Realistic Virtual System "Female Body – Dress" Based on Scanning Technologies

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Abstract

With the advancement of 3D technologies, such as body scanning, modeling and try-on systems, the realistic visualization of clothes outside shape under textile material properties influenced has become possible. With the body scan system, the 3D body shape can be imported into the virtual environment to serve as the avatar in the simulation which provides fitting and shaping information including the fabric properties' indicators. While distinct advantages of 3D technologies for improving clothes design and pattern making process, there are significant areas of challenge. Although the maturing clothing industry emphasis more on fit and fabric characteristics for 3D try-on module, to predict the shape of clothes around each body is very difficult to achieve as it has been proved [1]. In our study, the 3D shape obtained from the woman bodies and dresses that made from 3 kinds of fabrics were obtained by the body scanners. Through the dividing of the female torso into 6 sections from bust level to hip level, the volumetric air gaps between the body and dress were calculated to model and analyze the relations existing in "body-dress" system between the body sizes, pattern block indexes, and fabrics properties. The strong equations established by regression analysis include the fabrics properties' indicators tested by the KES-FB system [2] and the volumetric ease. Thus the legitimately prediction for outside shape of female dress in the "body-dress" system is realizable through testing physical and mechanical properties of fabric by the KEF-S devices.

Keywords: woman dress, body scanner, 3D volumetric ease, fabric properties, realistic shape

1. Introduction

In garment production process, pattern makers after receiving the sketches from the designers are created the pattern blocks on the own knowledge base, which integrate not only the intelligences of the clothes construction and pattern structure but also require the understanding of fabric material properties. Final clothes shapes might be different while the fabric properties changed, even though using the same pattern block [3]. While the relationship between 2D pattern and 3D garment is crucial in pattern making process through 3D simulation, the future success of the 2D shape is judging by the relationship joining the 3D garment and a specific 3D body in present 3D try-on systems [4].

The main area of scientific research is devoted to the development of 3D CAD systems for garment simulation, which intensively developed for the last two decades. In the initial phase of the development, the researcher efforts focused on the design of the computer simulation of clothes, which depends on the physic-mechanical properties of fabrics and the intention to achieve the best possible realistic simulations of system "body-clothes" [5]. Then the studies have been focused on the development of CAD systems that allow perform simulations in real time [6, 7]. Lately, the maturing clothing industry emphasis more on clothes fitting, fabric characteristics for 3D try-on technology improvement.

Nowadays, the rapid development of 3D body scanning technology provides realistic 3D digital shape, which allows studying the clothes in 2D or 3D view arbitrarily. Thus recently some explorations focused on the garment shapes by dint of the scanning technology which connect the physical, geometrical and scanning technologies [8]. Loker et al. [9] tried to describe how size-specific analyses of body scan data can provide information that can be used to adjust ready-to-wear sizing to improve apparel fit. Simmons et al. [10] worked with the sorting system of female shapes programmed in Visual Basic. The process involved using the 3D body scan data for the customization procedure to ensure the satisfactory fit. Zvereva et al [11] have studied 3D clothes shell and fabric properties by scanning technology, and found the relations between the fabric wrinkles and fabric indicators which help to design realistic surface of "body-trousers" 3D systems.

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However, the complex relation existing between the bodies and clothing were concerned not enough in nowadays studies, that database were build based on 2D sections parameters. In this way, the 3D shapes and apparel were torn into 2D shatters which ignored the impacts from textile materials in a whole 3D view. As a result, the simulation of clothes outside shapes in modern try-on systems is unsatisfied and impractical for pattern design.

As usual, present try-on systems are doing with 3D avatar which loads in stable standing posture. Clothes were simulated in accordance with the fabric properties indexes input in the software by means of special window. Fig. 4 has shown the example of virtual system in CAD “Marvelous Designer”. and list of textile materials properties including 11 parameters. However, the result of simulation is unsatisfactory as proved in our earlier research [12]. The simulation mistakes have been generated by the complex of serious factors including: 1. The avatar was lack of authenticity; 2. Incomplete of fabric properties in system design which cause the mistakes of fabric simulation; and etc. Thus the improvement for the try-on system simulation is in need, and many problems have to be solved during this process.

