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ALGORITHM FOR PARAMETRIC DESIGN OF COMPLEX SHAPES: OPTIMIZATION OF CONNECTION NODES IN STAGE AND ART COSTUME

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Abstract. The article discusses the process of intellectualizing the computer-aided design of stage and art costumes by introducing the author's methodology for parametric modeling of clothing parts of complex shapes - on the example of sleeves in products made of different materials. The necessity of transition from traditional image sketches to technical drawings in theater production is substantiated. Five basic algorithms for modeling the armhole-sleeve assembly are identified and the parametric characteristics that affect the external shape and functionality of the sleeve are systematized. The structure of the information description of the parametric modeling process with options for intellectual support of the designer-automated system dialog is proposed. The advantage of the proposed method of virtual design is the formalization of the creative stage of the designer's work and the reduction of the material-intensive stage of fitting product models. The proposed algorithm integrates parameterization, digital mannequin construction, stage image modeling, automated grading and pattern output, and technical preparation for sewing within a unified design workflow. Recommended sleeve parameters are differentiated according to the properties of suit fabrics, dense knitwear, natural and artificial fur, and materials used in 3D printing. The results provide a methodological basis for further software implementation of the algorithm and for expanding the parameter database to other types of garments.

Keywords: parametric design, stage costume, art costume, armhole-sleeve assembly, computer-aided design, CAD systems, 3D modeling.

Introduction.

Staging a new performance in the theater is a complex collective activity that integrates artistic creativity and design and organizational challenges, thus creating conditions favorable to the realization of a creative idea. Theatrical costume performs the function of an equal and, in some cases, a leading component of the scenographic solution of a performance. The law of the integrity of the performance becomes complete only if the costume design is organically incorporated into the overall artistic and ideological concept, which includes stage scenery, lighting and music design, as well as props and props.

In the design and creative work of a theatrical costume designer (as opposed to the work of a theatrical costume designer), three types of visual materials are used: a form sketch (preliminary sketch), an artistic sketch of a model, and a technical drawing. A technical drawing is one of the most important visualization tools in model development, as it provides an accurate reproduction of the silhouette, proportions, design solutions, and details. It is a form of visual communication between the designer and the manufacturer (Chen et al., 2025).

The apparel industry is currently undergoing an active transition from traditional methods of clothing design to digital technologies. This transition has revealed a number of challenges in several fields of knowledge, including anthropometry, textile materials science, and the theory of garments as anisotropic spatial shells. In order to transfer the processes of

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designing and trying on clothes in a virtual environment, it is necessary to create their virtual counterparts (Body type optimized pattern library, 2025; Development of a parametric production jacket pattern, 2025). The generation of virtual twins in the fashion industry has become an independent scientific field due to the significant amount of information obtained using specialized equipment for digitizing material objects, as well as the complexity of formalizing the professional knowledge accumulated by designers (Guo et al., 2025; Goal-oriented 3D pattern adjustment, 2025).

The aim of the work is to develop and substantiate recommendations for the design and modeling of shoulder garments with set-in sleeves aimed at improving the armhole-sleeve joint and creating universal and comfortable models of stage and art costumes.

Materials and Methods.

The methodological basis of the study is an integrated approach that organically combines theoretical principles with empirical methods. The formalization of the parametric characteristics necessary to describe the design solutions of the sleeve and the armhole-sleeve assembly was carried out by means of a background analysis of English-language scientific publications on this issue (Automatic generation of parametric patterns, 2023; Design and Research of Automatic Garment-Pattern-Generation System, 2023; Han, Han & Kim, 2021; Kang, Oh & Kim, 2021; Lin & Liu, 2023; Parametric sleeve patternmaking method, 2024; Vanderploeg, Lee & Mamp, 2017; Sun & Valtas, 2016; Tian et al. , 2019).

To synthesize the parametric algorithm, we analyzed existing design methods. Among them is the Uniform Method of Clothing Design (UMCD), developed in the 1980s by the member countries of the Council for Mutual Economic Assistance. It is based on a single system of increments and formulas for calculating design points, which ensures a high level of unification and the ability to design different types of clothing.

Another methodology under consideration is the one developed by the Central Research Institute of the Clothing Industry ("CRICI"). Created in the USSR, this methodology has long been the basis for mass production, including underwear. It is based on an anthropometric analysis of the population and uses more than 30 dimensional features (Ukay et al., 2012), which allows for high accuracy of product fit. The procedure includes scans for different types of fabrics and silhouettes.

Particular attention is paid to the method of digital (computer) three-dimensional design with parameterization elements (MDGs). This approach is adapted for individual and small-scale clothing production. Its advantages include simplified calculation formulas and a reduced number of measurements (up to 15 basic dimensional features). MDG provides acceptable fit accuracy and does not require lengthy calculations, which has led to its popularity in ateliers and costume workshops.

A comparative analysis of these methods has revealed their strengths and weaknesses from the point of view of the parametric approach. The Uniform Method of Clothing Design (UMCD) is the most unified and easiest to automate. The CRICI methodology provides a high level of accuracy, but it requires a significant amount of input data. The MDG methodology demonstrates a high speed of execution, but is inferior in accuracy when designing complex shapes.

The source base of the study also includes the results of implementations by leading manufacturers of fur clothing and products of complex shapes, as well as works by scientists on the analysis of production collections, parametric principles of clothing design, the use of 3D printing technologies in textile structures, and the adhesion of polymeric materials to fabric bases (Cnaani & Sterman, 2023; Development of fashion products with parametric design approach, 2024; Jeong et al, 2021; Kuncoro & Nurmasitah, 2026; Li, 2024; Lin, Lukáč & Leake, 2025; Mpofu et al.)

