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Collaborative 3D-To-2D Tight-Fitting Garment Pattern Design Process for Scoliotic People

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Abstract

This paper presents a virtual design process for a tight-fitting garment pattern for adapted consumer garments, aimed at consumers with scoliosis. The design process proposed is based on a virtual human model created using a 3D scanner, allowing simulation of the morphological shape of an individual with atypical physical deformations. Customized 2D and 3D virtual garment prototyping tools are used in combination to create products through interactions between the consumer, designer and pattern maker. After following an interactive sequence: Scanning – Design – Display – Evaluation – Adjustment, a final design solution acceptable to both the designer and consumer can be obtained. Through this process, traditional 2D garment design knowledge, especially design rules influenced by the fabric information, is fully utilized to support the design process proposed. Using the knowledge based collaborative design process, design satisfaction can be largely improved.

Key words: atypical morphology, virtual prototyping, collaborative design, sensory evaluation, design process.

Introduction

Scoliosis is a three-dimensional deformation (in the three planes of space) of all or part of the spine (cervical, thoracic or lumbar), causing the twisting of one or more vertebrae on each other, which results in a distortion of the thorax, abdomen and paravertebral areas (close to the vertebrae) [1]. The deformations related to scoliosis completely modify the classical 2D garment design process and related design knowledge, which were developed for normal body shapes [2]. In this context, new digital 3D technologies seem to be a unique way for adapting customized garments to the morphologies of physical deformations [3]. There are different researches focusing on the garment construction problem for scoliotic people [4]. For example, Zoran developed a 3D prototyping based method for people slightly scoliotic [5]. In this study, our research interest is garment construction for people with sever scoliosis.

There are several research results related to the 3D-to-2D pattern generation method, especially in the design area of personalization. For example, authors developed a 3D virtual prototyping based garment construction method [6]. However, this research only focuses on technical problems of the 3D-to-2D pattern generation method, ignoring the importance of the design process and interactions between different players in the process. Corresponding pattern design rules should be extracted to support the pattern

generation process. As a pattern design method for personalization design, the concept of collaborative and knowledge supported design should be introduced to these process to enhance the final design satisfaction [7]. To solve this problem, authors [1] proposed the garment design process “*Design – Display – Evaluation – Adjustment*” to enhance the concept of the “design process”. This paper provides a conceptual design process which makes the 3D-to-2D garment construction method more applicable for industrial application. In another paper, a method of introducing an interaction mechanism into the 3D-to-2D garment design process is outlined [8].

In this research, we propose the implementation of a new virtual reality-based design process for adapting consumer garments aimed at consumers with scoliosis, with the novelty being design perception validation and modification.

General scheme of the collaborative 3D-to-2D design process

The design process proposed is based on a virtual human model created using a 3D body scanner, which allows simulation of a consumer’s morphological shape with atypical physical deformations [1], [5]. Next customized 3D virtual draping and 2D pattern-making technology will be used interactively to create products.

The design process proposed is based on the concept of collaborative design,

which has been successfully applied to 3D garment design for normal body shapes [9]. In this process, the customized form of a product, including its basic elements, such as garment patterns and their compositions, is initially determined by applying the virtual draping technique to a specific atypical morphotype of a consumer and by using the 3D digital design concept. Classical 2D design knowledge is used to provide references or inspiration for new 3D design solutions. The 3D virtual product designed is displayed to both to designers and consumers. A normalised sensory evaluation procedure is proposed to facilitate their communication regarding the perception of the garment evaluated in terms of its fit. This evaluation procedure will be flexible and adapted to different categories of garments and atypical morphotypes. By investigating the classified atypical morphotypes, a designer can repeatedly adjust the initial garment patterns generated by 3D design software (from 3D to 2D) using his/her professional knowledge and can then quickly display the virtual 3D garment fit of the adjusted 2D patterns using another garment CAD software (from 2D to 3D). The corresponding parameters, such as materials, colours and styles, can be taken into consideration throughout the procedure. After multiple repetitions of the following sequence: *Scanning – Design – Display – Evaluation – Adjustment*, we identify the final design solution which will be accepted by both the designer and consumer. Additionally, successful design solutions will be integrated into the fashion design

