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Original Article

Constructing virtual mannequins with different postures for purposes of 3D design of the clothes

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Abstract

This article deals with the problem of constructing virtual mannequins with non-standard figures for the purposes of 3D design of clothes made of textiles. A definition of the notion “virtual mannequin” is suggested. The following classifying features of the virtual mannequin as a research model have been defined: according to the sphere of usage - scientific feature; to the form – information feature; to the development in time – static or dynamic; to the degree of reflecting basic features – parameter-based; to the degree of detailed representation – specified. The necessity of creating virtual mannequins with standard and non-standard figures of consumers is established. Practical requirements for transforming informational surface of the mannequin have been introduced in the article. Suggested here is a new mathematical model for transforming virtual mannequin with a standard figure into the mannequin with a non-standard figure, different from the standard one in the “frame position” parameter.

Keywords: 3D design, clothes, virtual mannequin, non-standard figure, transformation, textile material

1. Introduction

Computer technologies provide ample opportunities for automated design and marketing goals at all levels of the clothes’ life cycle: starting with constructing and production of textile materials, garment model design, construction and production technology, and ending with advertising and selling of ready-made items. At the stages of design, construction, advertising and selling of clothes, virtual mannequins can be widely used as a means of visualizing a garment model. Three-dimensional images of the models make it possible for designer to reach optimal compositional decisions that take into account material quality. The information model of virtual mannequin allows a designer to receive good-quality basic pattern for constructing a set of other model’s patterns. Realistic representation of the clothing items by means of mannequins helps the consumer make purchase decisions of clothes. Thus, a methodology of creating and transforming virtual mannequins with the purposes of making clothes for standard and individual figures becomes an actual problem.

The researchers have studied the problem of developing virtual mannequins for the design of clothes, as covered in the following publications.

Some particular approaches to constructing virtual mannequins for human figures with the purposes of constructing clothing items are given in the work (O. Surikova, G. Surikova, & Kuz'michev, 2015).

The importance of using realistic virtual mannequins for different consumers’ bodies to support clothing design is marked in (Carulli, Vitali, Caruso, Bordegoni, Rizzi, & Cugini, 2017) and synthesized in the article (Kornilova, Gorelova, & Smirnitskiy, 2013) where the authors describe advantages of three-dimensional design of clothes for an individual client. The article by Denisenko T.A. and Safronova M.V. (2015) deals with the problem of creating special personal mannequins for individual bodies using various modern materials. The use of modelling and numerical simulation of mannequins is shown in the article (Cichocka, Bruniaux, & Frydrych, 2014),

In the paper (Cremonesi, Garzotto, Gribaudo, Piazzolla, & Iacono, 2016) the current state of development of realistic dynamic virtual mannequin is presented.

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Possible ways of applying 3D morphological measurements of French female consumers are analyzed in the research (Kulinska, Bruniaux, Ainamo, Chen, & Zeng, 2016), as means of improving the fit quality of clothes.

The article (Paquet & Viktor, 2007) goes further in this direction and suggests an approach to adjust virtual mannequins through the use of body measurements.

New scanning and measuring technology in the design of clothes for handicapped persons in wheelchairs is presented in the article by Nejedlá M. (2016).

The article by Yezhova O. (2004) suggests methodology for transforming digital mannequins for bodies with different frame position, but the research methodology itself has not been clearly defined.

Many studies have been devoted to the design of clothes with the use of virtual mannequins.

The topic is developed in the article (Popescu, Olaru, & Niculescu, 2017), where the simulation of customized trousers is performed for the non-standard boy figure.

Patent (Xiaowu, Bin, Qinping, Feixiang, Lin, & Lang, 2017) specifies a method and system for generating three-dimensional (3D) garment models, and this is considered an important achievement in the development of three-dimensional garment modeling and virtual garment fitting technology.

In the article (Abtew, Bruniaux, Boussu, Loghin, Cristian, & Chen, 2018), the methodology of designing the female adaptive bust on 3D virtual mannequin through 3D design process is proposed.

The problem of visualization of the models of clothes on virtual mannequins in 3D design is the focus of the following publications.

The article (Lage & Ancutiene, 2017) examines the results of using software Modaris 3D Fit (CAD Lectra) for improving fit quality of clothes for the straight virtual dress on the virtual mannequin.