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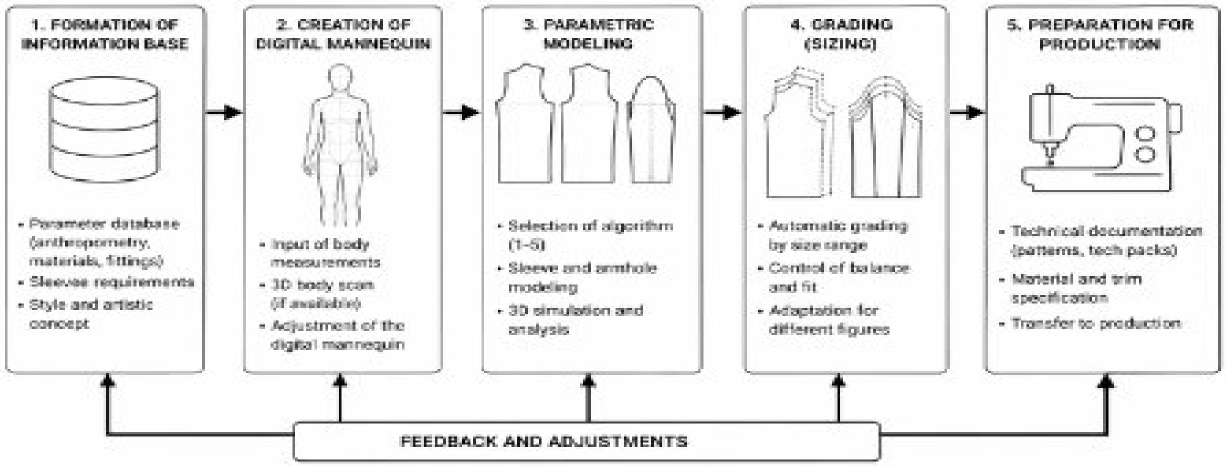
The parameterization was carried out at the constructive and anthropometric level, which covers anthropometric, morphological, and constructive quantitative characteristics of typical and individual figures in the amount sufficient to create their virtual twins.

To formalize the information description of the parametric modeling process, methods of structural analysis and design of dialogue systems were used. This made it possible to design options for organizing a dialogue between the designer and an automated system with elements of intelligent support (Parametric model fitting for textured and animated 3D avatar, 2025; Chen et al., 2025; Goal-oriented 3D pattern adjustment, 2025).

Literature review.

An analysis of modern scientific publications shows a steady increase in research interest in the issue of parametric clothing design. The basis of parametrization is the design and anthropometric level, which covers anthropometric, morphological and structural quantitative characteristics of conventionally typical and individual figures. This amount of information is sufficient to create their virtual twins.

The algorithm and content of the preparatory stage of creating a performance is clearly illustrated in Figure 1, which schematically reproduces the sequence of parametric design of the product. This sequence covers the following main stages: formation of an information base (anthropometry, material properties, artistic intent); creation of a digital mannequin; parametric modeling with the ability to choose one of five algorithms; automatic sizing; and preparation for production (development of patterns, preparation of technical documentation).



Source: author's own development.

Figure 1. The algorithm and content of the preparatory stage of the production of the play.

The study by Park and Choi (2013) was the first to systematically examine the possibilities of using CAD systems for modeling stage costumes. This work opened up new scientific and practical perspectives in the field. Subsequently, Liu et al. (2018) revealed in detail the principles of parametric clothing design based on anthropometric body measurements and proposed appropriate methods for constructing flat parts.

The issue of intellectualization of computer-aided design (CAD) systems for garments is currently being actively developed (Chen et al., 2025; Development of a parametric production jacket pattern, 2025; Goal-oriented 3D pattern adjustment, 2025). In particular, the papers "Automatic generation of parametric patterns" (2023) and "Design and Research of Automatic Garment-Pattern-Generation System" (2023) consider the automatic generation of parametric patterns using artificial intelligence methods.

The studies "Design2GarmentCode" (2024) and Guo et al. (2025) present approaches to creating flexible parametric modeling systems, among which the GarmentCode programming language occupies a special place. In turn, the papers "Body type optimized pattern library" (2025) and "Parametric model fitting" (2025) focus on interactive parametric pattern creation in three-dimensional space and connected editing of shapes based on contour lines.

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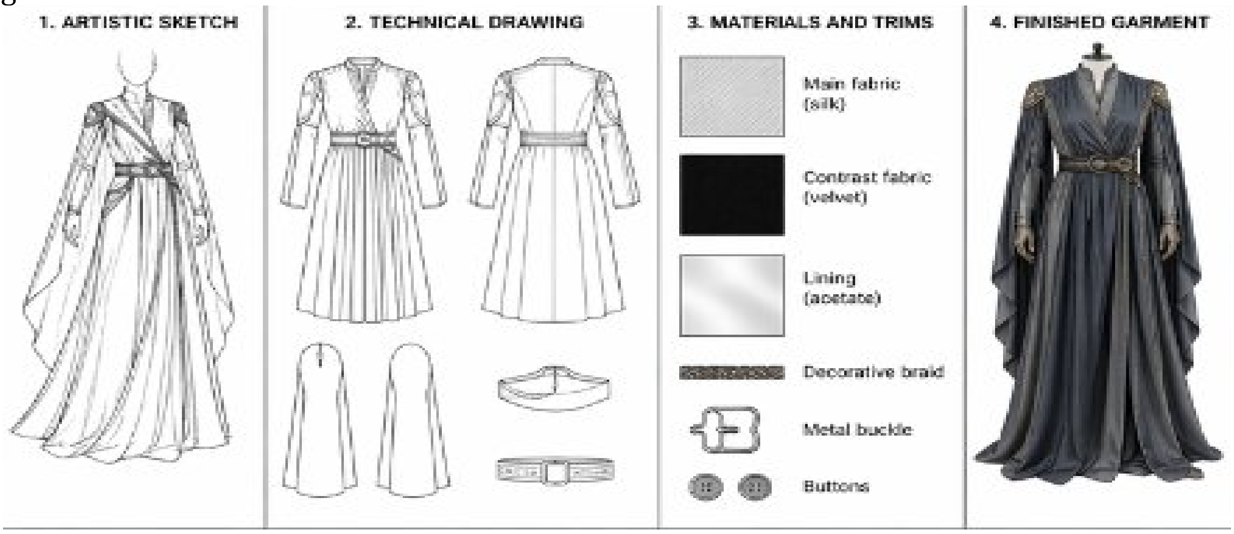
The process of designing a stage costume based on a parametric approach is not limited to technical calculations. Visualization of the artistic idea and the choice of materials play an important role in it. A diagram of the transition from sketch to finished product is shown in Figure 2.



Source: author's own development.

Figure 2. Example of illustrative and technical documents for the manufacture of costumes.

As the figure illustrates, the process begins with an artistic sketch, on the basis of which a technical drawing is created to clarify the design lines and proportions. The next step is to determine the materials and accessories: the main fabric (silk), contrasting fabric (velvet), lining (acetate), decorative braid, metal buckle, and buttons. The final stage is the finished product, which accumulates all the previous design and technological solutions.

