtual avatar, 3D fashion design, 3D pattern drafting, 3D sewing and 3D virtual try-on, etc..

Nowadays, virtual try-on CAD are increasingly used by apparel companies to reduce cost and time constraints in the product development process. Considering the fact that ready-to-wear clothing may not fit all companies' target market body shapes and sizes. Therefore, many researchers are working on how to use virtual try-on CAD to make clothing more suitable for morphological features of customers.

For example, the research team lead by Yan Hong developed a novel method using virtual try-on software to design customized garments for physically disabled people with scoliosis. At first, the virtual human model which can be simulated the consumer's morphological features with atypical physical deformations was created using 3D body scanner. Secondly, customized 2D and 3D virtual garment prototyping tools were used to create products through interactions using fashion design and garment pattern design knowledge. And both the morphological features of the disabled people with scoliosis and the relationship between human body and garment are applied as the main principles in the prototyping process. Thirdly, the proposed method was validated by the comparison experiments with current design solutions for designing personalized garment products for physically disabled peoplewith scoliosis. And the results indicated that the new method can solve the problem of customized design for disabled people with scoliosis [43].

Olaru Sabina et al. proposed and developed an innovative method to make pattern blocks for atypical bodies by using virtual try-on software. In this research, they selected the bodies with atypical characteristics from the database resulting from 3D body scanning. And based on these morphological features of body, the pattern blocks of trousers have been developed and applied by using 3D virtual try-on CAD. This paper brings contributions to clothing pattern making technology by 3D virtual try-on, taking into account morphological features of the users [78].

In summary, the modern virtual try-on CAD for clothing design provides much higher convenient and more possibilities owing to the versatile functions than the traditional 2D CAD.

1.5. Advantages of virtual technologies and its application

1.5.1.Advantages of virtual technologies

The application of virtual technology in garment industry began in 1980s. It is a 3D garment virtual technology based on virtual reality and digital simulation technology, which is inspired by the process of traditional pattern block drafting methods and clothing sample production [47]. 3D virtual try-on technology is not only different from multimedia technology, but also different from traditional hand-drawn clothing design. On the one hand, in 3D virtual try-on software, garment designer can use 3D virtual try-on technology to dress the designed garment on 3D virtual human body, and make a 360-degree omnidirectional observation of design style [28], as shown in Figure 1.7.

Figure 1.7 - Example of 360-degree virtual clothing display by using CLO3D

Figure 1.7 shows that after virtual try-on by using CLO3D, through the observation of various angles, designers, customers, sales personnel, technical personnel, etc. can evaluate the shortcomings of the design in a more comprehensive way, and make changes to 3D virtual clothing in time to achieve better garment design results. Based on CLO3D, different female avatar poses can be selected to display the clothes designed by 360 degrees, so as to test the fitting effect of avatars in different poses, whether there are unusual folds, whether there are holes, so as to evaluate the fit of clothes.

On the other hand, the designer can modify the size and shape of the 3D garment in real time, and add the design elements such as dart, seams, pleats, zippers, buttons, etc. [75]. It can also change the performance of clothing material to observe and study the section and internal structure of clothing, and then evaluate the feasibility of clothing. At the same time, the designer can also change the three-dimensional clothing fabric properties and patterns. For example, in Mu Shuhua's research on virtual garment design based on CLO3D, taking a dress skirt as an example, they described the flow of virtual garment design based on CLO3D virtual fitting platform in detail. Compared with the traditional fashion design, the virtual clothing design has the advantages of displaying garment design intuitively, convenient modification, low design cost, distinctive design effect and strong stereoscopic effect. The development of 3D virtual try-on technology provides convenience for garment design, can effectively save the cost of garment production, greatly reduce the production cycle of clothing, greatly reduce the risk of enterprises, and thus improve the competitive advantage of garment enterprises [75].

1.5.2.The application of virtual technologies

The application of 3D virtual try-on technology in the field of clothing mainly includes clothing design, reconstruction of historical clothing, clothing structure design, clothing comfort.

In the field of clothing design, designers can combine the design process with the clothing display based on 3D virtual try-on technology, so as to optimize the designer's design process and improve the clothing design effect.Yao Tong et al. based on CLO3D virtual try-on platform combines the traditional Chinese architectural design elements with 3D virtual try-on technology to design the virtual clothing with Chinese national characteristics. The researchers extracted architectural elements as the main elements in the design of clothing styles and structures. In the aspect of pattern, the traditional Chinese folk-custom patterns are summarized and extracted, and applied to the virtual clothing design. Finally, virtual stitching was carried out through CLO3D. At the same time, the rationality of garment pattern blocks were checked by viewing the overall effect of virtual clothing on 3D human body in the virtual window, and relevant modification and adjustment were carried out in real time. At last, a series of Chinese national characteristics, reasonable clothing was designed [109].

Using DCsuite virtual fitting software, Feng Jiaomei et al. explored the real performance of Chinese frog element in the virtual design of cheongsam. By adopting the comparative research method, they found a more convenient and effective virtual method which can be displayed different styles of cheongsam more realistically. Through the research, the style applicability of 3D virtual fitting field was improved, and the traditional Chinese cheongsam was effectively combined with 3D virtual fitting technology [34].

With the popularity of retro style, modern fashion designer all like to draw inspiration from the historical costumes, pursue retro style. By combining the contemporary design concept with the historical fashion style of a certain period, the modern retro style clothing with full sense of the times and fashion has been designed. At the same time, the reconstruction and styling of historical clothing has always been an important research topic for researchers at home and abroad [45]. The development of 3D virtual try-on technology provides a new research idea for the reconstruction and styling of historical clothing.

For example, in 2013, Yeonkyung Kang et al. who come from Seoul University in South Korea reconstructed the historical clothing of the 18th century rococo style, based on DC suite software as the virtual try-on platform. At first, they respectively created a male and a female virtual body by using Maya software. Then, the pattern blocks of two pieces of men's and women's clothes of the 18th century rococo style were generated using DC suite software. At then, two virtual bodies created by Maya software were imported in DC suite software, and two clothes of the 18th century rococo style were respectively tried on the virtual bodies. Thus, the 3D garment modeling of historical clothing was completed. At last, the 3D virtual historical clothing was presented in the online museum, which confirms the feasibility of 3D virtual fitting technology to reconstruct the historical clothing[110]. In the same year, Kathi Martin et al. who came from Drexel University in USA, used DC suite 3D virtual try-on software to reconstruct 25 sets of historical clothing in Europe in the 1930s. And they displayed these 3D historical costumes on the DHCC Museum website. This new and interactive experience enhances the experience of clothing exhibition in the museum[48].

In 2016, Victor Kuzmichev et al. used CLO3D software as a virtual fitting platform to study the reconstruction of 19th-century men's trousers. They analyzed and studied the reconstruction of trousers, the size of the human body and the method of pattern block making for historical men's trousers. Through the parameterization of historical men's trousers, the universal trousers pattern cutting algorithm was obtained. Using 3D virtual fitting technology to analyze the difference between the historical men's trousers chosen as prototype in the 19th century and the reconstructed 3D model of men's trousers, on the basis of which, the pattern blocks of historical men's trousers were further optimized [51].

Based methods of reconstruction in virtual reality, Aleksei Moskvin at al. proposed a method for generating numerical replicas of skirts of the late 1850s and the1860s. By applied 2D and 3D software, all the elements of the skirts were parameterized. A replica of a historical costume was generated and the similarity between the historical prototype and its replica was proved. Applying virtual fitting technology to reconstruct the visible and invisible elements of historical clothing can promote the scientific research of historical clothing [74].

With the development of virtual try-on software, virtual try-on technology can not only be used to create 3D virtual garment model, but also can be used to simulate mechanical behaviour of textile materials and clothing pressures, and on this basis of which, we can further study garment pattern block making.For instance, Agne Lage presented a method of investigating distance ease distribution between straight shape virtual dress and 3D body in respect to fabrics mechanical properties using virtual try-on software. They investigated the distance ease distribution as well as the values of simulated 3D garment at bust girth. And they verified that the distance ease in 3D garment was lower than ease allowance used for 2D basic construction [1].

Dong has studied the application of virtual try-on technology in pattern making method of collar, sleeve and pleated based on CLO3D virtual try-on platform. The author concluded that virtual try-on technology can simplify the process of garment pattern making, and help pattern-makers to carry out rapid garment pattern block design according to the human body features [28].

Lin studied pattern block making method of dress by using three-dimensional virtual try-on software. She proved the feasibility of using virtual try-on technology to study the pattern block making of dress by comparing the fitting effect of the real clothes with the virtual fitting effect [62].

Slavenka Petrak et al. studied the impact of body posture and the presence of functional and structural body changes on garment fit by using 3D garment simulation. They selected three body models with different body dimensions and physiological spine curvature and imported three body models into a virtual try-on system for garment simulation. Using virtual try-on technology, they respectively simulated the suit pattern block on the three virtual bodies, and altered the three suits pattern blocks according to the virtual fitting effect, so they could get the adjustment method of the suit pattern blocks according to the features of the individual human body. This new method can significantly meet people's requirements for personalized and comfortable clothing [84].

Kaixuan Liu proposed a new method to optimize cycling clothes' patterns based on the difference of static-to-dynamic clothing pressure using virtual try-on technology. According to the static and dynamic postures of the real human body while riding a bicycle, the postures of the 3D virtual model were adjusted, and the virtual bicycle clothing was simulated on the 3D virtual model. And then they obtained garment pressures in both static and dynamic conditions. They then analyzed static-to-dynamic clothing pressure value and adjusted garment pattern blocks according to the analyzed results [65].

In conclusion, the contemporary virtual technology for the field of clothing provides higher productivity and more possibilities owing to the exceptional advantages. By using virtual technologies, in the 3Dvirtual try-on software, using each module in the 3D virtual try-on software, after a series of simple operations, the realistic try-on effect can be immediately displayed without real sample trials.

1.6. Aims and steps of the research

Nowadays, the accuracy of pattern block is widely regarded as an important way to influence the appearance and the comfort of clothing.The clothes made with reasonable pattern blocks can not only be comfortable to wear, but also achieve the effect of modifying human body.through investigation and discovery, the pattern-maker of the factory often determine the data of bust width, back width and back length etc. according to experience and personal drafting methods. The compatibility of size has a great randomness and discreteness. Therefore, its appearance effect of clothing sometimes fails to reach the expected purpose.

At the same time, there are many manuals of sewing pattern blocks making and some of them aren't good for the customization in virtual reality (VR). Well-known methods of virtual try-on technologies are CLO3D, Marvelous Designer, Optitex, DC Suite, etc. which are showing own structural problems related to misfit, unreasonable distribution of ease allowance of pattern blocks, etc.. The fact is that the search for such analogs on the surface of body and drawings of details of model designs of clothing, combined in a single "body - clothing" system with a complex distribution of air gaps, is a very serious and multivariate scientific and practical task. Due to its lack of resolution in virtual clothing models, there is a leveling of fit defects, an undesigned distribution of increments, and other phenomena that lead to significant differences between virtual and material prototypes.

These situations make it necessary to study and predict the causes of defects, especially when there are obvious differences between real clothes and their analogues in VR. Often, a virtual fitting does not allow to identify all design errors in drawings, especially those that are responsible for the occurrence of pattern blocks defects, for a number of reasons: insufficient training samples formed in virtual reality programs; the absence of formalized dependencies between morphological features and techniques for modifying pattern blocks. Therefore, to improve virtual simulation and obtain realistic-looking clothing renders, it is necessary to develop an algorithm for qualimetry of structural drawings and determine the numerical values of the criteria.

Therefore, the aim of research is to develop scenario technology for customized virtual women blouse.

To get this aim, the next steps should be done following the flowchart of this research, as shown in Figure 1.8.

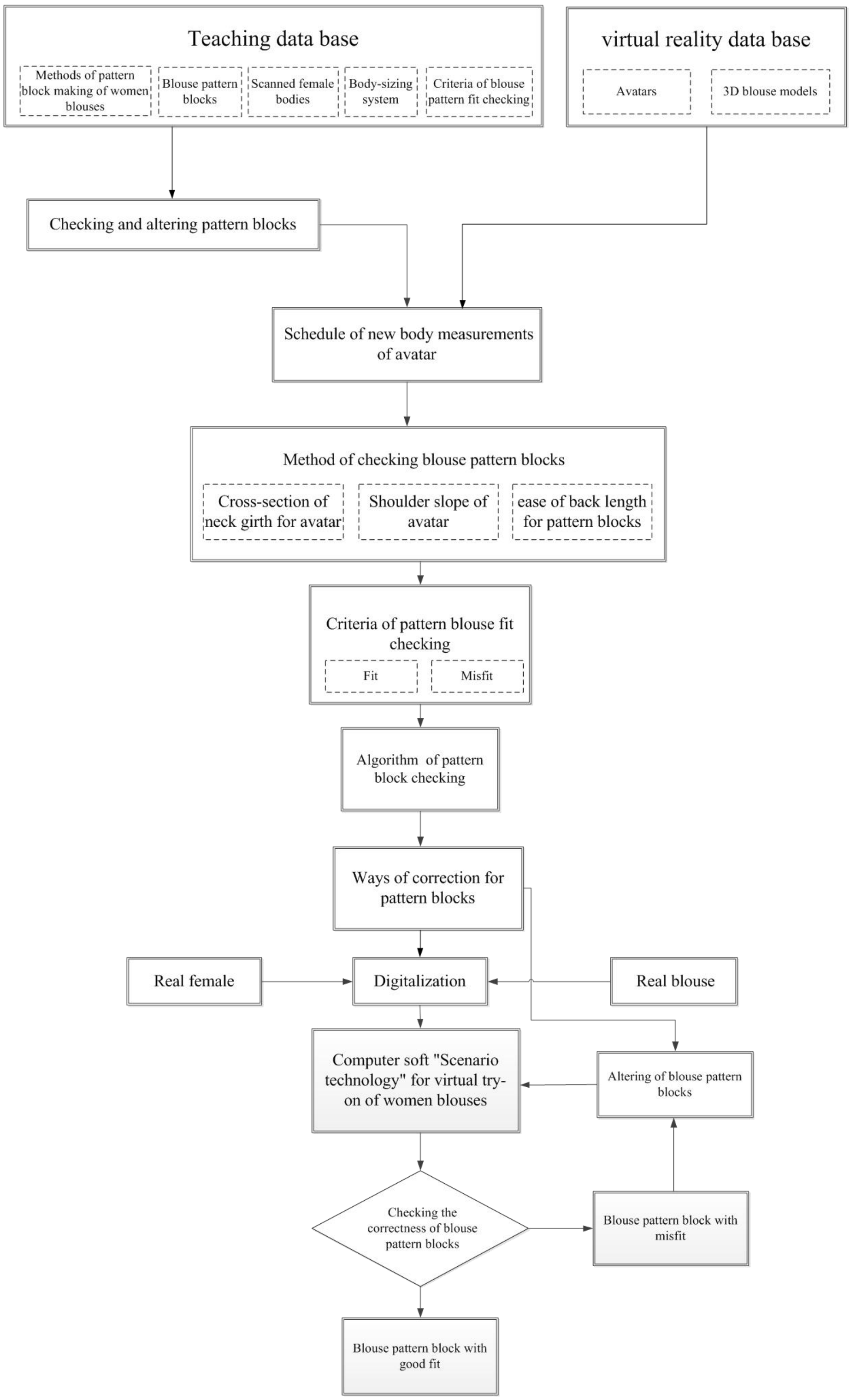


Figure 1.8 - The flowchart of predicting of quality of pattern blocks

1. The database of design parameters of pattern blocks of women's blouses with different silhouettes should be established. According to clothing silhouette, sewing patterns of women blouse should be first grouped. The control range of design variables for blouse pattern blocks with different style should be also obtained. And based on mathematical processing of pattern blocks for women's blouses with different silhouettes and degree of fit, the mathematical models of blouse pattern blocks with different style will be established, and blouse pattern blocks will be parameterized respectively.

2. 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 should be conducted. Digital twin of real body will be first made by CLO3D and imported into Rhinos software to measure key-measurements which can influence on garment fit. And digital twin will be parameterized by means of corresponding body measurements which can be used in parallel for the patterns analyzing.

3. The adequate amount of female respondents will be enrolled for the 3D body scanning and their scanning data will be saved. The scanning body will be transformed into 3D wireframe of body-surface prototype, and the body measurements which can be used to describe the features of female morphology will be measured.

4. The 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 should be developed.

5. The method for parametrizing the pattern blocks based on flattened sweeps of the surface of the torso of a women body will be developed. By means of 3D CLO software, the surfaces of 3D avatar will be flattened into 2D garment patterns with zero eases. An algorithm for overlapping blouse pattern block and the surfaces of 3D avatar will be developed. The range of ease allowance of blouse pattern blocks will be measured and blouse pattern blocks will be parameterized.

6. The criteria for evaluating the quality of the fit of women's clothing on the digital twin of human body should be developed. By means of virtual technology, an algorithm for checking pattern blocks defects by grey-scale image identification and pattern making, complex exploration about how body type and ease allowances together are influencing on women blouse fit should be developed. And in order to analyze the degree of people's attention to different clothing parts under the condition of clothing fit evaluation, subjective questionnaire evaluation experiment and eye tracking experiment should be conducted respectively.

7. The method for checking and correcting the pattern blocks, taking into account the morphological characteristics of female bodies should be developed. The databases of misfit pictures of women's blouse, digital twins of women blouse and the schedule of defects of women blouse should be first established. Combined with the virtual try-on technology, the women blouse with misfit caused by incorrect pattern blocks will be verified. By integrating the scheme of pattern blocks, images of the digital twins of the blouses, verbal evaluation of the blouses fit, the comprehensive five-level criteria for checking different structural parts of women's blouse will be established. Based on the subjective criteria, the numerical values of the criteria for checking different structural parts of women's blouse will be established further.

8. The testing of developed scenario technology for customizable virtual design of women's blouse will be conducted. The results of this research will be tested in an experimental test by integrating of all the previous experimental results, from the selection of women's blouse style, the checking the pattern blocks, the measuring grayscale of folds, to the correction of pattern blocks.

2. DEVELOPMENT OF INITIAL DATABASES

In this chapter, in accordance with the results of the collection and systematization of patterns, generalization of the principles of designing women's blouses, design variables of blouse patterns were collected. Then the design variables were considered as important variables for constructing mathematical models of patterns of blouses with different silhouettes. The main morphological features of the women body responsible for the construction of patterns and which can be used to effectively achieve a good fit have been comprehensively studied.

This chapter established the pattern block database of women' blouse, and the anthropometric database of women torso with essential morphology and body measurement by using 3D body scanner and the other software.

The results obtained in this chapter are published in three articles [16 - 18].

2.1. Data of blouse pattern blocks

2.1.1. Object of research

Women's blouse is a general term for womens single-layered clothing. An important feature of blouses is the variety of styles, which differ in terms of internal structure and external shape. It can be worn in the spring and autumn inside under the coat or separately in summer. It is not restricted by seasons and is used throughout the year as one of the important types of women's clothing. The women's blouse, as a rule, consists of several components: front piece, back piece, collar, front placket, sleeve, cuff, yoke and the other details. The shape of women's blouse differ in silhouettes. The factors that cause the change of the overall shape of the blouse include constructive additions, purpose, style, and the method of wearing, etc..

2.1.2. Research methods and tools

The blouse patterns were mainly collected by two ways: firstly, from 25 clothing pattern making books, and secondly, from the Internet. In total, 154 blouse patterns were collected for the standard female body 168/84A, and 122 patterns were left for research by excluding duplicate patterns, patterns with incomplete data, having inaccurate structural lines, non-standard specifications and dimensions.

122 blouse patterns were redrawn and corrected by using ETCAD software, which allowed avoiding errors caused by various factors, ensuring the accuracy of patterns and measurements to form an accurate and reliable data base for the experimental process. When redrawing patterns to eliminate differences in design methods in many books and magazines, uniformity of all patterns of blouses was ensured. The ETCAD files were saved according to the silhouette of the clothes, the title of the book, the author, the time of publication and the page numbers in the books.

2.1.3. Classification of blouse pattern blocks

The silhouette of clothing, also known as contour, outline, style, refers to the external contour of the frontal and profile projection of the three-dimensional shape of clothing [44]. In accordance with the outline of English letters, the silhouettes of clothes are divided into A, H, X, T, Y, O, etc. to establish clear communications with consumers. Typical silhouettes of women's blouses are mainly X, H, A, Y and O [19]. In the process of collecting patterns of blouses, it was found that there are more X, H and A styles than T and O styles. To ensure the integrity and efficiency of the data of the generated sample, patterns of blouses of X, H and A styles were selected for the study.

In accordance with the silhouette of the clothing, 122 women's blouse pattern blocks were grouped as follows: X style with a large difference between the bust and waist and an obvious narrowing of the waist; H style with similar widths at the levels of bust, waist and hip girths; A style with relatively narrow shoulders and a wide hem. Each structural part has been subdivided into main components as shown in Figure 2.1.

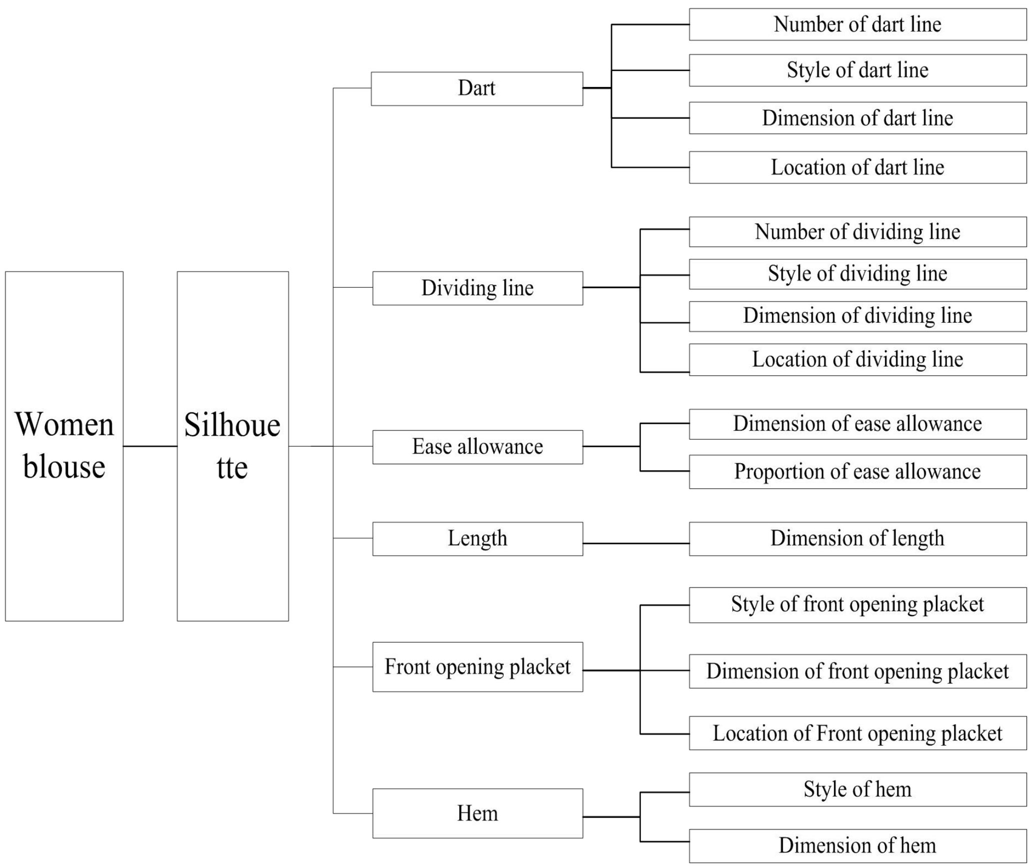


Figure 2.1 - Subdivision of the bodice women blouse

Figure 2.1 shows that the darts can be divided by size, type, location, quantity; the dividing lines can be divided depending on size and style; the ease is divided according to the amount and proportional ratios, and so on. Figure 2.2 shows women's blouses in four different styles due to different number of darts in front.

a b c d

Figure 2.2 - Women's blouse with different number of darts:
a - without darts, b - with two darts, c - with four darts, d - with six darts

Figure 2.2 shows that a women's blouse with a different number of darts in the front can have different silhouettes. Due to the change in the number of darts, the style of the woman's blouse changes. Figure 2.3 shows women's blouses of different styles with different dividing lines in front.

a b c d

Figure 2.3 - Women's blouse with different style of dividing line:
a - with knife back lines, b - with princess lines, c - with sloping dividing lines,
d - with circular dividing lines

Figure 2.3, a shows women's blouses with vertical lines. The vertical dividing line refers to the dividing line: the starting point of the line is at the armhole, and the end point is at the bottom. Figure 2.3, b shows a female blouse of the princess cut, the vertical lines of which run down from the middle of the shoulder line through the points BP.This allows you to sew the two pieces together, making the blouse more form-fitting, but not tight. In Fig. 2.3 c, d shows women's blouses with oblique and circular dividing lines, which not only play a functional role, improving the fit of women's blouses, but also have a certain decorative effect.

Through subdividing the bodice of women blouse, and decompose blouse style into the basic component elements, finally all blouse pattern blocks were classified by organizing these basic component elements in a reasonable range.

2.1.4. Prototype of blouse pattern blocks

2.1.4.1. Analysis of prototypes of blouse pattern blocks

Prototype also called basic pattern blocks, is a basic pattern blocks used in the flat-pattern design process, and a basic pattern blocks must be a simple pattern without any change in style, and fit the formation of human body [72]. As the basis of the structural design of the garment, the prototype has lots of characteristics: versatility, ease of preparation, flexible style change in constructive modeling [102].

The prototypes used in China mainly include the Japanese Bunka prototype, the prototype of Donghua University (Shanghai) and developed by Professor Liu Ruipu from the Beijing Institute of Fashion Technology [72, 119, 69]. By comparing and analyzing the methods of manufacturing patterns and structural principles of these three prototypes, the advantages and disadvantages of these three prototypes were established, the schemes of which are shown in Figure 2.4.

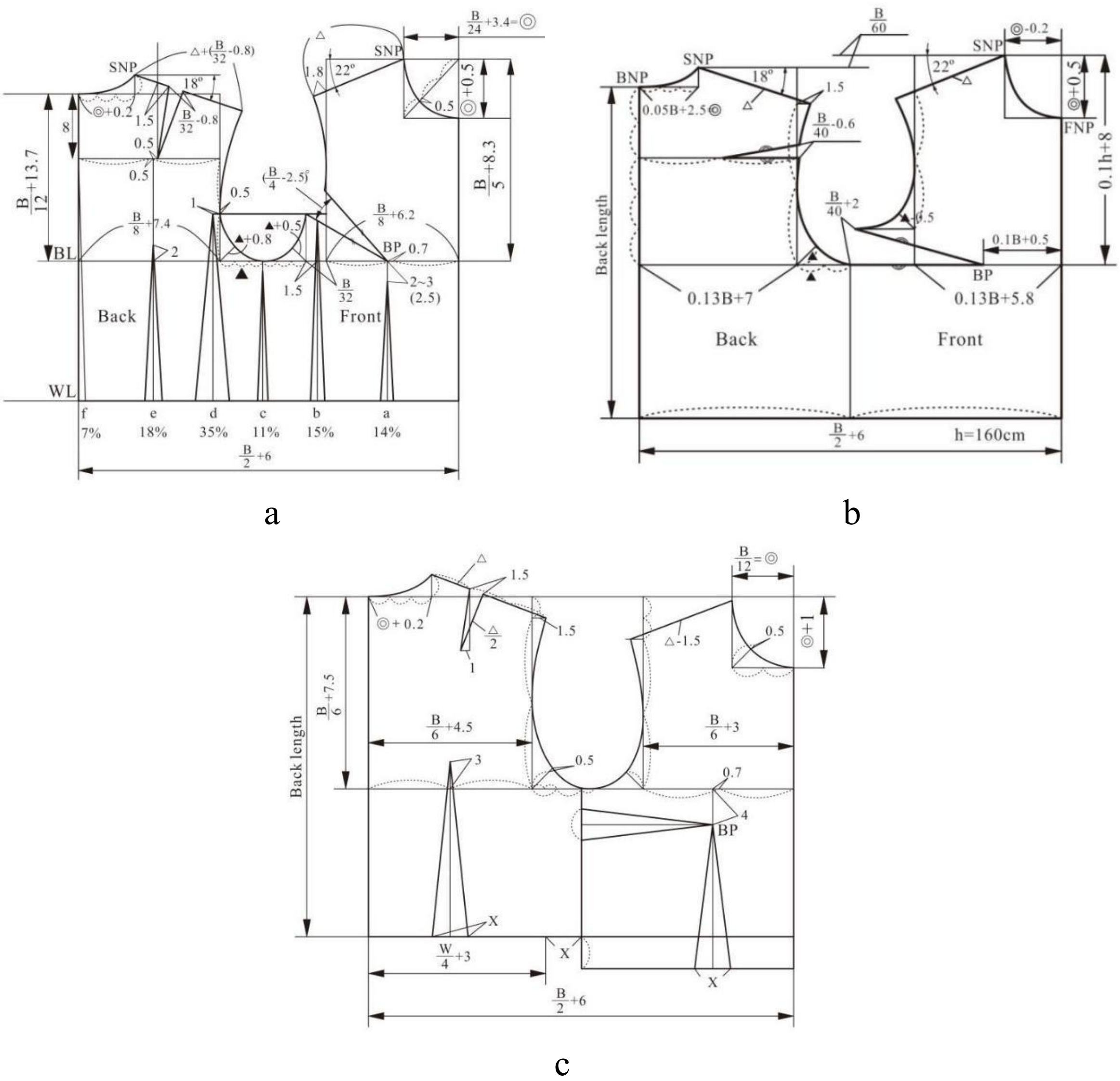


Figure 2.4 - Different upper womenswear prototypes drafting: a - Japanese Bunka prototype, b - Donghua University prototype, c - Liu Ruipu’s basis pattern blocks

Figure 2.4 (a) shows that Japanese Bunka prototype is very fit in the front and the back, and the waist darts are distributed reasonably; the bust and back width is also designed reasonably. The front and back slope of shoulder line accords with the dimensions of human body. The shape of armhole also fits the human body, and the front and back waist line of prototype parallels with the waist line of the body. The prototype has a high fitting degree, which belongs to the body-fitted prototype, and the prototype is more suitable for the production of the fitting garment.

Figure 2.4 (b) shows that the prototype from Donghua University fits the human body, the shape of armhole conforms to the movement law of human body. The front waist line of prototype parallels with the waist line of the body, and the back waist line of prototype slightly hangs down. The prototype is suitable for making loose blouse and fitting blouse.

Figure 2.4 (c) shows that the Liu Ruipu prototype is looser and suitable for a large number of types of clothing. The calculation formulas of the prototype require fewer dimensional features, are simple and easy to operate.

Thus, the Japanese Bunka prototype refers to prototypes that ensure the repetition of the shape of the torso, is based on scientific and rational design of darts to effectively improve the plasticity of female bodies. Compared to loose-fitted clothing, the prototype is more suitable for the production of dresses, cheongsam and other tight-fitting clothing. But the prototype formula is larger, the calculations are more complicated, and the period for creating mathematical modeling is longer. The prototypes of Liu Ruipu and Donghua University are suitable for a large number of types of clothing, including all kinds of voluminous shapes. Compared with the Donghua prototype, the formulas in the Liu Ruipu prototype are simpler and more practical, therefore, in the dissertation work, the basic pattern blocks of Liu Ruipu, which is famous for its efficiency, rationality and convenient operation, were chosen as a prototype for further research.

2.1.4.2. Graphic-mathematical models of prototype for blouse pattern blocks

Through the drawing and analysis of the basis pattern blocks, the calculation formula of the bust girth, waist girth, back length, bust width, back width, the front and back neck width, the front and back neck depth were summed up, as shown in Table 2.1.

Table 2.1 Basic formulas of the prototype of the pattern blocks of Liu Ruipu

Name	Bust line width (half)	Waist line width	The distance between BNP and Bust line	Bust width	Back width	Front neck width	Back neck width
Formula	B/2+6	Front：W/4+3 Back：W/4+3	B/6+7.5	B/6+3	B/6+4.5	B/12	B/12+0.3
The values of the parameter for the prototype, cm	48	20/20	21.5	17	18.5	7	7.3

Pattern is generally expressed by point, line, curve in the two-dimensional flat, and the structure of a straight line and a curve is determined by various points. In the flat, a point A is defined by a pair of coordinates A (x, y). Therefore, at first, the coordinates of the contour of the prototype were summarized. Then calculating the equations of these points coordinates, and the equations of these point coordinates were calculated by the main parts of the body measurements, such as the bust girth (S1), waist girth (S2), and back length (S3). Figure 2.5 shows the coordinate of mathematical model for Liu Ruipu’s prototype.

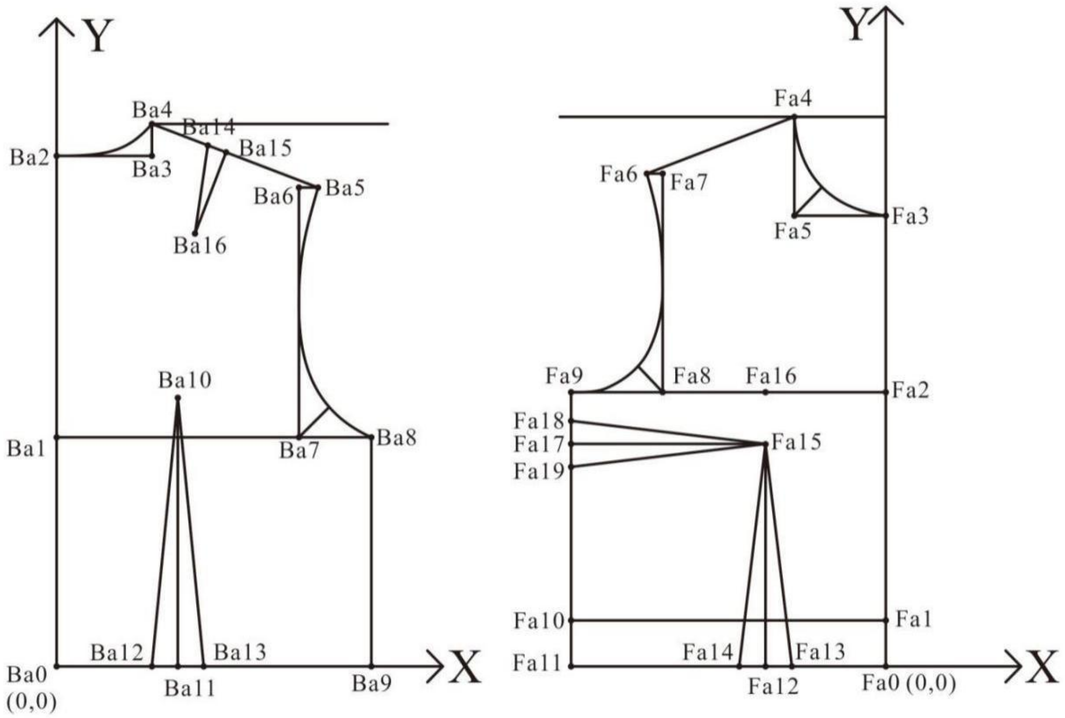


Figure 2.5 - The coordinate of mathematical model for Liu Ruipu's prototype

As shown in Figure 2.5, by treating the intersection of the back center line and the waist line as the back original point of the coordinate Ba0 (0,0), and the intersection of the front center line and the waist line as the front original point Fa0 (0,0), the mathematical model of Liu Ruipu's prototype were developed (detailed information is given in Appendix A), and the mathematical modeling of prototype for blouse were obtained in terms of the equations of points coordinates.

Table 2.2 -Mathematical modeling of back Liu Ruipu's prototype (bust girth: S1, waist girth: S2, back length: S3)

Point	Equations of back point coordinate	
Ba1	Ba1x=0	Ba1y= $S_3 - \frac{S_1}{6} - 7.5$
Ba2	Ba2x=0	Ba2y= S_3

Ba3	Ba3x= $\frac{S_1}{12}+0.3$	Ba3y= S_3
Ba4	Ba4x= $\frac{S_1}{12}+0.3$	Ba4y= $S_3+\frac{S_1}{36}+0.1$
Ba5	Ba5x= $\frac{S_1}{6}+6$	Ba5y= $S_3-\frac{S_1}{36}-0.1$
Ba6	Ba6x= $\frac{S_1}{6}+4.5$	Ba6y= $S_3-\frac{S_1}{36}-0.1$
Ba7	Ba7x= $\frac{S_1}{6}+4.5$	Ba7y= $S_3-\frac{S_1}{6}-7.5$
Ba8	Ba8x= $\frac{S_1}{4}+3$	Ba8y= $S_3-\frac{S_1}{6}-7.5$
Ba9	Ba9x= $\frac{S_1}{4}+3$	Ba9y=0
Ba10	Ba10x= $\frac{S_1}{12}+2.25$	Ba10y= $S_3-\frac{S_1}{6}-4.5$
Ba11	Ba11x= $\frac{S_1}{12}+2.25$	Ba11y=0
Ba12	Ba12x= $\frac{S_2}{8}-\frac{S_1}{24}+2.25$	Ba12y=0
Ba13	Ba13x= $\frac{5}{24}S_1-\frac{S_2}{8}+2.25$	Ba13y=0
Ba14	Ba14x= $\sqrt{\left[\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{3}\right]^2-\left(\frac{S_1}{54}+\frac{1}{15}\right)^2}+\frac{S_1}{12}+0.3$	Ba14y= $S_3+\frac{S_1}{108}+\frac{1}{30}$
Ba15	Ba15x= $\sqrt{\left[\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{3}+1.5\right]^2-\left(\frac{S_1}{54}+\frac{17}{30}\right)^2}+\frac{S_1}{12}+0.3$	Ba15y= $S_3+\frac{S_1}{108}-\frac{7}{15}$
Ba16	Ba16x= $\sqrt{\left[\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{3}\right]^2-\left(\frac{S_1}{54}+\frac{1}{15}\right)^2}+\frac{S_1}{12}-0.7$	Ba16y= $S_3+\frac{S_1}{108}-\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{2}+\frac{1}{30}$

Table 2.3 - Mathematical modeling of front Liu Ruipu's prototype

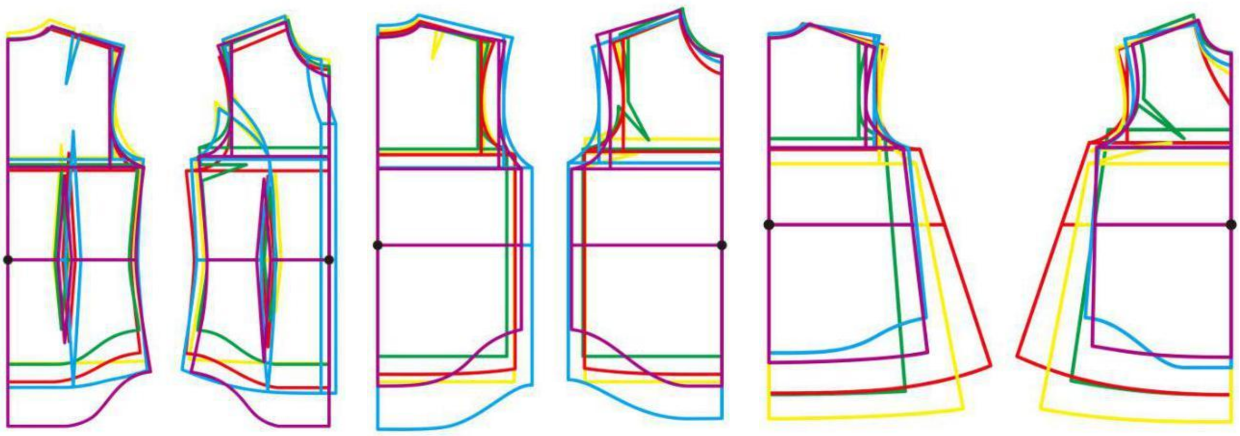
Point	Equations of front point coordinate

Fa1	Fa1x=0	Fa1y= $\frac{S_1}{24}$
Fa2	Fa2x=0	Fa2y= $S_3-\frac{S_1}{8}-7.5$
Fa3	Fa3x=0	Fa3y= $S_3-\frac{S_1}{24}-1$
Fa4	Fa4x= $\frac{S_1}{12}$	Fa4y= $S_3+\frac{S_1}{24}$ - 0.5
Fa5	Fa5x= $\frac{S_1}{12}$	Fa5y= $S_3-\frac{S_1}{24}-1$
Fa6	Fa6x = $\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}$	Fa6y= $S_3-\frac{S_1}{72}-0.2$
Fa7	Fa7x= $\frac{S_1}{6}+3$	Fa7y= $S_3-\frac{S_1}{72}-0.2$
Fa8	Fa8x= $\frac{S_1}{6}+3$	Fa8y= $S_3-\frac{S_1}{8}-7.5$
Fa9	Fa9x= $\frac{S_1}{4}+3$	Fa9y= $S_3-\frac{S_1}{8}-7.5$
Fa10	Fa10x= $\frac{S_1}{4}+3$	Fa10y= $\frac{S_1}{24}$
Fa11	Fa11x= $\frac{S_1}{4}+3$	Fa11y=0
Fa12	Fa12x= $\frac{S_1}{12}+2.2$	Fa12y=0
Fa13	Fa13x= $\frac{S_2}{8}-\frac{S_1}{24}+2.2$	Fa13y=0
Fa14	Fa14x= $\frac{5}{24}S_1-\frac{S_2}{8}+2.2$	Fa14y=0
Fa15	Fa15x= $\frac{S_1}{4}+3$	Fa15y= $S_3-\frac{S_1}{8}-11.5$
Fa16	Fa16x= $\frac{S_1}{12}+2.2$	Fa16y= $S_3-\frac{S_1}{8}-7.5$
Fa17	Fa17x= $\frac{S_1}{12}+2.2$	Fa17y= $S_3-\frac{S_1}{8}-11.5$

Fa18	Fa18x=$\frac{S_1}{4}+3$	Fa18y=$S_3-\frac{5}{48}S_1-11.5$
Fa19	Fa19x=$\frac{S_1}{4}+3$	Fa19y=$S_3-\frac{7}{48}S_1-11.5$

2.1.5. Algorithm for parameterization of blouse pattern blocks

The 122 garment patterns were collected in the ETCAD software by using the prototype method and the proportion method to make patterns, and a relatively perfect blouse pattern database was established. In order to better collect blouse pattern data, the structural design variables for blouse pattern should be summarized. In order to analyze the main structural parts of blouse patterns with different styles, the X, H, A style blouse patterns were respectively overlapped by using ETCAD software. Figure 2.6 shows that based on the intersection of front and back mid-line and waist line as a reference point, the blouse pattern blocks with X, H, A style were respectively overlapped.



a b c

Figure 2.6 - Blouse pattern blocks with different styles: a - X, b - H, c - A

As shown in Figure 2.6, through the dimensional changes of main structural parts such as neck line girth, neck line depth, bust width, back width, bust girth, waist girth, hip girth, armhole depth, the distance between waist line and hem line, back length, etc., pattern blocks with different silhouette and fitting were obtained.

According to the this research idea, based on the intersection of front and back mid-line and waist line as the alignment point,the prototype of blouse were overlapped with the blouse pattern blocks, as shown in Figure 2.7. Figure 2.7 shows the scheme of combining the prototype with the blouse pattern blocks from the database, according to which the design variables affecting the structural changes of the blouse were synthesized and summarized.

The statistical tables of frequency analysis were obtained by using SPSS21.0 statistical analysis software to analyze the size of design variables for blouses with X, H and A style. As shown in Table 2.4, the design variables of X style blouse were summed up to determine the value intervals. Through calculating the average value, the maximum value and the minimum value, the control range of design variables were obtained, as shown in appendix B.

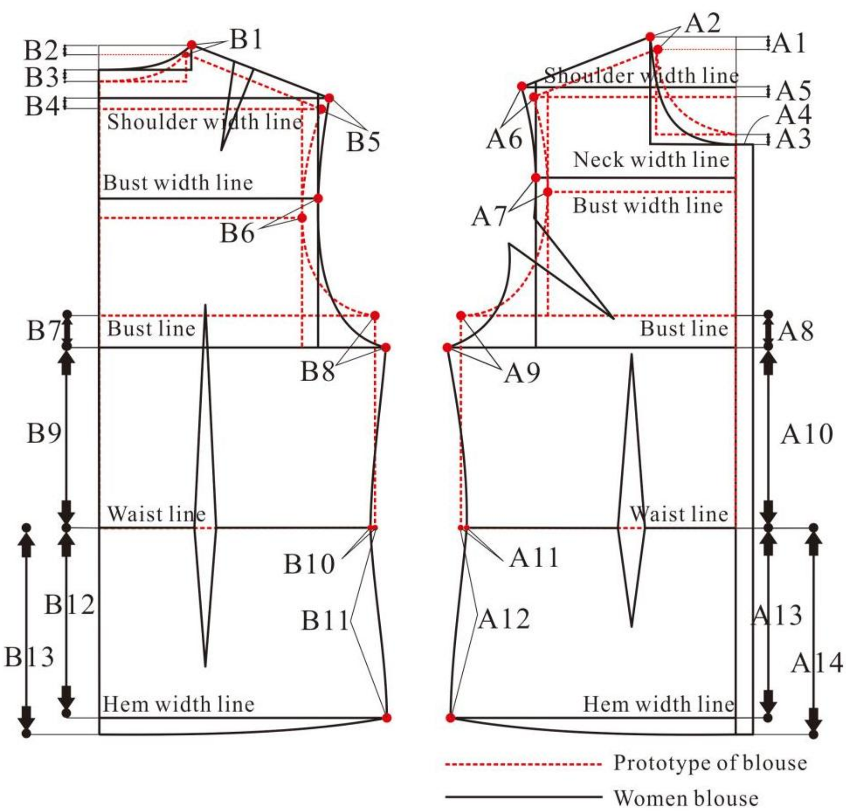


Figure 2.7- Scheme of measuring the design variables of pattern blocks in terms of the prototype of blouse

Table 2.4 - Frequency analysis results of design variables for X-style blouse pattern (n = 71)

Variables	The distance (difference) between prototype and blouse pattern blocks	Measurement results, cm		
		AVG.	MIN.	MAX.
1	2	3	4	5
A1	Moving the highest point of the front neck	-0.2	-2.2	0
A2	Elongation of the front neck line at the top	0.5	-2	5.5
A3	Lowering the lowest point of the front neck	-2.3	-24.7	0.4
A4	Expansion of the front neck	1.5	0	3
A5	The height position of the end points of the shoulder lines	-0.2	-0.9	1.3
A6	Offset of the shoulder lines of the front	0.2	-5.9	5.6
A7	Offset of the bust width line	0.06	-0.6	4.3
A8	Offset of the bust line	-2.5	-7.5	1
A9	Offset of the top of the sideline along the armhole of the front	-0.05	-1.6	2.5
A10	The distance between the waist and bust lines in front	17.5	12.5	21
A11	Changing the length of the waistline of the front	-3.4	-6	-0.5
A12	The distance between the waist and bottom lines along the side line of the front	0.7	-1.9	4.3
A13	The distance from the waist line to the bottom of the front	17.9	12	39
A14	The distance from the waist line to the lowest point of the bottom of the front	21.3	15	49
B1	Moving the highest point of the back neck	-0.2	-2.2	0.1

B2	Elongation of the back neck line at the top	0.8	-0.4	6
B3	Lowering the lowest point of the back neck	0	-3	1
B4	Lowering the end point of the back shoulder line	0.8	-0.6	2.4
B5	Offset of the shoulder lines of the back	-0.3	-1.6	5
B6	Offset the back bust width line	-0.3	-1.3	4.8
B7	Lowering the bust line	-0.1	-5.6	1.5
B8	Offset of the top of the side line along the armhole of the back	-0.9	-3.1	4.5
B9	The distance between the waist and bust lines in back	16.4	10.9	18
B10	Changing the length of the waistline of the back	-4.5	-7.7	1.4
B11	The distance between the waist and bottom lines along the side line of the back	-0.4	-3.1	4.4
B12	The distance from the waist line to the bottom of the back	18.1	12	41
B13	The distance from the waistline to the lowest point of the bottom of the back	20.5	14	49

As shown in Table 2.4, the design variables of the pattern blocks were described as distances from similar prototype parameters. With the help of the minimum and maximum values of variables, the control range of design variables was obtained, which laid the theoretical basis for the subsequent parameterization of blouse pattern blocks.

Then the dimensions of the structural parts and the dimensions of the structural variables of the blouse pattern blocks were measured. The structural parts are bust line width (BLW), waist line width (WLW), hem line width (HLW), front bust width (FBW), shoulder width (SW), neck width (NW), neck depth (ND), armhole depth (AD), front placket width (FPW), clothing length

(CL). In addition, the X, Y and A style blouse pattern blocks were further respectively subdivided into body-fitted, loose-fitted and looser-bodied style according to ease allowance to bust [119]:

- body-fitted: as one of the most usual style, the blouse with small volume around bust,waist, hip and arm. The range of ease allowance to bust is 0-8 cm;

- loose-fitted: as one of the most usual style, the blouse is provided adequate ease allowance to bust, waist, hip and arm for daily movement. And the range of ease allowance to bust is 8.1-18 cm;

- looser-bodied: the biggest, some time oversized, blouse with excessive ease allowance to bust, waist, hip and arm, and sometimes natural draping folds on the bodice. Wherein the range of ease allowance to bust is bigger than 18.1 cm.

After that, the size of the structural parts for blouse pattern blocks in X, H and A styles were respectively measured, as shown in appendix C. Table 2.5 shows the ranges of size of the structural parts for blouse pattern blocks in body-fitted, loose-fitted and looser-bodied styles were calculated respectively.

Table 2.5 - Ranges of the size of the structural parts for blouse pattern blocks in body-fitted, loose-fitted and looser-bodied styles, cm (female body 168/84A)

Front												
	Indexes		BLW	WLW	HW	FBW	SW	NW	ND	AD	FPW	CL
body-fitted	MIN.	X	22.4	18	22.1	16.4	18	6.7	7.1	15.8	0	59
		H	22.5	22.5	22.5	16.7	18.4	6.9	8.4	17.6	1.5	62.4
		A	23.9	26.2	27.5	15.6	16.7	5.5	6.5	17	0	50.9
	MAX.	X	24.5	21.5	27.9	17	19.2	9.7	37.6	21.6	2	90
		H	23.7	23.7	23.7	17.6	19.4	7.4	10.2	20.5	2	65.8
		A	23.9	26.4	29.4	18.4	19.1	8	18	17.9	1.3	70
	AVG.	X	23	19.6	24	16.8	18.4	7.3	11.1	18.3	1.4	63
		H	23.2	23.2	23.2	17.1	18.8	7	8.9	19.5	1.6	63.8
		A	23.9	26.3	28.5	17	17.9	6.75	12.3	17.5	0.7	60.5

loose-fitted	MIN.	X	23.5	18	22.7	16.4	12.5	5	6.7	15.9	0	56
		H	23.5	23.5	23.5	16.7	18.4	5.9	7.49	15	0	61.1
		A	24.5	26	27	17.1	18.4	5.5	5.5	18	0	62
	MAX.	X	25.7	23.5	27.7	19.8	21	12.5	19.5	22.5	3	69.4
		H	25.5	25.5	25.5	21.1	21	8	11	21.2	1.8	79.3
		A	27	27.5	32	21.5	24	12.8	12.1	23	1.5	76.2
	AVG.	X	24.2	20.9	24.9	17	18.5	7.6	9.3	18.7	1.5	61.5
		H	24.4	24.6	24.6	18.5	19.9	7.0	8.8	19.3	1.3	68.2
		A	25.8	27	29.2	19.9	21.7	9.5	9.2	20	0.6	70.3
looser-fitted	MIN.	X	24.5	19.2	23.5	17	19	6.9	7.5	20.7	1.5	59.5
		H	24.5	24.5	24.5	17.6	19	6.9	8.2	17.7	0	62
		A	25	25.8	26.4	16.6	17.7	6.5	7	16.52	0	50.6
	MAX.	X	26.5	22.9	28.3	21.3	24	7.6	32	24	2	72.5
		H	30.5	30.5	30.5	25.2	27	8.8	12.5	27	2	74
		A	35.5	37.7	45.3	26.9	29.4	13.8	19	25	2	83.4
	AVG.	X	25.8	21.3	25.4	18.7	20.9	7.3	14.9	22.3	1.8	66.1
		H	27.3	27.3	27.3	20.5	22.3	7.5	9.5	22.3	1.5	69.3
		A	27	28.8	32	19.9	21.9	8.4	10.5	20.7	1.3	71.6
Back												
body-fitted	Indexes		BLW	WLW	HW	BBW	SW	NW	ND	AD	CL	
	MIN.	X	20.9	16.3	20.9	17.2	18.8	7	1.9	18.2	56	
		H	22	22	22	17.9	19.9	7.1	2.1	19	57.3	
		A	22	22	22	16.16	17.1	6.3	2.2	19.7	51.5	
	MAX.	X	23.5	21	28.4	18.8	20.6	10	3.4	20.5	87	
		H	22.6	22.6	22.6	19.1	20.9	7.6	2.5	20.3	62.8	
		A	22	23	23.5	18	20.5	8.3	3	20.43	66.8	
	AVG.	X	22.4	18.7	23.3	17.9	19.5	7.7	2.3	19.4	59.4	
		H	22.4	22.4	22.4	18.4	20.3	7.3	2.3	19.5	59.8	
		A	22	22.5	22.8	17.1	18.8	7.3	2.6	20.1	59.2	
loose-fitted	MIN.	X	21.7	16.7	22	17.3	18.4	6.8	1.4	17.6	51.3	
		H	23.7	23.7	23.7	16.7	18.4	6.78	2	19.5	50	
		A	23.3	24.6	25.5	17.9	19.9	7.7	1.8	19.7	66	
	MAX.	X	25.5	23.5	25.5	20	21	13.2	5.4	22.5	64.8	
		H	25.6	25.6	25.6	23	21.5	8	8.4	23	73	
		A	28	28.5	30.4	22	25	14.2	13.1	30	74	
	AVG.	X	23.1	19.6	23.6	18.1	19.6	8.1	2.4	19.9	57.9	
		H	25	25	25	19.3	20.4	7.2	3.2	21.3	62.2	
		A	25.8	26.4	28.1	20.1	22.3	10.8	6.9	23.5	70.4	

looser-fitted	MIN.	X	26	18.8	23.6	18.1	20	7.2	2	21.9	52.5
		H	24.5	24.5	24.5	17.6	19	6.9	2	17.7	60.5
		A	26	26.4	27.5	17.6	18.7	7	2	18.7	48
	MAX.	X	28.5	25.4	26	23.3	25	8.1	2.5	26	70.5
		H	31	31	31	25.8	27	8.8	12	27	74
		A	40.5	42.8	50.3	28.5	30	14.8	20	29.1	80.5
	AVG.	X	26.9	22.2	24.6	20	21.7	7.6	2.4	23.4	61.6
		H	27.3	27.3	27.3	21	22.6	7.5	5.8	23	68
		A	29.1	30.7	34	21.6	23.1	9	5.4	22.8	69.9

Through collecting and sorting the size of the structural parts and the size of the design variables of 122 blouse pattern blocks, the Excel forms were established, and X, H, and A style blouse pattern database were obtained, as shown in Appendix C.

2.1.6. Graphic-mathematical models of blouse pattern blocks

2.1.6.1. Parameterization of X-style blouse pattern blocks

1) Correlation analysis

The size change of each part of blouse pattern is not isolated, but interact with each other. However, the compact degree of each part is not the same. Some parts are closely linked, and some parts are weakly linked. So before regression analysis, correlation analysis of data of blouse pattern database should be done firstly. Table 2.6 shows the correlation analysis of structural variables and design variables for X-style blouse. The structural variables are FBW (Front bust width), FNW (Front neck width), FND (Front neck depth), FAD (Front armhole depth), BBW (Back bust width), BSW (Back shoulder width), BNW (Back neck width). The design variables are A1, A3, A8, A10, B1, B12, B13, B2, B5, B6 (See Tables 2.4).

By analyzing the data of the table, it can seen that the correlation coefficient of FBW and B6 for X-style blouse is 0.9, $P=0.000<0.01$, which shows the significant correlation between FBW and B6 at the level of 0.01 (two-sided). In the same way, correlations between other control variables of pattern blocks were analyzed, as shown in Appendix D. Therefore, it lays a good foundation for regression analysis in the next step.

2) Regression analysis

According to the above analysis, B6 was treated as dependent variable, FBW was treated as independent variables for a linear regression analysis. So the coefficient table of regression analysis were obtained, and then the corresponding regression mathematical modeling were established. Table 2.7 shows the part of regression analysis for X-style blouse (the same tables were formed for the other structural variables of pattern blocks, as shown in Table D.1 - D.7 in Appendix D).

Table 2.6 - Table of correlation coefficients of blouses in X style (n = 71). r is the Pearson correlation coefficient, α - significant (two-sided)

Factors		Statistical values																
		FBW	FNW	FND	FAD	A1	A3	A8	A10	BBW	BSW	BNW	B1	B12	B13	B2	B5	B6
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FBW	r	1	0.1	-0.1	0.4	0.1	0	-0.3	-0.3	0.2	0.1	0.1	0.1	0	0.1	0	0.8	0.9
	α	/	0.4	0.5	0	0.3	1	0	0	0	0.4	0.3	0.2	0.7	0.3	0.7	0	0
FNW	r	0.1	1	0	0.3	-0.6	-0.1	0	0	0.2	0	0.8	-0.7	0	-0.2	0.9	0	0.2
	α	0.4	/	0.6	0	0	0.2	0.4	0.4	0.1	0.8	0	0	0.5	0.2	0	0.9	0.1
FND	r	0	0	1	0	0	-0.7	-0.2	-0.2	0	0	0	0	0	0	0	0	0
	α	0.6	0.6	/	0.5	0.6	0	0.2	0.2	0.6	0.6	0.8	0.7	0.5	0.6	0.5	0.9	0.7
FAD	r	0.4	0.3	0	1	0	-0.2	-0.8	-0.8	0	-0.1	0.1	0	0	0	0.2	0.4	0.2
	α	0	0	0.5	/	0.6	0.1	0	0	0.9	0.3	0.3	0.8	0.7	0.6	0.1	0	0
A1	r	0.1	-0.6	0	0	1	0.3	0	0	0	0.1	-0.8	0.9	0	0.1	-0.8	0	0
	α	0.3	0	0	0.6	/	0	0.6	0.6	0.7	0.4	0	0	0.7	0.2	0	0.6	0.7
A3	r	0	-0.1	-0.7	-0.2	0.3	1	0	0	-0.1	0	-0.3	0.2	-0.2	0	-0.3	0	0
	α	1	0.2	0	0.1	0	/	0.5	0.5	0.3	0.7	0	0.1	0.2	1	0	0.6	0.6
A8	r	-0.3	0	-0.2	-0.8	0	0	1	1	0	0.2	0	-0.1	0	0	0	-0.4	-0.1
	α	07	0.4	0.2	0	0.6	0.5	/	0	0.5	0.2	0.5	0.4	0.6	0.7	1	0	0.2
A10	r	-0.3	0	-0.2	-0.8	0	0	1	1	0	0.2	0	0	0	0	0	-0.4	-0.1
	α	0	0.4	0.2	0	0.6	0.5	0	/	0.5	0.2	0.5	0.4	0.6	0.73	1	0	0.2

Окончание табл. 2.6

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
BBW	r	0.2	0.2	0	0	0	-0.1	0	0	1	0.8	0.2	0	0.2	0.1	0.2	0.2	0.3
	α	0	0.1	0.6	0.9	0.7	0.3	0.5	0.5	/	0	0.1	0.8	0	0.3	0.2	0.1	0
BSW	r	0.1	0	0	-0.1	0.1	0	0.2	0.2	0.8	1	0	0	0.2	0	0	0.2	0.2
	α	0.4	0.8	0.6	0.3	0.4	0.7	0.2	0.2	0	/	0.6	0.7	0	0.5	0.7	0.1	0.2
BNW	r	0.1	0.8	0	0.1	-0.8	-0.3	0	0	0.2	-0	1	-0.8	-0.2	-0.2	0.9	0	0.27
	α	0.3	0	0.8	0.3	0	0	0.5	0.5	0.1	0.6	/	0	0.2	0.2	0	0.9	0
B1	r	0.2	-0.7	0	0	0.9	0.2	-0.1	-0.1	0	0	-0.8	1	0.1	0.2	-0.9	0.1	0
	α	0.2	0	0.7	0.8	0	0.1	0.4	0.4	0.8	0.7	0	/	0.4	0	0	0.3	0.8
B2	r	0	0.9	0	0.2	-0.8	-0.3	0	0	0.2	0	0.9	-0.9	-0.1	-0.2	1	-0	0.2
	α	0.7	0	0.5	0.1	0	0	1	1	0.2	0.7	0	0	0.3	0	/	0.7	0.1
B5	r	0.8	0	0	0.4	0	0	-0.4	-0.4	0.2	0.2	0	0.1	0	0.2	0	1	0.8
	α	0	0.9	0.9	0	0.6	0.6	0	0	0.1	0.1	0.9	0.3	0.7	0	0.7	/	0
B6	r	0.8	0.2	0	0.24	0	0	-0.1	-0.1	0.3	0.2	0.3	0	-0.1	0	0.2	0.8	1
	α	0	0.1	0.7	0	0.7	0.6	0.2	0.2	0	0.2	0	0.8	0.4	0.6	0.1	0	/
B12	r	0	0	0	0	0	-0.2	0	0	0.2	0.2	-0.2	0.1	1	0.8	-0.1	0	-0.1
	α	0.7	0.5	0.5	0.7	0.7	0.2	0.6	0.6	0	0	0.2	0.4	/	0	0.3	0.7	0.4
B13	r	0.1	-0.2	0	0	0.1	0	0	0	0	0	-0.2	0.2	0.8	1	-0.2	0.2	0
	α	0.3	0.2	0.6	0.6	0.2	1	0.7	0.7	0.3	0.5	0.2	0	0	/	0	0	0.6

Table 2.7 - Coefficients of regression equations FBW and B6 for X-style blouse (n = 71)

Regression model		Non standardized coefficient		Standardize dcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-16.6	1.2		-13.4	0
	FBW	0.96	0.07	0.85	13.1	0
a. dependent variable: B6						

As shown in Table 2.7, the Significant value represents the significance level of the hypothesis test, and P=0<0.05, which means that the single linear regression equation is significant.

Linear regression models are presented below.

