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MODELING OF DIGITAL TWINS OF HISTORICAL FASHIONABLE BODIES

МОДЕЛИРОВАНИЕ ЦИФРОВЫХ ДВОЙНИКОВ МОДНЫХ ИСТОРИЧЕСКИХ ФИГУР*

V.E. KUZMICHEV, A.YU. MOSKVIN, M.V. MOSKVINA

В.Е. КУЗЬМИЧЕВ, А.Ю. МОСКВИН, М.В. МОСКВИНА

(Ivanovo State Polytechnical University,
Saint Petersburg State University of Industrial Technologies and Design)

(Ивановский государственный политехнический университет,
Санкт-Петербургский государственный университет промышленных технологий и дизайна)

E-mail: wkd37@list.ru

The influence of historical costume on contemporary culture and lifestyle is huge because the national memory and fashion history are major components in modern society which needs new forms and ways of historical costume presentation. Numerical dematerialization becomes the only way of saving, reconstruction, pre-

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senting and shearing around the world culture heritage - the textiles and the costume as national and culture indicators. In history, fashionable human bodies had special silhouette and proportions due to special garments which were worn under upper clothes such corset, crinoline, and multilayer underwear. This study is devoted to new method of reconstruction outline shape of men and women historical fashionable bodies in the XIX century which were formed by means of different garments.

Влияние исторического костюма на современную культуру и образ жизни огромно по причине интереса в современном обществе к национальной памяти и истории моды как основным компонентам, которые нуждаются в новых формах и способах презентации исторического костюма. Цифровая дематериализация становится единственным способом сохранения, реконструкции, презентации и распространения в мире культурного наследия – текстиля и костюма как национального и культурного индикатора. В истории модные фигуры имели специфические силуэты и пропорции благодаря специальным носимым изделиям под верхней одеждой, такими как корсет, кринолин и многослойное нижнее белье. Это исследование посвящено разработке нового метода реконструкции внешней формы женских и мужских модных фигур XIX века, которые формировались с помощью различных изделий.

Keywords: historical costume, fashionable body, digital twin, corset, crinoline, body dimensions.

Ключевые слова: исторический костюм, модная фигура, цифровой двойник, корсет, кринолин, размерные признаки.

Major famous museums, universities and colleges are working on numerical dematerialization of historical costume to prepare multimedia, digital and online exhibitions. [1, 2] High-resolution images of historical costumes are being shared by the internet platforms, such as Google Arts and Culture project and Australian Dress Register. To get realistic looking digital twin (DT), three contributing factors - morphological features of historical fashionable bodies (HFB), methods of pattern block shaping, and properties of textile fabrics should be considered. In the history, fashionable shape of human body was constructed by means of special garments such as corset, crinoline and inner clothes and was the indicator of popular silhouette and proportions. The corset was inalienable part of women costume. The crinoline was other type of garment which played opposite role of increasing body sizes below waist. A number of underwear which were worn was different and also influenced on the body shape. So, a digital twin of HFB

should be formed under influence of mentioned garments as it historical prototype.

The aim of this research is to develop a computer method of generating DT of HFB of the 19th century by means of technologies of parametric 3D modeling.

In this study three digital twins were created – the native digital twin (NDT) in accordance with historical sizing systems; DT1 with native morphology as NDT but covering by underwear; deformed DT2 with changed morphology by means of corset and crinoline. All DT were generated by means of next software:

- AutoCAD to get vector and parameterized images;
- Clo3D for parametric modeling of NDT;
- Autodesk Inventor for parametric modeling of crinoline and DT deformed by corseting;
- 3DS MAX for generating DT1 and DT2.

All chosen software are completely compatible due to common export/import file formats, such as .obj, .fbx (for 3D objects) and .dxf (for 2D objects).

The scheme of men DT1 generation includes two steps: (1) generating NDT, (2) covering NDT by underwear. The scheme of women DT2 generation includes four steps: (1) generating NDT, (2) deforming a native avatar by corset, (3) covering a deformed twin by underwear, (4) putting underwear skirts on crinoline to get final DT2.

To generate old fashionable bodies in according with existing sizing systems, two types of resources were used – 35 published cutting systems which used by tailors in the XIX century (13 menswear and 22 womenswear) and authentic 62 corsets and 67 crinolines.