Body with dress in single stable posture (Obtained by data bases - thesis of sections in 2D view, which failed to analyze complex relations of “body-clothes” system in movement)	**Fabric properties data base for designer to choose** (Unsystematic with non-standard indicators, which cause a lot of mistake in the clothing simulation process)

Fig. 1. Simulation process of “body-clothes” in Marvelous Designer try-on system

How to get the realistic system “body-clothes”? Which kind of criteria can help to judge the row of virtual systems and make the decision which system is best and look like the real customer? In our study, we chosen the new approach for designing the virtual systems, which includes:

- Way of virtual shaping which similar to real one by means of new index (part 2.3),

- Handle textile materials properties for changing the outside shape (part 3.2).

In our study, the relation between the air gap volume existing between the body and clothes was studied in real 3D view with the help of 3D body scanners. With the fabric indicators (indexes) tested by KES-FB system, the equations were provided to show how the textile material properties and indicators are affected on outside shape of clothes. In this way, the realistic 3D outside shape becomes achievable in the virtual system “female body - dress”, which is helpful to improve the existing try-on module in a realistic way (Fig. 2).

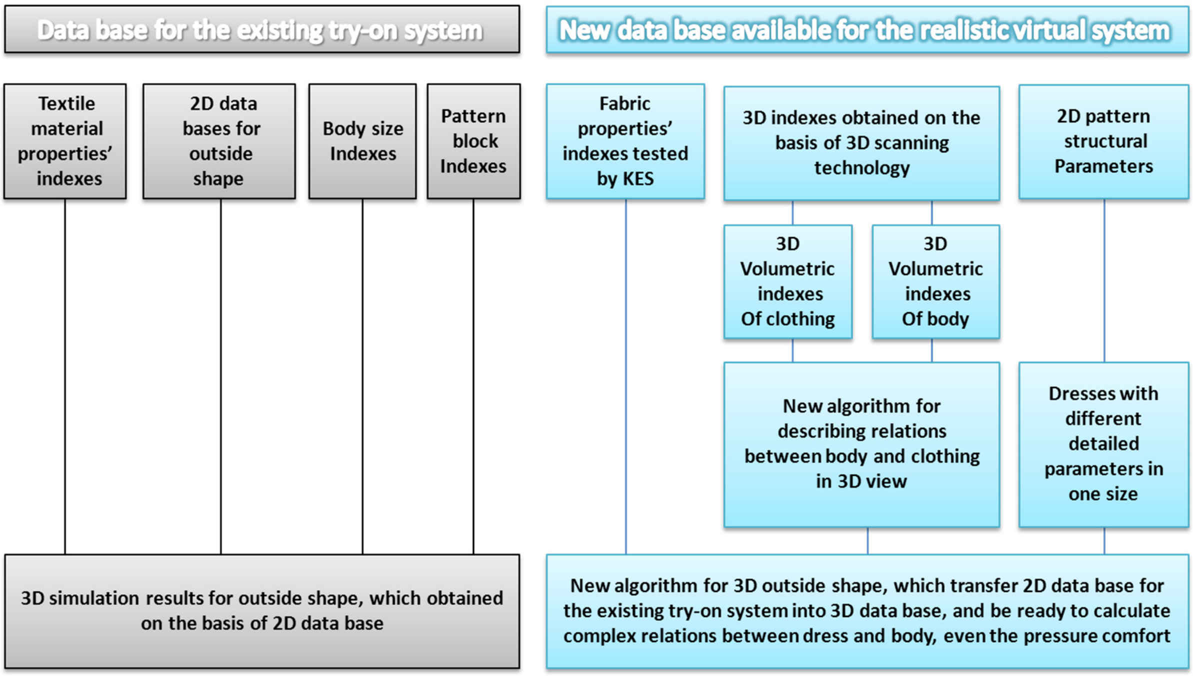

Fig. 2. Structure of data bases existing in present (left) and new realistic (right) virtual try-on module

2. Materials and methods

2.1. Textile materials testing

Under normal circumstances, almost all the thin textile materials could be used to make female dress for daily-wear. In this research, the - cotton (including blending types) fabrics were chosen as the objects and most common materials.
Based on the above considerations, the textile materials were chosen including two types of woven (I and II) and one knitting fabric III (Table 1). The main physical and mechanical characteristics of fabric were selected out after testing by KES. Each fabric was measured for five times to get the average indicator indexes. Thence, 11 parameters of tensile, shear, pure bending, and compression ability were obtained by KES and shown in Table 1. Results of measurements and the coefficient of variation have indicated the significant differences that exist in tensile and bending abilities, e.g. WT, F0.5, EMT and B indicators.