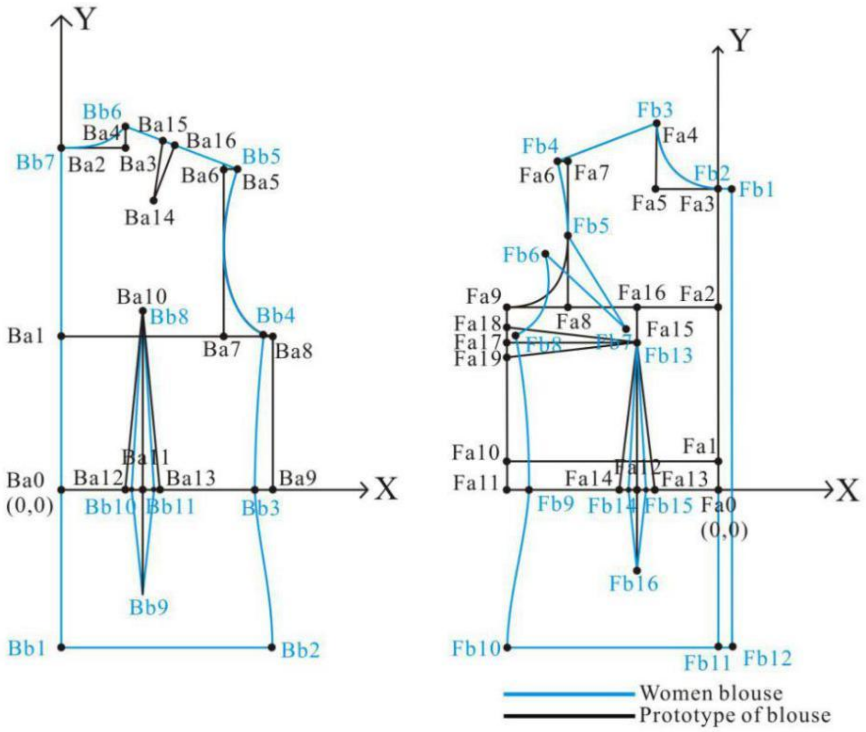
Table 2.8 - Regression models in X style

Front		
Regression equations	Converting the regression equations into coordinate points representation	N.
1	2	3
A1= 2-0.3BNW	A1=2-0.3Bb6y	(2.1)
A3= 3-0.5FND	A3= 3-0.5Fb2y	(2.2)
A8= 11.9-0.8FAD	A8= 11.9-0.8Fb8y	(2.3)
A10= 31.9-0.8FAD	A10= 31.9-0.8Fb8y	(2.4)
Back		
B1= 1.6-0.2 FNW	B1= 1.6-0.2Fb3x	(2.5)
B2= 0.95FNW-6.3	B2= 0.95Fb3x-6.3	(2.6)
B5= 0.85FBW-14.8	B5= 0.85Fb5x-14.8	(2.7)
B6=0.96FBW-16.6	B6=0.96Fb5x-16.6	(2.8)

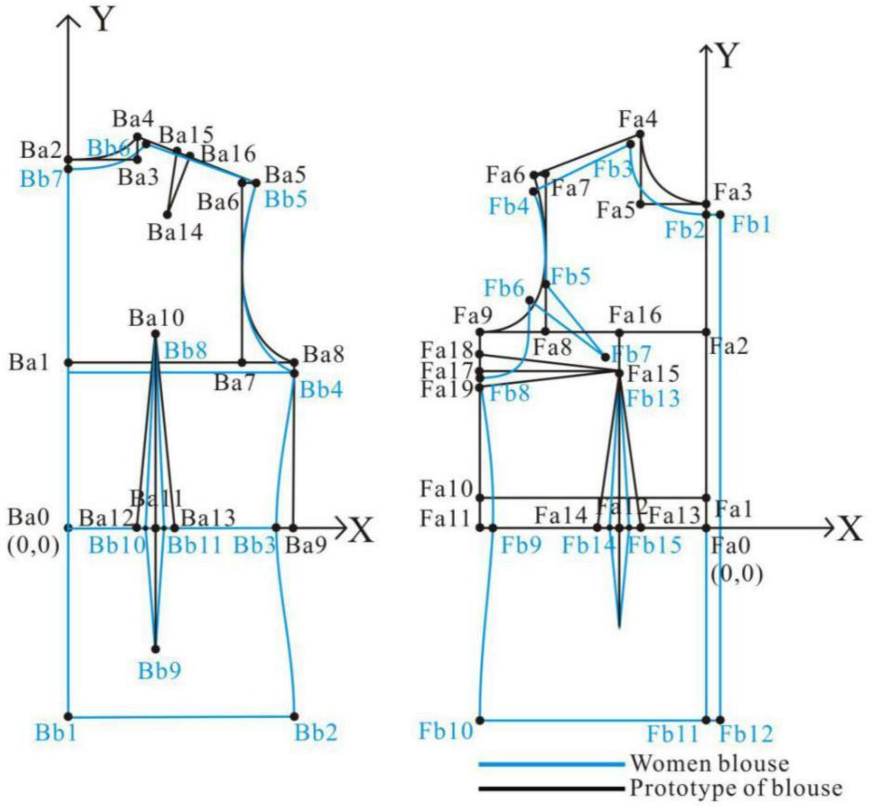
As shown in Table 2.8, regression equations were obtained between the structural variables of the blouse in X style, which could be used to create a mathematical model of the blouse. By converting the relationship of regression equations between two variables into coordinate points, the number of structural variables of the coordinate points of the mathematical blouse model was reduced in a later period.

2.1.6.2. Generation of mathematical model of X-style blouse pattern blocks

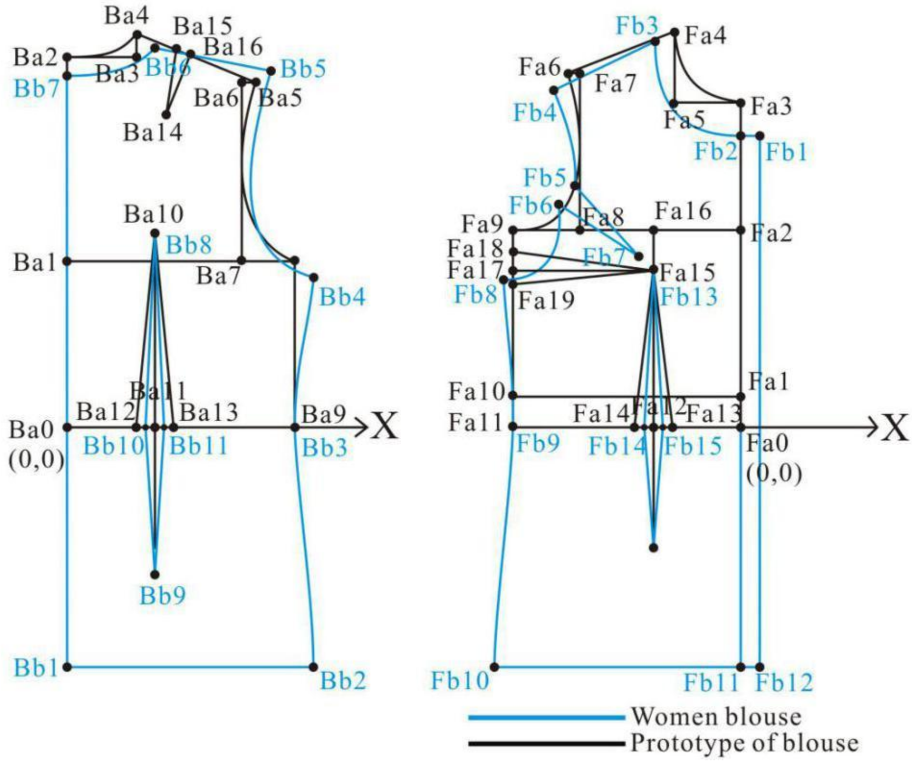
The method of obtaining the mathematical model of the blouse pattern block is the same as the method of a mathematical model of a prototype, which includes a corresponding mathematical equation for each of each key points of the outer contour of the pattern block, as shown in Figure 2.8.



a



b



c

Figure 2.8 - Characteristic points in pattern of X-style blouse: a - body-fitted

style, b - loose-fitted style, c - looser-bodied style

Figure 2.8 shows that based on the mathematical model of prototype, combined with the blouse structural design rules and analysis of X-style mathematical model involving structural change, and on the basis of the control range of design variables for X-style pattern, and then the mathematical models of X-style blouse with body-fitted style, loose-fitted style and looser-bodied style were set up respectively, as shown in Table D.8 - D.9 in Appendix D.

Taking the X-style blouse with body-fitted style as an example, the coordinates of the key points were set up respectively, as shown in Table 2.9.

Table 2.9 - Mathematical models of X-style blouse pattern with body-fitted style

Point	Equations of point coordinate	
	Back	
Bb1	Bb1x=0	Bb1y=Ba9y+18
Bb2	Bb2x=$\frac{S_1}{4}+1$	Bb2y=Ba9y+18
Bb3	Bb3x=$\frac{S_1}{4}-1$	Bb3y=0
Bb4	Bb4x=$\frac{S_1}{4}+1$	Bb4y=$S_3-\frac{S_1}{6}-6$
Bb5	Bb5x=$\frac{S_1}{6}+4$	Bb5y=$S_3-\frac{S_1}{36}-0.1$
Bb6	Bb6x=$\frac{S_1}{12}+0.3$	Bb6y=$S_3+\frac{S_1}{36}+0.35$
Bb7	Bb7x=0	Bb7y=S_3+1
	Front	
Fb1	Fb1x=Fa3x+1.5	Fb1y=$S_3-\frac{S_1}{24}$
Fb2	Fb2x=0	Fb2y=$S_3-\frac{S_1}{24}$
Fb3	Fb3x=$\frac{S_1}{12}-1$	Fb3y=$S_3+\frac{S_1}{24}-0.5$
Fb4	Fb4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}-1.5$	Fb4y=Fb8y-0.7Fb8y+31.4

Fb5	Fb5x=$\frac{S_1}{6}+2$	Fb5y=(Fb4y+Fb8y)/2
Fb6	Fb6x=Fb5x+($\frac{S_1}{18}+3.65$) $\tan 18^0$	Fb6y=Fb8y+$\frac{\left(\frac{S_1}{18}+3.65\right)*\tan 18^0}{\tan 23^0}$
Fb7	Fb7x=$\frac{S_1}{12}+2\sin 39^0+2.2$	Fb7y=$S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fb8	Fb8x=$\frac{S_1}{4}+2$	Fb8y=Bb4y
Fb9	Fb9x=$\frac{S_1}{4}$	Fb9y=0
Fb10	Fb10x=$\frac{S_1}{4}+2$	Fb10y=Fa11y+18
Fb11	Fb11x=0	Fb11y=Fa11y+18
Fb12	Fb12x=Fa3x+1.5	Fb12y=Fa11y+18

Table 2.9 shows that based on the mathematical model of prototype,the intersection of the back center line and the waist line of prototype was used as the coordinate origin. The waist line is set to the X axis and the back center line is set to the Y axis.According to the control range of these important variable which were obtained in the above study, the mathematical models of X-style blouse patterns were obtained, as shown in Table D.8 - D.9 in Appendix D.

2.1.6.3. Parameterization of H-style blouse pattern blocks

1) Correlation analysis

Similarly, by means of correlation analysis of each variable, the dependence between the variables was summed up, and finally, in accordance with correlation and regression analysis, the rationality of the dependence was determined. Structural variables are FBW (Front width), FSW (Front Shoulder Width), FAD (Front Armhole depth), BW (Back Width), BAD (Back Armhole depth). The calculated variables are A1, A8, A10, A2, A6, A9, B7, B9, B12 (Detailed information is given in Tables D.10 in Appendix D).

2) Regression analysis

According to the above analysis, A1 was considered as a dependent variable, and BNW as independent variables for linear regression analysis. Thus, the coefficient table of regression analysis was obtained, and then the corresponding regression mathematical equation was established. Table 2.10 shows part of the regression analysis for the H-style blouse (the same tables were formed for other structural variables of the pattern blocks, as shown in Table D.11 - D.18 in Appendix D).

Table 2.10 - Coefficients of regression equations BNW and A1 for H-style blouse (n = 29)

Regression model		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	1.6	0.4		3.9	0
	BNW	-0.2	0	-0.7	-4.1	0
a. dependent variable: A1						

Summed up the coefficient table of the regression analysis, the single linear regression model was obtained by treating A1 as the dependent variable, BNW as independent variable:

$$A1=1.6-0.2BNW. \quad (2.9)$$

Then, in the same way, the single linear regression models of other structural variables of pattern blocks were obtained.

Table 2.11 - Regression models in H style

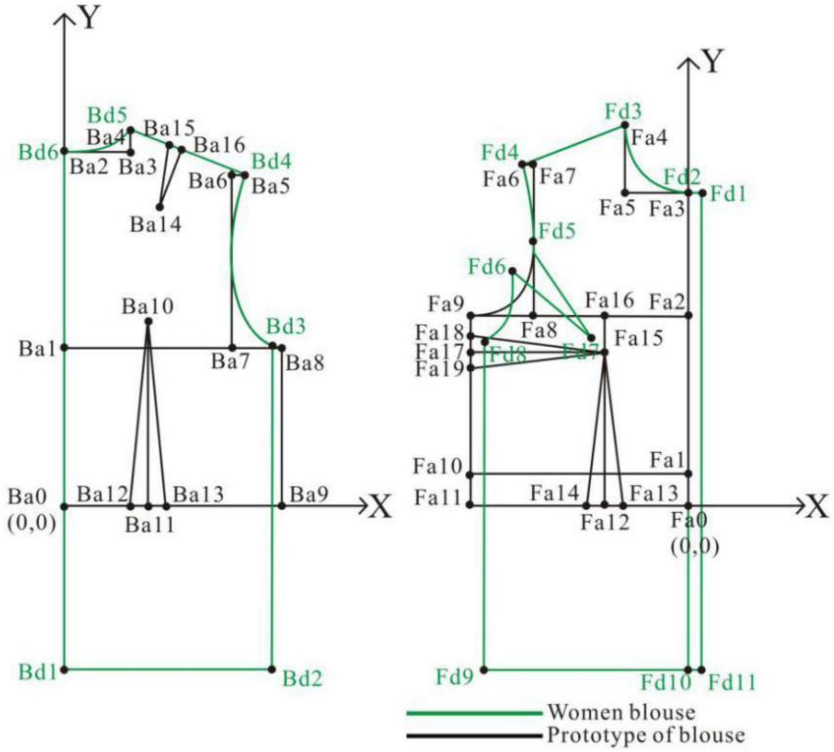
Front		
Regression equations	Converting the regression equations into coordinate points representation	N.
A1=1.6-0.2BNW	A1=1.6-0.2Bd5y	(2.9)

A2=BNW-7.6	A2=Bd5x-7.6	(2.10)
A6=1.1BSW-21.8	A6=1.1Bd4x-21.8	(2.11)
A8=12.5-0.8BAD	A8=12.5-0.8Bd3y	(2.12)
A9=0.7BAD-12.8	A9=0.7Bd3x-12.8	(2.13)
A10=32.5-0.8BAD	A10=32.5-0.8Bd3y	(2.14)
Back		
B7=15.3-0.8FSW	B7=15.3-0.8Fd4y	(2.15)
B9=29.7-0.8FBW	B9=29.7-0.8Fd5y	(2.16)
B12=49.4-1.8A10	B12=1.4Bd3y-9.1	(2.17)

Therefore, the regression equations between the structural variables of the H-style blouse were obtained, which could be used to establish the mathematical model of the H-style blouse in the later period.

2.1.6.4. Generation of mathematical model of H-style blouse pattern blocks

As shown in Figure 2.9, similar to the construction principle of the mathematical model of X-style blouse pattern, mathematical models of H-style blouse patterns with body-fitted style, loose-fitted style and looser-bodied style were established respectively.


Y
Bd5
Ba15
Ba4
Ba16
Bd6
Bd4
Ba2
Ba3
Ba6
Ba5
Ba14
Ba10
Bd3
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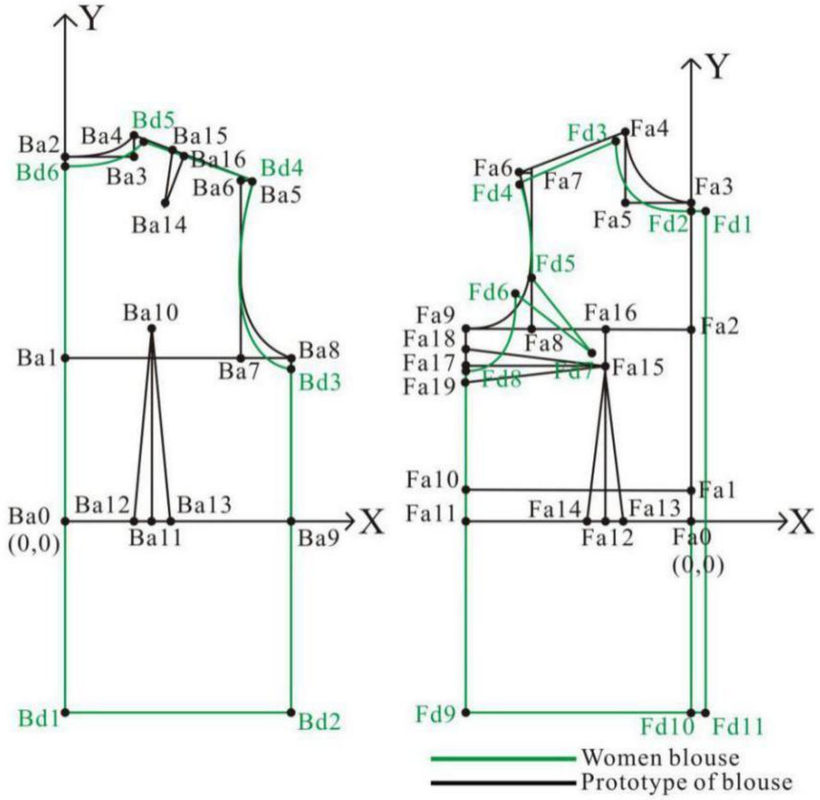
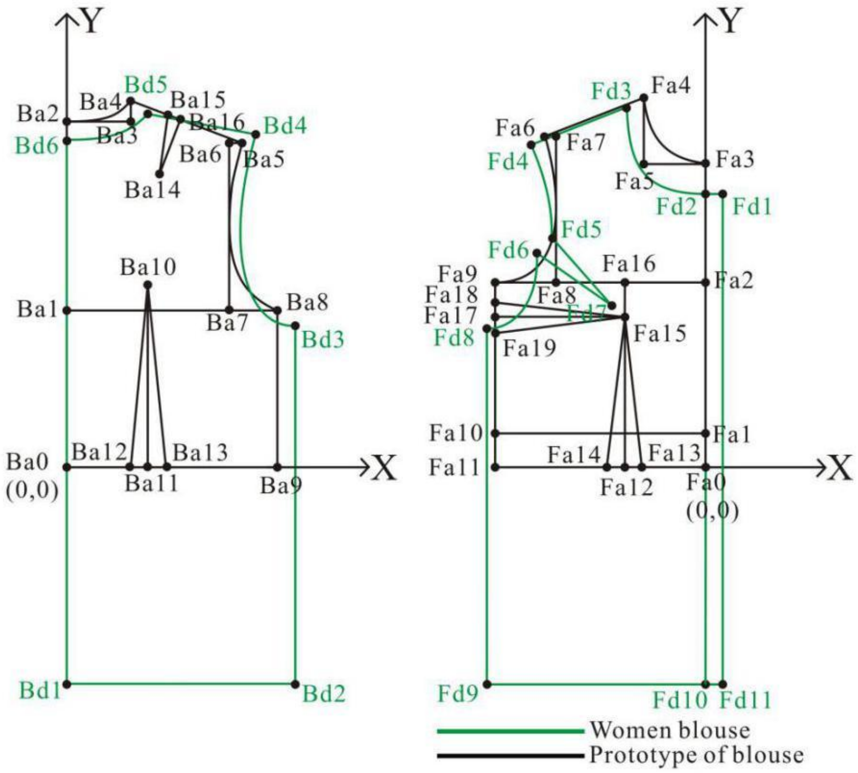
Ba7
Ba8
Ba0
(0,0)
Ba12
Ba13
Ba9
X
Ba11
Bd1
Bd2
Y
Fd3
Fd4
Fa4
Fa6
Fa7
Fd2
Fd1
Fa5
Fa3
Fd5
Fd6
Fa9
Fa16
Fa2
Fa18
Fa8
Fa15
Fa17
Fd8
Fd7
Fa19
Fa10
Fa1
Fa11
Fa14
Fa13
Fa12
Fa0
(0,0)
Fd9
Fd10
Fd11
Women blouse
Prototype of blouse

a


Y
Bd5
Ba2
Ba4
Ba15
Ba16
Bd4
Bd6
Ba3
Ba6
Ba5
Ba14
Ba10
Ba1
Ba8
Ba7
Bd3
Ba0
(0,0)
Ba12
Ba13
Ba11
Ba9
X
Bd1
Bd2
Y
Fd3
Fa4
Fa6
Fa7
Fa3
Fd4
Fa5
Fd2
Fd1
Fd5
Fd6
Fa9
Fa16
Fa2
Fa18
Fa8
Fa17
Fd7
Fa15
Fa19
Fd8
Fa10
Fa1
Fa11
Fa14
Fa13
Fa12
Fa0
(0,0)
X
Fd9
Fd10
Fd11
Women blouse
Prototype of blouse

b



c

Figure 2.9 - Characteristic points in pattern of H-style blouse: a - body-fitted style, b - loose-fitted style, c - looser-bodied style

Figure 2.9 shows that based on the mathematical model of the prototype in combination with the rules for designing a blouse and a control range of variables, mathematical models of H-style blouses with body-fitted style, loose-fitted style and looser-bodied style were set up respectively, as shown in Table D.19 - D.20 in Appendix D. Table 2.12 shows the coordinates of the key points for H-style blouse with body-fitted style.

Table 2.12 - Mathematical model of H-style blouse pattern with body-fitted style

Point	Equations of point coordinate	
Back		
Bd1	Bd1x=0	Bd1y=Ba9y+18
Bd2	Bd2x=$\frac{S_1}{4}+1$	Bd2y=Ba9y+18
Bd3	Bd3x=$\frac{S_1}{4}+1$	Bd3y=$S_3-\frac{S_1}{6}-6$

Bd4	Bd4x=$\frac{S_1}{6}+4$	Bd4y=$S_3-\frac{S_1}{36}-0.1$
Bd5	Bd5x=$\frac{S_1}{12}+0.3$	Bd5y=$S_3+\frac{S_1}{36}+0.35$
Bd6	Bd6x=0	Bd6y=S_3+1
Front		
Fd1	Fd1x=Fa0x+1.5	Fd1y=$S_3-\frac{S_1}{24}$
Fd2	Fd2x=0	Fd2y= $S_3-\frac{S_1}{24}$
Fd3	Fd3x=$\frac{S_1}{12}-1$	Fd3y=$S_3+\frac{S_1}{24}-0.5$
Fd4	Fd4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}-1.5$	Fd4y=Fd8y-0.97Fd8y+36.121
Fd5	Fd5x=$\frac{S_1}{6}+2$	Fd5y=(Fd4y+Fd8y)/2
Fd6	Fd6x=Fd5x+$(\frac{S_1}{18}+3.65)\tan 18^0$	Fd6y=Fd8y+$\frac{\left(\frac{S_1}{18}+3.65\right)\tan 18^0}{\tan 23^0}$
Fd7	Fd7x=$\frac{S_1}{12}+2\sin 39^0+2.2$	Fd7y=$S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fd8	Fd8x=$\frac{S_1}{4}+2$	Fd8y=Bd3y
Fd9	Fd9x=$\frac{S_1}{4}+2$	Fd9y=Fa11y+18
Fd10	Fd10x=0	Fd10y=Fa11y+18
Fd11	Fd11x=Fa0x+1.5	Fd11y=Fa11y+18

2.1.6.5. Parameterization of A-style blouse pattern blocks

1) Correlation analysis

By analyzing the correlation of structural variables to find the relationship between the variables, and finally using regression analysis to determine the rationality of the relationship to reduce the number of control variables. Structural variables are FBW (Front Bust Width), FSW (Front Shoulder Width), FAD (Front Armhole depth), BBW (Back Back Width), BSW (Back Shoulder Width), BNW (Back Neck Width). The calculated variables are A1, A2, A8, A10, B2, B5, B7, B8, B9 (Detailed information is given in tables D.21 in Appendix D).

2) Regression analysis

According to the above analysis, A1 was treated as dependent variable, BNW was treated as independent variables for a linear regression analysis. So the coefficient table of regression analysis were obtained, and then the corresponding regression mathematical modeling were established. Table 2.13 shows the part of regression analysis for A-style blouse (the same tables were formed for other structural variables of the pattern blocks, as shown in Table D.22 - D.29 in Appendix D).

Table 2.13 - Coefficient table of regression analysis of BNW and A1 for A-style blouse (n = 22)

<table>
<tr><th colspan="2" rowspan="2">Regression model</th><th colspan="2">Non standardized coefficient</th><th>Standardized coefficient</th><th rowspan="2">t</th><th rowspan="2">Sig.</th></tr>
<tr><th>B</th><th>standard error</th><th>Trial version</th></tr>
<tr><td rowspan="2">1</td><td>(constant)</td><td>1.5</td><td>0.5</td><td></td><td>3.1</td><td>0</td></tr>
<tr><td>BNW</td><td>-0.2</td><td>0</td><td>-0.7</td><td>-4</td><td>0</td></tr>
<tr><td colspan="7">a. dependent variable: A1</td></tr>
</table>

Summed up the coefficient table of the regression analysis, the single linear regression model was obtained by treating FBW as the dependent variable, BSWas independent variable:

Summarizing Table 2.13, the single linear regression model, considering A1 as a dependent variable, BNW as an independent variable, has the form:

$$A1=1.5-0.2BNW. \quad (2.18)$$

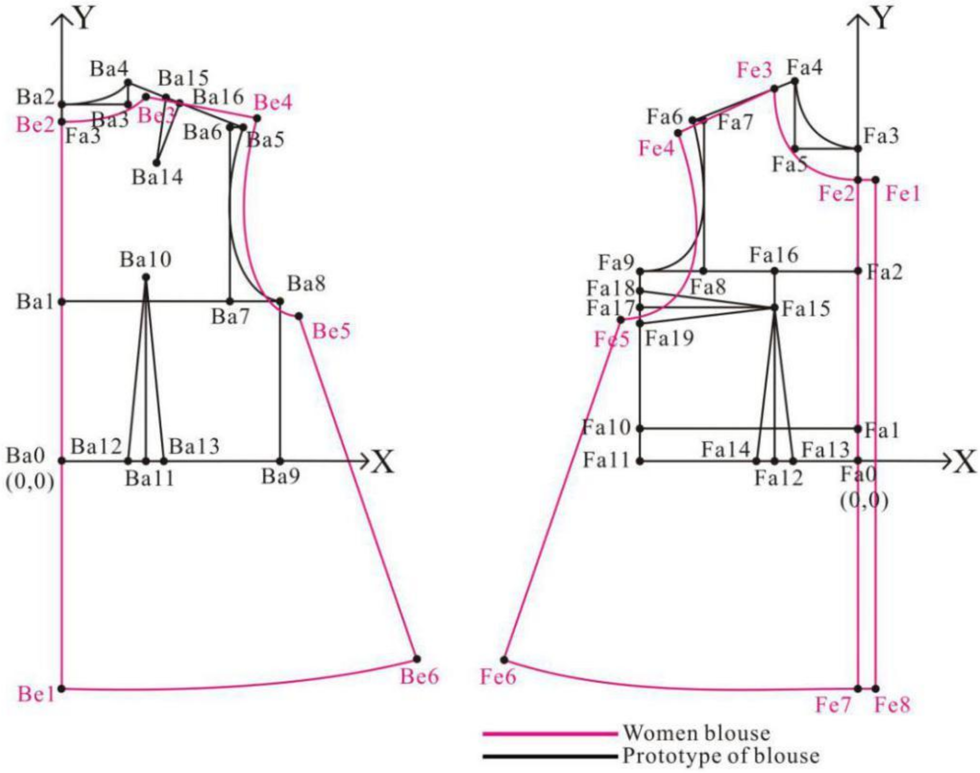
Then, in the same way, the single linear regression models of other structural variables of pattern blocks were obtained.

Table 2.14 - Regression models in A style

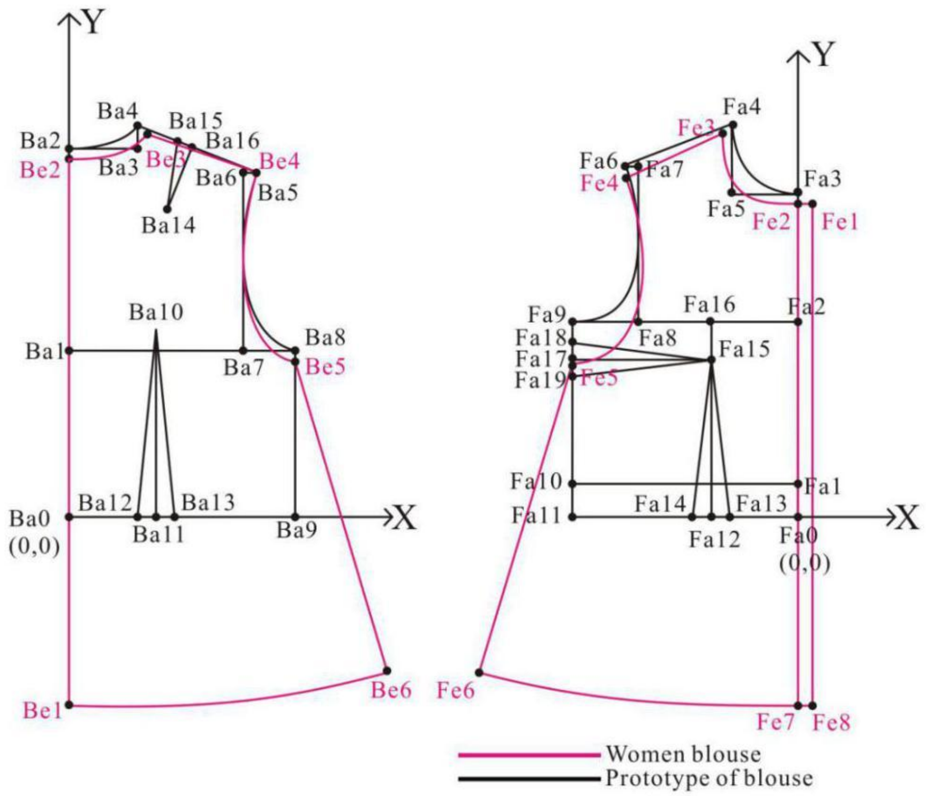
Front		
Regression equations	Converting the regression equations into coordinate points representation	N.
A1=1.5-0.2BNW	A1=1.5-0.2Be3y	(2.18)
A2=0.9BNW-6.4	A2=0.9Be3x-6.4	(2.19)
A8=17.8-0.97BSW	A8=17.8-0.97Be4y	(2.20)
A10=37.8-0.97BSW	A10=37.8-0.97Be4y	(2.21)
Back		
B2=0.6-2.5A1	B2=0.5Be3y-3.2	(2.22)
B5=1.1FAD-18.8	B5=1.1Fe5x-18.8	(2.23)
B7=14.3-0.8FSW	B7=14.3-0.8Fe4y	(2.24)
B8=1.4-23.5FAD	B8=1.4-23.5Fe5x	(2.25)
B9=29.6-0.7BSW	B9=29.6-0.7Be4y	(2.26)

2.1.6.6. Generation of mathematical model of A-style blouse pattern blocks

As shown in Figure 2.10, similar to the construction principle of the mathematical model of H-style blouse pattern, mathematical models of A-style blouse patterns with body-fitted style, loose-fitted style and looser-bodied style were established respectively.


Y
X
Ba0
(0,0)
Ba1
Ba2
Be2
Ba3
Fa3
Ba4
Ba15
Be3
Ba16
Be4
Ba6
Ba5
Ba14
Ba10
Ba7
Ba8
Be5
Ba12
Ba11
Ba13
Ba9
Be1
Be6
Fe3
Fa4
Fa6
Fa7
Fe4
Fa3
Fa5
Fe2
Fe1
Fa9
Fa16
Fa2
Fa18
Fa8
Fa17
Fa15
Fe5
Fa19
Fa10
Fa1
Fa11
Fa14
Fa12
Fa13
Fa0
(0,0)
Fe6
Fe7
Fe8
Women blouse
Prototype of blouse

a


Y
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Ba11
Ba13
Ba9
Be1
Be6
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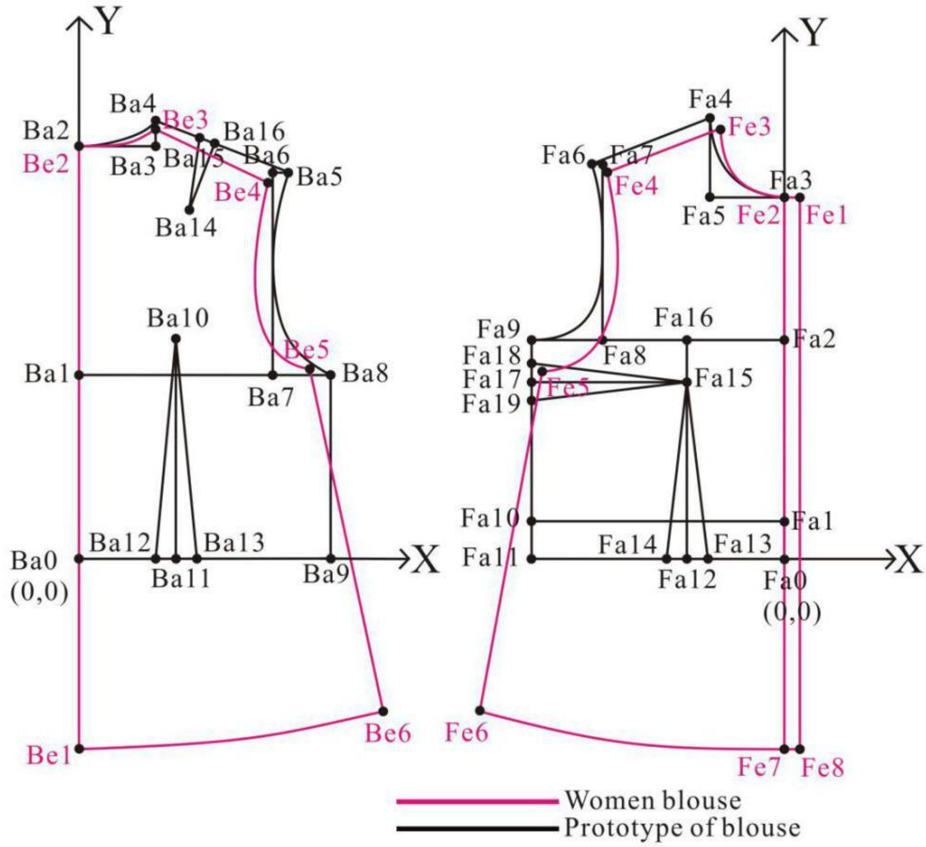
Fa7
Fa3
Fa5
Fe2
Fe1
Fa9
Fa16
Fa2
Fa18
Fa8
Fa17
Fa15
Fa19
Fe5
Fa10
Fa1
Fa11
Fa14
Fa12
Fa13
Fa0
(0,0)
Fe6
Fe7
Fe8
Women blouse
Prototype of blouse

b



c

Figure 2.10 - Characteristic points in pattern of A-style blouse: a - body-fitted style, b - loose-fitted style, c - looser-bodied style

Figure 2.10 shows that on the basis of the mathematical model of prototype, according to the control interval of the design variables, and combined with the single linear regression models obtained from the regression analysis, the mathematical models of A-style blouse patterns with body-fitted style, loose-fitted style and looser-bodied style were established respectively, as shown in Table D.30 - D.31 in Appendix D. Table 2.15 shows the coordinates of the key points for A-style blouse with body-fitted style.

Table 2.15- Mathematical model of A-style blouse pattern with body-fitted style

Point	Equations of point coordinate
Back	

Be1	Be1x=0	Be1y=0.98Be6y+3.7
Be2	Be2x=0	Be2y=S_3+1
Be3	Be3x=$\frac{S_1}{12}+0.3$	Be3y=$S_3+\frac{S_1}{36}+0.35$
Be4	Be4x=$\frac{S_1}{6}+4$	Be4y=$S_3-\frac{S_1}{36}-0.1$
Be5	Be5x=$\frac{S_1}{4}+1$	Be5y=$S_3-\frac{S_1}{6}-6$
Be6	Be6x=$\frac{S_1}{4}+8$	Be6y=Ba9y+14.5
Front		
Fe1	Fe1x=Fa0x+1.5	Fe1y=$S_3-\frac{S_1}{24}$
Fe2	Fe2x=0	Fe2y=$S_3-\frac{S_1}{24}$
Fe3	Fe3x=$\frac{S_1}{12}-1$	Fe3y=$S_3+\frac{S_1}{24}-0.5$
Fe4	Fe4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}-1.5$	Fe4y=Fe5y-0.63Fe5y+30.2
Fe5	Fe5x=$\frac{S_1}{4}+2$	Fe5y=Be5y
Fe6	Fe6x=$\frac{S_1}{4}+8$	Fe6y=Be6y
Fe7	Fe7x=0	Fe7y=Be1y
Fe8	Fe8x=Fe1x+1.5	Fe8y=Be1y

The mathematical models of A-style blouse patterns are shown in Table D.30- D.31 in Appendix D.

2.1.6.7. Inspection of mathematical model of blouse pattern blocks

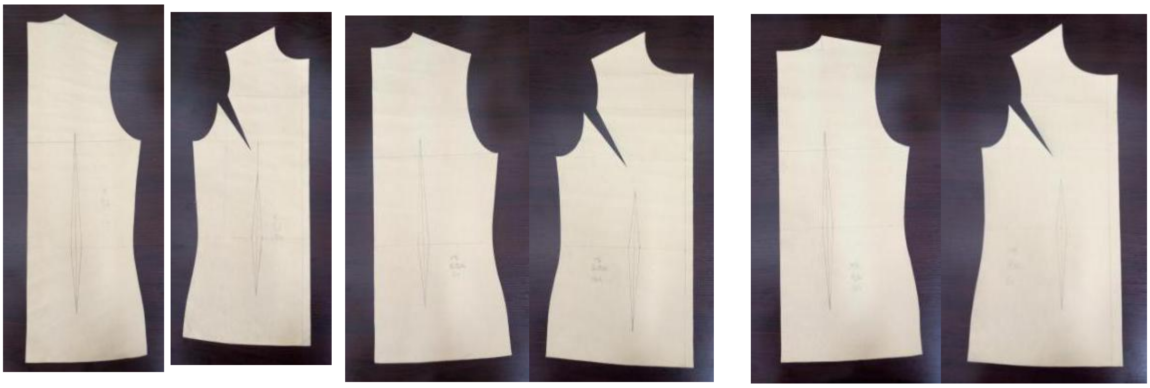
In this research, South Korea's CLO3D software was used as a virtual fitting platform.According to the normal production process, new structural approach, the pattern of blouses with different degree of fit and shapes were designed. CLO3D virtual try-on technology was used to do the three-dimensional virtual fitting. At the same time, virtual try-on effect was analyzed and evaluated, so as to make a reasonable correction to the new structural design method of the blouse, but also for the next step of standard dummy fitting to pave the way.

a b

Figure 2.11- 3D virtual model and size setting: a-3D virtual model, b-the size editor for 3D virtual model

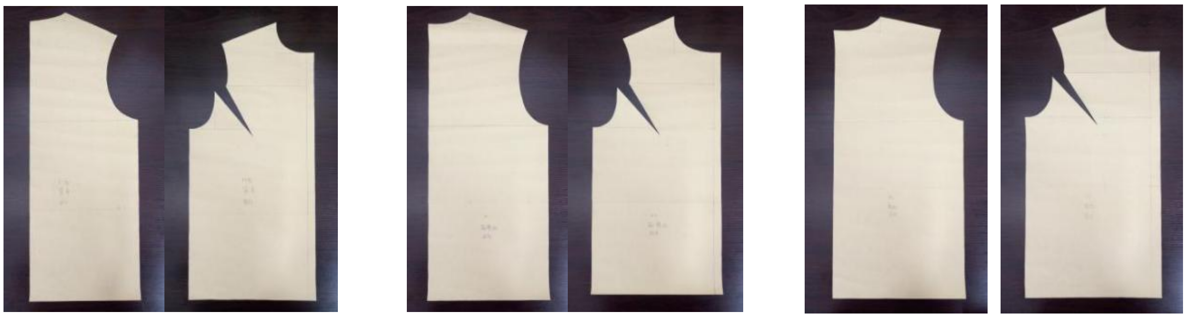
As shown in Figure 2.11, firstly, the 3D virtual model was obtained according to the 160/84A size of national standard body size table [76].

Then, the blouse pattern blocks were obtained using a new method of structural design. The pattern blocks were created in two versions: digital and using kraft paper, so that virtual and real fitting could be performed. The pattern blocks are shown in Figure 2.12.



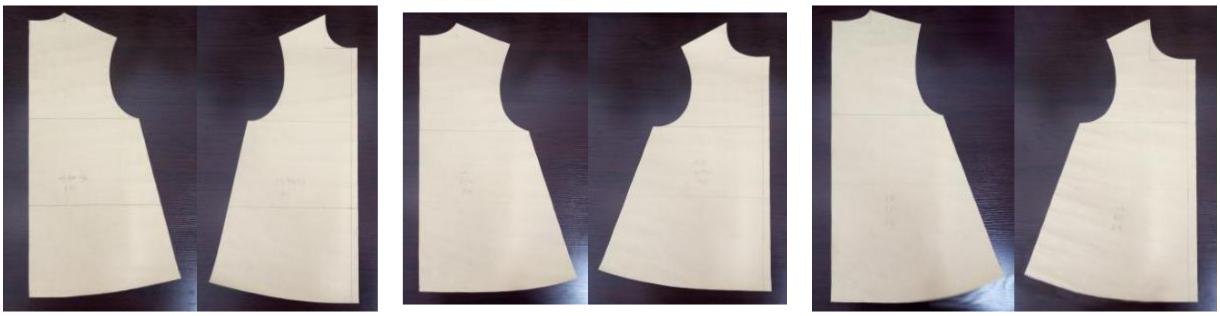
a b c

X-style blouse pattern



a b c

H-style blouse pattern



a b c

A-style blouse pattern

Figure 2.12 - Blouse patterns with different style: a - body-fitted, b - loose-fitted, c - looser-bodied

The two-dimensional blouse patterns were imported into the CLO3D, and the smart sewing tools in CLO3D were used to sew the front and back sections and the darts, according to the sewing principle of the blouse. Figure 2.13 shows the virtual fitting is done.

a b c

Virtual fitting effect diagrams of X-style blouse

a b c

Virtual fitting effect diagrams of H-style blouse

a b c

Virtual fitting effect diagrams of A-style blouse

Figure 2.13 -Virtual fitting effect diagram of blouses with different styles: a - body-fitted, b - loose-fitted, c - looser-bodied

Figure 2.13 shows that through the sewing of X, H, A-styles blouses and virtual fitting, blouses are well represented on the virtual model, and each style of the blouse is shown at 360 degrees in order to inspect virtual fitting effect with different perspective.And then virtual fitting effect diagrams were collected by the way of screenshot.

By observing virtual fitting effect with different perspective, analysis results were achieved:

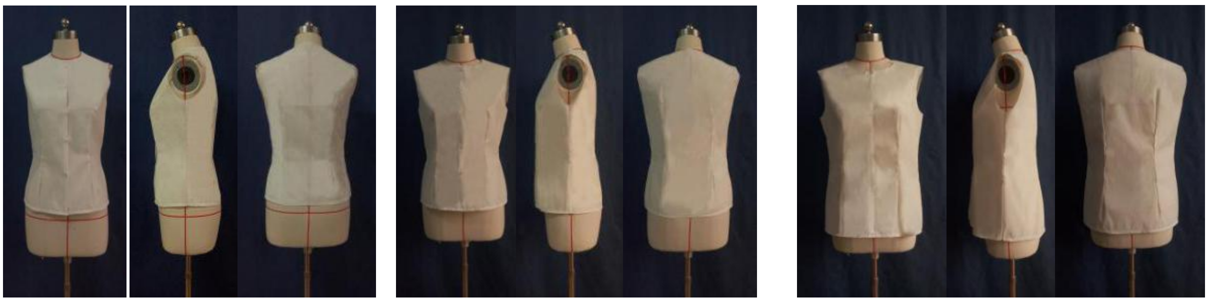
(1) The blouse with different silhouette respectively showed different shape characteristics, and the style of the blouse is very accurate;

(2) The ease of bust girth, waist girth and hip girth also changes along with the different fitdegree, no extra fold;

(3) The hem parallels the waist line, which accords with body piece structural balance;

(4) Neck width and neck depth meets the needs of different fitdegree, not too tight; the armhole depth is reasonable, which all expounds the rationality of the new structural design method of the blouse.

When the blouse patterns and the samples were completed, the blouse samples were fitted on the standard dummy. Figure 2.14 shows that the fitting effect of the blouse samples were took picture with three angles of view--front, back and side view.



a b c

Fitting effect diagrams of X-style blouses

a b c

Fitting effect diagrams of H-style blouses

a b c

Fitting effect diagrams of A-style blouses

Figure 2.14 -Fitting effect diagrams of blouse samples with different styles: a - body-fitted, b - loose-fitted, c - looser-bodied

By observing the fitting effect from different perspectives, the results are obtained:

1. On the whole, the shape of the blouse sample is accurate, which reflects the silhouette of blouse itself very well. The fitting degree of the sample is moderate, and the ease of bust girth, waist girth and hip girth are in accordance with the structural design requirements; Bust line, waist line and hem all parallel waist line of dummy, which accords with the requirements of body piece structural balance; The main structural line - the back center line, the front center line and the side seam are all located at the corresponding part of the dummy.

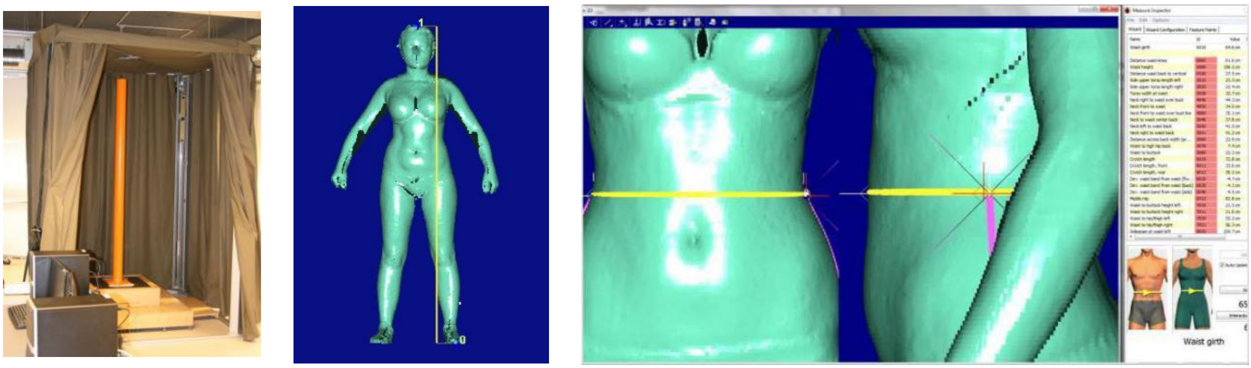
2. From the point of view of the details, the ease of neck girth is moderate, which accords with comfort requirements of human body; the shoulder seams basically were located on the shoulder lines of the dummy; bust width, back bust width, shoulder width and armhole curve were designed reasonably, which are all consistent with its style.

Therefore, the evaluation effect was consistent with that of virtual fitting, which verifies the rationality and practicability of mathematical model of blouse pattern blocks.

2.2. Database "Anthropometry"

2.2.1. Research methods and tools

In order to obtain and analyze the anthropometric measurements of the human body, the scanning processing was conducted by Vitus Smart XXL 3D body scanner (Human solution GmbH, Germany). Software Anthroscan (Human solution GmbH, Germany) was utilized for the visualisation, processing and evaluation of3D scan data, in general,delivered by the Vitus Smart XXL 3D body scanner. Anthroscan interactive measurements were used in place of the anthropometric measurements for the human body [13]. Then, the 3D scanning body were post processed and measured by 3D virtual try-on software CLO3D (CLO Virtual Fashion Inc., Korea) and Rhinoceros (Robert McNeel & Associates, USA). And SPSS (IBM, USA) software was used for statistical analysis.



a b c

Figure 2.15 - 3D scanning system: a - 3D body scanner, b - scheme of 3D body measurement, c - processing and evaluation of3D scan data in Anthroscan

2.2.2. Scanned body preparing and parameterization

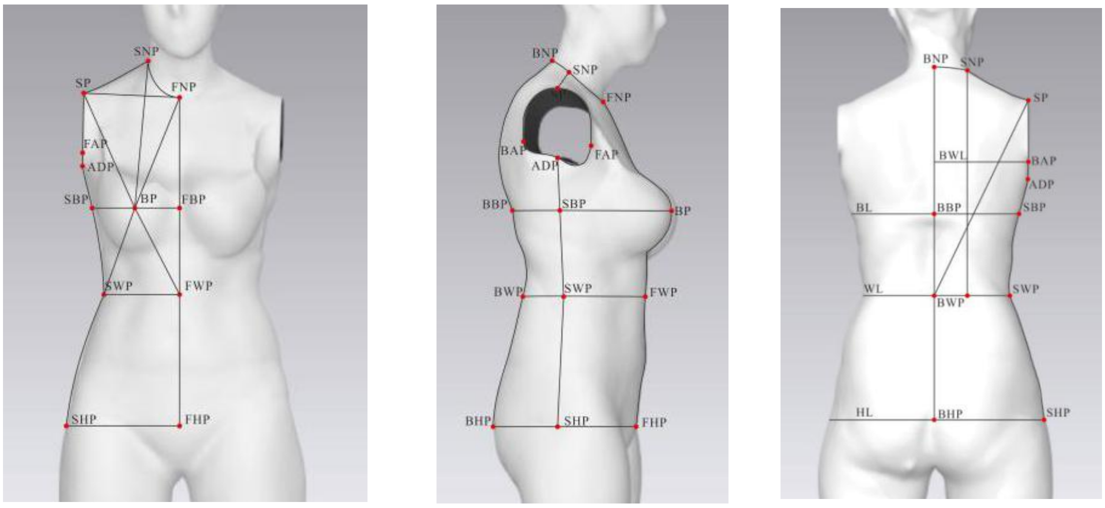
154 females aged 20 to 35 year have been measured by 3D laser scanner body VITUS Smart XXL (3 columns). 154 females were further grouped as Y

(76), A (48), B (24), C (6) body type in accordance with Chinese standard sizing systems for garments (GB/T 1335.1-2008) [35]. Software Anthroscan was used for collecting and converting 3D scanning data from 3D body scanner.Table 2.16 shows that the average measurements from body scans for different body type were obtained in terms of measurement parameters from Chinese standard sizing systems for garments (GB/T 1335.1-2008).

Table 2.16 - Average measurements from body scans for different body type

N.	Measurement parameters	Average measurements for different body type,cm			
		Y	A	B	C
1	Height	166	168	165	162
2	Neck height	142	143	140	138
3	Waist height	104	105	103	100
4	Bust girth	86	84	94	93
5	Waist girth	66	67	82	87
6	Hip girth	92	91	100	96
7	Neck girth	36	36	38	37
8	Length of cross shoulder over neck	38	38	39	39
9	Arm length	54	53	53	52

The avatars used for surface flattening were obtained by using software Anthroscan preprocessing the 3D scanning body.The avatars were imported into CLO3D software for constructing 3D wireframe of body-surface prototype. GB/T 16160-2017 standards [36] is used in the apparel industry for taking anthropometric measurements and locating anatomical landmarks on human bodies [121]. Figure 2.16 shows the feature points and the structural lines on avatar were set manually using software CLO3D.After the previous step, based on the feature structure lines, 3D wireframe of body-surface prototype has been created.



Front Side Back

Figure 2.16 - Structural lines of body-surface prototype based on avatar

3D wireframe of body-surface prototype were applied to generate the corresponding 2D pattern blocks using the flattening operation. The right half bodice's surface of 3D avatar were automatically and easily flattened into 2D body-surface patterns with zero eases.

As shown in Table 2.17, through analyzing 2D body-surface prototype of female scanning bodies, the schedule of body characteristics of torso part was created.

Table 2.17 - Average measurements of the crucial feature points from body scans for different body type

N.	Measurement parameters	Average measurementsfor different body type, cm			
		Y	A	B	C
Traditional dimensional features					
1	Length of SNP - SP (shoulder slope width)	11	11.5	12	11
2	Length of SNP - BP - FWP (Front waist length)	40	40	42	42
3	Bust width	18	17	19	17
4	Back width	15	16	16	17
New dimensional features					

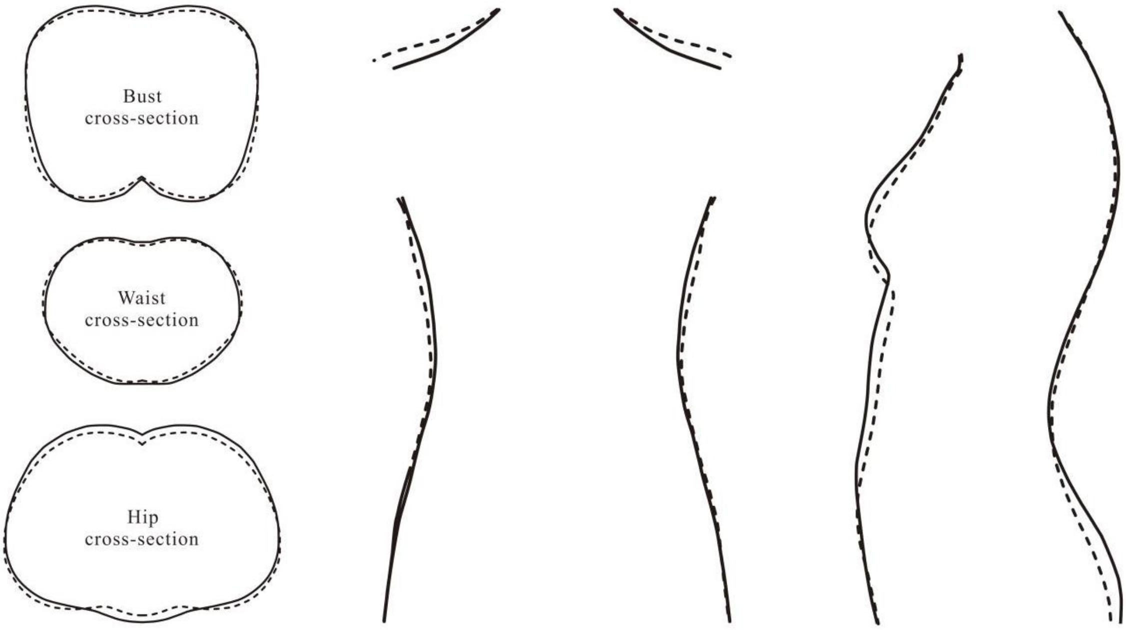
1	Length of SP - BP - WL	40	40	41	40
2	Length of SP -BP - FWP	42	41	43	43
3	Length of SP - FAP - FWP	35	36	36	37
4	Length of FNP-BP- FWP	34	36	36	36
5	Length of FNP-FBP-FWP	33	33	34	36
6	Length of ADP - SBP - SWP	22	22	19	22
7	Length of FWP - FHP	21	20	19	18
8	Length of FNP - SNP	11	11	11	11
9	Length of BNP - BBP - BWP	40	40	40	42
10	Length of SP - BAP - BWP	37	37	37	37
11	Length of SP - BWP	40	40	40	41
12	Length of BWP - BHP	21	20	20	18
13	Length of BNP - SNP	7	8	7	7
14	Length of FNP - SP	18	17	18	17
15	Length of FBP - BP	7	7	8	8
16	Length of FBP - BP - SBP	23	22	24	22
17	Length of FWP - SWP	16	16	20	20
18	Length of FHP - SHP	23	23	26	25
19	Length of BNP - SP	16	17	18	17
20	Length of BBP - SBP	20	19	21	22
21	Length of BWP - SWP	17	17	22	23
22	Length of BHP - SHP	22	24	25	24

Table 2.17 shows that 26 important measurements were obtained, which can be used to describe the features of female morphology and to create digital twins. Then, in order to compare the differences between avatars with measurements according to the Chinese standard GB/T 1335.1-2008 [35] and new measurements, a standard avatar with measurements in GB (see Table 2.16) and an individual avatar with measurements in GB and new measurements (see Tables 2.16 and 2.17) were generated in CLO3D, respectively.

a b

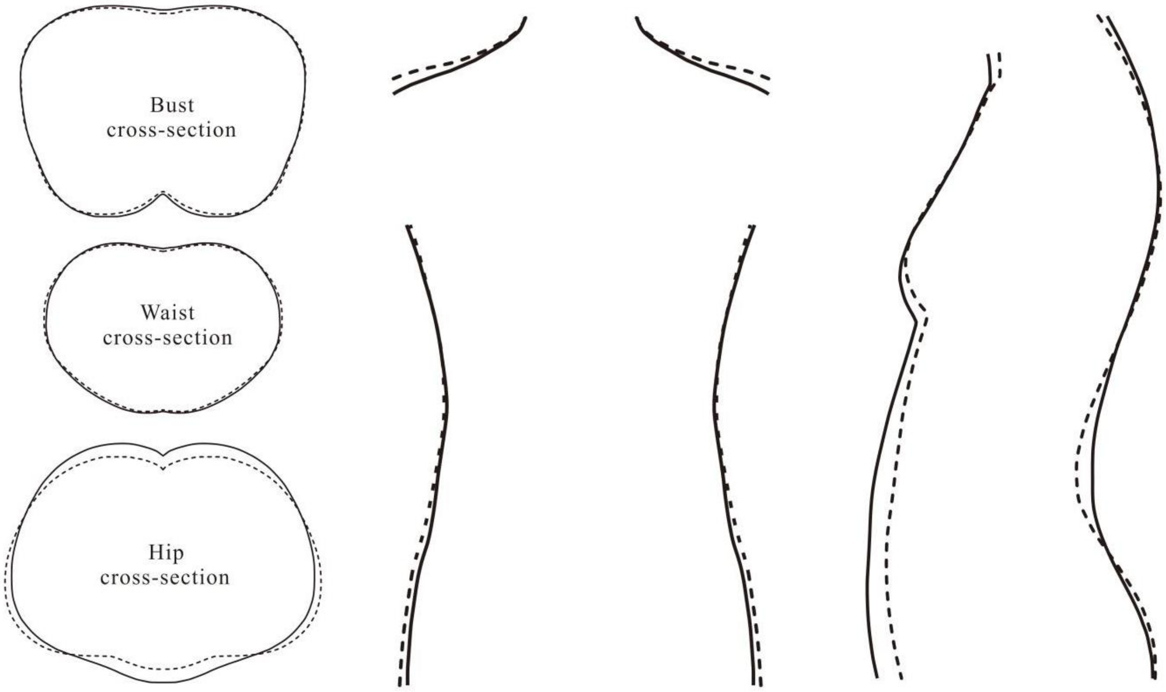
Figure 2.17 - Generation of avatar (168/84A) in CLO3D: a - standard avatar with measurements from the Chinese GB standard (see Table 2.16), b - individual avatar with GB and new measurements (see Tables 2.16 and 2.17)

As shown in Figure 2.17, standard avatar and individualized avatar were generated respectively in CLO3D. From the front and back view, the torso of avatars were highly similar. However, from the profile view, the differences of back curves and hip curves were observable. In order to conduct the detailed comparisons, the two avatars were sliced simultaneously in different directions in Rhinoceros to obtain the coronal, profile and horizontal cross-sections of the torsos. Figure 2.18 shows the cross-sections of avatars in coronal, profile and horizontal views (solid lines belong to individualized avatar, dashed lines belong to standard avatar).



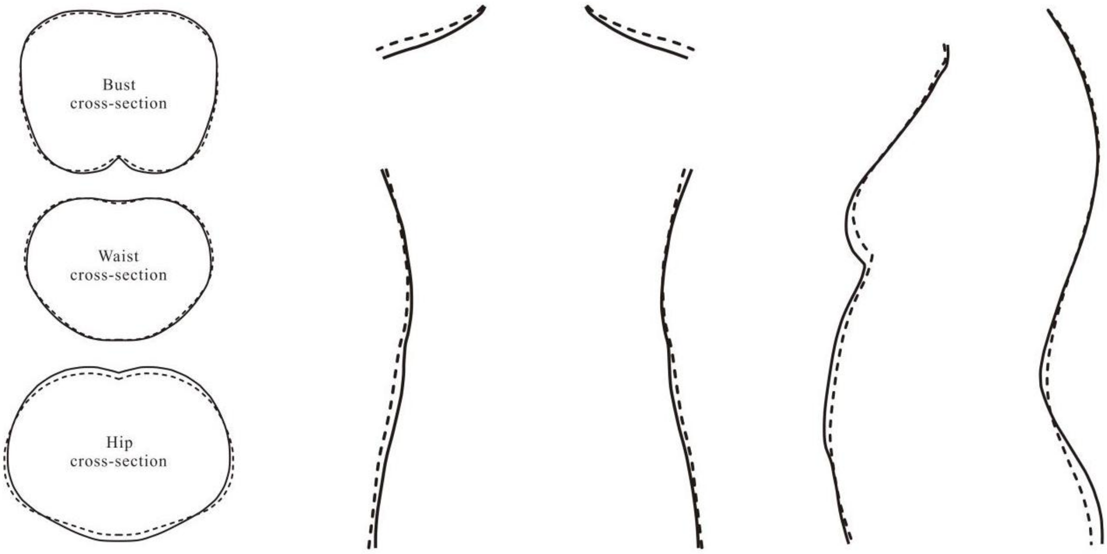
a b c

Cross-sections of avatars in Y type: a - torsos in horizontal view, b - torsos in coronal view, c - torsos in profile view



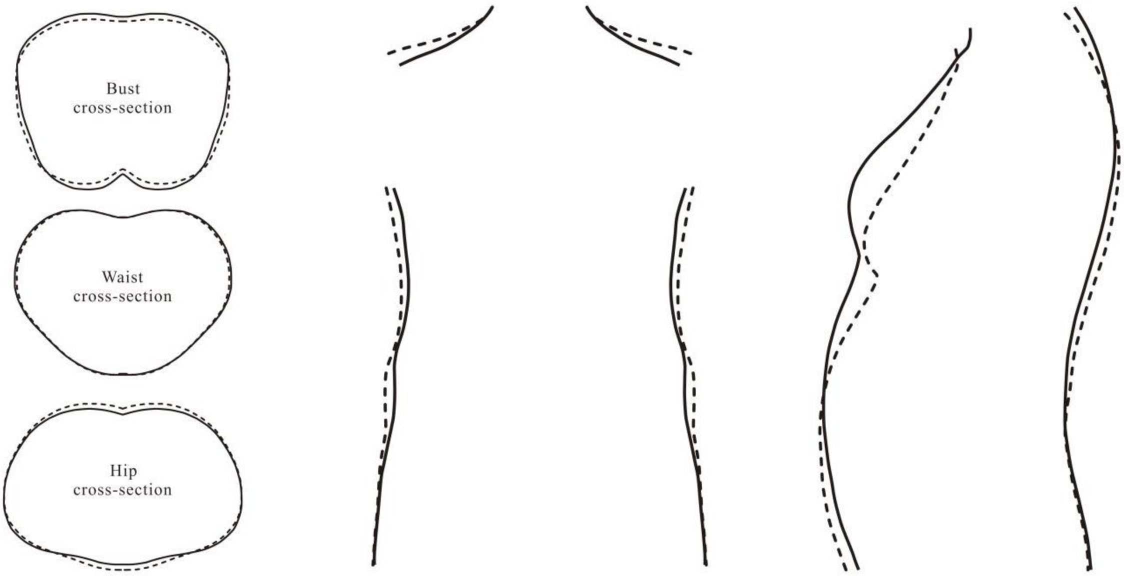
a b c

Cross-sections of avatars in A type: a - torsos in horizontal view, b - torsos in coronal view, c - torsos in profile view



a b c

Cross-sections of avatars in B type: a - torsos in horizontal view, b - torsos in coronal view, c - torsos in profile view



a b c

Cross-sections of avatars in C type: a - torsos in horizontal view, b - torsos in coronal view, c - torsos in profile view

Figure 2.18 - Cross-sections of avatars in Y type: a - torsos in horizontal view, b - torsos in coronal view, c - torsos in profile view

As shown in Figure 2.18, in horizontal view, the main torso sections of avatars were highly similar as the cross-sections were overlapped at the close positions. However, the detail differences in coronal and profile view were observable, such as in coronal view, the angle of shoulder lines and hip width of avatars were different.

Therefore, although the avatars had the generally similar exterior shapes and appearances, the detailed morphological features were different in their contours and body measurement. The individualized avatar with GB and new measurements were higher accuracy and more realistic than standard avatar with GB, which could be used to imported to CLO3D as the virtual body model for virtual try-on.

Summary of chapter 2

1.Based on the mathematical model of prototype and the control range of design variables for blouse pattern blocks, and the combination of linear regression models, andX, Hand A-style mathematical models with three different fitting degree were established, and blouse pattern blocks were parameterized respectively.