The paper of (Decaudin, Julius, Wither, Boissieux, Sheffer, & Cani, 2006) presents a way to design virtual clothing with 3D surface.

The patent (Souza, M. S., De Souza, M., Bauer, Botamedi, Cunha, & Da Silva, 2018), proposed a method for creating surfaces in order to represent garments on the body of a mannequin in 3D projection.

The interconnection between the physical and mechanical properties of the fabrics and the form of the clothes is important for visualization of the finished products on the virtual mannequins. The article (Pashkevich, Kolosnichenko, Yezhova, Kolosnichenko, & Ostapenko, 2018) provides the results of studies on the influence of the properties of suit and coat fabrics on the three-dimensional silhouette of the clothes. The research (Pashkevich, Yezhova, Kolosnichenko, Ostapenko, & Kolosnichenko, 2018) illustrates the influence of properties of fabrics on structure and appearance of decorative elements, such as volantes.

The review of scientific publications has shown that the problem of development of virtual mannequins for designing of clothes is relevant, and that the peculiarities of designing the mannequins` surfaces for figures with different postures are a research gap.

The aim of the article is to present the methodology of virtual mannequins' construction reflecting human figures with different postures.

2. Methodology of Generating Virtual Mannequins for Non-Standard Figures

The article represents author's definition of the notion "virtual mannequin". Therefore, we define *a virtual mannequin* of human body as a three-dimensional representation of the body surface, generated with the help of a computer with the use of digital model of body surface. All coordinating measurements, that define the surface of the human body figure, coincide with the coordinating measurements of the modeled body surface of the mannequin.

We relate virtual mannequins to the scientific and research model type, which is used for conducting both real and cognitive (virtual) experiments. Informational model, by its form, reflects a certain system, represented in a form of symbols, signs, images, outlining the object under research and discloses peculiar and essential qualities of the object, and gives new information. Virtual mannequins used for clothes construction can mostly be static rather than dynamic, according to the time parameter, and they can be both static and dynamic for design and marketing. At the stage of clothes construction it is possible to generate dynamic mannequins for defining dynamic effects of changing figure parameters while performing assigned/planned movements.

This allows scientific grounding of the additional amount of cloth needed for free movements of the body.

Virtual mannequins are parametric models, since they allow establishing quantitative relationships between system parameters. According to the degree of specification, virtual mannequins represent themselves as detailed models, as they can provide discrete information about the surface of the consumer`s body.

By the notion of "standard figure" we understand here the figure/body of the consumer, sizable characteristics obtained in the process of constructing sizable typology of population and represented in anthropometric standards for clothes design.

Virtual mannequins for standard figures/bodies can be viewed as permanent conditional information for automated clothes design, because they contain static and concrete information for the whole period of duration of population size-typology. Such mannequins, generated once by the scientific departments can be used further many times for designing new garment models.

But the majority of consumers have non-standard figures. By "non-standard" figure we understand such figure of the consumer, that has the same measurements of height, breast and thigh, but different in subcategories of measurements for not less than 0,5…1,0 cm (Radchenko, 2015). In relation to this, we suggest in this article a mathematical model of transformation of virtual mannequin with standard figure into a virtual mannequin with non-standard figure, different in posture and frame parameters.

By frame parameters we mean here "individual peculiarities of human figure configuration in quite (relaxed) vertical standing, demanding minimum use of muscle energy to maintain the body balance" (Dunayevskaya, Koblyakova, & Ivleva, 2007).

We take the measurement of "frame position" (Fp) as a quantitative criterion of posture in the process of profile projection of human body. It is measured horizontally according to the State Standards (GOST R 52771-2007) as a distance from the neck to vertical surface, adjusted to the mostly prominent backward points of both shoulder blades (Figure 1).

Figure 1. The scheme of measuring point of "frame position"

2.1 Basic requirements for transformation mechanism

In order to generate the pattern for non-standard figure, it is necessary to have a basic pattern of the model, created for standard figure with the same size, height and fullness. Thus, the main requirement for transformation of information model of the mannequin surface is stability (non-changeability) of the leading measurement parameters corresponding to the model. This requirement can be reached when there is stability of the cutting on the level of bust measurement of the third one level (the level of point B, Fig.2), as well as stability of the data of the points of application, forming the following model.