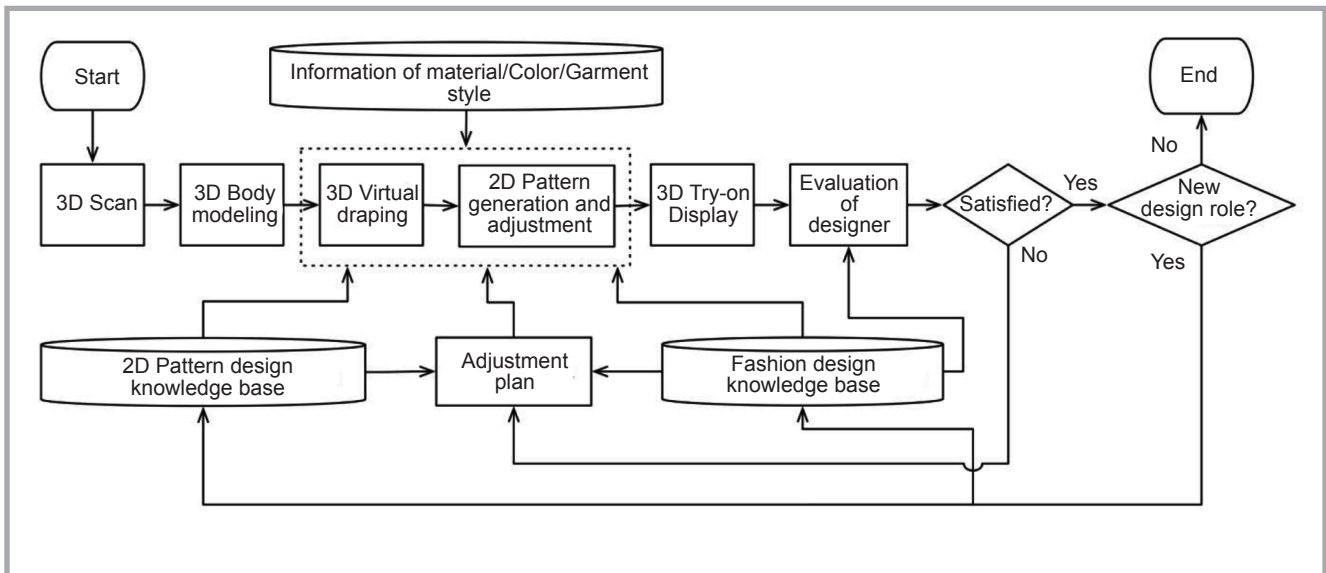


Figure 1. General scheme of the collaborative 3D design process.

knowledge base to generate new design rules and to enhance professional design knowledge. The general scheme of this collaborative-based design process is shown in *Figure 1*.

3D-to-2D pattern generation process

3D pattern-making using virtual try-on is an empirical method that uses the knowledge and know-how of pattern makers [10]. The process of 3D virtual garment generation comprises the following steps: 1) 3D human body modeling; and 2) 3D pattern-making through virtual try-on

3D scanning and 3D human body modelling

The data acquired from a body scanner constitute a set of three-dimensional points describing the human body surface. From these points, a triangular mesh model of the human body formed of small facets can be created. Each facet corresponds to a small area of the body surface, which can be modified. The number of facets determine the accuracy of the virtual body surface. To characterise the body shape, we need to set up a complete digitalised human model using data previously measured. The steps of modeling are as follows:

- Step 1 – Uniformly take 4 scanned pictures of the human body from different views, each corresponding to 1/4 of the full scan result (*Figure 2.a, b, c, d*), using a 3D scanner and ScanWorX software from the Human Solutions Company.

