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Virtual Fitting – Innovative Technology for Customize Clothing Design

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Abstract

The study proposes an innovative methodology for the clothing design activity, which allows the designer to adapt basic patterns developed for type bodies in the actual body form of a certain subject, using simulation in virtual environment of body-garment fitting. For the application of this innovative technology, the paper provides theoretical and practical information on:
• Development of two methods for morphological assessment of subjects in order to obtain the information required in patterns design for clothing based on concrete body form of potential users;
• Methodology to adapt basic patterns developed for a body type to the concrete form of subjects, applying simulation technology of body-product fitting in virtual environment.
The present paper is the case study on completion of basic patterns, for " women dress" by applying innovative simulation in 3D virtual space, on the correspondence between designed product and actual body of the subject.

Keywords: virtual; simulation; clothing; design

1. Introduction

In the classic technology of clothing design using industrial system, the basic patterns are designed for bodies that make up the dimensional typology model for a given population. Defining basic and model patterns shall follow the practical manufacturing of the product, laborious process that involves high costs of labor and raw materials.

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Current requirement for achieving garments in very small series or customized clothing determine the adaptation of actual design process to dynamic markets and requirements of potential users.

Currently, widespread use in the clothing industry of CAD systems to design patterns along with database resulting from 3D scanning technology of the human body, are prerequisites to extend virtual modeling of the dimensional correspondence body-dress in the work of finalizing the 2D patterns after the concrete dimensions of subjects [1, 2].

CAD systems performance for clothing determines the whole process of patterns design to develop more quickly and at a quality level that allows manufacturers quickly renewing collections. In this respect, it is necessary in the design of clothing to reconsider the preplanning stages, steps to develop research directed toward morphological characterization of the human body and adaptation of base patterns on actual body shape through the use of 3D virtual simulation techniques for body-product fitting [3, 4].

In this context, the present study is the case study on completion of basic patterns, for "women dress" by applying innovative simulation in 3D virtual space, on the correspondence between designed product and actual body of the subject. For this purpose, a methodology is proposed which allows the clothing designer the use of all facilities offered by the current performance of CAD systems, at a high technical level.

To implement the proposed methodology, we started from the idea that there are people which differ by their body size from the standard, within limits that allow the designer to adapt the type of patterns developed for bodies in the concrete form of the wearer. In this respect, the role of the designer is very important in two ways:

- Complex morphological characterization of tested body to assess deviations between the actual and standardized body;
- Adoption of optimal solution for remodeling patterns, during the virtual simulation, interactive stage between technical specialist and CAD system.

In this context, the research objectives were:

- Developing and implementing morphological characterization of women, essential step in establishing scientific database needed for innovative use of simulation techniques in virtual environment of body-product fitting;
- Application of the methodology for patterns validation, patterns developed for a certain body using "virtual fitting".

To address the objectives of the paper, we used the primary database (the values of anthropometric sizes), resulting from anthropometric investigation by 3D scanning method of adult women population in Romania. Primary data was processed mathematically (one-dimensional statistical method) and compared with the corresponding values given in the literature [5].

2. The theoretical methods developed for morphological analysis of subjects

In the activity of creating clothing in customized system, it is very important that the designer assesses quickly and accurately the customer's morphology in order to design patterns, with maximum efficiency.

To address this overall objective, we have developed two methods to allow more complete characterization of the shape of the human body to design clothing [6,7]:

- *development of a specific algorithm for calculating,* in the electronic system, which, based on a relatively small number of anthropometric sizes taken from a certain subject, the designer must have information that would allow its classification to a body type (size, heights groups, conformation) and to **basic morphological indicators** (stature, proportions, vertical balance and shoulder position);
- *complex morphological characterization* of the human body by calculating averages and inter-dimensional ranges of introduced indicators for assessing torso curves and prominences, on front and back side.

Table 1 presents anthropometric sizes that were selected for practical application of morphological evaluation methods proposed in the paper.

Table 1. Selected anthropometric sizes.

