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THE DEVELOPMENT OF E-BESPOKE OF MEN'S SHIRT

СОВЕРШЕНСТВОВАНИЕ ТЕХНОЛОГИИ КАСТОМИЗИРОВАННОГО ПРОЕКТИРОВАНИЯ МУЖСКИХ СОРОЧЕК*

JIAQI YAN, V.E. KUZMICHEV

ЦЗЯЦИ ЯНЬ, В.Е.КУЗЬМИЧЕВ

(Ivanovo State Polytechnical University)

(Ивановский государственный политехнический университет)

E-mail: wkd37@list.ru

Apparel customization has been spread for the exclusive custom-fitted clothing since the emergence of Haute Couture in XIX century. Contemporarily, the MtM (Made-to-Measure) and bespoke apparel can better fit the individual bodies than RtW (Ready-to-Wear) through customized pattern construction, which are now evolving into the new e-bespoke that can digitally and virtually accomplish the process. However, the existing e-bespoke apparel is still defective in evaluation of virtual apparel fitting. This paper proposed an essential method of improving e-bespoke well-fitted men's shirt with the development of body morphological features, original customized pattern blocks, and the evaluation of virtual shirt. With the 3D body scanning and VR (virtual reality) technologies, the virtual clone or virtual twin were generated with new pattern-oriented body measurements discovered, the individual pattern was drafted accordingly, and the digital twin of shirt was established and evaluated with multi-dimension in software CLO 3D. The developed virtual e-bespoke method can assure the fit of men's shirt with higher efficiency and quality than the existing customization.

Кастомизация одежды получила распространение для эксклюзивной индивидуальной одежды с расцветом от-кутюр в XIX веке. Одежда так называемого адресного проектирования MtM (Made-to-Measure) и индивидуального пошива bespoke лучше соответствует индивидуальным фигурам, чем одежда массового производства RtW (Ready-to-Wear), благодаря кастомизации чертежей конструкций, которые сейчас используются в новом e-bespoke процессе благодаря цифровизации и виртуализации. Однако производимая одежда e-bespoke все еще имеет недостатки в виртуальном внешнем

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виде. В статье рассмотрен существенный метод улучшения мужских сорочек e-bespoke с хорошей посадкой на основе нового описания морфологии фигур, оригинальных кастомизированных чертежей и оценки качества виртуальных сорочек. Используя технологии трехмерного сканирования и виртуальной реальности, виртуальные клоны и двойники были сгенерированы с использованием новых предложенных конструктивно-ориентированных размерных признаков, соответствующих индивидуальных чертежей, а цифровые двойники сорочек были созданы и оценены в программе CLO 3D. Разработанный виртуальный e-bespoke метод может улучшить посадку мужских сорочек параллельно с высокой эффективностью и качеством, чем существующие варианты кастомизации.

Keywords: e-bespoke, men's shirt, digital twin, apparel fit, 3D body scanning, body measurement, pattern block, virtual reality.

Ключевые слова: индивидуальный пошив, мужская сорочка, цифровой двойник, посадка, трехмерное сканирование, размерный признак, чертеж конструкции, виртуальная реальность.

Rady-to-Wear (RtW) garments are mass-produced based on the basic typical body measurements organized in the sizing systems [1]. The consumers have frequently complained about the fit problems because that a limited people have typical morphology for one thing, and the limited traditional body measurements and pattern sketching are inadequate for untypical bodies.[2]

As a result of consumers' higher demands of individuality and fit, the prevalence of customized Made-to-Measure (MtM) garments has been escalating.[3] The MtM garments are made through extra process: body measuring, design selection, adjustment from the RtW pattern block, and individual fit evaluation. However, the high-level garment fit cannot be assured. The foremost reason is that process is still based on the traditional body measurements and landmarks, which is not enough for characterizing the morphological features especially in sewing pattern block. Moreover, the traditional MtM mode involves the complex but sometimes inaccurate measuring and repeatable number of real try-on trials.

Contemporarily, the new mode of garment customization named e-bespoke that the whole customization process is digitalized in body measuring, pattern drafting, try-on exhibition, fit evaluation, etc. has been emerging with the evolution of digitalization technologies such as 3D body scanning, virtual reality (VR), etc. 3D body scanner can instantly generate one-to-one virtual twin and accurate body measurements.[4] VR-based 3D CAD can provide the realistic 3D virtual try-on model with optional avatars, sewing pattern blocks, textile materials, and craft details [5].

