

Virtual technology of Made-to-Measure Men Shirt

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Abstract. The aim of this research is to propose the enhanced method of pattern block drafting with novel pattern-oriented body measurements and to optimize the fit of men shirts and customization process that demonstrating by the virtual system “body-garment”. To investigate and devise this method, 119 young male bodies were scanned by 3D body scanner. New anthropometric indexes were proposed according to the theories and basic rules of sketching patterns^[1]. Competitive neural networks and self-organized mapping neural networks^[2] (*SOMNN*) were trained and tested to clustering the male body features into certain types. Thereby novel patterns for diverse types were employed as the database of customized men shirts. Compared with the traditional pattern blocks, the new ones are providing the better fit in virtual environment. Based on the proposed method, the individual pattern could be generated immediately from the existed database with facilitated precision and efficiency, by matching the body measurements of customers to certain anthropometric features.

1. Introduction

Made-to-Measure (*MTM*) garments have become pervasive especially since the flourish of 3D body scanning technologies in fashion industry^[3]. While the final products are either hardly improved, or time-consuming comparing with conventional ones. One of the critical reason is the lack of applicable pattern-oriented anthropometric methods, which could be attained by 3D body scanner and directly utilized in pattern sketching^[4]. To achieve the optimum fit and efficient procedure, new indexes of male bodies were extracted after body scanning^[5], as the components for the individualized pattern blocks. Moreover, with *SOMNN*, the intricate indexes were automatically narrowed down into discernible clusters to express the features of body postures. Meanwhile, the database of men shirt pattern blocks was established, correlated with features of different body segments.

To achieve the fit and eliminate the misfit in individualized men's shirts, this research proposed the exemplary pattern block customization methods with novel scanned body measurements, and validated the feasibility in realistic virtual system “male body-shirt”.

2. Methods and procedure

2.1. Attainment of pattern-oriented anthropometric indexes

119 males from China and Russia at the age of 18 to 30 were classified into Y, A, B, C type in advance according to Chinese standard sizing systems for garments (GB/T 1335.1-2008)^[6]. Moreover, to acquire and validate new anthropometric indexes which are informative for personalized patterns, four pivotal



body segments were processed respectively: neck, area between torso and arm, shoulder, and torso. Hereby all subjects were scanned with 3D body scanner (Human Solutions GmbH) with naturally standing posture and uplifted arm. The generated 3D body mesh models were imported and processed in 3D modeling software Rhinoceros.

As Figure 1 shows, considering the protocol measurements and 3D models, the basic body anthropometrical points were marked as *FNP* (front neck point), *SNP* (shoulder neck point), *BNP* (back neck point), *SP* (shoulder point), *BP* (breast point), *ADP* (armpit depth point). Thus 16 new additional anthropometric indexes were procured and calculated, which were marked as *NGF* (neck girth front), *NGB* (neck girth back), *NDV* (neck depth in vertical), *HDH* (neck depth in horizontal), *D1* (distance between *SP* and *BP*), *D2* (distance between *SP* and *FNP*), *D3* (distance between *SP* and *BNP*), *D4* (distance between *SP* and back waist center), *SA* (shoulder angle), *DSFW* (distance between *SNP* and front waist), *DSBW* (distance between *SNP* and back waist), *DFPB* (distance between front center and profile center on bust level), *DBPB* (distance between back center and profile center on bust level), *DFPW* (distance between front center and profile center on waist level), *DBPW* (distance between back center and profile center on waist level), *AGA* (arm girth through *ADP*), *AD* (armpit depth) respectively in accordance with the segment located.

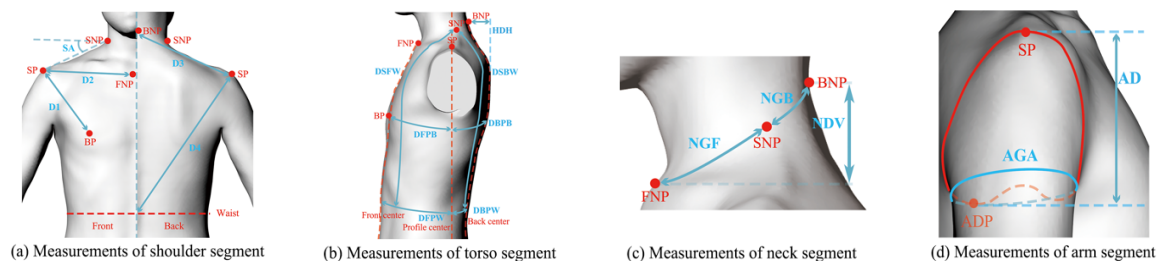


Figure 1. The new anthropometric indexes from 3D scanned bodies.