Body dimensions for DT generation were established after comparison 75 historical body dimensions and contemporary 31 body dimensions which were taken from Clo3D data base. The both schedules have been compared with each other to determine whether historical dimensions are sufficient to generate DT in contemporary software. Only 12 historical di-

mensions (36%) for men and 12 dimensions (29%) for women. are equal to contemporary ones. So, first part of fashionable body dimensions was used for DT modeling:

- for men DT - height, girths (chest, waist, hip, neck, wrist, thigh, knee, calf), back width;
- for women DT - height, girths (bust, waist, hip, neck, elbow, wrist), bust width, back width, arm length, shoulder width, and width of shoulders.

Chosen dimensions are enough to generate the basic structure of NDT for both genders.

Second part of fashionable bodies dimensions was extracted from authentic corsets and crinolines which were collected from museum exhibitions, patents and books [3...6]. Each garment had one or several elements or details with known sizes which can be measured exactly on its image. Figure 1 shows the schemes of corset and crinoline parameterization.

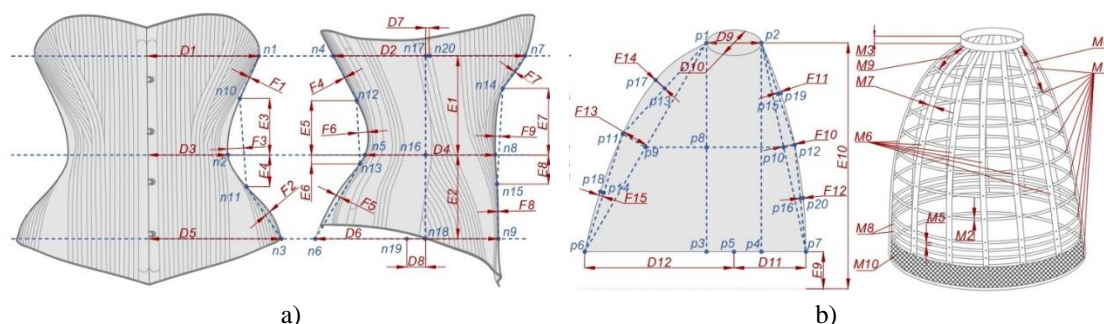


Fig. 1

As shown in Fig.1, to parameterize the both garments, next parameters were chosen:

for corset - horizontal D1...D8, vertical E1...E8 and sloping F1...F9 (Fig. 1, a);

for crinoline- horizontal D9...D12, vertical E9...E10 and sloping F10...F15 (Fig. 1, b).

Additionally, the schedule includes numerical

parameters: the number of hoops M1, M8, ribbons M6, and sections M10, several measurements M2...M5, M7...M10 (Fig. 1, b).

In total 25 parameters of corset and 22 parameters of crinoline were measured. Tables 1 and 2 shows measured parameters.

Table 1

Parameter	Description	Statistics	
		Range, mm	Average variable, %
Horizontal, mm			
D1	Bust front width	106.3...152.1	28.2
D2	Bust profile width	187.2...265.4	
D3	Waist front width	69.1...86.7	
D4	Waist profile width	122.9...191.6	
D5	Hip front width	111.2...190.1	
D6	Hip profile width	186.4...242.1	
D7	Displacement of bust cross-section	3.1...16.3	
D8	Displacement of hip cross-section	1.9...26.4	

Vertical, mm			
E1	Bust-waist distance	103.3...154.2	40.0
E2	Waist-hip distance	63.4...149.1	
E3	Distance between waist and fold of side contour	30.0...89.9	
E4		14.1...64.8	
E5	Distance between waist and fold of back contour	38.7...93.9	
E6		22.1...86.6	
E7	Distance between waist and fold of front contour	43.2...77.4	
E8		18.0...87.4	
Sloping, mm			
F1	Curvature of side contour	0.1...4.3	73.4
F2		0.2...5.1	
F3		3.6...22.5	
F4	Curvature of back contour	0.1...2.3	
F5		0.2...7.8	
F6		0.1...27.8	
F7	Curvature of front contour	0.5...3.3	
F8		0.2...2.9	
F9		1.3...18.6	

Table 2

Parameter	Description	Statistics	
		Range	Average variable, %
Vertical, mm			
E9	Bottom-floor distance	7.6...129	40.7
E10	Profile prominence of front contour	865...987	
Horizontal, mm			
D9	Waist profile width	168...229	137.8
D10	Waist front width	212...342	
D11	Front width	186...1203	56.5
D12	Back width	214...1203	
Sloping, mm			
F10	Curvature of front contour	0...167	89.5
F11		3...79	
F12		-12...46	
F13	Curvature of back contour	32...184	
F14		12...129	
F15		-17...51	
Numerical			
M1	Number of hoops	3...60	156.3
M2	Diameter of hoop's cross section, mm	4...37	
M3	Width of waistband, mm	14...42	
M4	Length of fastening, mm	0...9	
M5	Diameter of bottom hoops, mm	4...18	
M6	Number of ribbons	0...22	
M7	Width of ribbons, mm	12...68	
M8	Number of additional bottom hoops	0...5	
M9	Distance between waist and first hoop, mm	0...342	
M10	Number of sections covered with fabric	0...23	