- Step 2 – Using Rapidform software to combine the different pictures (*Figure 2.e*), rotating and merging them to generate one complete 3D virtual human body model (*Figure 2.f*). A reference axis is applied here to find the corresponding positions of different images or different views to generate a unique virtual human body model.
- Step 3 – In Rapidform software, fill the holes (invariably made) of the human body model, and remove the excess part near the hands and feet; cut the feet at a plane parallel to the ground, smooth out the body form, and ensure that all holes are filled in on Rapidform.
- Step 4 – Using the same software, mesh the surface of the body model with 600-700 facets in Rapidform.
- Step 5 – In DesignConcept 3D software, import the modified digitalized 3D human body model from the Rapidform software for subsequent use.

The result obtained from the Design Concept 3D software is the final digitalised 3D human body model, from which a 3D garment can be created.

3D garment modelling and 2D pattern generation

In this research, in order to simplify the problem, the design object is a customised garment block. As the primary design of a garment, it can be extended to all other types of products of the same category (T-shirt, vest, jacket) using various design ideas and allowance values;

this process can fully satisfy the wearer's needs for various types of styles. Moreover the design process proposed can be completely explained when creating the garment block. In fact, if we design garments with too much wearing ease, some advantages of the design process proposed will not be shown.

The garment block proposed and its corresponding patterns developed should fulfil the following requirements: (1) the 3D virtual garment is constructed to align with the human body feature lines so that the wearing ease values can be controlled and distributed for different wearing purposes; (2) the seam and style lines of the 3D virtual garment are constructed to follow the body contour and facilitate the flattening process; (3) the 3D virtual garment can be flattened without distortion, satisfying textile properties and manufacturing constraints; (4) the garment block proposed and its corresponding 2D pattern should fully consider the physical disfigurement of the customer, as well as fit problems. The design process for generating a 3D virtual garment and corresponding 2D patterns follows the following steps:

- Step 1 – Take knowledge of human anatomy to observe the body shape and define the reference coordinate axes (*Figure 3.a*)
- Step 2 – Using DesignConcept software, locate the fit and fashion points on the human body, and then determine the fit points on the garment that correspond directly to those of the human body (*Figure 3.b, Figure 3.c*)

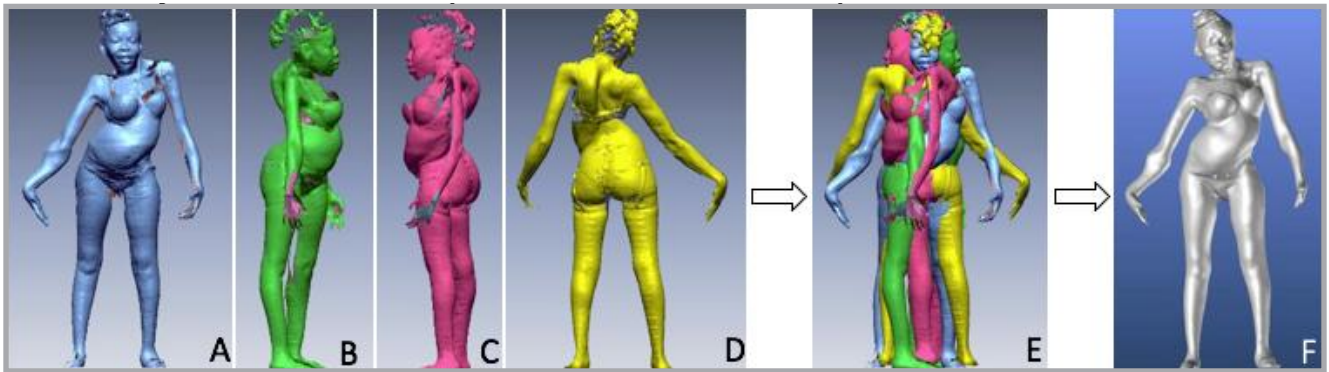


Figure 2. Method for creating atypical body surface [6].