2.2. Attainment of pattern-oriented anthropometric indexes

According to the air volume between the shirt and the body, the styles of men shirts were generally classified as body fit, slim fit, regular, loose, etc., in accordance with E_{WG} (ease to half waist girth) ranging from 2 to 12 cm. Body fit, slim fit and regular shirts (E_{WG} from 2 to 10 cm) were primarily performed in this research.

At first, in terms of the features of different segments, the pattern prototype could be amended into certain categories accordingly. Besides, the fundamental frame was drawn from the initial prototype and basic body measurements such as chest girth, back length, etc. In consideration of these pattern-oriented body measurements, the shirt pattern prototype^[1] was sketched as Figure 2 indicates.

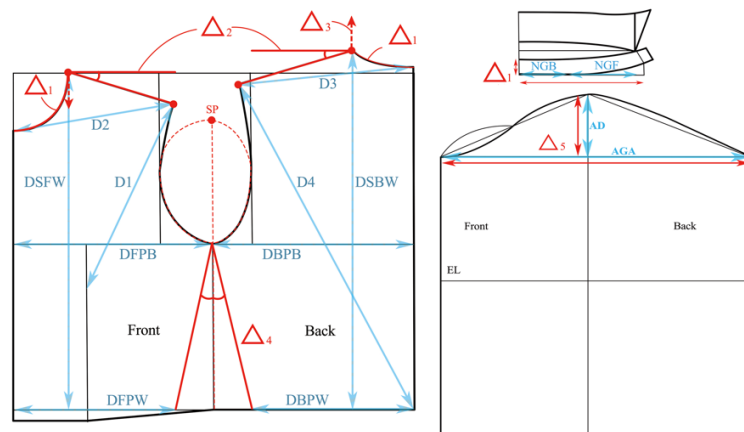


Figure 2. Pattern prototype of male shirts with pattern-oriented body measurements.

The patterns of torso, sleeve and collar were finalized in terms of corresponding new measurements with the pattern block parameters expressed as follow:

$$\Delta_1 = f(NGF, NGB, NDV) \quad (1)$$

$$\Delta_2 = f(D1, D2, D3, D4, SA) \quad (2)$$

$$\Delta_3 = f(DSFW, DSBW, HDH) \quad (3)$$

$$\Delta_4 = f(DFPB, DBPB, DFPW, DBPW) \quad (4)$$

$$\Delta_5 = f(AGA, AD) \quad (5)$$

where Δ_1 is the length and height of collar band, Δ_2 is the sloping angle and length of shoulder deployed by *SP*, Δ_3 is the vertical length of front and back torso deployed by *SNP*, Δ_4 is the proportion of front and back girth in bust and waist level deployed by side line, Δ_5 is the height and width of sleeve cap.

2.3. Classification of the new indexes with neural networks

The pattern blocks of *MTM* shirt are conventionally drafted with detailed measurements according to the basic pattern prototype whereas the postures and features of bodies are variable, sometimes particular and abnormal. Intricate adaption should be conducted to obtain the customized patterns deriving from the prototypes. To simplify the procedure of customization and to improve the fit of final products, the new anthropometric indexes responsible to Δ_1 , Δ_2 , Δ_3 , Δ_4 , Δ_5 were classified, determining the corresponding prototype pattern segments for different categories. Therefore, based on the body measurements and the database of categorized pattern segments, the unique customized pattern could be generated immediately without subsequent adaption.

As one of the most essential unsupervised learning methods in neural network, the competitive neural networks and *SOMNN* were utilized to clustering the new indexes. Figure 3 shows the models of these networks, two layers constitute the network: input layer and competitive layer. The indexes were imported in the input layer, after the calculation of the negative Euclidean distance of input matrix *P* and weight matrix *W* (plus bias matrix *b* in competitive neural networks), the results were exported in the competitive layer with winner neuron outputted 1, and other neurons outputted 0, which indicated the category of the inputs. Moreover, 36 neurons in the competitive layer of *SOMNN* were arranged as the topological structure (6×6 hexagon structure in this research), and the weight were modified with winner neurons (in competitive neural networks) or the neighborhood of winner neurons (in *SOMNN*) in every learning iteration.

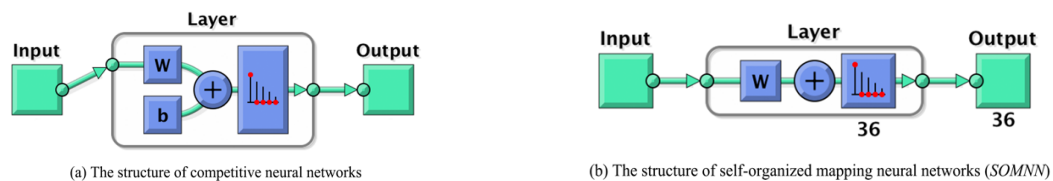


Figure 3. The models of competitive neural network and *SOMNN*.

