UDC 646

VIRTUAL SHAPING OF HISTORICAL MEN AND WOMEN CLOTHES*

ВИРТУАЛЬНОЕ ФОРМООБРАЗОВАНИЕ ИСТОРИЧЕСКОЙ МУЖСКОЙ И ЖЕНСКОЙ ОДЕЖДЫ

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The article presents new approach how to apply computer-aided design for transformation 2D historical costume images into 3D digital twins. Three historical costume with different methods of shaping from the XIX century – 1840s men dress suit, 1860s women visiting dress and 1887s women sidesaddle riding habit – were taken as the examples for generating its digital twins. Developed reverse engineering

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method which was enriched by new data bases related to costume structure, textile materials properties, and conditions of garment production was applied on the base of computer parametric 3D modeling, automated pattern drafting, and virtual fitting. High accuracy of 3D digital twins of all historical prototypes obtained was proved after comparison its silhouettes with its 2D images.

В статье описан новый подход к использованию САПР для преобразования плоских изображений исторических костюмов в трехмерные цифровые двойники. Три исторических костюма 19 века с различными методами формообразования – мужской костюм 1840 г., женское повседневное платье 1860 г. и женский костюм для верховой езды 1887 г. – были взяты в качестве примеров для генерирования цифровых двойников. Усовершенствованный метод реверсивного инжиниринга в сочетании с новыми базами данных о структуре костюмов, показателях свойств текстильных материалов и условиях изготовления был применен для компьютерного параметрического трехмерного моделирования, автоматического построения чертежей и виртуальной примерки. Высокая точность трехмерных цифровых двойников всех сгенерированных исторических прототипов была подтверждена сравнением их силуэтов с исходными изображениями.

Keywords historical costume, reconstruction, virtual reality, digital twin, textile materials, pattern block.

Ключевые слова: исторический костюм, реконструкция, виртуальная реальность, цифровой двойник, текстильные материалы, чертеж конструкции.

Historical costumes can be transferred into virtual reality (VR) due to development of computer technologies. This new direction will allow to enrich and increase the area of historical costume presentation. A lot of historical costumes were lost and only a paintings, photos and engravings saved its 2D images. Of course, these images contain limited information about costume shape, structure, and specific features. For this reason, computer-aided design (CAD) can be considered as a technological basis to obtain digital twin of historical costume (DTHC) and to enrich content of virtual museums. Due to CAD, 3D DTHC can been generated with high accuracy [1], [2].

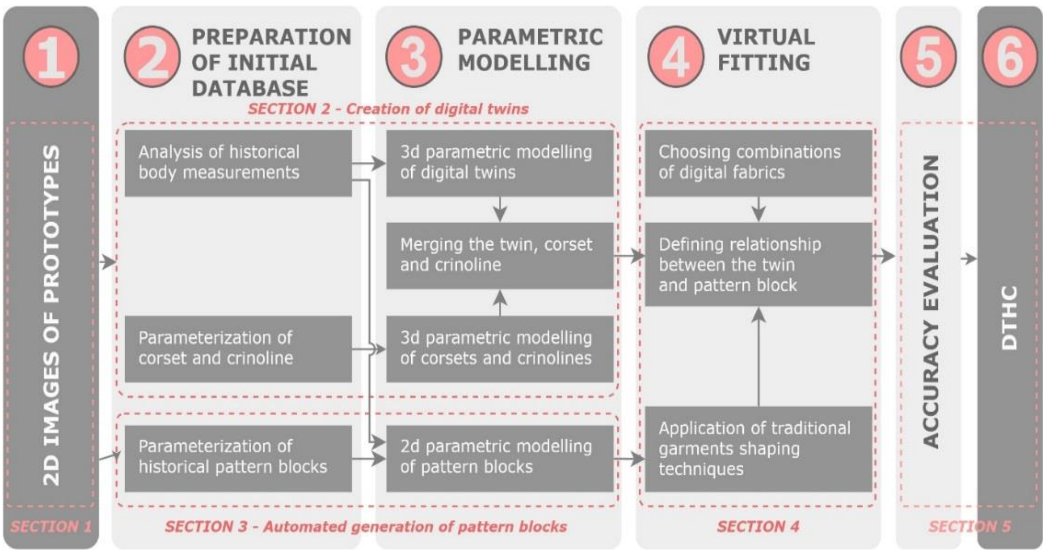


Fig. 1

Aim of research

The aim of this study is to develop an algorithm of the men trousers and women skirts 3D DTHC generating from published 2D images. To obtain DTHC, new algorithm which is joining computer technologies, data bases of human body dimensions, textile materials, and pattern block drafting, have been created. Figure 1 shows the algorithm of DTHC generating from the initial 2D image "body - historical costume".