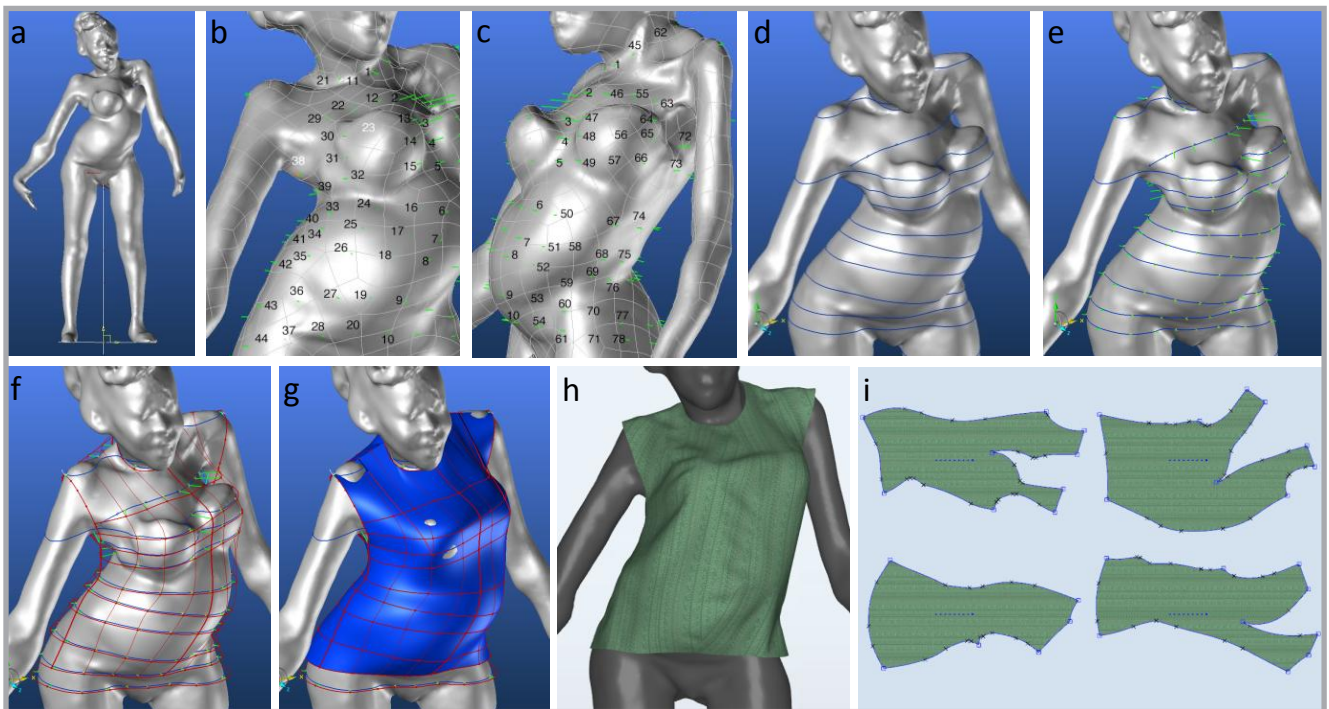


Figure 3. Generation of a 3D virtual garment and corresponding 2D patterns [6].

- Step 3 – Using DesignConcept software, determine the fashion curves with different wearing ease values according to the fit points and wearing purpose (Figure 3.d, Figure 3.e)
- Step 4 – Using Design Concept software, establish a garment model wire-frame and model the 3D garment surface (Figure 3.f, Figure 3.g)
- Step 5 – Using Modaris software, generate 3D and 2D patterns according to the principle of classical 2D pattern design, including darts, folds, opening, fabric direction (warp and weft directions) and other important 2D pattern elements (Figure 3.h, Figure 3.i)
- Step 6 – Adjustment of 2D patterns using Modaris software satisfies the industrial applications.

In this study, the wearing eases on different positions of the garment have been designed to have minimal values, meeting the requirements of the garment block. Table 1 shows some representative feature points and their corresponding wearing eases for different wearing purposes. In this process, the values of wearing eases are carefully defined using

fashion design knowledge and 2D pattern-making knowledge using the related design rules according to the fabric information proposed.