No.	Significance of anthropometric size	Symbol
1	Body height	Ic
2	Bust circumference	Pb
3	4th bust circumference	PbIV
4	Waist circumference	Pt
5	Hips circumference	Ps
6	Shoulders length	Lu
7	Thorax length from neck to waist	L'tf
8	Vertical arch of the back	Avs
9	Shoulders inclination angle	α
10	Back width between acromial points (distance between shoulders)	Du
11	Distance from cervical point to a reference plane, placed behind the subject	D1
12	Distance from scapula projection to a reference plane, placed behind the subject	D2
13	Distance from back waist point to a reference plane, placed behind the subject	D3
14	Distance from buttock point to a reference plane, placed behind the subject	D4
15	Distance from clavicular point to a reference plane, placed behind the subject	D5
16	Distance from breast point to a reference plane, placed behind the subject	D6
17	Distance from the front waist point to a reference plane, placed behind the subject	D7
18	Distance from the maximum abdomen point to a reference plane, placed behind the subject	D8

Some of these anthropometric sizes have been used to identify the body type which may or may not fit with a certain subject, while others have been used for the calculation of the morphological indicators for complex evaluation of the body shape (Table 2).

Table 2. Calculation of morphological indicators.

No.	Significance of indicator	Calculation equation
1	Body stature (Pc)	D1–D2 (cm)
2	Back waist depth (Ats)	D3–D2 (cm)
3	Buttocks prominence (Pfes)	D3–D4 (cm)
4	Shoulders height	$î_u$=Lu*sin α (cm)
5	Vertical balance (Ev)	L'tf–Avs (cm)
6	Thoracic perimeter index (Ipt);	(Pb/Ic)*100 (%)
7	Bust prominence (Pbust)	D6–D5
8	Waist depth compared to bust prominence (Atf)	D6–D7
9	Abdomen prominence compared to bust prominence (Pabd)	D6–D8
10	Abdomen prominence compared to waist prominence (Pabd-t)	D8–D7

2.1. Mathematical model for primary morphological evaluation of the body shape

In order to develop the mathematical model was necessary to create a database enabling automated evaluation of morphological features of test subjects.

Framing subjects from one body type (size, group heights, conformation) and basic morphological indicators (stature, proportions, vertical balance and shoulder position) required:

- selection of anthropometric sizes allowing the specific calculations for morphological characterization (Table 1);

- taking information from anthropometric standard necessary for framing the subject in a standardized body type, on groups of sizes, heights and conformation [8];
- morphological characterization of selection subjects by calculating averages and inter-dimensional ranges, on the selection under study (volume of selection n = 675 subjects, adult women aged between 20 and 65 years) to assess: posture (Pc) on types of stature, back waist depth (Ats) on types of stature, buttocks prominence (Pfes), shoulder height (îu), vertical balance (Ev1) and thoracic perimeter (Ipt).

The body stature or body position (Pc), the back waist depth (first waist depth) Ats and the buttocks prominence (second waist depth) Pfes have the following interpretation:

- Tense stature: Pc < 4,69; Ats < 2,9; Pfes < 3,49;
- Normal stature: Pc = 6,2 ± 1,5; Ats = 4,5±1,5; Pfes = 5±1,5;
- Crooked stature: Pc > 7,71; Ats > 6,1; Pfes > 6,51.

The interpretation of shoulders height (îu) is:

- Shoulders lifted, îu < 5,19;
- Shoulders in normal position, îu = 5,9± 0,75;
- Shoulders descend, îu > 6,7.

Vertical balance (Ev) offers information about thorax position:

- Leaned forward, Ev < -0,21;
- Normal vertical balance, Ev = 1.8±2;
- Leaned back, Ev > 3,81.

Thoracic perimeter index (Ipt) offers information about the thorax type:

- Narrow thorax, Ipt < 56,9;
- Average thorax, Ipt = 60±3;
- Large thorax, Ipt = 66±3;
- Round thorax, Ipt > 69.

The mathematical model was developed to assess the overall exterior body shape, but for a complex evaluation is proposed a comparative analysis between the morphological indicators of a random subject and standardized values of the body type that fits the selected subject by the principal dimensions (height body, bust circumference and hips circumference).