As shown in Table 1 and Table 2, all parameters were changed significantly through the XIX century. The average variables of corsets (28.2 - 73.4%) are smaller than average variable of crinolines (40.7 - 156.3%). The two ranges of average variables indicate that the

crinoline shapes were more flexible, while the corset shapes were more stable.

For corsets, D-parameters measured along horizontal lines of bust, waist and hip are more stable (average variable is 28.2%), F-parameters which are indicating the sloping of side,

front, and back contours are more flexible (average variable is 73.4%).

For crinolines, parameters D11 and D12 shown that the volume of crinoline was changed in huge range (average variable is 56.5%) because the diameter of bottom hoop has changed in six times: from 400 to 2406 mm. The vertical parameters E9 and E10 were more stable (average variable is 40.7%). The number of hoops M1 was from three to 60 (average variable is 113.8%).

$$\text{Waist grith} \approx \pi 3 \left(D3 + \frac{D4}{4} \right) - \sqrt{\left(3D3 + \frac{D4}{2} \right) \left(D3 + 3 \frac{D4}{2} \right)}$$

The diameter of bottom hoop of crinoline is equal to the sum of D11 and D12.

For modeling of women DT2, two modules of Autodesk Inventor were developed: first module allows to deform women torso under corsetting effect; second module allows to reproduce down part of women body under influence of crinoline. Fig.2 shows the structures of upper and down parts of women DT2.

The corsets deformed women bodies between bust and hip levels. Five cross-sections were chosen to describe the morphology of torso (Fig. 2-a): first one is in coronal (frontal) plane (thick dotted lines), second one is in midsagittal (profile) plane (thick dashed lines), and other three ones are in horizontal planes on bust, waist and hip (thick solid lines). The dimensions and configurations of all cross-sections were drawn in accordance with the similar cross-sections of 3D corset (Fig. 1-a; Table 1). Parameters D1, D3, D5, F1-F3, E3 and E4 were used to generate coronal cross section; parametrs D2, D4, D6- D8, E1, E2, E5-E8 and F4-F8 - midsagittal cross section; D1-D6 - horizontal cross sections. The distances between horizontal cross sections on bust, waist and hip levels were adequate to D7 and D8 respectively.

Because the crinoline consisted from joined horizontal hoops and each hoop has torus shape with a solid of revolution, two cross-sections were drawn (Fig. 2-b). The first cross-section is in vertical midsagittal (profile) plane (thick dashed lines), and the second one

D-parameters have strong relationship with body dimensions: D1 and D2 are related to bust girth, D3 and D4 - to waist girth, D5 and D6 - to hip girth, and D11 and D12 - to diameter of crinoline's hemline. Since horizontal cross sections of body are similar to ellipses, their perimeters were calculated by Ramanujan's equation. For example, the waist girth of fashionable body was calculated by equation:

is in horizontal cross-section on waist level (thick dotted line). The dimensions and configurations of all cross-sections were drawn in accordance with corresponding average parameters of 3D crinoline (Fig. 1-d; Table 2). Parameters D11, D12, E9, E10 and F11-F15 have been used to draw midsagittal cross section, parameters D9 and D10 - horizontal cross section. The transformation of these cross-sections into 3D object had been done by rotating circular sections of the hoops around their axes (vertical thick solid lines). The ribbons which are joining the hoops have been designed by means of parametric array tool. The number of hoops and ribbons and their location are adequate to parameters M1-M10.

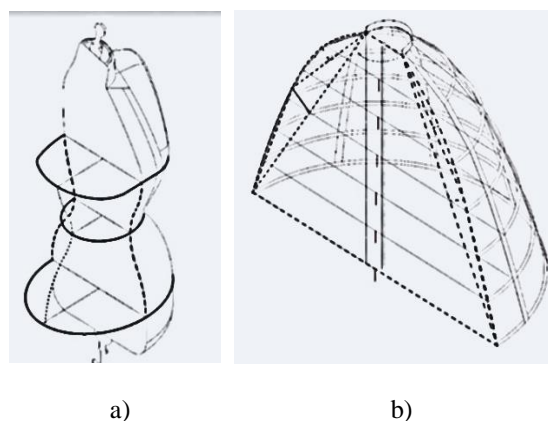


Fig. 2

The both modules allow to generated DT2 automatically in accordance with the inside and outside deformation and transformation of women bodies by corset and crinoline.