The processes of garment production are different in many aspects [1]:

a. Different number of body measurements: basic measurements from sizing system of RtW, manual basic measurements from individual body of MtM, and new digital body measurements from virtual twin of e-bespoke;

b. Different construction of pattern block: normalized prototypes based on typical sizes of RtW, customized pattern adjusted from the prototype of MtM, and originally customized pattern of e-bespoke;

c. Kinds of sample making: the real samples of RtW and MtM, and the virtual sample of e-bespoke;

d. Procedure of fit evaluation: fit evaluation by using a real dummy of RtW, fit evaluation by using a real body of MtM, and the fit evaluation based on virtual simulation of e-bespoke;

Some e-bespoke services contemporarily involve the virtual fitting, instant virtual twin generation, etc. [6], [7]. However, the main existing problems are that the applied body measurements are still traditional and inadequate, the pattern is sketched by the RtW or MtM ways, and above all the virtual images are helpful to examine the exterior aesthetics rather than the accurate fit evaluation. These problems will make the fit level of the end-product unpredictable.

Therefore, it's inevitable to improve the process of body measuring, pattern sketching, and fit evaluation, etc. to extend the contemporary e-bespoke. This paper aimed to introduce one important method of developing e-bespoke men's shirt through 3D body scanning and VR technologies with new scheme of body measurements, new pattern customization method, and virtual fit evaluation. The case study of e-bespoke men's shirt validated the feasibility and priority by comparing with RtW and MtM shirts.

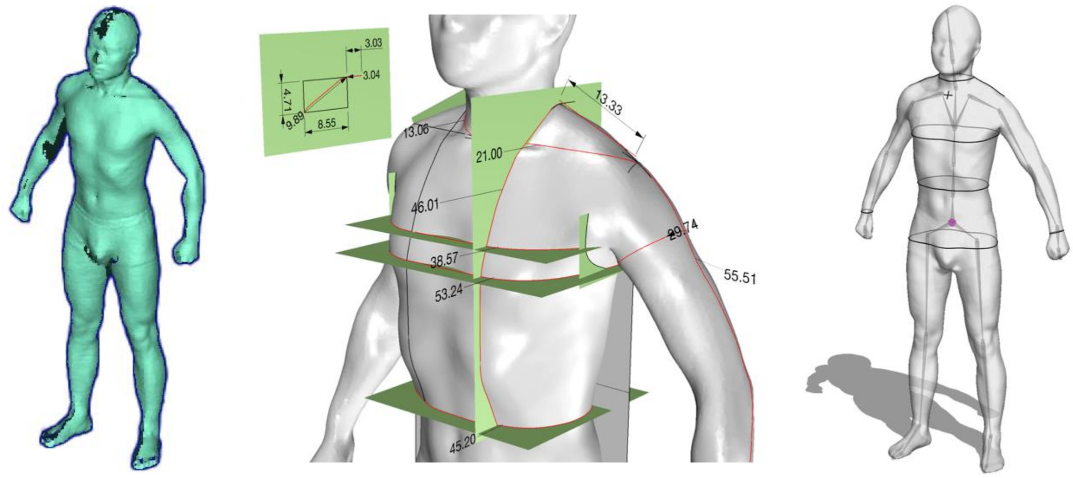
Methods

Devices and software

To develop the e-bespoke shirt, a variety of instrumental devices and software are utilized. 3D body scanner VITUS Smart XXL and the software Anthroscan (Germany) were used to generate 3D virtual clones of male bodies. 3D modeling software Rhinoceros was used to process the body measuring of the virtual twin. Mixamo (USA) was used to convert the raw virtual twin into boned digital twin for subsequent try-on. CLO 3D (version 5.0.156.38765, Korea) was used to conduct both the 2D pattern drafting, the 3D virtual try-on and fit evaluation processes. The mechanical properties of textile materials were measured by KES-F (Japan).

Generation of digital twin and new body measurements

Through 3D body scanning, the one-to-one 3D virtual clone (format obj.) was generated by Anthroscan (Fig.1-a). For one thing, in consideration of the subsequent virtual fitting process, the virtual clone was converted into digital twin (format fbx.) with skeletons inserted by Mixamo. For another, the virtual twins were utilize to conduct the body measuring in Rhinoceros. Fig. 1 (the generation of virtual clone from Anthroscan (a), body measuring in Rhinoceros (b) and boned digital twin in CLO 3D (c)) shows the raw virtual clone, converted digital twin, and the body measuring in Rhonoceros.