2.2. Complex evaluation of human body by comparative method

In order to characterize the body shape by this method were introduced along with the above mentioned indicators (Pc, Ats and Pfes), the indicators characterizing the body prominence in the frontal plane, on its anterior part. For these indicators, averages and ranges are presented that have resulted from a mathematical processing of anthropometric values for the selection under study. In this analysis method, the calculated values for random test subject will be compared with those from the overall selection, values and body types specified in anthropometric standard [6].

The first additional indicator is the bust prominence (Pbust), characterizing the bust type:

- Less prominent bust, Pbust < 9;
- Bust with normal prominence, Pbust = 10,5±1,5;
- Bust prominent, Pbust > 12,1.

The waist depth compared to bust prominence (Atf) offers information about the prominence type:

- Waist is more prominent than bust, Atf < 0;
- Waist is as prominent as bust, Atf = 0;
- Bust is more prominent than waist, Atf > 0.

Abdomen prominence compared to bust prominence (Pabd) gives information about the prominence type:

- Abdomen is more prominent than bust, Pabd < 0;
- Abdomen is as prominent as bust, Pabd = 0;
- Bust is more prominent than abdomen, Pabd > 0.

The last indicator is the abdomen prominence compared to waist prominence (Pabd-t) characterizing the prominence type:

- Abdomen is more prominent than waist, Pabd-t < 0;
- Abdomen is as prominent as waist, Pabd-t = 0;
- Waist is more prominent than abdomen, Pabd-t > 0.

3. Experimental part

The case study is focus on the simulation of the correspondence between human body and designed product, making use of the morphological research on women body, in order to design patterns for different bodies for which we know the anthropometric values, resulting from 3D scanning.

For example, we retrieved from the database (resulting from 3D scanning) a certain body, the selection criterion was that the subject, the main dimensions to fit the body type C from the anthropometric standard (Ic=160 cm, Pb=100 cm and Ps=104 cm). Figure 1 shows the scanned body image of studied subject.

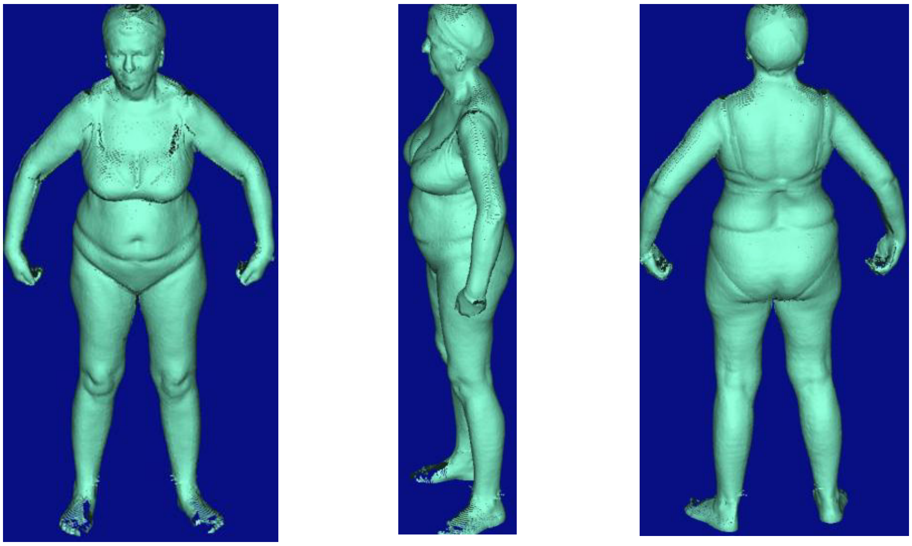

Fig. 1. Image of scanned subject.

For basic pattern design for this particular body, by simulating in 3D environment the correspondence between the body and the product were followed the following stages:

- body type research on which the main dimensions fit this subject, being the requirement for the selection of subjects that frame in group C conformation (Ic=160 cm, Pb=100 cm and Ps=104 cm);
- developing basic pattern for the dress [9] for representative type body that frames the subjects by using the Modaris Expert, LECTRA;
- morphological characterization of the subject by the two testing methods developed for determining the deviation of the shape of its body to the body type that is covered;

- simulation in 3D environment of the correspondence between the test subject body shape and the product made with based patterns designed for body type;
- analyze the discrepancies between body and product by using the Map of tensions;
- developing and implementing technical solutions for remodeling the initial patterns in order to adapt them to specific morphological features of the tested subject;
- re-simulation of body-product correspondence after patterns adjustment.