Table 1. Physical and mechanical properties of the experimental fabrics

Characteristic or properties of indexes		Warp, weft	Testing result for indexes			Coefficient of variation C=(max-min)/Av
			Fabric I	Fabric II	Fabric III	
Structure type			Woven	Woven	Knitting	
Fiber content, %		-	Cotton 100	Cotton 100	Polyester 85, Cotton 15	-
The surface density, g/m²		-	88	92	165	0.757
Shear (Tester KES-FB-1)	Shear stiffness 8°, G, cN/cm. degree	Warp	0.722	1.072	0.626	0.553
		Weft	0.726	0.926	0.6	0.434
Tensile (Tester KES-FB-1)	Linearity of the stress/strain curve , LT	Warp	0.823	0.82	0.611	0.282
		Weft	0.674	0.714	0.567	0.225
	Tensile energy (maximum load: 500 gf/cm),WT, cN.cm/cm²	Warp	3.7	3.49	24.663	1.994
		Weft	20.3	25.85	43.525	0.777
	Tensile recovery following extension, RT, %	Warp	57.782	60.3	45.55	0.27
		Weft	21.088	22.976	43.858	0.777
	Necessary deformation for elongation in 0.5 %, F 0.5, cH	Warp	293.667	288.32	2.32	1.496
		Weft	12.08	13.95	0.94	1.447
	Elongation at a set load (maximum load: 500 cN/cm), EMT, %	Warp	1.782	1.704	16.148	2.207
		Weft	12.062	14.464	30.743	0.979
Bending (Tester KES-FB-2)	Bending stiffness, B, cN.cm²/cm	Warp	0.404	0.108	0.008	2.289
		Weft	0.04	0.039	0.01	1
	Hysteresis of shear force at ±0,5° of shear angle, 2HG, cN/cm	Warp	0.982	1.332	1.276	0.246
		Weft	1.262	1.482	1.436	1.393
	Hysteresis of shear force at ±5° of shear angle, 2HG5, cH/cm	Warp	2.958	4.232	1.296	0.125
		Weft	3.242	4.166	1.418	0.62
Compression (Tester KES-FB-3)	Work done in compressing the fabric, WC, cN. cm/cm²	-	0.126	0.157	0.169	0.283
	Compressive resilience of the fabric, RT, %	-	57.266	48.862	64.274	0.123

2.2 Indexes of 2D patter blocks

The dresses in the “tight-fitting” style were designed with the same eases allowance: to bust girth is 2 cm; to waist girth is 2 cm; to hip girth is 2 cm. Through historical analysis of female dress structure, five patterns were prepared with the eases mentioned above for the standard female body size (height is 160 cm; bust girth is 84 cm; waist girth is 64 cm; hip girth is 89 cm) but in different ways of dart parameters design on the waist level. In this way, the pattern blocks were prepared in the same size but with different parameters of the darts which including the place, length (up and down) and value.
The samples designed by each pattern block were sewing form the 3 kinds of fabrics to find out how the fabric indicators could be affected on the outside shape.

2.3 Constructive ease volume (*CEV*) for describing of 3D gap between dress and body

For finding the relations between which can consist between the chosen fabrics properties and the 3D shapes, 3D volumetric eases in system "body - dress" analyzed by means of 3D body scanning technology. The steps are as follows:

a. 3D female bodies without dress and in dress were scanned by the 3D body scanners (TELMAT, France, and ScanWorx, Human Solution, Germany);

b. 6 cross-sections of female body where varied as the body curves changed were selected out to construct the digital 3D shapes. In this process, the missing information between the lines was analyzed and supplement intelligently by Rhinoceros (Fig. 3).