Generating of DT2 could be done in accordance or with the exact parameters of chosen corset and crinoline or average values of its parameters calculated from Table 1 and Table 2. Finally to obtain DT of HFB, next procedure was done:

1. NDT was builded in Clo3D with the same body dimensions as more typical historical prototype have had and which were taken from the sizing systems. The basic men dimensions of NDT were, cm: for man digital twin - height 172.7, chest 94, waist 71.1, and hip 96.5; for woman digital twin - height 167.6, bust 88.9, waist 61, and hip 112.

2. Corseted torso of DT2 was modeled in Autodesk Inventor as a copy of 3D corset by using the scheme as Figure 2, a, shown.

3. Crinoline was modeled after measuring its dimensions on front and profile views by Autodesk Inventor module. Parameters L1-L12 and M1-M10 (Fig. 1, b) were measured directly and were taken from the historical patent [7].

4. Three objects - NDT from Clo3D, DT with corseted torso and the crinoline from Autodesk Inventor - were uploaded into 3dsMAX.

5. The underwear were put on the both DT. The underwear were drafted in accordance with a historical pattern cutting system [8, 9]. The similar approach was used for reconstruction men coat [10].

Figure 3 shows DT1 and DT2 and its compasion with NDT.

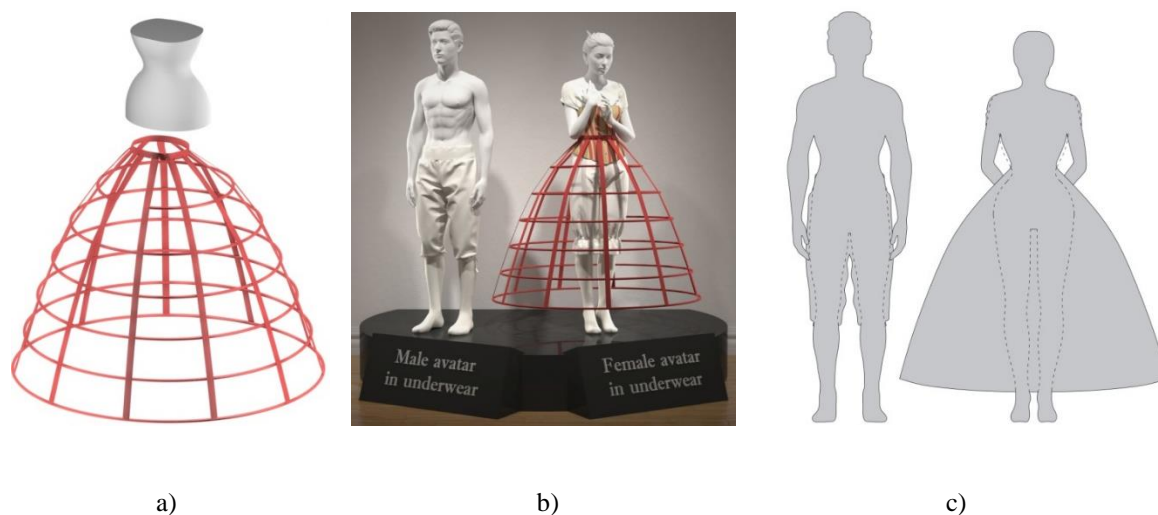


Fig. 3

Figure 3 shown that the contours of DT1 and DT2 (solid fill) are different from the silhouette of NDT (dashed lines). After covering men NDT by underwear its body dimensions didn't change greatly. Women NDT was changed due to the corset and crinoline which affected the body morphology and transformed it into fashionable.

The frontal contours obtained of 3D DT1 and DT2 present the HFB in the XIX century which are reflected many historical factors such as morphological features of historical fashionable bodies and popular garments which were worn under historical costume.

CONCLUSIONS

1. Original data base which are including the historical body dimensions from sizing systems as traditional sizes, on the one side, and the parameters extracted from authentic historical corsets and crinolines as new sizes, on the other side, was developed

2. An algorithm of generating realistic looking 3D digital twins of fashionable bodies including step-by-step deformation of upper part of native body by corset compressing and enlarging of down part by underwear and crinoline was developed.

3. Digital twins of historical fashionable men and women bodies which were popular in the XIX century have been generated by means of contemporary software programs AutoCAD, Clo3D, Autodesk Inventor and 3DsMax.

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