The final design obtained using the design process proposed as well as the corresponding garment patterns are shown in Figure 3.h.

Table 1. Wearing ease distribution on some key features points (fashion points) of the body for different wearing purposes.

| Purpose | Feature points (fashion points) in Figures. 3–6 and Figures 3–7 | | | | | | | | |
|-------------------|---|----|----|----|----|-----|-----|-----|-----|
| | 22 | 26 | 46 | 71 | 93 | 102 | 110 | 115 | 135 |
| Basic fitting, mm | 30 | 8 | 30 | 10 | 12 | 9 | 10 | 32 | 30 |
| Sports, mm | 40 | 16 | 40 | 18 | 22 | 16 | 18 | 44 | 40 |
| Home, mm | 35 | 13 | 35 | 15 | 17 | 14 | 15 | 37 | 35 |
| Dinner, mm | 32 | 10 | 32 | 12 | 14 | 11 | 12 | 34 | 32 |

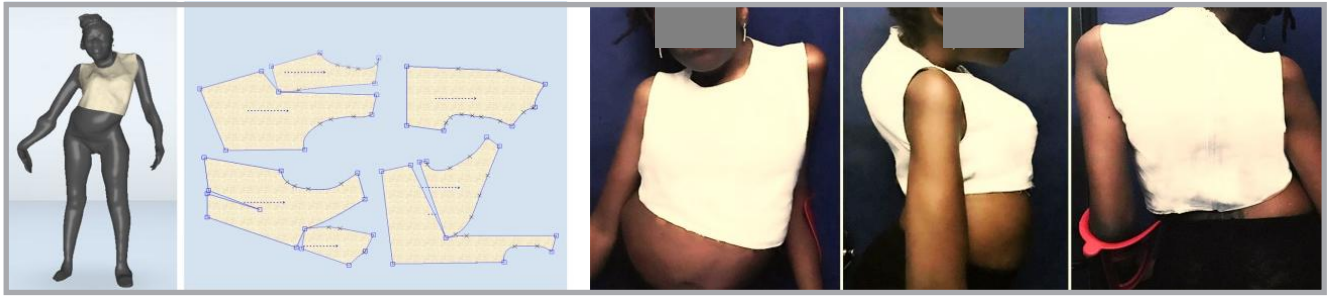


Figure 4. Final garment block and corresponding 2D patterns [6].

Evaluation and adjustment of the design result

In this study, a session of sensory evaluation is used by a group of fashion designers to quantitatively characterise 3D virtual try-on perception. The adjustment of garment patterns can be accomplished in the garment technical space according to sensory evaluation results regarding the performance of the finished product in the 3D virtual environment, which is generated using the virtual draping method [11]. The product here is a garment block. As an unfinished product, it is widely used to help designers and pattern makers with further designs; obviously, it will not be on sale in a garment store in industry. Consequently the wearer will be not involved in the evaluation procedure, which is a bit different from a ready-to-wear product.

Evidently the key issue of this adjustment is to set up a model characterising the relationship between the technical space and 3D virtual product perceptual space [12]. This model will permit the generation of appropriate technical parameters of the garment according to the desired values of sensory evaluation of the effects of 3D garment try-on.

The quality of apparel appearance can be described using its visual 3D shape, whereas aesthetic appearance can be done so through its drape and fit quality [13]. Both can be evaluated according to either expert opinions or wearer responses. Rating scales for the number of critical fit locations are often used to measure the fit evaluations of both the wearer and expert designer [14]. The evaluation of 3D garment fit has been studied by many researchers using classical descriptive sensory analyses. These techniques permit quantitative characterisation of the human perception of 3D garment virtual try-on results, enhancing communications between different players of the textile supply chain regarding the

finished product. In our project, the aim of garment fit in 3D virtual try-on evaluation is to identify normalised sensory descriptors which constitute the common communication language between fashion designers, pattern makers and garment consumers. In our study, five experienced fashion designers are involved in the evaluation.