2. 154 females aged 20 to 35 year have been measured by 3D laser scanner body VITUS Smart XXL, and 154 females were further grouped as Y, A, B, C body type. Based on of which 3D wireframe of body-surface prototype was constructed. Through analyzing 2D body-surface prototype of female scanning bodies, 26 crucial measurements which can be used to describe the features of female morphology were obtained.

3. DEVELOPMENT OF NEW METHODS OF PATTERN BLOCK PREPARING BEFORE VIRTUAL TRY-ON

Pattern block is a prerequisite and basis for the realization of garment production. The correctness of pattern block has a great impact on the survival of the fit in the competition between enterprises. This chapter developed the method of checking pattern block before virtual try-on by integrating the generation of digital twin of human body, parameterization of pattern blocks of women' blouse, and parameterization of virtual systems "avatar - blouse".

The results obtained in this chapter are published in five articles [19, 20, 96, 97, 98].

3.1. Research methods and tools

In order to obtain and parameterizing the digital twin, 19 body measurements were used in parallel for the patterns analyzing. The criteria of blouse fit or misfit were respectively established to detect possible an errors in sewing patterns and improve the efficiency of its checking. By means of 3D CLO software, the surfaces of 3D avatar were flattened into 2D garment patterns with zero eases, and the body prototype of 2D pattern block of avatar can be used in blouse pattern block checking.

In order to obtain and analyze the virtual try-on effect, the virtual try-on processing was conducted by 3D virtual try-on software CLO3D (CLO Virtual Fashion Inc., Korea). Software Rhinoceros (Robert McNeel & Associates, USA) was utilized for the visualisation, processing and measuring of virtual twin of blouse. SPSS (IBM, USA) software was used for statistical analysis.

3.2. Body measurements of digital twin

Digital twin of real body was obtained by CLO3D and imported into Rhinos software to measure key-measurements which can influence on garment fit. Body measurements which are related to shoulder and neck areas, such as the distance from side neck point (SNP) to front waist position (FWP) across bust point (BP), the distance between shoulder point (SP) to FWP, the distance between SP to back waist position (BWP) and so on were chosen for analyzing the patterns[27]. Figure 3.1 and Table 3.1 shows the scheme of digital twin parameterization by means of 19 body measurements which can be used in parallel for the patterns analyzing.

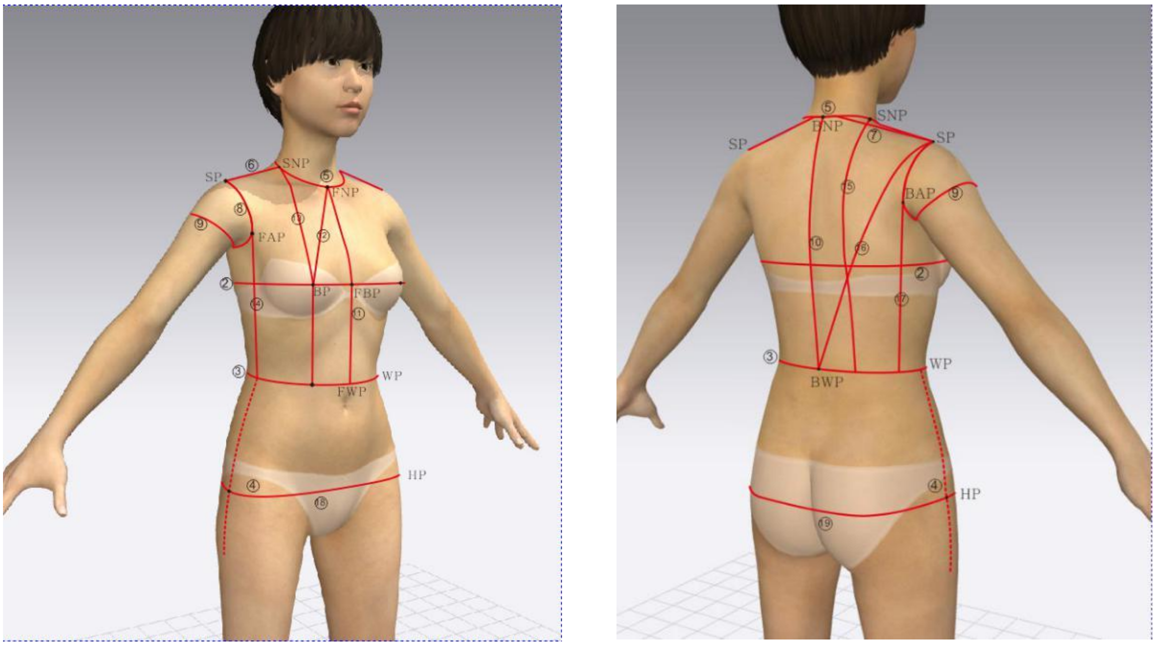


Figure 3.1 - Basic body measurements

Table 3.1 - Body measurements for checking the correctness of the patterns

Symbol	Measurement name	Body measurements of A type, cm
①	Height	168

②	Bust girth	84
③	Waist girth	67
④	Hip girth	91
⑤	Neck girth	36
⑥	Shoulder length	11.5
⑦	Shoulder width	32.9
⑧	Armhole girth	28.8
⑨	Upper arm girth	28.1
⑩	Back length	38
⑪	Length of *FNP-FBP-FWP*	33
⑫	Length of *FNP-BP-FWP*	36
⑬	Length of *SNP-BP-FWP*	40
⑭	Length of *SP-FAP-FWP*	36
⑮	Length of *SNP-BWP*	39.4
⑯	Length of *SP-BWP*	40
⑰	Length of *SP-BAP-BWP*	37
⑱	Front segment of hip girth($WHGF_B$)	45.2
⑲	Back segment of hip girth($WHGB_B$)	44.8

As shown Table 3.1, the digital twin 160/84A of most average typical female body type in China was established in terms of Chinese standard sizing system for garment in this research[119]. Then, by using the key-measurements of digital twin, the basis for analyzing the pattern block can be obtained further.

In order to obtain 2D bodies prototype, we used technology of 3D pattern block making in 3D CLO software. The surfaces of 3D avatar were flattened into 2D garment patterns with zero eases. The general scheme of flattening process is shown in Figure3.2 and 3.3.

Figure 3.2 shows that the lines were drawn on the avatar directly according to its morphological features and garment prototype.

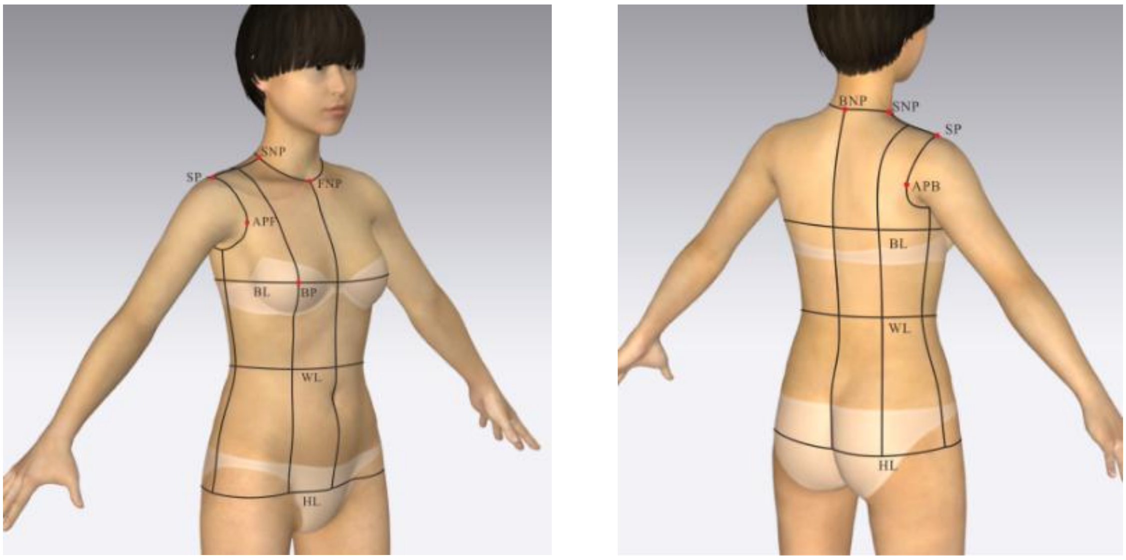
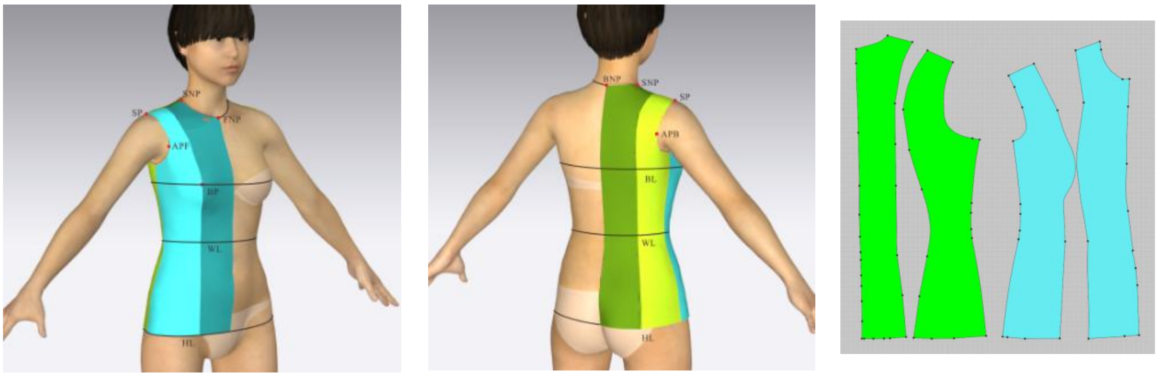


Figure 3.2 - Structural lines of garment prototype based on avatar

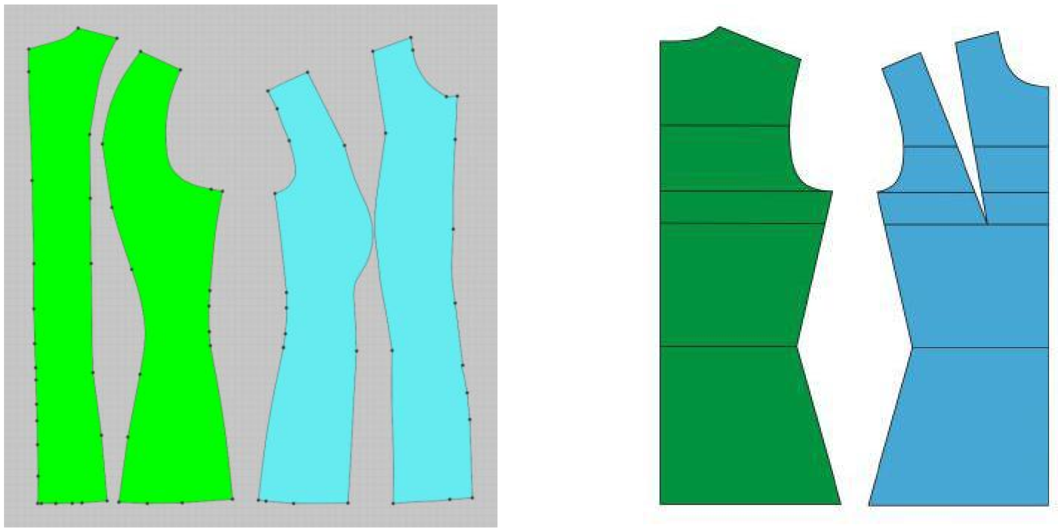
Figure 3.3 shows the surface of avatar which was obtained by using the flattening tool, and 2D pattern block of garment was obtained after flattening body prototype[107].



a b

Figure 3.3 - Scheme of flattening body prototype: a - Body prototype based on avatar, b - flattened 2D surface

Figure 3.4 shows that in order to ensure the accuracy of flattened 2D pattern block with zero eases, the 2D body prototype were checked and corrected.



a b

Figure 3.4 -Scheme of checking and correcting 2D body prototype: a - flattened 2D body prototype before modified, b - flattened 2D pattern blocks after modified

Firstly, according to structure principle of the Japanese Bunka's prototype [72], the change of dart and the combination of the front and back pieces of the flattened prototype were respectively carried out. The armhole curve and the front and back neckline of the body prototype were smoothed. In addition, the front center line, side line and back center line of the body prototype were modified to make them more regular and conform to the requirements of prototype structural design. At last, the lengths of key structural curves of 2D pattern blocks and main structural curves of 3D avatar, the sizes of each important structural part were compared with the measurements of avatar, respectively, such as lengths of armhole curves, length of bust line, and so on. Then, the flatted 2D bodies prototype can be used in analyzing of armhole line of blouse pattern blocks.

3.3. Parameterizing of pattern blocks

Ease is the extra allowance added on the body measurement in pattern construction. When designing ease allowance of pattern blocks for a ready-to wear garment style, the reasonable ease allowance of pattern blocks should prevent the garment from not fitting properly[60]. At the same time, as one of the important fit criteria of clothing, the lack or excess ease allowance to back length all will affect the wearer's comfort and activity. Therefore, before virtual sewing by patterns, the positions of the both waist lines - digital twin and pattern - should be known.

3.3.1. Graphic-mathematical model for measuring ease allowance of pattern blocks

This study focuses on the ease allowance as the core evaluation criteria for predicting the accuracy of blouse pattern blocks. Figure 3.5 shows how to describe2D pattern block, the ease allowance was indicated as projection on X and Y axis.

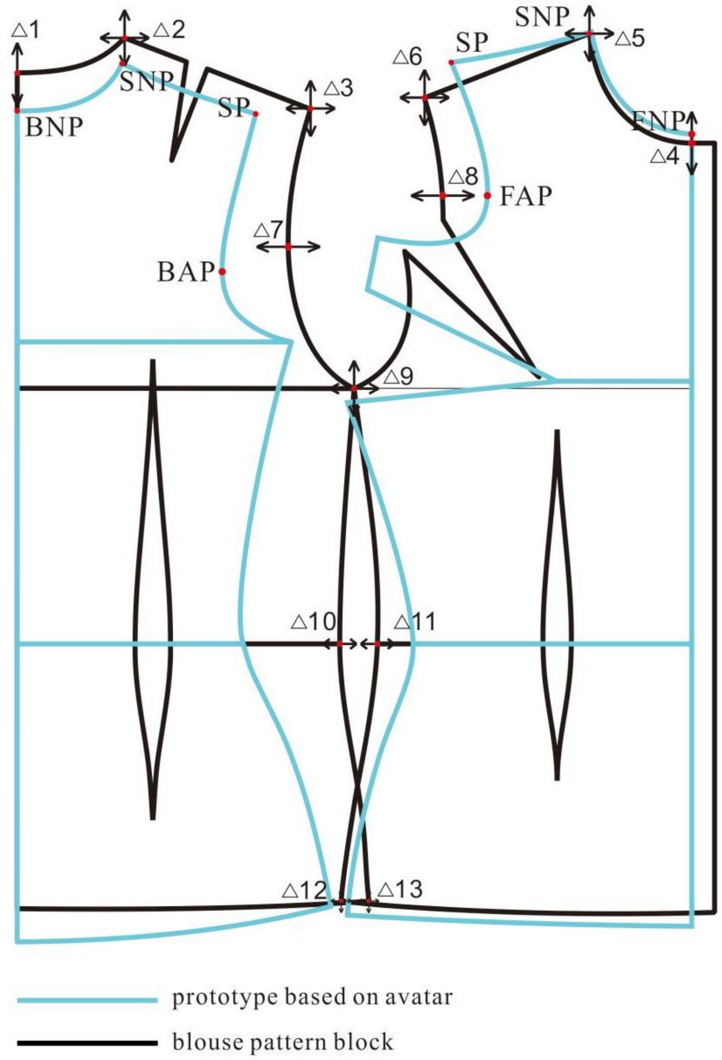


Figure 3.5-The scheme of overlapping blouse pattern blocks and body prototype

Next abbreviations were used in Figure 3.5. △ is the distance or range between specific point of body prototype and corresponding point of pattern block, △1 is the range between the both BNP, △2is the range between the both SNP, △3 is the range between the both SP, △4 is the range between the both FNP, △7 is the range between the both APB, △9 is the range between the both upper points of back seams, △10 is the range between the both intersections of the waist lines and the seam lines in back, △13 is the range between the both bottom points of seam lines in front.

As shown in Figure 3.5, each blouse pattern blocks and the body prototype were overlapped based on the avatar to obtain the ease values of blouse pattern blocks in X and Y directions respectively.Table 3.2 shows the ranges of ease allowance of blouse pattern blocks in the directions of X-axis and Y-axis were calculated respectively.

Table 3.2 - Ranges of ease allowance of blouse in body-fitted style with X, H and A

Front X / Front H / Front A									
X	Ease allowance indexes, cm		△4	△5	△6	△8	△9	△11	△13
	MIN.	X	0	-1	0.3	1	-1.1	-1	-1.4
		H	0	0	1.9	2.7	0.2	4.7	0.2
		A	0	-1.4	1.9	2.1	0.4	7.1	3.9
	MAX.	X	0	2.8	2.7	3.2	1.3	3.2	5.2
		H	0	0.5	2.9	3.6	1.2	5.7	1.2
		A	0	6	5.4	5.8	1.1	8.4	6.6
	AVG.	X	0	0.5	1.8	2.7	-0.3	0.5	0.4
		H	0	0.1	2.3	3.1	0.9	5.4	0.9
		A	0	1.6	3.1	3.8	0.7	7.6	5.1
Y	MIN.	X	-15.1	-1.6	-4.4	0	-3.9	0	-6.1
		H	-4.3	-1.1	-4	0	-0.4	0	-6.4
		A	-8	-3.9	-4.6	0	0	0	-14.9
	MAX.	X	0	0	-1.9	0	-2.3	0	6.9
		H	-1.1	0.3	-2.2	0	0.5	0	-1.9
		A	0.6	0	-1.9	0	4.3	0	9.6
	AVG.	X	-2.4	-0.7	-2.9	0	-3	0	-1.7
		H	-2.2	-0.4	-3.3	0	0.2	0	-3.7
		A	-2.9	-1.8	-3.3	0	2	0	-6.6
Back X / Back H / Back A									
X	Ease allowance indexes, cm		△1	△2	△3	△7	△9	△10	△12

	MIN.	X	0	0	2.5	3.3	2.2	0.9	0.7
		H	0	0	2.9	3.6	1	5.5	0.9
		A	0	-0.9	3.2	2.8	3.3	6.6	0.6
	MAX.	X	0	2.8	3.7	4.6	4.8	5.6	3.3
		H	0	0.5	4	5.1	5.8	9.1	3.1
		A	0	7	7	7.3	6.8	11.5	7.3
	AVG.	X	0	0.5	3	4	3.6	3.3	1.8
		H	0	0.2	3.6	4.2	3.8	7.4	1.7
		A	0	2	4.5	4.6	4.5	8.7	3.7
Y	MIN.	X	-0.4	0	-0.8	0	-4.6	0	-5.8
		H	0.9	0	-0.2	0	-4.4	0	-6.6
			0.8	0	0	0	-5.7	0	-17.1
	MAX.	X	1.9	1.8	1	0	-3.2	0	7.2
		H	0.5	0.8	0.3	0	-3.4	0	-2.1
		A	2.2	2	0.8	0	-3.4	0	9
	AVG.	X	1.6	0.7	0.2	0	-3.7	0	-1.3
		H	1.3	0.4	0	0	-3.9	0	-3.9
		A	1.5	0.8	0.4	0	-4.1	0	-8.6

Таблица 3.3 - Ranges of ease allowance of blouse in loose-fitted style with X, H and A

Front X / Front H / Front A									
X	Ease allowance indexes, cm		△4	△5	△6	△8	△9	△11	△13
	MIN.	X	0	0	0.5	1.5	0	-1	-0.7
		H	0	0	2.9	3.9	2	6.5	1.9
		A	0	-1.4	2.2	3	1.5	5.3	1.5
	MAX.	X	0	6.5	7.5	7.3	3	5.5	5
		H	0	1.1	6	7.1	3	7.5	3
		A	0	4.7	6.8	7.6	3	8.4	5
	AVG.	X	0	1.1	2.3	3.1	1.1	2	1.5
		H	0	0.5	4.3	5.1	2.5	6.9	2.3
		A	0	1.1	4.4	4.9	2	6.9	3.6
Y	MIN.	X	-12.7	-3.4	-5.1	0	-5.7	0	-6.4
		H	-6.1	-4.6	-6.5	0	-3.3	0	-16.8
		A	-10.2	-4.7	-5.8	0	-5.4	0	-19.8

	MAX.	X	0	1.6	-1.6	0	-3.7	0	6.9
		H	-1.6	-0.9	-2.8	0	0	0	-0.4
		A	0.4	-0.9	-2	0	3.2	0	11.1
	AVG.	X	-3.7	-1.3	-3.5	0	-2.9	0	-0.5
		H	-3.5	-1.7	-3.7	0	-1.5	0	-6.4
		A	-5	-2	-3.8	0	-0.4	0	-4.2
Back X / Back H / Back A									
X	Ease allowance indexes, cm		△1	△2	△3	△7	△9	△10	△12
	MIN.	X	0	0	2.7	3.4	-3.7	1.3	0.5
		H	0	-0.2	3.8	4.6	6.8	10.1	4.1
		A	0	0.3	4	3.9	5.8	9.3	3.7
	MAX.	X	0	7.7	8.7	9.3	8.3	10.2	6.6
		H	0	0.9	7.2	9.1	8.8	12.1	6.1
		A	0	4.7	10.7	11.3	12.3	16	10.9
	AVG.	X	0	1.2	3.4	4.3	4.3	4.4	2.5
		H	0	0.4	5	5.9	8	11.2	5
		A	0	1.7	6	6.5	8.3	12.2	7.1
Y	MIN.	X	-1.4	-1.5	-1.1	0	-9.8	0	-6.6
		H	1.1	0.4	-1.4	0	-7.7	0	-8.1
			-3	-0.9	-0.6	0	-11.2	0	-20.1
	MAX.	X	2.1	0.9	1.8	0	-3.2	0	7.1
		H	1.9	0.8	0.8	0	-5.7	0	17.1
		A	1.6	1.9	2.4	0	13.3	0	14.7
	AVG.	X	1.2	0.3	0	0	-4.5	0	-0.5
		H	1.6	0.6	0	0	-6.6	0	-1.5
		A	0	0.7	1	0	-2.6	0	-1.9

Таблица 3.4 - Ranges of ease allowance of blouse in looser-fitted style with X, H and A

Front X / Front H / Front A									
X	Ease allowance indexes, cm		△4	△5	△6	△8	△9	△11	△13
	MIN.	X	0	0	2.5	3	2.5	0.2	0.9
		H	0	0	3.1	4.2	3.2	7.5	3

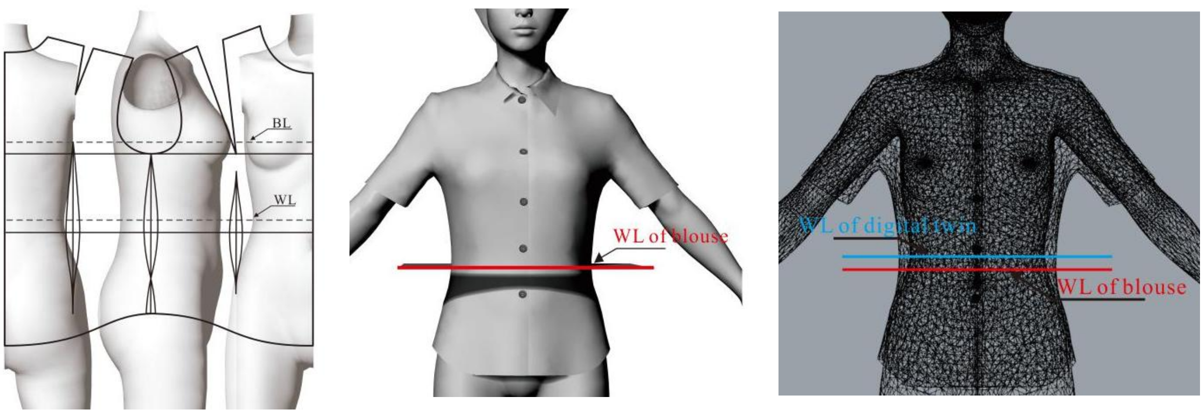
		A	0	-0.4	2.1	2.7	2	6.8	2.8
	MAX.	X	0	0.7	4	5.1	5.1	3	3
		H	0	7	15.5	13	12	14.4	9.9
		A	0	4.6	12.9	13	12	18.7	20.4
	AVG.	X	0	0.3	3.5	4	3.3	1.6	1.6
		H	0	0.9	4.9	7.2	5.4	8.7	4.2
		A	0	1	6.3	6.9	5.3	11.1	9.9
Y	MIN.	X	-6,3	-2.7	-4.3	0	-4.4	0	-9.9
		H	-9,7	-4.7	-8.2	0	-8.3	0	-13.9
		A	-6,7	-2.6	-6.4	0	-8.3	0	-21.4
	MAX.	X	-2.3	-0.9	-2.4	0	0	0	3.8
		H	0	0	-2.2	0	-1.4	0	3.2
		A	-1.1	-0.5	-2	0	0.3	0	0
	AVG.	X	-9.7	-1.7	-3.6	0	-2.1	0	-0.9
		H	-5.2	-2.1	-4.8	0	-3.9	0	-8.4
		A	-4.8	-1.6	-4.4	0	-2.6	0	-12.9
Back X / Back H / Back A									
X	Ease allowance indexes, cm		△1	△2	△3	△7	△9	△10	△12
	MIN.	X	0	0	3.7	4.2	6.3	3.4	2.2
		H	0	-0.2	4.1	5.6	7.1	10.4	4.4
		A	0	-0.2	4.2	5	7.3	10.6	4.6
	MAX.	X	0	1	5.7	6.1	9.8	7.1	4
		H	0	1.7	11.7	13	13.8	17.1	11.1
		A	0	4.9	14.3	15.1	21.8	27.3	25.6
	AVG.	X	0	0.5	4.6	5.3	7.7	5.4	3.3
		H	0	0.6	7.1	8	9.3	12.5	6.5
		A	0	1.3	7.5	8.3	11.3	16.4	13.4
Y	MIN.	X	1,6	0.6	-0.7	0	-7.2	0	-12.1
		H	0,9	0	-0.9	0	-12.2	0	-14.1
			-0,4	0	-2.2	0	-12.2	0	-21.8
	MAX.	X	1,8	0.9	1.3	0	-5.7	0	4.5
		H	2,9	1.8	1.3	0	11.3	0	2.9
		A	2,3	1.2	2	0	-3.6	0	-0.8
	AVG.	X	1,7	0.8	0.3	0	-6.2	0	-1.6
		H	1,7	0.7	0.4	0	-6.9	0	-9
		A	1,3	0.7	0	0	-7.4	0	-14

As shown in Table 3.2-3.4, the ease amount of the key parts of the blouse pattern block were obtained by measuring the difference value between the important parts of the blouse pattern blocks and the body prototype. The range of ease allowance of blouse pattern blocks in the directions of X-axis and Y-axis were calculated respectively. Based on this,a “avatar-blouse” prediction system for the accuracy of blouse pattern was established to predict the accuracy of pattern blocks.

3.3.2. Method of ease allowance to back length analyzing

In addition to considering the fit degree of neck line and armhole line, the rationality of ease allowance to back length also has a great influence on the fit degree of the pattern blocks.

When comparing a back length of pattern with body measurement “Back length”,two ease allowances - to back length and BNP could be calculated. Thus, in this study, in order to find the ease allowance to back length, the complicated procedure of calculating the ease allowance to back length was carried out. Figure 3.6 explains the procedure how the ease to back length could be calculated.



a b c

Figure 3.6 - 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

Firstly, 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, as shown in Figure 3.6 (a). Secondly, the blouse render was generated from the patterns on digital twin in CLO3D, as shown in Figure 3.6 (b) in accordance with waist line of patterns. Thirdly, after exporting the file into Rhinos, the blouse render was transformed in the transparent triangulation grid, as shown in Figure 3.6 (c). The anthropometric waist line of the digital twin was defined as the narrowest place of torso through a transparent mesh.

Because the both waist lines of the digital twin and patterns were determined, the ease allowance to back length which equal to the distance between them could be measured. Table 3.5 shows the part of ease allowance to back length of blouse in X, H and A styles, see Appendix E.

Table 3.5 - Ease allowance to back length of blouse in X, H and A styles

Ease allowance to back length of blouse, cm					
X-style		H-style		A-style	
MIN.	-3	MIN.	-0.2	MIN.	-0.1
MAX.	1	MAX.	0.9	MAX.	0.9
AVG.	-0.2	AVG.	0.3	AVG.	0.5

In addition, in order to find the ease allowance to BNP, by comparing back length of pattern with back length of body prototype, the ease allowance to BNP could be calculated. Figure 3.7 shows the scheme of calculating the ease allowance to BNP.

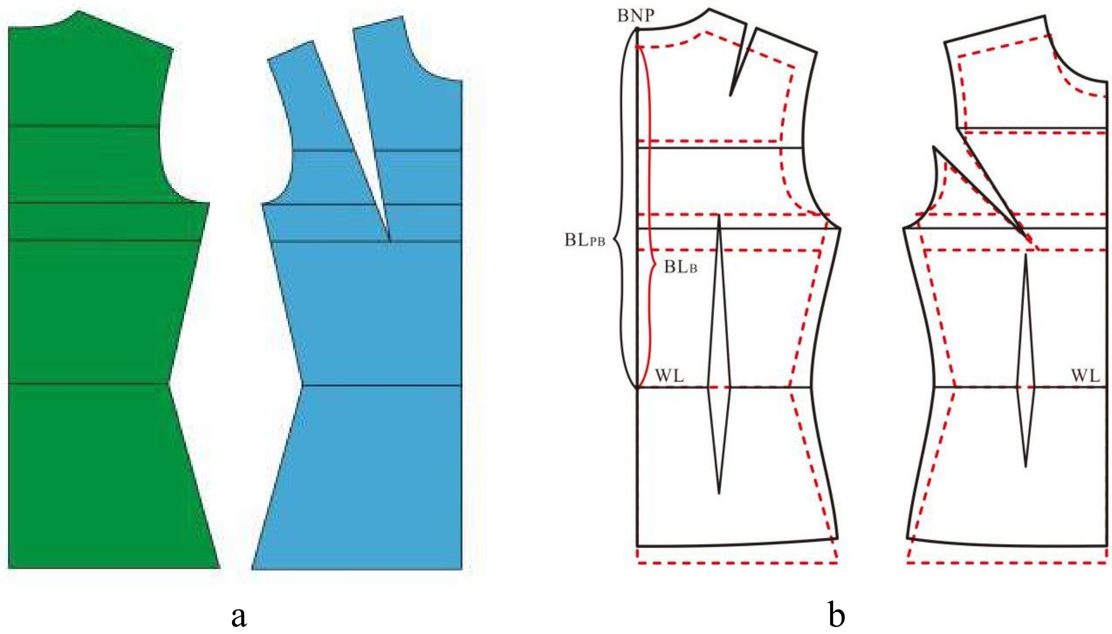


Figure 3.7 - Scheme of calculating the ease allowance to BNP: a -flattened 2D body prototype, b - overlapping body prototype with blouse pattern blocks

Firstly, the flattening body prototype which presents its morphological features was generated (As Section 3.3.1), as shown in Figure 3.7 (a).Secondly, based on the waist line, the body prototype and the blouse pattern blocks were overlapped respectively, as shown in Figure 3.7 (b). Because the both back length of the digital twin and patterns were determined, the ease allowance to BNP which equal to the distance between them could be measured. Table 3.4 shows the part of ease allowance to BNP of blouse in X, H and A styles, see Appendix E.

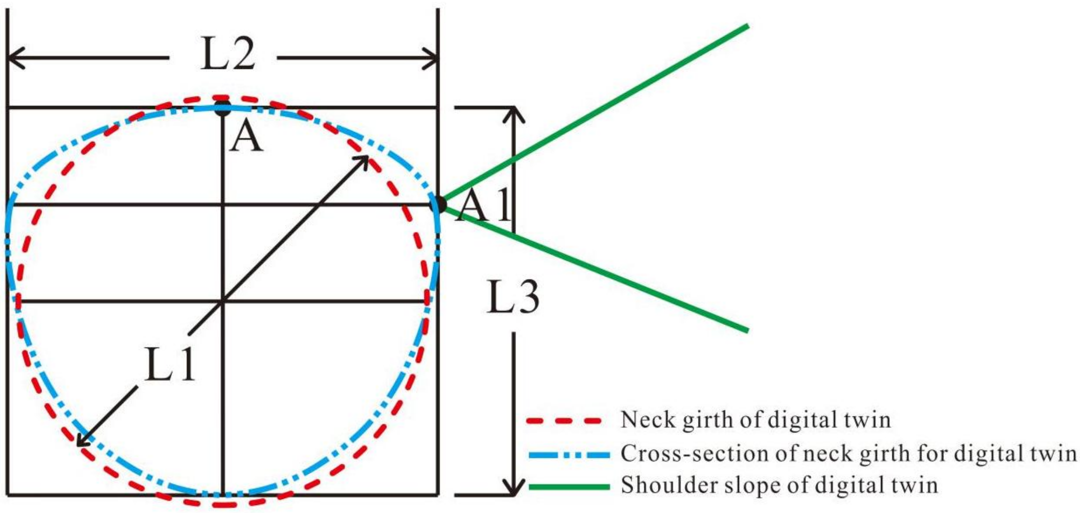
Table 3.4 - Ease allowance to BNP of blouse in X, H and A styles

Ease allowance to BNP of blouse, cm					
X-style		H-style		A-style	
MIN.	-3	MIN.	-0.7	MIN.	-0.1
MAX.	1.3	MAX.	1	MAX.	0.9
AVG.	-0.2	AVG.	0	AVG.	0.5

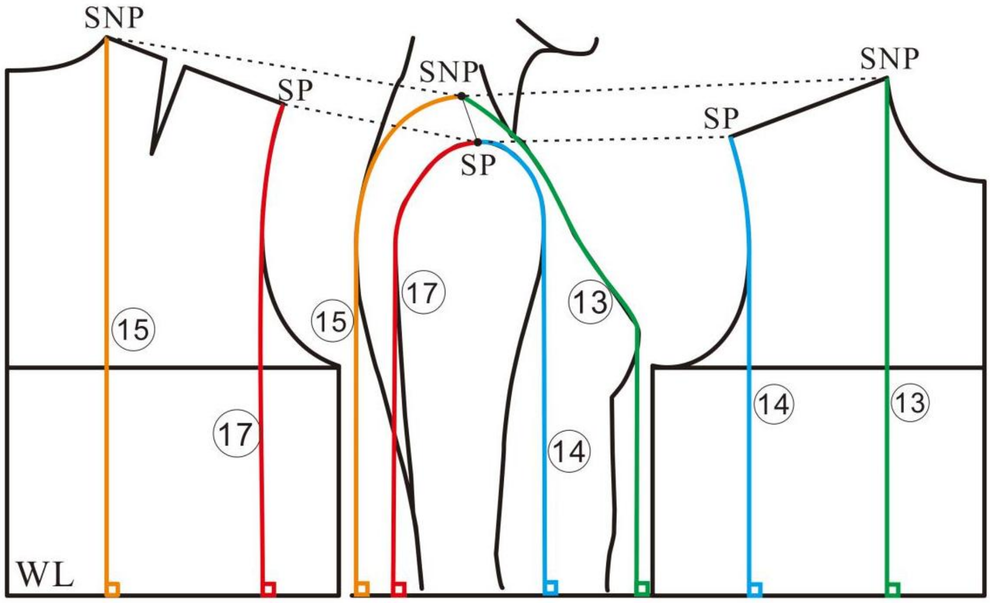
Then, these values of ease allowances - to back length and BNP will not only help to put on the patterns in according with outline shape and style of blouse, but also provide the basis for checking the fit degree of the pattern blocks.

3.3.3.Method of neck line preparing

In addition to take into account the fit degree of bust, waist and hip line, the comfort of neck line also greatly affect the fit of the pattern block. Therefore the cross-section of neck girth from digital twin was generated to check the pattern block. Figure 3.8 shows the method of obtaining cross-section of basic neck girth and shoulder line for checking the pattern block.



a



b

Figure 3.8 -Scheme of neck line preparing for checking the pattern blocks: a - drawing cross-section of neck girth and shoulder slope of digital twin, b - relationship between the body measurements and the direction of shoulder lines of the pattern block

As shown in Figure 3.8 (a), firstly, based on the neck girth of the digital twin (As Section 3.2), the cross-section of neck was drawn by means of the diameter of neck and a series calculations by equations.

$$L1=\frac{NG}{\pi} \quad (3.1)$$

$$L2=0.95L1 \quad (3.2)$$

$$L3=1.05L2 \quad (3.3)$$

where: L1 is the theoretical diameter of neck girth, L2 is the transverse diameter, L3 is the anteroposterior diameter, A is *BNP*, A1 is *SNP*.

Secondly, in order to obtain the shoulder lines consistent with the shoulder slope of the digital twin, five body measurements - the distances between SP and FWP (14), SNP and FWP (13), SP and BWP (17), SNP and BWP (15) and shoulder length from the digital twin were used (As Section 3.2). As shown in Figure 3.8 (b), the distance between SP and FWP of digital twin (14) are equal to the distance between SP and FWP of pattern block, and the distance between SNP and FWP of digital twin (13) are equal to the distance between SNP and FWP of pattern block, and the distance between SP and BWP of digital twin (17) are equal to the distance between SP and BWP of pattern block, and the distance between SNP and BWP of digital twin (15) are equal to the distance between SNP and BWP of pattern block. Then, according to shoulder length of digital twin, two angles of shoulder sloping of the front and the back were obtained[38].

Thirdly, based on A1 point, two angles of shoulder sloping of digital twin were overlapped with cross-section of neck girth. Finally, the basis which is reflecting the body morphology and combining the shoulder angles and cross-section of neck girth was obtained for checking the pattern block.

Because the neck line of digital twin were determined, the ease allowance of neck line for pattern blocks could be measured. Table 3.7 shows the part of ease allowance to neck line of blouse in X, H and A styles, see Appendix E.

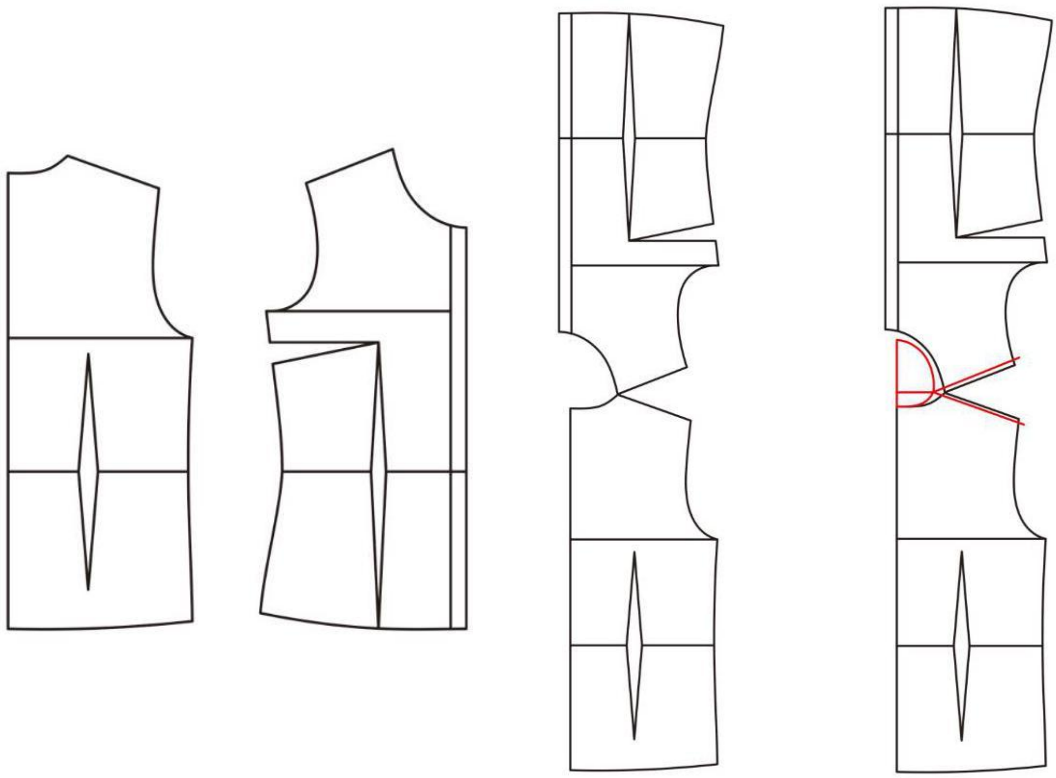
Table 3.7 - Ease allowance to neck line of blouse in X, H and A styles

Ease allowance to neck line of blouse, cm					
X-style		H-style		A-style	
MIN.	-3	MIN.	-0.7	MIN.	-0.1
MAX.	1.3	MAX.	1	MAX.	0.9
AVG.	-0.2	AVG.	0	AVG.	0.5

As shown in Table 3.7, the ease allowance of neck line for blouse pattern blocks with X, H and A style were measured respectively. Thus, the basis of checking the correctness of neck line of blouse pattern blocks were obtained, see Appendix E.

3.3.4. Method of neck and shoulder lines analyzing

The structural lines of the pattern blocks must follow the natural lines of wearers. Out-of-line pattern blocks will show poor postures and wearers will not feel comfortable. Moreover, shoulder lines of pattern block without conforming to the morphological characteristics of the human body will cause extra wrinkles and folds in the garment [56]. Therefore, as an important criteria of clothing fit, right shoulder lines location of the pattern blocks should be known. Figure 3.9 explains the scheme how the neck and shoulder lines location could be analyzed.



a b c

Figure 3.9 -Scheme of checking neck and shoulder lines: a - an initial patterns, b - patterns with closed neck line, c - pattern with closed neck line overlapped with Figure 3.8

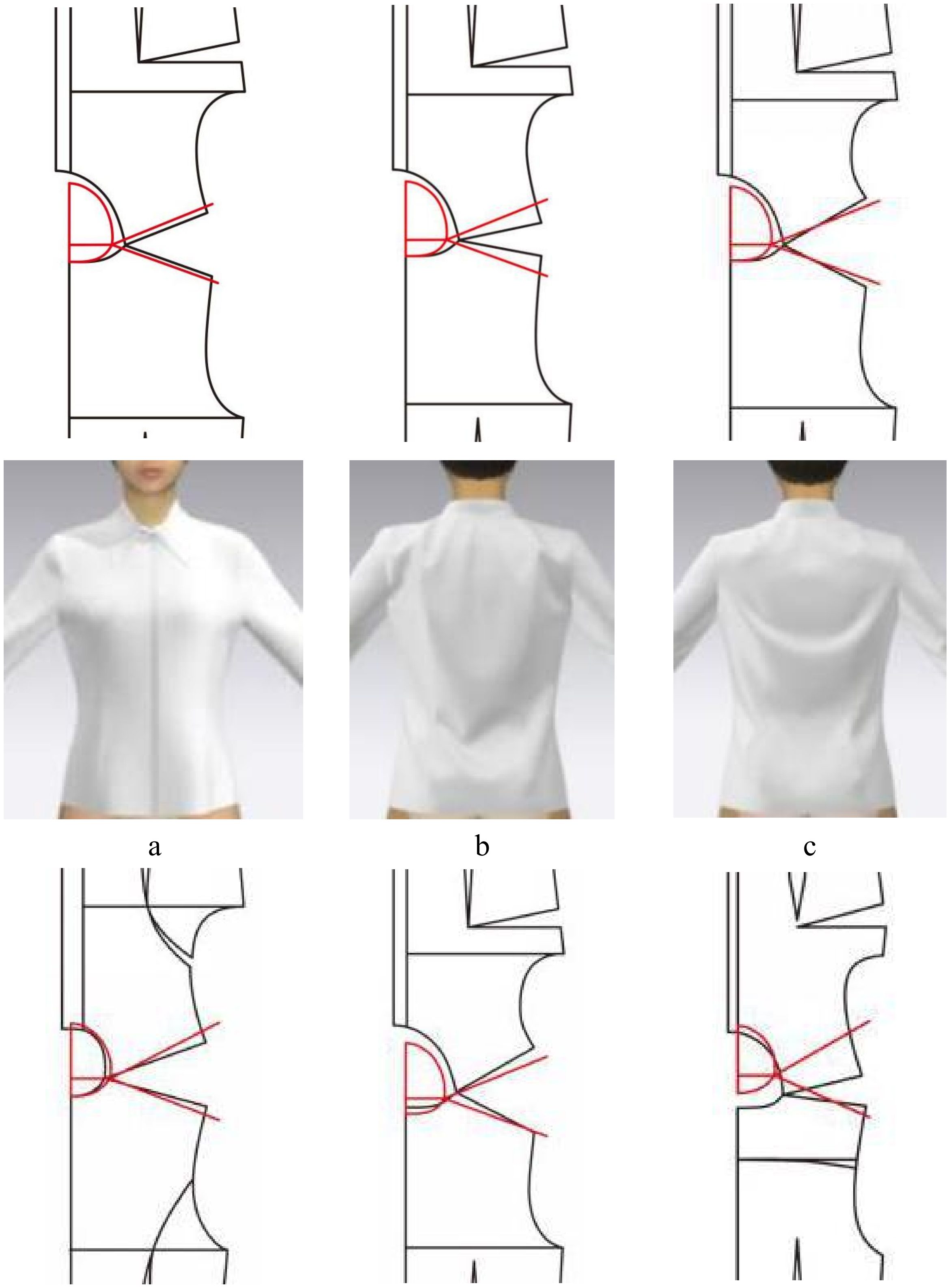
The neck and shoulder lines of blouse pattern blocks were checked by following three steps:

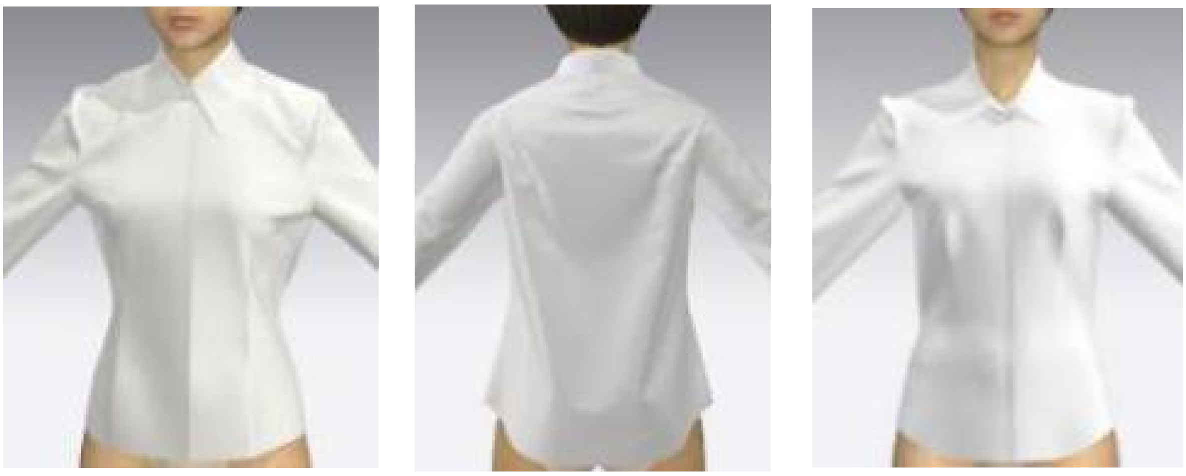
Firstly, based on SNP, the front and the back of patterns were coincided, and the neck girth of digital twin and the neck line of the patterns were overlapped, as shown in Figure 3.9 (b).

Secondly, the neck girth and shoulder lines of the digital twin as shown in Figure 3.8 were overlapped on the patterns in according with the ease to BNP obtained (See Table 3.6). Because the ease to BNP of pattern blocks is 0cm, the BNP of pattern blocks and the digital twin were coincided, as shown in Figure 3.9 (c).

Finally, the neck and shoulder lines of digital twin were compared with the similar lines of patterns to check the both shoulder lines.

Figure 3.10 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.


a
b
c



d e f

Figure 3.10 - Possible variations for the mutual arrangement of identical lines of the digital twin and patterns and the corresponding appearance of virtual try-on

Figure 3.10 (a) shows the situation when the neck girth of digital twin is located inside the patterns neckline, and the shoulder lines of the both are parallel. Fulfillment of these conditions means that the patterns is adequate to the morphological features of the digital twin, and the render will have a good fit.

Figure 3.10 (b) shows the correct location of the both neck lines, however, there is no parallelism of shoulder lines, which (if shoulder pads absence) can lead to non-vertical directions of edges and seams and the possible arising of folds on the shoulder and back.

The situations of Figure 3.10 (c), (d) will lead to the appearance of a defect because the shoulder line of patterns are inconsistent with the digital twin.

And then, in Figure 3.10 (e), (f), several defects will be present at once: horizontal folds on the back under the collar, and vertical folds on the sides and the bust part.

In addition, because the shoulder lines of digital twin were determined, the front and back angle of shoulder lines of difference between digital twin and pattern blocks could be measured. Table 3.8 shows the part of huge data for the angle of shoulder lines of difference between digital twin and pattern blocks with X, H and A style, see Appendix E.

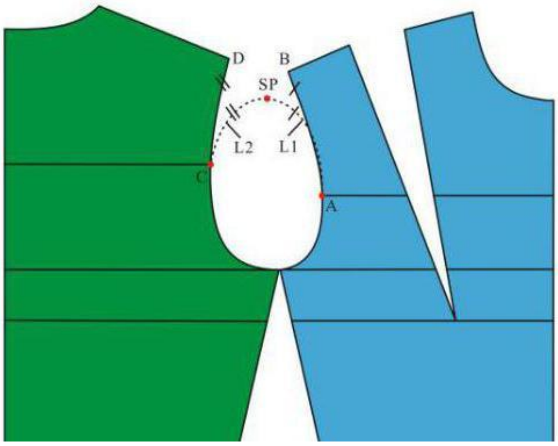
Table 3.8 - Angle of shoulder lines of difference between digital twin and pattern blocks in X, H and A styles

Angle of shoulder lines of difference between digital twin and pattern blocks, degree					
X-style		H-style		A-style	
Front					
MIN.	-11.5	MIN.	-12.7	MIN.	-14.3
MAX.	0	MAX.	-2	MAX.	-2
AVG.	-3.2	AVG.	-5.5	AVG.	-5.7
Back					
MIN.	-12.7	MIN.	-14	MIN.	-16
MAX.	4.1	MAX.	-5	MAX.	-3
AVG.	-5.7	AVG.	-9.2	AVG.	-8.9

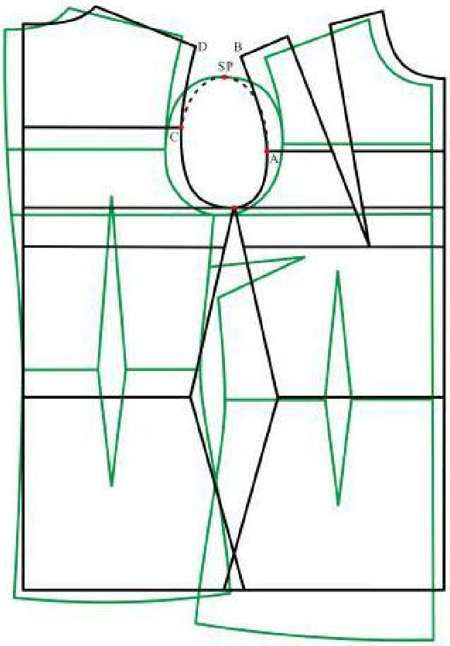
As shown in Table 3.8, the front and back angle of shoulder lines of difference between digital twin and pattern blocks with X, H and A style were measured respectively, which provided the basis of checking the correctness of blouse pattern blocks, see Appendix E.

3.3.5.Method of armhole line analyzing

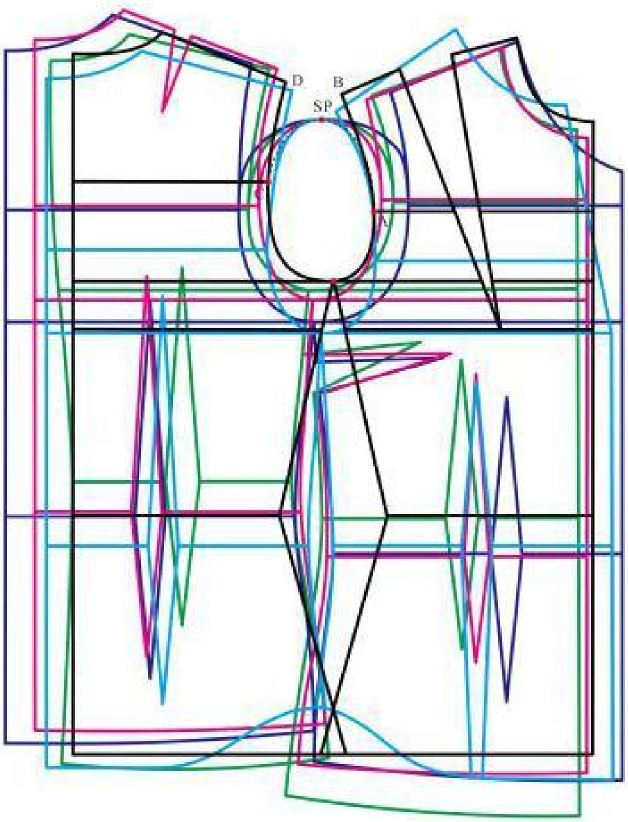
In this study, armhole depth, front armpit point and back armpit point were taken as the key points to study armhole line. In order to find the ease to armhole depth, by means of body measurements obtained before- Bust girth (2), Waist girth (3), Hip girth (4), Neck girth (5), Shoulder length (6), Shoulder width (7), Armhole girth (8), Upper arm girth (9), Back length (10), the surface of digital twin was flattened to get out the flattening body prototype and to present its morphological features. The armhole line of the flattening body prototype were carried out.Figure 3.11 shows the scheme of analyzing ease allowance of armhole line for blouse pattern blocks.



a



b



c

Figure 3.11 - Schemes of analyzing ease allowance of armhole line for blouse pattern blocks: a - virtual sewing for armhole line of body prototype, b - overlapping body prototype and blouse pattern blocks, c - overlapping of blouse pattern blocks

As shown in Figure 3.11 (a), in order to obtain an ease value to armhole of pattern blocks, virtual sewing of the armhole line of the flattening body prototype was carried out. Firstly, the lengths of armhole intersections between the point A belonging to bust width line and the point B (SP), and the point C belonging to back width line and point D (SP) were measured respectively. Secondly, the curves L1= AB and L2= CD were made through point A and point C respectively, and intersected at SP, so as to obtain the digital twin prototype and complete armhole line. Finally, after the virtual sewing completed, SP can be used to pattern blocks overlapping.

Figure 3.11 (b) shows that, after the virtual sewing of the blouse pattern blocks completed, the SP point of blouse pattern blocks were defined. Then, thedigital twin prototype and the blouse pattern blocks were further overlapped together according to SP point. Thus, it’s possible to analyze the armhole line of blouse pattern blocks by this method.

Figure 3.11 (c) shows blouse pattern blocks with different ease allowance of armhole line were overlapped with the digital twin prototype in terms of SP point. The armhole depth, front armpit point and back armpit point were compared and analyzed with the digital twin prototype. Thus, ease allowance of armhole line for blouse pattern blocks were analyzed by using this method.Table 3.9 shows the ease allowance of armhole line for blouse pattern blocks with X-style(the same tables were formed for H, A styles), see Appendix E.

Table 3.9 - Ease allowance of armhole line for blouse pattern blocks in X, H and A styles

Ease allowance of armhole line for blouse pattern blocks, cm				
Values		E_{AD}	E_{FAP}	E_{BAP}
MIN.	X	-2.5	0	-1.7
	H	0.7	-3.1	-1.5
	A	-3.7	-4.4	-1.2
MAX.	X	9.2	5.2	3.7
	H	11	4.8	4
	A	8.9	7	6.4
AVG.	X	2	1.4	1.9
	H	4.7	2	1.9
	A	3	2.3	2.8

As shown in Table 3.9, the ease allowance of armhole line for blouse pattern blocks with X- style were measured respectively from three aspects: ease to armhole depth, ease to front armpit point and ease to back armpit point. Thus, the basis of checking the correctness of armhole line in terms of ease allowance of the armhole depth, front armpit point and back armpit point were obtained.

Summary of Chapter 3

1. By means of 3D CLO software, the surfaces of 3D avatar were flattened into 2D garment patterns with zero eases. Then, after comparing key structural measurements of flattened 2D pattern block and 3D avatar, the accuracy of flattened 2D pattern block with zero eases was ensured, which indicates that the 3D-2D flattening results are precise, and the body prototype of 2D pattern block of avatar can be used in blouse pattern block checking.

2. Each blouse pattern block and the body prototype were overlapped based on the avatar to obtain the ease values of pattern blocks in X and Y directions respectively. The range of ease allowance of blouse pattern blocks in the directions of X-axis and Y-axis were respectively calculated.

3. For the first time, methods have been developed for checking patterns before their virtual fitting for their correct positioning along the neck, shoulder and armhole lines relative to the avatar surface lines of the same name and predicting possible fit defects.

4. DETECTING DEFECTS OF PATTERN BLOCKS IN VIRTUAL REALITY

Nowadays, the accuracy of pattern block is widely regarded as an important way to influence an appearance and comfort of virtual clothing. In addition, the existing criteria of patterns validation are still inadequate in predicting the fit in virtual reality. In real practice many pattern makers are using own non-formalized workmen craft to improve the fit of clothes but these unique methods aren't included in program modules of CAD. Many CAD are applying simplest approach to patterns drawing without specific and very important know-how. In the meantime, eye-tracking technology is mainly applied in the aspects of brand recognition, visual evaluation, feature extraction, display design and so on [58]. However, eye-tracking technology can be used to study fit and it influencing on clothing performance. In order to improve the pattern making method and blouse quality, the more comprehensive scheme of detecting defects of pattern blocks before virtual try-on should be developed.

This chapter developed the method of detecting defects of pattern blocks by integrating the method of measuring grayscale of folds and applying an eye-tracking technology to understand of consumer preferences under clothing fit evaluation.

The results obtained in this chapter were published in 3 articles [21, 22, 99].

4.1. Objective evaluation by means of gray-scale technology

4.1.1. Research methods, objects and tools

In order to analyze the gray values of folds in misfit parts for women blouse, ImageJ software was used to perform gray processing to calibrate the gray values in pixels. SPSS software was used for statistical analysis.

As discussion in Section 2.1.5, 132 women blouse patterns were collected, digitized by using ETCAD software, and classified between X, H, and A styles. Then, one typical women blouse pattern was chosen to perform gray-scale experiment, as shown in Figure 4.1.

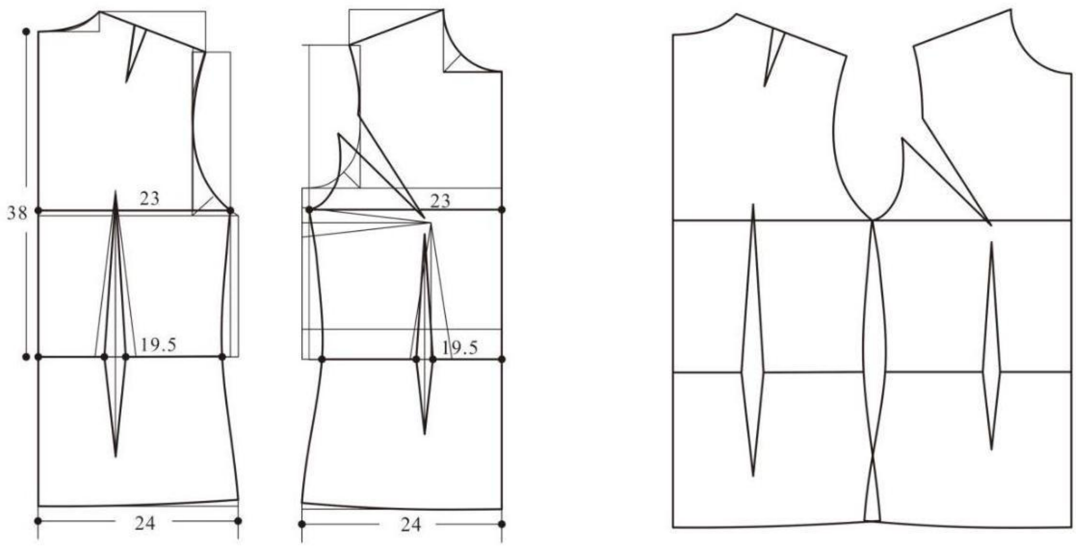
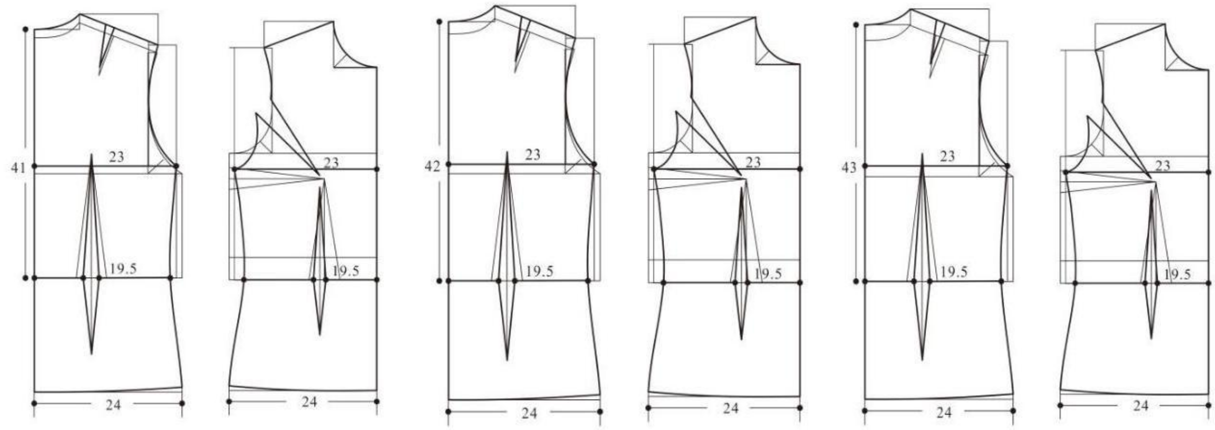


Figure 4.1 - Structure of X- style women blouse pattern blocks

Figure 4.1 shows that based on the Liu Ruipu's basis pattern blocks [69], the women blouse pattern blocks were drafted, and the dimensions of main structure parts for women blouse pattern blocks were measured. The size of main structure parts for X- style women blouse pattern blocks are: bust line (92), waist line (78), hip line (96), back length (38), bust width line (34) and back width line (37), unit: cm.

Then, in order to analyze women blouses with misfit in back length, three women blouse pattern blocks with different back length were drafted according to the X- style women blouse pattern blocks above, as shown in Figure 4.2.



a b c

Figure 4.2 - Women blouses with different back length (BL), cm: a - 41, b - 42, c - 43

As discussion in Section 2.2.2, virtual twins of women bodies were generated on the base of experimental anthropometrical measurements to get full schedule of body measurements. Based on an average measurements of Y, A, B, C body types, the software of CLO3D 5.2 were applied to establish virtual twins of each body types.

Table 4.1 - Body measurements for virtual twins of different body type

N.	Measurement parameters	Measurements for different body type, cm			
		Y	A	B	C
1	Height	166	168	165	162
2	Bust girth	86	84	94	93
3	Waist girth	66	67	82	87
4	hip girth	92	91	100	96
5	Neck girth	36	36	38	37
6	Length of *SNP* - *SP*	11	11.5	12	11
7	Length of cross shoulder over neck	38	38	39	39
8	Back length	38	38	38	38
9	Armhole girth	28.8	28.8	28.8	28.8

10	Arm length	54	53	53	52
10	Upper arm girth	28.1	28.1	28.1	28.1
11	Bust width	18	17	19	17
12	Backwidth	15	16	16	17
13	Length of *FNP-FBP-FWP*	33	33	34	36
14	Length of *FNP-BP-FWP*	34	36	36	36
15	Length of *SNP-BP-FWP*	40	40	42	42
16	Length of *SP-FAP-FWP*	35	36	36	37
17	Length of *SP-BWP*	40	40	40	41
18	Length of *SP-BAP-BWP*	40	40	40	41

To get a virtual twin of blouse, the blouse pattern blocks with different back length were virtually stitched on the virtual twins of bodies [9]. After that, the digital twins of the women blouses for the gray-scale experiment was obtained.