3.1. Morphological characterization of the subject using the developed mathematical model

For the subject studied, the noted above algorithm was followed for morphological assessment using developed mathematical model [5]. For example, the type of stature that fits the subject is showed in Figure 2.

Figure 2 presents the values of the test subject's specific anthropometric required its framing in a standard body type and the main indicators characterizing the morphological body shape introduced in the structure of the mathematical model developed according to theoretical information specified in 2.1.

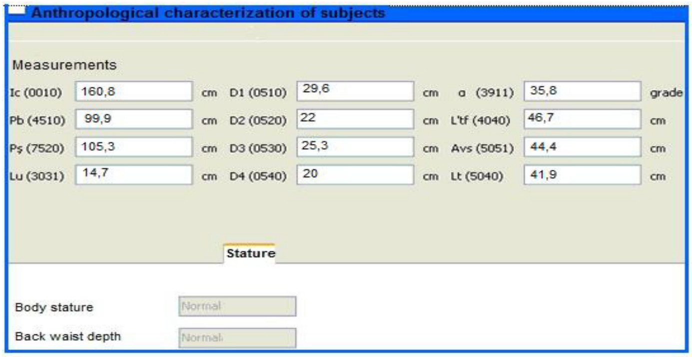

Fig. 2. Assignment of subject to the type of stature.

Using the mathematical model, after processing the initial data (actual values of anthropometric sizes) showed that the test subject:

- Frame in standardized body type: 160-100-104;
- has normal stature, after posture morphological indicator;
- shoulders have a normal position;
- after the indicator "vertical balance", the body is bent backwards;
- thorax is medium developed.

This characterization of the subject body shape is not enough to clothing design in customized system. For full characterization of individual body shape and constitution of the database required for patterns completion in correlation with the concrete particulars of the subject body is necessary to extend the morphological analysis by assessing the degree of curvature and prominence in sagital plane. Therefore is necessary to use the second method - complex morphological analysis of the subject.

3.2. Complex morphological analysis of the subject

For a more comprehensive characterization of the tested subject, to store information necessary to base pattern design and to ensure the best possible fitting between body and garment, it was used the complex method of assessing the subject's body shape as specified in paragraph 2.2. For subject tested (S), values of the indicators were calculated for assessing body prominences and depth on the front and the rear.

Table 3 presents comparative values of these indicators calculated on account of anthropometric standard [4] and calculated with the values of anthropometric test subject. Morphological analysis of the subject has been extended to some curved dimensions, important to assess vertical balance and degree of back vertical development in the transverse plane, on some indicators of global proportions and on transversal proportions through the differences between main circumferences.

Table 3. Indicators for prominence and depths assessing projections for studied subject.

Evaluation indicator	Values according to the anthropometric standard (cm)	Values od the subject (cm)	Difference (cm)
Body stature (Pc)	7	7,6	-0,6
Back waist depth (Ats)	3,7	3,7	+0,4
Buttocks prominence (Pfes)	5,2	5,3	+0,3
Bust prominence (Pbust)	9	8,8	+0,2
Waist depth compared to bust prominence (Atf)	1	0,8	+0,2
Abdomen prominence compared to bust prominence (Pabd)	0,7	1	- 0,3
Abdomen prominence compared to waist prominence (Pabd-t)	0,3	-0,2	+0,1
L_T	39,6	41,9	-2,3
Avs	43,0	44,4	-1,4
L'tf	45,2	46,7	-1,5
$e = L'tf - L_T$	5,6	4,8	+0,8
e' = L'tf - Avs	2,2	2,3	-0,1
Thoracic perimeter index (Ipt)	62,5	62,1	+0,4
Indicators of shoulders width (Ilu)	27,7	29,2	-1,5
Ps - Pb	4,0	5,4	-1,4
Pb - Pt	16	5,1	+10,9
Ps - Pt	20	10,5	+9,5
PbIII - PbIV	15,0	16,2	-1,2

According to this analysis, the following can be concluded:

- for the three curved dimensions L_T , L'tf and Avs, the subject has greater values than the standardized ones for that reason the vertical balance is within normal limits;
- the pattern made for the body type will not ensure correct correspondence between the subject and designed product from the bust line to the upper contour lines for both the front and the rear, from the waistline to the neck the body length is greater than that of the body type;
- the subject has medium developed thorax but with broad shoulders;
- the subject has a much higher value for Pt, compared to standard, which is reflected in the large deviations between differences that are recorded involving waist circumference.