The second requirement is preserving the symmetry of the model according to the central sagittal surface. It means, in particular, that the points of the initial information model, placed in the sagittal surface, will still be placed in it in the transformed model.

The third requirement is a smooth character of deviation gradation while the distance of application points is increasing.

It means, that in the bust measurement plane the deviation is 0. With increasing applique points, at first there is insignificant, and then a gradual increase in the parallel transportation vector of each point. At the level of the base point of the neck, the magnitude of the parallel transportation vector reaches the specified magnitude of variation of the "frame position" factor.

2.2 Constructing deviations in frame position

Primary data for modeling deviation degree in frame position (Fp) is informational model of the mannequin surface and the rate of interval of deviation factor of *Fp*. The placement of the axes is shown on Figure 2. Imitation of Fp deviation is reached here with the help of parallel transportation, conducted with respect to the requirements, mentioned above. During this process, the vector of parallel transportation of each concrete surface is horizontal and parallel to sagittal surface. Its absolute amount that equals 0 on the level of bust measurement of the third, gradually increases with the increase of level of application and reaches its maximum on the level of the neck foot at the back (point N, Figure 2).

In order to define the length of the parallel transportation vector we use the following quadratic function (1):

$$r=kZ^2, \tag{1}$$

where r – is an absolute amount of the parallel transportation vector;

Z – point application;

k – proportion coefficient.

To define k we need to point Z_1 application of the foot of the neck through r_1– the length of the parallel transportation of the surface, defined by the equation $z=Z_1$. Then

$$k=r_1/Z_1^2 \tag{2}$$

As it is seen in Figure 2 above the deviation in measuring feature of "Frame Position" from the standard is defined according to the formula (3):

$$\Delta Fp = r_1-r_2, \tag{3}$$

where ΔFp – is deviation degree of the measuring feature «Frame position» from typical amount; r_1,r_2 – transition from the corresponding neck point to the shoulder point.

If Z_2 – is application of the neck point, then judging from (1) and (3) it follows that:

$$\Delta Fp = r_1-kZ_2^2=r_1-(r_1/Z_1^2)Z_2^2 \tag{4}$$

and

$$r_1=\Delta Fp/(1-Z_2^2/Z_1^2) \tag{5}$$

On substituting equation (5) into formula (3), the result is:

$$k=\Delta Fp/(Z_1^2-Z_2^2) \tag{6}$$

Substituting equation (6) into formula (1), gives an equation defining the vector length of parallel transition of the point with application Z (7):

$$r=\frac{\Delta Fp}{Z_1^2-Z_2^2}\bullet Z^2, \tag{7}$$

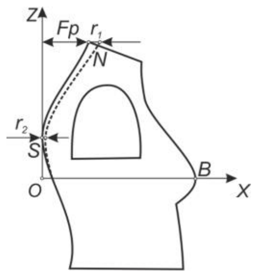


Figure 2. Calculating/measuring scheme for transforming back surface of the garment (torso)

Here r – is absolute degree of the parallel transportation vector; ΔFp – deviation in the measuring feature "Frame Position" from standard amount; Z – point application; Z_1– neck point application (point N, Figure 2); Z_2 – the point of the most prominent shoulder application (Point S, Figure 2).

Graphically, the dependence of the absolute degree of the parallel transportation vector r on the applicate of point Z for a female figure with a height 164 cm, a chest perimeter 112 cm and a hip perimeter 120 cm is presented in Figure 3 for straightened (Figure 3, a) and round-shouldered (Figure 3, b) postures.

While modeling the figure different from the standard in Frame Position with amount ΔFp, with the chosen position of zero coordinate system (Figure 2), Cartesian positions of unspecified point $M(X_M, Y_M, Z_M)$ in result of parallel transportation will equal:

$$X'_M = X_M + r_M,\ Y'_M = Y_M,\ Z'_M = Z_M, \qquad (8)$$

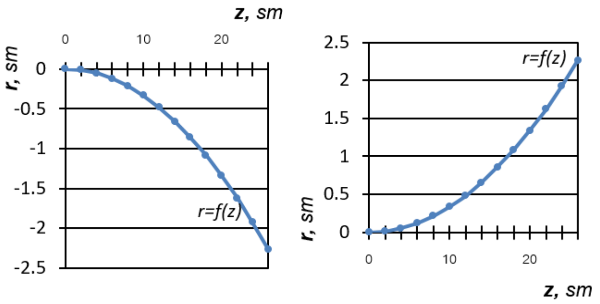
where r_M is calculated according to the formula (7).