4.1.2. Principle approach

A fold is an important factor which visually reflects the ease allowance and clothing fit. To evaluate the folds, the image processing technology was used to analyze the change of gray value of image. It is known that under constant light conditions, the reflection effect of concave and convex parts of fold is different, and this difference can be represented by gray images. If the gray value is large, the fold is raised. The gray value is small, then the fold is concave. If the gray value is stable and unchanged, there is no fold in this part [58].

Figure 4.3 shows the fragment of established database of virtual women blouse with different defects.

Y body type (166/86)

A body type (168/84)

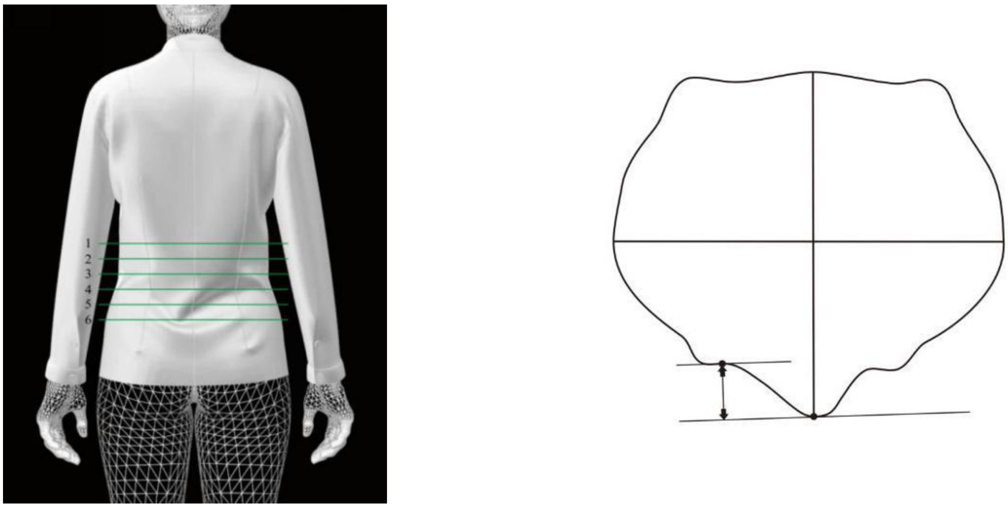
B body type (165/94)

C body type (162/93)

a b c

Figure 4.3 - Women blouses with folds causing by ease allowance to back length (E_{BL}), cm: a - 3, b - 4, c - 5

To analyze the folds and its distribution, the horizontal cross-sections were made on waist level (WL), upper WL (WL+3, WL+6) and below WL (WL-3, WL-6, WL-9), as shown in Figure 4.4.



a b

Figure 4.4 -Scheme of analyzing the folds and its distribution in waist level: a - location of horizontal cross-sections on virtual women blouses, b - measuring fold depth of blouse in Rhino CAD

3D Rhino CAD was used to establish the folds database by intercepting the horizontal cross-sections mentioned and the fold depth measuring [114]. Figure

4.4 shows the scheme of fold depth measuring as distance from highest point to lowest point.

ImageJ software was used to calibrate the gray values in pixels at above six horizontal cross-sections. Each pixel of image has 256 gray levels ranging from 0 to 255. Minimum level 0 represents the darkest part of gray image, that is black. Maximum level 255 represents the brightest part in gray image, which is white. Since the gray matrix takes into account for the both characteristics (fold position and parameters), the data of these gray values are accurate and reliable [88].

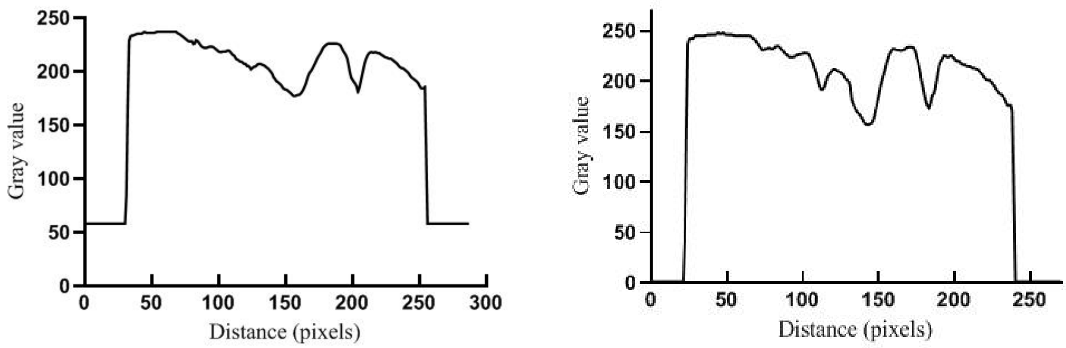
When the fabric folds are not obvious or close to situation yes-no folds, its gray characteristics will maintain a relatively stable value. When the fabric has folds, its gray value will fluctuate accordingly. The part with a large gray value represents the raised area of the fold, and the part with a low gray value represents the recessed place of the fold. The crests (valleys) in the gray curve represent the number of folds. The more crests or troughs that appear, the denser the number of folds. The difference between the maximum and minimum gray values of adjacent peaks and troughs represents the depth of the folds, and the distance between two adjacent peaks or troughs represents the width of the folds. Because the folds are not evenly distributed, the fit can be evaluated by two aspects: width and depth. Each fold can be evaluated by means of the width and depth. Among them, the unevenness of fold is smaller, the fold is more uniform [117]. The unevenness of fold are defined by the following formulas:

$V_D = 100\frac{\sum_i \left\|V_{Di} - \overline{V}_D\right\|}{\overline{V}_D}$	(4.1)
$V_H = 100\frac{\sum_i \left\|V_{Hi} - \overline{V}_H\right\|}{\overline{V}_H}$	(4.2)

where: V_{Di} is the width of the i-th fold, unit: pixel; V_{Hi} is the depth of the i-th fold respectively, gray value. V_D is the average width of fold, pixel; V_H is the average depth of fold, gray value [117].

4.1.3. Method of fold parameter calculation

The extracted gray values were exported to Excel. Figure 4.5 shows the gray curves as an examples from horizontal level WL-6 and two values of E_{BL}. The gray value difference 20 was taken as set as the fold discrimination threshold [87].



a b

Figure 4.5 - Grayscale of folds with misfit in back length (Y body type, WL-6) for E_{BL}, cm: a –3, b –4

Figure 4.5 (a) and (b) shows the gray curves from horizontal level of WL-6 with E_{BL} 3cm and 4cm respectively. The X-axis is the position of the pixels along the position line of the image collection, and Y-axis is the gray value of the pixels at this position line. Figure 4.5 (a) shows that along the image collection line, the gray value changes gently at the beginning, and gradually the gray value of the curve decreases. A wide and large trough appears, indicating that there is a fold here, and it is the fold subsidence part; Then the gray value of the curve gradually rises, and an obvious wave peak appears, indicating that there is a fold here and it is the prominent part of the fold. According to such rules, the fold of image collection location was analyzed further. For example, when X-axis value is close to 140, a significant trough appears in the gray curve, and the gray value suddenly decreases, indicating that there is a relatively deep fold here. Subsequent troughs and crests are also distinct, indicating a deeper fold. Combined with the fold analysis of the location line of the image collection, the analysis shows that there are two folds in the area of the location line of the image collection. Then, the difference between the minimum gray value (177) of the trough region of the fold and the maximum gray value (205.5) of the adjacent wave peak is further calculated, and the fold depth of the first fold was obtained; The width of the first fold was obtained by calculating the distance between the two adjacent peaks of the first trough, and the fold depth and width of the second fold were further calculated according to such rules.

Figure 4.5 (b) shows that at the beginning the curve of the gray level change is quite gentle, corresponds to the clothing part is smooth, no fold, in the position of X-axis value is close to 100 or so, gray value gradually reduce, gray curve appeared an obvious troughs, gray value and then gradually rise, gray curve appeared an obvious peaks, indicating that there is a fold here. Then several successive troughs and peaks are also more obvious.

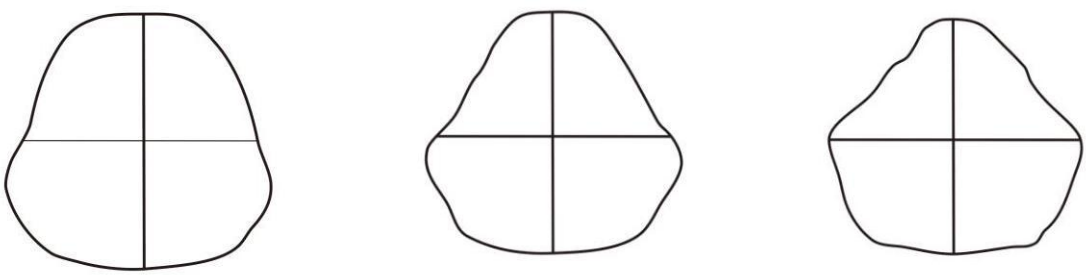
Therefore, after the treatment of statistical data base the number of folds, fold depth, fold width and unevenness of fold for defects were calculated for all objects explored. Table 4.2 shows the part of this huge data base for Y body type (the same tables were formed for A, B, C body types), see Appendix F.

Table 4.2 - The fold information of each line in the waist area for women blouse with back length (Y body type)

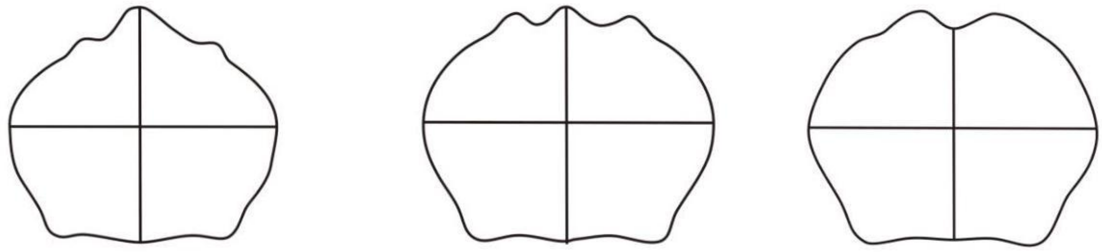
E_{BL}, cm	Cross-section	Folds parameter	Unevenness of fold, pixel/gray value

		number	width (for each fold), pixel (VDi)	depth (for each fold), grey value (VHi)	width	depth
3	WL+6	0	0	0	1.91	0.87
	WL+3	0	0	0		
	WL	0	0	0		
	WL-3	3	29/74/30	33/42/45.5		
	WL-6	2	57/32	28.5/45		
	WL-9	1	45	40		
4	WL+6	0	0	0	3.69	2.32
	WL+3	0	0	0		
	WL	1	77	38		
	WL-3	3	35/60/25	29.5/68.5/60		
	WL-6	3	19/39/21	36/55/60.5		
	WL-9	2	21/30	39/39		
5	WL+6	0	0	0	3.92	3.59
	WL+3	0	0	0		
	WL	1	96	76		
	WL-3	3	36/49/24	36/73.5/29		
	WL-6	4	22/21/38/28	30/22/69/40		
	WL-9	2	21/34	53/40		

According to the previously proposed method, in order to analyze the influence of ease allowance on the blouse fit, the cross-sections of six horizontal positions in the waist area of the blouse were taken respectively, and the fold depth of this area was measured, as shown in Figure 4.6.



a b c



d e f

Figure 4.6 -Horizontal cross-sections in the waist area(Y body type, E_{BL}+5) : a - WL+6, b - WL+3, c - WL, d -WL-3, e - WL-6, f - WL-9

Combined with the gray value of the fold depth analyzed in the fold image, and the corresponding measured fold depth of cross-section, Table 4.3 shows the fold information of the 6 horizontal lines of the blouse with different ease allowance of back length under Y body types was converted into centimeter (the same tables were formed for A, B, C body types), see Appendix G.

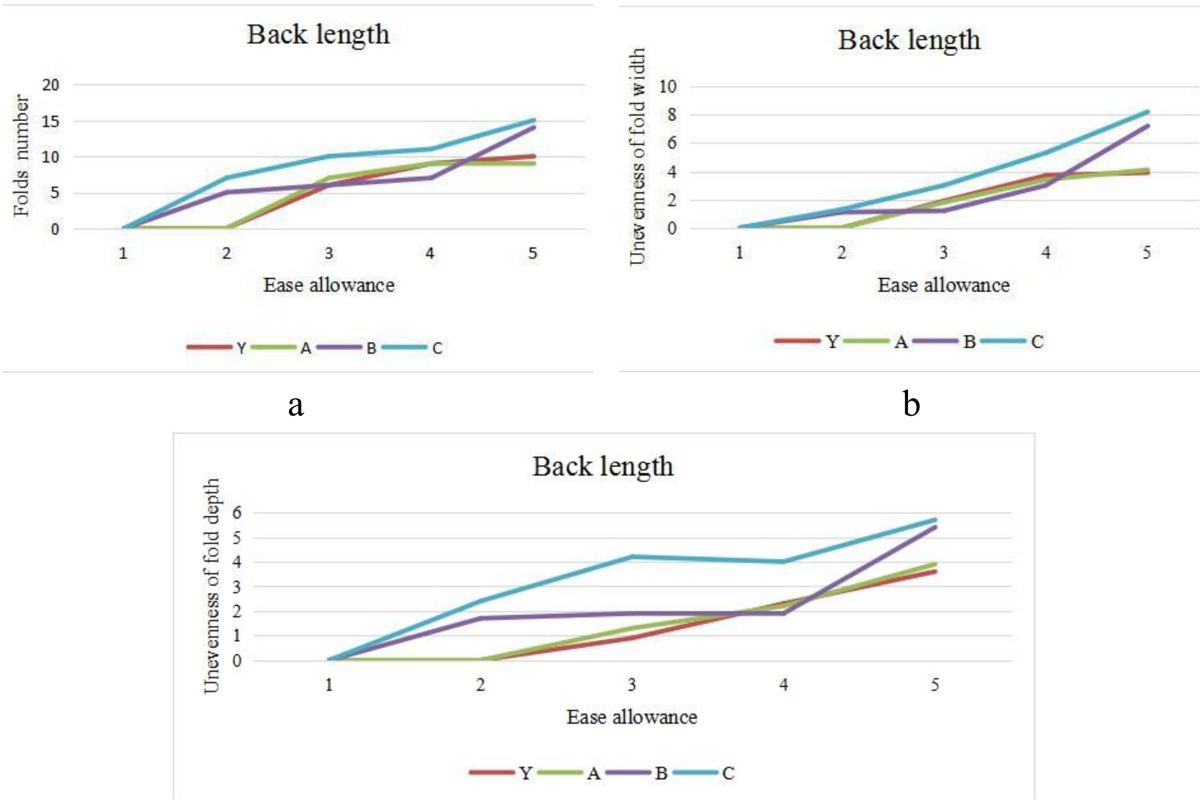
Table 4.3 - Calibration of the fold information of each line in the waist area (Y body type)

Cross-section	Depth of folds, depending on E_{BL}, см						Number of folds
	3		4		5		
	grey value	depth, cm	grey value	depth, cm	grey value	depth, cm	
WL+6	0	0	0	0	0	0	0
WL+3	0	0	0	0	0	0	0
WL	0	0	38	1.9	76	3.8	0
WL-3	33/42/45.5	1.65/2.1/2.3	29.5/68.5/60	1.5/3.4/3	36/73.5/29	1.8/3.7/1.5	9
WL-6	28.5/45	1.43/2.3	36/55/60.5	1.8/2.8/3	30/22/69/40	1.5/1.1/3.5/2	7
WL-9	40	2	39/39	2/2	53/40	2.7/2	5
Number of folds	6		9		9		

As shown in Table 4.3, with the increase of ease allowance to back length, the number of folds gradually increases, and the depth of folds gradually increases, which indicates that with the increase of ease allowance to back length, the smoothness of waist area decreases, and the comfort of clothing was significantly affected.

4.1.4. Relations between blouse style and fold parameters

The scheme of patterns checking before virtual try-on was further developed based on the fold analysis and calibration E_{BL}. Figure 4.7 shows the number of folds and its depth and width and were compared and analyzed respectively.



a b

c

Figure 4.7 - Relations between the folds and E_{BL}: a - fold number, b - fold width, c - fold depth

As shown in Figure 4.7, a, E_{BL} bigger, the number of folds also bigger. The number of folds for body type C is significantly larger than other types. At the same time, when E_{BL} is 1 cm, the folds for each body type are absent, which means that the blouses are very fit for Y, A, B, and Ctypes. When E_{BL} exceeds 2 cm, the number of folds in clothing greater than five for each body types.

Figure 4.7, b, c show that when E_{BL} increases, the width and depth of folds also increase, especially for Ctype. However, for B body type, the unevenness of fold width is smaller than that of Y and A body types excepting when E_{BL} is within the range of 3-4 cm. In addition, in terms of fold depth unevenness, except for E_{BL} of 4 cm, the garment fold width is smaller than the Y, Atype, and the rest of the ease allowance is greater than the garment fold width of the Y, Atype.

Furthermore, according to the comparison of the results of fold image analysis and E_{BL}, the fit criteria were established for X-style.Table 4.4 shows the fit criteria for evaluation of women blouse with X-stylein back length.

Table 4.4 - Fit criteria for evaluation of women blouse in back length

Body type	E_{BL}, cm, following for folds arising and quality of fit	
	fit	misfit
Y, A	0–2	more 3
B, C	0–1	more 2

As shown in Table 4.4, when the E_{BL} of X-style blouse within the range of 0-2 cm, the blouse will fit for Y and A body type, and the back part will not appear redundant folds. When the E_{BL} of blouse more than 2 cm range, the waist part of the back will appear redundant folds because of E_{BL} is not accordance with body morphology. Similarly, when a blouse with the E_{BL} of X-style blouse within the range of 0-1 cm, the blouse will fit well for B and B body type and there will be no extra wrinkles on the back length. And when the E_{BL} of X-style blouse more than 1 cm range, the blouse will appear as a result of the mismatch and the emergence of redundant folds.

So, the results obtained are the recommendation for pattern making and the prognosis for fit identification. The similar limitations could be established for other ease allowances such as to front and back width, arm girth, which are depending on body morphology and should be separated not only between body sizes but body type also.

4.2. Subjective evaluation by means neuropsychological technology

Nowadays, eye-tracking technology is a common method widely used in psychological research, which can transform human visual observation results into objective data output. At present, eye-tracking technology is mainly applied in the aspects of brand recognition, visual evaluation, feature extraction, display design and so on[56]. However, never eye-tracking technology have been used to study fit and it influencing on clothing performance, evaluation of the difference between real apparel and its virtual twin on clothing performance.

In this research, real women blouse sample and its virtual twin have been taking as research objects to do research experiment, statistical analysis, to conduct multivariate variance analysis on area of interest, to establish main areas of clothing parts that people paid the most attention to. The results obtained can help to quantify people's visual perception between real and virtual costume, and furthermore improve virtual try-on technology.

4.2.1. Research device

Tobii Pro (Tobii Company, Sweden) is the most portable eye-tracking system in nowadays market; it is equipped with binocular motion sensors and dual tracking modes, which allow to adapt the eye tracker to different research objects, scenarios and data needs through flexible data collection methods[91].

4.2.1.1. Participants

21 teachers and students were randomly invited as experimental participants to study the factors which are influencing on fit of women blouse and areas of interest. In order to exclude potential influence of objective factors such as participant's vision and eyeglasses on experimental results, it is necessary to ensure normal naked eye vision of each participant. For myopic participants, they can wear contact lenses or choose lenses suitable for themselves according to myopia lens provided by eye tracker. Ensure that there are no other visual diseases other than myopia[118].

In addition, in order to ensure that the invited participants have the ability to correctly evaluate the clothing fit and the accuracy of the participants' eye-tracking data, questionnaire experiment was conducted, and each picture will receive subjective evaluation scores from the participants, ranging from "perfect fit", "good fit", "acceptable fit", "bad fit" to "very bad fit", and the scores are successively marked as "5", "4", "3", "2" and "1"[41].

Table 4.5 shows a five-level grade scale (1- very bad, 2- bad, 3- acceptable, 4- good, 5- perfect) which applied to compare with subjective evaluation scores from the participants in the questionnaire evaluation experiment. And the corresponding features of each fit level was described in the grade scale.

Table 4.5 - Grade criteria for evaluation of women blouse

Scale	Fit	Features
1	Very bad	Too much redundant folds on the garment because of ease allowance of garment structural part is not accordance with body morphology
2	Bad	Several redundant folds on the garment structural part
3	Acceptable	Few folds on the garment structural part

4	Good	Without observable folds on the garment structural part
5	Perfect	The garment is completely smooth and without folds

4.2.1.2. Experiment materials

Five representative pictures of X - style women blouse were collected through clothing shopping websites of Christian Dior, George Armani and etc.. They were ranked from ideal (high level quality) fit to worst one, as shown in Figure 4.8.

Picture 1	Picture 2	Picture 3	Picture 4	Picture 5

Very bad	Bad	Acceptable	Good	Perfect
Tommy Hilfiger	HommeGirls	Balmain	Balenciaga	Ralph Lauren

Figure 4.8 - Five representative pictures of X - style women blouse with different fit

In addition, the pattern blocks of X - style women blouse were completed by ETCAD, and 3D simulation was completed by CLO virtual try-on software. Then, 15 representative pictures of X - style women blouse within different fit degree were obtained, and also ranking them from bad fit to perfect fit, Figure 4.9 shows the eye-tracking experiment materials.

In order to eliminate the interference caused by human face and background, all the pictures include only the blouse style.

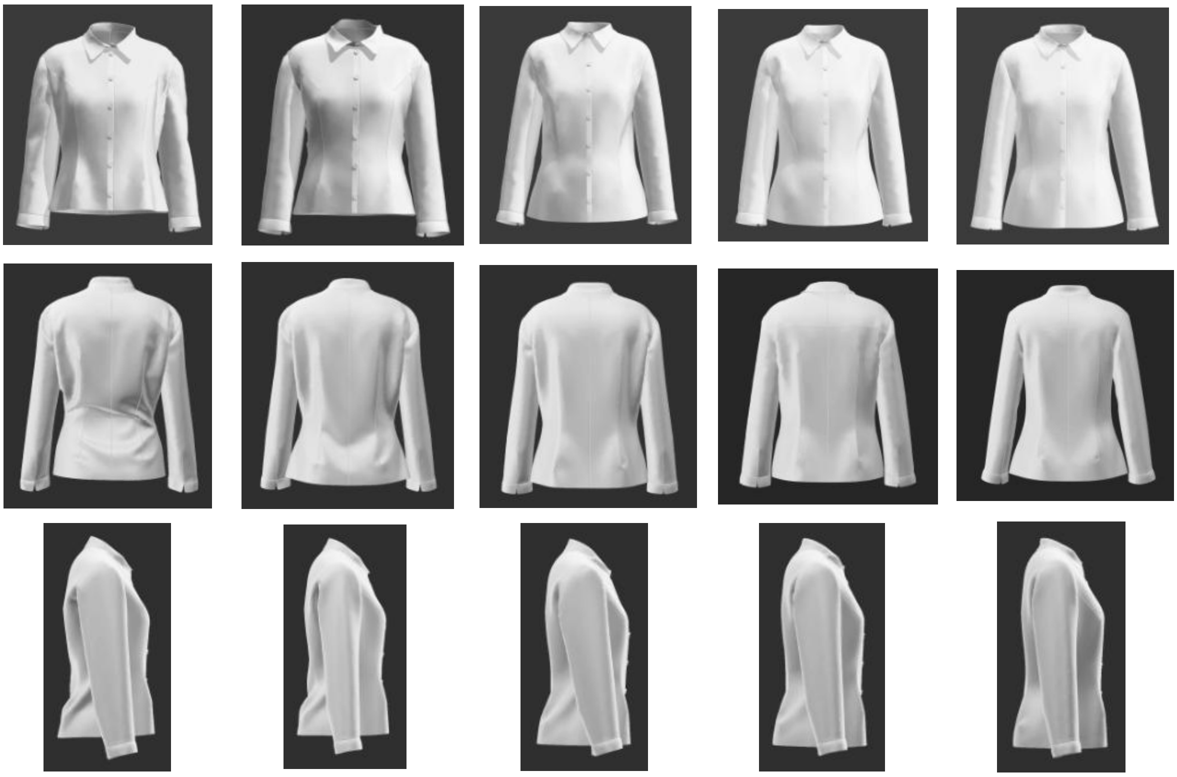


Figure 4.9 - Fifteen representative pictures of women blouse with different fit in different view

4.2.1.3. Experiment scheme

This experiment is divided into two parts: questionnaire evaluation and eye tracking experiment. In order to ensure that the invited participants have the ability to correctly evaluate the clothing fit and the accuracy of the participants' eye-tracking data, the sequence of subjective questionnaire evaluation experiment and eye-tracking experiment were adopted. Different experimental materials were used to avoid the interference of material leakage to the participants' eye-tracking test. Moreover, by comparing the clothing fit evaluation results of grade criteria, whether the experiment participants have the ability to correctly evaluate the clothing fit was studied.

We designed the experimental questionnaire - Subjective questionnaire on fit degree of women blouses(see Appendix H). In the questionnair eexperiment, each picture will receive subjective evaluation scores from the participants. After identifying differences in subjective evaluation results of the participants, Kendall's W test was used to analyze whether the scoring criteria of participants were consistent.

Moreover, during the eye-tracking experiment preparation phase, the experimenters checked the experimental materials, guidelines, questionnaires, experimental equipment, and maintain a quiet and comfortable experimental environment. In order to minimize experimental errors, participants were been given an explanation of the rules, the tasks and the purpose of the experiment. Participants were asked to avoid seeing pictures before test andrequired to sit on a chair 60cm away from the eye tracker, keep the sitting position upright, and look at the computer monitor horizontally. In addition, each image was randomly presented for 10 s in order for participants to have enough time and not lose interest in the picture area[94]. The eye tracker automatically records the entire visual activity of the participant. And then before the eye-tracking experiment begins, equipment and participants' eye data should be calibrated. After the calibration of the experimental equipment, the formal experiment can be carried out.

4.2.1.4. Measured values

These measurement indicators of this study include the following two parts: eye-tracking indicators and heat map.

During the eye-tracking experiment, the eye-tracker can provide a whole set of eye-tracking indicators, whose indicators mainly include: fixation count, time to first fixation, total duration of fixation in AOI, visit count, average duration of fixation in AOI and so on. According to research purpose of this paper, total duration of fixation in AOI and fixation count were finally selected for data analysis. Wherein, total duration of fixation in AOI refers to time spent to keep fixation point in different AOI. Fixation count means total number of fixation points produced in different AOI[86].

Area of interest (AOI) is a term for eye-tracking technology, which refers to the segmentation of an image into multiple areas, each of which will be analyzed as an independent factor, that is, the fixation time and visit counts of each person in differentare as are compared, as shown in Figure 4.10.

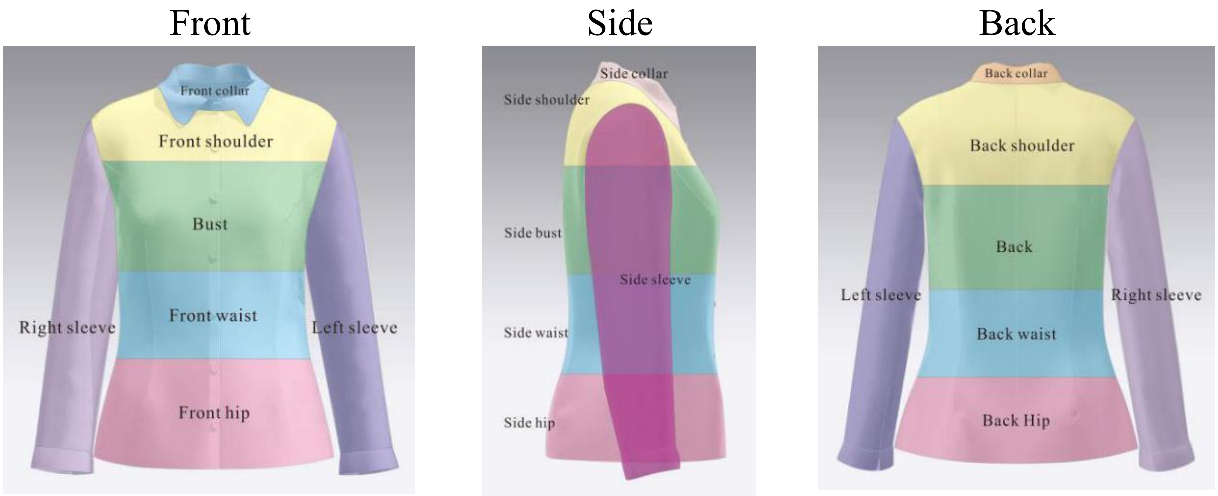


Figure 4.10 - Areas of Interest(AOIs)

Figure 4.10 shows that based on reference and the structural division of women' blouse pattern blocks, the areas of interest from the front, side and back of the X-style women blouse are divided into 20 areas of interest, such as shoulder part, bust part, waist part and hip part and etc. [87, 91].

In addition, when participants watch the picture in the screen, the eyeball movement does not have a certain regularity. The average jump of the eyeball and the average gaze time in this case are larger than the movement trajectory when reading the text[76]. The heat map of eye tracking was used to know what is prefer to see or ignore in an object. The heat map was presented the locations in the observed object with the longest number of gaze or gaze time. This is indicated by a color scale. The heat map shows colors ranging from green to red. Red regions indicate strong fixation, yellow regions indicate moderate fixation and green regions indicate the least fixation. Regions without color represent areas that were ignored, thus helping to understand the distribution of the eye sight of the participants while viewing[89]. Figure 4.11 shows the color distribution of the heat map for X- style women blouse in front view, side view and back view.

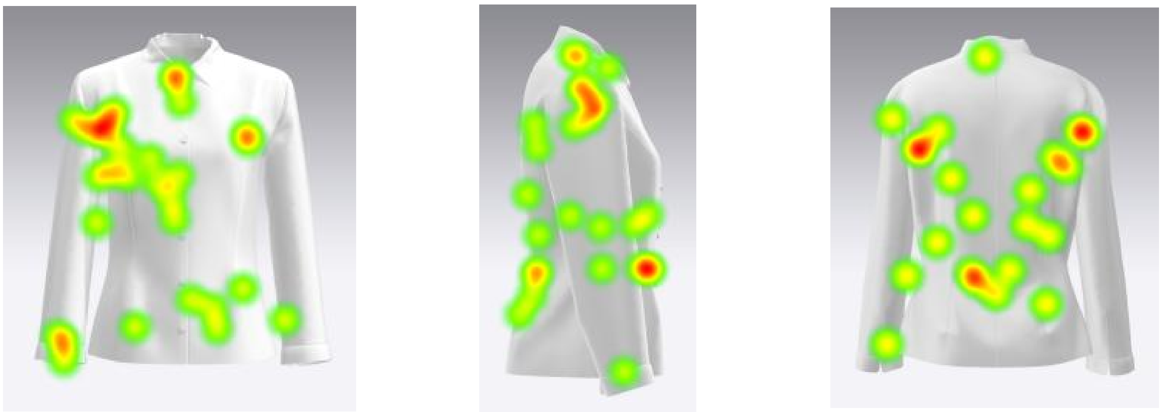


Figure 4.11 - Examples of heat map for X- style women blouse

4.2.2. Research results

4.2.2.1. Analysis of subjective evaluation results

To verify whether the subjective evaluation results of clothing fit of participants are consistent. SPSS data analysis software was used to conduct Kendall's W consistency test for the subjective evaluation results. The results of Kendall's W consistency test are W=0.887, Detection statistics=72.622, and P=0.00<0.001,which was pointed out that the Kendall's W is significant, rejecting the null hypothesis, and the results were statistically significant. The greater the Kendall's W coefficient, the stronger the consistency of the data results[115]. The Kendall's W coefficient is 0.887, indicating that the data in this study have a strong consistency, so the questionnaire experimental results are stable.

In addition, after result treatment, professional ability of an participant after comparison with grade criteriawas concluded further.Table 4.6 shows the results of subjective questionnaire evaluation experiment, by analyzing the subjective evaluation scores of the participants.

Table 4.6 - Mean value and standard deviation of subjective questionnaire experimental results (see Figure 4.8)

Participant	Picture 1	Picture 2	Picture 3	Picture 4	Picture 5
1	1	2	3	5	4
2	1	2	3	5	4
3	1	2	3	5	4
4	1	2	3	4	5
5	2	1	3	4	5
6	2	1	3	5	4
7	1	2	3	4	5
8	1	2	3	4	5
9	1	2	3	4	5
10	1	2	3	4	5
11	1	2	3	4	5
12	1	3	2	4	5
13	1	2	4	3	5
14	1	2	4	3	5
15	1	2	3	4	5
16	1	3	4	3	5
17	1	2	3	4	5
18	1	2	4	3	5
19	1	2	3	5	4
20	1	2	3	4	5
21	1	2	3	4	5
Mean	1.10	2	3.14	4.05	4.76
SD	0.30	0.45	0.48	0.67	0.44

As shown in Table 4.6, it can be seen that the evaluation results ofeach participant are very consistent, and the difference value is maintained at about 1 point. At the same time, by analyzing the mean value of each picture, we can find that the score of Picture 5 is the highest, followed by Picture 4, and the score of Picture 1 is the lowest. The score of each Picture was ranked as Picture 5>Picture 4>Picture 3>Picture 2>Picture 1, which showed that the participants' evaluation result of each picture is very consistent with grade criteria. This indicates that participants have the ability to correctly evaluate the comfort of clothing, and can further conduct eye-tracking experimental research.

4.2.2.2. Multivariate analysis of different fit of women blouse

After the eye-tracking experiment, the two indexes were obtained: total duration of fixation and fixation counts in different areas of interest. Table 4.7-4.10 shows that combined with SPSS 20. data statistics software, the eye-tracking data of the two indexes were analyzed by multivariate variance analysis and mean value comparison.

The eye-tracking analysis software was used to process the data. The heat map was generated to analysis participants' eye-tracking data further, as shown in Figure 4.12-4.14.

Table 4.7 -Multivariate analysis of variance for different fit of women blouse from different views

View	Source	Sum of squares	DOF	Mean square error	F	P	Results
Front	Total duration of fixation in AOI						
	Fit degree	0.017	4	0.004	0.014	1.000	Not significant
	AOI	21.313	6	3.552	11.459	0.000	Significant
	Fit degree*AOI	4.141	24	0.173	0.557	0.932	Not significant

	Fixation counts in AOI						
	Fit degree	0.612	4	0.153	0.182	0.946	Not significant
	AOI	159.371	6	26.562	31.596	0.000	Significant
	Fit degree*AOI	11.367	24	0.474	0.563	0.928	Not significant
Back	Total duration of fixation in AOI						
	Fit degree	0.010	4	0.002	0.009	1.000	Not significant
	AOI	30.092	6	5.015	18.246	0.000	Significant
	Fit degree*AOI	12.825	24	0.534	1.944	0.036	Significant
	Fixation counts in AOI						
	Fit degree	0.665	4	0.166	0.178	0.948	Not significant
	AOI	167.509	6	27.918	29.918	0.000	Significant
	Fit degree*AOI	56.046	24	2.335	2.503	0.007	Significant
Side	Total duration of fixation in AOI						
	Fit degree	0.109	4	0.027	0.034	0.998	Not significant
	AOI	23.524	5	4.705	5.936	0.001	Significant
	Fit degree*AOI	6.078	20	0.304	0.383	0.986	Not significant
	Fixation counts in AOI						
	Fit degree	0.849	4	0.212	0.044	0.996	Not significant
	AOI	153.917	5	30.783	6.418	0.000	Significant
	Fit degree*AOI	22.729	20	1.136	0.237	0.999	Not significant

Where: DOF is the degree of freedom, refers to when sampling statistics are used to estimate population parameters, the amount of independent or freely varying data in the sample is called the degree of freedom of statistics; F is the value for the distribution of F. The value can be used to determine whether the test is statistically significant in the analysis of variance; P is the confidence probability. When the p value is less than 0.05 (usually <0.05), the result is statistically significant. This points to convincing evidence against the null hypothesis.

Table 4.7 shows that the multivariate analysis of variance for eye-tracking data of blouse with different fit in front, back and side. According to the test of the analysis of total duration of fixation in AOI and fixation count, the P values of fit degree in front, side and back were all greater than the significant level of 0.05, indicating that the blouse with different fit degree had no significant influence on the total duration of fixation in AOI and fixation count of participants. On the contrary, the P values of AOI were all lower than the significant level of 0.05,indicating that the division of AOI from different views had a significant impact on the total duration of fixation in AOI and fixation count of participants.

In addition, according to the test of the analysis of total duration of fixation in AOI and fixation count,the P values of fit degree in front, side were all greater than the significant level of 0.05 except in back, indicating that the main effect of interaction between fit degree and AOI had no significant influence participant’s total duration of fixation in AOI and fixation count.

Through above analysis of experimental data shows that there was no significant difference among total duration of fixation and fixation count in blouse with different fit degree, but in different AOI. Different AOI can be used to study the degree to which people pay attention to the parts of the women blouse with different fit in front, back and side.

Table 4.8- Mean value of participants’ eye-tracking data for blouse with different fit in front

AOI	Women blouse with different fit in front

	Very bad	Bad	Acceptable	Good	Perfect	AVG
Total duration of fixation in AOI/s						
Front bust (F1)	1.74	2.18	2.31	2.35	2.12	2.05
Front collar(F2)	1.42	1.44	1.41	1.51	1.68	1.58
Front hip(F3)	0.50	0.16	0.14	0.18	0.07	0.21
Front shoulder(F4)	0.85	0.55	0.33	0.66	0.40	0.56
Front waist(F5)	1.24	1.23	1.29	0.87	0.88	1.10
Left sleeve(F6)	0.65	0.98	0.85	1.11	0.86	0.89
Right sleeve(F7)	1.63	1.56	1.76	1.70	1.92	1.71
Fixation counts in AOI						
Front bust (F1)	6.52	5.29	6.24	5.00	6.95	6.00
Front collar(F2)	3.43	3.33	2.81	4.24	3.48	3.46
Front hip(F3)	2.33	0.81	0.81	1.29	0.90	1.23
Front shoulder(F4)	2.00	2.67	1.57	1.14	2.19	1.91
Front waist(F5)	2.24	2.76	3.86	3.19	2.90	2.99
Left sleeve(F6)	1.62	2.57	2.81	2.90	3.29	2.64
Right sleeve(F7)	6.29	5.10	4.29	3.67	3.90	4.65

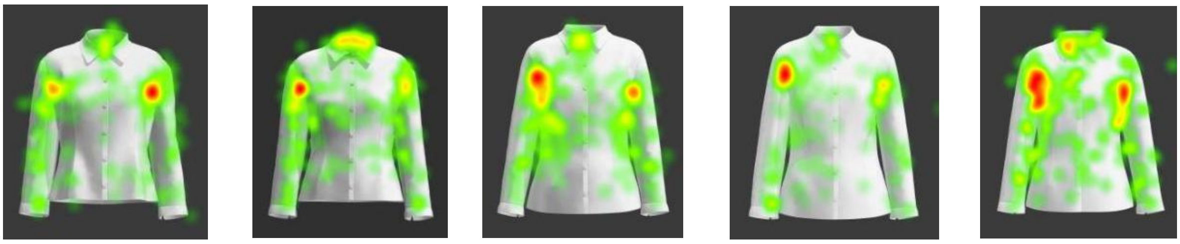
According to the above experimental data, participants showed significant differences in the two indexes in different AOI, therefore, different AOI can be used to study the degree to which people pay attention to the parts of the women blouse with different fit in front.

As shown in Table 4.8, based on the total duration of fixation in AOI, in general, value of F1 and F7 were obviously higher than other values, followed by the F2, which is the same as the results of fixation counts.

Thus, according to the average values, the duration of fixation of seven AOIs were ranked as:

$$F1>F7>F2>F5>F6>F4>F3$$

And then, seven AOIs were further divided into two groups - important (F1, F7, F2, F5) and non-important (F6, F4, F3).



(1) Very bad (2) Bad (3) Acceptable (4) Good (5) Perfect

Figure 4.12 -Heat map of women blouse with different fitin front

Figure 4.12 shows that there are red regions on the front bust (F1) and right sleeve (F7), whichpoints that the participants' duration of fixation of the front bust area was the longest, followed by the right sleeve. The presence of yellow regions on the front collar (F2) indicates that the participant's the duration of fixation of the front collar area is longer. In addition, there were more green regions in the front waist (F5) and left sleeve (F6), which was indicated that there was a certain amount of the duration of fixation in the front waist and left sleeve area.

Therefore, combined with the analysis results of multivariate analysis of variance and mean value of participants' eye-tracking data above, we can conclude that in front view, the degree of attention paid to the part of blouse is front bust, right sleeve, front collar, front waist, left sleeve, front shoulder and front hip, in turn.

Table 4.9- Mean value of participants' eye-tracking data for blouse with different fit in back

AOI	Women blouse with different fit in back					
	Very bad	Bad	Acceptable	Good	Perfect	AVG
Total duration of fixation in AOI/s						
Back bust (B1)	2.29	2.77	2.71	3.87	2.24	2.78
Back collar(B2)	0.11	0.26	0.12	0.15	0.21	0.17
Back hip(B3)	3.68	1.56	0.61	0.64	0.71	1.44
Back shoulder(B4)	0.48	1.05	0.87	0.42	1.14	0.79

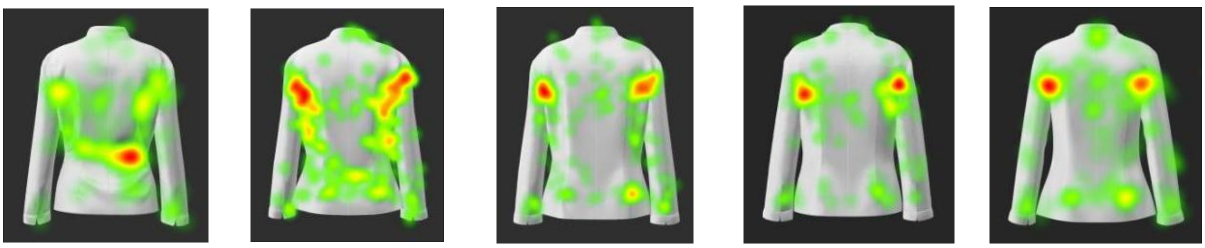
Back waist(B5)	1.28	1.94	2.41	1.88	1.59	1.82
Left sleeve(B6)	0.61	0.65	1.19	0.77	1.45	0.93
Right sleeve(B7)	0.38	0.65	1.05	1.29	1.35	0.94
Fixation counts in AOI						
Back bust (B1)	6.24	7.76	7.10	8.43	5.52	7.01
Back collar(B2)	0.24	0.62	0.38	0.33	0.43	0.40
Back hip(B3)	7.86	4.48	2.19	2.19	2.38	3.82
Back shoulder(B4)	1.19	1.29	2.48	2.10	3.10	2.03
Back waist(B5)	2.76	4.33	4.95	4.10	4.71	4.17
Left sleeve(B6)	1.19	1.67	2.52	2.57	3.48	2.29
Right sleeve(B7)	1.62	2.81	2.67	1.38	3.29	2.35

Similarly, according to the above experimental data, different AOI was used to study the degree to which people pay attention to the parts of the women blouse with different fit in back.

According to the Table 4.9, based on the eye-tracking index of the total duration of fixation in AOI, in general, value of B1 and B5 was obviously higher than other values, followed by the B3, which is the same as the results of fixation counts. Thus, according to the average values, the duration of fixation of seven AOIs were ranked as:

$$B1>B5>B3>B7>B6>B4>B2$$

And seven AOIs were further divided into two groups - important (B1, B5, B3, B7) and non-important (B6, B4, B2).



(1) Very bad (2) Bad (3) Acceptable (4) Good (5) Perfect

Figure 4.13 -Heat map of women blouse with different fit in back

As shown in Figure 4.13, we can clearly see that the red regions are mainly concentrated on the back bust and back waist area, which means that the participants have the longest fixation time on the back bust, followed by the back waist. There are more yellow regions in the back hip, indicating that the participants have a longer gaze at the back hip area. In addition, there were some green regions in the left and right sleeve, indicating that there was a certain amount of gaze time in the left and right sleeve.

Thus, combined with the analysis results of multivariate analysis of variance and mean value of participants' eye-tracking data above, we can conclude that in back view, the degree of attention paid to the garment part of the women blouse is:

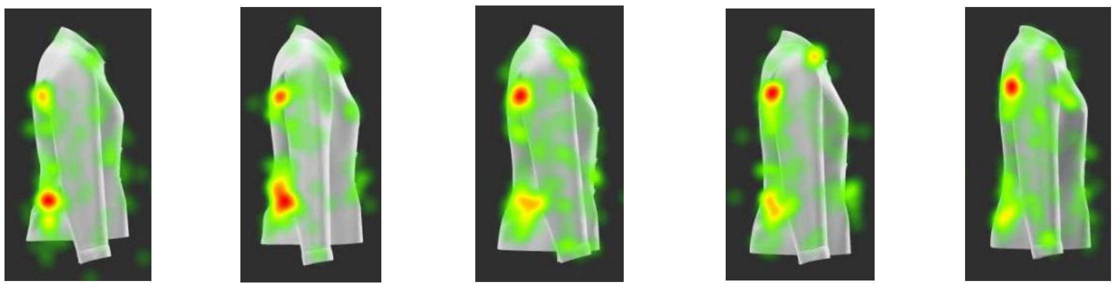
back bust-back waist-back hip-right sleeve-left sleeve-back shoulder-back collar.

Similarly, blouses were examined on the side views (Table 4.10).

Table 4.10 - Mean value of participants' eye-tracking data for blouse with different fit in side

AOI	Women blouse with different fitin side					
	Very bad	Bad	Acceptable	Good	Perfect	AVG
Total duration of fixation in AOI/s						
Side bust (S1)	2.26	3.08	2.77	3.14	3.55	2.96
Side collar(S2)	0.29	0.27	0.57	0.57	0.44	0.43
Side hip(S3)	2.02	1.58	0.94	1.22	1.46	1.44
Side shoulder(S4)	0.25	0.55	0.83	0.59	1.34	0.71
Side waist(S5)	2.62	2.75	3.02	2.31	2.57	2.65
Side sleeve(S6)	2.54	2.91	2.32	2.57	1.49	2.37
Fixation counts in AOI						
Side bust (S1)	6.00	8.57	6.71	8.57	8.81	7.73
Side collar(S2)	0.48	0.62	1.10	0.95	0.90	0.81
Side hip(S3)	4.52	3.10	2.81	2.86	3.95	3.45
Side shoulder(S4)	0.86	1.10	1.71	1.52	2.95	1.63
Side waist(S5)	6.67	6.00	7.33	6.10	6.71	6.56
Side sleeve(S6)	6.57	7.19	5.43	6.24	4.24	5.93

Similarly, as shown in Table 4.10, based on the total duration of fixation in AOI, in general, value of S1 and S5 was obviously higher than other values, followed by the S6, which is the same as the results of fixation counts. Thus, according to the average values, the duration of fixation of seven AOIs were ranked as S1>S5>S6>S3>S4>S2. And seven AOIs were further divided into two groups - important (S1, S5, S6, S3) and non-important (S4, S2).



(1) Very bad (2) Bad (3) Acceptable (4) Good (5) Perfect

Figure 4.14 -Heat map of women blouse with different fit in side

As shown in Figure 4.14, it can be seen clearly that the red regions are mainly concentrated on the side bust and waist, indicating that the participants'fixation time on the side bust position is the longest, followed by the side waist. However, there were more yellow regions in the side sleeve area, indicating that participants gazed for a longer time in the side sleeve area. In addition, there were some green regions in the side hip, indicating that the participants had a certain amount of gaze time in the side hip area.

Therefore, combined with the analysis results of multivariate analysis of variance and mean value of participants' eye-tracking data above, we can conclude that in side view, the degree of attention paid to the garment part of the women blouse is side bust, side waist, side sleeve, side hip, side shoulder and side collar, in turn.

Finally, combined with the analysis results of participants' eye-tracking data above, Table 4.11 shows that the important areas of interest for fit evaluation in different fit were further concluded.

Table 4.11 - List of very important areas of interest for fit evaluation

Fit criteria	Important areas of interest			
Front	Front bust	Right sleeve	Front collar	Front waist
Back	Back bust	Backwaist	Backhip	Rightsleeve
Front waist length	Side bust	Side waist	Sidesleeve	Side hip

As shown in Table 4.11, the important areas of interest for fit evaluation are mainly bust, waist, sleeve and hip when evaluating blouse fit with different fit criteria.

Summary of Chapter 4

1. By means of virtual technology, gray-scale image identification and pattern making, complex exploration about how body type and ease allowances together are influencing on women blouse fit was done. The number of folds and its distribution could be ruled during pattern making.

2. In order to analyze the degree of people's attention to different clothing parts under the condition of clothing fit evaluation, different fit of women blouse were taken as the research object. In this research,questionnaire evaluation experiment and eye-tracking experiment were conducted respectively.

3. In terms of eye-tracking indexes data such as fixation duration and fixation counts of 20 areas of interest of 15 blouses with different fit, the mean values of eye-tracking data of different fit degree and areas of interest were

compared and multivariate analysis of variance was conducted. And the heat map which can present the duration of fixation in the areas of interest was analyzed.

4. The results showed that the total duration of fixation and the fixation counts of participants in different areas of interest were significantly different, and the degree of attention paid to the clothing parts of the women blouse was the bust, shoulder, waist and sleeve when evaluating clothing comfort with different fit, which provides reference significance for improving the method of pattern making and women blouse comfort.

5. DEVELOPMENT OF ALGORITHEM FOR SCENARIO VIRTUAL FITTING TECHNOLOGY AND QUALITY OF FIT

The fundamental and extended criteria for checking women's blouse fit by the exterior appearance have been proposed. However, the existing criteria of patterns validation are still inadequate in predicting the fit in virtual reality. In order to accurately conduct the fit evaluation in virtual and real environments, the more comprehensive fit criteria should be developed.

This chapter developed the criteria for virtual fit evaluation of women's blouse by integrating the misfit pictures, digital twins of women blouse, the databases of existing constructive defects for fit evaluation, virtual try-on pictures, and constructive analysis by establishing the fit criteria charts composed with quality level of the fit, scheme of pattern blocks, images of the digital twins of the blouses and verbal evaluation of the blouses fit, and numerical values of the criteria.

In addition, this chapter developed the virtual fitting technology and virtual fit evaluation of women blouse by integrating: analyzing blouse pattern blocks based on Section 2.1.5 and 2.1.6, generation of digital twin of female body based on Section 2.2, analyzing neck line, shoulder line, back length, ease to bust and horizontal sizes of blouse pattern blocks before virtual try-on based on Charpter 3, generation of digital twin of "avatar-blouse" system based on Charpter 4, objective evaluation of women blouse by means of grey-scale technology based on Section 4.2, and verification of the scenario virtual fitting technology.

The results obtained in this chapter are published in three articles [20, 23, 100].

5.1. Research methods and tools

The massive information of try-on pictures were collected from the clothing shopping websites to discover the misfit problems. The corresponding virtual and real women blouse samples with different fit level were sewed in CLO3D and actually, which were validated by sensory analysis with eye-tracker technology.

The compatible software was applied: Adobe Photoshop for image processing and measuring the objects in pictures. CLO3D was applied for accomplish the virtual simulation of women blouse try-on.

5.1.1. Pictures of women blouse from Internet

Through searching official clothing shopping websites, 185 pictures which shown the real try-on effect of women blouse were collected [79, 82, 116]. These pictures were supposed to exhibit the whole body or structural parts of the women blouse from different views (front, back and side) with different fit problems. Figure 5.1 shows the examples of the pictures analyzed.

a b c

Figure 5.1 - Real women’s blouses: a - front, b - side, c - back

Figure 5.1 shows obvious excessive ease allowance of bust with (a), non-horizontal location of the hem (b),too much horizontal wrinkles upper hip level (c). All collected pictures revealed the good or bad fit level of several structural parts from different views in the same way.

5.1.2. Digital twins of women blouse for validation

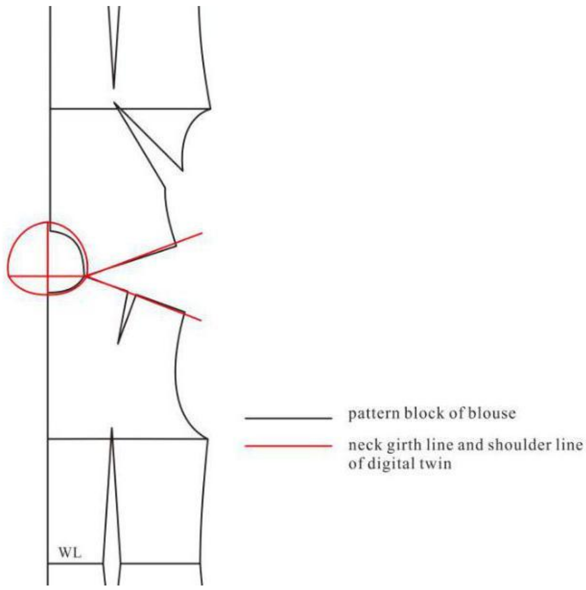
The digital twins (DT) were generated. For one thing, the virtual simulation was conducted in CLO3D. One DT which transformed from the real typical women's body with typical morphology (160/84A based on Section 2.2) was utilized for virtual fitting. And one frequently-used digital fabric for women's blouse was selected from the default library in CLO3D (name - Cotton 40S Stretched Poplin, content - 96% cotton and 4% stretched yarn, density - 119.2g/cm^2, thickness - 0.26mm).

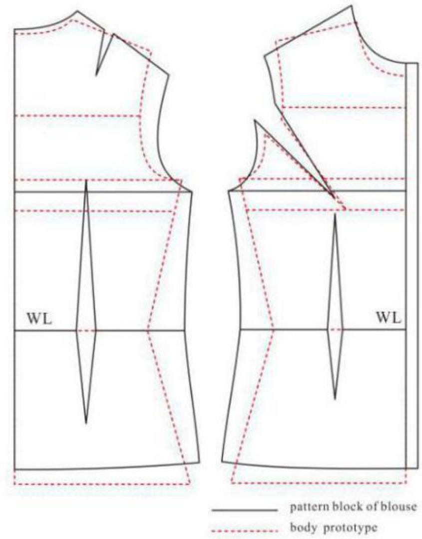
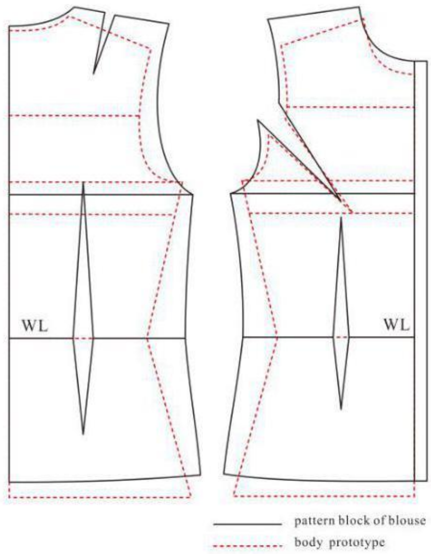
5.1.3. Constructive data base

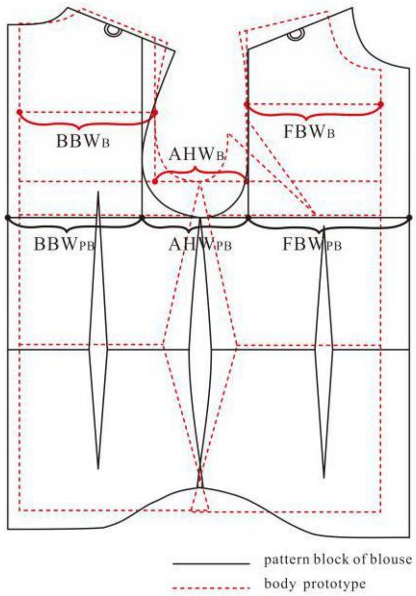
The fit criteria charts composed with quality level of the fit, scheme of pattern blocks, images of the digital twins of the blouses and verbal evaluation of the blouses fit was established.

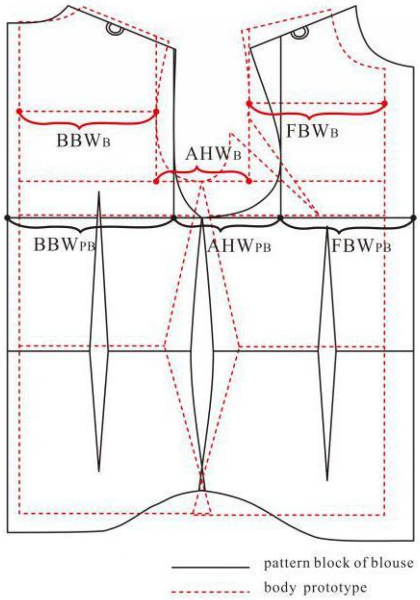
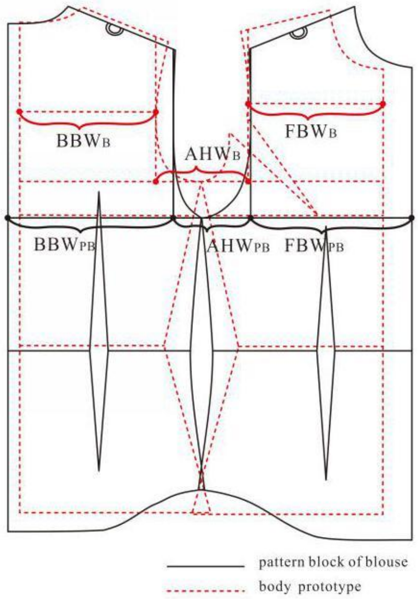
The emergence of the misfit was mainly caused by the incompatibility between the body morphology and the dimensions of different women's blouse structural parts. The former could be reflected by body measurement, and the latter was determined by construction of pattern blocks for women's blouse. According to method of women blouse pattern-making, the schedule of defects was summarized. Combined with the virtual try-on technology, the women blouse with misfit caused by incorrect pattern blocks were verified. Thus, the responsible body measurement and constructive defects of women's blouse for the the misfit were analyzed as shown in Table 5.1 (black lines are the misfit pattern blocks of women’s blouse, red lines are the body prototype of digital twin).

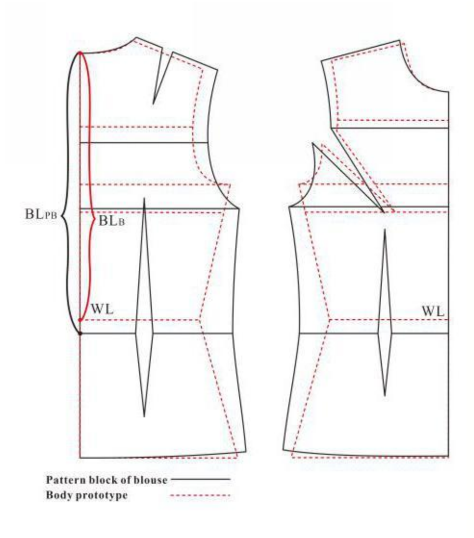
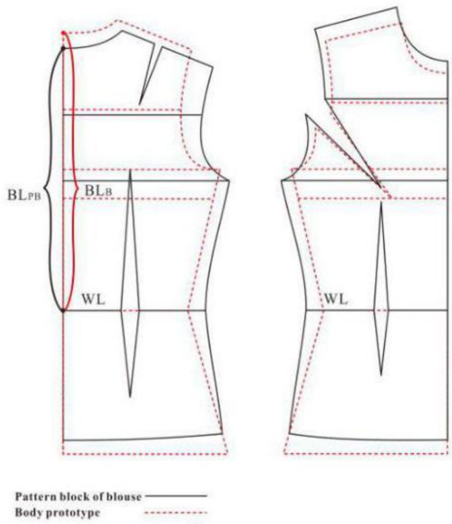
Table 5.1 - Constructive defects for fit evaluation

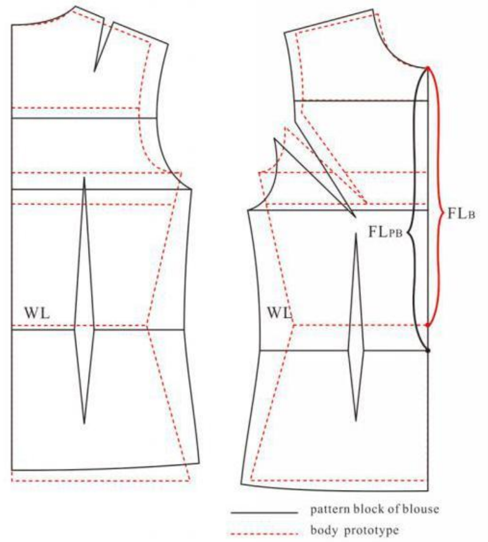
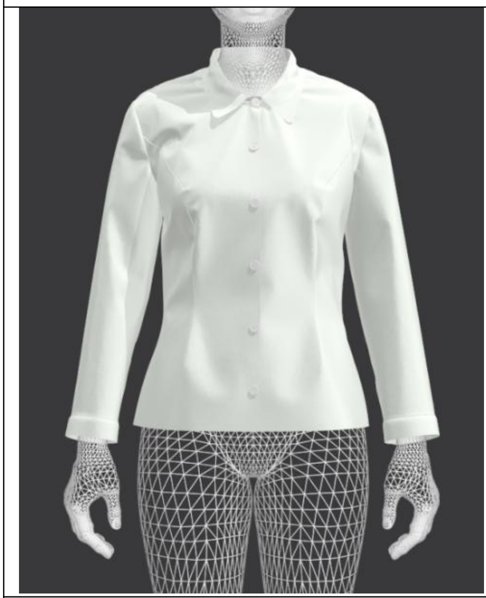
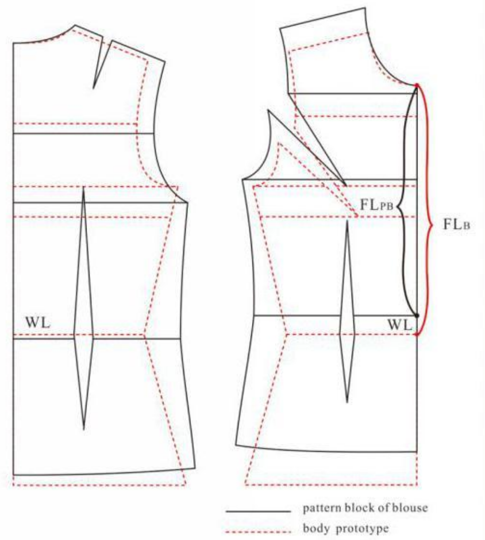
Defect location	Criteria of evaluation	Reason of defect appearing due to patterns
1. Neck		
1.1. Neck line	Collar is too tight or has excess folds	The ease to the neck girth E_{NLPB} = NL - NG is not enough.
		
(a)		(b)
2. Shoulder		
2.1. Shoulder line	Excess folds on the shoulder part	The angle between two shoulder lines of pattern blocks is too large (a, b) or too small (c, d) than the shoulder slope of human body.