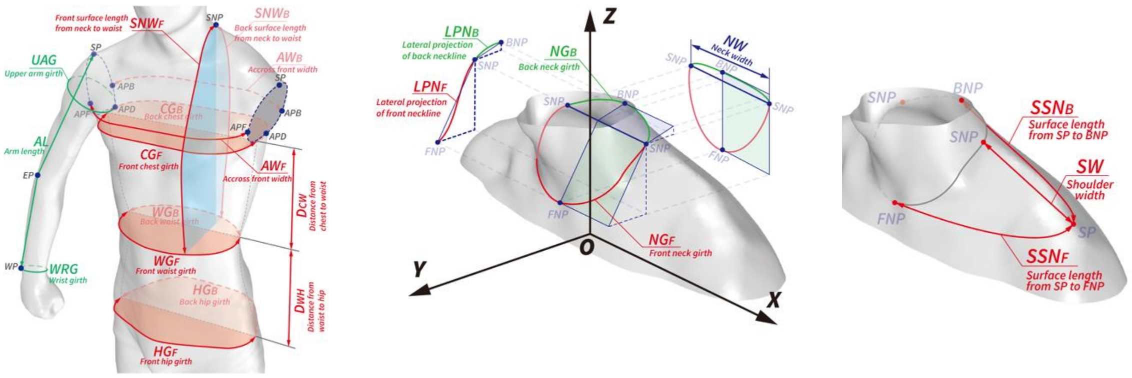


a) b) c)

Fig. 1

As shown in Figure 1, the virtual clone and digital twin had the same morphologies but digital twin can be formed into various body posts for subsequent virtual fitting. The body measurements were measured by making straight lines, cross-sections, projection lines, and surface lines in Rhinoceros.

As usual, the RtW and MtM shirts are made from sizing system or particular body with the basic traditional body measurements (BM_T): chest girth (CG), waist girth (WG), hip girth (HG), neck girth (NG), shoulder width (SW), arm length (AL), etc.[8] To roundly represent the body morphology, more new body measurements (BM_N) were introduced into e-bespoke, which were supposed to be applicable in pattern construction. Figure 2 shows the new body measurements.



a) b) c)

Fig. 2

As shown in Figure 2 (23 new body measurements for e-bespoke men's shirts: a – torso and arm (12 measurements), b – neck (5), c – shoulder (3)), in total 23 BM_N were applied to characterize four body segments:

1. Torso: front girths CG_F, WG_F, HG_F and back girths CG_B, WG_B, HG_B together horizontally represented the anteroposterior torso segments, SNW_F and SNW_B vertically represented the anteroposterior segments, AW_F and AW_B helped to defined the armhole, and DCW, CWH defined the distances between each level;

2. Arm: AL was the arm length, UAG and WRG represented the arm girth and wrist girth, respectively;

3. Neck: NG_F, NG_B were the front and beck neck girths, NW represented the width, and LPN_F, LPN_B represented the front and back lateral projections;

4. Shoulder: surface lengths SSN_F, SSN_B and straight length SW together defined the position of SP.

Through these disposals, the accurate and adequate BM_N can not only depict the body morphology, but also be used in customizing shirt pattern on one thing. On another, the real-sized digital twin can perform the real-time virtual try-on.

Construction of shirt pattern block

The pattern indexes calculated by adding corresponding BM_N and ease allowances are proposed to arrange the feature points and lines of the pattern, cm:

$$I_{P\text{-}BMN} = BM_N + E_{BMN}, \qquad (1)$$

where are $I_{P\text{-}BMN}$ is the pattern index, E_{BMN} is the ease to corresponding body measurement.

According to Equation (1), three types of I_P were applied: $I_{P1\text{-}BMN}$ that equals BM without an ease; $I_{P2\text{-}BMN}$ that equals BM with an invariable ease; $I_{P3\text{-}BMN}$ that equals BM with an ease that varies depending on the shirt style. Both the invariable and variable ease items are predefined before pattern sketching. when the shirt style varies from body-fit to slim-fit, regular-fit and loose fit, $I_{P1\text{-}BMN}$, $I_{P2\text{-}BMN}$ maintain the constant values, while $I_{P3\text{-}BMN}$ should become larger with ease escalating.

The shirt pattern blocks of different segments were constructed by three types of indexes.

Virtual fitting and evaluation in CLO 3D

To keep the consistence between real and virtual environments, three primary elements were considered:

1. Pattern block: the real-sized customized pattern block was sketched in CLO, and the crafting works are arranged as the real ones such as interlining, bottom, sewing, etc.

