

Hierarchical fit criteria of made-to-measure men shirt with virtual technology

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Abstract. In this research we explored the new hierarchical fit criteria of made-to-measure (MTM) men shirt in consideration of the male torso types and shirt styles. As the most pivotal factor of MTM products, clothing fit directly determines consumer's satisfaction towards the clothing. To improve the fit of MTM men shirt with an optimized customization process, 118 male bodies were scanned to attain the conventional and novel anthropometric measurements. Meanwhile, the torso type were classified into five distinct groups in accordance with proportions of anteroposterior girths of different levels. Based on the specific groups, the acceptable eases distribution of the pattern were investigated to form the good-fitted men shirts of different styles in virtual try-on platform. With this methodology, the new fit criteria were proposed especially for improving the mass-production of customized men shirt.

1. Introduction

As the prevalent trends in fashion market, the mass customization which are produced in a highly-digitalized process has been developed^[1], facilitated with new technologies such as 3D body scanning, 3D virtual try-on, artificial intelligent, etc. Novel investigations of new body measurements^[2], detailed morphological features^[3] have been conducted with 3D body scanner, the customization process has been also accelerated by observing the virtual try-on effects of pattern blocks instead of making real samples. Even though, precisely predicting and evaluating the fit and appearance of MTM garments before mass-production is still a tough problem for pattern makers and designers.

To make real and virtual good-fitted customized clothing, a more systematic and efficient procedure should adopted with pattern-oriented anthropometric indexes, individualized pattern blocks and optional clothing styles, etc. This research is aimed to propose the hierarchical fit criteria of MTM men shirt and corresponding pattern block drafting method concerning the male torso shapes and shirt styles with virtual technology. Figure 1 shows the methodology of attaining hierarchical fit criteria of virtual system "body-shirt".



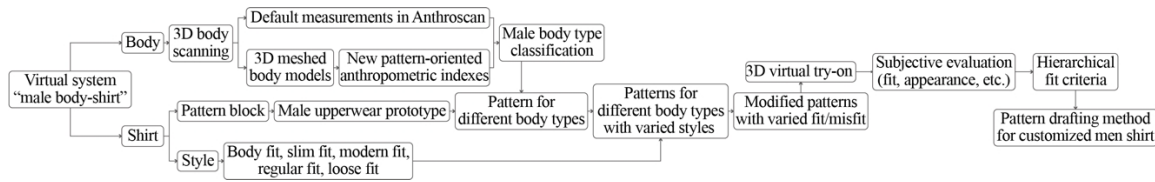


Figure 1. The methodology of investigating the hierarchical fit criteria.

2. Methods

In the virtual environment, the “male body-shirt” was employed as a system considering that the fit and the clothing appearance was formed under the synergy effects of body morphology, pattern blocks, shirt styles, etc. To accomplish the experiment, the following primary software or devices were leveraged: 3D body scanner VITUS Smart XXL for capturing 3D body data, scanning image processing software Anthroscan for generating scanned body models and default measurements, ET CAD 2012 for drafting the 2D pattern blocks, Rhinoceros for marking the feature points and measuring complementary indexes, CLO 3D for 3D virtual simulation, SPSS for data statistics.

2.1. Attainment of pattern-oriented anthropometric indexes

According to the Chinese standard sizing systems for garments (GB/T 1335.1-2008)^[4], the essential body measurements utilized for men’s wear are height, bust girth, waist girth, hip girth, arm length, neck girth, etc., which is far from adequacy for MTM garments. Thus, 118 male bodies without physiological defects at the age of 18 to 30 were recruited to accomplish the 3D body scanning.