For simplicity, in our experiment, we use only one fabric (100% plain cotton) to generate different virtual garments (sleeveless T-shirts) by changing the parameters of the garment patterns. The parameters of this fabric sample as well as the patterns selected constitute the inputs to the Modaris software for using 3D virtual try-on. Different from ready-to-wear, which includes various design elements and wearing ease due to personalised experience and preference, the product considered here is a basic garment block, regarding which designers can generally have a common idea with respect to garment style. In this context, the sensory evaluation results of garment fit given by different designers can be very similar. The sensory evaluation procedure used in our study is as follows:

- Each trained designer generates an exhaustive list of categories describing the apparel fit performance according to his/her professional knowledge. Next the most relevant categories describing the key positions of the specific garment are selected. For the garment block in our study, the designers select three categories: “Overall image”, “fit in width” and “fit in details”. Finally a list of descriptors describing the apparel fit in different categories is generated by the designers using their garment design knowledge and pattern design knowledge.
- Redundant descriptors and those irrelevant to garment fit are reduced by performing a “round table” discussion among the panelists. This step leads to the generation of 8 normalized de-

scriptors describing the apparel fit performance (see **Table 2**). Moreover for each descriptor a scale of five evaluation scores ranging from -2 to 2 is also obtained. “-” means that the garment is tight or small in relation to the body shape, while “+” means the opposite (big or loose). 0 denotes a perfect fit on the wearer. Each score of the scale is semantically defined in **Table 2**.

- By repeating the evaluation twice and taking the average of the evaluation scores for each sensory descriptor, we finally obtain a matrix composed of all evaluation scores.

The adjustment of the current patterns will be accomplished using a rule-based model characterising the relation between evaluation values of the garment fit (perceptual space) and modifications of garment patterns (technical space). This has been established by exploiting the common professional knowledge of designers and pattern makers through a round table discussion between the panelists.

The procedure of modelling comprises the following two steps:

- Step 1 – Identification of the garment modification rules

These rules will enable determination of the key points or key lengths of the garment patterns corresponding to each sensory descriptor to make the final design product very close to the target size sought by the designers. The final modification rules provided by the designers and pattern makers are given in **Table 2**. There often exist several modification rules of each sensory descriptor. However, in practice, only one rule is applied during the adjustment. One example is given below.

If we wish to modify the “overall fit” (D_{A1}), then we can change the length of either the waistline (D_{A1a}), breast line (D_{A1b}) or shoulder line (D_{A1c}).

■ Step 2 – Identification of new values of change for garment patterns

For each modification rule, the change in the identified key point or key length is determined according to the evaluation score of the corresponding sensory descriptor. Values of the change in patterns in relation to all the modification rules, provided by the designers, are shown in **Table 2**. For example, when applying modification rule D_{A1a} in relation to the “overall fit”, if the evaluation score is -1 (a little tight), then 4 cm will be added to the length of the waistline.

In practice, one modification rule and its corresponding pattern changing value can be arbitrarily selected, and its try-on result can be quantitatively characterised using the sensory evaluation. If the adjustment result is not satisfactory, another rule of the same sensory descriptor will be selected to generate a new try-on result. This procedure can be repeatedly carried out until the most relevant adjustment plan is found.

By using the previous two steps, we set up the relationship between the 3D virtual garment try-on results and 2D pattern parameters (key points and key lengths). This rule-based model allows the achievement of a desired perception of garment fit by adjusting the 2D pattern parameters. In this study, the procedure of *Scanning – Design – Display – Evaluation – Adjustment with the Model* can be repeatedly performed until a satisfying design solution is obtained.

After several interactions, the final block is realised. Fabric information including fabric texture and physical parameters is also simulated in the final block, as presented in **Figure 4**. A real garment block is also made to validate the design method proposed. It can be concluded that the design method proposed is able to control the design result based on the morphology using a collaborative design process.