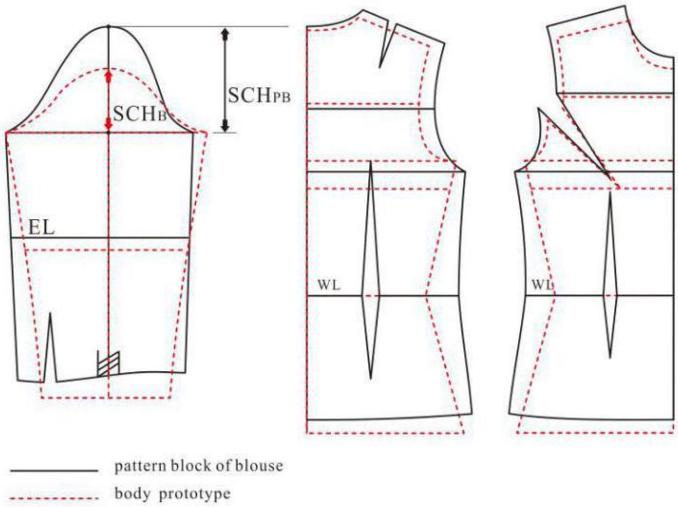
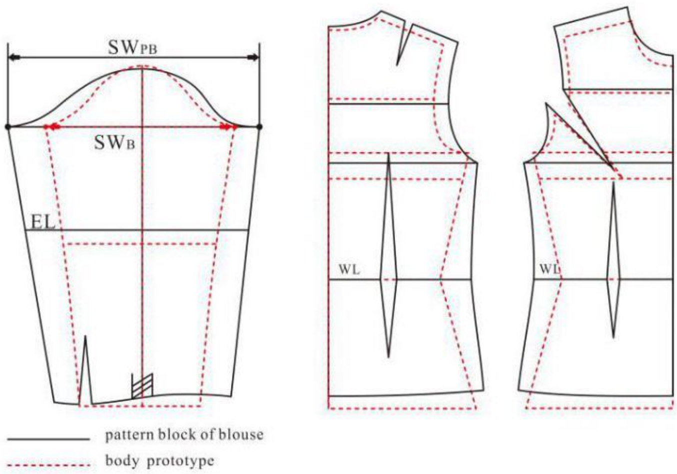
<table>
<tr><td></td><td>
</td></tr>
<tr><td>(a)</td><td>(b)</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>(c)</td><td>(d)</td></tr>
<tr><td colspan="2">3. Bodice</td></tr>
</table>

<table>
<tr><td>3.1. The proportion of the ease allowance distribution in bust girth</td><td>1. Several sloping foldsaround bust girth
2. Excess soft vertical wrinkles upper back bust level
3. Many big bulges and folds around bust girth</td><td>1. The proportion of E_{FBW} in the ease allowance distribution in bust girth is too big (a, b).
2. The proportion of E_{BBW} in the ease allowance distribution in bust girth is too big (c, d).
3. The proportion of E_{AHW} in the ease allowance distribution in bust girth is too small (e, f).
$E_{BG}= BG_{PB} - BG_B, BG_B$ - the measurement “Bust girth”
The proportion of the ease allowance distribution in bust girth = $E_{FBW}: E_{AHW}:E_{BBW}$</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="2">(a)</td><td>(b)</td></tr>
</table>

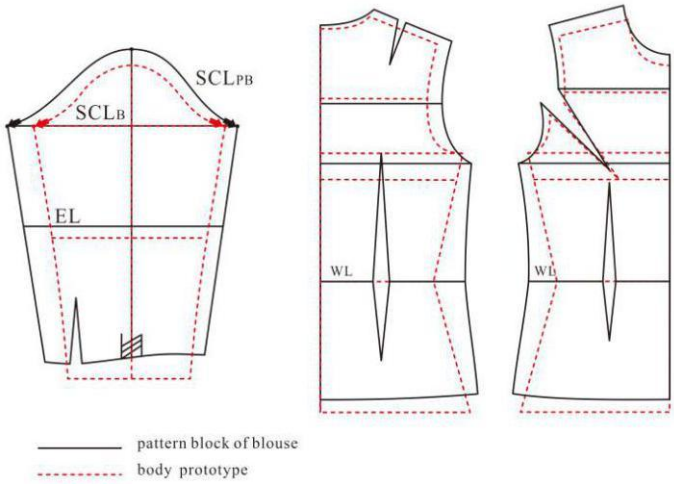
<table>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(e)</td><td>(f)</td></tr>
<tr><td>3.2.Back length</td><td>1. Redundant horizontal folds above waist
2. Excess wrinkles</td><td>1. The ease to back length $E_{BL} = BL_{PB} - BL_B > 0$ is too big (a, b).
2. The ease to back length $E_{BL} = BL_{PB} - BL_B < 0$ is too small (c, d).
BL_B - the measurement “Back length”
WL - waist level of body</td></tr>
</table>

<table>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(a)</td><td>(b)</td></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td>3.3.Front length</td><td>Excess wrinkles upper bust level and shoulder level</td><td>1. The ease to front length $E_{FL} = FL_{PB} - FL_{B} > 0$ is too big (a, b).
2. The ease to front length $E_{FL} = FL_{PB} - FL_{B} < 0$ is too small (c, d).
FL_{B} - the measurement “Front length”</td></tr>
</table>

<table>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(a)</td><td>(b)</td></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td colspan="3">4. Sleeve</td></tr>
<tr><td>4.1. Sleeve cap height</td><td>Excess wrinkles</td><td>The sleeve cap height (SCH_{PB} - SCH_B) is too large.</td></tr>
</table>

<table>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(a)</td><td>(b)</td></tr>
<tr><td>4.2. Sleeve width</td><td>Extra folds</td><td>The difference (SW_{PB} - SW_{B}) is too large</td></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(a)</td><td>(b)</td></tr>
<tr><td>4.3. Sleeve cap length</td><td>Excessive wrinkles on the armholes</td><td>The difference (SCL_{PB} - SCL_{B}) is too large</td></tr>
</table>

(a)



(b)

As shown in Table 5.1, for the neck section, NG was the decisive body measurement applied in neck line and collar design. The too small or large collar was constructed by the neck line pattern blocks with negative or excessive ease.

For the shoulder section, shoulder sloping angle was the common body measurement applied in shoulder line design. The corresponding responsible pattern blocks is the length which should be equal to the angle of shoulder line. The misfit on shoulder section was caused by wrong angle of shoulder line.

For the bodice section, the proportion of the ease allowance distribution in bust girth was related to the proportion of the ease allowance between bust width, armhole width and back width. The unreasonable proportion of the ease allowance among the three cause the deformation around bust girth. The back length and front length were related to BL and FL and the pattern index back length and front length. The inadequate or excessive lengths on pattern blocks caused the deformation around back waist and front bust.

For the sleeve section, sleeve cap height was determined by body measurement armhole depth (AD), sleeve cap length was determined by body measurement armhole girth (AG), sleeve width was determined by body measurement upper arm girth. The misfit on sleeve section was caused by the too long or short length, width and sleeve cap.

Finally, the possible constructive defects in different structural parts of women blouse were concluded in appendix I. The constructive data base could be referred as the fit criteria for evaluation the women blouse by subjective perceptions and visualization of misfit.

5.2. Neck line evaluation

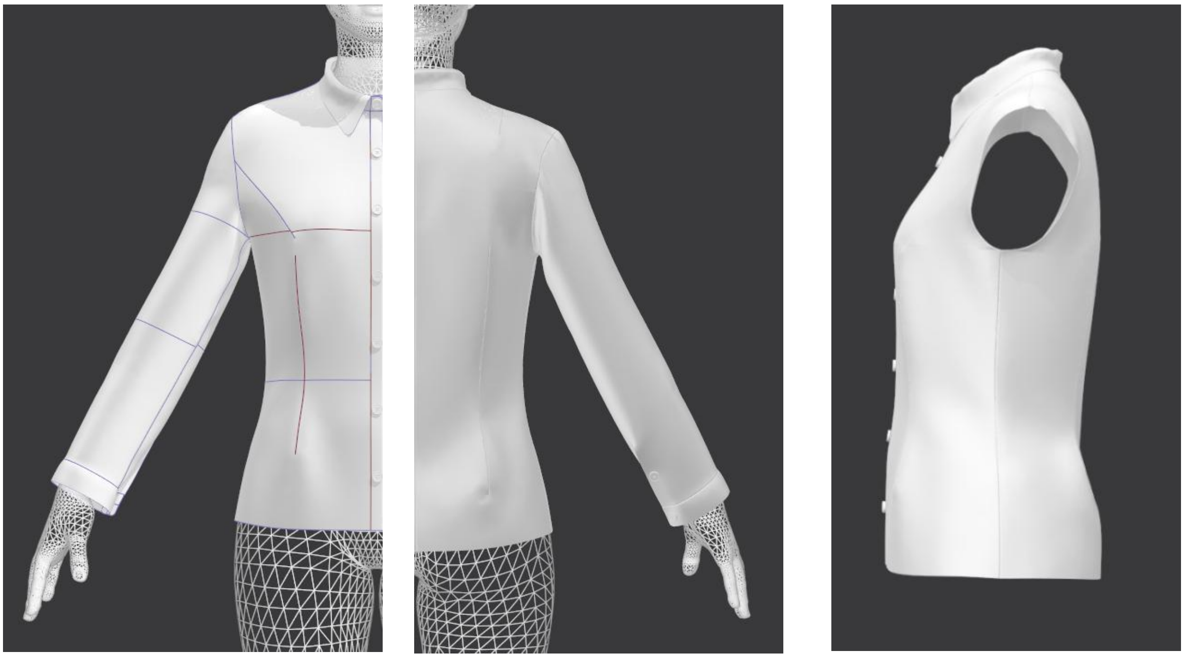
Based on the initial databases and the analysis of constructive defects for fit evaluation, a "avatar-blouse"systemwas established to predict the accuracy of pattern blocks.In order to calculate the criteria for checking the neck lineof pattern blocks, the following indicators were selected:

NG - neck girth of human body, cm;

NL - neck length of pattern block, cm.

$\triangle = E_{NG} = NL - NG$, cm. (5.1)

Firstly, the well-fitted pattern blocks of women's blouse in X-style was generated with corresponding body measurements from Table 3.1 by previous method, and the virtual women's blouse was sewed in CLO3D, as shown in Figure 5.2.

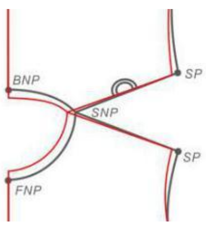
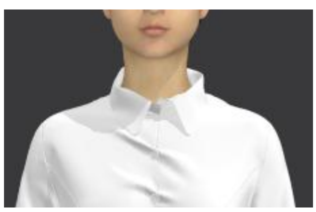


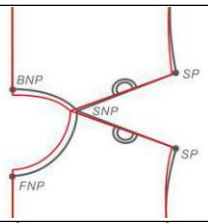
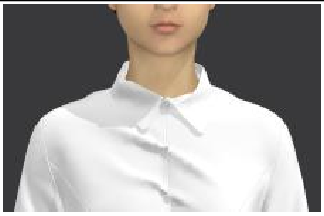
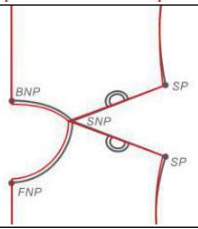
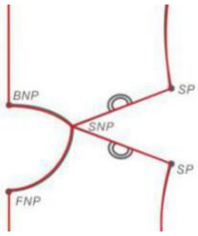
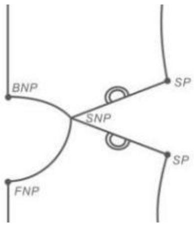
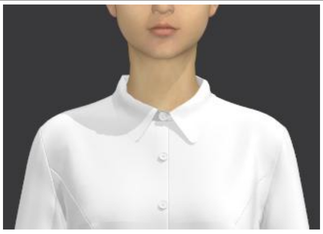
a b b

Figure 5.2 - 3D virtual visualization of the women's blouse from the view of: a - front, b - back, c - side

Table 5.2 shows that derived from the well-fitted pattern blocks, the pattern blocks with estimated misfit in neck line were constructed by gradually increasing or decreasing the indexes of pattern blocks, after that the virtual women's blouses were sewed in CLO3D respectively.

Table 5.2 - Fit criteria of checking neck line

Qualitylevel of the fit	Scheme of pattern blocks	E_{NG}, cm	Images of the digital twins of the blouses	Verbalevaluation of the blouses fit	Defect symbol (Table 5.1)
1		7.5		Several sloping folds upper bust level; front placket is deformed; the buttons can	1.1 (a)

				not be tied.	
2		6.5		Many sloping folds upper bust level; front placket is deformed.	1.1 (a)
3		5.5		Several sloping folds upper bust level.	1.1 (a)
4		4.5		Few sloping folds upper bust level.	1.1 (a)
5		3.5		Fit without fold.	/

As shown in Table 5.2, the fit criteria with five different qualitylevel described in detail the misfit images of the digital twins of the blouses, and verbalevaluation of the blouses with different fit level. With the fit varying from 5 to 1, the difference between NL and NG became more negative. Thus the qualitylevel of the fit of the blouse collar could be determined based on the criteria. Based on the fit criteria charts, by analyzing the pattern blocks of blouse, the numerical values of the criteria that lead to the defects of neck line were determined. Table 5.3 shows the numerical values of the criteria for two versions of blouses: real and their renders, which were generated by virtual modeling.

Table 5.3 - Numerical values of fit criteria for real blouses and their renders

Contact area of avatar and render	Indicators	Test conditions	Quality of fit criteria		Defect exampl es(Table. 5.1)
			Renders in Rhinoceros 3D	Real blouse	
Neck	$\triangle = NL - NG$	NG<NL	≤ 5,5 cm	≤ 2..2,5 cm	1.1

As shown in Table 5.3, by calculating the difference between NL and NG, the numerical values of fit criteria for neck line of real blouses and their renders were determined.The numerical valuesof fit criteria for virtual renders are 2.2...2.8 times higher than those confirmed by the practice of real design, which indicates that the existing software ignores the small differences and does not identify them as defects. Therefore, by combining the numerical values of fit criteria for neck lineof real and their renders,it's possible to evaluate the correctness of pattern blocks.

5.3. Shoulder line evaluation

In order to calculate the criteria for checking the shoulder lineof pattern blocks, the following indicators were selected:

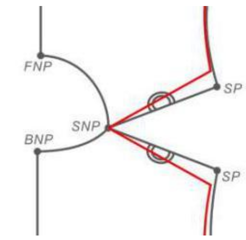
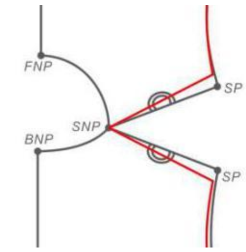
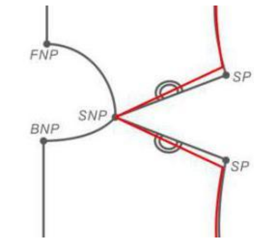
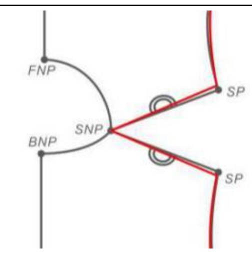
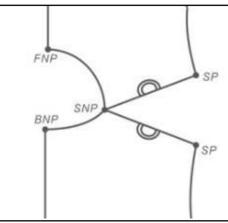
$\Sigma\alpha_B$ - the sum of shoulder angle of human body;

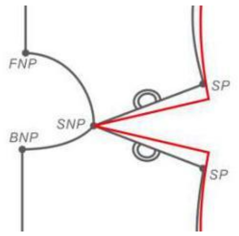
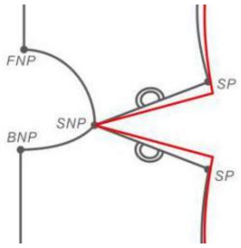
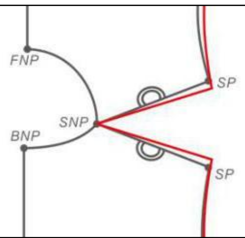
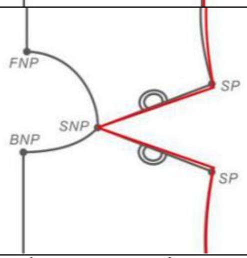
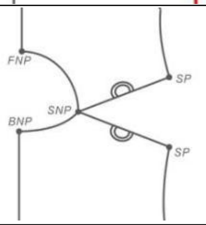
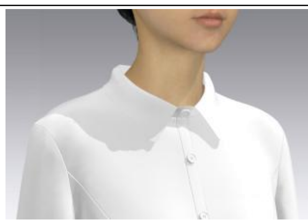
$\Sigma\alpha_{PB}$- the sum of the shoulder angle of pattern blocks.

$\triangle = \Sigma\alpha_B - \Sigma\alpha_{PB}$, degree. (5.2)

Similarly, derived from the well-fitted pattern blocks, the pattern blocks with estimated misfit in the angle of shoulder line were constructed by gradually increasing or decreasing the indexes of pattern blocks, after that the virtual women's blouses were sewed in CLO3D respectively. Then, the fit criteria charts composed with quality level of the fit, scheme of pattern blocks, images of the digital twins of the blouses and verbal evaluation of the blouses fit was established. (gray lines are the well-fitted pattern blocks, red lines are the misfit pattern blocks).

Table 5.4 - Fit criteria of checking shoulder line

Qualitylevel of the fit	Scheme of pattern blocks	△, degree	Images of the digital twins of the blouses	Verbalevaluation of the blouses fit	Defect symbol (5.1)
a. When $\Sigma\alpha_B < \Sigma\alpha_{PB}$.					
1		22		Several sloping folds upper bust level; many big bulges and folds around SNP.	2.1 (a)
2		18		Many sloping folds upper bust level; many big bulges and folds around SNP.	2.1 (a)
3		14		Several sloping folds upper bust level; small bulges around SNP.	2.1 (a)
4		10		Fewsmall bulges around SNP.	2.1 (a)
5		6		Smooth without fold.	/

b. When $\Sigma\alpha_B > \Sigma\alpha_{PB}$.					
1		22		Several sloping folds upper bust level; many big bulges and folds around SP.	2.1 (c)
2		18		Many sloping folds upper bust level; many big bulges and folds around SP.	2.1 (c)
3		14		Few sloping folds upper bust level; small bulges around SP.	2.1 (c)
4		10		Fewsmall sloping folds upper bust level.	2.1 (c)
5		6		Smooth without fold.	/

As shown in Table 5.4, the fit criteria with five different quality level described in detail the misfit the digital blouses, and verbal evaluation of the blouses with different fit level. With the fit level varying from 5 to 1, the difference between $\Sigma\alpha_{PB}$ and $\Sigma\alpha_B$ became more negative or excessive. Based on the fit criteria charts, by analyzing the pattern blocks of blouse, the numerical values of the criteria that lead to the defects of shoulder line were determined.

Table 5.5 shows the numerical values of the criteria for two versions of blouses: real and their renders, which were generated by virtual modeling.

Table 5.5 - Numerical values of the criteria for real blouses and their renders

Contact area of avatar and render	Indicators	Test conditions	Quality of fit criteria		Defect examples (Table. 5.1)
			Renders in Rhinoceros 3D	Real blouse	
Shoulder angle	$\triangle = \Sigma\alpha_B - \Sigma\alpha_{PB}$	$\Sigma\alpha_B > \Sigma\alpha_{PB}$	$\leq 22^o$	$\leq 14...16^o$	2.1(c)
		$\Sigma\alpha_B < \Sigma\alpha_{PB}$	$\leq 20^o$	$\leq 10...12^o$	2.1(a)

As shown in Table 5.5,by calculating the difference between $\Sigma\alpha_{PB}$ and $\Sigma\alpha_{B,}$ the numerical values of fit criteria for shoulder angle of real blouses and their renders were determined. On average, the fit criteria valuesfor virtual objects are 1.4...2 times higher than those for material objects, while the existing software ignores small differences and does not identify them as defects. This difference indicates the insufficiency of programs that simulate the performance of textile materials as triangulation shells on the surface of the avatar. Of course, the content of Rhinos in terms of prediction of fit defects needs to be adjusted. By combining the numerical values of fit criteria for shoulder angleof real and their renders,it's possible to evaluate the correctness of pattern blocks.

5.4. Evaluation of distribution of ease for bust line

The criteria of distribution of ease allowance for the bust linecould was established. Because bust girth is composed of three parts: front bust width, armhole width and back bust width. Therefore, the proportion of the ease allowance distribution in the three parts determine the fit level of the women' blouse. In order to calculate the criteria for checking the distribution of ease allowance for the bust line, the following indicators were selected:

BG_B - Bust girth of human body, cm;

BG_{PB}-Bust girth of pattern block, cm;

$\triangle = E_{BG} = BG_{PB} - BG_B$; (5.3)

FBW_B-Front bust width of human body, cm;

FBW_{PB}-Front bust width of pattern block calculated in Table 3.3, cm;

$\triangle = E_{FBW} = FBW_{PB} - FBW_B$; (5.4)

BBW_B-Back bust width of human body, cm;

BBW_{PB}-Back bust width of pattern block in Table 3.3, cm;

$\triangle = E_{BBW} = BBW_{PB} - BBW_B$; (5.5)

AHW_B-Armhole width of human body, cm;

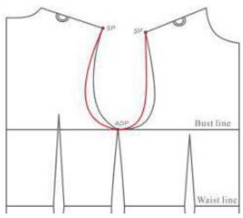
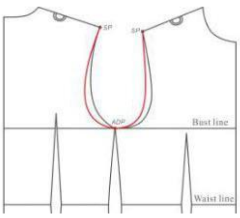
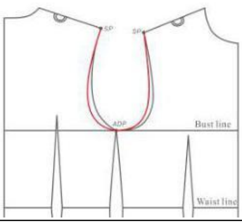
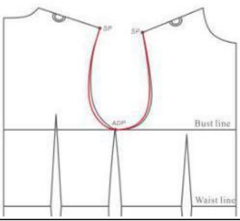
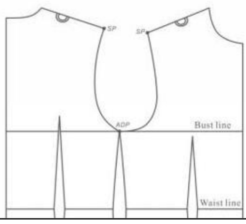
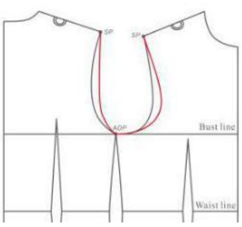
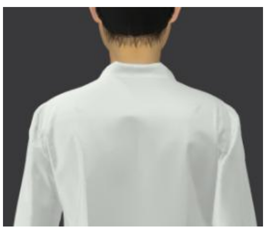
AHW_{PB}-Armhole width of pattern block in Table 3.3, cm.

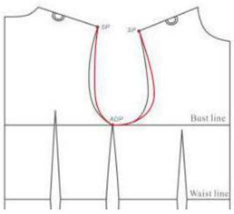
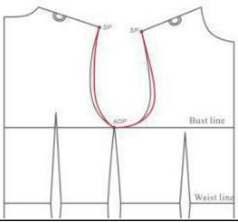
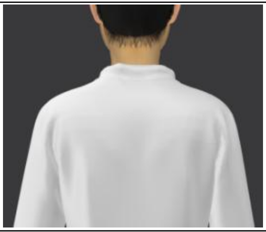
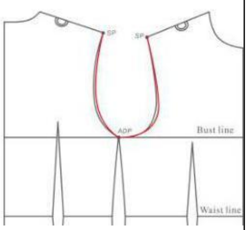
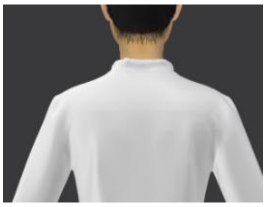
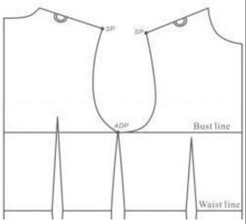
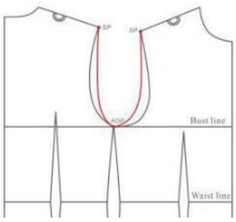
$\triangle = E_{AHW} = AHW_{PB} - AHW_B$; (5.6)

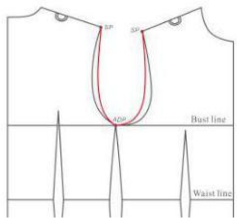
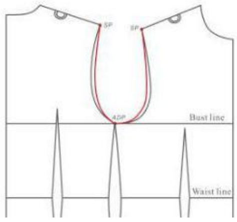
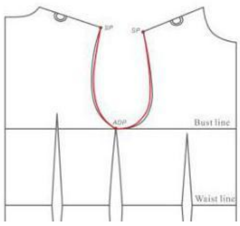
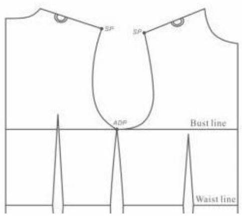
Derived from the well-fitted pattern blocks, the pattern blocks with estimated misfit in the bust line were constructed by gradually increasing or decreasing the indexes of pattern blocks which is the ease allowance distribution between front bust width, armhole width and back bust width.

Table 5.6 - Fit criteria of the distribution of ease allowance for the bust line

Qualitylevel of the fit	Scheme of pattern blocks	Images of the digital twins of the blouses	The proportion of the ease allowance distribution in bust girth, $E_{FBW} : E_{AHW} : E_{BBW}$ (%)	Verbale valuation of the blouses fit	Defect symbol (Table 5.1)
1	2	3	4	5	6

a. When the front bust width of pattern is too big.					
1			80:15:5	Several sloping folds upper bust level; many big bulges and folds around BP.	3.1 (a)
2			70:20:10	Many sloping folds upper bust level; many big bulges and folds around BP.	3.1 (a)
3			60:25:15	Several sloping folds upper bust level.	3.1 (a)
4			50:30:20	Fewsmall sloping folds upper bust level.	3.1 (a)
5			40:35:25	Completely smooth without fold.	/
b. When the back bust width of pattern is too big.					
1			10:20:70	Several sloping folds upper back level; many big bulges and folds	3.1 (c)

				around back bust.	
2			15:25:60	Many sloping folds upper back level; many big bulges and folds around back bust.	3.1 (c)
3			20:30:50	Several sloping folds upper back level.	3.1 (c)
4			25:35:40	Fewsmall folds upper back level.	3.1 (c)
5			30:40:30	Smooth without fold.	/
c. When the armhole widthof pattern is too small.					
1			55:5:40	Several sloping folds upper bust level; many big bulges and folds around bust girth.	3.1 (e)

2			50:15:35	Many sloping folds upper bust level; many big bulges and folds around bust girth.	3.1 (e)
3			45:25:30	Several sloping folds upper front and back bust level.	3.1 (e)
4			40:35:25	Fewsmall folds upper front and back level.	3.1 (e)
5			35:45:20	Smooth without fold.	/

As shown in Table 5.6, the fit criteria with five different quality level described in detail the misfit of the digital blouses, the distribution of the ease allowance of bust girth and verbal evaluation of the blouses with different fit level. With the fit level varying from 5 to 1, the distribution of the ease allowance of bust girth became more unreasonable. Thus the quality level of the fit could be determined based on the criteria.

By analyzing the pattern blocks of blouse, the numerical values of the distribution of ease allowance to bust girth were summarized. Table 5.7 shows the numerical values of ease to bust girth distribution along bust width of pattern blocks, which were obtained by calculating the distribution of the ease allowance of bust girth in front bust width, back bust width and armhole width.

Table 5.7 - Numerical values ofease to bust girth distribution along bust width of pattern block

E_{FBW}, %	E_{BBW},%						
	5	10	20	30	40	50	60
	E_{AHW},%						
5	90	85	75	65	55	45	35
15	80	75	65	55	45	35	25
25	70	65	55	45	35	25	15
35	60	55	45	35	25	15	5
45	50	45	35	25	15	5	-5

where: grey area means the reasonable numerical values of the proportion of the ease allowance distribution in bust girth .

As shown in Table 5.7, the fit criteria described in detail the distribution of ease allowance to bust girth from the proportion of front bust width, back bust width and armhole width when the the proportion of ease allowance distribution in the front bust width ranges from 5% to 45%, as well as the incompatibility caused by the unreasonable distribution of ease allowance to bust girth. After that, based on the fit criteria charts, by analyzing numerical values of the proportion of the ease allowance distribution in bust girth, the criteria thatlead to the defects of bust line were determined. The fit criteria can be applied for providing concrete recommendations for pattern making.

5.5. Evaluation of longitudinal and transverse directions

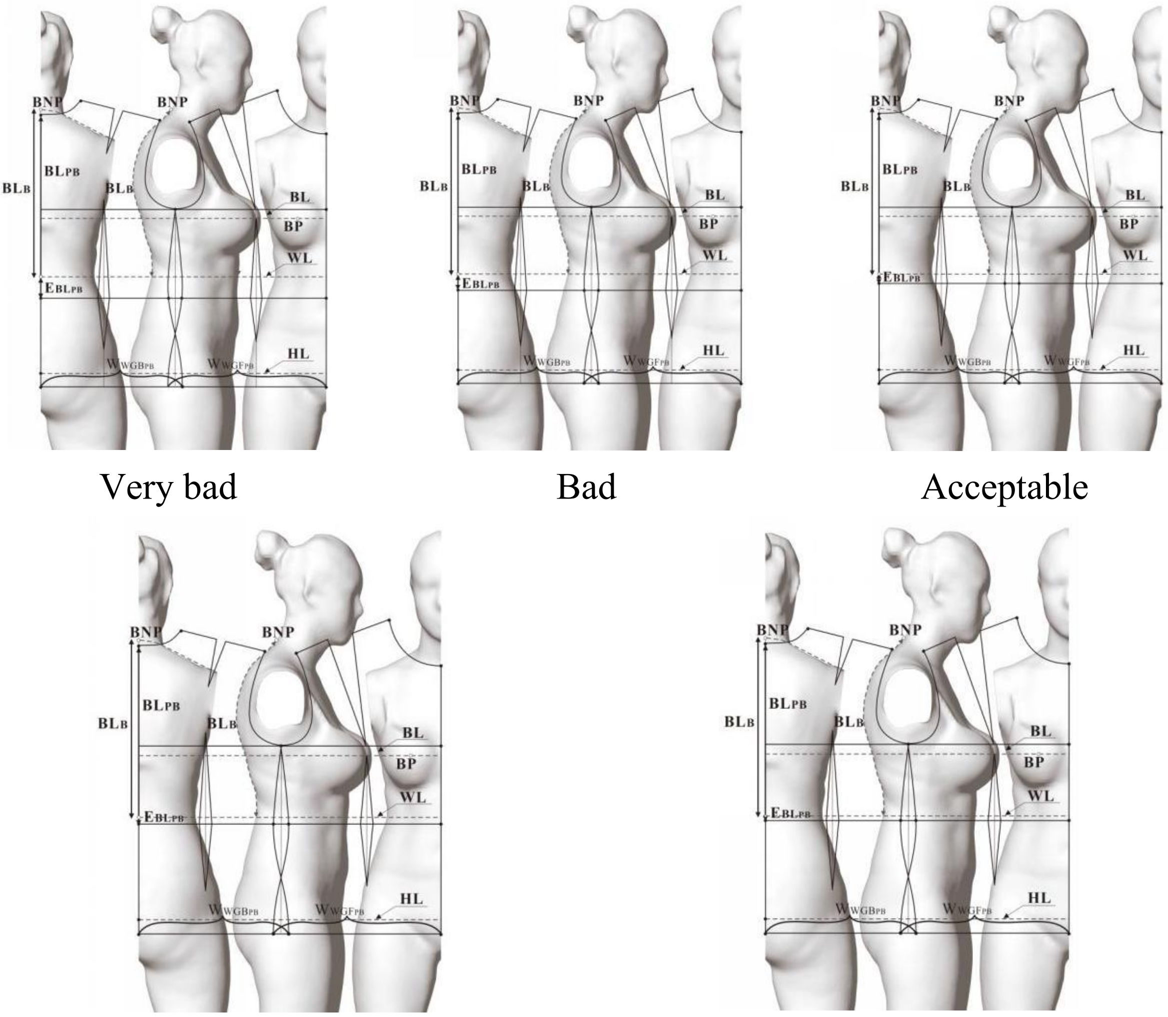
Before checking a correctness of sewing patterns, the criteria of blouse fit or misfit should be established to detect possibleerrors in sewing patterns and improve the efficiency of its checking. Blouse fit is defined as the result influencing by sizes and contour of the garment, on the one side, and the same characteristics of human body, on the other side. To show common approach how to coordinate the both group of characteristics.

Then, the pattern blocks were completed by ETCAD, and by using virtual simulation technology, five digital twins ofblouses withdifferent fitaccording to the appearance of ready-to wear blouse were created. Figure 5.3 shows virtual simulation of X- style women blouses with different fit in back length.

(a) Very bad (b) Bad (c) Acceptable (d) Good (e) Perfect

Figure 5.3 -Virtual simulation of women blouse with different fitin back length

As shown in Figure 5.3, five digital twins of blouses with different fit in back length were created by using virtual simulation technology. Due to the difference ease allowance in back length, blouses show different fit levels, and thus rank them from very bad to perfect. Figure 5.4 shows the scheme of the simulation of virtual "sewing" with different fit in two perpendicular directions - along theback length and along hip width.



Very bad Bad Acceptable

Good Perfect

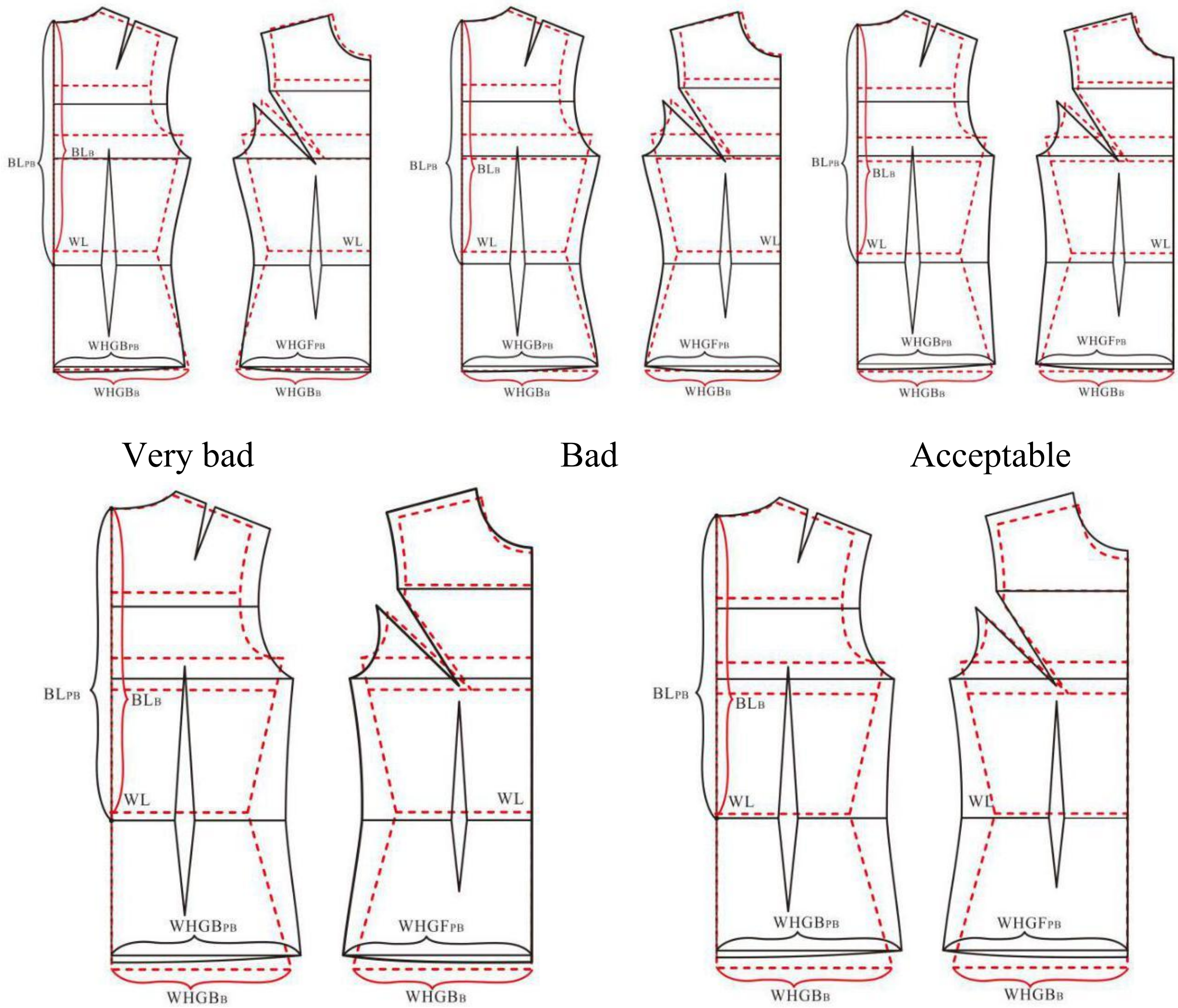
Figure 5.4 - Scheme of the simulation of virtual “sewing”with different fitin back length

Thefit will depend on the factors measured in two perpendicular directions - first, along the back length, front length, bust width, and second, along the back width, which together can be considered as the fit criteria of garment appearance[101]. As shown in Figure 5.4, the basic dimensions of patterns and body measurements for fit evaluation were:

- BL_B is the back length of body;
- BL_{PB} is the back length of sewing pattern;
- E_{BLPB} is the ease allowance to BL_{PB};

- $WHGB_{PB}$ is the back width of sewing pattern along a hip;
- $WHGF_{PB}$ is the front width of sewing pattern along a hip;
- $WHGB_{B}$ is the back segment of hip girth HG;
- $WHGF_{B}$ is front segment of hip girth HG.

The basic sewing pattern blocks in terms of body measurements as flattened digital twins were created by means of function flattening of CLO3D. Then, the scheme of calculating the ease allowance to back length and hip width for blouse pattern blocks were developed. Figure 5.5shows the scheme of comparing the body prototypewith the blouse pattern blocks in different fit in back length and hip width (black lines are pattern blocks of blouse, red lines are body prototype).



Good Perfect

Figure 5.5 - Scheme of comparing the body prototype of digital twins with the blouse pattern blocks in different fit levels

where: vertical axis = $E_{BLPB} = BL_{PB} - BL_{B}$,Horizontal axis = $E_{HGBPB} = (WHGB_{PB}+WHGF_{PB}) - (WHGB_{B}+WHGF_{B})$.

As shown in Figure 5.5, by comparing the body prototype of digital twins with the blouse pattern blocks, the ease allowance to back length and hip width for blouse pattern blocks were obtained in accordance with the difference between the two pattern blocks. Finally, the fit criteria for five different levels of fit were respectively established. Table 5.8 shows the fit criteria for back length and hip width of blouse pattern blocks.

Table 5.8 - Criteria of blouse back fit evaluation

	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 hem.	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	1st fit criteria. $E_{BLPB}= BL_{PB} - BL_{B}$, cm				
	E_{BLPB} ≥4.8±0.3	E_{BLPB} ≤3.8±0.3	E_{BLPB} ≤2.8±0.3	E_{BLPB} ≤1.8±0.3	E_{BLPB} ≤ 0.8±0.3
6	2nd fit criteria. $\Delta = (WHGB_{PB}+WHGF_{PB}) - (WHGB_{B}+WHGF_{B})$, 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

As shown in Table 5.8, the relations which are existing between chosen dimensions and measurements and are influencing on fit. Therefore, by analyzing the ease allowancesto back length and hip width as fit criteria, it's possible to evaluate the correctness of sewing pattern blocks.

Finally, according to the method of the criteria of blouse back fit evaluation, criteria of blouse bust width, front length, etc. were developed respectively, as shown in appendix J.

5.6. Examples of technology application

In order to inspect the availability and practical of the algorithm for scenario virtual fitting technology, the application of scenario virtual fitting technology was carried out.

The whole technology application was operated by the following procedure:

1) a representative blouse pattern block was chosen and examed in term of the style and fitting;

2) based on traditional and new body dimensions, a digital twin of female body was generated in CLO3D;

3) the quality of fit of the chosen blouse pattern block was analyzedby checking neck line, shoulder line, back length, ease to bust and horizontal sizes of blouse pattern blocks;

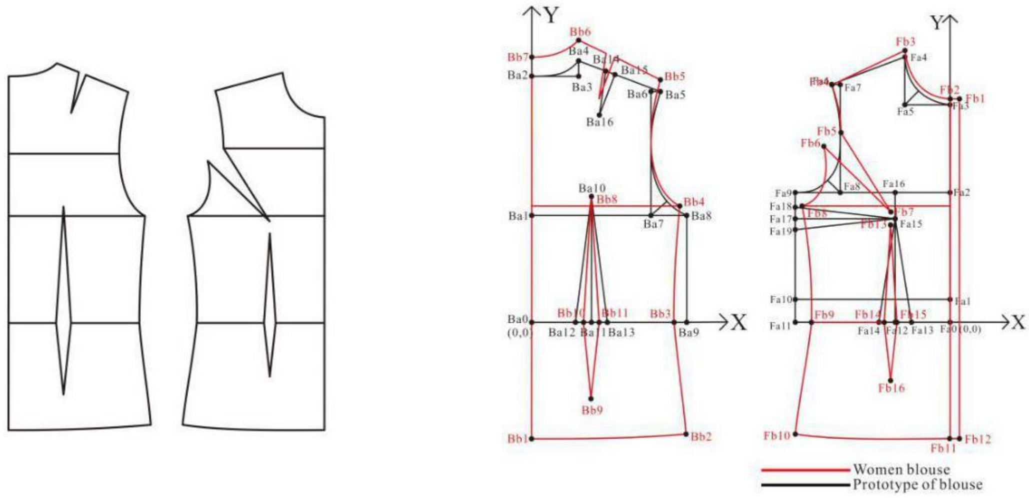
4) with the digital twin of female body, the blouse pattern block and the digital twin of women blouse were processed in CLO3D, the digital twin of "avatar-blouse" system was generated;

5) the objective evaluation of the virtual women blouse was conducted by means of grey-scale technology after virtual try-on;

6) the blouse pattern block was corrected according to the conclusion about fit, and real sample of blouse was further made to verify the scenario virtual fitting technology;

5.6.1. Analyzing of blouse pattern blocks

As discussion in Section 2.1.5 and 2.1.6, by overlapping the prototype of blouse and blouse pattern blocks, the size of the structural parts and the size of the design variables were analyzed, then the style and fitting degree of the pattern blocks was further analyzed. Figure 5.6shows the scheme of analyzing blouse pattern blocks. A representative blouse pattern blocks was chosen as an example to conduct the application of scenario virtual fitting technology.



a b

Figure 5.6 - Scheme of analyzing blouse pattern blocks: a - X-style blouse pattern blocks with body-fitting, b - overlapping blouse pattern blocks and prototype of blouse

Figure 5.6 (b) shows that by overlapping blouse pattern blocks and prototype of blouse, the structural design variables of the blouse pattern blocks (As Section 2.1.5) were analyzed. According to variables of A9, A11, A12, B8, B10 and B11, the style and fitting of blouse pattern blocks would be recognized. Table 5.9 shows the size of design variables for blouse pattern blocks.

Table 5.9 - Size of design variables for blouse pattern blocks (unit: cm)

Front		Front	
A1	-0.2	B1	-0.2
A2	0.4	B2	0.4
A3	-1.6	B3	0.2
A4	1.5	B4	0.6
A5	-0.2	B5	-0.9
A6	0.1	B6	-0.4
A7	0	B7	0.8
A8	-3.2	B8	-0.5

A9	-0.5	B9	17.3
A10	16.8	B10	-5.5
A11	-2.6	B11	-0.5
A12	-1	B12	17.2
A13	17.2	B13	18
A14	18		

As shown in Table 5.9, the size of design variables (A9, A11, A12, B8, B10 and B11) which could be used to recognize the style of blouse pattern blocks were obtained. By contrastive analyzing the frequency analysis results of design variables for X-style blouse and the size of design variables (see Section 2.1.5), the blouse pattern block was judged as X-style.

Table 5.10 - Dimensions of structural parts for pattern blouses

Front,cm		Front,cm	
BLW	22.5	BLW	23
WLW	19.5	WLW	19.5
HLW	23.9	HLW	23.9
FBW	16.9	BBW	15.9
SW	18.3	SW	20
NW	7	NW	7.3
ND	7.5	ND	2.4
AD	16.6	AD	19.1
FPW	1.5	CL	60
CL	60		

As shown in Table 5.10, the dimensions of the structural parts (BLW, WLW, HLW) were obtained, which could be used for further recognition of the style of drawings of blouses. By comparative analysis of the size range of structural parts for drawings of blouses in a fitted, loose and looser style for style X (see Table 2.5) and the size of the structural parts of the blouse drawing, it was found that the size of the structural parts of the blouse drawing is within the size range of the structural parts of drawings of blouses in a fitted silhouette. Based on this, it can be determined that the drawing of the blouse refers to a fitted style.

In combination with the analysis results given above, the blouse pattern was rated as X-style with a fitted silhouette.

5.6.2. Generation of digital twin of female body

As discussion in Section 2.2, parameteric digital twin of real body with adaptive morphology was generated by input traditional and new body dimensions from database of Anthropometry.Table 5.10 shows the body dimensions for generation of digital twin of female body.

Table 5.10 - Body dimensions for digital twin of female body

N.	Measurement parameters	Body dimensions, cm
1	Height	160
2	Neck height	143
3	Waist height	105
4	Bust girth	84
5	Waist girth	67
6	Hip girth	91
7	Neck girth	36
8	Length of cross shoulder over neck	38
9	Shoulder width	32.9
10	Armhole girth	28.8
11	Upper arm girth	28.1
12	Arm length	53

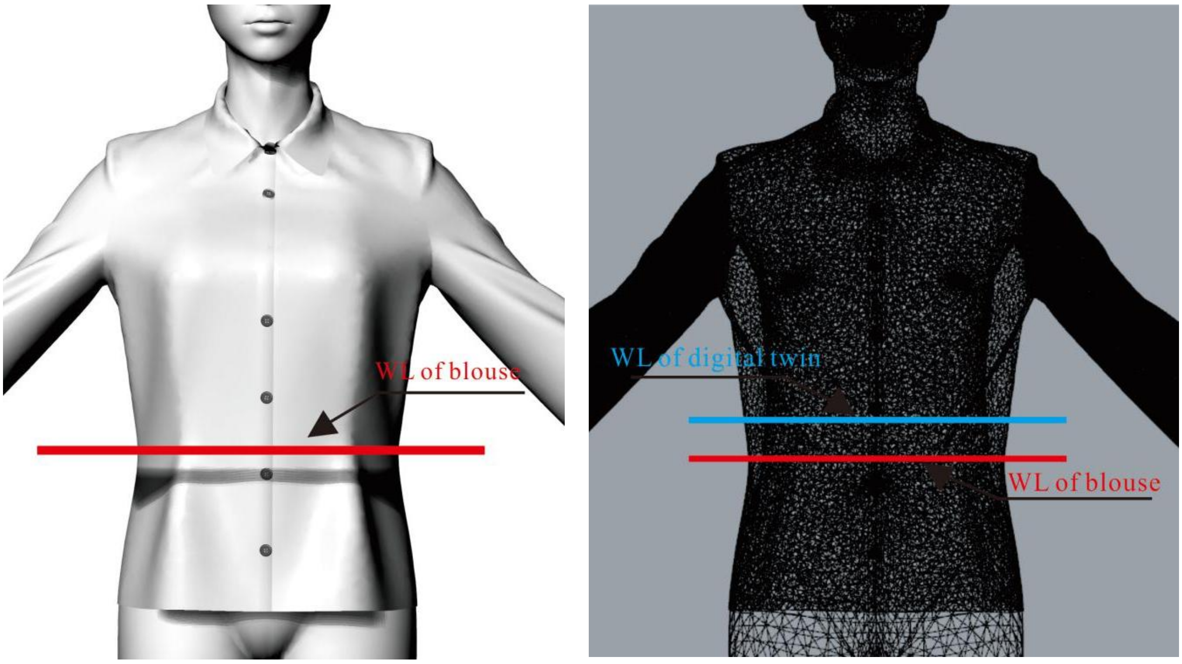
13	Bust width	17
14	Back width	16
15	BNP - BBP - BWP	38
16	FNP-FBP-FWP	33.5
17	FNP-BP-FWP	36
18	SNP-BP-FWP	40
19	SP-FAP-FWP	36
20	SP-BWP	40
21	SP-BAP-BWP	37
22	SNP - SP	11.5
23	FWP - FHP	20
24	SNP - BP	25.7

Figure 5.7 - Digital twin of female body (160/84A)

As shown in Figure 5.7, by utilizing the traditional and new body dimensions and inputting the body dimensions in CLO3D (As Section 3.2), the digital twin of female body was generated.

5.6.3. Checking of blouse pattern blocks

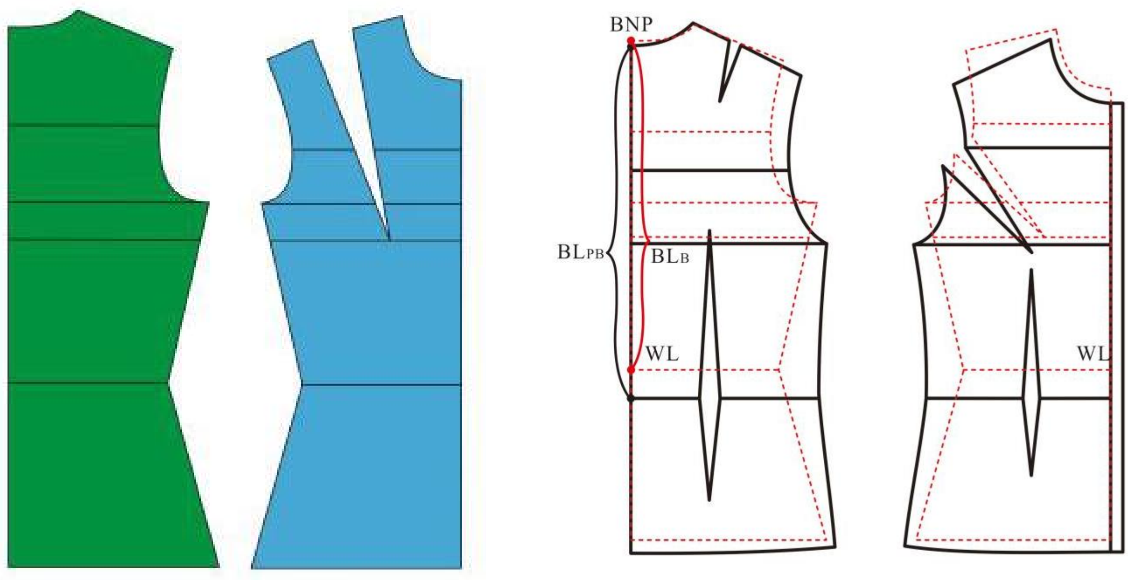
As discussion in Section 3.3.4, the both waist lines of the digital twin and patterns were determined, the ease allowance to back length which equal to the distance between them were measured. Figure 5.8shows the scheme of analyzingease allowance to back length.



a b

Figure 5.8 -Scheme of analyzingease allowance to back length: a - Render of blouse with waist line at narrowest waist place, b - Shearing render of blouse with the both waist lines

As Figure 5.8(a) showsthat the render of blouse was generated from the patterns on digital twin (160/84A) in CLO3D in accordance with waist line of patterns (AsSection3.3.4). As shown in Figure 5.8 (b), after exporting the file of the blouse render into Rhinos, the blouse render was transformed in the transparent triangulation grid. The anthropometric waist line of the digital twin was found (AsSection3.3.4). Then, by measuring the distance between the waist line of the digital twin and the blouse render, the ease allowance to back length was obtained, and the ease allowance to back length is 4cm.



a b

Figure 5.9 - Scheme of calculating the ease allowance to BNP: a -flattened 2D body prototype, b - overlapping body prototype with blouse pattern blocks

As shown in Figure 5.9 (a), the flattening body prototype which presents its morphological features was generated (As Section 3.3.1). Based on the waist line, the body prototype and the blouse pattern blocks were overlapped respectively, as shown in Figure 5.9 (b).Then, the ease allowance to BNP which equal to the distance between them was measured, and the ease allowance to BNP is 4cm.

As discussion in Section 3.3.2 and 3.3.5, the neck girth and shoulder lines of the digital twin were overlapped on the pattern blocks, then the neck and shoulder lines of the pattern blocks were checked. Figure 5.10 shows the scheme of checking neck and shoulder lines.

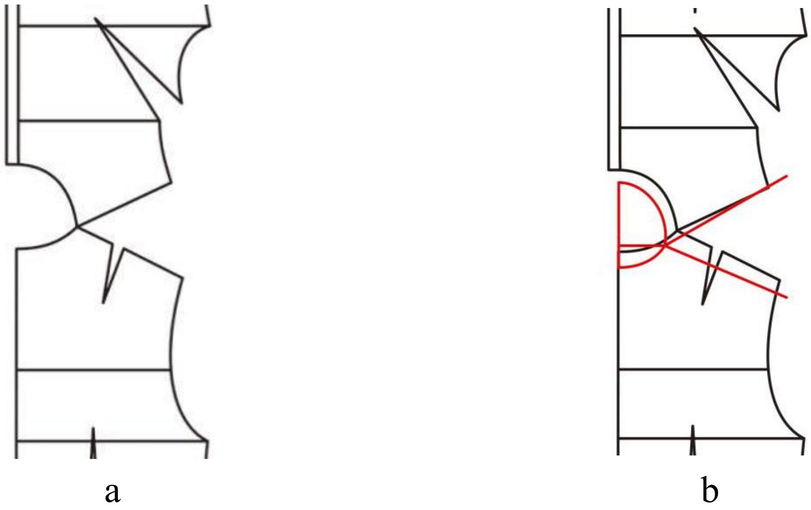


Figure 5.10 -Scheme of checking neck and shoulder lines

As Figure 5.10 shows the incorrect location of the both neck lines. There is no parallelism of shoulder lines, and the shoulder line of patterns are inconsistent with the digital twin(AsSection3.3.5). And the front and back angle of shoulder line of pattern blocks are 25.1° and 25.6° respectively. Then $\Sigma\alpha_B < \Sigma\alpha_{PB}$, $\triangle = \Sigma\alpha_B - \Sigma\alpha_{PB} = 16.9°$(AsSection3.3.5). Therefore, the defects of pattern blocks could lead to the possible arising of folds on the shoulder and back.

In addition, by comparing the body prototype of digital twins with the blouse pattern blocks, the ease allowance to hem width for blouse pattern blocks were analyzed further (AsSection3.3.3 and 5.5). Figure 5.11 shows the scheme of calculating the ease allowance to hip width by comparing body prototype with blouse pattern blocks.

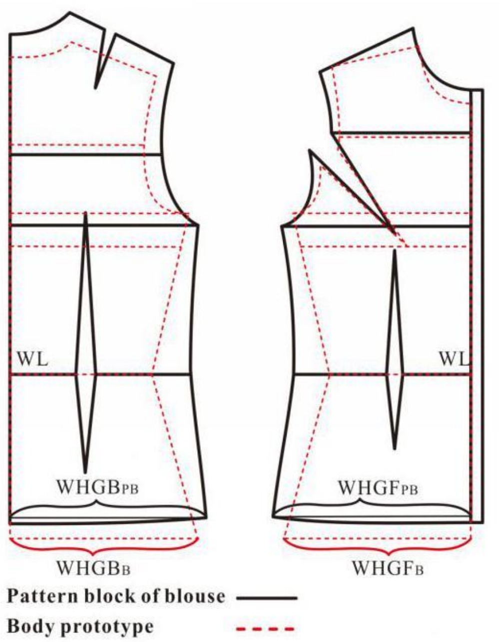


Figure 5.11 -Scheme of comparing body prototype with blouse pattern blocks

As Figure 5.11 shows that using the waist line of the body prototype as a reference line, blouse pattern blocks were overlapped with the body prototype (As Section 5.5). Then, the ease allowance to hip width of blouse pattern blocks was calculated, and E_{HW} is 5.6cm.

As discussion in Section 5.4, bust girth is composed of three parts: front bust width, armhole width and back bust width. Therefore, according to the proportion of the ease allowance distribution in the three parts, the ease to bust girth of pattern blocks was analyzed.Figure 5.12 shows the scheme of analyzing ease to bust girth of pattern blocks.

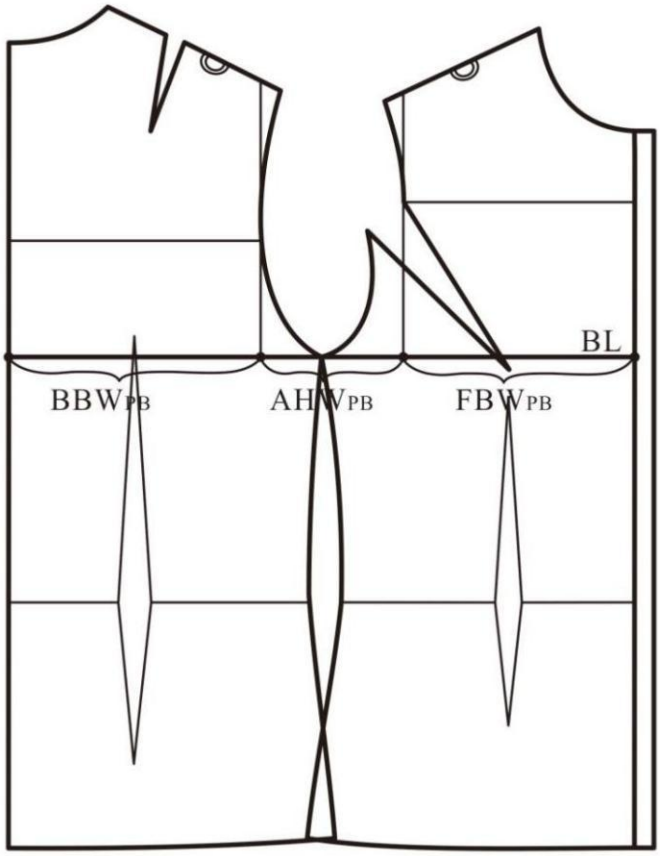


Figure 5.12 -Scheme of analyzingease to bust girth of pattern blocks

As Figure 5.12 shows that based on the ease allowance to front bust width, armhole width and back bust widthof pattern blocks, the proportion of the ease allowance distribution in the three parts were calculated, and the proportion of the ease allowance distribution in bust girth is 30:40:30 (E_{FBW} : E_{AHW} : E_{BBW}).

Combined with the checking results of neck line, shoulder line, back length, ease to bust girth and hip line width, and the corresponding fit criteria, the fit of pattern blocks was concluded. Then, the misfit situation in shoulder line and back length was found. Table 5.11 shows the conclusion about fit of pattern blocks.

Table 5.11 - Conclusion about fit of pattern blocks

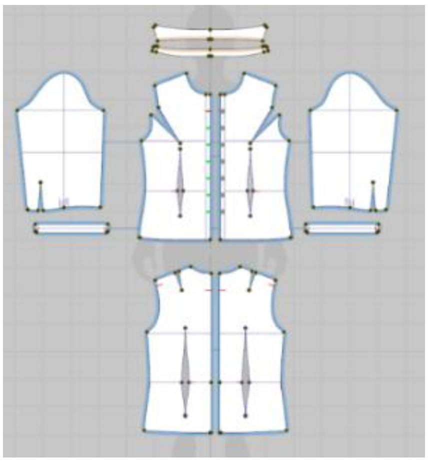
Detect location	Fit indicators (cm, degree, %)	Analyzing results
Neck line	$\Delta = NL - NG = 2.5$	Fit

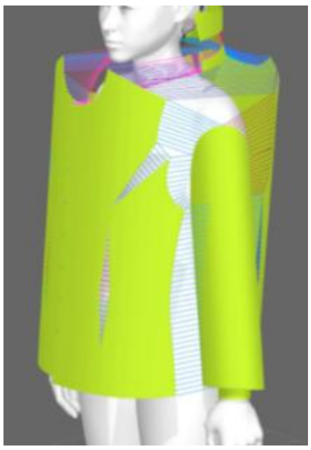
Shoulder line	When $\Sigma\alpha B < \Sigma\alpha PB$, $\triangle = \Sigma\alpha B - \Sigma\alpha PB = 16.9^{o}$	Misfit
Back length	$\Delta = BL_{PB} - BL_{B} = 4$	Misfit
Ease to BNP	Ease to BNP= -0.5	Misfit
Ease to bust girth	$\Delta = E_{FBW} : E_{AHW} : E_{BBW} = 30:40:30$	Fit
Hem line width	$\Delta = (WHGB\mathrm{PB}+WHGF\mathrm{PB}) - (WHGB\mathrm{B}+WHGF\mathrm{B})=5.6$	Fit

As Table 5.12 shows that because of the shoulder slope of pattern blocks was do not accord with the morphological features of the digital twin, the structure location of pattern blocks in shoulder line was incorrect. The ease allowance to back length is too large also does not accord with the morphological features of the digital twin. Thus we can conclude that the blouse pattern blocks is not accurate enough especially in back length and shoulder line, so that we can further modify the pattern blocks according to this conclusion.

5.6.4. Generation of digital twin of "avatar-blouse" system

Based on Section 2.1, 2.2 and 3.4, the digital twin of "avatar-blouse" system were genetated by integrating the virtual twin of female body, digital twin of textile materials and blouse pattern blocks.Figure 5.13 shows the scheme of generation of digital twin of "avatar-blouse" system.





a b

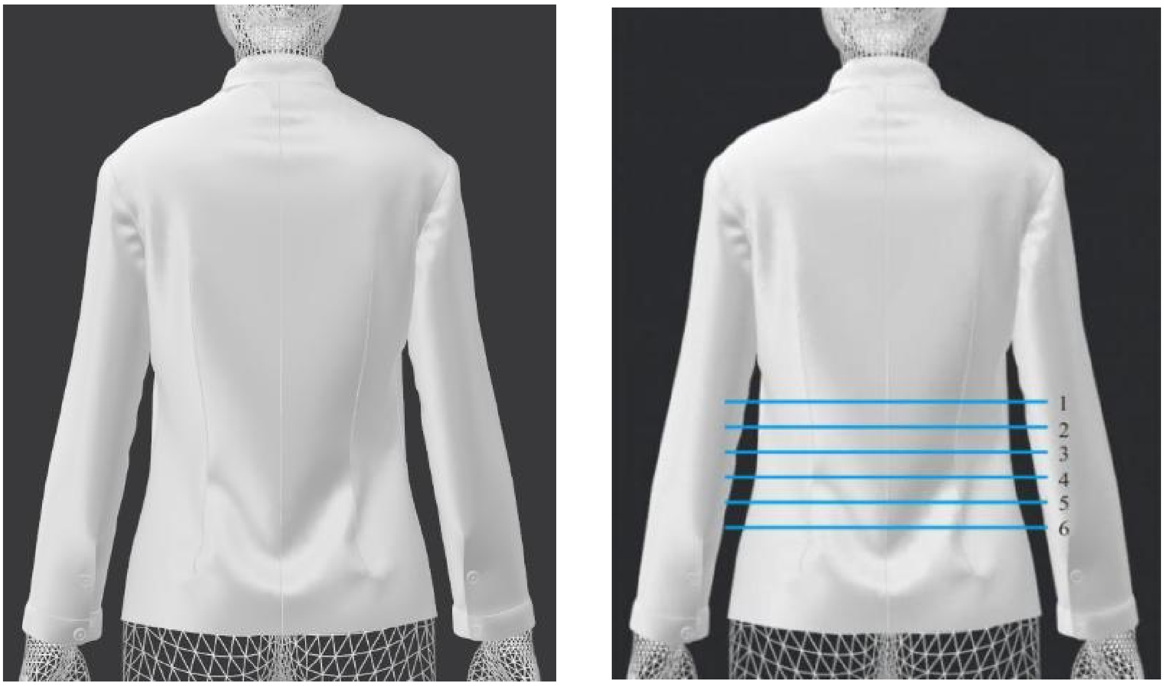
c d

Figure 5.13 - Scheme of generation of digital twin of “avatar-blouse” system: a - women blouse pattern blocks in CLO3D, b - virtual sewing process, c - editing digital properties of virtual fabrics, d - virtual try on of women blouse

Firstly, as Figure 5.13(a) shows that by inputting traditional and new body dimensions, a parameteric digital twin of real body (160/84A) with adaptive morphology was generated (As Section 2.2). Secondly, as Figure 5.13(b) shows that the blouse pattern blocks (.dxf format) drafted in ET CAD was imported to CLO3D, and the sewing craftsmanship for the 3D pattern pieces was edited. Each 3D pattern piece (front bodice, back bodice, collar stand and turnover collar, sleeve, its placket and cuff) were arranged on the corresponding body segments (body, neck and arm), respectively. Finally, the seams of the adjacent pieces were sewed up. Thirdly, the digital properties of virtual fabrics were determined as Section 5.1.2. Finally, the 3D virtual fitting visualization of women blouse was conducted automatically with all pieces sewed up and draped on the digital twin of female body.