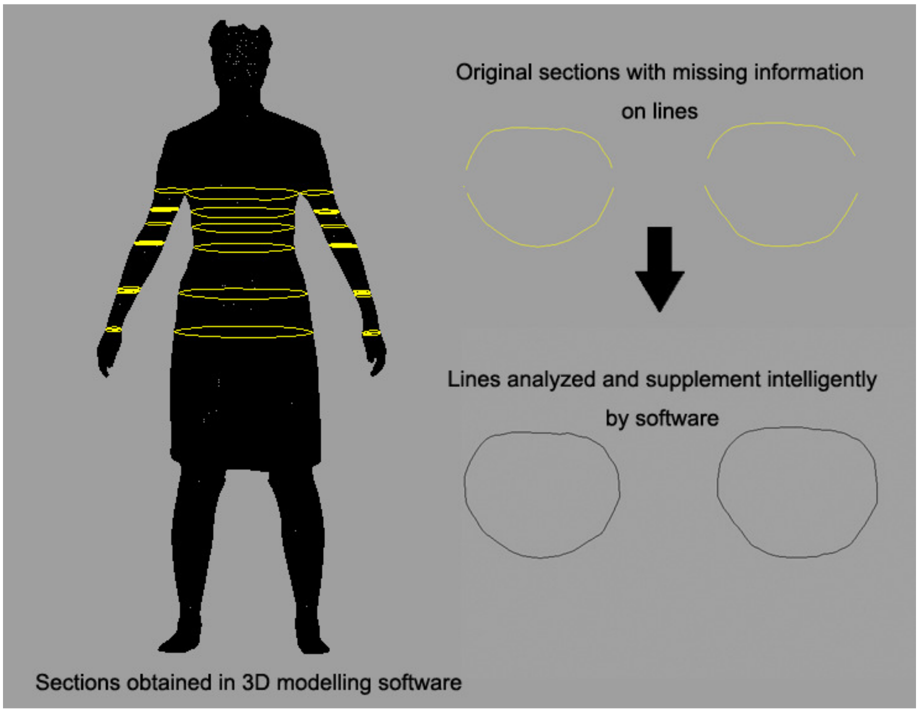

Fig. 3. Sections obtained and revise intelligently in software

c. The adjacent sections were combined into new shapes of body torso. The volume of the torso was calculated by Rhinoceros (Fig. 4). The "constructive ease volumes" were divided into three groups (it's shown in Fig.4 in different colors) in accordance with the possible impact on the dress shaping and volumetric gaps beneath reliable minimum ease:

- Volumetric ease that influenced directly by morphological feature of breast level ($CEV_{3,4}$),

- Volumetric ease located between the upper and lower abutment surfaces which do not the directly impact by body morphology ($CEV_{4,6}$),

- Volumetric ease located directly above the hip area ($CEV_{6,h}$).

d. The volumetric ease located between the body and dress was calculated out in the following way:

Volume of dress –Volume of body = Constructed ease volume (CEV).

In the above four steps, *CEV* were obtained to compare with KES indicators for samples which made of different fabrics.