The samples were separated into training set with 84 objects for training and testing set with 35 for validating the models.

With configuration of necessary parameters (learning rate, weight, bias, learning function, transfer function, etc.), categories of different segments were clustered, and the results of test set proved the veracity of models. As table 1, 2, 3, 4, 5 demonstrates, the indexes were clustered into 4, 3, 3, 4, 2 categories respectively.

Table 1. The mean values of indexes responsible to Δ_1 .

	<i>NGF</i> (cm)	<i>NGB</i> (cm)	<i>NDV</i> (cm)	Neck girth (cm)	Neck diameter(cm)
Cluster 1	14.1	6.9	7.7	42.0	12.4
Cluster 2	14.2	8.1	6.8	44.6	14.1
Cluster 3	12.6	7.5	5.6	40.1	12.9
Cluster 4	12.5	6.8	6.5	38.6	11.8

Table 2. The mean values of indexes responsible to Δ_2 .

	<i>SA</i> (cm)	<i>DI</i> (cm)	<i>D2</i> (cm)	<i>D3</i> (cm)	<i>D4</i> (cm)
Cluster 1	21.3	24.9	21.9	21.1	46.7
Cluster 2	25.4	23.0	21.8	21.5	44.8
Cluster 3	26.9	22.0	20.8	20.0	42.2

Table 3. The mean values of indexes responsible to Δ_3 .

	<i>DSFW</i> (cm)	<i>DSBW</i> (cm)	<i>HDH</i> (cm)
Cluster 1	43.5	42.3	6.3
Cluster 2	46.7	46.1	9.1
Cluster 3	47.1	44.6	6.5

Table 4. The mean values of indexes responsible to Δ_4 .

	<i>DFPB</i> (cm)	<i>DBPB</i> (cm)	<i>DFPW</i> (cm)	<i>DBPW</i> (cm)
Cluster 1	54.1	50.4	49.4	37.0
Cluster 2	45.4	41.3	44.1	29.9
Cluster 3	46.7	51.5	40.4	38.9
Cluster 4	51.8	47.8	44.7	29.3

Table 5. The mean values of indexes responsible to Δ_5 .

	<i>ADP</i> (cm)	<i>AGA</i> (cm)
Cluster 1	15.3	31.3
Cluster 2	13.2	28.2

Additionally, these categories revealed the certain feature of everybody segments. Taking neck indexes as an example, 4 categories of neck type were discovered after classification. The superposition of neck lines shows as Figure 4 obviously, with *SNPs* of all neck lines fixed at the same position. *NDV* of first type was much bigger than others, and the first type and second type had the similar girth while the first one had the biggest *NGB* and diameter. Moreover, the third type had the big *NGB* and small *NGF*, with the *NDV* smallest. The fourth had the smallest neck diameter and *NGB*, leading to the smallest girth. Thus, the classification of neck lines manifested the communality within each cluster, and the observable differentiations between clusters.

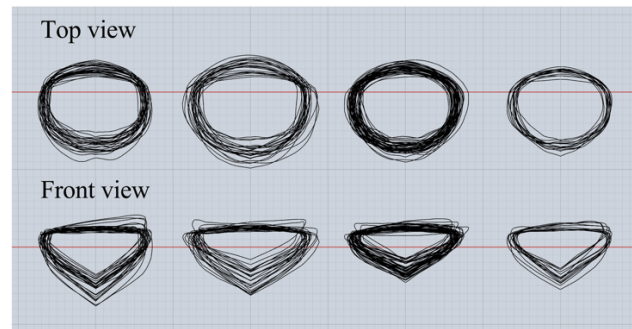


Figure 4. The superposition of different neck types in top and front views.

These classifications of the new anthropometric indexes, related to pattern block parameters, would contribute to the database of categorized pattern segments, which enabled the direct generation of customized patterns for unique people.

3. Results and discussion

According to the Chinese standard sizing systems for garments, the male type 170/92A was selected as an example. Bust girth, waist girth, back length and the ease allowances (ease to half bust girth = 5.6 cm, $E_{WG} = 11$ cm) were used to draw the shirt pattern block^[9] with regular fit by concrete linear regression equations from conventional drafting methods as Figure 5 shows. Afterwards, the scanned male as avatar and the pattern block were imported into Marvelous Designer 6 (3D virtual clothing simulation software). As Figure 6 shows, the try-on results are unsatisfactory. The front piece is attached with the body with little wrinkles, showing proper fit with front torso. While the back piece is squeezed on the buttock area because the body has curved protruding buttock. Moreover, malignant protruding wrinkles are gathering around *SP* and back armhole, indicating the misfit of the shoulder, armhole and sleeve. The bust line and waist line aren't horizontal, indicating the improper proportion of front and back pieces.