Conventionally, the pattern was sketched according to the predefined linear equations of body measurements. Without considering the specific anthropometric features, the misfit of clothing will appear. Thus, the new indexes revealing morphology for individualized pattern should be proposed with the scanned bodies. Firstly, influential levels were determined as the horizontal plane of SP(shoulder point), bust, waist, the most prominent point of belly, the most concave point of back waist, and hip. Then, the height of these levels were measured as H_{SP} , H_B , H_W , H_C , H_P , H_H , respectively. As the proportionality of body being the main factor influencing the clothing fit^[5], anteroposterior girths of different levels were secondly measured. The vertical plane of SP from sagittal view were applied as the bound of front and back torso because of the consistent bound of front and back pieces of pattern. The anterior girths were marked as G_{FB} , G_{FW} , G_{FC} , G_{FP} , G_{FH} , respectively, and the posterior girths were marked as G_{BB} , G_{BW} , G_{BC} , G_{BP} , G_{BH} , respectively. For practicability, the longitudinal distance between SP and other levels were calculated based on the heights as matrix D :

$$D = [D_1, D_2, D_3, D_4, D_5] = [H_{SP} - H_B, H_{SP} - H_W, H_{SP} - H_C, H_{SP} - H_P, H_{SP} - H_H] \quad (1)$$

Where: D_1, D_2, D_3, D_4, D_5 are the difference between H_{SP} and H_B, H_W, H_P, H_C, H_H , respectively. Similarly, the anterior and posterior girths were marked as matrix GF and GB :

$$GF = [G_{FB}, G_{FW}, G_{FC}, G_{FP}, G_{FH}] \quad (2)$$

$$GB = [G_{BB}, G_{BW}, G_{BC}, G_{BP}, G_{BH}] \quad (3)$$

As Figure 2 shows, longitudinal indexes and latitudinal indexes were measured in both Anthroscan and Rhinoceros.

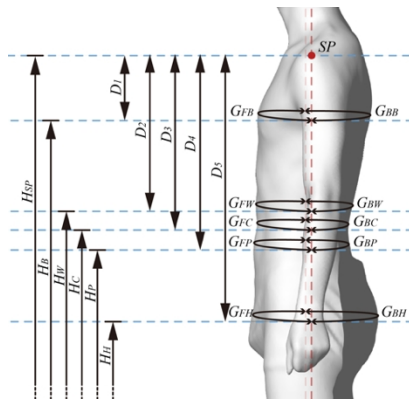


Figure 2. Longitudinal and latitudinal measurements in Anthroscan and Rhinoceros.

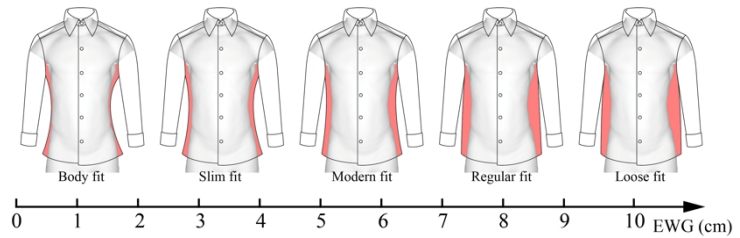


Figure 3. Five shirt styles with different eases to half waist girth (E_{WG}).

2.2. Classification of male torsos

For mass customized clothing, it's time-consuming and intricate to adapt one prototype or original block to individual measurements. To simplify the customization, the more representative male torso shape should be investigated to propose the alternative pattern for certain body. To express the proportion of torso, the Matrix P was marked as:

$$P = [P_B, P_W, P_C, P_P, P_H] = GF - GB = [G_{FB} - G_{BB}, G_{FW} - G_{BW}, G_{FC} - G_{BC}, G_{FP} - G_{BP}, G_{FH} - G_{BH}] \quad (4)$$

Where: P_B, P_W, P_P, P_C, P_H are the difference of front and back girth on the level of bust, waist, the most prominent point of belly, the most concave point of back waist, hip, respectively.

The male torso was classified by K-means clustering method according to the anteroposterior proportional indicator P . With the certain groups of torso, fit criteria could be established for individuals with different morphology.

2.3. Hierarchical fit criteria based on ease parameters

On account of that varied clothing styles have various acceptable ease ranges^[5], shirts in five styles as shown in Figure 3 were investigated synchronously to comprehensively reflect the fit and the appearance variants. Hierarchical ease values of different body locations contribute to various shirt styles, the eases to waist girth (E_{WG}) of five styles were primarily explored in this study.