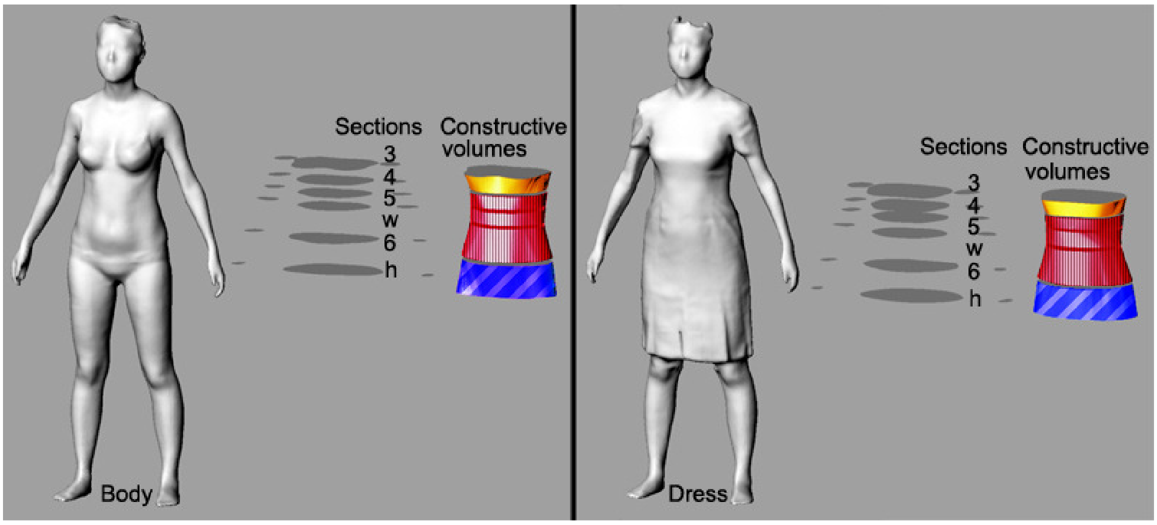

Fig. 5. Torso volumes obtained from system "body-dress" scanned

Where: *3* – bust girth; *4* – under-bust girth; *w* – waist girth; *h* – hip girth, *5* - torso girth between under-bust and waist levels; *6* - torso girth in the middle between waist and hip

3. Results and analysis

3.1 Testing of *CEV* parameters

The results of *CEV* parameters for samples made of different fabrics were shown in the following table (Table 2):

Table 2. Volumetric eases in "body-dress" systems

CEV between horizontal cross-sections in "body-dress" system	The average value of *CEV* in systems "body-dress" which made of different fabrics, cm³		
	Fabric I	Fabric II	Fabric III
Located under the upper bearing surface			
$CEV_{3,4}$	71.6	22.2	14
Located between the upper and lower abutment surfaces			
$CEV_{4,5}$	89.3	147.8	70.4
$CEV_{5,w}$	197.9	228.4	197.2
$CEV_{w,6}$	358.3	314.9	186.4
Sum	645.5	691.1	454.3
Located above the bottom bearing surface			
$CEV_{6,h}$	1617.9	1417.5	1417
The total volumetric ease			
$CEV_{3,h}$	2335	2130.8	1885

Indexes in the above table indicated how each fabric influenced on CEV in different part of female body. E.g. $CEV_{3,4}$ (bust to under-bust) are smaller for all types of fabrics due to it is more closely to the female body. While in the part located between the upper and lower abutment surfaces, the fabrics have different influence on *CEV* in the separated three parts, thus the sum value of this part is more important. Finally, the total volumetric ease ($CEV_{3,h}$) describes the comprehensive fabric properties impact on 3D ease between the body and dress during the dress shaping process.

3.2 New algorithm for describing outside shape of "female body – dress" system

However, some indicators of KES system were correlated with others, so it is necessary to choose the important ones for investigation. Thus the next way of choosing the textile materials properties related to the dress shaping has been created:

a. Correlative coefficients between each KES indicators were analyzed to find out the independent variables.

b. The independent variables of fabric indicators were compared in warp and weft; if it influenced shaping in both directions similarly then it is judged as the valid variables.

c. After the above two steps, the final valid variable were chosen to get the equation.

In this way, the correlative relations between the material properties and *CEV* were analyzed. Thus, the prediction for the final silhouettes by *CEV* is achievable with the fabric properties been selected, which express the deformation of dresses by means of indexes obtained through KES-F.

In the tensile property group, the linearity of the curve stress/strain LT (average of warp and weft) which indicate how the stress uniformity increased within the material under tension was proved more important than others. In the case of dress shaping, this indicator can be related to the ability that the fabric resists the adaptation during the shaping. The decreasing of the LT-value implied the increase of the difficulty for changing outside shape.

In the bending property group, the flexural rigidity B (average of warp and weft) which represents the resist ability of bending the textile fabric was chosen. The increasing of B-value indicates the increasing of difficulty for bending the fabric.