To summarize, we can say that the sequence "sketch - technical drawing - definition of materials - finished product" is universal for the parametric design of stage and art costumes. It makes it possible to systematically link the artistic concept with technological parameters (type of fabric, cut, accessories), which, in turn, ensures effective optimization of joints and automation of production preparation.

The study of parametric design has been significantly deepened by the publication "Development of fashion products with parametric design approach" (2024) and the work of Kang, Oh and Kim (2021). These works describe in detail the evolution of pattern creation practices - from traditional approaches to the formation of parametric blocks. The study by Jeong et al. (2021) on the development of fashion products with parametric design using 3D printing technologies is indicative in this context. At the same time, Mpofu et al. (2019) and Vanderploeg, Lee, and Mamp (2017) highlight the current problems of adhesion of 3D printed polymers to fabric bases and outline the prospects for the use of 3D printing in the fashion industry.

The problem of stage costume in the context of digitalization is discussed in the studies of Ciammaichella (2025) and Kuncoro and Nurmasitah (2026). The authors emphasize the importance of digitization and adequate representation of costumes for the needs of the theater stage. In turn, the research of Lin, Lukáč, and Leake (2025), Cnaani and Sterman (2023), and Lin and Liu (2023) is devoted to the issues of modular design, reconfiguration of clothing, and the use of interchangeable weaving borders to create three-dimensional and seamless products.

Of particular interest in the context of parametric sleeve modeling are Han, Han, and Kim (2021), Kim (2012), "Parametric sleeve patternmaking method" (2024), Sun and Valtas (2016), Tian et al. (2019), and Li (2024). These studies form the direct theoretical basis for the present work.

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The final stage of the parametric design of a stage costume is the preparation of illustrative and technical documentation. Such documentation should contain not only pattern drawings and calculations of the joints, but also visual images that capture the artistic solution and material embodiment of the product. A sample of the relevant documentation for the characters of the performance is shown in Figure 3.

Source: author's own development.

Figure 3. An example of illustrative and technical documents for the production of costumes for the characters in a play: artistic sketch, technical drawing, materials, finished product.

Results.

1. Algorithm for parametric design of a stage costume

The proposed algorithm for parameterized design is based on the integration of the results of the analysis of existing scientific and practical approaches and the data of our own research. The developed algorithm includes five consecutive stages.

The first stage is the construction of a parameter base (dimensional grid). At this stage, the performer's dimensional characteristics (girth, length, and width) are entered, and specific stage tolerances for loose fitting are taken into account. These tolerances are necessary to ensure freedom of movement during dance or active stage actions (Liu et al., 2018; Kim, 2012).

The second stage is the definition of the construction algorithm (digital mannequin). This stage includes the construction of the basic structure (base) using a system of formulas that are defined in terms of parameters rather than fixed points. At the same time, formulas are introduced that determine the balance of the costume, the configuration of the armhole and sleeve - all to ensure the comfort of the performer (Chen et al., 2025; Goal-oriented 3D pattern adjustment, 2025).

The third stage is dedicated to modeling the stage image. At this stage, the basic design is transformed into a sketchy image by changing the silhouette, length of the product, and adding decorative elements. An important tool here is 3D visualization, which allows for a virtual fitting on a digital mannequin before sewing begins (Body type optimized pattern library, 2025; Guo et al., 2025).

The fourth stage provides automatic grading and output of patterns. This stage involves the automatic reconstruction of the drawing when changing the size (for example, in the case

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of replacing the performer) and the formation of finished patterns taking into account technological allowances for seams (Development of a parametric production jacket pattern, 2025; Development of fashion products with parametric design approach, 2024).

The fifth stage includes technical preparation and sewing. The final stage involves the creation of technical sketches with exact dimensions and the selection of fabrics that can withstand stage loads. Particular attention is paid to the use of thermal fabrics and elastic materials that provide the necessary functionality of the stage costume (Chen et al., 2025; Ciammaichella, 2025).

2. Systematization of algorithms for modeling the armhole-sleeve assembly

Based on the analysis of the unified methodology for garment design (UMGD), as well as other scientific and educational sources (Automatic generation of parametric patterns, 2023; Design and Research of Automatic Garment-Pattern-Generation System, 2023; Han, Han & Kim, 2021; Kang, Oh & Kim, 2021; Lin & Liu, 2023; Parametric sleeve patternmaking method, 2024; Vanderploeg, Lee & Mamp, 2017; Sun & Valtas, 2016; Tian et al, 2019), five variants of algorithms for modeling the armhole-sleeve assembly were identified. These variants are systematized in Table 1.

Table 1. Algorithms for modeling the “armhole-sleeve” junction.

Algorithm	Characteristics	Feature
1	Input data - drawing of the base armhole design (the armhole is not modeled); construction of the model sleeve design on the armhole drawing	The armhole remains the base
2	Input data - armhole drawing of the base design (the armhole is not modeled); modeling of the sleeve design on the drawing of the base sleeve design	Base armhole, sleeve is modeled
3	Modeling the armhole on the basic design drawing; constructing the model sleeve design on the armhole drawing	The armhole is modeled first
4	Modeling the armhole on the basic construction drawing; modeling the sleeve pattern on the basic sleeve construction drawing	Both elements are modeled
5	Modeling the "armhole-sleeve" assembly in garments with complex cuts (raglan sleeves, one-piece sleeves)	Combination of techniques from algorithms 1-4

Source: author’s own development

For the practical implementation of the parametric modeling of the armhole-sleeve assembly, it is important to clearly identify the key design points that ensure the connection of parts and are responsible for the freedom of movement of the performer. An example of marking such points on a schematic drawing is shown in Figure 4.