2. Digital twin: the digital twin was imported into CLO to fit the garments instead of the default typical avatar.

3. Textile material: the real textile material is converted into virtual ones by following the both methods of material conversion: using the exact algorithms to transforming manual-measured values (tensile, shearing, bending) from KES-F to indexes in CLO (weight, thickness, stretch, stiffness, shear); sensory experiments comparing the real and virtual draping images.[9], [10] The virtual fabrics shown the

re-alistic appearance of draping and fitting through the conversion.

The concrete criteria of shirt fit were involved for evaluation: the grain direction of fabric, the ease and air gap between the body (digital twin) and the shirt, the stress folds and unnecessary creases on the surface, the balance in the front, profile, and back views, etc.[11] Through virtual fitting, the multiple fit evaluation can be done. First, the subjective experiment was conducted by analyzing the 3D fitting models and marking scores by experts (there are five levels: 1 – poorest, 2 – poor, 3 – medium, 4 – good, 5 – perfect). Second, the objective experiment was conducted by visualizing the strain map of the shirt and measuring the distortion rates (distortion of the fabric take place when the exterior force is applied).

Results and discussion

To validate the developed e-bespoke method, we accomplished the men's shirts for different bodies following the before-mentioned process, and here we exhibit one case (very untypical male body of 170/92Y type) by comparing with the RtW, and MtM shirts.

Pattern blocks

All virtual clones after scanning, and customized the e-bespoke pattern block were measured (Table 1 – ehe primary BM_N, ease allowances, and corresponding body-fit shirt pattern indexes).

Table 1

Item	Value, cm										
BM_N	CG_F	CG_B	WG_F	WG_B	HG_F	HG_B	NG_F	NG_B	SSN_F	SSN_B	SW
	53.2	40.7	45.2	28.2	49.9	41.5	25.6	15	21.4	20.2	13.7
Ease	E_{CGF}	E_{CGB}	E_{WGF}	E_{WGB}	E_{HGF}	E_{HGB}	E_{NGF}	E_{NGB}	E_{SSNF}	E_{SSNB}	E_{SW}
	2.5	2.5	4.8	9.2	5.5	1.5	1.5	0.5	0	0	0
Index	$I_{P3\text{-}CGF}$	$I_{P3\text{-}CGB}$	$I_{P3\text{-}WGF}$	$I_{P3\text{-}WGB}$	$I_{P3\text{-}HGF}$	$I_{P3\text{-}HGB}$	$I_{P2\text{-}NGF}$	$I_{P2\text{-}NGB}$	$I_{P1\text{-}SSNF}$	$I_{P1\text{-}SSNB}$	$I_{P1\text{-}SW}$
	55.7	43.2	50	37.5	55.5	43	27.1	15.5	21.4	20.2	13.7

As Table 1 shows, the body was particular in anteroposterior proportion of the torso, neckline shape, shoulder position, and arm. The ease allowances were predefined for body-fit shirt that was apt to exhibit the misfit than other styles. And the pattern indexes were accordingly arranged for the body. Figure 3 shows the bodice blocks of RtW, MtM, and e-bespoke patterns for the body [12].

As we can see in Fig. 3 (pattern blocks of RtW, MtM, and e-bespoke shirts [12]), the different quantity and values of the applied body measurements, and the different pattern constructing methods led to the distinguishing between RtW, MtM and e-bespoke pattern blocks. The three kinds of patterns are distinctly different in terms of front and back segments, neckline, shoulder line position, and armhole shape.

Subjective fit evaluation

The fit of three kinds of shirts (made by stretched poplin fabric) can be evaluated and compared subjectively first. The experts were invited to analyze 3D images of three body-fit shirts and mark the scores by sensory experiment (as Fig. 4 (the 3D virtual images of RtW, MtM and e-bespoke shirts. (bright grey - front segment; grey - back segment)) and Table 2 (the scores fit of sensory analysis.)).