Fig.1 shown, that the algorithm of 3D DTHC generating includes five steps.

1. Choosing of 2D image of historical costume and its digitization by AutoCAD.

2. Creation of data bases on historical body dimensions, costume construction, and pattern blocks. The content is based on parameterization of 2D and 3D objects by AutoCAD.

3. Parametric modeling of 2D pattern blocks and 3D digital twins (DT) of historical bodies by means of AutoCAD, Clo3D, Autodesk Inventor, and 3DS MAX.

4. Choosing of digital textiles, methods of shaping body twins and virtual garments, and establishing a relationship between them during virtual fitting in Clo3D.

5. Evaluation of adequacy between silhouettes of DTHC and real historical prototype in AutoCAD.

To realize the algorithm, three key technologies were chosen:

1. Parametric 3D modelling.

2. Automated pattern drafting. This technology requires two data bases: first, body sizes, and second, parameters of pattern block.

3. Virtual try-on. Because the physical and mechanical properties of historical materials are unknown, traditional methods of virtual try-on should be modified to evaluate an adequacy between contemporary and historical textile materials. In addition, methods of historical costume shaping should be considered during 3D modelling to get a realistic look of historical materials and clothes.

Objects and methods of research

The costumes of the XIX century were chosen as the objects of reconstruction because many pattern drafting systems and sizing tables were published [3]. Figure 2 shows three chosen historical costumes. Their shapes reflect different methods of cutting, shaping and producing.

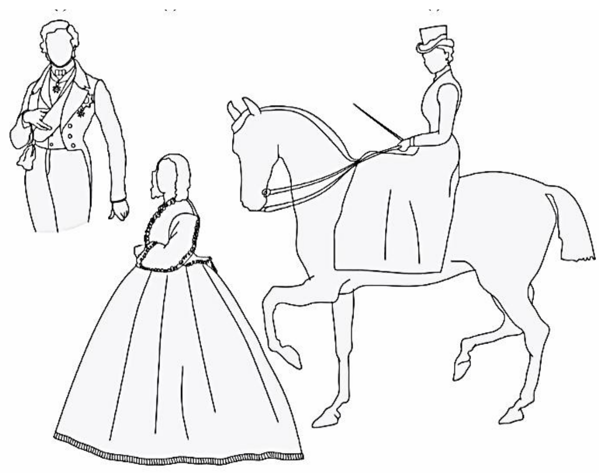


Fig. 2

1. Men full dress suit of Prince Albert of Saxe-Coburg and Gotha (Fig. 2-a) [4]. The suit includes following garments: a dress coat, a vest, a shirt, a pair of trousers, and a pair of undergarment drawers. Shape of men suit copied the body morphology by means of special method of pattern drafting and textile fabrics deformation under heat-moisture treatment. So, this suit is an example of historical costume which is following body morphology.

2. Women visiting dress (Fig. 2-b) [5]. The visiting dress consists of a pair of drawers, a chemise (chemise is a historical type of women's undergarment), a corset (corset is a garment worn to deform the torso into a fashionable shape), a crinoline (crinoline is a stiff petticoat made up of steel, whalebone or cane hoops connected by textile ribbons and designed to support a skirt), a petticoat (petticoat is an undergarment worn under a skirt to soften the edges of crinoline's hoops and achieve the fashionable volume of skirt), a lined skirt, a blouse and a jacket. The bodice has been fitted after torso compression by a corset. A hidden crinoline formed a shape of draped skirt by increasing the dimensions of body. So, the woman's visiting dress is an example of historical costume which was reshaping a body by means of upper and down garments hidden under shell fabrics.

3. Women sidesaddle riding habit (Fig. 2-c) [6]. The riding habit included a jacket, a skirt, a pair of riding-breeches (breeches are a type

of trousers made for riding and worn under a riding skirt) and a blouse. The riding habit is an example of historical costume which shape is produced by draping of fabrics and their ability to follow a morphology of body.

These images do not allow to say exactly which textile fabrics were used, which body measurements and which methods of pattern drafting and garment production were applied to get the final shapes. To answer, next resources about historical costume were used:

tailor's systems of pattern drafting;

sizing tables;

pattern blocks;

instructions and manuals of garment production;

historical and contemporary manuals and handbooks about fashionable costume;

images of historical costumes;

sidesaddle riding manuals;

pattern blocks from historical cutting systems.