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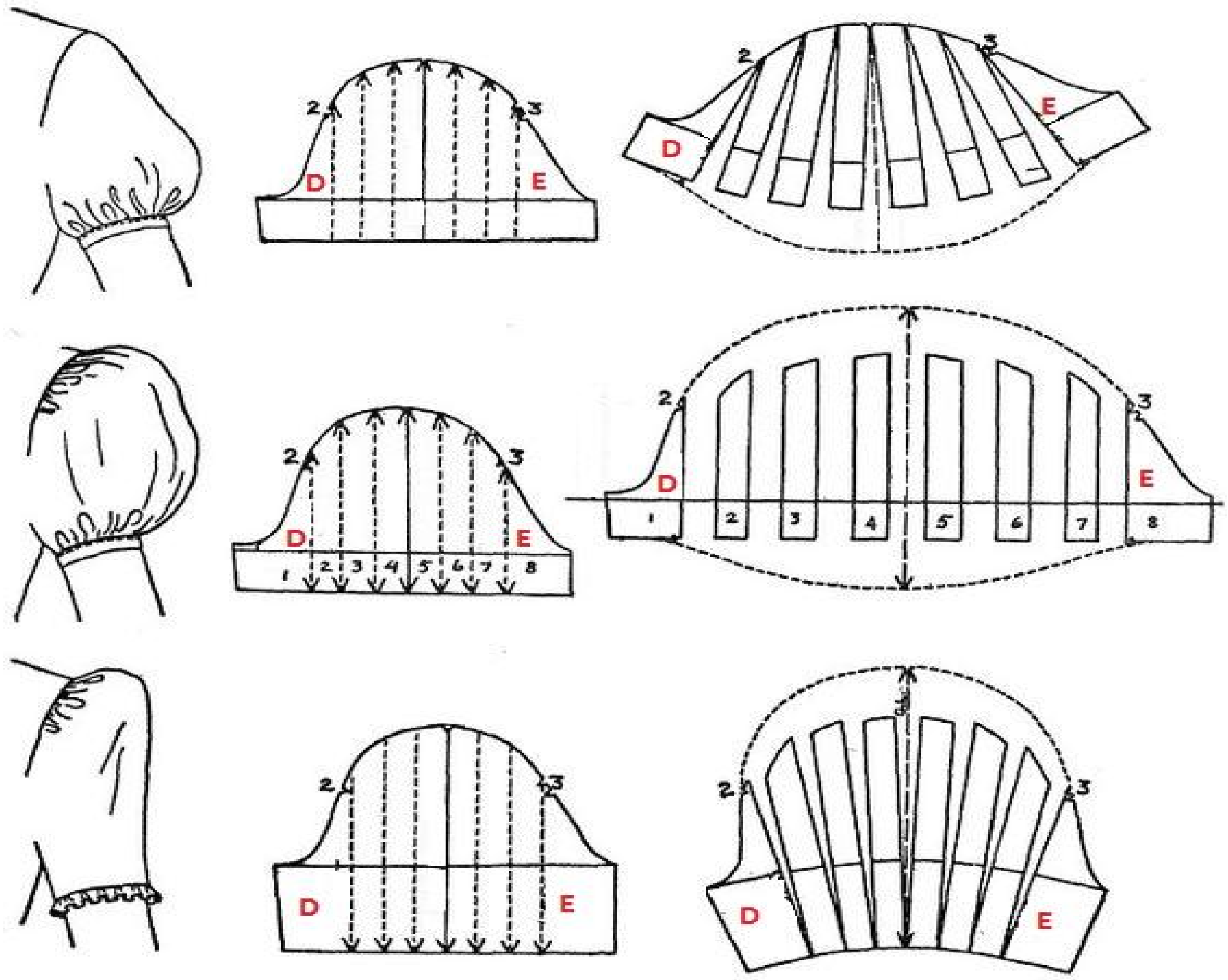

Source: author's own development.

Figure 4. Options for modeling the design of set-in sleeves at the armhole (algorithm 2): a) conical dilatation; b) parallel dilatation; c) combined dilatation.

Figure 4 shows the design points D and E, which are repeated in different positions. Point D marks the upper boundary of the armhole (shoulder knot), while point E corresponds to the lower boundary of the armhole (armpit knot). The location of these points is determined relative to the anthropometric parameters of the performer - chest girth, arm length, armhole depth. In the parametric algorithm, the coordinates of points D and E are not set fixed, but through formulas, which allows you to automatically rebuild the drawing when the dimensional characteristics change.

In the parametric modeling of a sleeve, one of the key techniques is to expand the basic structure by making cuts (slashes) and separating parts to obtain the required volume or shape. Depending on the desired configuration, different methods of such separation are used. Figure 5 schematically shows the three main options for unfolding the sleeve.

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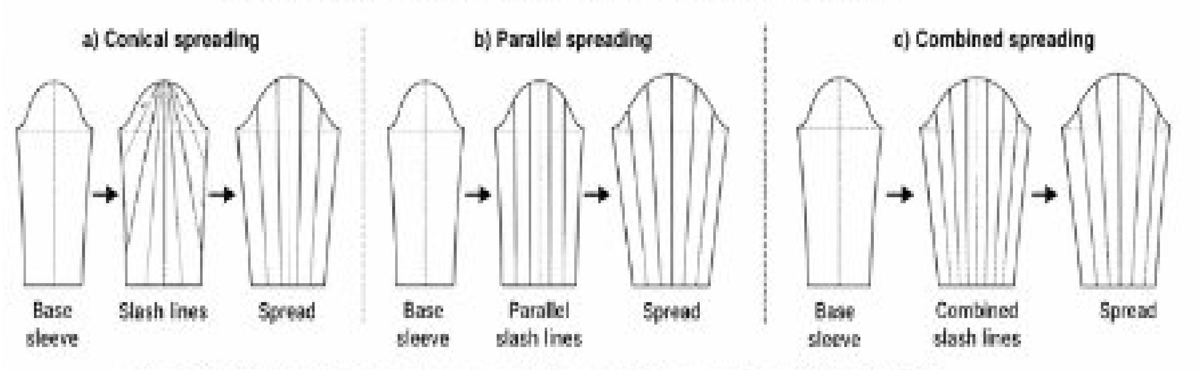
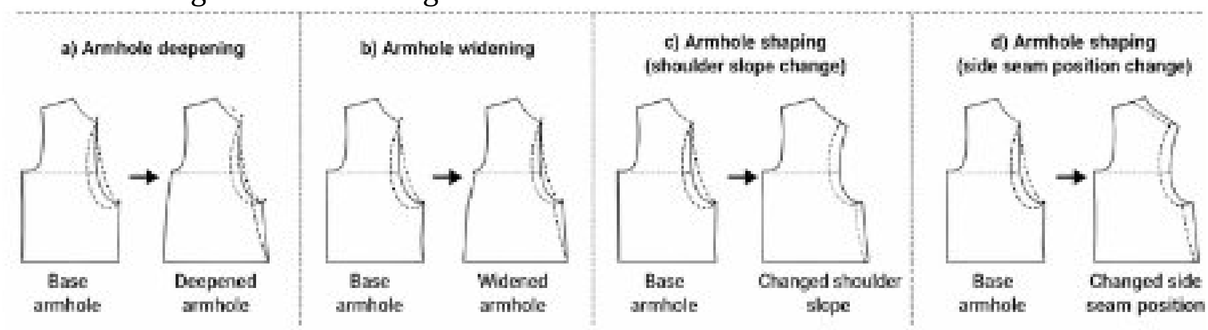


Source: author's own development.