5.6.5. Objective evaluation of women blouse by means of gray-scale technology

In addition, in order to check the virtual women blouse, the fit evaluation was conducted objectively by using gray-scale technology (As Section 4.1). Figure 5.14 shows the virtual women blouse with misfit in back and analysis location of horizontal cross-sections on virtual women blouse.



a b

Figure 5.14 -Virtual women blouse with misfit (a) and location of horizontal cross-sections on virtual women blouse(b)

As Figure 5.14(a) shows that after 3D virtual fitting, because of the virtual women blouse with defect in back length, there are some sloping folds upper waist level. As shown in Figure 5.14(b), to analyze the folds and its distribution, the horizontal cross-sections were made on waist level (As Section 4.1.2).

As discussion in Section 4.2, by means of gray-scale technology, the information about the folds at waist area which are located on 6 horizontal lines were demonstrated.Table 5.12 shows the fold information on 6 horizontal lines in the waist area.

Table 5.12 - The fold information in the waist area (160/84A body type)

E_{BL}, cm	Cross-section	Folds parameter			Unevenness of fold, pixel/grey value	
		Number	Width (for each fold), pixel (VDi)	Depth (for each fold), grey value (VHi)	Width	Depth
4	WL +6	0	0	0	3.39	4.4
	WL +3	0	0	0		
	WL	2	31/99	20/38		
	WL-3	3	40/75/27	19/82/37		
	WL-6	2	47/29	80/31		
	WL-9	2	33/43	20/20		

Then, the information about the folds located on 6 horizontal lines were converted into centimeter. Table 5.13 shows the calibration of the fold information of each line in the waist area as centimeter.

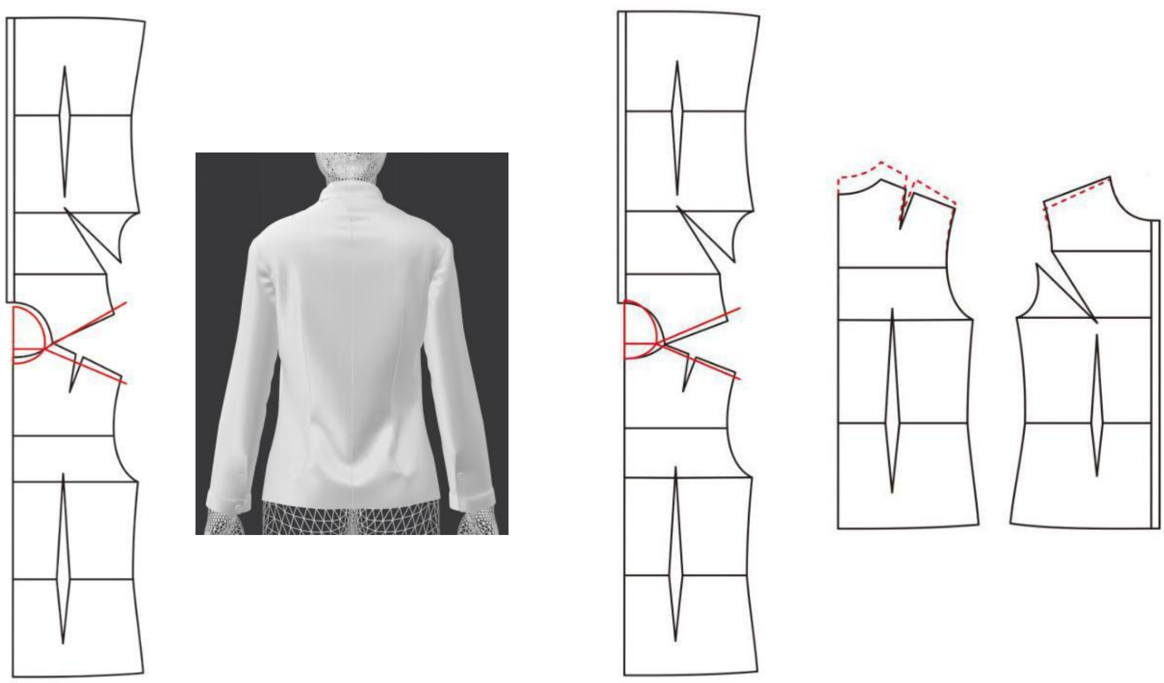
Table 5.13 - Calibration of the fold information of each line in the waist area (A body type)

Cross-section	Depth of folds, width of folds, depending on E_{BL}			
	E_{BL}= 4, cm			
	Depth of folds		Width of folds	
	gray value	cm	gray value	cm
WL+6	0	0	0	0
WL+3	0	0	0	0
WL	20/38	1/1.9	31/99	1.6/5
WL–3	19/82/37	1/4.1/1.9	40/75/27	2/3.8/1.4
WL–6	80/31	4/1.6	47/29	2.4/1.5
WL–9	20/20	1/1	33/43	1.7/2.2

As Table 5.13shows that folds were mainly concentrated at the waist level (WL), and below WL (WL-3, WL-6, WL-9). In addition, fold depth and fold width varied greatly in cross-section of WL-3 and WL-6, indicating that folds were obvious in this area. Furthermore, it is further proved that folds were accumulated in waist area due to excessive ease allowance of back length, which were mainly concentrated in cross-section of WL-3 and WL-6.

5.6.6. Correction of pattern blocks

Combined with conclusion about fit of pattern blocks and the fold information on 6 horizontal lines in the waist area, the blouse pattern blocks were further corrected. Figure 5.15 shows the blouse pattern blocks with misfit (a) and after correction (b).



a b

Figure 5.15 - Patterns and “digital twin - digital blouse” systems with misfit (a) and pattern block after correction (b)

As shown in Figure 5.15 (a), the shoulder line of digital twin is almost non parallel to the shoulder line of pattern. Because the shoulder lines cross-shaped, its structureand neck lines of patterns do not accord with the morphological features of the digital twin. At the same time, after the CLO3D virtual fitting, the shoulder slope of the blouse are large. For these reasons, there are superfluous folds on the shoulder and back length, which indicates that the correctness of the pattern block is not good.

This method opens the way of altering the patterns when morphological features of digital twin are known. According to summary of problems, the patterns from Figure 5.16 (a) was further modified. As shown in Figure 5.16 (b), *BNP* and *SNP* of pattern was firstly declined to a certain size, and *SP* was raised in proportion of *SNP* moving; so,after these manipulations the armhole length will not change. Thus, the shoulder angles and back length of the patterns were reduced to fit the morphological features of the digital twin.

a b

c d

Figure 5.16 - Virtual simulation before (a,b) and after modification of patterns(c,d)

The modified pattern block were further virtually tried on by using the CLO3D. Compared with before modification, due to new shoulder angles after modification is consistent with the morphological features of the digital twin, the excess vertical folds on the front and side waist of the blouse were eliminated. In the armhole part, the oblique folds caused by the misfit also disappeared, and the armhole part have also become more smooth, as shown in Figure 5.16 (c) and (d). In addition, by reducing the ease allowance to back length, the horizontal folds at the waist and the excessive armhole folds were eliminated by the reduction of the shoulder sloping angle of pattern blocks.

Furthermore, the real blouse sample was simultaneously produced based on the corrected patterns. Figure 5.17 shows the real blouse sample draped on the dummy in two views (front and back).

a b

Figure 5.17 - Real blouse sample draped on the dummy: a - front view, b - back view

As shown in Figure 5.17, the real X-style blouse with body-fitting exhibited the smooth exterior contours with vertical placket and side seams, appropriate lengths of bodice and sleeve without excessive folds. As a result, the accuracy of the patterns become very high, which can meet the requirements of the human body for garment fit.

Thus, the practical application validated the availability and practical of the scenario virtual fitting technology.

Summary of Chapter 5

1. The initial databases of misfit pictures of women's blouse and digital twins of women blouse were established. According to method of women blouse pattern-making, the schedule of defects was summarized. Combined with the virtual try-on technology, the women blouse with misfit caused by incorrect

pattern blocks were verified, which could be applied as the subjective criteria for checking clothing fit of women' blouse.

2. The comprehensive five-level criteria for checking different structural parts of women's blouse were established with subjective items (scheme of pattern blocks, images of the digital twins of the blouses, verbal evaluation of the blouses fit). Based on the subjective criteria, the numerical values of the criteriafor checking different structural parts of women's blouse were established further. These criteria can be not only used to check possible an errors in sewing patterns and improve the efficiency of its checking, but also provide concrete recommendations for pattern making.

3. The practical application testing of scenario virtual fitting technology shows a high degree of availability and practical. The scenario virtual fitting technology is recommended to be applied in customized virtual try-on of women's apparel.

CONCLUSIONS

Final results of research

1. According to clothing silhouette, 122 effective sewing patterns of women blouse collected before were divided into X type, H type, A type three categories. Based on the mathematical model of prototype and the control range of design variables for women blouse patterns, and the combination of linear regression models, and then X type, H type and A type mathematical models with three different fitting degree were respectively established.

2. Digital twin of real body was parameterized by means of 17 body measurements which can be used in parallel for the patterns analyzing.154 females aged 20 to 35 year have been measured by 3D laser scanner body VITUS Smart XXL, and 154 females were further grouped as Y, A, B, C body type. 3D scanning data from 3D body scanner were collected by using software Anthroscan, based on of which 3D wireframe of body-surface prototype was constructed. Through analyzing 2D body-surface prototype of female scanning bodies, 33 crucial measurements which can be used to describe the features of female morphology were obtained.

3. In terms of relationship between the digital twin measurements and the direction of shoulder lines of the pattern block, the basis which is reflecting the body morphology and combining the shoulder angles and cross-section of neck girth was obtained for checking the pattern block.By using virtual overlapping of the armhole line of the flattening bodies prototype, the method of analyzing the ease value of the armhole depth, front armpit point and back armpit point, the database of ease value of armhole line, and the basis of checking the quality of armhole were established.New method of ease allowance to back length analyzing and method of shoulder line analyzing were respectively obtained.By

means of 3D CLO software, the surfaces of 3D avatar were flattened into 2D garment patterns with zero eases. And the body prototype of 2D pattern block of avatar can be used in blouse pattern block checking. Then the blouse pattern blocks and the body prototype were overlapped based on the avatar to obtain the ease values of pattern blocks in X and Y directions respectively. The range of ease allowance of blouse pattern blocks with good fit in the directions of X-axis and Y-axis were respectively calculated.

4. By means of virtual technology, gray-scale image identification and pattern making, complex exploration about how body type and ease allowances together are influencing on women blouse fit was done. The number of folds and its distribution could be ruled during pattern making. In terms of eye -tracking technology, the degree of people's attention to different clothing parts under the condition of clothing fit evaluation were analyzed.According to eye -tracking indexes data such as fixation duration and fixation counts of 20 areas of interest of 15 blouses with different fit degree, the results showed that the total duration of fixation and the fixation counts of participants in different areas of interest were significantly different, and the degree of attention paid to the clothing parts of the women blouse was the bust, shoulder, waist and sleeve when evaluating clothing comfort with different fit criteria.

5. According to the online resources of misfit pictures of women's blouse, digital twins of women blouse and the constructive defects in women blouse, the initial databases were established for revealing the existing misfit problems in women's blouse. According to method of women blouse pattern-making, the schedule of defects was summarized. Combined with the virtual try-on technology, the women blouse with misfit caused by incorrect pattern blocks were verified. The comprehensive five-level criteria for checking different structural parts of women's blouse were established with subjective elements (scheme of pattern blocks, images of the digital twins of the blouses, verbal

evaluation of the blouses fit). Based on the subjective criteria, the numerical values of the criteriafor checking different structural parts of women's blouse were established further, which can be used to predict possible an errors in sewing patterns, check the fit of women's blouse, and provide concrete constructive recommendations for pattern making.

RECCOMENDATIONS, PERSPECTIVE OF FUTURE DEVELOPMENT

1. It is promising to use body scanning technologies to obtain more accurate anthropometric information, describe morphological characteristic of human body, and develop a labeling scheme for women blouse.

2. The results of the work can be used in the field of practical artistic and industrial design, education and advanced training for a qualitative change in existing concepts and the development of new, digitalization-oriented economies.

3. The scenario virtual fitting technology which integrating digital twin of "avatar-blouse" system, fit criteria of neck line, shoulder line, back length, ease to bust and horizontal sizes of blouse pattern blocks will be applied in customized virtual try-on of women's apparel.

List of aberrations

AD	–	Armhole depth
ADP	–	Armhole depth point
AG	–	Armhole girth
AHW	–	Armhole width
BP	–	Bust point
BL_B	–	Back length of body
BL_{PB}	–	Back length of sewing pattern
BLW	–	Bust line width
BAP	–	Back armpit point
BBW	–	Back bust width
BWP	–	Back waist position
BWW_{PB}	–	Back waist width of sewing pattern
BHP	–	Back hip position
BHW_{PB}	–	Back hip width of sewing pattern
BW	–	Bust width
BG	–	Bust girth
BG_{PB}	–	Bust girth of sewing pattern
BBW_{PB}	–	Back bust width of sewing pattern
$BBGL_{PB}$	–	Back segment of bust girth of sewing pattern
CL	–	Clothing length
EBL_{PB}	–	The ease allowance to BL_{PB}
EFL_{PB}	–	The ease allowance to FL_{PB}
$EFBW_{PB}$	–	The ease allowance to FBW_{PB}
$EBBW_{PB}$	–	The ease allowance to BBW_{PB}
EBG_{PB}	–	The ease allowance to BG_{PB}
FAP	–	Front armpit point
FBP	–	The intersection point between the hull curve at the level of bust point and the central vertical plane of body
FBW_{PB}	–	Front bust width of sewing pattern
FWW_{PB}	–	Front waist width of sewing pattern
FHP	–	Front hip position
FHW_{PB}	–	Front hip width of sewing pattern
FNP	–	Front neck point
FPW	–	Front placket width
FWP	–	Front waist position
FL_B	–	Front length of body
FL_{PB}	–	Front length of sewing pattern

FBW_{PB}	–	Front bust width of sewing pattern
$FBGL_{PB}$	–	Front segment of bust girth of sewing pattern
H	–	Height
HG	–	Hip girth
HLW	–	Hemline width
ND	–	Neck depth
NG	–	Neck girth
NW	–	Neck width
WG	–	Waist girth
WLW	–	Waist line width
$WHGF_{B}$	–	Front segment of hip girth HG
$WHGB_{B}$	–	Back segment of hip girth HG
$WHGB_{PB}$	–	The back width of sewing pattern along a hip
$WHGF_{PB}$	–	The front width of sewing pattern along a hip
SP	–	Shoulder point
SNP	–	Side neck point
SBP	–	Side bust position
SWP	–	Side waist position
SHP	–	Side hip position
SL	–	Shoulder length
SW_{B}	–	Shoulder width of body
SW_{PB}	–	Shoulder width of sewing pattern
$(SNP - WL)F_{PB}$	–	The length of side neck point to waist length of front sewing pattern
$(SNP - WL)B_{PB}$	–	The length of side neck point to waist length of back sewing pattern

LIST OF TABLES

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APPENDIX A

The coordinate of mathematical model for Liu Ruipu's basis pattern blocks in Chapter 2

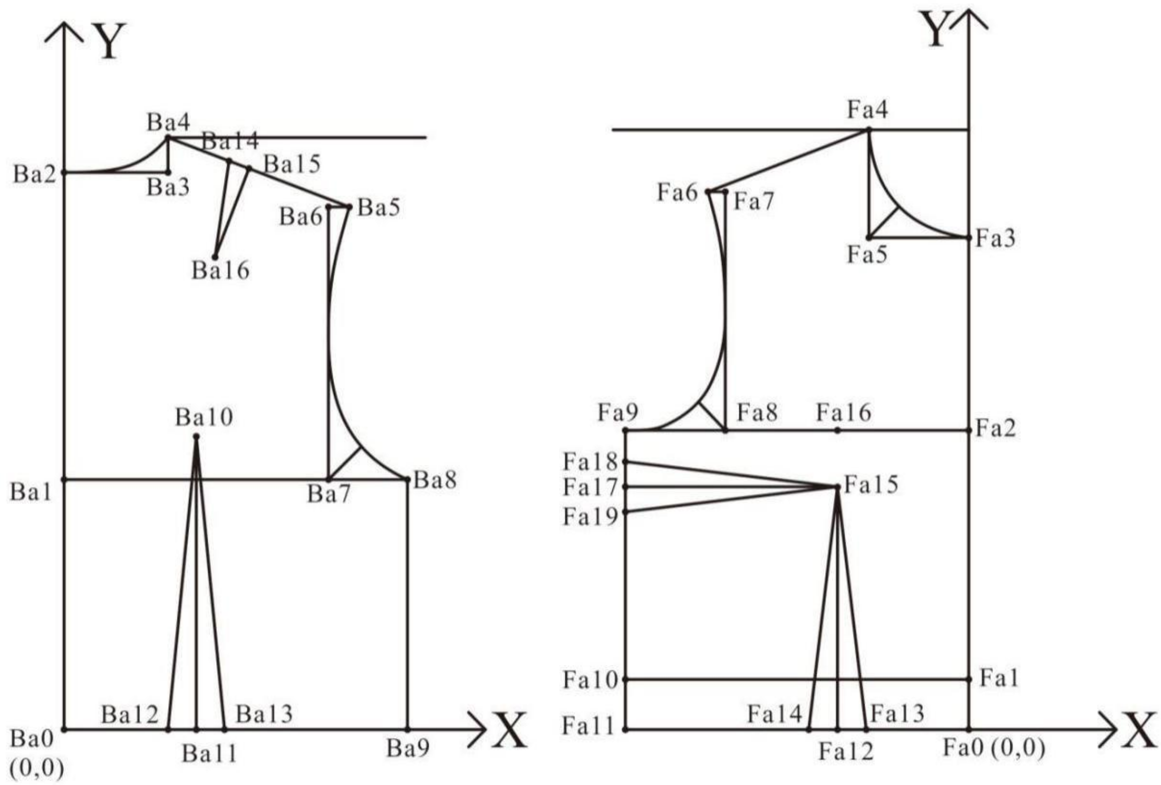


Figure A.1 - The coordinate of mathematical model for Liu Ruipu's basis pattern blocks

(1)Treating the intersection of the back center line and the waist line as the back original point of the coordinate, at the same time, regarding the central line as the Y axis, the back waist line as the X axis, and the point coordinates of the Ba0 point is (0,0).

(2)Treating the intersection of the central line and the armhole depth line as the Ba1 point, and the point coordinate value of the Ba1 point is obtained by the length of the back center line.

(3)Treating the top point of back center line as the Ba2 point, and the point coordinate value of the Ba2 point is obtained by the length of the back center line.

(4)Treating the back neck width as the Ba3 point, at the same time, the Y coordinate value of the Ba3 point is obtained by the back center line, and the X coordinate value of the Ba3 point is obtained by the back neck width. According to the equations of Table 3.1, the point coordinates of the Ba3 point is obtained.

(5)Treating the intersection of the back neck depth line and the back shoulder line as the Ba4 point. Because the X coordinate value is same with those in (4), the X coordinate value of the Ba4 point is obtained; Since the back neck depth is 1/3 of the back neck width, the Y coordinate value of the Ba4 point is obtained.

(6)Treating shoulder point as Ba5 point, the Y coordinate value is obtained according to back length subtracting $\frac{S_1}{36}+0.1$. And the X coordinate value is same with shoulder width, so the point coordinate value of the Ba5 point is obtained.

(7)The X coordinate value is same with back width, and the Y coordinate value is same with those in (6)， so the point coordinate value of the Ba6 point is obtained.

(8)Treating the intersection of the vertical line of back width line and the armhole depth line as the Ba7 point, the X coordinate value is same with those in (7), and the Y coordinate value is same with those in (2), so the point coordinate value of the Ba7 point is obtained.

(9)Treating the intersection of the side seam and the bust line as the Ba8 point, the X coordinate value is obtained according to the width of back bust line, the Y coordinate value is same with those in (2), so the point coordinate value of the Ba8 point is obtained.

(10)Treating the intersection of the side seam and the waist line as the Ba9 point, the X coordinate value is same with those in (9). Since the Ba9 point is located on the X axis, the Y coordinate value is 0, so the point coordinate value of the Ba9 point is obtained.

(11)Treating the waist dart ends as the Ba10 point, because the waist dart is located in the 1/2 of back width, so the X coordinate value is $\frac{S_1}{12}+2.25$; according to the armhole depth line plus 3, the Y coordinate value is obtained.

(12)Treating the intersection between the center line of waist dart and waist line as the Ba11 point, the X coordinate value is same with those in (11), and the Y coordinate value is 0, so the point coordinate value of the Ba11 point is obtained.

(13)Treating the intersection of the left waist dart line and the waist line as the Ba12 point. The X coordinate value is $\frac{S_2}{8}-\frac{S_1}{24}+2.25$ by X value of the central line for the waist dart minus 1/2 of the waist dart value, and the Y coordinate value is 0, so the point coordinate value of the Ba12 point is obtained.

(14)Treating the intersection of the right waist dart line and waist line as Ba13 point. The X coordinate value is $\frac{5}{24}S_1-\frac{S_2}{8}+2.25$ by the X value of the central line for waist dart plus 1/2 of the waist dart value, and the Y coordinate value is 0, so the point coordinate value of the Ba13 point is obtained.

(15)Treating the intersection of shoulder dart and shoulder line as the Ba14 point. According to the coordinate value of the Ba5 being known in (6), the vertical distance between the shoulder point and the side neck point is $\frac{S_1}{18}+0.2$, and the vertical distance between the shoulder point and the back neck depth line is $\frac{S_1}{12}+5.7$, so the length of the shoulder line is obtained by using the Pythagorean theorem. Because the Ba14 point is located in 1/3 of the shoulder line, the length of Ba4 point--Ba14 point is $\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{3}$. At the same time, setting the horizontal distance between Ba14 point and Ba4 point equal to a, and the a value is $\frac{S_1}{54}+\frac{1}{15}$ by using sine theorem， and then the Y coordinate value of Ba14 point is obtained by using the Pythagorean theorem, so the point coordinate value of the Ba14 point is obtained.

(16)Treating the intersection of shoulder dart and shoulder line as the Ba15 point. The shoulder dart value is 1.5cm, and the length of Ba4point--Ba14point has been obtained in (15), so the length of Ba4point--Ba15point is $\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{3}+1.5$. At the same time, setting the horizontal distance between Ba15 point and Ba4 point equal to b, and the b value is $\frac{S_1}{54}+\frac{17}{30}$, so the point coordinate value of the Ba15 point is obtained.

(17)Treating the shoulder dart ends as the Ba16 point. Because the vertical distance between Ba16 point and Ba14 point is 1 cm, X value of the Ba16 point coordinates is obtained by X value of the Ba14 point coordinates minus 1cm. At the same time, the vertical distance between Ba14 point and Ba16 point is $\frac{\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}}{2}$, and the vertical distance between the Ba14 point and the back neck depth line is $\frac{S_1}{108}+\frac{1}{30}$, and then the vertical distance between the Ba14 point and the back neck depth line is equal to the difference between the vertical distance of the Ba14 point and the Ba16 point and the vertical distance of the Ba14 point and the back neck depth line, so the vertical distance between the Ba14 point and the back neck depth is obtained. The Y value of the Ba16 point coordinates is obtained by the back length minus the vertical distance between the Ba14 point and the back neck depth, so the point coordinate value of the

Ba16 point is obtained. As shown in table 3.2.

2, the front point coordinates of prototype for blouse:

(1)Treating the intersection of the front center line and the waist line as the front original point, and Treating the center line as the Y axis, waist line as the X axis, so the point coordinate value of the Fa0 point is (0,0).

(2)Treating the intersection of the front center line and the auxiliary line for waist line as Fa1 point. Because the distance between the Fa1 point and the waist line is equal to 1/2 of the neck width, the Y value of the Fa1 point coordinates is $\frac{S_1}{24}$, so the point coordinate value of the Fa1 point is obtained.

(3)Treating the intersection of the armhole depth line and the front center line as the Fa2 point. Because the distance between the armhole depth line and the waist line is equal to the sum of the distance from the armhole depth line to the waist auxiliary line and the distance from the waist auxiliary line to the waist line. At the same time, the distance between the armhole depth line and the waist line is equal to the Y value of the Ba1 point coordinate, and the distance from the waist auxiliary line to the waist line has been obtained in (2), so the point coordinate value of the Fa2 point is obtained.

(4)Treating the intersection of the neck depth line and the center line as the Fa3 point, according to the front neck depth is equal to the back neck width plus 1cm, at the same time, the distance from the Fa3 point to the waist line is equal to the back length minus the front neck depth and plus the distance from the waist auxiliary line to the waist line, so the point coordinate value of the Fa3 point is obtained.

(5)Treating side neck point as the Fa4 point, the front neck width is obtained from Table 3.1 above, and the Y value of the Fa4 point coordinate is equal to the back length minus 0.5cm and plus the distance from the waist auxiliary line to the waist line, so the point coordinate value of the Fa4 point is obtained.

(6)Treating the intersection of the front neck width line and the neck depth line as Fa5 point, the X coordinate value is same with those in (5), and the Y coordinate value is same with those in (4), so the point coordinate value of the Fa5 point is obtained.

(7)Treating front shoulder points as Fa6 point, the front shoulder length is equal to the shoulder length minus 1.5cm, and the vertical distance from shoulder point to front neck width line is obtained by using the Pythagorean theorem, so the X value of the Fa6 point coordinate is obtained, and the Y value of the Fa6 point coordinate is obtained according to Liu Ruipu's basic pattern making principle, and then the point coordinate value of the Fa6 point is obtained.

(8)Treating the vertex of bust width line as the Fa7 point, the Y coordinate value is same with those in (7), and bust width is obtained according to Liu Ruipu's basic pattern making principle, so the point coordinate value of the Fa7 point is obtained.

(9)Treating the intersection of the bust width line and the armhole depth line as the Fa8 point, the X coordinate value is same with those in (8), the Y coordinate value is same with those in (3), so the point coordinate value of the Fa8 point is obtained.

(10)Treating the intersection of the side seam and the armhole depth line as the Fa9 point, the X coordinate value is obtained according to Liu Ruipu's basic pattern making principle, and the Y coordinate value is same with those in (9), so the point coordinate value of the Fa9 point is obtained.

(11)Treating the intersection of waist auxiliary line and side seam as the Fa10 point, the X coordinate value is same with those in (10), the Y coordinate value is same with those in (2), so the point coordinate value of the Fa10 point is obtained.

(12)Treating the intersection of the waist line and the side seam as the Fa11 point, the X coordinate value is same with those in (11), so the point coordinate value of the Fa11 point is obtained.

(13)Treating the intersection of the center line for waist dart and waist line as the Fa12 point, because the central line of waist dart is located at BP point according to Liu Ruipu's basic pattern making principle, the X value of the Fa12 point coordinate is equal to 1/2 bust width plus 0.7cm, so the point coordinate value of the Fa12 point is obtained.

(14)Treating the intersection of right waist dart line and waist line as Fa13 point, the X coordinate value of the Fa13 point coordinate is equal to the X value of the central line for waist dart minus 1/2 waist dart value, and the X coordinate value is $\frac{S_2}{8}-\frac{S_1}{24}+2.2$, so the point coordinate value of the Fa13 point is obtained.

(15)Treating the intersection of the left waist dart line and the waist line as the Fa14 point, the X value of Fa14 point coordinate is equal to the X value of the central line for the waist dart plus 1/2 of the waist dart value, and the X coordinate value is $\frac{5}{24}S_1-\frac{S_2}{8}+2.2$, so the point coordinate value of the Fa14 point is obtained.

(16)Treating the waist dart ends as the Fa15 point, the X coordinate value is same with those in (13), and the Y coordinate value is obtained according to the location of BP point, so the point coordinate value of the Fa15 point is obtained.

(17)Treating the intersection of the extensional line of the central line for waist dart and the armhole depth line as the Fa16 point, the X coordinate value is same with those in (13), the Y coordinate value is same with those in (3), so the point coordinate value of the Fa16 point is obtained.

(18)Treating the intersection of the central line for side seam dart and side seam as the Fa17 point, the X coordinate value is same with those in (10), the Y coordinate value is same with those in (16), so the point coordinate value of the Fa17 point is obtained.

(19)Treating the intersection of the side seam dart line and the side seam as the Fa18 point, the X coordinate value is same with those in (10), the Y coordinate value is equal to the Y value of the central line for side seam dart plus 1/2 of side seam value, so the point coordinate value of the Fa18 point is obtained.

(20)Treating the intersection of the side seam dart line and the side seam as the Fa19 point, the X coordinate value is same with those in (19), the Y coordinate value is equal to the Y value of the central line for side seam dart minus 1/2 of side seam value, so the point coordinate value of the Fa19 point is obtained.

APPENDIX B

Frequency analysis results of design variables for women blouse pattern in Chapter 2

Table B.1 - Frequency analysis results of design variables for X-style blouse (n = 71)

Variables	The distance (difference) between prototype and blouse pattern blocks	AVG.	MIN.	MAX.
A1	Front neck width line	-0.2	-2.2	0
A3	Front neck depth line	-2.3	-24.7	0.4
A4	Front opening placket width	1.5	0	3
A5	Shoulder width line	-0.2	-0.9	1.3
A8	Bust line	-2.5	-7.5	1
A10	Waist and bust lines	17.5	12.5	21
A13	Waist and hem width line	17.9	12	39
A14	Waist line and the bottom point of the hem	21.3	15	49
A2	Front neck width	0.5	-2	5.5
A6	Shoulder width	0.2	-5.9	5.6
A7	Front bust width	0.06	-0.6	4.3
A9	Bust line width	-0.05	-1.6	2.5
A11	Waist line width	-3.4	-6	-0.5
A12	Waist line width and hem width line	0.7	-1.9	4.3
B1	Back neck width	-0.2	-2.2	0.1
B3	Back neck depth line	0	-3	1
B4	Shoulder width line	0.8	-0.6	2.4
B7	Bust line	-0.1	-5.6	1.5
B9	Waist and bust lines	16.4	10.9	18
B12	Waist and hem width line	18.1	12	41
B13	Waist line and the bottom point of the side seam	20.5	14	49

B2	Back neck width	0.8	-0.4	6
B5	Shoulder width	-0.3	-1.6	5
B6	Back bust width	-0.3	-1.3	4.8
B8	Bust line width	-0.9	-3.1	4.5
B10	Waist line width	-4.5	-7.7	1.4
B11	Waist line width and hem line width	-0.4	-3.1	4.4

Table B.2 - Frequency analysis results of design variables forH-style blouse pattern (n = 29)

Variables	The distance between prototype and blouse pattern blocks	AVG.	MIN.	MAX.
A1	Front neck width line	-0.1	-0.4	0
A3	Front neck depth line	-1.5	-5	0
A4	Front opening placket width	1.5	0	2
A5	Shoulder width line	-0.3	-1.7	0.6
A8	Bust line	-4.8	-10	-1.3
A10	Waist and bust lines	15.2	10	18.7
A13	Waist and hem width line	23.6	11.6	38.3
A14	Waist line and the bottom point of the hem	27.7	20.3	38.3
A2	Front neck width	0.1	-1.1	1
A6	Shoulder width	3	0	8.6
A7	Front bust width	2.6	-0.3	8.2
A9	Bust line width	2.5	-0.3	6.5
A11	Waist line width	2.5	-0.3	6.5
A12	Waist line width and hem width line	2.5	-0.3	6.5
B1	Back neck width	0	-0.3	0
B3	Back neck depth line	0.2	-0.1	0.4
B4	Shoulder width line	1	-0.4	1.8
B7	Bust line	-2.5	-7.1	1.5

B9	Waist and bust lines	14	9.4	18
B12	Waist and hem width line	22.7	12	31.6
B13	Waist line and the bottom point of the side seam	26.2	12	34.6
B2	Back neck width	0.3	-0.4	0.8
B5	Shoulder width	2.2	0	7
B6	Back bust width	2.1	-0.6	7.3
B8	Bust line width	2.5	-1.7	7
B10	Waist line width	2.5	-1.7	7
B11	Waist line width and hem line width	2.5	-1.7	7

Table B.3 - Frequency analysis results of design variables forA-style blouse pattern (n = 22)

Variables	The distance between prototype and blouse pattern blocks	AVG.	MIN.	MAX.
A1	Frontneck width line	-0.4	-2.2	0
A3	Front neck depth line	-2.6	-10.5	2
A4	Front opening placket width	1.5	0	2
A5	Shoulder width line	-0.6	-3.2	1.3
A8	Bust line	-4.3	-10.5	1.1
A10	Waist and bust lines	15.7	9.5	21.1
A13	Waist and hem width line	28.1	6.9	41.9
A14	Waist line and the bottom point of the hem	31.9	9.9	47.9
A2	Front neck width	1.1	-1.5	5.8
A6	Shoulder width	3.4	-1.7	11
A7	Front bust width	2.6	-0.2	8.8
A9	Bust line width	2.8	-0.1	11.5
A11	Waist line width	4.6	1.8	13.7
A12	Waist line width and hem width line	8.1	2.4	21.3
B1	Back neck width	-0.1	-1.3	1.2

B3	Back neck depth line	-0.4	-4.6	0.6
B4	Shoulder width line	1	-2.2	3.1
B7	Bust line	-3.1	-9.1	0.8
B9	Waist and bust lines	13.4	7.4	17.3
B12	Waist and hem width line	29.5	8.9	37
B13	Waist line and the bottom point of the side seam	32.7	9.9	47.9
B2	Back neck width	1.5	-0.2	7
B5	Shoulder width	2.8	-2.9	10
B6	Back bust width	2.1	-0.4	7.6
B8	Bust line width	4.3	-2	16.5
B10	Waist line width	5.7	-2	18.8
B11	Waist line width and hem line width	8.9	-2	26.3

APPENDIX C

Size of structural parts for women blouse pattern in Chapter 2

Table C.1 - Size of front structural parts for X-style blouse pattern (cm)

N.	BLW	WLW	FBW	SW	NW	ND	HW	AD	FPW	CL
1	2	3	4	5	6	7	8	9	10	11
X-1	24.5	21	17	18.5	6.9	7.9	24.5	17.26	2	56.25
X-2	24.5	21	17	18.5	8.8	8	25.5	18.26	0	59.78
X-3	23.5	19.5	17	12.5	12.5	6.7	25	16.26	1.7	57
X-4	24.5	21	17.1	19.2	8.3	8	25	18.75	1.25	62
X-5	24.7	20.3	16.7	18.1	8.3	18.8	26.6	22.11	2.5	66.84
X-6	24.7	20.7	16.7	18.2	9.2	8.8	27.7	22.09	2	61.39
X-7	23.5	21	16.5	17.8	7.3	7	24	16.7	1.5	57.55
X-8	24.7	21.5	16.7	18.4	8.8	16.6	24.9	20.47	1.7	59.55
X-9	23.7	20.5	19.8	21	9	12	24.5	22.5	1.5	59.5
X-10	25.5	23.5	19	19.5	11	13.2	25.5	20	2	56
X-11	25.7	22.7	16.4	17.4	10.2	8.09	25.7	21.84	1.5	57.09
X-12	23.5	18	17	18.6	10.6	12	23.5	20.34	1.5	59.57
X-13	24.5	19	17	18.6	8.2	9.8	24.5	18.34	1.5	58.4
X-14	26	19.2	17	19	7.6	32	24.4	20.65	2	71.99
X-15	24.5	20.5	17	18.5	8.3	10.3	24.5	18.26	1.5	58.7
X-16	23.7	19.7	16.4	18	9.7	9.3	23.6	21.64	2	68.28
X-17	26	22	17.4	20	6.9	11.4	25.5	23.24	1.5	60.25
X-18	24.5	22.9	21.3	24	7.5	7.5	23.5	24	1.5	72.5
X-19	25.2	20.2	16.7	18.4	7.2	7.5	25.4	20.47	1.5	64.29
X-20	23.5	19.5	17	18.5	7.4	9.7	24.3	16.26	2	61
X-21	23.5	22.5	17	18.5	6.9	7.9	25	17.25	1.5	66.25
X-22	24.5	21	17	19	6.9	7.8	25.5	18.28	1.5	65
X-23	24	20.5	16.9	19	7.1	13	25	17	1.5	58
X-24	24.5	21	17.2	19	7.1	15.5	25.4	18.36	1.5	62
X-25	23.5	22	17	18.5	6.9	7.9	24.4	17.25	1.5	64.25
X-26	24.7	20.3	16.7	18.5	6.9	7.4	26.6	18.34	1.5	69.4
X-27	24.5	23.5	16.5	17.8	5.9	8.5	24.5	16.71	2	57.5
X-28	23.5	20	17	18.5	5	19.5	24.4	17.96	1.5	62
X-29	23.5	19	17	18.5	7.4	9.7	23.5	16.26	1.5	59.07
X-30	23.5	22	17	18.5	6.9	8.4	25	16.76	1.5	65.75

Продолжение табл. С1

1	2	3	4	5	6	7	8	9	10	11
X-31	24.5	21	16.9	19	7.4	15.8	25.1	19.81	1.2	65
X-32	23.5	22	17	18.5	6.9	8.2	24.5	17.25	1.5	65.25
X-33	22.5	19.5	17	18.3	7	7.5	23.9	16.62	1.5	60
X-34	22.7	19.2	16.5	18	8.3	16.3	24.1	20.6	1.25	60.54
X-35	22.7	21.2	16.5	18	8.3	16	22.7	20.6	1.25	60.54
X-36	22.7	19.2	16.7	18.4	6.9	22.4	22.1	20.47	1.5	60.4
X-37	24.5	20.3	16.7	18.4	7.9	8	25.2	21.47	1.5	67
X-38	24.5	20.5	17	18.5	7.4	9.7	24.5	18.26	1.7	61.07
X-39	23.5	22	17	18.6	7.3	8.6	25	17.41	1.5	58.73
X-40	23.5	19.5	17	18.4	7.3	7.3	22.7	15.87	1.25	62.73
X-41	23.5	20.5	16.5	18.3	7.4	37.6	23.6	15.79	0	61.07
X-42	23.5	19	17	18.3	7.4	8.2	23.4	15.79	1.5	62.07
X-43	23	18.5	17	18.5	6.9	8.6	24	16.81	1.5	61.25
X-44	22.4	20.9	16.6	18.6	6.9	8.4	23.9	15.81	1.5	62.9
X-45	23.5	22.5	17	18.5	6.9	8.4	25	17.25	1.5	65.75
X-46	22.5	18	16.6	18.5	6.9	8.4	24	15.76	1.5	61.25
X-47	22.5	20	17	18.5	7.1	8.4	22.7	17.3	1.5	59.15
X-48	22.5	18.5	16.7	19.2	7.4	9.2	27.9	19	1.5	90
X-49	24	20.7	16.8	19	6.7	7.1	25	18.3	1.5	59
X-50	24.5	21	17.1	19	6.7	7.1	24.9	19.6	1.5	62
X-51	24.5	21	17.1	19	6.7	7.1	24.8	19.6	1.5	62
X-52	24.5	21	17.1	19	6.7	7.1	24.9	19.6	1.5	62
X-53	24.5	21.2	17.1	19	6.7	7.1	25	19.6	1.5	60
X-54	24.5	21	17.1	19	6.7	7.1	25.2	19.6	1.5	60
X-55	24.5	21	17.1	19	6.7	7.1	25	19.6	1.5	62
X-56	24.5	21	17.1	19	6.7	7.1	25.3	19.6	1.5	60
X-57	24.5	21	17.1	19	6.7	7.1	25.4	19.6	1.5	62
X-58	24.5	21	17.1	19	6.7	7.1	25.4	19.6	1.25	62
X-59	22.5	19.5	17	18.3	7	7.5	23.9	16.6	1.5	60
X-60	23.5	21.4	17	18.5	7.4	9.2	23	16.26	0	59.07
X-61	23.7	21.5	16.7	18.4	7.4	7.9	24.1	20.47	1.7	61.21
X-62	23.7	20.2	16.8	18.4	7.4	7.72	25.3	20.47	1.25	65.21
X-63	22.7	19.2	16.7	18.3	6.8	7.4	24.1	20.47	1.5	60.4
X-64	23	19	17	18.3	7	7.5	23.9	16.63	1.25	62
X-65	23	19	17	18.3	7	9	23.1	16.63	1.25	62
X-66	26.5	21	19.1	20.5	7	8.5	28.3	21.5	2	59.5
X-67	23.5	22	17	18.4	7	7.9	24.5	16.29	2	59.95
X-68	22.5	19.5	17	18.5	6.9	7.9	24.5	19.6	1.5	62.25
X-69	24.7	20.3	16.7	18.4	8.3	8.2	25.9	22	3	66.84

Окончание табл. C1

1	2	3	4	5	6	7	8	9	10	11
X-70	24.5	21	17.1	19	6.7	7.1	25.4	19.63	1.5	62
X-71	24.5	21	17.1	19	6.7	7.1	25.4	19.63	1.25	62
AVG.	24	20.6	17.1	18.6	7.5	10.2	24.7	18.8	1.5	62.2
MIN.	22.4	18	16.4	12.5	5	6.7	22.1	15.8	0	56
MAX.	26.5	23.5	21.3	24	12.5	37.6	28.3	24	3	90

Table C.2 - Size of back structural parts for X-style blouse pattern (cm)

N.	BLW	WLW	BBW	SW	NW	ND	HW	AD	CL
1	2	3	4	5	6	7	8	9	10
X-1	24.5	21	18.5	19.1	11.4	3.4	24.5	20.1	53
X-2	24.5	20.5	18.5	19.1	10.9	4.4	24.5	20.1	56
X-3	23.5	18.6	18.5	19.6	13.2	5.4	23.5	19.0	53
X-4	22.1	19	17.6	19.5	8.6	3	24	20.6	58
X-5	22.3	16.7	17.9	19.4	8.5	1.9	23	21.1	59.21
X-6	21.9	17.3	18.1	19.4	9.5	2.9	24.3	21.0	56.5
X-7	23.5	21	17.9	20.3	8.2	2.9	23.5	17.6	57.95
X-8	22.3	18.5	18.3	19.6	9	3.3	22.4	19.1	54.31
X-9	23	19.5	19.8	21	9	2	25.5	22.5	57.5
X-10	25.5	23	20	20	11.5	2	23.9	20.0	52
X-11	24	20.3	18	19	11	1.4	23.6	20.3	51.3
X-12	23.5	19	18.5	20.5	11.3	2.9	22	20.2	53
X-13	24.5	20.5	18.5	19.1	8.4	2.8	24.5	20.7	55
X-14	26	18.8	18.1	20	8.1	2.5	23.6	21.9	69
X-15	24.5	20.5	18.5	19.6	8.5	2.9	24.5	20.5	55
X-16	21	16.3	17.2	18.9	10	3.4	20.9	20.2	62
X-17	26	22	18.5	20.9	7.2	2.4	24.4	23.0	52.5
X-18	27	25.4	23.3	25	7.5	2	26	26.0	70.5
X-19	23.4	17.2	18.1	19.2	7.4	2.3	23.3	20.7	60
X-20	23.5	20.5	18.5	19.3	7.6	2.2	23.5	19.1	58
X-21	23.5	22.5	18.5	20.3	7.2	2.7	24	19.0	62.2
X-22	22.1	19	17.6	19.5	7.2	2.2	23.5	20.6	61.8
X-23	21.7	18.5	17.3	19.5	7.4	2.2	23	19.4	55.8
X-24	22.1	19	17.6	19.5	7.4	2	23.4	20.7	59

Продолжение табл. С2

1	2	3	4	5	6	7	8	9	10
X-25	23.5	22	18.5	20.5	7.2	2.4	24.5	18.6	60
X-26	22.4	16.7	17.8	19.8	7.2	2.4	24.2	20.0	64
X-27	24.5	23.5	17.5	18.4	6.8	2	24	18.4	56
X-28	23.5	19.5	18.5	20	8.8	2	23.5	20.1	58
X-29	23.5	19.5	18.5	19.1	7.6	2.2	23.5	19.1	55
X-30	23.5	22	18.5	19.8	7.2	2.4	24	18.9	64.5
X-31	22.1	19	17.6	19.5	7.7	2.5	23.1	20.8	57.5
X-32	23.5	22	18.5	20	7.2	2.4	24.5	18.8	64
X-33	23	19.5	18.5	20	7.3	2.4	24	19.1	57
X-34	21.5	17.8	18	19.6	8.9	2	23.2	19.1	56
X-35	21.8	20.3	17.8	19.6	8.9	2.1	23.2	19.1	56
X-36	21.6	16.3	17.9	20.6	7.2	2.4	23.2	18.7	56
X-37	20.9	16.8	18.4	19.4	8.1	2.1	22.1	20.1	62
X-38	24.5	20.5	18.5	19.1	7.6	2.2	24.5	20.1	58
X-39	23.5	19.5	18.5	19.1	7.6	2.2	24.2	19.2	56
X-40	23.5	18.5	17.9	18.9	7.5	1.9	23.5	18.8	60.3
X-41	23.5	19	17.6	18.9	7.6	2.2	23.7	18.7	58
X-42	22.2	19	18.8	20.3	7.6	1.9	23.4	18.2	58.3
X-43	22.7	18.5	18.3	19.8	7.2	2.1	23	18.9	59.3
X-44	22.6	21	18.1	18.9	7.2	2.1	23	19.7	60.3
X-45	23.5	22.5	18.5	19.8	7.2	2.1	24	18.9	64.8
X-46	22	18	18.1	18.9	7.2	2.1	22.4	19.7	59.3
X-47	22.5	18.5	17.6	19.7	7.6	2.2	22.7	19.9	56
X-48	23.5	19.5	17.5	19.5	7.6	2.2	28.4	20.5	87
X-49	21.7	18.5	17.3	19.5	7	2	23	19.2	56
X-50	22.5	19	17.6	19.5	7	2	23	20.5	59
X-51	22.5	19	17.6	19.5	7	2	22.9	20.5	59
X-52	22.5	19	17.6	19.5	7	2	22.3	20.5	59
X-53	22.5	19	17.6	19.5	7	2	23.2	20.5	57
X-54	22.5	19	17.6	19.5	7	2	23.3	20.5	57
X-55	22.5	19	17.6	19.5	7	2	23	20.5	59
X-56	22.5	19	17.6	19.5	7	2	22.4	20.5	57

Окончание табл. C2

1	2	3	4	5	6	7	8	9	10
X-57	22.5	19	17.6	19.5	7	2	23.4	20.5	59
X-58	22.5	19	17.6	19.5	7	2	23.3	20.5	59
X-59	23	19.5	18.5	20	7.3	2.4	23.9	19.1	57
X-60	23.5	18.5	18.1	19.1	7.6	2.2	24.5	19.1	58
X-61	22.3	18.8	17.9	19.9	7.7	2.2	22.7	19.7	56
X-62	23.3	19.3	17.9	19.9	7.6	2.2	24.1	19.7	60
X-63	21.8	18.3	17.9	20.6	7.2	2.4	23.2	18.7	56
X-64	23	19	17.4	18.8	7.3	2.4	23.8	19.5	59
X-65	23	19	17.6	18.8	7.3	2.4	22.8	19.5	59
X-66	28.5	22.5	20.1	21	7.5	2.5	24.5	22.5	54.5
X-67	23.5	22	18.5	20.3	7.2	2.4	23.5	18.2	56
X-68	23.5	19.5	17.8	19.2	8	2	23.7	19.6	57
X-69	22.4	16.7	17.8	19.4	9.2	2	25.1	21.1	60
X-70	22.5	19	17.6	19.5	7	2	23	20.5	59
X-71	22.5	19	17.6	19.5	7	2	22.4	20.5	57
AVG.	23.1	19.5	18.2	19.7	8	2.3	23.6	20	58.5
MIN.	20.9	16.3	17.2	18.4	6.8	1.4	20.9	17.6	51.3
MAX.	28.5	25.4	23.3	25	13.2	5.4	28.4	26	87

TableC.3 - Size of front structural parts for H-style blouse pattern (cm)

N.	BLW	WLW	HW	FBW	SW	NW	ND	AD	FPW	CL
1	2	3	4	5	6	7	8	9	10	11
H-1	27	27	27	21.53	23	7.5	11	23	1.5	68
H-2	30.5	30.5	30.5	25.23	27	7	12.5	27	1.5	74
H-3	25.5	25.5	25.5	21.1	22.5	7	8.5	20	1.25	63
H-4	27	27	27	19.8	21.7	6.9	9.4	22.5	2	71.25
H-5	26.5	26.5	26.5	19.3	21	8	11	21	1.5	62
H-6	24.7	24.71	24.7	16.7	18.37	6.9	8.4	20.5	1.5	62.4
H-7	26.7	26.71	26.7	20	22.37	7.4	8.21	24	1.5	67.21

Окончание табл. C3

1	2	3	4	5	6	7	8	9	10	11
H-8	24.5	24.5	24.5	17.55	19.38	7.4	10.2	19.4	2	64.07
H-9	25.5	25.5	25.5	18.5	20	7.4	9.72	21.2	0	61.09
H-10	26.5	26.5	26.5	19.3	20.83	7.4	8.1	22.3	1.5	72.73
H-11	24.5	24.5	24.5	17.4	18.92	6.9	8.4	17.5	1.5	65.75
H-12	27.5	27.5	27.5	21.9	23.33	6.9	8.4	20.5	1.5	72.25
H-13	25.5	25.5	25.5	17.9	19.38	6.9	7.9	15	1.8	79.25
H-14	29	29	29	19.7	22.55	7.8	9.03	24.1	1.5	69.88
H-15	27.5	27.5	27.5	22.3	24.28	6.9	8.4	19.6	1.5	71.25
H-16	23.7	23.7	23.7	16.7	18.37	6.9	8.4	20.4	1.5	63.1
H-17	28	28	28	19.7	21.47	7.5	8.32	23.3	1.5	72.8
H-18	26.5	26.5	26.5	18.4	20.83	5.9	7.49	20	1.5	76
H-19	27.5	28	29	22	22.6	7.3	8.4	21	1.5	73
H-20	26.5	27	27	19	21	7.5	8.2	23	1.5	74
H-21	26.7	26.7	26.7	21	22	7.4	8.3	25	1.5	67
H-22	24.5	24.5	24.5	17.6	19	6.9	8.5	17.7	1.5	66
H-23	27	27	27	20	23	6.9	9.4	22.5	2	72
H-24	28	28	28	22.5	24	8.5	12	24	1.5	68
H-25	25.5	25.5	25.5	18.4	19	8	9.4	18	1.5	67
H-26	30	30	30	20	23	8.8	10	25	1.5	70
H-27	23.7	23.7	23.7	16.7	18.4	6.9	8.4	20.5	1.5	63.1
H-28	27.5	27.5	27.5	22.3	24.3	6.9	8.4	19.8	1.5	72
H-29	25.5	25.5	25.5	18.5	20	7.4	9.8	21.2	0	62
AVG.	26.5	26.6	26.6	19.7	21.4	7.3	9.1	21.5	1.5	68.6
MIN.	23.7	23.7	23.7	16.7	18.4	5.9	7.5	17.6	0	61.1
MAX.	30.5	30.5	30.5	25.2	27	8.8	12.5	27	2	79.3

Table C.4 - Size of back structural parts for H-style blouse pattern (cm)

N.	BLW	WLW	HW	BBW	SW	NW	ND	AD	CL
H-1	27	27	27	22	23.5	7.5	2	24	65
H-2	31	31	31	25.8	27	7	2	27	70
H-3	27.5	27.5	27.5	23	23.5	7	2.5	22	60.5
H-4	27	27	27	20.9	22.57	7.1	2.37	25.66	68
H-5	27.5	27.5	27.5	20.4	21	8	2.5	23	60.5
H-6	23.29	23.29	23.29	17.9	19.94	7.1	2.37	19.03	57.3
H-7	25.79	25.79	25.79	21.7	22.95	7.57	2.24	22.77	62.3
H-8	24.5	24.5	24.5	18.5	20.86	7.57	2.2	20.26	61
H-9	25.5	25.5	25.5	18.5	20.5	7.57	2.2	21.13	58
H-10	27.5	27.5	27.5	19.5	21.34	7.72	2.1	23.99	70.3
H-11	24.5	24.5	24.5	19.1	20.3	7.1	2.1	19.52	62.8
H-12	27.5	27.5	27.5	22.5	24	7.1	2.1	23.3	72.3
H-13	25.5	25.5	25.5	18.9	20	7.1	2.37	21.82	50
H-14	29	29	29	21.5	23	8.04	2.04	25.58	67
H-15	27.5	27.5	27.5	22.7	25	7.1	2.37	23.1	70
H-16	22.29	22.29	22.29	17.9	19.94	7.43	2.46	19.03	58
H-17	28	28	28	20.4	22.1	8	2.12	24.05	71.3
H-18	26.5	26.5	26.5	18.8	21.3	6.78	2	21.35	73
H-19	27.5	28	29	22	22.6	7.3	8.4	21	73
H-20	26.5	27	27	19	21	7.5	8.2	23	74
H-21	26.7	26.7	26.7	21	22	7.4	8.3	25	67
H-22	24.5	24.5	24.5	17.6	19	6.9	8.5	17.7	66
H-23	27	27	27	20	23	6.9	9.4	22.5	72
H-24	28	28	28	22.5	24	8.5	12	24	68
H-25	25.5	25.5	25.5	18.4	19	8	9.4	18	67
H-26	30	30	30	20	23	8.8	10	25	70
H-27	23.7	23.7	23.7	16.7	18.4	6.9	8.4	20.5	63.1
H-28	27.5	27.5	27.5	22.3	24.3	6.9	8.4	19.8	72
H-29	25.5	25.5	25.5	18.5	20	7.4	9.8	21.2	62
AVG.	26.5	26.6	26.6	20.3	21.9	7.4	4.9	22.2	65.9
MIN.	22.3	22.3	22.3	16.7	18.4	6.8	2	17.7	50
MAX.	31	31	31	25.8	27	8.8	12	27	74

Table C.5- Size of front structural parts for A-style blouse pattern (cm)

N.	BL W	WL W	HW	FBW	SW	NW	ND	AD	FPW	CL
A-1	26.5	27.5	28.5	21.54	23	5.5	5.5	18	1.5	62
A-2	28.5	34	42.9	20.9	22.8	7.3	16.4	18.84	1.5	74.73
A-3	28.5	30.9	38.1	21.42	23.3	7.3	11.1	20.67	1.5	80.73
A-4	35.5	37.7	45.3	26.94	29.4	8.2	10.3	25	2	83.4
A-5	25	25.8	27.9	20.1	23.3	8.2	8.8	23.67	1.7	70.4
A-6	29	29.9	33.5	23.85	25.9	7.7	8	23	2	88.57
A-7	25	27.4	28.5	17.98	19.5	7.7	10.5	21	2	50.57
A-8	26.5	29	34	19.41	21	8.7	8.6	19.45	1.5	76.23
A-9	27	27.4	28	18.34	20	6.5	7	20.5	1.5	67.5
A-10	25.5	25.9	26.4	20.92	23	8.7	11.1	20.5	0	65
A-11	26.5	27.8	29.2	19.47	21.5	7	8.5	21	1.5	69
A-12	24.5	26.4	30.2	19.73	21.8	12.8	11.1	18.5	0	74.2
A-13	26	26.5	27.5	19.31	20.5	11.5	8.5	22	0	72
A-14	23.9	26.2	29.4	15.6	16.7	8	18	17.9	1.3	70
A-15	25.7	27.6	31.8	16.7	18.6	6.5	7.7	16.52	1.5	79.6
A-16	24.6	27.4	32	17.08	18.4	7.5	7.7	18.79	1.5	76.2
A-17	28	28.4	29	19.3	22	7.5	8	21.5	1.5	68.5
A-18	26.5	26	27	21	24	9	12.1	21.5	0	66
A-19	27.5	28.8	30.2	20.5	22.5	8	9.5	22	1.5	70
A-20	25.5	27.4	31.2	20.7	22.8	13.8	12.1	19.5	0	75.2
A-21	27	27.5	28.5	20.3	21.5	12.5	9.5	23	0	73
A-22	25	27.2	30.4	16.6	17.7	9	19	19	1.3	71
AVG.	26.7	28.3	31.3	19.9	21.8	8.6	10.4	20.5	1.2	72
MIN.	23.9	25.8	26.4	15.6	16.7	5.5	5.5	16.5	0	50.6
MAX.	35.5	37.7	45.3	26.9	29.4	13.8	19	25	2	88.6

Table C.6- Size of back structural parts for A-style blouse pattern (cm)

N.	BLW	WLW	HW	BBW	SW	NW	ND	AD	CL
A-1	24.5	24.9	25.5	17.86	21	8.5	7	30	66
A-2	30.5	35.4	44.6	21.8	22.9	7	2.3	21	72
A-3	29.5	31.9	39.1	22	23.7	7.5	2.2	23.21	77
A-4	40.5	42.8	50.3	28.52	30	8.4	2.3	25.62	80.5
A-5	31	31.5	33	25.21	27	7.9	3.5	29.13	69
A-6	31	31.7	35.2	23.6	25.8	8	3	24.84	85
A-7	29	30.2	30.9	21.8	22.6	8.3	2.4	24.8	48
A-8	31.5	32.9	36.3	21.6	22.6	9.6	3.4	24.3	74.5
A-9	27	28.8	31.8	19.52	21.5	8	3	20	65
A-10	26.5	26.8	27.5	22.14	23.9	8.9	2.7	22.82	62
A-11	28	29.6	31.5	21	22	7	2	22.5	64
A-12	25.5	27	30.4	21.29	23.3	14.2	1.8	21.42	73.2
A-13	26	26.4	27.5	19.86	21.5	12	2.4	23.5	71.1
A-14	22	22	22	16.16	17.1	8.3	2.2	20.43	66.8
A-15	26.5	28.5	32.8	18.92	20.5	7.5	2.6	18.72	76.3
A-16	23.3	24.6	27.2	17.9	19.9	7.7	2.2	19.65	72
A-17	29	29.4	30	20.3	23	8.5	9	22.5	69.5
A-18	27.5	27	28	22	25	10	13.1	22.5	67
A-19	28.5	29.8	31.2	21.5	23.5	9	10.5	23	71
A-20	26.5	28.4	32.2	21.7	23.8	14.8	13.1	20.5	76.2
A-21	28	28.5	29.5	21.3	22.5	13.5	10.5	24	74
A-22	26	28.2	31.4	17.6	18.7	10	20	20	72
AVG.	28.1	29.4	32.2	21.1	22.8	9.3	5.5	22.9	70.6
MIN.	22	22	22	16.2	17.1	7	1.8	18.7	48
MAX.	40.5	42.8	50.3	28.5	30	14.8	20	30	85

APPENDIX D

Parameterization of blouse pattern blocksin Chapter 2

Table D.1- Correlation index table of X-style blouse (n=71)

Parts		FBW	FNW	FND	FAD	A1	A3	A8	A10	A13	A14	A2	A6	A7	A11	BBW	BSW	BNW	B1	B12	B13	B2	B5	B6
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
FBW	Pearson correlation	1	0.1	-0.1	0.4	0.1	0	-0.3	-0.3	0	0.1	0.1	0.7	1	0.3	0.2	0.1	0.1	0.1	0	0.1	0	0.75	0.85
	Significant(two-sided)	/	0.4	0.5	0	0.3	1	0	0	0.7	0.4	0.4	0	0	0	0	0.4	0.3	0.2	0.7	0.3	0.7	0	0
FNW	Pearson correlation	0.1	1	0	0.3	-0.6	-0.1	0	0	-0.1	-0.2	1	-0.4	0.1	0	0.2	0	0.77	-0.7	0	-0.2	0.85	0	0.2
	Significant(two-sided)	0.4	/	0.6	0	0	0.2	0.4	0.4	0.3	0.2	0	0	0.4	0.7	0.1	0.8	0	0	0.5	0.2	0	0.9	0.1
FND	Pearson correlation	0	00	1	0	0	-0.67	-0.2	-0.2	0	0	0	0	0	-0.1	0	0	0	0	0	0	0	0	0
	Significant(two-sided)	0.6	0.6	/	0.5	0.6	0	0.2	0.2	0.6	0.7	0.6	0.9	0.5	0.3	0.6	0.6	0.8	0.7	0.5	0.6	0.5	0.9	0.7
FAD	Pearson correlation	0.4	0.3	0	1	0	-0.2	-0.83	-0.83	0	0.2	0.3	0.4	0.4	0.2	0	-0.1	0.1	0	0	0	0.2	0.4	0.2
	Significant(two-sided)	0	0	0.5	/	0.6	0.1	0	0	0.6	0.2	0	0	0	0.2	0.9	0.3	0.3	0.8	0.7	0.6	0.1	0	0

Продолжение табл. D.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A1	Pearson correlation	0.1	-0.62	0	0	1	0.3	0	0	0.1	0.2	-0.62	0.5	0.1	0	0	0.1	-0.75	0.86	0	0.1	-0.77	0	0
	Significant(two-sided)	0.3	0	0	0.6	/	0	0.6	0.6	0.33	0.2	0	0	0.3	0.7	0.7	0.4	0	0	0.7	0.2	0	0.6	0.7
A3	Pearson correlation	0	-0.1	-0.67	-0.2	0.3	1	0	0	-0.2	0	-0.2	0	0	0.1	-0.1	0	-0.3	0.2	-0.2	0	-0.3	0	0
	Significant(two-sided)	1	0.2	0	0.1	0	/	0.5	0.5	0.2	1	0.2	1	1	0.2	0.3	0.7	0	0.1	0.2	1	0	0.6	0.6
A8	Pearson correlation	-0.3	0	-0.2	-.83	0	0	1	1	0	-0.2	0	-0.4	-0.27	-0.2	0	0.2	0	-0.1	0	0	0	-.36	-0.1
	Significant(two-sided)	07	0.4	0.2	0	0.6	0.5	/	0	0.7	0.2	0.4	0	0	0.2	0.5	0.2	0.5	0.4	0.6	0.7	1	0	0.2
A10	Pearson correlation	-0.27	0	-0.2	-0.83	0	0	1	1	0	-0.2	0	-0.39	-0.28	-0.2	0	0.2	0	0	0	0	0	-0.36	-0.1
	Significant(two-sided)	0	0.4	0.2	0	0.6	0.5	0	/	0.7	0.2	0.4	0	0	0.2	0.5	0.2	0.5	0.4	0.6	0.73	1	0	0.2

Продолжение табл. D.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A13	Pearson correlation	0	-0.1	0	0	0.1	-0.2	0	0	1	0.83	-0.1	0	0	0	0.3	0.2	-0.2	0.2	0.92	0.75	0	0	-0.1
	Significant(two-sided)	0.7	0.3	0.6	0.5	0.2	0.2	0.7	0.7	/	0	0.3	0.5	0.7	1	0	0	0	0.1	0	0	0.16	0.67	0.4
A14	Pearson correlation	0.1	-0.2	0	0.2	0.2	0	-0.2	-0.2	0.83	1	0	0.26	0.1	0	0.13	0	-0.2	0.2	0.81	0.89	-0.25	0.22	0
	Significant(two-sided)	0.4	0.2	0.7	0.2	0.2	1	0.2	0.2	0	/	0.2	0	0.4	1	0.34	0.5	0.1	0	0	0	0	0	0.8
A2	Pearson correlation	0.1	1	0	0.27	-0.62	-0.2	0	0	-0.1	-0.2	1	-0.4	0.1	0	0.2	00	0.77	-0.69	0	-0.2	0.85	0	0.2
	Significant(two-sided)	0.4	0	0.6	0	0	0.2	0.4	0.4	0.3	0.2	/	0	0.4	0.7	0.1	0.846	0	0	0.5	0.2	0	1	0.1
A6	Pearson correlation	0.69	-0.36	0	0.41	0.5	0	-0.39	-0.39	0	0.26	-0.36	1	0.69	0.2	0	0	-0.3	0.55	0	0.2	-0.4	0.59	0.5
	Significant(two-sided)	0	0	0.9	0	0	1	0	0	0.4	0	0	/	0	0	0.5	0.8	0	0	0.78	0	0	0	0