14 pattern blocks of garments from which each costume consisted were drafted.

Because pattern blocks were designed in accordance with hade-made technologies of garment producing, three new methods to carry out virtual try-on were developed. These methods have special functions that mirrored the historical technologies of costume production:

1) duplicating historical shaping under producing of the trousers (Fig. 2, a).

2) applying the mechanism of covering a crinoline by historical skirts (Fig. 2, b).

3) finding a relationship between the body posture and draping of textile fabrics for sidesaddle riding skirt (Fig. 2, c).

Results and discussion

To form historical costumes, all historical methods were divided into two groups.

In first group, 3D shape of historical garments relies heavily on shrinking and stretching textile fabrics during the ironing. Contemporary software programs have not functions to shrink or elongate the edges of sewing details and to transform an areas locating inside the details from 2D to 3D. Therefore, the results obtaining by hand-made treatment - deformation of textile fabrics by shrinking and stretching several areas - were replaced by special means of virtual pattern drafting such as the darts which were oriented as the perpendiculars to the edges of details. The sum of darts was equal to the shrinking and stretching deformations.

In second group, 3D shaping of historical skirts was influenced by crinoline and draping properties of textile fabrics which were located on the crinoline. To copy historical shaping in VR, a number of layers of textiles which covering a crinoline and their draping properties should be known. Digital fabrics can be generated after testing similar real fabrics, for example, by means of KES-F or FAST.

Firstly, the digital fabrics from Clo3D library were chosen as contemporary analogies of historical prototypes with similar fiber content and weight [7]. According to historical books and results of museum collections studying, cotton and wool fabrics were chosen for men full-dress suit; for women visiting dress - silk fabrics for shell skirts, hard cotton fabrics - for lining skirts, and light cotton - for petticoats [8], [9]; for women sidesaddle riding habit - cotton and wool fabrics. Because the women visiting dress has more complex structure, it was taken as example. Figure 3 shows the fabrics chosen for the ensemble of skirt.

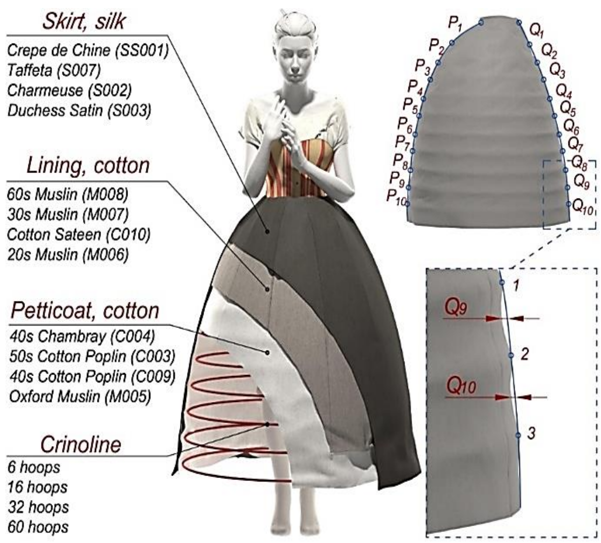


Fig. 3

For skirt of women visiting dress, the identity between real and digital fabrics was evaluated by next criteria: smoothness; an invisibility of hoops contour; an absence of unnecessary folds and creases [10,11]. To evaluate an applicability and combination of chosen fabrics, four crinolines with 6, 16, 32 and 60 hoops were generated. Secondly, three DTHC were generated from shell skirt, lining, and petticoat (Fig. 3 – the list of Clo3D possible digital fabrics and number of crinoline hoops (a); structure of skirt including a crinoline and three covering layers of textiles (b); parameters of shell fabric buckling (c)):

(1) DT + crinoline + shell skirt (one fabric).

(2) DT + crinoline + petticoat + shell skirt (two fabrics gathered).

(3) DT + crinoline + petticoat + lining + shell skirt (three fabrics gathered).

Thirdly, the inward buckling of shell fabric between two neighboring hoops have been measured for each system obtained as Figure 3 shows. The points where the hoops and shell fabric were contacted were marked as points *1*, *2* and *3* and joined as NURBS curve (solid lines). The indicators of deviations have been measured along front Q1-Q10 and back P1-P10 contours separately several times.