Figure 5. Options for modeling armholes.

As illustrated in Figure 5, there are three main ways to deploy a sleeve design. Tapered folding is done by making cuts that diverge from the top of the sleeve to the bottom; this results in a uniform downward expansion that creates a tapered silhouette. In contrast, parallel folding involves making parallel cuts, after which the pieces are separated by the same distance along the entire height; this allows you to increase the width of the sleeve without changing its overall shape. Combined folding combines elements of both previous approaches: the cuts have different configurations and the spreading is uneven. This method opens up the widest possibilities for modeling complex three-dimensional shapes, which are often necessary in stage and art costumes.

An important stage in the parametric design of a stage costume is the adaptation of the armhole to the requirements of stage movement and artistic intent. Depending on the required sleeve freedom or cut features, the armhole can be modified in several ways. The main options for such modeling are shown in Figure 6.



Source: author's own development.

Figure 6. Options for modeling armholes.

As illustrated in Figure 6, armhole modeling can be done in four main ways. Deepening the armhole (a) involves increasing its vertical size downward from the baseline, which allows for a wider range of arm movement - this is especially important for dance routines or costumes with wide gestures. In contrast, the armhole expansion (b) is performed by horizontally increasing the armhole sideways, which allows you to freely position the sleeve of any design (set-in, raglan, one-piece) without excessive fabric tension. Changing the slope of the shoulder line (c) directly affects the configuration of the upper part of the armhole, so you can adjust the fit of the garment on the shoulders to suit the individual characteristics of the performer's physique or costume style. Lastly, changing the position of the side seam (d) allows you to move the lower side armhole point forward or backward, which affects the overall balance of the garment and the comfort of body movement.

The parametric design of the bodice front requires a clear definition of the key design points that ensure the accuracy of construction and subsequent automation of changes. Figure 7 shows a schematic representation of the bodice front drawing with the corresponding points marked.

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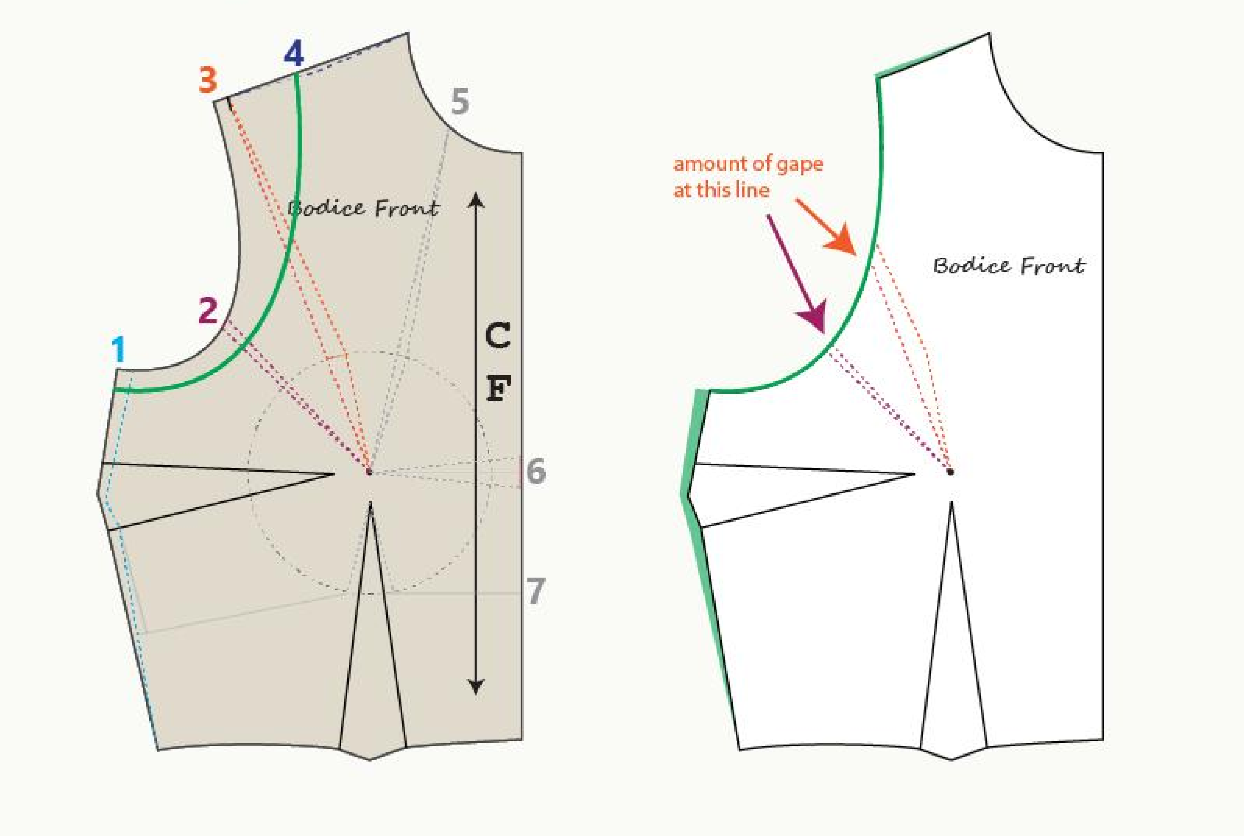

Source: author's own development.

Figure 7. Options for modeling armholes according to the 3rd and 4th algorithms.

As can be seen in Figure 7, the front bodice design includes seven main marked points (labeled with numbers 1-7). Points 1 and 2 are likely to define the upper bodice boundaries (shoulder and neckline), while points 3 and 4 may be responsible for the side boundaries. Point C is likely the center of the front piece, and point F' is an auxiliary reference point (possibly the chest level or the end of the bust dart). The designation "Bodice Front" indicates that the drawing is for the front of the bodice.

In the parametric algorithm, each of these points is not set fixed, but rather through formulas linked to anthropometric parameters such as bust measurement, waist length, shoulder width, etc. Thus, the diagram in Figure 7 shows how a traditional bodice drawing can be organized as a system of parametric points. Such an organization is a prerequisite for automatic reconstruction of the design when dimensional characteristics change (for example, in the case of replacing the performer or graduation to different sizes). Further parameterization can extend not only to the coordinates of the points, but also to the lengths of segments, angles of inclination, and radii of arcs, which significantly speeds up the process of designing a stage costume.