Продолжение табл. D.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A7	Pearson correlation	1	0.1	0	0.36	0.1	0	-0.27	-0.27	-0	0.1	0.1	0.691	1	0.3	0.2	0.12	0.126	0.2	0	0.1	0	0.75	0.85
	Significant(two-sided)	0	0.4	0.5	0	0.3	1	0	0	0.7	0.4	0.3	0	/	0	0	0.385	0.3	0.2	0.7	0.2	0.719	0	0
BBW	Pearson correlation	0.2	0.2	0	0	0	-0.1	0	0	0.3	0.1	0.2	0	0.2	0.2	1	0.8	0.2	0	0.2	0.1	0.2	0.2	0.3
	Significant(two-sided)	0	0.1	0.6	0.9	0.7	0.3	0.5	0.5	0	0.3	0.1	0.5	0	0.2	/	0	0.1	0.8	0	0.3	0.2	0.1	0
BSW	Pearson correlation	0.1	0	0	-0.1	0.1	0	0.2	0.2	0.2	0	0	0	0.1	0	0.8	1	0	0	0.2	0	0	0.2	0.2
	Significant(two-sided)	0.4	0.8	0.6	0.3	0.4	0.7	0.2	0.2	0	0.5	0.8	0.8	0.4	0.5	0	/	0.6	0.7	0	0.5	0.7	0.1	0.2
BNW	Pearson correlation	0.1	0.77	0	0.1	-0.75	-0.3	0	0	-0.2	-0.2	0.77	-0.3	0.1	0.1	0.2	-0	1	-0.77	-0.2	-0.2	0.87	0	0.27
	Significant(two-sided)	0.3	0	0.8	0.3	0	0	0.5	0.5	0.1	0.2	0	0	0.3	0.4	0.1	0.6	/	0	0.2	0.2	0	0.9	0

Продолжение табл. D.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B1	Pearson correlation	0.2	-0.7	0	0	0.86	0.2	-0.1	-0.1	0.2	0.2	-0.69	0.55	0.2	0.2	0	0	-0.77	1	0.1	0.2	-0.87	0.1	0
	Significant(two-sided)	0.2	0	0.7	0.8	0	0.1	0.4	0.4	0.1	0	0	0	0.2	0.2	0.8	0.7	0	/	0.4	0	0	0.3	0.8
B12	Pearson correlation	0	0	0	0	0	-0.2	0	0	0.92	0.8	0	0	0	0	0.2	0.2	-0.2	0.1	1	0.84	-0.1	0	-0.1
	Significant(two-sided)	0.7	0.5	0.5	0.7	0.7	0.2	0.6	0.6	0	0	0.5	0.8	0.7	1	0	0	0.2	0.4	/	0	0.3	0.7	0.4
B13	Pearson correlation	0.1	-0.2	0	0	0.1	0	0	0	0.75	0.89	-0.2	0.2	0.1	0	0	0	-0.2	0.2	0.84	1	-0.2	0.2	0
	Significant(two-sided)	0.278	0.159	0.599	0.55	0.229	1	0.732	0.732	0	0	0.158	0.053	0.281	0.689	0.261	0.471	0.239	0.066	0	/	0.051	0	0.6
B2	Pearson correlation	0	0.85	0	0.2	-0.77	-0.32	0	0	-0.2	-0.2	0.85	-0.4	0	0	0.2	0	0.87	-0.87	-0.1	-0.2	1	-0	0.2
	Significant(two-sided)	0.7	0	0.5	0.1	0	0	1	1	0.2	0	0	0	0.7	0.8	0.2	0.7	0	0	0.3	0	/	0.7	0.1
B5	Pearson correlation	0.75	0	0	0.4	0	0	-0.4	-0.4	0	0.2	0	0.59	0.75	0.2	0.2	0.2	0	0.1	0	0.2	0	1	0.79
	Significant(two-sided)	0	0.9	0.9	0	0.6	0.6	0	0	0.7	0	1	0	0	0	0.1	0.1	0.9	0.3	0.7	0	0.7	/	0

Окончание табл. D.1

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
B6	Pearson correlation	0.84	0.2	0	0.24	0	0	-0.1	-0.1	-0.1	0	0.2	0.5	0.85	0.26	0.3	0.2	0.3	0	-0.1	0	0.2	0.79	1
	Significant(two-sided)	0	0.1	0.7	0	0.7	0.6	0.2	0.2	0.4	0.8	0.1	0	0	0	0	0.2	0	0.8	0.4	0.6	0.1	0	/

Table D.2 - Coefficient table of regression analysis of FBW and B6 for X-style blouse (n = 71)

Regressionmodel		Non standardized coefficient		Standar dizedc oefficie nt	t	Sig.
		B	standard error	Trial version		
1	(constant)	-16.6	1.2		-13.4	0
	FBW	0.96	0.07	0.85	13.14	0
a. dependent variable: B6						

Table D.3 - Coefficient table of regression analysis of FNW and B2 for X-style blouse(n = 71)

Regression model		Non standardized coefficient		Standar dizedc oefficie nt	t	Sig.
		B	standard error	Trial version		
1	(constant)	-6.3	0.55		-11.4	0
	FBW	0.95	0.07	0.85	13	0
a. dependent variable: B2						

Table D.4 - Coefficient table of regression analysis of FAD and A10 for X-style blouse(n = 71)

Regression model		Non standardized coefficient		Standar dizedc oefficie nt	t	Sig.
		B	standard error	Trial version		
1	(constant)	31.4	1.7		18.1	0
	A10	-0.7	0	-0.68	-7.3	0
a. dependent variable: FAD						

Table D.5 - Coefficient table of regression analysis of FAD and A8 for X-style blouse(n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	11.9	1.19		9.96	0
	FAD	-0.77	0	-0.83	-12.15	0
a. dependent variable: A8						

Table D.6 - Coefficient table of regression analysis of BNW and A1 for X-style blouse(n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	2	0.2		12	.000
	BNW	-0.3	0	-0.86	-13.57	.000
a. dependent variable: A1						

Table D.7 - Coefficient table of regression analysis of B12 and A13 for X-style blouse(n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	1.7	0.8		2	0
	B12	0.9	0	0.92	19.7	0
a. dependent variable: A13						

Table D.8 - Coefficient table of regression analysis of B13 and A14 for X-style blouse(n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	3.5	1.1		3.3	0
	B13	0.9	00	0.9	17.3	0
a. dependent variable: A14						

Table D.9 - Coefficient table of regression analysis of BNW and A2 for X-style blouse(n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-5.5	0.5		-11.8	0
	BNW	0.8	0	0.8	13	0
a. dependent variable: A2						

Table D.10 - Coefficient table of regression analysis of B6 and A7 for X-style blouse (n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	0.3	0		5.9	0
	B6	0.75	0	0.85	13	0
a. dependent variable: A7						

Table D.11 - Coefficient table of regression analysis of FBW and B5 for X-style blouse(n = 71)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-14.8	1.56		-9.5	0
	FBW	0.85	0	0.75	9.3	0
a. dependent variable: B5						

Table D.12 - Mathematical model ofX-style blouse pattern with body-fitted style

Point	Equations of point coordinate	
Back		
1	2	3
Bb1	Bb1x=0	Bb1y=Ba9y+18
Bb2	Bb2x=$\frac{S_1}{4}+1$	Bb2y=Ba9y+18
Bb3	Bb3x=$\frac{S_1}{4}-1$	Bb3y=0
Bb4	Bb4x=$\frac{S_1}{4}+1$	Bb4y=$S_3-\frac{S_1}{6}-6$
Bb5	Bb5x=$\frac{S_1}{6}+4$	Bb5y=$S_3-\frac{S_1}{36}-0.1$
Bb6	Bb6x=$\frac{S_1}{12}+0.3$	Bb6y=$S_3+\frac{S_1}{36}+0.35$
Bb7	Bb7x=0	Bb7y=S_3+1
Front		
Fb1	Fb1x=Fa3x+1.5	Fb1y=$S_3-\frac{S_1}{24}$
Fb2	Fb2x=0	Fb2y=$S_3-\frac{S_1}{24}$
Fb3	Fb3x=$\frac{S_1}{12}-1$	Fb3y=$S_3+\frac{S_1}{24}-0.5$
Fb4	Fb4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}-1.5$	Fb4y=Fb8y-0.722*Fb8y+31.362

Окончание табл. D.12

1	2	3
Fb5	Fb5x= $\frac{S_1}{6}+2$	Fb5y=(Fb4y+Fb8y)/2
Fb6	Fb6x=Fb5x+($\frac{S_1}{18}+3.65$) $\tan 18^0$	Fb6y=Fb8y+ $\frac{\left(\frac{S_1}{18}+3.65\right)\tan 18^0}{\tan 23^0}$
Fb7	Fb7x= $\frac{S_1}{12}+2\sin 39^0+2.2$	Fb7y= $S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fb8	Fb8x= $\frac{S_1}{4}+2$	Fb8y=Bb4y
Fb9	Fb9x= $\frac{S_1}{4}$	Fb9y=0
Fb10	Fb10x= $\frac{S_1}{4}+2$	Fb10y=Fa11y+18
Fb11	Fb11x=0	Fb11y=Fa11y+18
Fb12	Fb12x=Fa3x+1.5	Fb12y=Fa11y+18

Table D.13 - Mathematical model of X-style blouse pattern with loose-fitted style

Point	Equations of point coordinate	
Back		
1	2	3
Bb1	Bb1x=0	Bb1y=Ba9y+20
Bb2	Bb2x= $\frac{S_1}{4}+3$	Bb2y=Ba9y+20
Bb3	Bb3x= $\frac{S_1}{4}+1$	Bb3y=0
Bb4	Bb4x= $\frac{S_1}{4}+3$	Bb4y= $S_3-\frac{S_1}{6}-7.5$
Bb5	Bb5x= $\frac{S_1}{6}+6$	Bb5y= $S_3-\frac{S_1}{36}-0.9$
Bb6	Bb6x= $\frac{S_1}{12}+1.3$	Bb6y= $S_3+\frac{S_1}{36}+0.35$
Bb7	Bb7x=0	Bb7y= S_3
Front		
Fb1	Fb1x=Fa3x+1.5	Fb1y= $S_3-\frac{S_1}{24}-1$

Окончание табл. D.13

1	2	3
Fb2	Fb2x=0	Fb2y=$S_3-\frac{S_1}{24}-1$
Fb3	Fb3x=$\frac{S_1}{12}+1$	Fb3y=$S_3+\frac{S_1}{24}-0.5$
Fb4	Fb4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}$	Fb4y=Fb8y-0.722*Fb8y+31.362
Fb5	Fb5x=$\frac{S_1}{6}+3$	Fb5y=(Fb4y+Fb8y)/2
Fb6	Fb6x=Fb5x+($\frac{S_1}{18}+3.65$) $\tan 18^0$	Fb6y=Fb8y+$\frac{\left(\frac{S_1}{18}+3.65\right)\tan 18^0}{\tan 23^0}$
Fb7	Fb7x=$\frac{S_1}{12}+2\sin 39^0+2.2$	Fb7y=$S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fb8	Fb8x=$\frac{S_1}{4}+3$	Fb8y=Bb4y
Fb9	Fb9x=$\frac{S_1}{4}+1.5$	Fb9y=0
Fb10	Fb10x=$\frac{S_1}{4}+3$	Fb10y=Fa11y+20
Fb11	Fb11x=0	Fb11y=Fa11y+20
Fb12	Fb12x=Fa3x+1.5	Fb12y=Fa11y+20

Table D.14 - Mathematical model ofX-style blouse pattern with looser-bodied style

Point	Equations of point coordinate	
Back		
1	2	3
Bb1	Bb1x=0	Bb1y=Ba9y+25
Bb2	Bb2x=$\frac{S_1}{4}+5$	Bb2y=Ba9y+25
Bb3	Bb3x=$\frac{S_1}{4}+3$	Bb3y=0
Bb4	Bb4x=$\frac{S_1}{4}+5$	Bb4y=$S_3-\frac{S_1}{6}-8.2$
Bb5	Bb5x=$\frac{S_1}{6}+7.5$	Bb5y=$S_3-\frac{S_1}{36}+1.9$
Bb6	Bb6x=$\frac{S_1}{12}+2.3$	Bb6y=$S_3+\frac{S_1}{36}-0.4$

Окончание табл. D.14

1	2	3
Bb7	Bb7x=0	Bb7y=S_3-1
Front		
Fb1	Fb1x=Fa3x+2	Fb1y=$S_3-\frac{S_1}{24}-3.5$
Fb2	Fb2x=0	Fb2y=$S_3-\frac{S_1}{24}-3.5$
Fb3	Fb3x=$\frac{S_1}{12}+2$	Fb3y=$S_3+\frac{S_1}{24}-0.5$
Fb4	Fb4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}+1.5$	Fb4y=Fb8y-0.72Fb8y+31.362
Fb5	Fb5x=$\frac{S_1}{6}+3.5$	Fb5y=(Fb4y+Fb8y)/2
Fb6	Fb6x=Fb5x+$(\frac{S_1}{18}+3.65)\tan 18^0$	Fb6y=Fb8y+$\frac{\left(\frac{S_1}{18}+3.65\right)\tan 18^0}{\tan 23^0}$
Fb7	Fb7x=$\frac{S_1}{12}+2\sin 39^0+2.2$	Fb7y=$S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fb8	Fb8x=$\frac{S_1}{4}+4$	Fb8y=Bb4y
Fb9	Fb9x=$\frac{S_1}{4}+3$	Fb9y=0
Fb10	Fb10x=$\frac{S_1}{4}+5$	Fb10y=Fa11y+25
Fb11	Fb11x=0	Fb11y=Fa11y+25
Fb12	Fb12x=Fa3x+2	Fb12y=Fa11y+25

Table D.15 -Correlation index table of H-style blouse (n=29)

Parts		FBW	FSW	FAD	A1	A8	A10	A2	A6	A7	A9	BBW	BSW	BNW	BAD	B1	B7	B9	B12	B13	B2	B5	B6	B8
FBW	Pearson correlation	1	0.98	0.6	0.1	-0.66	-0.66	0	0.98	1	0.82	0.96	0.97	-0.1	0.78	0.2	-0.76	-0.76	0.58	0.55	0	0.97	0.97	0.85
	Significant(two-sided)	/	0	0	0.6	0	0	0.7	0	0	0	0	0	0.6	0	0.5	0	0	0	0	0.9	0	0	0
FSW	Pearson correlation	0.98	1	0.66	0.03	-0.7	-0.7	0	1	0.98	0.88	0.96	0.98	-0.1	0.8	0	-0.8	-0.8	0.56	0.6	0	0.98	0.96	0.87
	Significant(two-sided)	0	/	0	0.9	0	0	0.7	0	0	0	0	0	0.7	0	0.8	0	0	0	0	0.8	0	0	0
FAD	Pearson correlation	0.6	0.66	1	-0.4	-0.89	-0.89	0.4	0.67	0.61	0.78	0.6	0.62	0.3	0.76	-0.2	-0.7	-0.7	0.53	0.4	0.4	0.6	0.6	0.6
	Significant(two-	0	0	/	0.1	0	0	0.1	0	0	0	0	0	0.2	0	0.5	0	0	0	0	0	0	0	0

	sided)																							
A1	Pearson correlation	0.1	0	-0.4	1	0.3	0.3	-0.6	0	0.1	-0.2	0.1	0	-0.7	-0.2	0.83	0.2	0.2	-0.2	-0.1	-0.68	0	0.1	-0.2
	Significant(two-sided)	0.6	0.9	0.1		0.3	0.3	0	0.9	0.6	0.4	0.7	0.8	0	0.4	0	0.4	0.4	0.5	0.7	0	0.8	0.7	0.5
A8	Pearson correlation	-0.66	-0.7	-0.89	0.3	1	1	-0.3	-0.7	-0.66	-0.82	-0.61	-0.68	-0.2	-0.82	0.2	0.79	0.79	-0.72	-0.5	-0.3	-0.68	-0.61	-0.69
	Significant(two-sided)	0	0	0	0.3		0	0.3	0	0	0	0	0	0.4	0	0.5	0	0	0	0	0.2	0	0	0
A10	Pearson correlation	-0.66	-0.7	-0.89	0.3	1	1	-0.3	-0.7	-0.66	-0.82	-0.61	-0.68	-0.2	-0.8	0.2	0.79	0.79	-0.72	-0.5	-0.3	-0.7	-0.6	-0.69
	Significant(two-sided)	0	0	0	0.3	0		0.3	0	0	0	0	0	0.4	0	0.5	0	0	0	0	0.2	0	0	0

A2	Pearson correlation	0	0	0.4	-0.56	-0.3	-0.3	1	0	0	0.2	0.1	0	0.88	0.3	-0.4	-0.2	-0.2	0.4	-0.2	0.93	0	0.1	0.2
	Significant(two-sided)	0.7	0.7	0.1	0	0.3	0.3		0.7	0.7	0.5	0.6	0.9	0	0.2	0	0.4	0.4	0.1	0.5	0	0.9	0.6	0.4
A6	Pearson correlation	0.98	1	0.67	0	-0.7	-0.7	0	1	0.98	0.88	0.96	0.98	-0.1	0.8	0	-0.8	-0.8	0.6	0.6	0	0.98	0.96	0.87
	Significant(two-sided)	0	0	0	0.9	0	0	0.7		0	0	0	0	0.7	0	0.8	0	0	0	0	0.8	0	0	0
A7	Pearson correlation	1	0.98	0.6	0.1	-0.66	-0.66	0	0.98	1	0.82	0.97	0.97	-0.1	0.78	0.2	-0.76	-0.76	0.58	0.55	0	0.97	0.97	0.84
	Significant(two-sided)	0	0	0	0.6	0	0	0.7	0		0	0	0	0.6	0	0.5	0	0	0	0	0.9	0	0	0
A9	Pearson correlati	0.8	0.88	0.77	-0.2	-0.8	-0.8	0.2	0.88	0.82	1	0.79	0.81	0.1	0.92	0	-0.9	-0.9	0.6	0.65	0.2	0.81	0.79	0.93

	on					2	2										3	3						
	Significant(two-sided)	0	0	0	0.4	0	0	0.5	0	0		0	0	0.6	0	0.8	0	0	0	0	0.3	0	0	0
BBW	Pearson correlation	0.97	0.96	0.6	0.1	-0.6	-0.6	0.1	0.96	0.97	0.79	1	0.97	-0.1	0.75	0.1	-0.7	-0.7	0.6	0.5	0	0.96	1	0.82
	Significant(two-sided)	0	0	0	0.7	0	0	0.6	0	0	0		0	0.6	0	0.6	0	0	0	0	0.8	0	0	0
BSW	Pearson correlation	0.97	0.98	0.6	0	-0.68	-0.68	0	0.98	0.97	0.81	0.97	1	-0.2	0.75	0	-0.72	-0.72	0.6	0.6	0	1	0.97	0.8
	Significant(two-sided)	0	0	0	0.8	0	0	0.9	0	0	0	0		0.45	0	0.7	0	0	0	0	1	0	0	0
BNW	Pearson correlation	-0.1	-0.1	0.3	-0.72	-0.2	-0.2	0.88	-0.1	-0.1	0.	-0.1	-0.2	1	0.2	-0.49	-0.1	-0.1	0.3	0	0.95	-0.2	-0.1	0.1
	Significant(two-sided)	0.6	0.7	0.2	0	0.4	0.4	0	0.7	0.6	0.6	0.6	0.5		0.4	0	0.6	0.6	0.3	0.9	0	0.5	0.6	0.6
BAD	Pearson correlation	0.78	0.81	0.76	-0.22	-0.82	-0.82	0.3	0.81	0.78	0.92	0.75	0.75	0.2	1	0	-0.97	-0.97	0.61	0.57	0.3	0.7	0.76	0.91
	Significant(two-sided)	0	0	0	0.4	0	0	0.2	0	0	0	0	0	0.4		0.8	0	0	0	0	0.2	0	0	0
B1	Pearson correlation	0.2	0	-0.2	0.83	0.2	0.2	-0.4	0	0.2	0	0.1	0	-0.5	0	1	0	0	0	0.1	-0.5	0	0.1	0
	Significant(two-sided)	0.5	0.8	0.5	0	0.5	0.5	0	0.8	0.5	0.8	0.6	0.7	0	0.9		0.8	0.8	0.9	0.6	0	0.8	0.6	0.9

B7	Pearson correlation	-0.76	-0.8	-0.7	0.2	0.79	0.79	-0.2	-0.8	-0.76	-0.93	-0.7	-0.72	-0.1	-0.97	0	1	1	-0.6	-0.6	0	-0.7	-0.7	-0.9
	Significant(two-sided)	0	0	0	0.4	0	0	0.4	0	0	0	0	0	0.6	0	0.8		0	0	0	0.3	0	0	0
B9	Pearson correlation	-0.8	-0.8	-0.7	0.2	0.8	0.8	-0.2	-0.8	-0.76	-0.93	-0.7	-0.72	-0.1	-0.97	0	1	1	-0.6	-0.6	-0.2	-0.72	-0.7	-0.92
	Significant(two-sided)	0	0	0	0.4	0	0	0.4	0	0	0	0	0	0.6	0	0.8	0		0	0	0.3	0	0	0
B12	Pearson correlation	0.6	0.6	0.5	-0.2	-0.7	-0.72	0.4	0.6	0.58	0.6	0.57	0.59	0.3	0.6	0	-0.6	-0.6	1	0.6	0.4	0.6	0.6	0.6
	Significant(two-sided)	0	0	0	0.5	0	0	0.1		0	0	0	0	0.3	0	0.9	0	0		0	0.1	0	0	0

B13	Pearson correlation	0.6	0.6	0.4	-0.1	-0.5	-0.5	-0.2	0.6	0.6	0.7	0.5	0.6	0	0.57	0.1	-0.65	-0.65	0.57	1	0	0.59	0.5	0.62
	Significant(two-sided)	0	0	0	0.6	0	0	0.5	0	0	0	0	0	0.9	0	0.6	0	0	0		0.9	0	0	0
B2	Pearson correlation	0	0	0.4	-0.68	-0.3	-0.3	0.92	0	0	0.2	0	0	0.95	0.3	-0.5	-0.2	-0.2	0.4	0	1	0	0	0.3
	Significant(two-sided)	0.9	0.8	0	0	0.2	0.2	0	0.8	0.9	0.3	0.8	1	0	0.2	0	0.3	0.3	0.1	0.9		1	0.8	0.2
B5	Pearson correlation	0.97	0.98	0.62	0	-0.7	-0.68	0	0.98	0.97	0.81	0.96	1	-0.2	0.7	0	-0.7	-0.72	0.6	0.6	0	1	0.96	0.79
	Significant(two-sided)	0	0	0	0.8	0	0	0.9	0	0	0	0	0	0.5	0	0.8	0	0	0	0	1		0	0
B6	Pearson correlation	0.97	0.96	0.6	0.1	-0.6	-0.6	0.1	0.96	0.97	0.79	1	0.97	-0.1	0.76	0.1	-0.7	-0.7	0.6	0.5	0	0.96	1	0.82
	Significant(two-sided)	0	0	0	0.7	0	0	0.6	0	0	0	0	0	0.6	0	0.6	0	0	0	0	0.8	0		0
B8	Pearson correlation	0.85	0.87	0.6	-0.2	-0.7	-0.69	0.2	0.87	0.84	0.93	0.82	0.8	0.1	0.91	0	-0.92	-0.92	0.6	0.6	0.3	0.79	0.82	1
	Significant(two-sided)	0	0	0	0.5	0	0	0.4	0	0	0	0	0	0.6	0	0.9	0	0	0	0	0.	0	0	

Table D.16 Coefficient table of regression analysis of FBW and BSW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-4.5	1.5		-2.98	0
	BSW	1.1	0	0.97	16.1	0
a. dependent variable: FBW						

Table D.17 Coefficient table of regression analysis of FSW and BAD for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	3.5	3.2		1.1	0
	BAD	0.8	0.14	0.81	5.6	0
a. dependent variable: FSW						

Table D.18 Coefficient table of regression analysis of FAD and A10 for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	36.1	1.9		19.2	0
	A10	-0.97	0.12	-0.89	-7.9	0
a. dependent variable: FAD						

Table D.19 Coefficient table of regression analysis of A1 and BNW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	1.6	0.4		3.9	0
	BNW	-0.2	0	-0.7	-4.1	0
a. dependent variable: A1						

Table D.20 Coefficient table of regression analysis of A8 and BAD for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	12.5	3.1		4	0
	BAD	-0.8	0.14	-0.81	-5.7	0
a. dependent variable: A8						

Table D.21 Coefficient table of regression analysis of A10 and BAD for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	32.5	3		10.6	0
	BAD	-0.8	0.14	-0.82	-5.7	0
a. dependent variable: A10						

Table D.22 Coefficient table of regression analysis of A2 and BNW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-7.6	1		-7.2	0
	BNW	1	0.14	0.9	7.4	0
a. dependent variable: A2						

Table D.23 Coefficient table of regression analysis of A6 and BSW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-21.8	1.2		-18.7	0
	BSW	1.1	0	0.98	21.4	0
a. dependent variable: A6						

Table D.24 Coefficient table of regression analysis of A9 and BAD for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-12.8	1.7		-7.6	0
	BAD	0.7	0	0.92	9	0
a. dependent variable: A9						

Table D.25 Coefficient table of regression analysis of BBW and FSW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	0.9	1.4		0.6	0
	FSW	0.9	0	0.96	14.1	0
a. dependent variable: BBW						

Table D.26 Coefficient table of regression analysis of BAD and FSW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	4.7	3.2		1.5	0
	FSW	0.8	0.15	0.8	5.6	0
a. dependent variable: BAD						

Table D.27 Coefficient table of regression analysis of B7 and FSW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	15.3	3.4		4.6	0
	FSW	-0.8	0.2	-0.8	-5.3	0
a. dependent variable: B7						

Table D.28 Coefficient table of regression analysis of B9 and FBW for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	29.7	3.4		8.7	0
	FBW	-0.8	0.2	-0.8	-4.6	0
a. dependent variable: B9						

Table D.29 Coefficient table of regression analysis of B12 and A10 for H-style blouse pattern(n = 29)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	49.4	6.5		7.6	0
	A10	-1.8	0.4	-0.7	-4.2	0
a. dependent variable: B12						

Table D.30 - Mathematical model ofH-style blouse pattern with body-fitted style

Point	Equations ofpoint coordinate	
Back		
Bd1	Bd1x=0	Bd1y=Ba9y+18
Bd2	Bd2x=$\frac{S_1}{4}+1$	Bd2y=Ba9y+18
Bd3	Bd3x=$\frac{S_1}{4}+1$	Bd3y=$S_3-\frac{S_1}{6}-6$
Bd4	Bd4x=$\frac{S_1}{6}+4$	Bd4y=$S_3-\frac{S_1}{36}-0.1$
Bd5	Bd5x=$\frac{S_1}{12}+0.3$	Bd5y=$S_3+\frac{S_1}{36}+0.35$

Bd6	Bd6x=0	Bd6y=S_3+1
Front		
Fd1	Fd1x=Fa0x+1.5	Fd1y=$S_3-\frac{S_1}{24}$
Fd2	Fd2x=0	Fd2y= $S_3-\frac{S_1}{24}$
Fd3	Fd3x=$\frac{S_1}{12}-1$	Fd3y=$S_3+\frac{S_1}{24}-0.5$
Fd4	Fd4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}-1.5$	Fd4y=Fd8y-0.97Fd8y+36.121
Fd5	Fd5x=$\frac{S_1}{6}+2$	Fd5y=(Fd4y+Fd8y)/2
Fd6	Fd6x=Fd5x+$(\frac{S_1}{18}+3.65)\tan 18^0$	Fd6y=Fd8y+$\frac{\left(\frac{S_1}{18}+3.65\right)\tan 18^0}{\tan 23^0}$
Fd7	Fd7x=$\frac{S_1}{12}+2\sin 39^0+2.2$	Fd7y=$S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fd8	Fd8x=$\frac{S_1}{4}+2$	Fd8y=Bd3y
Fd9	Fd9x=$\frac{S_1}{4}+2$	Fd9y=Fa11y+18
Fd10	Fd10x=0	Fd10y=Fa11y+18
Fd11	Fd11x=Fa0x+1.5	Fd11y=Fa11y+18

Table D.31 - Mathematical model ofH-style blouse pattern with loose-fitted style

Point	Equations ofpoint coordinate	
Back		
Bd1	Bd1x=0	Bd1y=Ba9y+20
Bd2	Bd2x=$\frac{S_1}{4}+3$	Bd2y=Ba9y+20
Bd3	Bd3x=$\frac{S_1}{4}+3$	Bd3y=$S_3-\frac{S_1}{6}-7.5$
Bd4	Bd4x=$\frac{S_1}{6}+6$	Bd4y=$S_3-\frac{S_1}{36}+0.9$
Bd5	Bd5x=$\frac{S_1}{12}+1.3$	Bd5y=$S_3+\frac{S_1}{36}+0.35$
Bd6	Bd6x=0	Bd6y=S_3
Front		
Fd1	Fd1x=Fa0x+1.5	Fd1y=$S_3-\frac{S_1}{24}-1$
Fd2	Fd2x=0	Fd2y= $S_3-\frac{S_1}{24}-1$

Fd3	Fd3x= $\frac{S_1}{12}+1$	Fd3y= $S_3+\frac{S_1}{24}-0.5$
Fd4	Fd4x= $\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}$	Fd4y=Fd8y-0.97Fd8y+36.121
Fd5	Fd5x= $\frac{S_1}{6}+3$	Fd5y=(Fd4y+Fd8y)/2
Fd6	Fd6x=Fd5x+($\frac{S_1}{18}+3.65$) $\tan 18^0$	Fd6y=Fd8y+ $\frac{\left(\frac{S_1}{18}+3.65\right)\tan 18^0}{\tan 23^0}$
Fd7	Fd7x= $\frac{S_1}{12}+2\sin 39^0+2.2$	Fd7y= $S_3-\frac{S_1}{8}+2\sin 51^0-11.5$
Fd8	Fd8x= $\frac{S_1}{4}+3$	Fd8y=Bd3y
Fd9	Fd9x= $\frac{S_1}{4}+3$	Fd9y=Fa11y+20
Fd10	Fd10x=0	Fd10y=Fa11y+20
Fd11	Fd11x=Fa0x+1.5	Fd11y=Fa11y+20

Table D.32 - Mathematical model of H-style blouse pattern with looser-bodied style

Point	Equations ofpoint coordinate	
Back		
Bd1	Bd1x=0	Bd1y=Ba9y+25
Bd2	Bd2x= $\frac{S_1}{4}+5$	Bd2y=Ba9y+25
Bd3	Bd3x= $\frac{S_1}{4}+5$	Bd3y= $S_3-\frac{S_1}{6}-8.2$
Bd4	Bd4x= $\frac{S_1}{6}+7.5$	Bd4y= $S_3-\frac{S_1}{36}+1.9$
Bd5	Bd5x= $\frac{S_1}{12}+2.3$	Bd5y= $S_3+\frac{S_1}{36}+0.4$
Bd6	Bd6x=0	Bd6y= S_3-1
Front		
Fd1	Fd1x=Fa0x+2	Fd1y= $S_3-\frac{S_1}{24}-3.5$
Fd2	Fd2x=0	Fd2y= $S_3-\frac{S_1}{24}-3.5$
Fd3	Fd3x= $\frac{S_1}{12}+2$	Fd3y= $S_3+\frac{S_1}{24}-0.5$
Fd4	Fd4x= $\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}+1.5$	Fd4y=Fd8y-0.97Fd8y+36.121

Fd5	Fd5x=$\frac{S_1}{6}+3.5$	Fd5y=(Fd4y+Fd8y)/2
Fd6	Fd6x=Fd5x+$(\frac{S_1}{18}+3.65)\tan18^0$	Fd6y=Fd8y+$\frac{\left(\frac{S_1}{18}+3.65\right)*\tan18^0}{\tan23^0}$
Fd7	Fd7x=$\frac{S_1}{12}+2\sin39^0+2.2$	Fd7y=$S_3-\frac{S_1}{8}+2\sin51^0-11.5$
Fd8	Fd8x=$\frac{S_1}{4}+4$	Fd8y=Bd3y
Fd9	Fd9x=$\frac{S_1}{4}+4$	Fd9y=Fa11y+25
Fd10	Fd10x=0	Fd10y=Fa11y+25
Fd11	Fd11x=Fa0x+2	Fd11y=Fa11y+25

Table D.33 -Correlation index table of A-style blouse (n=22)

Parts		FBW	FSW	FAD	A1	A8	A10	A2	A6	A9	BBW	BSW	BNW	BAD	B1	B7	B9	B12	B13	B2	B5	B8
FBW	Pearson correlation	1	0.99	0.68	-0.2	-0.74	-0.74	0	0.99	0.85	0.8	0.86	0	0.5	-0.3	-0.78	-0.78	0.2	0.5	0	0.86	0.78
	Significant(two-sided)	/	0	0	0.5	0	0	1	0	0	0	0	1	0	0.3	0	0	0.6	0	1	0	0
FSW	Pearson correlation	0.99	1	0.7	-0.2	-0.77	-0.77	0	1	0.83	0.85	0.9	0	0.6	-0.2	-0.78	-0.78	0.2	0.5	0	0.9	0.8
	Significant(two-sided)	0	/	0	0.4	0	0	0.9	0	0	0	0	0.9	0	0.4	0	0	0.6	0	0.9	0	0
FAD	Pearson correlation	0.7	0.7	1	0	-0.9	-0.9	0.2	0.7	0.6	0.82	0.8	0	0.5	00	-0.6	-0.6	-0.2	0.1	0	0.81	0.72
	Significant(two-sided)	0	0	/	1	0	0	0.6	0	0	0	0	0.9	0	0.8	0	0	0.5	0.6	0.9	0	0
A1	Pearson correlation	-0.2	-0.2	0	1	0.1	0.1	-0.7	-0.2	0	-0.3	-0.3	-0.73	0	0.6	0	0	-0.2	-0.1	-0.73	-0.3	0
	Significant(two-sided)	0.5	0.4	1	/	0.6	0.6	0	0.4	0.7	0.3	0.2	0	1	0	0.9	0.9	0.5	0.6	0	0.2	0.8
A8	Pearson correlation	-0.74	-0.77	-0.91	0.1	1	1	-0.1	-0.77	-0.64	-0.87	-0.87	0	-0.4	0	0.6	0.6	0	-0.3	0	-0.87	-0.76

	Significant(two-sided)	0	0	0	0.6	/	0	0.6	0	0	0	0	0.8	0.1	0.8	0	0	1	0.2	0.8	0	0
A10	Pearson correlation	-0.74	-0.77	-0.91	0.1	1	1	-0.13	-0.8	-0.6	-0.9	-0.9	0	-0.4	0	0.6	0.6	0	-0.3	0	-0.87	-0.76
	Significant(two-sided)	-0.74	-0.77	-0.91	0.1	1	/	0.6	0	0	0	0	0.8	0.1	0.8	0	0	1	0.2	0.8	0	0
A2	Pearson correlation	0	0	0.2	-0.72	-0.12	-0.13	1	0	-0.17	0.16	0.14	0.9	0	-0.5	0.14	0.14	0.19	0	0.9	0.14	0
	Significant(two-sided)	0.9	0.9	0.6	0	0.6	0.6	/	0.9	0.5	0.6	0.6	0	0.7	0	0.6	0.6	0.5	0.7	0	0.6	0.9
A6	Pearson correlation	0.99	1	0.7	-0.2	-0.77	-0.77	0	1	0.83	0.85	0.9	0	0.55	-0.2	-0.78	-0.78	0.2	0.5	0	0.91	0.81
	Significant(two-sided)	0	0	0	0.4	0	0	0.9	/	0	0	0	0.9	0	0.4	0	0	0.6	0	0.9	0	0
A9	Pearson correlation	0.85	0.83	0.58	0	-0.64	-0.64	-0.17	0.83	1	0.7	0.7	-0.22	0.22	-0.18	-0.48	-0.48	0.2	0.5	-0.22	0.7	0.85
	Significant(two-sided)	0	0	0	0.7	0	0	0.5	0	/	0	0	0.4	0.4	0.5	0	0	0.6	0	0.4	0	0

BBW	Pearson correlation	0.8	0.85	0.82	-0.3	-0.87	-0.87	0.2	0.85	0.7	1	0.98	0	0.4	0	-0.57	-0.57	0	0.3	0	0.98	0.92
	Significant(two-sided)	0	0	0	0.3	0	0	0.6	0	0	/	0	0.9	0	0.9	0	0	0.9	0.3	0.9	0	0
BSW	Pearson correlation	0.86	0.9	0.8	-0.3	-0.87	-0.87	0.1	0.9	0.7	0.98	1	0	0.5	0	-0.67	-0.67	0	0.4	0	1	0.88
	Significant(two-sided)	0	0	0	0.2	0	0	0.6	0	0	0	/	1	0	0.8	0	0	0.9	0.2	1	0	0
BNW	Pearson correlation	0	0	0	-0.73	0	0	0.9	0	-0.2	0	0	1	0	-0.5	0	0	0.3	0	1	0	-0.2
	Significant(two-sided)	1	0.9	0.9	0	0.8	0.8	0	0.9	0.4	0.9	1	/	1	0	0.9	0.9	0.3	0.8	0	1	0.5
BAD	Pearson correlation	0.54	0.55	0.5	0	-0.4	-0.4	0	0.55	0.2	0.4	0.5	0	1	0.2	-0.9	-0.9	0	0	0	0.5	0.4
	Significant(two-sided)	0	0	0	1	0.1	0.1	0.7	0	0.4	0	0	1	/	0.4	0	0	0.9	1	1	0	0.2
B1	Pearson correlation	-0.3	-0.2	0	0.6	0	0	-0.5	-0.2	-0.2	0	0	-0.5	0.2	1	0	0	0	-0.2	-0.5	0	0
	Significant(two-sided)	0.3	0.4	0.8	0	0.8	0.8	0	0.4	0.5	0.9	0.8	0	0.4	/	0.9	0.9	0.8	0.5	0	0.8	0.9

B7	Pearson correlation	-0.78	-0.78	-0.59	0	0.59	0.59	0.1	-0.78	-0.5	-0.6	-0.67	0	-0.9	0	1	1	0	-0.3	0	-0.67	-0.5
	Significant(two-sided)	0	0	0	0.9	0	0	0.6	0	0	0	0	0.9	0	0.9	/	0	0.8	0.3	0.9	0	0
B9	Pearson correlation	-0.78	-0.78	-0.59	0	0.59	0.59	0.1	-0.78	-0.48	-0.57	-0.67	0.04	-0.9	0	1	1	0	-0.29	0	-0.67	-0.5
	Significant(two-sided)	0	0	0	0.9	0	0	0.6	0	0	0	0	0.9	0	0.9	0	/	0.8	0.3	0.9	0	0
B12	Pearson correlation	0.16	0.15	-0.2	-0.2	0	0	0.2	0.15	0.15	0	0	0.3	0	0	0	0	1	0.83	0.3	0	0
	Significant(two-sided)	0.6	0.6	0.5	0.5	1	1	0.5	0.6	0.6	0.9	0.9	0.3	0.9	0.8	0.8	0.8	/	0	0.3	0.9	1
B13	Pearson correlation	0.5	0.5	0.14	-0.13	-0.3	-0.3	0	0.5	0.52	0.28	0.35	0	0	-0.2	-0.3	-0.3	0.83	1	0	0.35	0.35
	Significant(two-sided)	0	0	0.6	0.6	0.2	0.2	0.8	0	0	0.3	0.2	0.8	1	0.5	0.3	0.3	0	/	0.8	0.2	0.2
B2	Pearson correlation	0	0	0	-0.73	0	0	0.9	0	-0.22	0	0	1	0	-0.54	0	0	0.3	0	1	0	-0.2

	Significant(two-sided)	1	0.9	0.9	0	0.8	0.8	0	0.9	0.4	0.9	1	0	1	0	0.9	0.9	0.3	0.8	/	1	0.5
B5	Pearson correlation	0.86	0.90	0.81	-0.3	-0.87	-0.87	0.14	0.9	0.71	0.98	1	0	0.5	0	-0.67	-0.67	0	0.3	0	1	0.88
	Significant(two-sided)	0	0	0	0.2	0	0	0.6	0	0	0	0	1	0	0.78	0	0	0.9	0.2	1	/	0
B8	Pearson correlation	0.78	0.8	0.72	0	-0.76	-0.76	0	0.8	0.85	0.92	0.88	-0.2	0.37	0	-0.5	-0.5	0	0.35	-0.2	0.88	1
	Significant(two-sided)	0	0	0	0.8	0	0	0.9	0	0	0	0	0.5	0.2	0.9	0	0	1	0.2	0.5	0	/

Table D.34 - Coefficient table of regression analysis of FSW and BBW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	3.3	3		1	0
	BBW	0.9	0.14	0.85	6	0
a. dependent variable: FSW						

Table D.35 - Coefficient table of regression analysis of FBW and BSW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	1.8	3		0.6	0
	BSW	0.8	0.13	0.86	6.2	0
a. dependent variable: FBW						

Table D.36 - Coefficient table of regression analysis of FAD and A10 for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	30.2	1.2		24.8	0
	A10	-0.6	0	-0.9	-8.2	0
a. dependent variable: FAD						

Table D.37 - Coefficient table of regression analysis of A1 and BNW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	1.5	0.5		3.1	0
	BNW	-0.2	0	-0.73	-4	0
a. dependent variable: A1						

Table D.38 - Coefficient table of regression analysis of A8 and BBW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	16	3.2		5	0
	BBW	-0.96	0.15	-0.87	-6.5	0
a. dependent variable: A8						

Table D.39 - Coefficient table of regression analysis of A10 and BBW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	36	3.2		11.3	0
	BBW	-0.96	0.15	-0.87	-6.5	0
a. dependent variable: A10						

Table D.40 - Coefficient table of regression analysis of A2 and BNW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-6.4	1		-6.5	0
	BNW	0.9	0.11	0.9	7.8	0
a. dependent variable: A2						

Table D.41 - Coefficient table of regression analysis of BSW and A8 for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	19.5	0.6		30.4	0
	A8	-0.8	0.12	-0.87	-6.5	0
a. dependent variable: BSW						

Table D.42 - Coefficient table of regression analysis of B7 and FSW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedcoefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	14.3	3.8		3.8	0
	FSW	-0.8	0.17	-0.8	-4.6	0
a. dependent variable: B7						

Table D.43 - Coefficient table of regression analysis of B9 and FBW for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	31	3.9		8	0
	FBW	-0.9	0.19	-0.8	-4.6	0
a. dependent variable: B9						

Table D.44 - Coefficient table of regression analysis of B2 and A1 for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	0.6	0.4		1.4	0
	A1	-2.5	0.6	-0.7	-4	0
a. dependent variable: B2						

Table D.45 - Coefficient table of regression analysis of B5 and FAD for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	-18.8	4.2		-4.5	0
	FAD	1.1	0.2	0.8	5.2	0
a. dependent variable: B5						

Table D.46 - Coefficient table of regression analysis of B8 and A10 for A-style blouse pattern(n = 22)

Regressionmodel		Non standardized coefficient		Standardizedc oefficient	t	Sig.
		B	standard error	Trial version		
1	(constant)	19.9	3.6		5.5	0
	A10	-0.9	0.2	-0.8	-4.4	0
a. dependent variable: B8						

Table D.47 -Mathematical model ofA-style blouse pattern with body-fitted style

Point	Equations ofpoint coordinate	
Back		
Be1	Be1x=0	Be1y=0.98Be6y+3.7
Be2	Be2x=0	Be2y= S_3+1
Be3	Be3x= $\frac{S_1}{12}+0.3$	Be3y= $S_3+\frac{S_1}{36}+0.35$
Be4	Be4x= $\frac{S_1}{6}+4$	Be4y= $S_3-\frac{S_1}{36}-0.1$
Be5	Be5x= $\frac{S_1}{4}+1$	Be5y= $S_3-\frac{S_1}{6}-6$
Be6	Be6x= $\frac{S_1}{4}+8$	Be6y=Ba9y+14.5
Front		
Fe1	Fe1x=Fa0x+1.5	Fe1y= $S_3-\frac{S_1}{24}$
Fe2	Fe2x=0	Fe2y= $S_3-\frac{S_1}{24}$
Fe3	Fe3x= $\frac{S_1}{12}-1$	Fe3y= $S_3+\frac{S_1}{24}-0.5$
Fe4	Fe4x= $\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}-1.5$	Fe4y=Fe5y-0.63Fe5y+30.2
Fe5	Fe5x= $\frac{S_1}{4}+2$	Fe5y=Be5y
Fe6	Fe6x= $\frac{S_1}{4}+8$	Fe6y=Be6y

Fe7	Fe7x=0	Fe7y=Be1y
Fe8	Fe8x=Fe1x+1.5	Fe8y=Be1y

Table D.48- Mathematical model ofA-style blouse pattern with loose-fitted style

Point	Equations of point coordinate	
Back		
Be1	Be1x=0	Be1y=0.98Be6y+3.7
Be2	Be2x=0	Be2y=S_3
Be3	Be3x=$\frac{S_1}{12}+1.3$	Be3y=$S_3+\frac{S_1}{36}+0.35$
Be4	Be4x=$\frac{S_1}{6}+6$	Be4y=$S_3-\frac{S_1}{36}+0.9$
Be5	Be5x=$\frac{S_1}{4}+3$	Be5y=$S_3-\frac{S_1}{6}-7.5$
Be6	Be6x=$\frac{S_1}{4}+13$	Be6y=Ba9y+16.5
Front		
Fe1	Fe1x=Fa0x+1.5	Fe1y=$S_3-\frac{S_1}{24}-1$
Fe2	Fe2x=0	Fe2y=$S_3-\frac{S_1}{24}-1$
Fe3	Fe3x=$\frac{S_1}{12}+1$	Fe3y=$S_3+\frac{S_1}{24}-0.5$
Fe4	Fe4x=$\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}$	Fe4y=Fe5y-0.63Fe5y+30.2
Fe5	Fe5x=$\frac{S_1}{4}+3$	Fe5y=Be5y
Fe6	Fe6x=$\frac{S_1}{4}+13$	Fe6y=Be6y
Fe7	Fe7x=0	Fe7y=Be1y
Fe8	Fe8x=Fe1x+1.5	Fe8y=Be1y

Table D.49- Mathematical model ofA-style blouse pattern with looser-bodied style

Point	Equations ofpoint coordinate	
Back		
Be1	Be1x=0	Be1y=0.98Be6y+3.7
Be2	Be2x=0	Be2y= S_3-1
Be3	Be3x= $\frac{S_1}{12}+2.3$	Be3y= $S_3+\frac{S_1}{36}-0.4$
Be4	Be4x= $\frac{S_1}{6}+7.5$	Be4y= $S_3-\frac{S_1}{36}+1.9$
Be5	Be5x= $\frac{S_1}{4}+5$	Be5y= $S_3-\frac{S_1}{6}-8.2$
Be6	Be6x= $\frac{S_1}{4}+18$	Be6y=Ba9y+21.7
Front		
Fe1	Fe1x=Fa0x+2	Fe1y= $S_3-\frac{S_1}{24}-3.5$
Fe2	Fe2x=0	Fe2y= $S_3-\frac{S_1}{24}-3.5$
Fe3	Fe3x= $\frac{S_1}{12}+2$	Fe3y= $S_3+\frac{S_1}{24}-0.5$
Fe4	Fe4x= $\sqrt{\left[\sqrt{\left(\frac{S_1}{12}+5.7\right)^2+\left(\frac{S_1}{18}+0.2\right)^2}-1.5\right]^2-\left(\frac{S_1}{18}-0.3\right)^2}+\frac{S_1}{12}+1.5$	Fe4y=Fe5y-0.63Fe5y+30.2
Fe5	Fe5x= $\frac{S_1}{4}+5$	Fe5y=Be5y
Fe6	Fe6x= $\frac{S_1}{4}+18$	Fe6y=Be6y
Fe7	Fe7x=0	Fe7y=Be1y
Fe8	Fe8x=Fe1x+2	Fe8y=Be1y

APPENDIX E

Ease allowance of blouse pattern blocks in Chapter 3

Table E.1 - Ease allowance to back lengthof blouse in X, H and A styles

Ease to back length, cm					
X-1	0.5	H-1	0.8	A-1	0.5
X-2	-0.9	H-2	-0.2	A-2	0.8
X-3	-0.5	H-3	0.5	A-3	0.3
X-4	-1.5	H-4	0.5	A-4	0.5
X-5	-2.5	H-5	-0.2	A-5	0.5
X-6	-0.5	H-6	0.9	A-6	0.5
X-7	-0.5	H-7	0.5	A-7	0
X-8	-1	H-8	0.8	A-8	0.5
X-9	-0.5	H-9	0.5	A-9	0.5
X-10	-0.5	H-10	0.5	A-10	0.5
X-11	-1.5	H-11	0.8	A-11	0.5
X-12	-0.5	H-12	0.5	A-12	0.9
X-13	-1.5	H-13	0.5	A-13	-0.1
X-14	-1.5	H-14	0.8	A-14	0.5
X-15	0.5	H-15	0.5	A-15	0.5
X-16	0.5	H-16	0.5	A-16	0.5
X-17	0.5	H-17	0.5	A-17	0.5
X-18	0.5	H-18	0	A-18	0.5
X-19	0.2	H-19	-0.2	A-19	0.5
X-20	0.5	H-20	0.5	A-20	1.2
X-21	-0.7	H-21	0	A-21	0
X-22	0	H-22	0	A-22	0.5
X-23	0	H-23	0	/	/
X-24	0	H-24	0	/	/
X-25	0.5	H-25	0	/	/
X-26	0	H-26	0	/	/
X-27	0	H-27	0	/	/
X-28	0	H-28	0	/	/
X-29	0	H-29	1	/	/
X-30	0	/	/	/	/
X-31	1	/	/	/	/
X-32	0	/	/	/	/
X-33	0	/	/	/	/
X-34	-0.5	/	/	/	/

X-35	-0.7	/	/	/	/
X-36	-0.7	/	/	/	/
X-37	0	/	/	/	/
X-38	-0.5	/	/	/	/
X-39	0	/	/	/	/
X-40	0	/	/	/	/
X-41	0	/	/	/	/
X-42	0	/	/	/	/
X-43	0	/	/	/	/
X-44	0	/	/	/	/
X-45	0	/	/	/	/
X-46	0	/	/	/	/
X-47	0	/	/	/	/
X-48	0	/	/	/	/
X-49	0	/	/	/	/
X-50	0	/	/	/	/
X-51	0	/	/	/	/
X-52	0	/	/	/	/
X-53	0.3	/	/	/	/
X-54	0	/	/	/	/
X-55	0	/	/	/	/
X-56	0.3	/	/	/	/
X-57	0	/	/	/	/
X-58	0.3	/	/	/	/
X-59	0.3	/	/	/	/
X-60	1	/	/	/	/
X-61	0.3	/	/	/	/
X-62	1	/	/	/	/
X-63	0	/	/	/	/
X-64	0	/	/	/	/
X-65	0	/	/	/	/
X-66	0	/	/	/	/
X-67	0	/	/	/	/
X-68	0	/	/	/	/
X-69	0	/	/	/	/
X-70	0	/	/	/	/
X-71	-1.5	/	/	/	/
AVG.	0.2	AVG.	0.5	AVG.	0.5
MIN.	-2.5	MIN.	-0.2	MIN.	-0.1
MAX.	1.5	MAX.	1	MAX.	1.2

Table E.2 - Ease allowance to neck line of blouse in X, H and A styles

Ease to neck line, cm					
X-1	25.7	H-1	2	A-1	3.4
X-2	17.4	H-2	2.2	A-2	1.2
X-3	31.2	H-3	6.2	A-3	1.6
X-4	25.2	H-4	6	A-4	5.4
X-5	21	H-5	3	A-5	14.8
X-6	8	H-6	1.6	A-6	7.2
X-7	1.8	H-7	3.2	A-7	8.8
X-8	21.6	H-8	2	A-8	7.6
X-9	14.2	H-9	2	A-9	-2
X-10	19.6	H-10	8.4	A-10	9.8
X-11	9	H-11	5	A-11	12.6
X-12	9.4	H-12	2.2	A-12	1.2
X-13	13.8	H-13	6	A-13	1
X-14	21.4	H-14	3.2	A-14	30
X-15	14	H-15	2	A-15	22.4
X-16	46.8	H-16	3.9	A-16	11.2
X-17	5.2	H-17	9.4	A-17	14.6
X-18	1.2	H-18	2.4	A-18	10.4
X-19	2.2	H-19	3.8	A-19	10.6
X-20	2	H-20	15.8	A-20	6.6
X-21	9.2	H-21	4.4	A-21	28.6
X-22	13.8	H-22	4.2	A-22	9.6
X-23	2	H-23	6.6	/	/
X-24	13.8	H-24	11.2	/	/
X-25	-0.8	H-25	3.2	/	/
X-26	7.2	H-26	8.8	/	/
X-27	2.4	H-27	3.7	/	/
X-28	4.6	H-28	30.4	/	/
X-29	5.6	H-29	8.6	/	/
X-30	5.2	/	/	/	/
X-31	1.8	/	/	/	/
X-32	2.2	/	/	/	/
X-33	2.2	/	/	/	/
X-34	3.4	/	/	/	/
X-35	8.4	/	/	/	/
X-36	8.4	/	/	/	/
X-37	1.2	/	/	/	/

X-38	0.2	/	/	/	/
X-39	0.2	/	/	/	/
X-40	0.2	/	/	/	/
X-41	0.2	/	/	/	/
X-42	0.2	/	/	/	/
X-43	0.2	/	/	/	/
X-44	0.2	/	/	/	/
X-45	0.2	/	/	/	/
X-46	0.2	/	/	/	/
X-47	0.2	/	/	/	/
X-48	3.7	/	/	/	/
X-49	3.6	/	/	/	/
X-50	5	/	/	/	/
X-51	0.8	/	/	/	/
X-52	5.6	/	/	/	/
X-53	3.4	/	/	/	/
X-54	1.2	/	/	/	/
X-55	5.6	/	/	/	/
X-56	3	/	/	/	/
X-57	3.6	/	/	/	/
X-58	1	/	/	/	/
X-59	2.4	/	/	/	/
X-60	1.8	/	/	/	/
X-61	2.2	/	/	/	/
X-62	1.8	/	/	/	/
X-63	4.2	/	/	/	/
X-64	5	/	/	/	/
X-65	2.4	/	/	/	/
X-66	6.8	/	/	/	/
X-67	2	/	/	/	/
X-68	3.2	/	/	/	/
X-69	13.6	/	/	/	/
X-70	3	/	/	/	/
X-71	24.4	/	/	/	/
AVG.	7.2	AVG.	5.9	AVG.	9.8
MIN.	-0.8	MIN.	1.6	MIN.	-2
MAX.	46.8	MAX.	30.4	MAX.	30

Table E.3 - Angle of shoulder lines of difference between digital twin and pattern blocks in X, H and A styles

Front, degree					
X-1	-2	H-1	-2.5	A-1	-2
X-2	-5	H-2	-2	A-2	-2
X-3	-2.5	H-3	-2.5	A-3	-2
X-4	-2.5	H-4	-4.8	A-4	-14.3
X-5	-2.5	H-5	-2	A-5	-4.5
X-6	-6.7	H-6	-9.5	A-6	-4.5
X-7	-6.2	H-7	-2.5	A-7	-8.2
X-8	-2	H-8	-4.8	A-8	-4.5
X-9	-4.5	H-9	-8.5	A-9	-12
X-10	-2.5	H-10	-12.7	A-10	-4.5
X-11	-2	H-11	-7.8	A-11	-7.3
X-12	-10	H-12	-4.8	A-12	-12.3
X-13	-2	H-13	-7.6	A-13	-3.7
X-14	-4.5	H-14	-9.3	A-14	-4.5
X-15	-10	H-15	-2.5	A-15	-5.6
X-16	-7.4	H-16	-2.5	A-16	-4.5
X-17	-2.5	H-17	-6.9	A-17	-5.3
X-18	-4.3	H-18	-9.5	A-18	-5.8
X-19	-2.5	H-19	-7.5	A-19	-5
X-20	-2.5	H-20	-7	A-20	-4.9
X-21	-2.5	H-21	-2.5	A-21	-2.5
X-22	-2	H-22	-7.4	A-22	-5
X-23	-2	H-23	-5	/	/
X-24	-2	H-24	-4.8	/	/
X-25	-6.3	H-25	-6	/	/
X-26	-4.8	H-26	-5.8	/	/
X-27	-8.7	H-27	-2.5	/	/
X-28	-2.5	H-28	-2.5	/	/
X-29	-2.5	H-29	-5	/	/
X-30	-2	/	/	/	/
X-31	-2.8	/	/	/	/
X-32	-2.5	/	/	/	/
X-33	-2.5	/	/	/	/
X-34	-2	/	/	/	/
X-35	-2	/	/	/	/
X-36	-2	/	/	/	/

X-37	-2	/	/	/	/
X-38	-2	/	/	/	/
X-39	-2	/	/	/	/
X-40	-2	/	/	/	/
X-41	-2	/	/	/	/
X-42	-2	/	/	/	/
X-43	-2	/	/	/	/
X-44	-2	/	/	/	/
X-45	-2	/	/	/	/
X-46	-2	/	/	/	/
X-47	-2	/	/	/	/
X-48	-2.5	/	/	/	/
X-49	-2	/	/	/	/
X-50	-5	/	/	/	/
X-51	-2.1	/	/	/	/
X-52	0	/	/	/	/
X-53	0	/	/	/	/
X-54	-2	/	/	/	/
X-55	-2.5	/	/	/	/
X-56	-2.5	/	/	/	/
X-57	-4.5	/	/	/	/
X-58	-4.5	/	/	/	/
X-59	-2.5	/	/	/	/
X-60	-2.8	/	/	/	/
X-61	-2.5	/	/	/	/
X-62	-2.8	/	/	/	/
X-63	-2.8	/	/	/	/
X-64	-2.5	/	/	/	/
X-65	-2	/	/	/	/
X-66	-4.5	/	/	/	/
X-67	0	/	/	/	/
X-68	-2.5	/	/	/	/
X-69	-11.5	/	/	/	/
X-70	-2.5	/	/	/	/
X-71	-2.5	/	/	/	/
AVG.	-3.2	AVG.	-5.5	AVG.	-5.7
MIN.	-11.5	MIN.	-12.7	MIN.	-14.3
MAX.	0	MAX.	-2	MAX.	-2
Back, degree					
X-1	-6	H-1	-4.5	A-1	-9

X-2	-9.9	H-2	-9.4	A-2	-2.7
X-3	-4.5	H-3	-8.7	A-3	-6
X-4	-4.5	H-4	-4.5	A-4	-10.5
X-5	-4.5	H-5	-8.7	A-5	-8.9
X-6	-6	H-6	-13.4	A-6	-7
X-7	-2.2	H-7	-10.5	A-7	-11.6
X-8	-6	H-8	-10.5	A-8	-15.4
X-9	-5	H-9	-4.5	A-9	-6
X-10	-4.5	H-10	-12.7	A-10	-15.6
X-11	-6	H-11	-8.6	A-11	-9.6
X-12	-10	H-12	-10.5	A-12	-14.5
X-13	-6	H-13	-11	A-13	-3.7
X-14	-5	H-14	-10.2	A-14	-8
X-15	-10	H-15	-8.6	A-15	-6.5
X-16	-7	H-16	-10.5	A-16	-15
X-17	-4.5	H-17	-6.9	A-17	-9.3
X-18	-10.2	H-18	-13.7	A-18	-6.7
X-19	-5.7	H-19	-13	A-19	-11.1
X-20	-4.5	H-20	-8.5	A-20	-6.2
X-21	4.1	H-21	-8.7	A-21	-4.5
X-22	-4	H-22	-8.7	A-22	-8.1
X-23	-6	H-23	-9.3	/	/
X-24	-4	H-24	-10.5	/	/
X-25	-2.2	H-25	-8.7	/	/
X-26	-6.5	H-26	-10.5	/	/
X-27	-12.7	H-27	-10.5	/	/
X-28	-4.5	H-28	-4.5	/	/
X-29	-4.5	H-29	-7.5	/	/
X-30	-6	/	/	/	/
X-31	-3.1	/	/	/	/
X-32	-4.5	/	/	/	/
X-33	-4.5	/	/	/	/
X-34	-6	/	/	/	/
X-35	-8.8	/	/	/	/
X-36	-8.7	/	/	/	/
X-37	-6	/	/	/	/
X-38	-6	/	/	/	/
X-39	-6	/	/	/	/
X-40	-6	/	/	/	/
X-41	-6	/	/	/	/

X-42	-6	/	/	/	/
X-43	-6	/	/	/	/
X-44	-6	/	/	/	/
X-45	-6	/	/	/	/
X-46	-6	/	/	/	/
X-47	-6	/	/	/	/
X-48	-6.7	/	/	/	/
X-49	-9.4	/	/	/	/
X-50	-6.8	/	/	/	/
X-51	-2.9	/	/	/	/
X-52	-2.4	/	/	/	/
X-53	-4.5	/	/	/	/
X-54	-6	/	/	/	/
X-55	-4.5	/	/	/	/
X-56	-4.5	/	/	/	/
X-57	-5	/	/	/	/
X-58	-5	/	/	/	/
X-59	-4.5	/	/	/	/
X-60	-3.1	/	/	/	/
X-61	-4.5	/	/	/	/
X-62	-5.4	/	/	/	/
X-63	-5.5	/	/	/	/
X-64	-4.5	/	/	/	/
X-65	-9.4	/	/	/	/
X-66	-6	/	/	/	/
X-67	-4.5	/	/	/	/
X-68	-7	/	/	/	/
X-69	-11.5	/	/	/	/
X-70	-8.7	/	/	/	/
X-71	-4.5	/	/	/	/
AVG.	-5.7	AVG.	-9.2	AVG.	-8.9
MIN.	-12.7	MIN.	-13.7	MIN.	-15.6
MAX.	4.1	MAX.	-4.5	MAX.	-2.7

Table E.4 - Easeallowance of armhole linefor blouse pattern blockswith X-style

N.	Ease allowance of armhole line, cm

	E_{AD}	E_{FAP}	E_{BAP}
X-1	3.4	1.1	1.8
X-2	3.8	1.8	1.1
X-3	0.4	1.8	3
X-4	0.8	2.3	2.5
X-5	0.3	0.4	2.4
X-6	2.7	1.4	2.1
X-7	-0.6	2.2	2.1
X-8	2.1	1.9	1
X-9	2.6	3.5	1.9
X-10	0.3	0.7	2.1
X-11	0.9	2.4	2.4
X-12	1.3	2.1	2.7
X-13	3.3	1.5	-0.5
X-14	1	2.8	0.6
X-15	6.7	0.9	-1.2
X-16	2	4.6	3.7
X-17	0.3	0.5	2.4
X-18	3	1.2	1.7
X-19	1.2	0.8	2
X-20	0.9	1.4	1.6
X-21	1.9	0.3	2.1
X-22	3.1	0.6	2.3
X-23	1.6	1	1.6
X-24	3.5	1.9	1.8
X-25	-2.5	3.3	3.4
X-26	5.3	4.7	2.2
X-27	9.2	0	-1.7
X-28	1.7	0.8	2
X-29	0.2	0.6	2.2

X-30	3.3	1.6	1.3
X-31	0.6	0.2	1.4
X-32	0.6	0.7	2.2
X-33	0.8	1.3	1.7
X-34	3.7	1.9	1.7
X-35	2.4	0.4	1
X-36	2.3	0.6	0.9
X-37	1.1	1.8	2.3
X-38	1.2	2.1	2.8
X-39	1.2	1.3	1.6
X-40	0	1.2	2.5
X-41	0.3	1.1	3.2
X-42	0.5	0.2	2.7
X-43	1.9	0.2	2.4
X-44	0.6	0.5	2.1
X-45	1.9	0.6	2.4
X-46	1.3	0	1.7
X-47	1.9	0	1.7
X-48	3.2	1.1	2
X-49	1.9	1.6	1.7
X-50	3	1.9	1.9
X-51	3.3	1.9	1.7
X-52	3.3	1.9	1.8
X-53	3.3	1.9	1.7
X-54	3.3	1.9	1.8
X-55	3.3	1.9	1.7
X-56	3.3	1.9	1.8
X-57	3.3	1.9	1.7
X-58	3.3	1.9	1.8
X-59	0.9	0	2.5