The suggested model allows generating virtual mannequins of bodies, different in measuring feature Fp (Frame Position) from the standard. Such mannequins enable the process of designing clothes and garments for non-standard figures with different frame deviations.

3. Results and Discussion

To test the effectiveness of the suggested methodology of modeling frame deviation, we constructed the informational model of the figure surface, different in measuring feature "frame position" from the standard one. The initial primary data for transformation were the informational model of the mannequin surface of typical standard figure, on the one hand, and the amount of variation degree of intervals of the factor "Frame position" on the other hand.

In the role of a typical figure we took a big-sized figure with the following basic measuring points: height 164 cm, chest perimeter 112 cm, hip perimeter 120 cm. The degree of "Frame Position" for the chosen figure, according to size standards is 6,5 cm. The amount of variation interval in the parameter "Frame position" is set to 2 cm. All this resulted in generating virtual mannequins with the stoop-shouldered (ΔFp = +2cm) posture, and with straight (ΔFp = -2cm) posture shown in Figure 4. Figure 5 represents schematically only the part of the pattern that has undergone transformation, i.e. a shoulder constructing belt. It is situated on the consumer`s body between the horizontal surfaces, including the most prominent points of the bust and the neckline (Figure 6).



a b

Figure 3. The dependence of the absolute degree of the parallel transportation vector r on the applicate $r=f(z)$ for a female figure 164-112-120: a - when ΔFp = -2cm; b - when ΔFp = 2cm

a b c

Figure 4. Virtual mannequins of figures with different frame position: a – straight; b – normal; c - stoop-shouldered figure

The basic usage of virtual mannequins with non-standard figure in the design of clothes gives possibility of:

- receiving full information about the geometry of the body surface of the human being, including the curving of the surface at different places;
- the shape of the lines on the surface, such as the lines of cutting and the lines of conjunction of separate elements;
- measuring radial and projection distance between anthropometric points etc.;
- visual representation of sketch decisions of new models for their evaluation and assessment in respect of composition perfection;
- conducting virtual try-on of the garment for preliminary evaluation of the quality of fit with the body.

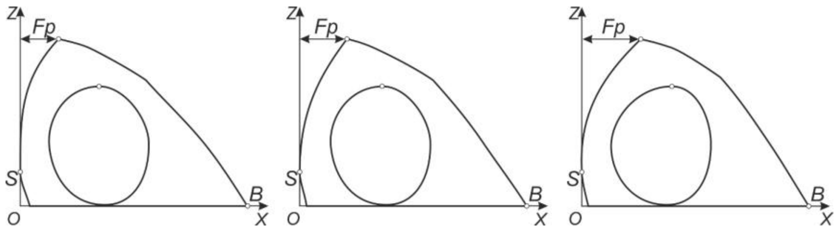


Figure 5. Lineal frame of the shoulder constructing belt for virtual mannequin with different frame position: a – straight (ΔFp = -2cm); b – normal; c - stoop-shouldered (ΔFp = +2cm)

Figure 6. The location of the shoulder constructing belt on the consumer`s figure

The novelty of the work lies in the fact that the methodology of generating virtual mannequins for non-standard figures with different postures is proposed and verified in this study.

4. Conclusions

The article makes a contribution to the theory of virtual construction and design of clothes, as it introduces author-invented definitions to the notions of "virtual mannequin", and presents classifying features of the virtual mannequin as a research model. The necessity of creating virtual mannequins for typical/standard and non-standard figures of people is underlined in the article.

The new requirements to the mechanism of transformation of the informational model of the mannequin surface have been worked out and were presented here. Measuring feature "frame position" has been chosen as a quantitative posture criterion for virtual profile projection of the human body. The author presents a new methodology of generating virtual mannequins for non-standard figures with different degrees of deviation in "frame position", as well as outlines the sphere of use for virtual mannequins for non-standard figures with the purpose of designing clothes.

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