3. Parametric description of the sleeve design

Based on the analysis of various options for model designs of shoulder products, as well as taking into account the recommendations set forth in the educational and technical literature (Cnaani & Sterman, 2023; Development of fashion products with parametric design approach, 2024; Jeong et al, 2021; Kuncoro & Nurmasitah, 2026; Li, 2024; Lin, Lukáč & Leake, 2025; Mpofu et al., 2019), the parameters characterizing the design of the sleeve and the armhole-sleeve assembly were identified. These parameters are summarized in Table 2. To designate them, we used the nomenclature of structural segments adopted in the relevant methodology.

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Table 2: Parameters describing the design of the sleeve and armhole-sleeve assembly.

Group of parameters	Designation	Name	Characteristics
Armhole output parameters	Larm	Armhole length	Determines the fit of the sleeve
	Harm	Armhole height	Affects the depth of the armhole
	Warm	Armhole width	Affects the volume of the sleeve at the top
Parameters of the modified armhole	ΔLarm	Change in armhole length	The consequence of unmodeling darts
	ΔHarm	Change in armhole height	Affects the configuration of the armhole
	ΔWarm	Change in armhole width	Affects the volume of the sleeve
Parameters of the modified sleeve	Lsl	Sleeve length	Determined by the model
	Wsl_top	Sleeve width at the top	Affects the volume and shape of the upper rounded cut of the sleeve
	Wsl_bot	Sleeve width at the bottom	Determines narrowing/expansion
	Hcap	Sleeve cap height	Affects the fit of the sleeve

Source: author's own development.

One of the key tasks of parametric design is to establish a clear correspondence between the three-dimensional shape of the sleeve and its two-dimensional sweep (pattern). This is necessary to ensure that any change in spatial characteristics - volume, flare height, sleeve width - automatically leads to a correct update of the flat drawing. To demonstrate this relationship, Figure 8 shows a diagram of the parameterization of the external shape and model construction of the sleeve.

The key stage in the parametric design of a stage costume is to establish a correspondence between the three-dimensional shape of the sleeve and its two-dimensional scan (pattern). This correspondence makes it possible to automatically recalculate the coordinates of a flat drawing when changing spatial parameters such as sleeve height, width, angle of inclination, volume, etc. To visualize this relationship, Figure 9 shows a diagram of the parameterization of the external shape and model construction of the sleeve.

As Figure 9 illustrates, the diagram consists of two parts. Fragment “a” shows the front and profile projections of the sleeve, as well as its spatial (three-dimensional) shape. The key structural points O, O_1, O_2, O_3, O_4 and auxiliary points P, P_1, P_2, P_n are marked here. Fragment “b” illustrates the comparison of the parameters of a three-dimensional shape with the parameters of a model structure (flat scan). This part of the diagram shows the correspondence between the spatial points (M, M_1, M_2, M_{11}, M_{21}) and the plane scan, and also shows the system of parametric relations through the notation n_1, n_2, n_3, n_{11}, n_{21}, n_{22}, etc. Such labeling allows you to trace how a change in a spatial parameter (for example, length or curvature at a certain point) affects the corresponding areas of the pattern.

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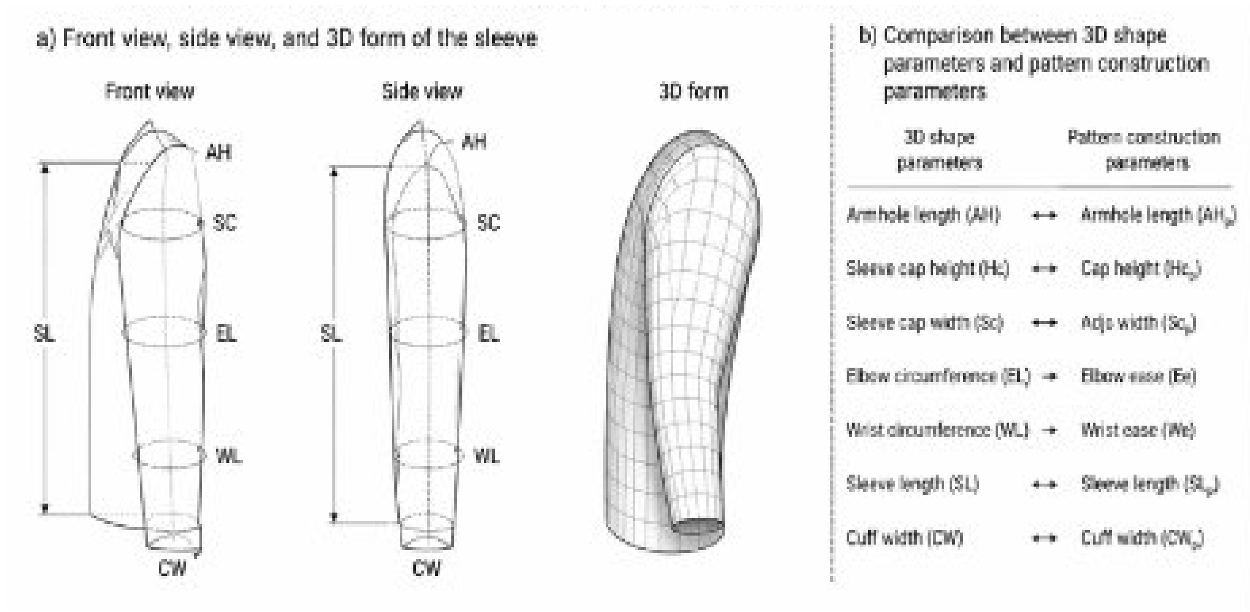
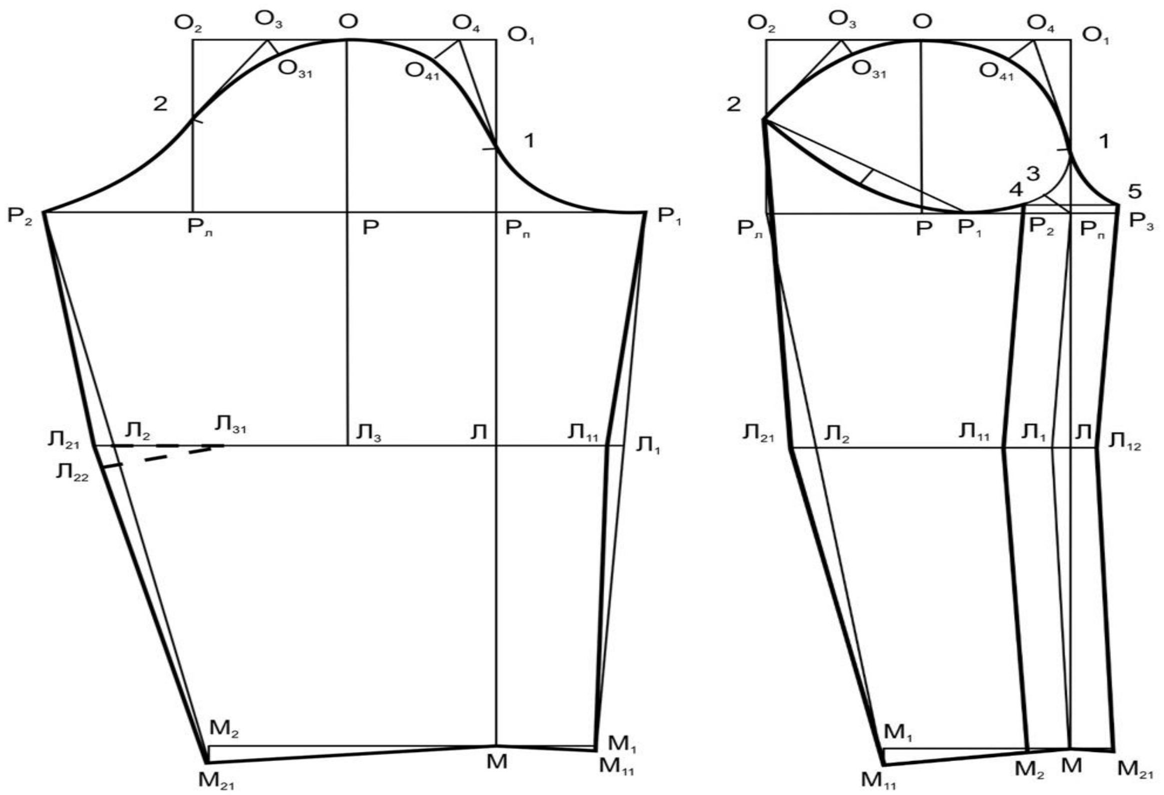