Equations for calculating the CEV values located between different levels on female torso are as shown in the following table (statistical significance of equations verified by Fisher-criteria and Student-criteria, as well as the multiple correlation coefficients, $n = 15$, $p = 95$ %, $F = 2.4$):

Table 3. Equations for CEV prediction

Constructive ease	Equations for constructive ease volume (CEV) prediction	
$CEV_{3,4}$	$CEV\ \mathbf{3,4} = 323.77\ B$ *(F=2.58)*	(3)
$CEV_{4,6}$	$CEV\mathbf{4,6} = 1381.2\ LT - 358.34$ *(F=19.6)*	(4)
$CEV_{6,h}$	$CEV\mathbf{6,h} = 1680 + 1291.4\ B$ *(F=4.33)*	(5)
$CEV_{3,h}$	$CEV\mathbf{3,h} = 1374 + 844.4\ LT + 1480\ B$ *(F=14.85)*	(6)

The above equations (1-4) revealed how the selected indexes increased the volumetric ease, which confirmed the validity of the assumption and verified that they are related to the dress shaping. They indicate how the fabric properties impact on different part of dress shaping. In the upper part "3,4" (1) and bottom bearing surface part "6,h" (3) the indicator B (bending stiffness) is the contributing factor; meanwhile for the part between upper and bottom abutment surfaces (2) the indicator LT of tensile ability became the causative factor; consequently both indicators influenced the dress shaping (4). Thus, the legitimately prediction for outside shape of female dress in the "body-dress" system is realizable through testing physical and mechanical properties of fabric at low loads by the KES devices.

Consequently, the data base of outside shape was established for the realistic virtual system "female body - dress", which creates the new method to predict the 3D shape with KES fabric indicators.

4. The superior try-on simulation in "Realistic virtual system" compared with the existing one

New databases obtained before allowed create the realistic virtual system, some improvements are used to upgrade the technical basis of the existing software (Fig. 6):

- The avatar with stable standing postures replaced by 3D body shapes in movements from the body scanner, which obtained by two methods: first - scanned directly by 3D body scanner; second - adjusted by 3D modeling software (e.g. MAYA) from the scanned body.

- Some important KES indicators put of the old unsystematic ones, which can improve the fabric simulation as it is more accurate than the traditional ones.

-, the simulation of dress would be obtain under the relations between two groups of indexes of the body and dress that we introduced in this study, and the basis of avatar with different postures and KES fabric indicators. In this way, more complex simulation e.g. deformation of fabrics or pressure from clothing is achievable.

With the improvements above, the realistic system is achieving with the results, which make further analysis of “body-clothes” system become possible.