This session were conducted in virtual try-on software CLO 3D. To eliminate the influence of other fit indicators, the patterns were sketched exactly based on body measurements D, GF, GB . The shoulder and neck area were also modified into balance with corresponding measurements^[6]. By adopting the gradient proportion of front E_{WG} (marked as E_{WGF}) and back E_{WG} (marked as E_{WGB}) with interval of 0.5 cm, the fit and appearance of shirt varied. With subjective evaluation of fit, the exact criteria to get good fit and desired styles were concluded with certain values of E_{WGF} and E_{WGB} .

3. Results and discussion

3.1. Male torso types

K-means clustering method was utilized to classified the torso types with cluster number was defined from 2 to 10 gradually. The results shows 5 clusters led to comparatively lower MSE (mean square error). Table 1 shows the average P of different clusters. The associated sagittal views of different body types varied accordingly as Figure 4 shows. The first type has the flat front and concave back contour, the second one has contractive belly and flat back contour with forward thrust shoulder, the third one has the prominent front and concave back contour with forward thrust shoulder, the forth one has the most concave back with backward thrust shoulder, and the fifth one has the flat front and moderately flat back

contour. Bodies of different clusters differentiate from the others, hereby the individualized pattern and fit criteria varied enormously with the torso type changes.

Table 1. The average P of different clusters.

	P_B (cm)	P_W (cm)	P_P (cm)	P_C (cm)	P_H (cm)
Cluster 1	3.8	13.1	14.8	14.3	8.2
Cluster 2	- 10.4	- 10.4	- 8.7	- 12.1	- 16.6
Cluster 3	- 6.9	- 0.4	0.3	- 0.4	- 4.8
Cluster 4	9.2	22.8	25.4	24.4	17.6
Cluster 5	- 0.9	6.9	7.7	6.3	0.6

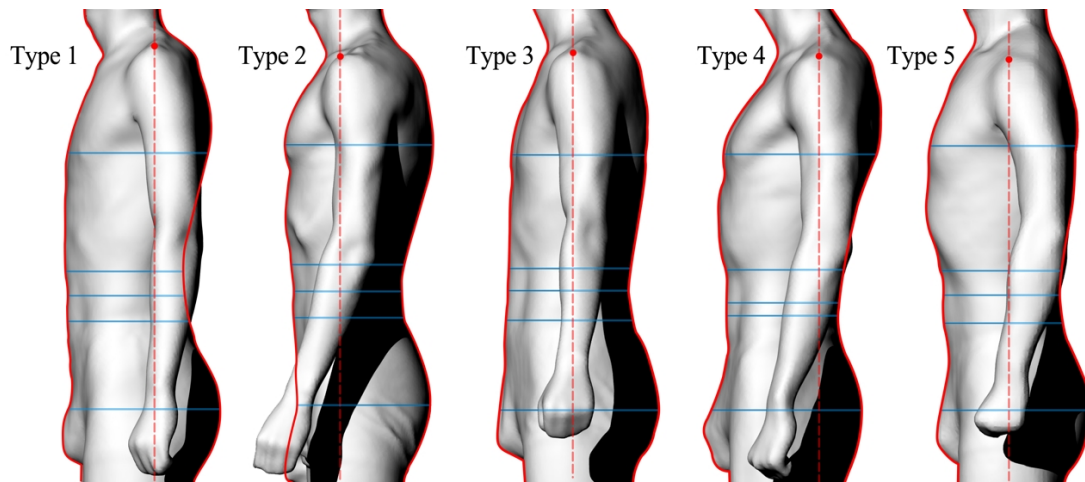


Figure 4. The sagittal views of five types of male torsos.

3.2. The establishment of hierarchical fit criteria

To taking the body of fifth type as an example, the pattern of ready-to-wear men shirt was modified by D , GF , GB , etc. with the ease distributions on bust and hip level were determined. For different styles mentioned before, E_{WGF} was gradually increased from 0 cm to E_{WG} , and E_{WGB} varied accordingly as equation:

$$E_{WGB} = E_{WG} - E_{WGF} \quad (5)$$

E_{CGF} (ease to the half front girth at the level of concave back waist), E_{CGB} (ease to the half back girth at the level of concave back waist), E_{PGF} (ease to the half front girth at the level of prominent belly), E_{PGB} (ease to the half back girth at the level of prominent belly) were modified accordingly with E_{WG} to maintain good fit. The patterns with varied ease allowances were sketched as Figure 5.