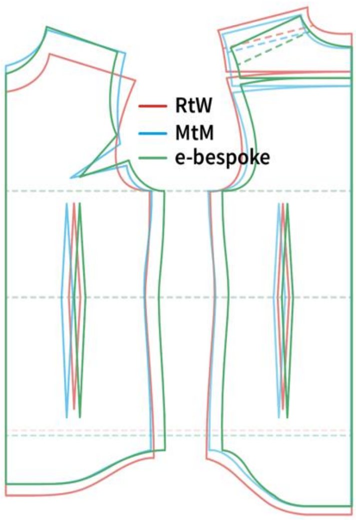


Fig. 3

a) b) c)

Fig. 4

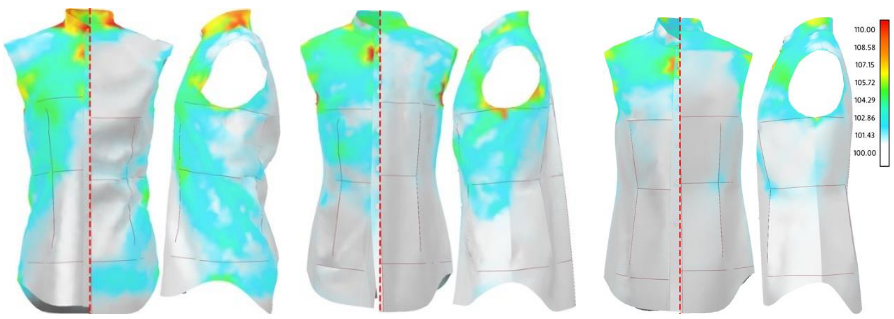
Table 2

Shirt type	Segment				Average
	Bodice	Sleeve	Neck	Shoulder	
RtW	1	2	1	1	1.25
MtM	2	3	3	4	3
e-bespoke	4	4	5	4	4.25

As shown in Fig. 4, the RtW shirt exhibited the poorest fit, and e-bespoke shirt exhibited the best fit, MtM shirt was better than RtW with less folds. The misfit were found on both RtW and MtM shirts: oblique structural lines on the bodice, unsmooth armhole, malposed neck line, and bulge over shoulder. On the contrary, the e-bespoke shirt eliminated these existed misfit with good balance, smooth surface and armhole, and few folds. As shown in Table 2, experts' sensory results proved the comprehensive improvement of e-bespoke shirt especially in bodice, neck and shoulder.

Objective fit evaluation

The objective experiment was conducted by analyzing the strain map and distortion rates of the shirts (As Fig. 5 (the strain maps of RtW, MtM and e-bespoke shirts: a) – RtW shirt, b) – MtM shirt c) – e-bespoke shirt) and Table 3 – the distortion rates of different segments of RtW, MtM and e-bespoke shirts).



a) b) c)

Fig. 5

Table 3

Shirt type	Segment (%)								
	Front chest	Back chest	Front waist	Back waist	Front hip	Back hip	FNP	SNP	BNP
RtW	109.42	101.88	104.53	101.45	104.53	101.91	113.43	108.7	107.43
MtM	110.24	101.83	103.61	101.19	101.99	101.9	103.52	103.77	103.0
e-bespoke	110.02	100.98	101.04	100.77	101.4	100.34	105.83	106.75	101.96

Figure 5 shows the strain maps of three shirts, varied color indicated the different distortion by external forces (white: no distortion, red: highest distortion). RtW shirt was serious distorted around the bodice, neck because of the unbalanced anteroposterior segments and too tight collar. MtM was distorted around the front waist, scapula and armhole because of the unbalanced anteroposterior segments. E-bespoke shown lest distortion, that the fabric hanged on the body usually led to the train around upper chest. Table 3 illuminates the strain areas of three shirts, the e-bespoke shirt shown lowest distortion rates in most areas. The exceptional lowest distortion of FNP, SNP area of MtM was caused by the too large front neck girth.

From the case study, the developed e-bespoke method is better than the contemporary RtW and MtM methods in the new body measurements, new sketched pattern, and improved shirt fit. The ultimate virtual model is helpful to evaluate the fit of the customized product, which isn't provided by the contemporary e-bespoke services.

However, our experiments involved only static pose and one wearing way, which still cannot cover all the situations occur in daily life. In the future, the active poses (such as stoop, squat, walk, etc.) and multiple wearing ways (such as unbuttoning, tucked hem, etc.) will be validated by real and virtual experiments.

C O N C L U S I O N

In this paper, the new e-bespoke men's shirt with the help of 3D body scanner and 3D VR CAD was developed. To accomplish the good fit, new body measurements were proposed to characterize the morphological features of torso, arm, neck, and shoulder, on the one side, to build the new pattern customizing method, and the virtual fit evaluation, on the other side. The RtW and MtM shirt was poorly-fitted, while the e-bespoke shirt shown good fit.

This e-bespoke method could be utilized to improve the contemporary men's shirt customization, and other kinds of possible application. In the future, several aspects such as the real and virtual experiments involving different active postures, ways of wearing, the generation of digital twin will be conducted.

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