Source: author's own development.

Fig. 8. Scheme of parameterization of the external shape and model construction of the sleeve.

Thus, the above diagram demonstrates how the main spatial parameters of the sleeve (hem height, width at the top and bottom, slope angle, volume along the inner seam) are converted into flat scan parameters - hem length, position of control points, amount of cut separation, and bottom cut configuration. This parameterization allows you to automatically rebuild the sleeve design when the original anthropometric data or artistic idea changes, which significantly speeds up the process of designing a stage costume.



Source: author's own development.

Figure 9. Scheme of parameterization of the external shape and model of the sleeve: a) frontal, profile projection and spatial shape; b) comparison of parameters of the 3D shape and model construction.

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Thus, the diagram shown in Figure 9 reflects a systematic approach to the parameterization of the sleeve. It establishes a mutually unambiguous correspondence between the spatial points (O, O_1-O_4, M, M_1-M_{21}) and the control points on the flat scan, as well as between the spatial curves and the corresponding segments of the pattern. In addition, the diagram connects the outer shape of the sleeve with the internal design lines, such as the hemline, side seams, and bottom line.

This parameterization is a necessary prerequisite for design automation: changes in the anthropometric parameters of the performer or artistic intent can be automatically translated into the construction of a flat pattern without the intervention of the designer. This is especially important for stage and artistic costumes, where it is often necessary to adapt the form to different performers or quickly vary the silhouette.

4. Informational description of the parametric modeling process

For the practical implementation of the parametric modeling of a sleeve, it is not enough to determine the list of parameters - it is also necessary to formalize the relationship between the spatial shape of the product and its flat model construction (MC), as well as to provide options for the interaction of the designer with the automated system. With this in mind, we have developed a structure for the information description of the process of parametric modeling of the sleeve, which is shown in Table 3. This structure includes parameters of the three-dimensional shape, parameters of the model structure, a description of the relationship between them, options for dialog boxes, and types of intellectual support.

As shown in Table 3, using the sleeve as an example, three key parameters are considered: sleeve length (Lsl), sleeve width at the top (Wsl_top), and sleeve width at the bottom (Wsl_bot). For each of them, a base value is provided (base form (BF), base construction (BC)), possible increment (Δ), and equations describing the relationship between the spatial form and the pattern construction (for example, Lsl_MF = Lsl_MC). For each parameter, a corresponding dialog window option is also proposed (for example, “Enter new sleeve length”), as well as a type of intelligent support — a recommendation of values depending on the material or automatic calculation of derived parameters.

Thus, the structure shown in Table 3 solves several important problems of parametric design. It clearly formalizes the relationship between the three-dimensional shape of the sleeve and its flat scan, which is the basis for automatic pattern reconstruction. In addition, this structure offers specific options for dialog interaction between the designer and the system, which increases the convenience of work.

Table 3: Informational description of the process of parametric modeling of garment parts (for example, a sleeve).

№	3D shape parameters	Pattern parameters (MC)	Description of the “3D form - MK” connection	A variant of the dialog box	Types of intellectual support
1	Lsl_MF = Lsl_BF + ΔLsl	Lsl_MC = Lsl_BC + ΔLsl	Lsl_MF = Lsl_MC	Enter a new sleeve length	Recommended sleeve length value (ΔLsl = 0)
2	Wsl_top_MF = Wsl_top_BF + ΔWsl_top	Wsl_top_MC = Wsl_top_BC + ΔWsl_top	Wsl_top_MF = Wsl_top_MC	Enter the sleeve width at the top	Recommended value for different materials (Jeong et al., 2021)

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№	3D shape parameters	Pattern parameters (MC)	Description of the "3D form - MK" connection	A variant of the dialog box	Types of intellectual support
3	Wsl_bot_MF = Wsl_bot_BF + ΔWsl_bot	Wsl_bot_MC = Wsl_bot_BC + ΔWsl_bot	Wsl_bot_MF = Wsl_bot_MC	Enter the sleeve width at the bottom	Calculated values depending on top width and material properties

Note: At each stage, it is necessary to visualize the graphic solution in the sketch and design to be able to evaluate the decision. All dialog options should be implemented in the systems, which will provide the designer with greater comfort in the work process.
Source: author's own development

It also includes elements of intelligent support - recommendations or automatic calculations that help make informed, constructive decisions. As noted in the note to the table, a prerequisite is the visualization of a graphical solution at each stage, as well as the implementation of all dialog options in the system. This provides the designer with a higher level of comfort in the work process.