X-60	0	0.9	2.4
X-61	2	0	2.4
X-62	1.7	0	3.6
X-63	1.2	0	0.6
X-64	0.8	0	2.9
X-65	0.7	0	2.3
X-66	2.3	1.1	3.6
X-67	0.6	1	1.9
X-68	0.9	0.8	2.2
X-69	3	5.2	1.9
X-70	5.3	2	1
X-71	0.5	2.5	1.7
AVG.	2	1.4	1.9
MIN.	-2.5	0	-1.7
MAX.	9.2	5.2	3.7

Table E.5 - Easeallowance of armhole linefor blouse pattern blockswith H-style

N.	Ease allowance of armhole line, cm		
	E_{AD}	E_{FAP}	E_{BAP}
H-1	7.3	0.6	1.2
H-2	11	1.9	0
H-3	4.7	0.2	0
H-4	6.6	1.1	3.7
H-5	4	2.9	2.8
H-6	1.5	2.1	2.2
H-7	6.6	2.2	0
H-8	2.6	2.3	2
H-9	3.2	3	2.4
H-10	4.9	3.3	3.3
H-11	0.9	1.4	2.5

H-12	5.2	0	1.9
H-13	0.7	2.2	3.3
H-14	6.7	4.8	3.4
H-15	4.6	2.6	-1.2
H-16	3	1.3	0
H-17	5.5	4	3.3
H-18	2.6	3.5	3.7
H-19	7.1	3.7	-1.5
H-20	6.5	2	2.2
H-21	6.8	0.5	2.6
H-22	4.8	1.6	0.7
H-23	5.1	1.2	2
H-24	4.5	3.4	3.6
H-25	2.9	-3.1	4
H-26	3.2	4.2	2.1
H-27	5.8	3	0.2
H-28	3.2	0.5	2.3
H-29	4.2	1.6	2.7
AVG.	4.7	2	1.9
MIN.	0.7	-3.1	-1.5
MAX.	11	4.8	4

Table E.6 - Easeallowance of armhole linefor blouse pattern blockswith A-style

N.	Ease allowance of armhole line, cm		
	E_{AD}	E_{FAP}	E_{BAP}

A-1	1.7	1.3	1.8
A-2	-3.7	4.3	3.6
A-3	1.2	1.2	3.1
A-4	1.5	1.7	1.3
A-5	-0.3	4.2	3.5
A-6	5.2	3.7	2.2
A-7	5	7	4.8
A-8	8.9	-4.4	6.4
A-9	1.7	-1.6	2.4
A-10	4.9	1.2	4.5
A-11	5.5	1.3	-1
A-12	4.2	2.8	2.6
A-13	0.4	4	3.6
A-14	3.7	1.5	-1.2
A-15	5.1	1.9	2.3
A-16	2.3	2.9	5.4
A-17	4.4	1.8	1
A-18	3.6	2.1	2
A-19	2	4.4	3.9
A-20	5.6	1	2
A-21	-1.3	2.5	1.5
A-22	5.3	5.2	5.4
AVG.	3	2.3	2.8
MIN.	-3.7	-4.4	-1.2
MAX.	8.9	7	6.4

APPENDIX F

The fold information of each line in the waist area for women blouse with back length in Chapter 4

Table F.1 - The fold information of each line in the waist area for women blouse with back length (Y body type)

E_{BL}, cm	Cross-section	Folds parameter			Unevenness of fold, pixel/grey value	
		number	Width (for each fold), pixel	Depth(for each fold), grey value	width	depth
3	WL+6	0	0	0	1.91	0.87
	WL+3	0	0	0		
	WL	0	0	0		
	WL-3	3	29/74/30	33/42/45.5		
	WL-6	2	57/32	28.5/45		
	WL-9	1	45	40		
4	WL+6	0	0	0	3.69	2.32
	WL+3	0	0	0		
	WL	1	77	38		
	WL-3	3	35/60/25	29.5/68.5/60		
	WL-6	3	19/39/21	36/55/60.5		
	WL-9	2	21/30	39/39		
5	WL+6	0	0	0	3.92	3.59
	WL+3	0	0	0		
	WL	1	96	76		
	WL-3	3	36/49/24	36/73.5/29		
	WL-6	4	22/21/38/28	30/22/69/40		
	WL-9	2	21/34	53/40		

Table F.2 - The fold information of each line in the waist area for women blouse with back length (A body type)

E_{BL}, cm	Cross-section	Folds parameter			Unevenness of fold, pixel/grey value	
		number	Width (for each fold), pixel	Depth(for each fold), grey value	width	depth
3	WL+6	0	0	0	1.8	1.29
	WL+3	0	0	0		
	WL	1	68	28		
	WL-3	2	78/33	36/53		
	WL-6	2	88/40	45/50		
	WL-9	2	58/55	35/47		
4	WL+6	0	0	0	3.39	2.24
	WL+3	0	0	0		
	WL	2	31/99	39/66		
	WL-3	3	40/75/27	34/72/55		
	WL-6	2	47/29	67/48		
	WL-9	2	33/43	37/39		
5	WL+6	0	0	0	4.07	3.92
	WL+3	0	0	0		
	WL	1	104	73.5		
	WL-3	2	46/75	35.5/90		
	WL-6	3	22/17/47	30/25/75		
	WL-9	3	22/28/47	26/68.5/40		

Table F.3 - The fold information of each line in the waist area for women blouse with back length (B body type)

E_{BL}, cm	Cross-section	Folds parameter			Unevenness of fold, pixel/grey value	
		number	Width (for each fold), pixel	Depth(for each fold), grey value	width	depth
2	WL+6	0	0	0	1.1	1.28
	WL+3	0	0	0		

	WL	2	33/34	22/20		
	WL-3	1	30	33.5		
	WL-6	1	43	26.5		
	WL-9	1	58	43		
3	WL+6	0	0	0	1.23	2.11
	WL+3	0	0	0		
	WL	2	29/40	20/20		
	WL-3	1	32	42		
	WL-6	1	39	32		
	WL-9	2	61/47	20/51		
4	WL+6	0	0	0	2.95	2.58
	WL+3	0	0	0		
	WL	2	27/36	24/22		
	WL-3	2	135/35	62/44		
	WL-6	1	41	39		
	WL-9	2	54/54	18/53		
5	WL+6	2	13/77	17.5/33	7.2	6.02
	WL+3	1	78	28		
	WL	2	63/24	23/51		
	WL-3	4	11/26/61/13	26.5/21/80/25		
	WL-6	2	37/34	21.5/18		
	WL-9	3	60/60/25	20/57/20		

Table F.4 - The fold information of each line in the waist area for women blouse with back length (C body type)

E_{BL}, cm	Cross-section	Folds parameter			Unevenness of fold, pixel/grey value	
		number	Width (for each fold), pixel	Depth(for each fold), grey value	width	depth
2	WL+6	0	0	0	1.32	2.66
	WL+3	0	0	0		
	WL	2	26/35	20/20		
	WL-3	2	34/17	29/46		
	WL-6	1	30	19		
	WL-9	2	45/31	52/20		

3	WL+6	0	0	0	2.96	3.15
	WL+3	0	0	0		
	WL	3	21/49/25	21/41/20		
	WL-3	2	28/32	20/30.5		
	WL-6	2	11/29	31/20.5		
	WL-9	3	21/44/21	26/58/20		
4	WL+6	0	0	0	5.34	3.26
	WL+3	1	103	29		
	WL	2	81.5/60.5	25.5/30.5		
	WL-3	4	35/91/72/35	24.5/19/25/52.5		
	WL-6	1	26	30		
	WL-9	3	14/45/22	27/61/20		
5	WL+6	4	27/98/31/20	40.5/40/24.5/27	8.24	4.66
	WL+3	2	59/81	40.5/39		
	WL	3	16/106/106	23/25/48.5		
	WL-3	2	22/43	23.5/56		
	WL-6	1	43	47.5		
	WL-9	3	19/47/22	27/61/18.5		

APPENDIX G

Calibration of the fold information of each line in the waist area in Chapter 4

Table G.1 - Calibration of the fold information of each line in the waist area (Y body type)

Cross-section	Depth of folds, depending on E_{BL}					
	E_{BL}, cm					
	3		4		5	
	grey value	cm	grey value	cm	grey value	cm
WL+6	0	0	0	0	0	0
WL+3	0	0	0	0	0	0
WL	0	0	38	1.9	76	3.8
WL–3	33/42/45.5	1.65/2.1/2.3	29.5/68.5/60	1.5/3.4/3	36/73.5/29	1.8/3.7/1.5
WL–6	28.5/45	1.43/2.3	36/55/60.5	1.8/2.8/3	30/22/69/40	1.5/1.1/3.5/2
WL–9	40	2	39/39	2/2	53/40	2.7/2

Table G.2 - Calibration of the fold information of each line in the waist area for women blouse with back length (A body type)

Cross-section	Depth of folds, depending on E_{BL}					
	E_{BL}, cm					
	3		4		5	
	grey value	cm	grey value	cm	grey value	cm
WL+6	0	0	0	0	0	0
WL+3	0	0	0	0	0	0
WL	28	1.4	39/66	2/3.3	73.5	3.7
WL–3	36/53	1.8/2.7	34/72/55	1.7/3.6/2.8	35.5/90	1.8/4.5
WL–6	45/50	2.3/2.5	67/48	3.4/2.4	30/25/75	1.5/1.3/3.8
WL–9	35/47	1.8/2.4	37/39	1.9/2	26/68.5/40	1.3/3.4/2

Table G.3 - Calibration of the fold information of each line in the waist area for women blouse with back length (B body type)

Cross-section	Depth of folds, depending on E_{BL}							
	E_{BL}, cm							
	2		3		4		5	
	grey value	cm	grey value	cm	grey value	cm	grey value	cm
WL+6	0	0	0	0	0	0	17.5/33	0.9/1.7
WL+3	0	0	0	0	0	0	28	1.4
WL	22/20	1.1/1	20/20	1/1	24/22	1.2/1.1	23/51	1.2/2.6
WL–3	33.5	1.7	42	2.1	62/44	3.1/2.2	26.5/21/80/25	1.3/1.1/4/1.3
WL–6	26.5	1.3	32	1.6	39	2	21.5/18	1.1/0.9
WL–9	43	2.2	20/51	1/2.6	18/53	0.9/2.7	20/57/20	1/2.9/1

Table G.4 - Calibration of the fold information of each line in the waist area for women blouse with back length (C body type)

Cross-section	Depth of folds, depending on E_{BL}							
	E_{BL}, cm							
	2		3		4		5	
	grey value	cm	grey value	cm	grey value	cm	grey value	cm
WL+6	0	0	0	0	0	0	40.5/40/24.5/27	2/2/1.2/1.4
WL+3	0	0	0	0	29	1.5	40.5/39	2.1/2
WL	20/20	1/1	21/41/20	1.1/2.1/1	25.5/30.5	1.3/1.5	23/25/48.5	1.2/1.3/2.4
WL–3	29/46	1.5/2.3	20/30.5	1/1.5	24.5/19/25/52.5	1.2/1/1.3/2.6	23.5/56	1.2/2.8
WL–6	19	1	31/20.5	1.6/1	30	1.5	47.5	2.4

WL–9	52/20	2.6/1	26/58/ 20	1.3/2. 9/1	27/61/ 20	1.4/3. 1/1	27/61/ 18.5	1.4/3. 1/0.9

APPENDIX H

Subjective questionnaire on fit degree of women blousesin Chapter 4

Table H.1 - Subjective questionnaire on fit degree of women blouses

<table>
<tr><td colspan="2">Subjective questionnaire on fit degree of women blouses</td></tr>
<tr><td colspan="2">Hello! Thank you for participating in this questionnaire. This questionnaire aims to to form the requirements to clothes quality. Your opinion is very important for this research. Please evaluate it based on your true inner feelings. The results of your answers are confidential and used only for research and analysis of the thesis. Please feel free to answer, thank you!</td></tr>
<tr><td colspan="2">Age： Sex： Male□ Female□
Education degree： Major：
There are five representative pictures of X - style women blouse with different degrees of fit below. Please check each picture carefully, and compare the two pictures, then choose which one is better. At last, sort the women blouses of pictures from left to right according to the degree of fit, such as very bad, bad, good, very good, perfect.</td></tr>
<tr><td colspan="2">For example, the following two women blouses are compared according to their degree of fit.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>1</td><td>2</td></tr>
<tr><td colspan="2">The better picture you think is : 2</td></tr>
<tr><td colspan="2">For example, the following five women blouses are sorted according to their degree of fit.</td></tr>
</table>

				
1	2	3	4	5
The order you think is : 21345				
First set of pictures				

	
1	2
The better picture you think is :	
Second set of pictures	

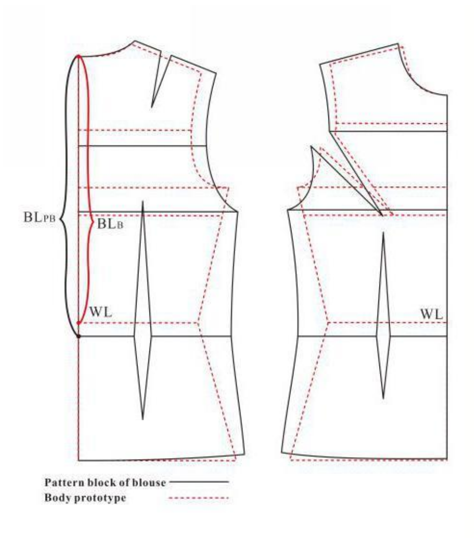
<table>
<tr><td></td><td></td></tr>
<tr><td>2</td><td>3</td></tr>
<tr><td colspan="2">The better picture you think is :</td></tr>
<tr><td colspan="2">Third set of pictures</td></tr>
<tr><td></td><td></td></tr>
<tr><td>3</td><td>4</td></tr>
<tr><td colspan="2">The better picture you think is :</td></tr>
<tr><td colspan="2">Fourth set of pictures</td></tr>
</table>

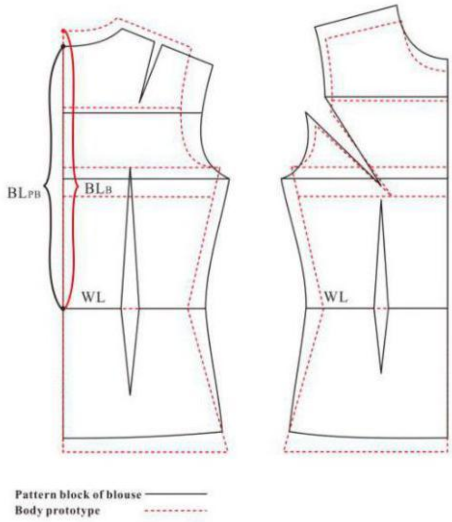
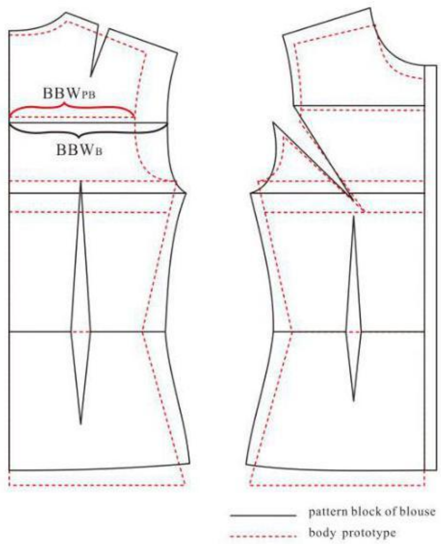
<table>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">4</td><td colspan="3">5</td></tr>
<tr><td colspan="6">The better picture you think is :</td></tr>
<tr><td colspan="6">Fifth set of pictures</td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td colspan="2">5</td></tr>
<tr><td colspan="6">The order you think is :</td></tr>
</table>

APPENDIX I

Constructive defects for fit evaluationin Chapter 5

Table I.1 - Constructive defects for fit evaluation

<table>
<tr><td>Defect location</td><td>Criteria of evaluation</td><td>Reason of defect appearing due to patterns</td></tr>
<tr><td colspan="3">1. Back</td></tr>
<tr><td>1.1.Back length</td><td>1. Redundant horizontal folds above waist
2. Excess wrinkles</td><td>1. The ease to back length $E_{BL} = BL_{PB} - BL_B > 0$ is too big (a, b).
2. The ease to back length $E_{BL} = BL_{PB} - BL_B < 0$ is too small (c, d).
BL_B - the measurement "Back length"
WL - waist level of body</td></tr>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(a)</td><td>(b)</td></tr>
</table>

<table>
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td>1.2. Back width</td><td>Excess longitudinal near armholes</td><td>The ease of back width EBW = BBW_{PB} - BBW_B> 0 is too big, the back is too loose and not fit, resulting in excess longitudinal folds.</td></tr>
<tr><td colspan="2"></td><td>
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<tr><td colspan="3">2. Front</td></tr>
<tr><td>2.1.Front length</td><td>Excess wrinkles upper bust level and shoulder level</td><td>1. The ease to front length E_{FL} = FL_{PB} - FL_B> 0 is too big (a, b).
2. The ease to front length E_{FL} = FL_{PB} - FL_B< 0 is too small (c, d).
FL_B - the measurement "Front length"</td></tr>
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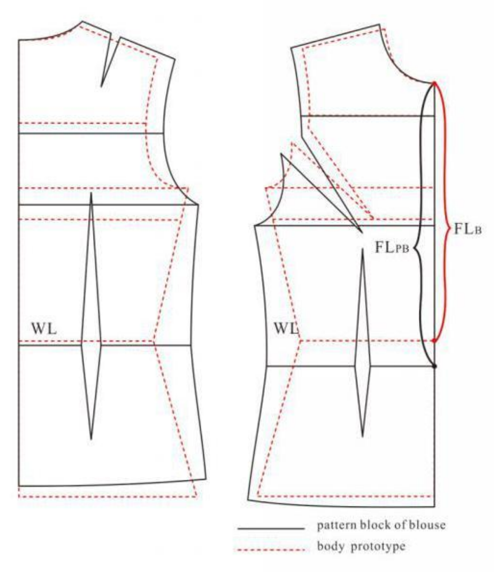
<tr><td colspan="2"></td><td>
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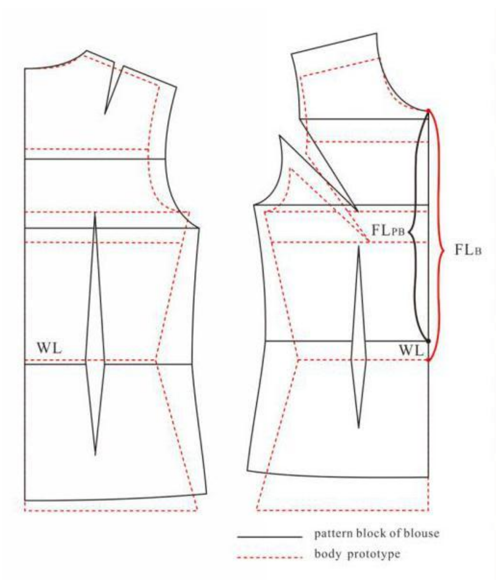
<tr><td colspan="2"></td><td>
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<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td>2.2. Front waist length</td><td>Excess wrinkles upper bust level, the hem unbalanced</td><td>$BL_{PB}>FL_{PB}$.</td></tr>
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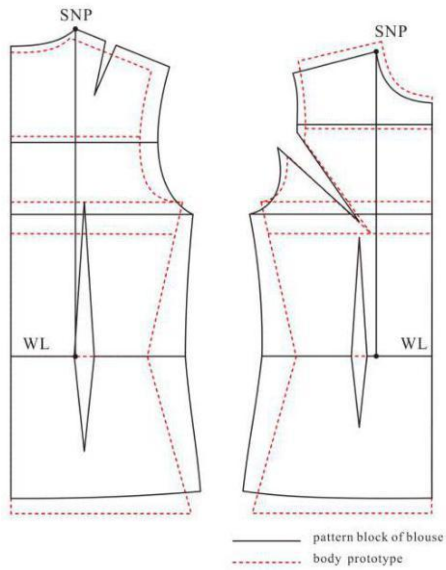
<tr><td colspan="2"></td><td>
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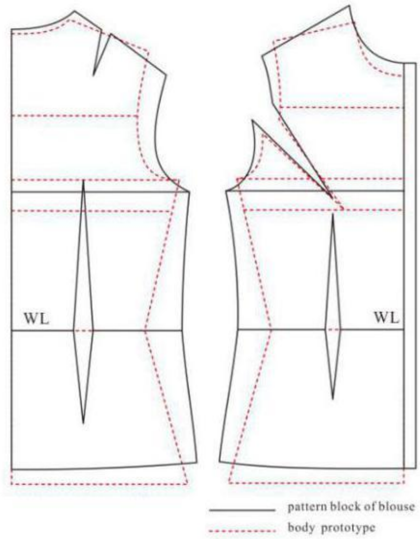
<tr><td>2.3. Shoulder slope</td><td>Excess folds on the shoulder part</td><td>The angle between two shoulder lines of pattern blocks is too large (a, b) or too small (c, d) than the shoulder slope of human body.</td></tr>
<tr><td colspan="2"></td><td>
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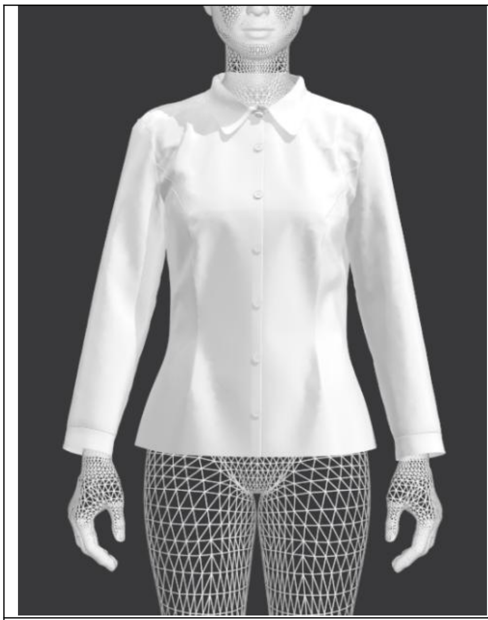
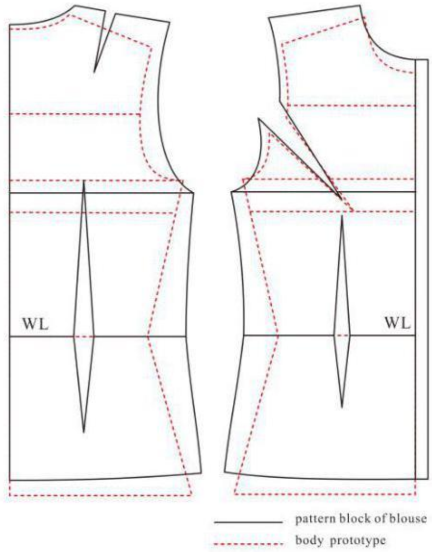
<tr><td colspan="2"></td><td>
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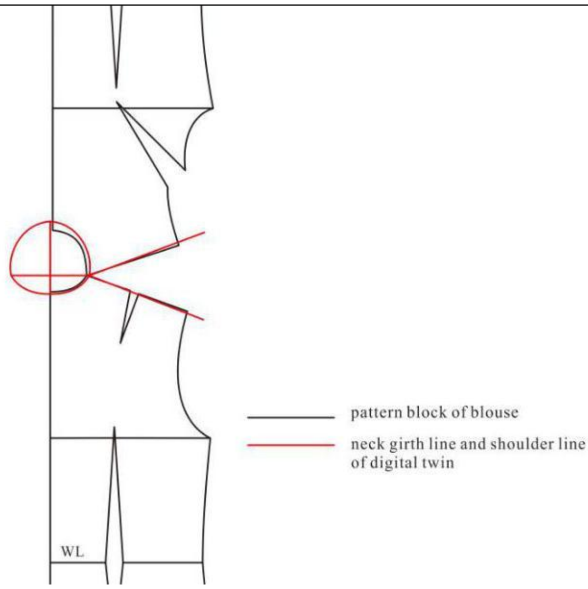
<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td>2.4. Neck line</td><td>Collar is too tight or has excess folds</td><td>The ease to the neck girth E_{NLPB} = NL - NG is not enough.</td></tr>
<tr><td colspan="2"></td><td>
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<tr><td>2.5. Shoulder length</td><td>1. Excess vertical wrinkles,
2. Excess horizontal wrinkles</td><td>1. The ease of shoulder width E = SW_{PB} - SW_{B} is too large (a, b).
2. The ease of shoulder width E = SW_{PB} - SW_{B} is too small (c, d).</td></tr>
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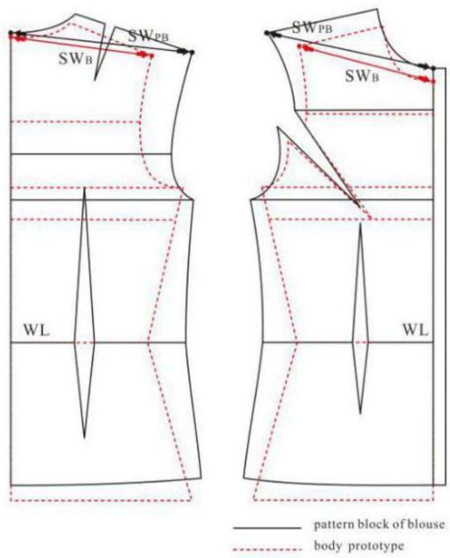
<tr><td colspan="2"></td><td>
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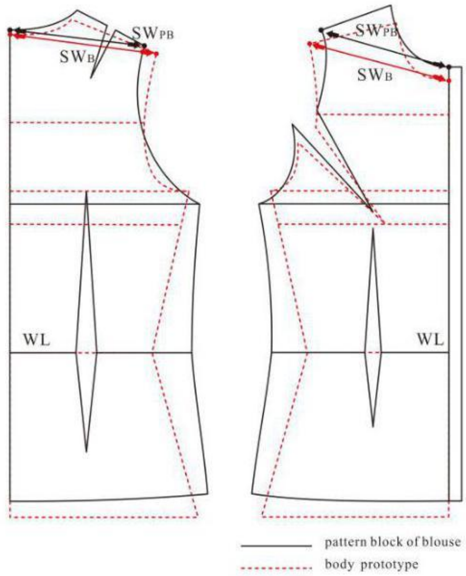
<tr><td colspan="2"></td><td>
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<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td>2.7. Bust width</td><td>1. Extra folds upper bust level
2. Bust pulling</td><td>1. The ease of bust width $E_{BWPB} = FBW_{PB} - FBW_{B}$ is too big (a, b).
2. The ease of bust width $E_{BWPB} = FBW_{PB} - FBW_{B}$ is too small (c, d).</td></tr>
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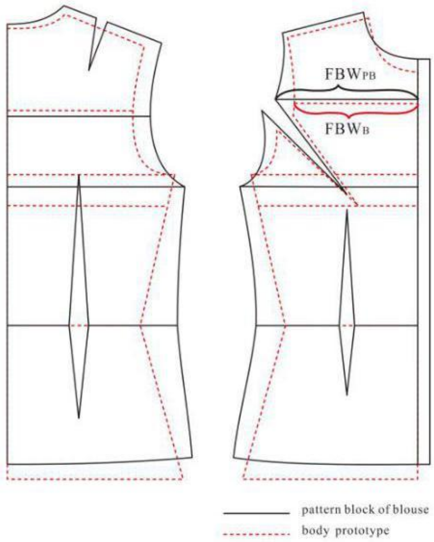
<tr><td colspan="2"></td><td>
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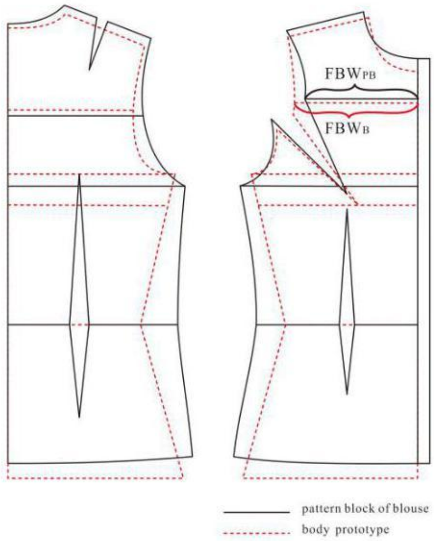
<tr><td colspan="2"></td><td>
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<tr><td colspan="2">(c)</td><td>(d)</td></tr>
<tr><td>2.8. Hem width</td><td>1. excess horizontal folds upper waist and hip level
2. the hem position is not horizontal</td><td>The difference (HWF_{PB} + HWB_{PB}) - (HWF_B + HWB_B) is too small</td></tr>
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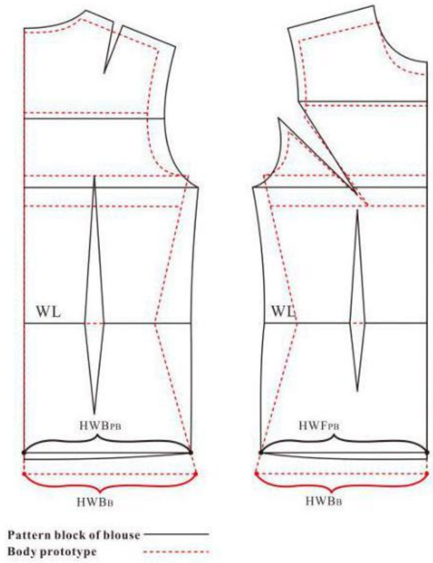
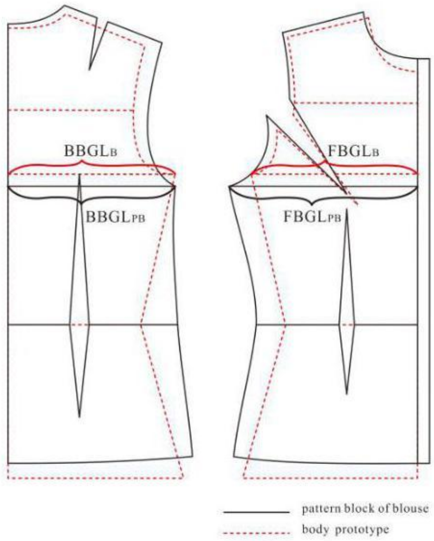
<tr><td colspan="2"></td><td>
</td></tr>
<tr><td colspan="2">(a) Virtual twin of women blouse with defects in hem width</td><td>(b) Pattern blocks of women blouse with defects in hem width</td></tr>
<tr><td>2.9. Distribution of an ease to bust girth E_{BG} between front and back</td><td>1. Excess soft vertical wrinkles upper bust level
2. Front is tight</td><td>1. $(FBGL_{PB} - FBGL_{B}) > (BBGL_{PB} - BBGL_{B})$ (a, b).
2. $(FBGL_{PB} - FBGL_{B}) < (BBGL_{PB} - BBGL_{B})$ (c, d).</td></tr>
<tr><td colspan="2"></td><td>
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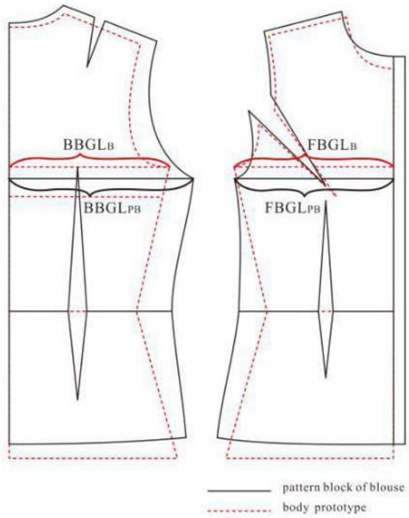
<tr><td colspan="2"></td><td colspan="2">
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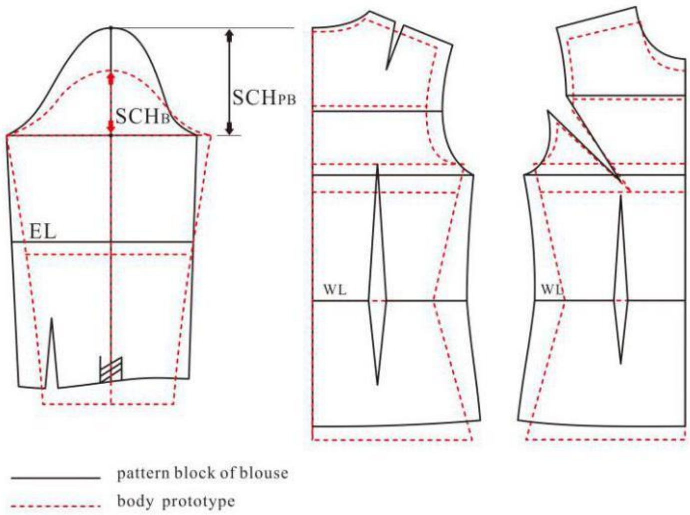
<tr><td colspan="2">(c)</td><td colspan="2">(d)</td></tr>
<tr><td colspan="4">3. Sleeve</td></tr>
<tr><td>3.1. Sleeve cap height</td><td>Excess wrinkles</td><td colspan="2">The sleeve cap height (SCH_{PB} - SCH_{B}) is too large.</td></tr>
<tr><td colspan="2"></td><td colspan="2">
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<tr><td colspan="2">(a)</td><td colspan="2">(b)</td></tr>
<tr><td>3.2. Sleeve width</td><td>Extra folds</td><td colspan="2">The difference (SW_{PB} - SW_{B}) is too large</td></tr>
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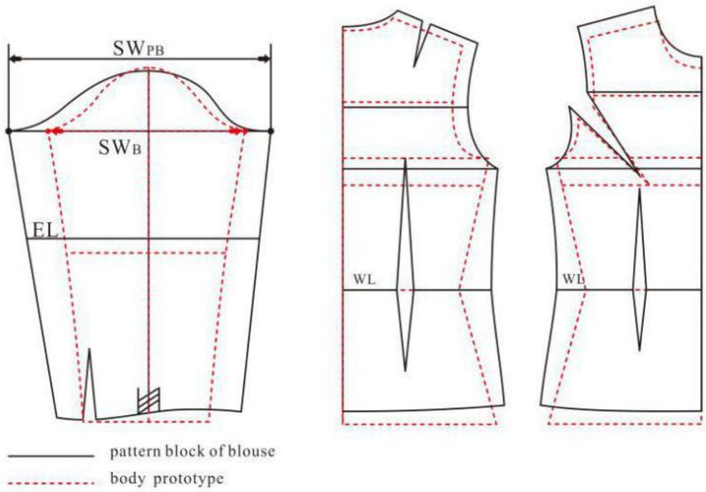
<tr><td colspan="2"></td><td colspan="2">
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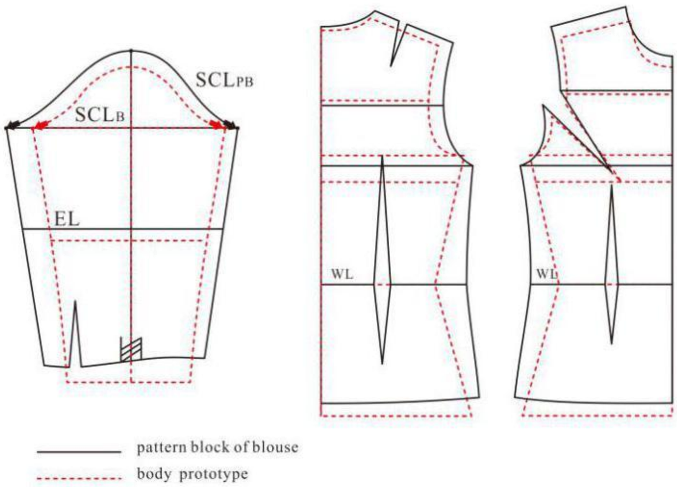
<tr><td colspan="2">(a)</td><td colspan="2">(b)</td></tr>
<tr><td>3.3. Sleeve cap length</td><td colspan="2">Excessive wrinkles on the armholes</td><td>The difference (SCL_{PB} - SCL_{B}) is too large</td></tr>
<tr><td colspan="2"></td><td colspan="2">
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<tr><td colspan="2">(a)</td><td colspan="2">(b)</td></tr>
<tr><td colspan="4">4. Collar</td></tr>
<tr><td>4.1. Upwarp angle of collar band's</td><td colspan="2">Band cannot be completely covered the top collar</td><td>The upwarp angle of collar band's bottom line is too large, so the collar' band is too close to the neck.</td></tr>
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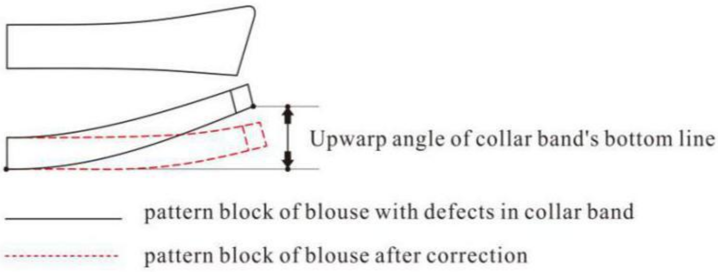
<tr><td colspan="3">
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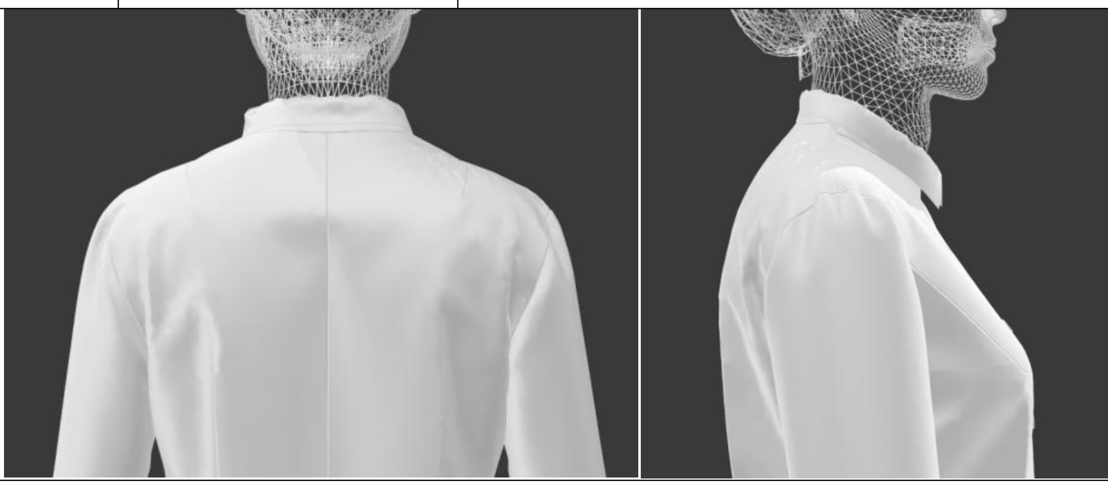
<tr><td colspan="3">(b)</td></tr>
<tr><td>4.2. Downward angle of top collar's</td><td>Top collar cannot be completely covered the collar band</td><td>Downward angle of top collar's bottom line is too small, and the outer collar line of the top collar is short.</td></tr>
<tr><td colspan="3"></td></tr>
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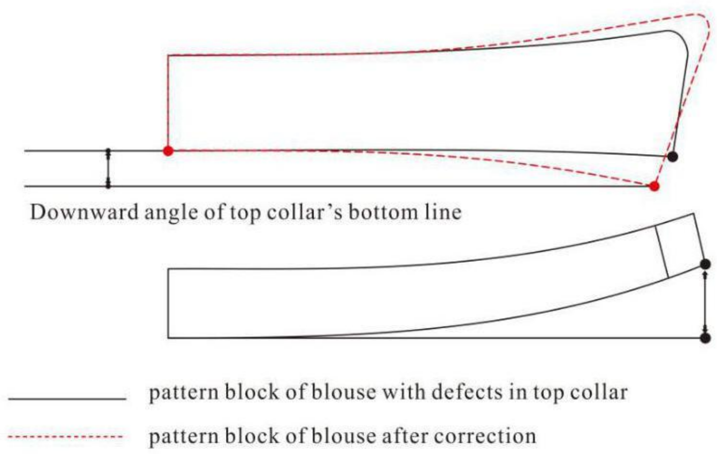

(b)

In total: A balanced women blouse evenly hangs on the body, so the distance from the right side of the body to the center isthe same as the distance from the left side to the center, and the front and back garment can keep fit and smooth, and there are no wrinkles on the surface of the garment, which defines the garment is in balance, stable state.

APPENDIX J

Fit criteria of blouse in Chapter 5

Table J.1 - Criteria of blouse front length fit evaluation

	Quality fit levels of women blouses				
1	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
2	Too much vertical wrinkles upper hip level; non-predictable location of the hem.	Several verticalwrinkles on the front.	Few soft sloping folds.	The front is smooth; the hem is in normal position.	The front is completely smooth; the hem is in normal position.
3					
4					

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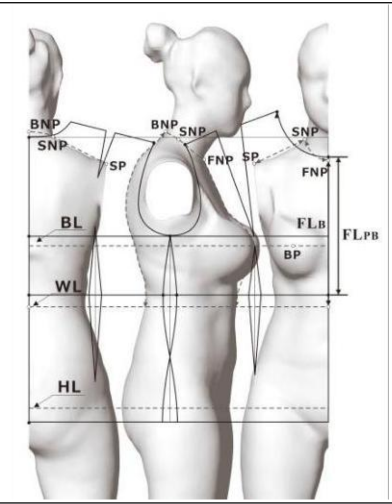
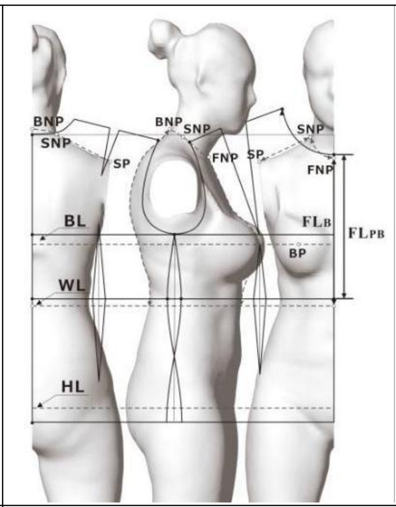
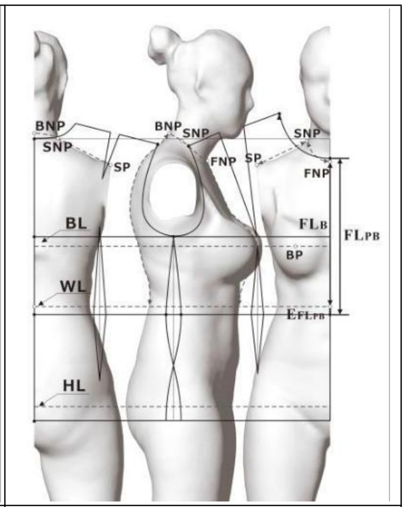
<tr><td rowspan="4">5</td><td>
</td><td>
</td><td>
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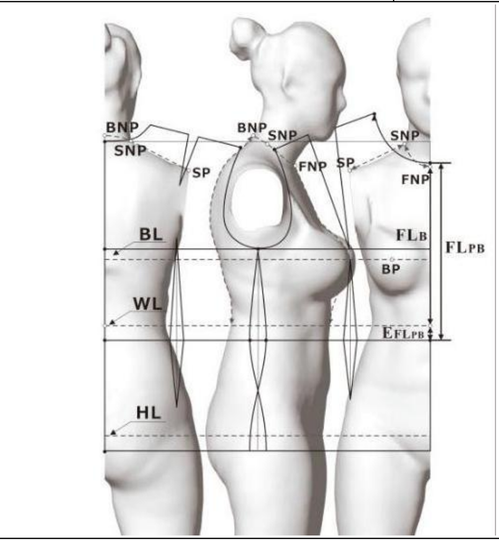
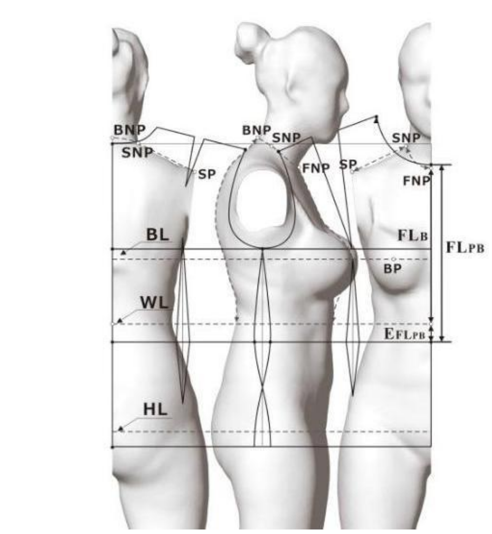
<tr><td>Very bad fit</td><td>Bad fit</td><td>Acceptable fit</td></tr>
<tr><td colspan="2">
</td><td>
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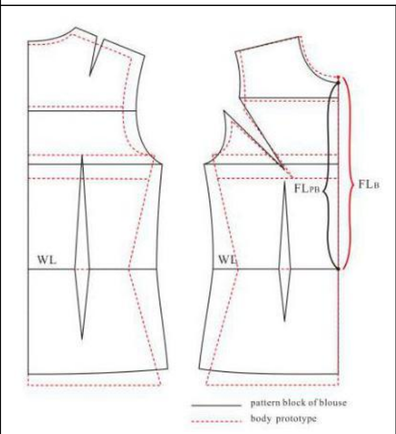
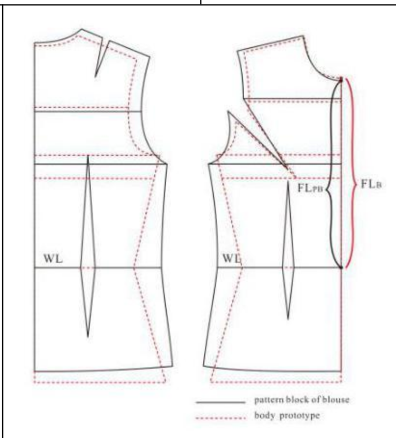
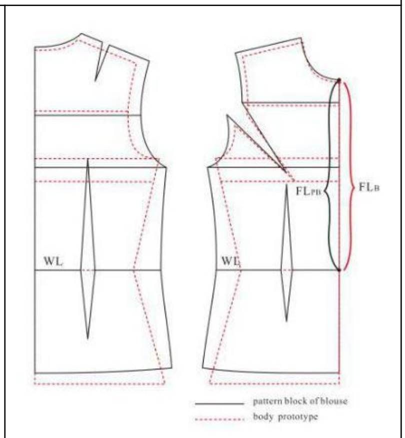
<tr><td colspan="2">Good fit</td><td>Perfect fit</td></tr>
<tr><td rowspan="2">6</td><td>
</td><td>
</td><td>
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<tr><td>Very bad fit</td><td>Bad fit</td><td>Acceptable fit</td></tr>
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	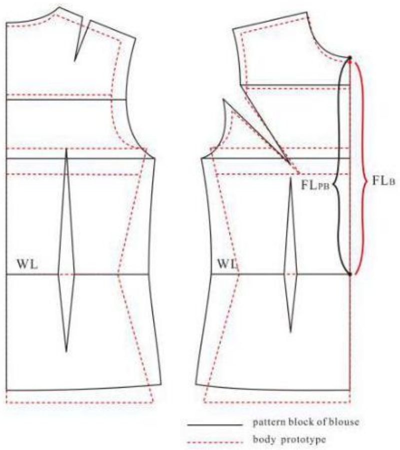			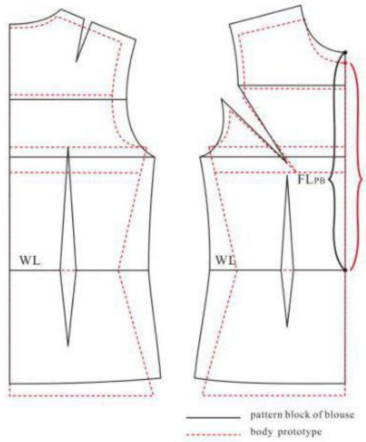	
	Good fit			Perfect fit	
7	Where: FL_B is the front length of body, FL_{PB} is the front length of sewing pattern, E_{FLPB} is the ease allowance to FL_{PB}.				
8	1st fit criteria. $E_{FLPB} = FL_{PB} - FL_B$, cm				
	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
	$E_{FLPB} \leq -4\pm1$	$E_{FLPB} \leq -2\pm1$	$E_{FLPB} \leq 5\pm1$	$E_{FLPB} \leq 4\pm1$	$E_{FLPB} \leq 2\pm1$

Table J.2 - Criteria of blouse bust width fit evaluation

	Quality fit levels of women blouses				
1	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
2	Too much sloping wrinkles upper bustand waist level.	Several sloping folds upper bustand waist level.	Some soft sloping folds on the front.	Few soft sloping folds; the hem is in normal position.	The back is completely smooth; the hem is in normal position.
3					

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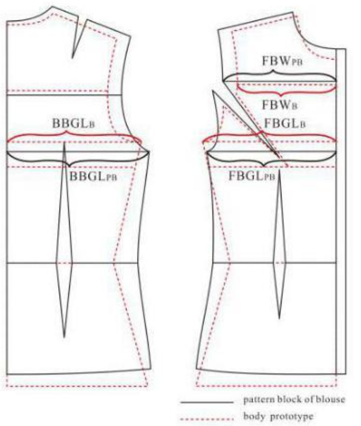
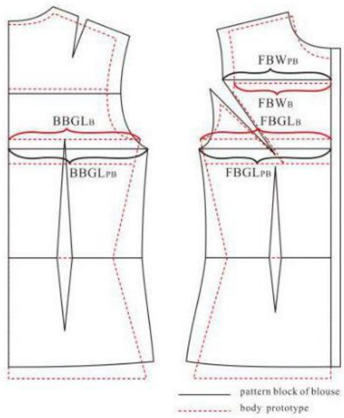
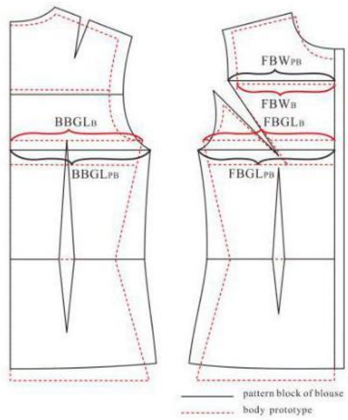
<tr><td rowspan="4">5</td><td colspan="2">
</td><td colspan="3">
</td><td colspan="2">
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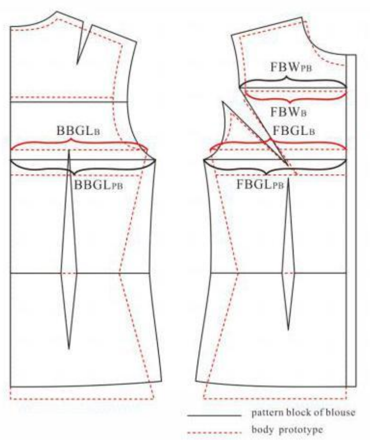
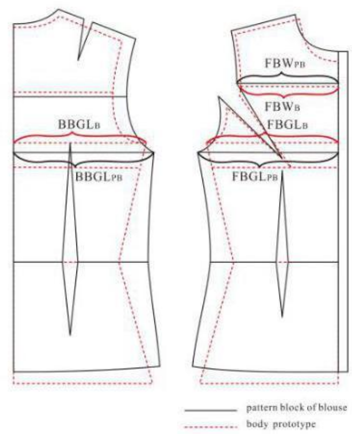
<tr><td colspan="2">Very bad fit</td><td colspan="3">Bad fit</td><td colspan="2">Acceptable fit</td></tr>
<tr><td colspan="3">
</td><td colspan="4">
</td></tr>
<tr><td colspan="3">Good fit</td><td colspan="4">Perfect fit</td></tr>
<tr><td>6</td><td colspan="7">Where: BW is the bustwidth of body, BG is the bustgirth of body, FBW_{PB} is the front bust width of sewing pattern, E_{FBWPB} is the ease allowance to FBW_{PB}, BGL_{PB} is the bust girth line of sewing pattern, $BBGL_{PB}$ is the back bust girth line of sewing pattern, $FBGL_{PB}$ is the frontbust girth line of sewing pattern, E_{BGPB} is the ease allowance to BGL_{PB}.</td></tr>
<tr><td>7</td><td colspan="7">1st fit criteria. $E_{FBWPB}= 2FBW_{PB}-BW$, cm</td></tr>
</table>

	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
	$E_{FBWPB} \geq 6.4 \pm 0.4$	$E_{FBWPB} \leq 5.4 \pm 0.4$	$E_{FBWPB} \leq 4.4 \pm 0.4$	$E_{FBWPB} \leq 3.4 \pm 0.4$	$E_{FBWPB} \leq 2.4 \pm 0.4$
8	2nd fit criteria. $E_{BGPB}= (2FBGL_{PB}+2BBGL_{PB})-BG$, cm				
	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
	$E_{BGPB} \leq -1.25 \pm 0.75$	$E_{BGPB} \leq 1.25 \pm 0.75$	$E_{BGPB} \leq 3.25 \pm 0.75$	$E_{BGPB} \leq 5.25 \pm 0.75$	$E_{BGPB} \leq 7.25 \pm 0.75$

Table J.3 - Criteria of blouse back width fit evaluation

	Quality fit levels of women blouses				
1	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
2	Too much vertical wrinkles upper bustand waist level.	Several vertical folds upper bustand waist level.	Some soft vertical folds on the waist level.	The back is smooth; the hem is in normal position.	The back is completely smooth; the hem is in normal position.
3					
4					

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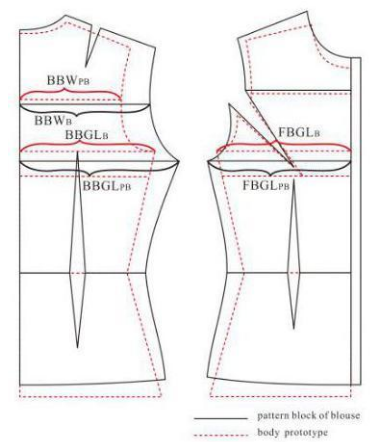
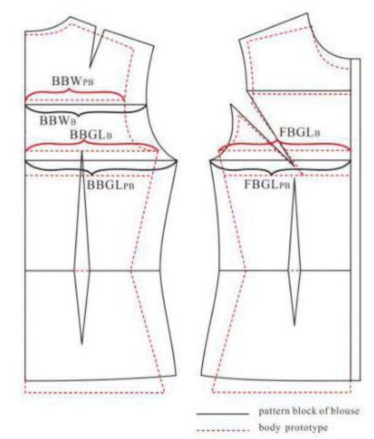
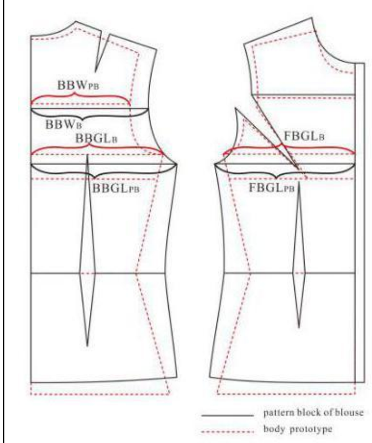
<tr><td rowspan="4">5</td><td colspan="2">
</td><td colspan="2">
</td><td>
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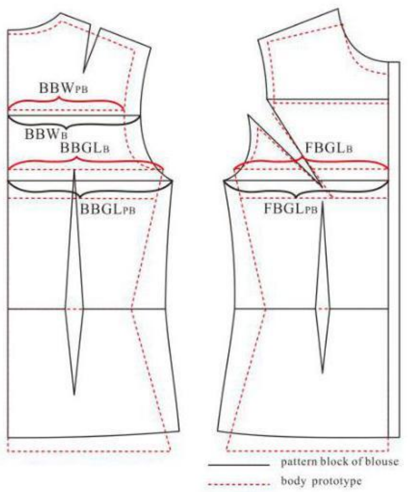
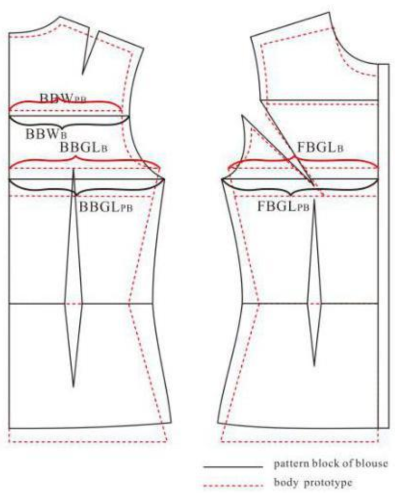
<tr><td colspan="3">
</td><td colspan="2">
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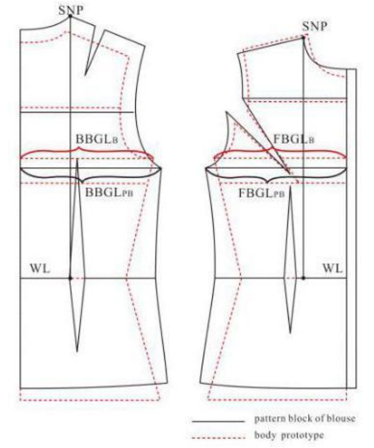
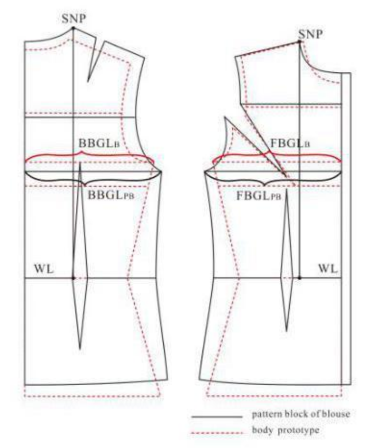
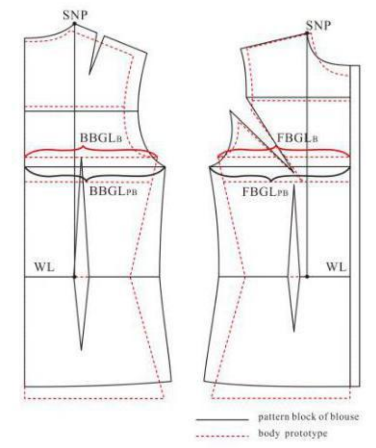
<tr><td colspan="3">Good fit</td><td colspan="2">Perfect fit</td></tr>
<tr><td>6</td><td colspan="5">Where: BW is the back width of body, BG is the bust girth of body, BBW_{PB} is the back bust width of sewing pattern, E_{BBWPB} is the ease allowance to BBW_{PB}, BGL_{PB} is the bust girth line of sewing pattern, $BBGL_{PB}$ is the back bust girth line of sewing pattern, $FBGL_{PB}$ is the frontbust girth line of sewing pattern, E_{BGPB} is the ease allowance to BGL_{PB}.</td></tr>
<tr><td rowspan="3">7</td><td colspan="5">1st fit criteria. $E_{BBWPB} = 2BBW_{PB} - BW$, cm</td></tr>
<tr><td>Very bad fit</td><td>Bad fit</td><td>Acceptable fit</td><td>Good fit</td><td>Perfect fit</td></tr>
<tr><td>$E_{BBWPB} \geq 15 \pm 1$</td><td>$E_{BBWPB} \leq 11 \pm 1$</td><td>$E_{BBWPB} \leq 8 \pm 1$</td><td>$E_{BBWPB} \leq 5 \pm 1$</td><td>$E_{BBWPB} \leq 2 \pm 1$</td></tr>
<tr><td rowspan="2">8</td><td colspan="5">2nd fit criteria. $E_{BGPB} = (2FBGL_{PB} + 2BBGL_{PB}) - BG$, cm</td></tr>
<tr><td>Very bad fit</td><td>Bad fit</td><td>Acceptablefit</td><td>Good fit</td><td>Perfect fit</td></tr>
</table>

	$E_{BGPB} \leq -18.5 \pm 1.5$	$E_{BGPB} \leq 14.5 \pm 1.5$	$E_{BGPB} \leq 10.5 \pm 1.5$	$E_{BGPB} \leq 6.5 \pm 1.5$	$E_{BGPB} \leq 2.5 \pm 1.5$

Table J.4 - Criteria of blouse front waist length fit evaluation

	Quality fit levels of women blouses				
1	Very bad fit	Bad fit	Acceptable fit	Good fit	Perfect fit
2	Too much sloping wrinkles upper bust and waist level; non-horizontal location of the hem.	Several sloping folds upper bust and waist level; non-horizontal location of the hem.	Some soft sloping folds on the waist level; the hem is horizontal.	The side is smooth; the hem is horizontal.	The side is completely smooth; the hem is horizontal.
3					
4					

<table>
<tr><td rowspan="4">5</td><td colspan="2">
</td><td colspan="2">
</td><td colspan="2">
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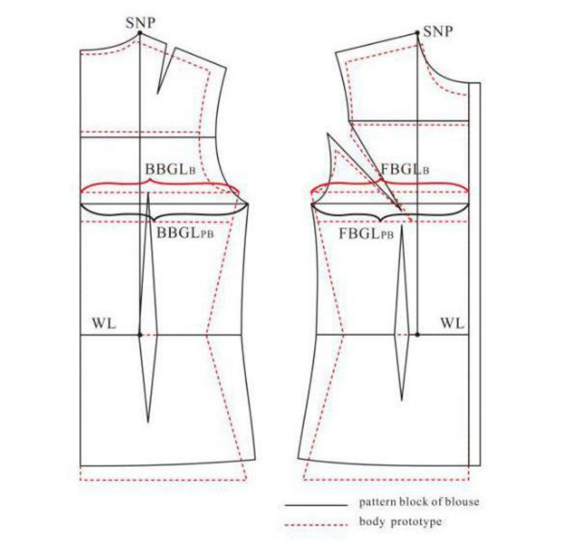
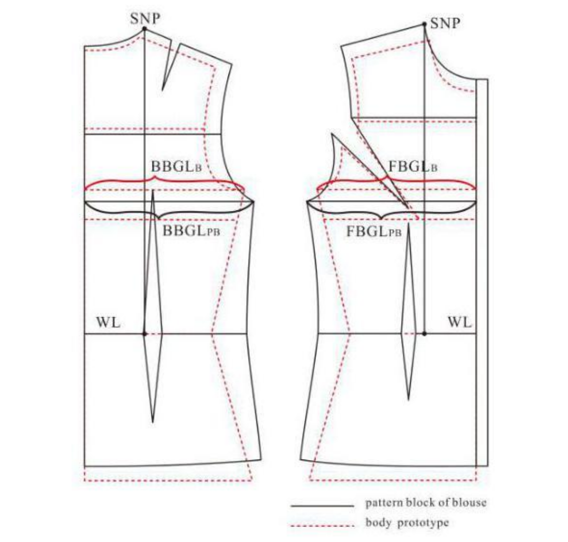
<tr><td colspan="2">Very bad fit</td><td colspan="2">Bad fit</td><td colspan="2">Acceptable fit</td></tr>
<tr><td colspan="3">
</td><td colspan="3">
</td></tr>
<tr><td colspan="3">Good fit</td><td colspan="3">Perfect fit</td></tr>
<tr><td>6</td><td colspan="6">Where: $(SNP\text{-}WL)_{FPB}$ is the length of SNP-WL of front sewing pattern, $(SNP\text{-}WL)_{BPB}$ is the length of SNP-WL of back sewing pattern.</td></tr>
<tr><td rowspan="3">7</td><td colspan="6">1st fit criteria.□= $(SNP - WL)_{FPB} - (SNP - WL)_{BPB}$, cm</td></tr>
<tr><td>Very bad fit</td><td>Bad fit</td><td>Acceptable fit</td><td>Good fit</td><td colspan="2">Perfect fit</td></tr>
<tr><td>□ ≤ -4.4±0.5</td><td>□ ≤ -2.9±0.5</td><td>□ ≤ -1.4±0.5</td><td>□ ≤ 0.1±0.5</td><td colspan="2">□ ≤ 1.1±0.5</td></tr>
</table>