■ **Conslusions**

In this study, we developed a collaborative garment design process using 3D virtual draping for disabled people with scoliosis. A digitalized 3D human body model created from 3D scanning was investigated to define the feature points of the human body. Then the garment feature points were used to shape the 3D

Table 2. Evaluation and adjustment of 3D try-on perception.

| Categories | Sensory descriptors of garment fit | Modification rules | Evaluation Scores and modification values | | | | |
|--|------------------------------------|--|---|----------------------|---------|--------------------|----------------|
| | | | -2 | -1 | 0 | 1 | 2 |
| | | | Very tight/small | A little tight/small | Perfect | A little loose/big | Very loose/big |
| D_A : Overall image | D_{A1} Overall fit | D_{A1a} Change the length of waistline | +8 cm | +4 cm | 0 | -4 cm | -8 cm |
| | | D_{A1b} Change the length of breast line | +8 cm | +4 cm | 0 | -4 cm | -8 cm |
| | | D_{A1c} Change the length of shoulder line | +4 cm | +2 cm | 0 | -2 cm | -4 cm |
| | D_{A2} Length | D_{A2a} Change the length of garment | +4 cm | +2 cm | 0 | -2 cm | -4 cm |
| D_B : Fit in width | D_{B1} Waist fit | D_{B1a} Change the cut of side seam | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| | | D_{B1b} Change the value of waist dart | +2 cm | +1 cm | 0 | -1 cm | -2 cm |
| | D_{B2} Breast fit | D_{B2a} Change the cut of side seam | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| | | D_{B2b} Change the value of breast dart | +2 cm | +1 cm | 0 | -1 cm | -2 cm |
| | D_{B3} Hem fit | D_{B3a} Change the cut of side seam | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| | D_C : Fit in details | D_{C1} Shoulder | D_{C1a} Change the slope of shoulder line | +4° | +2° | 0 | -2° |
| D_{C1b} Change the length of shoulder line | | | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| D_{C1c} Change the width of neckline | | | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| D_{C2} Neck | | D_{C2a} Change the width of neckline | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| | | D_{C2b} Change the depth of neckline | +3 cm | +1 cm | 0 | -1 cm | -3 cm |
| D_{C3} Armhole | | D_{C3a} Change the position of sleeve top | +2 cm | +1 cm | 0 | -1 cm | -2 cm |
| | | D_{C3b} Change the curvature of the arm hole | +2 cm | +1 cm | 0 | -1 cm | -2 cm |

garment wireframe, from which 2D garment patterns could be generated. Then a quantitative sensory evaluation procedure was conducted. By using the evaluation results, a knowledge-based pattern modification model could be applied to progressively converge the virtual try-on results with the perception desired. By adjusting the 2D garment patterns, a 3D virtual try-on could be performed. By following the cycle of *Scanning – Design – Display – Evaluation – Adjustment*, the garment collaborative design process enables interactions between designers, shoppers and consumers for generating a relevant design solution that meets their requirements. The method proposed has been successfully applied to people with atypical morphologies and has been validated via a quantitative comparison with the classical garment CAD method. As a collaborative design process, the application of the 3D virtual draping and sensory evaluation method can fully control the relationship between the garment design technical space and the conceptual space of the finished garments so

that a desired 3D garment fit can easily be realised via the adjustment of technical parameters. 3D scanning technology is used to generate a complete digitalized 3D human model, permitting the extraction of the main features of body shapes without accurate measurements. As a knowledge-based design process, both fashion design knowledge and 2D pattern-making knowledge can be extracted to provide inspiration and references. Successful design solutions can be integrated into the fashion design knowledge base to generate new design rules and to enhance professional design knowledge. The design process proposed can be further applied to the customised design area.

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- Vertex 70 FTIR spectrometer with Hyperion 2000 microscope, Brüker
- Differential scanning calorimeter DSC 204 F1 Phenix, Netzsch
- Thermogravimetric analyser TG 209 F1 Libra, Netzsch with FT-IR gas cuvette
- Sigma 701 tensiometer, KSV
- Automatic drop shape analyser DSA 100, Krüss
- PGX goniometer, Fibro Systems
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