5. Experimental determination of recommended parameters

Parametric sleeve design involves not only formalizing the relationship between spatial shape and planar scan, but also quantifying the recommended increments (Δ) depending on the type of material. The same parameter, such as the width of the sleeve at the top, requires different increments for suit fabric, dense knitwear, natural fur, or rigid elements made by 3D printing. Based on the analysis of industrial collections of leading manufacturers of fur products and clothing of complex shapes, as well as taking into account the data from scientific publications (Cnaani & Sterman, 2023; Development of fashion products with parametric design approach, 2024; Jeong et al., 2021; Kuncoro & Nurmasitah, 2026; Li, 2024; Lin, Lukáč & Leake, 2025; Mpofu et al., 2019), the recommended values of parameters for different types of materials were determined. These values are summarized in Table 4.

As illustrated in Table 4, for each material the ranges of recommended increments are provided for the sleeve width at the top (ΔWsl_top), sleeve width at the bottom (ΔWsl_bot), and sleeve cap height (ΔHcap). The smallest increments are characteristic of classic models made from suiting fabrics (ΔWsl_top - 2.0-4.0 cm). Dense knitwear, due to its elasticity, allows for somewhat larger values, while the sleeve cap height may even decrease (negative increment). For natural and artificial fur, the increments are increased to compensate for the thickness of the pile. The largest values (ΔWsl_top - 5.0-10.0 cm) are предусмотрені for rigid plastic elements created by 3D printing in art costumes (Jeong et al., 2021; Mpofu et al., 2019; Vanderploeg, Lee & Mamp, 2017).

Table 4. Recommended sleeve parameter values depending on the material.

Material	ΔWsl_top, cm	ΔWsl_bot, cm	ΔHcap, cm	Notes
Suit fabric	2.0 - 4.0	1.0 - 2.0	0 - 1.0	For classic styles
Heavyweight knit	3.0 - 6.0	2.0 - 4.0	-1.0 - 0	Provides elasticity
Natural fur	4.0 - 8.0	3.0 - 5.0	1.0 - 2.0	Takes into account the thickness of the hair
Artificial fur	3.0 - 6.0	2.0 - 3.0	0.5 - 1.5	Thinner than natural hair

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Material	ΔWsl_top, cm	ΔWsl_bot, cm	ΔHcap, cm	Notes
Plastic (3D printing)	5.0 - 10.0	4.0 - 8.0	2.0-4.0	For rigid elements of an art costume (Jeong et al., 2021; Mpofu et al., 2019; Vanderploeg, Lee & Mamp, 2017)

Source: Author's own work.

Thus, the system of recommended values shown in Table 4 performs several important functions in parametric design. It provides the designer with quantitative guidelines for choosing increments depending on the type of material, which reduces the time spent searching for optimal parameters. In addition, the system takes into account the specifics of various groups of materials - from traditional fabrics to elastic knitwear, natural fur, and 3D printed plastic, which is especially relevant for stage and art costumes. These ranges are an open system: it is advisable to periodically update the values obtained taking into account current seasonal trends. This approach allows for effective communication between the designer, constructor, technologist, and other specialists involved in the process of designing a stage costume.

Disscussion.

The results of the study confirm that parametric modeling of stage and art costumes has significant advantages over traditional design. This approach is especially valuable in modern theater production, where productions are often carried out under conditions of limited budget and tight deadlines (Park & Choi, 2013).

The identification of five algorithms for modeling the armhole-sleeve assembly and the systematization of the relevant parameters make it possible to formalize the design process, which is an important step towards digital clothing design. Thanks to this approach, it becomes possible to visualize and predict the final shape of the product already at the design stage (Body type optimized pattern library, 2025; Guo et al., 2025; Goal-oriented 3D pattern adjustment, 2025).

The proposed structure of the information description (Table 3) provides intelligent support during the dialog between the designer and the automated system. This was achieved through a detailed study of the designer's actions and an in-depth analysis of the parametric description of the design object (Chen et al., 2025; Development of a parametric production jacket pattern, 2025; Parametric model fitting, 2025). The implementation of all possible dialog options in the system significantly increases the convenience of the designer's work.

Material properties play an important role in parametric modeling. According to the studies by Mpofu et al. (2019) and Vanderploeg, Lee, and Mamp (2017), the adhesion of 3D printed elements to fabric bases, as well as the elasticity of materials, significantly affect the final shape of the product. With this in mind, we have developed recommended values for the parameters (Table 4), which can serve as initial guidelines for clothing designers.

A comparative analysis (Development of fashion products with parametric design approach, 2024; Kang, Oh & Kim, 2021) confirms that the parametric approach, although it takes more time at the initial stage, shows a significant advantage when making changes to the design. For stage costumes, where there is often a need to quickly adapt the product to different performers or due to changes in the production, this property is critical.

At the same time, further research is needed to fully automate the design of complex shapes, including those using leather or 3D printed elements (Amelynck & Van Mierlo, 1996). First of all, it is necessary to develop more accurate mathematical models that would describe the influence of visual optical characteristics of materials and their physical and mechanical properties on design parameters (Cnaani & Sterman, 2023; Li, 2024; Lin, Lukáč & Leake, 2025).

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Conclusion.

Based on the results of the study, a generalized algorithm for the parametric design of stage and art costumes is proposed, which includes five stages: parameterization, formation of a construction algorithm (digital mannequin), modeling of the stage image, automated grading and pattern output, as well as technical preparation and sewing. Such an algorithm makes it possible to reduce the material-intensive stage of trying on product models and formalize the creative stage of the designer's work.

Based on the study of industrial collections, the recommended values of sleeve parameters were determined depending on the type of material (suit fabric, dense knitwear, natural fur, artificial fur, plastic for 3D printing). These values should be updated to reflect the trends of the current season.

Further research will be aimed at developing software to implement the proposed algorithm, expanding the parameter database for other types of clothing, and studying in detail the relationships between parameters, material properties, and anthropomorphic features of the human figure.

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