So, after testing the fabrics by KES-F, an examination all possible combinations in according with established criteria of identity between real and digital fabrics, the system "crinoline with six hoops + shell skirt “Taffeta” (S007) + lining “20s Muslin” (M006) + petticoat “40s Chambray” (C004)" was chosen for generating of DTHC of visiting dress in accordance with its 2D image (Fig. 2, b).

Table 1 shows the properties of chosen digital fabrics in Clo3D for reconstruction of other costumes.

Table 1

Garments	Fabric type and ID	Content	Properties									
			Weight (density) (g/m$^{2)}$	Thickness (mm)	Stretch weft stiffness (g/s$^{2)}$	Stretch warp stiffness (g/s$^{2)}$	Bending weft stiffness (g/mm^2/s^2/grad)	Bending warp stiffness (g/mm^2/s^2/grad)	Buckling ratio weft (0-1)	Buckling ratio warp (0-1)	Buckling stiffness weft (0-1)	Buckling stiffness warp (0-1)
Men full-dress suit												
Drawers	Cotton sateen (C010)	Cotton	136.9	0.27	594694	1600000	742	1601	0.90	0.90	0.20	0.20
Shirt	Cotton poplin (C009)	Cotton	125.8	0.24	1363880	877343	976	1445	0.90	0.90	0.20	0.20
Vest	Cotton gabardine (C003)	Cotton	189.0	0.35	1700000	1700000	2200	4500	0.10	0.10	0.80	0.80
Dress coat and trousers	Coat-weight twill (W002)	Wool	345.0	0.84	368706	489034	29052	1300	0.00	0.00	0.20	0.20
Women visiting dress												
Chemise and drawers	Cotton poplin (C003)	Cotton	105.0	0.21	280769	356091	15120	938	0.90	0.80	0.50	0.50
Corset	D_Cotton	Cotton	189.0	0.45	150000	150000	1700	1700	0.50	0.50	0.30	0.30
Dress	Taffeta (S007)	Silk	66.1	0.15	700000	700000	1406	153	0.01	0.01	0.80	0.80
Lining	Muslin (M006)	Cotton	143.5	0.35	356725	467417	1367	2773	0.90	0.90	0.20	0.20
Petticoat	Chambray (C004)	Cotton	103.1	0.23	378944	486772	750	1078	0.90	0.90	0.30	0.30

Continuation of table 1

Women sidesaddle riding habit												
Corset	D_Cotton	Cotton	189.0	0.45	150000	150000	1700	1700	0.50	0.50	0.30	0.30
Drawers	Cotton poplin (C003)	Cotton	105.0	0.21	280769	356091	15120	938	0.90	0.80	0.50	0.50
Blouse	Cotton poplin (C009)	Cotton	125.8	0.24	1363880	877343	976	1445	0.90	0.90	0.20	0.20
Jacket, skirt and breeches	Coat-weight twill (W002)	Wool	345.0	0.84	368706	489034	29052	1300	0.00	0.00	0.20	0.20

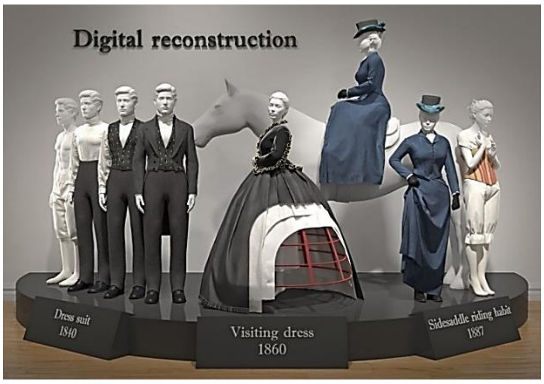


Fig. 4

After finding digital textile fabrics, DTHC were generated with different levels of preparedness as Fig. 4 shows:

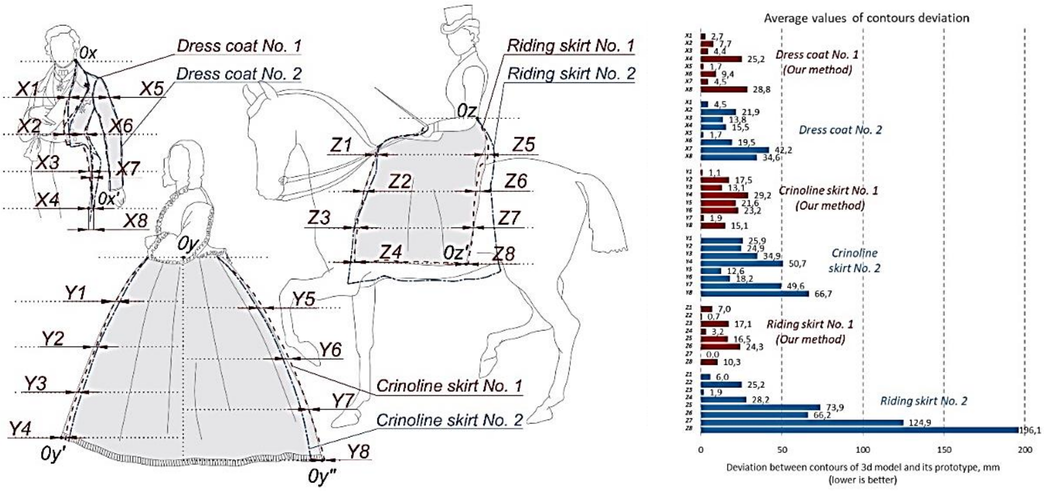
1) DTHC of men full-dress suit: DT + drawers, DT + drawers + trousers +shirt, DT + drawers + trousers +shirt + vest, DT + drawers + trousers + shirt + vest + dress coat;

2) DTHC women visiting dress: DT + crinoline + petticoat + lining + shell skirt;

3) DTHC of sidesaddle riding habit was generated in standing posture and sitting posture.

Fig. 5-a shows three overlapped contours for all generated DTHC: first contour belongs to initial prototype (solid fill), second contour belongs to DTHC obtained by developed method (No.1dashed lines), and third contour belongs to DTHC obtained by known algorithm realized by CLO3D (No.2, dash-dotted lines).

Fig. 5-b shows the values of deviation between the overlapped contours.



a) b)

Fig. 5

As shown in Figure 5 (d), developed method provides smaller deviations between 3D DTHC and its historical images then the known method in 1,8 - 6,6 times. The average values of deviation are (for developed method and known method respectively):

1) for men dress coat - 10.6 (No. 1) and 19.2 (No. 2) mm,

2) for women crinoline skirt - 15.3 (No. 1) and 35.4 (No. 2) mm,

3) for women riding skirt - 9.9 (No. 1) and 65.3 (No. 2) mm.

The higher adequacy of men dress coat No. 1 in comparing with dress coat No. 2 was got due to improvement of virtual try-on by applying new method of virtual shaping which allows to use the darts instead of shrinking and stretching the edges of coat parts. For men dress coat No. 2, values of *X2* and *X6* (-21.9 and 19.5 mm respectively) reflect the absence of heat-moisture shrinkage along front edge, and values *X7* and *X8* (42.2 and 34.6mm respectively) reflects the similar shrinkage in hip area. But for men dress No.1 these deviations *X2*, *X6*, *X7* and *X8* are smaller (-7.7, 9.4, 4.5 and 28.8 mm respectively) due to taking into account the heat-moisture treatment, shrinking and stretching fabrics in new method of virtual shaping.

To get 3D DTHC of women crinoline skirt No. 1, the contemporary analogies of historical fabrics were used which allowed to obtain right location and position of the shell skirt on the crinoline. Known methods of virtual fitting didn't allow to recognize an analogies of historical fabrics and by this reason default fabric from Clo3D library to create the crinoline skirt No. 2 was used. For the both crinoline skirts No. 1 and No. 2, the biggest deviations took place at the bottom of front contour (*Y3* and *Y4* parameters) and back contour (*Y7* and *Y8* parameters). The reason of this effects is the increasing of air gaps between the crinoline and skirts which push digital fabrics to drape and fold in different ways.

For riding skirts No. 1 and 2, the average deviations are 9.9 mm and 65.3 mm respectively.

Thus, developed methods of virtual shaping based on deeply knowledge about historical costume heritage - pattern blocks, technologies of garment production, textile fabrics, costume structure - allow to generate realistic looking digital twins. These methods of step-by step reconstruction of 3D costume from their 2D images in VR will allow to increase a number of historical artifacts in cultural area of many countries.

C O N C L U S I O N

1.The universal approach based on complex application of different types 2D and 3D CAD, new methods and data base were developed for generating digital twins of historical costume presented by 2D images.

2. Three new virtual try-on methods related to "body - historical costume" systems with different ways of shaping - by copying and covering an anthropometrical morphology of human body in static posture, by covering the shape of human body which was deformed by corset and crinoline in static posture, and by covering the deformable shape of body in dynamic posture - were developed.

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