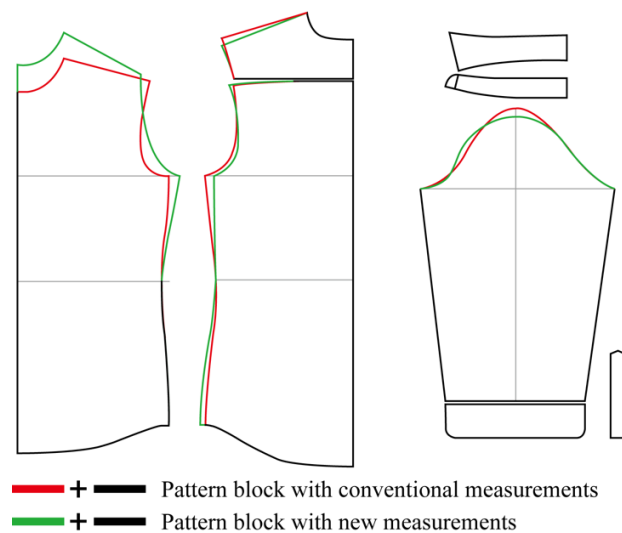


Figure 5. Pattern blocks sketched with conventional and new measurements.

The pattern block was drawn by applying the new pattern-oriented measurements and homologous clusters. The avatar is distinct as broad neck with large girth (42.2 cm) and small *NDV* (5.6 cm) in the second cluster of Δ_1 , quite sloping shoulder with big *SA* (27.6 cm) and small *D1* (21.4 cm), *D2* (20.7 cm), *D3*(21.5 cm), *D4* (43.0 cm) in the third cluster of Δ_2 . Moreover, the avatar has the prominent bust

with *DSFW* (46.3 cm) much bigger than *DSBW* (41.7 cm) in the first cluster of Δ_3 , and concave contour of back with similar *DFPB* (49.1 cm) and *DBPB* (43.7 cm) while *DFPW* (40.9 cm) is much bigger than *DBPW* (32.6 cm) in the second cluster of Δ_4 . The armhole belongs to the second cluster in Δ_5 because of his small *ADP* (12.6 cm) and *AGA* (29.2 cm).

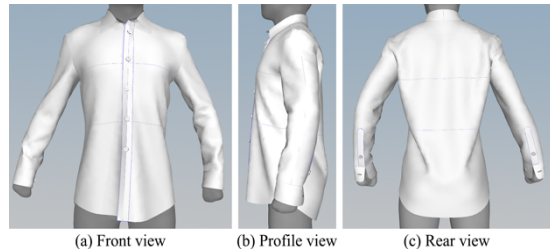


Figure 6. The try-on results of the conventional pattern block.

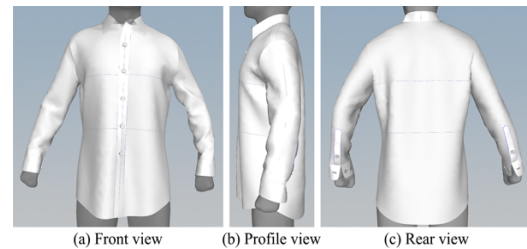


Figure 7. The try-on results of the pattern block utilizing the new measurements.

As shown in Figure 5, new pattern has been strongly modified to adapting the body feature. Firstly, to eliminate the wrinkles on the back piece, *SP* was moved down according to Δ_2 . Secondly, to eliminate the folds and squeeze on the back piece, the bottom was increased and the bust girth was decreased considering Δ_4 . *APD* of the front piece moved backwards accordingly. Then *SP* moved upwards to balance the front and the back pieces considering Δ_3 , to keep the neck line and armhole length, *FNP* and *ADP* moved accordingly. Finally, because of the short armhole depth of this object according to Δ_5 , the sleeve cap was decreased. As Figure 7 shows, the virtual shirt has the good fit. The surface of front piece is smooth with little wrinkle. And there's no squeezed folds around buttock. The bust line and waist line are more horizontal as well.

4. Conclusion

With male bodies scanned, new pattern-oriented anthropometric indexes were observed and measured. Hereby different bod segments were classified into distinct types through unsupervised learning neural networks, on the basis of which shirt pattern blocks were also accessible to be enormously individualized for a certain body. The optimized *MTM* men shirts enhanced by virtual technology revealed better fit than the conventional ones.

In the future, more objects and in-depth measurements will be involved, and the body posture classification model will be intensified gradually. The database of categorized pattern segments will be established accordingly, with which dedicated personalized shirt patterns will be generated immediately in virtual and real system for any customer.

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