4. Simulation in virtual 3D environment of body-product correspondence

Simulation in 3D environment of the correspondence between design product and the human body is an innovative technique to improve the design process of clothing. This technique has many advantages among which a crucial role is the rapid renewal of models and the reduced costs of practical prototypes manufacturing. Simulation in the 3D virtual environment was performed using 3D CAD system OPTITEX PDS, basic patterns were made with the Modaris Expert, LECTRA.

The main steps of the simulation in virtual 3D space of the correspondence between the body and the product are the following:

- visualization of cut parts (import of basic patterns made for the body type and application of assembly directions);
- mannequin parameterization;

- simulation of sewing for product parts;
- visualization of the body-product system;
- analysis of virtual correspondence (tension map).

Figure 3 shows the main steps of the body-product fitting simulation in 3D virtual environment.

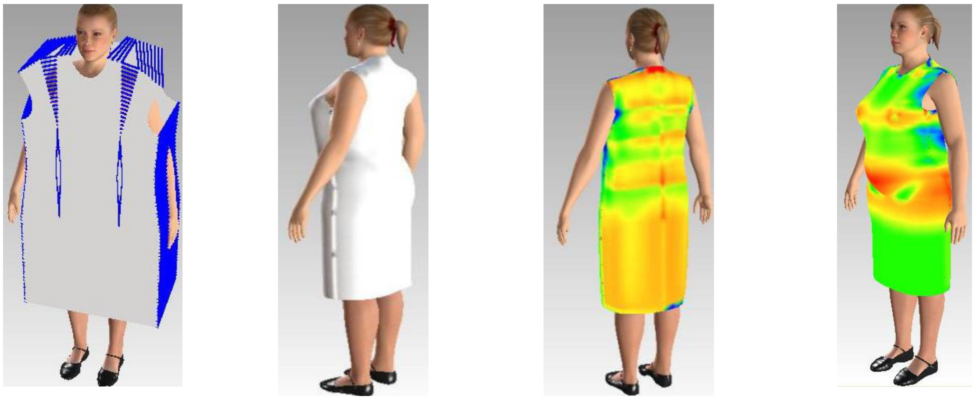

Fig. 3. Steps of the simulation process.

From Figure 3 (tension map) is found that at the waist level in the back and abdomen, the product is considered undersized because the subject has a greater value for the waist circumference than the body type. The morphological analysis of this subject and the results obtained from simulation in 3D environment indicate the directions of changing the basic pattern, developed for average body of conformation type C, due to the concrete shape of the studied subject.

The largest deviation of this subject is the value for the waist circumference; the subject has a waist circumference with 9 cm higher than the standard. In these conditions, also the contour length on abdomen back part of the subject is greater than the body type.

The subject presents a dorsal kyphosis, evidenced by the increase in back length from the cervical point to the waist line and the increasing of back vertical spring by 1.5 cm.

Knowing these dimensional differences between the subject's body and the body type, visualized in the simulation, allows the adoption of optimal solutions to remedy the initial basic patterns.

Thus, it is necessary to resize the pattern on the waist line and increasing the contour on the front symmetry line, more specifically increase the front pattern in the vertical direction on the whole surface, from the waist line to the termination line with an amount required by the abdomen prominence.

Figure 4 shows the steps to adapt the front pattern to the peculiarities of the studied subject.