The patterns of various styles and distribution of anteroposterior E_{WG} were simulated in the 3D virtual try-on platform CLO 3D. After subjective evaluation of the fit and appearance of virtual clothing (including side-seam, folds and referential lines of different levels, etc.), the best and acceptable ease distribution to attain desired styles were proposed. The best ease distribution revealed best fit with the vertical side-seam, the horizontal referential lines and the minimum folds, and the acceptable one signified slightly skew side-seam and referential lines with few folds, while the unacceptable one represent obvious misfit with the shirt. Figure 6 shows distribution of E_{WGF} and E_{WGB} for attaining the best and acceptable fit for different shirt styles. Obviously, The difference between E_{WGF} and E_{WGB} should be ranged from 2cm to 4cm to maintain good fit. Moreover, the bigger the E_{WG} is, the acceptable range of E_{WGF} and E_{WGB} is wider. And the limit of the acceptable range is the best value ± 2 cm, distinct misfit will appear when the eases are out of the range. To achieve the good fit of shirt with certain style for different body type, the fit criteria concerning the distribution of E_{WG} should be applied to balance the proportionality of body and clothing.

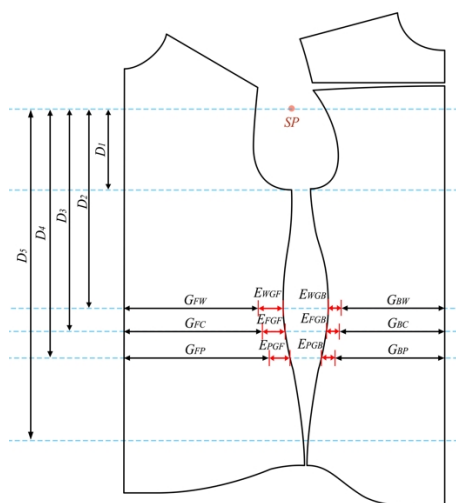


Figure 5. The pattern drafted by D , GF , GB and varied ease distributions.

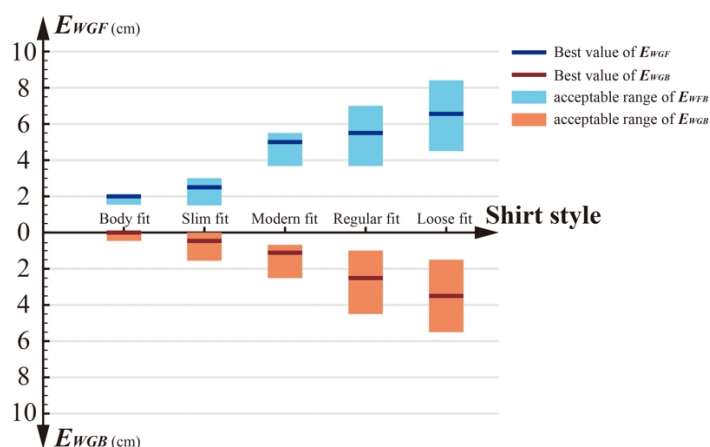


Figure 6. The ease distribution of waist level to attain the best and acceptable fit for different shirt styles.

4. Conclusion

This research proposed the hierarchical fit criteria of MTM men shirt in consideration of the male torso type and shirt styles. With the advised ease ranges for good-fitted shirt, pattern maker or intellectual CAD will be able to draft the customized patterns accurately in desired style and fit for a certain consumer. The new classification of male torso will be helpful to other kinds of individualized clothes. Moreover, the methodology of establishing fit criteria can be applied to other male and female garments.

In the future, the experiments with real bodies and samples will be conducted to verify the results based on the virtual technology. Additionally, more fit indicators will be investigated to acquire the comprehensive and systematic fit criteria for men shirt.

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