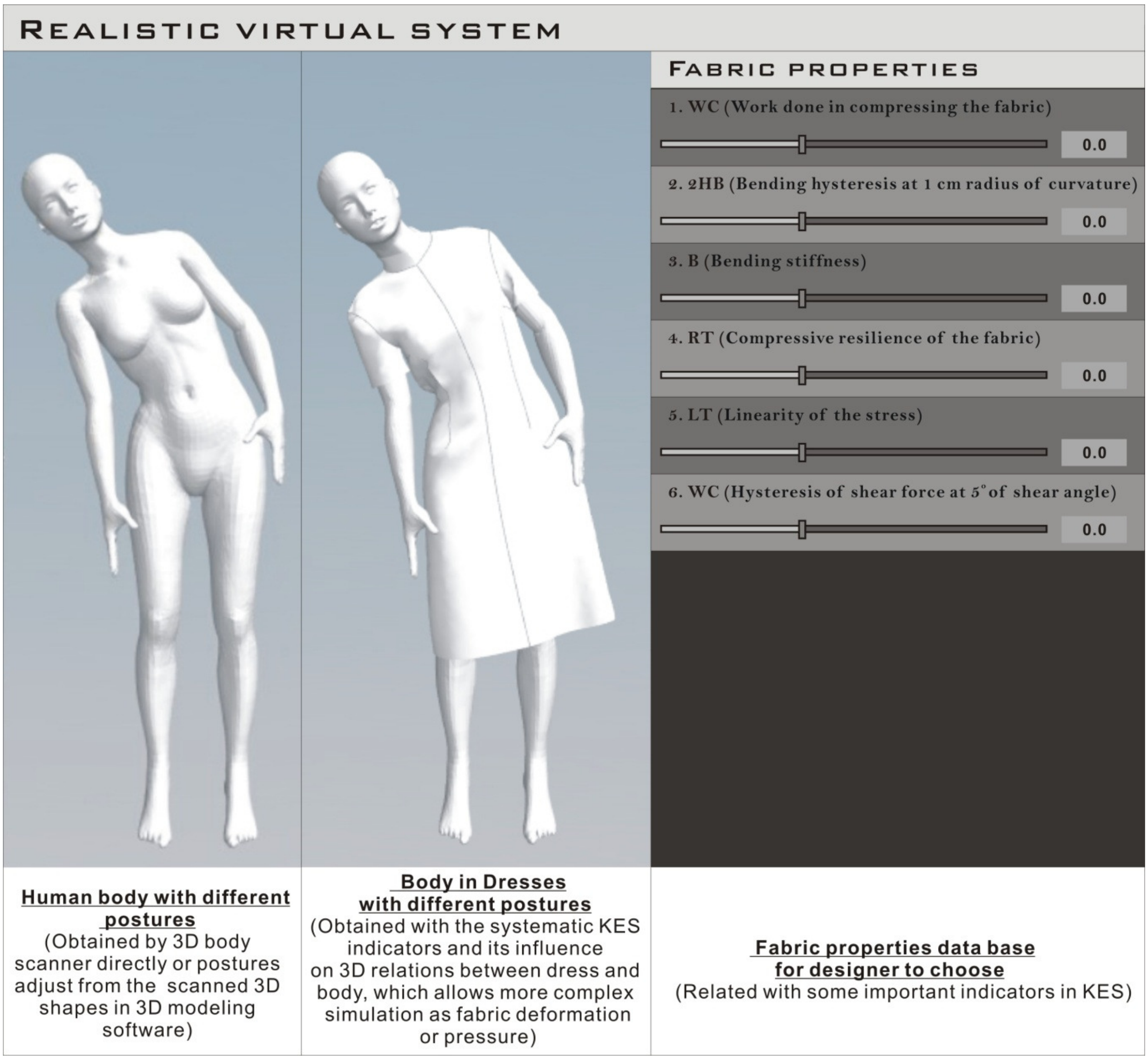

Fig. 6. Simulation process of “body-clothes” in Realistic virtual system created in this study

Conclusion:

Traditionally, the data bases which helped to achieve the 3D simulation results were divided into four parts: Textile material properties’ indexes; 2D outside shape indexes; body size indexes, and pattern block indexes (Fig. 1). For improving the existing try-on system, new data bases for the realistic virtual system were proposed to be added or instead of the old ones in this research:

- The “KES fabric properties’ indexes” took place of the old “Textile material properties’ indexes”, the former was superior to the latter as it introduced the method which provides the important fabric indicators in a standardized system. So, the data base of textile materials was upgrade in an undifferentiated way that solves the problem of fabric testing error or indicators’ inadequate.

- The old “2D outside shape indexes” and “body size indexes” was replaced by the “3D volumetric ease indexes”, which consists of volumetric data base for both female body and dress. With 3D body scanning technique, the CEV indexes can help to describe the 3D relations between the body and clothes more accurately. Segmentation allowed detailing CEV indexes of system “body-clothes”. In this way, the simulation process of shaping would transform from the simple 2D section’s view into the 3D view, it allow to take the fully consider of the relations between body and clothing in a three-dimensional way.

- The “2D pattern structural parameters” were upgraded for old “pattern block indexes”, which considered detailed parameters design might bring a slight difference for dress shaping. However, the tiny structural difference will not influence the 3D volume while the size is stable.

Through improvement of the above data bases, new algorithm of outside shape was achieved, which constructed the more realistic virtual system than the existing ones. Last but not least, the 3D body scanning technique were suggested to help improve the avatar from fake to real, then not only the designers could check their designing results, but also the customer could observe their statements in clothes if they have the electronic 3D shape file from body scanners.

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