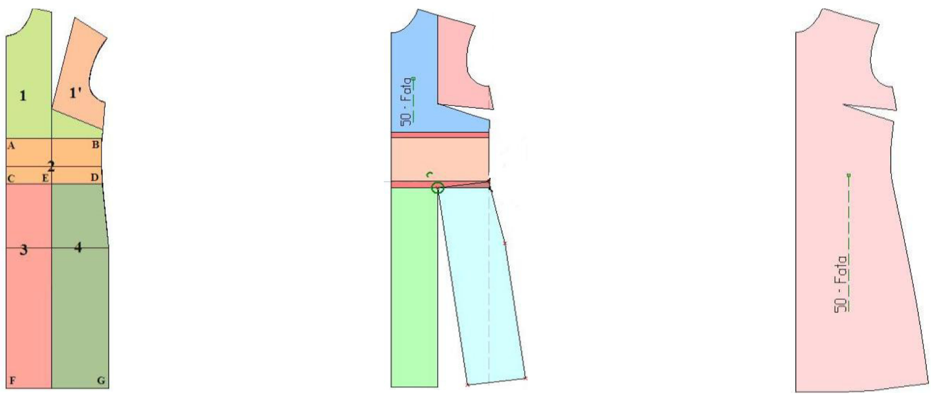

Fig. 4. Steps of front pattern processing.

At this stage, the basic pattern was divided into four distinct areas based on experience in pattern design and in strict correspondence with obtaining the final effect, that of increasing in the longitudinal direction of front pattern. To process this element, the principles of parallel and radial arrangement were used.

The final version of the element patterns (Figure 5) is obtained by tracing the contour line termination and the side seam, contour shrinks to the bottom with 1.5 cm.

Adapting the back pattern (Figure 5) involves changing the superior contour lines imposed by the dorsal kyphosis. For this purpose, both the radial and parallel arrangement were used to increase the contour on back symmetry line and the depth of blade dart, solution needed to transform patterns to the rounded form of the back (dorsal kyphosis).

Figure 5 shows the preparation of back element (the surface from the bust line to the superior contour lines), the delimitation of areas a and b. Area a will be translated with 1.5 cm up and area b will pivot around the point O. the effect imposed by body shape will be achieved and the final form of back basic pattern.

Fig. 5. Steps of back pattern processing.

After the adjustment of the basic patterns on studied subject's body features, a re-simulation was performed by following the same steps. Figure 6 shows the result of this simulation.

Figure 6 shows that the changes to the original basic patterns have been routed correctly because they provide a good correlation with analyzed subject's body shape. This is argued by the absence of red color which, as noted, the pattern shows a under-dimensions in certain areas.

Fig. 6. Visualization of body-product correspondence after adjustment of basic patterns on analyzed subject's body shape.

It can be concluded that the correct modeling principles have been used for the adaptation of basic patterns to to analyzed body shape.

5. Conclusion

The paper brings contributions to development of the clothing design technology by simulating the body- product correspondence in the 3D environment, taking into account the body shape.

The current research proposes and exemplifies an integrated technology for clothing design from systematization of morphological indicators characterizing the body shape, as initial information required in 2D clothing design, to performing virtual fitting by simulating the body-product correspondence in 3D environment, for completion of the initial pattern geometry in accordance to the body shape.

The concrete results of this research can be summarized as follows:

- Development of morphological indicators for assessing female body shape: stature, conformation, proportions and specific indicators to characterize the depth and prominences of trunk on its front and back side. For these indicators, the mean and range of variation were calculated which allows qualitative comparison of a subject's body shape with some basic morphological types, information of great importance to the work of clothing design according to individual measures of potential users.
- Morphological characterization of women body shape, the development of two methods that exploit information from 3D body scanning for inventory the features of tested subject.
- 2D design of dress basic pattern the body type: 160-100-104, for which the main dimensions fit the tested subject.
- Simulation in 3D environment of the correspondence between the product originally designed for the body type and specific form of the tested body.
- Observation and analysis of dimensional correspondence between body and product, using the Tensions map specific for the simulation technique.
- Apply techniques of remodeling the original patterns in correspondence with the particular tested subject‘s concrete body shape by image analysis through visualization of the body-product system and of the tensions map.

The methodology presented in this paper can easily be used in designing clothes for women, taking into account the concrete form of the body as it provides specific information regarding:

- Morphological analysis of adult women to specify: body type that fits (or not) , the type of stature, conformation, total proportions, shape and prominence of the trunk on the front and rear.
- Application of simulation algorithms on body-product system in the virtual 3D environment.
- Development of technical solutions to remodeling patterns in correlation with the concrete form of the body.

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