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3D Garment Modelling – Conception of its Structure in 3D

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Abstract
This work presents the results of our approach in the field of modelling and numerical simulation of a garment in a 3D virtual environment. In our study we take into account the strategic point of approach where the numerical avatar model integrates the garment model by association without difficulty. On the other hand the flattening of 2D and 3D garment patterns need to be associative, accurate and impose the existing fabric deformation linked with a garment drape. The results mentioned in our previous paper showed that the adaptive mannequin morphotype model follows the human body morphology from the scanner, although large deformations were imposed to the initial human body during the creation process presented. This model is dedicated to the ready-to-wear garment sectors except for garments very close-fitting to the body (ease allowance value = 0 or negative) such as corsetry, because in this particular case it is necessary to consider the evolution of the chest for women. Moreover the concept of design offered is of sufficient interest to follow the results of the measurement. With this adaptive mannequin morphotype model, we will describe the study on the development of garment models in a 3D environment.

Key words: *3D garment modelling, virtual garment, morphotype.*

Introduction

Until now, the creative process has been conducted by many repetitive and precise adjustments using the draping technique on a real or wooden mannequin, which required the manual know-how of an expert [2 - 4]. However, the increasing demand for product individuality and the quick development of products required the reduction of the creation time, which, in turn, led to the development of new software and hardware dedicated to this problem in the fashion industry [7 - 11]. The ability of interactive modification of a 2D garment pattern directly in 3D has been presented by many research teams over many decades [7 - 11]. Many scientific papers focused on the proposition of a kind of software solution that is able to transfer all changes onto 2D patronages and reproduce these changes by 3D garment simulation [13 - 18]. Our study can be considered as a new methodological concept, available for any user, which aims at the development of a garment pattern in 3D. Moreover this garment pattern is appropriate for use in the garment industry. Following this context, our work could be applied in two directions of the fashion industry: mass customization or ready-to-wear, which is the topic of the work presented [1].

For ready-to-wear, we use the adaptive mannequin morphotype model [1] to develop a garment model. A garment can cover different parts of the human body separately or in combination with some segments We chose the example of trousers in order to study the segmentation of the lower part of the human body. This representation of a garment is based on the adaptive mannequin model. The control parameters developed are carefully controlled by the dynamic garment ease allowance model. The example chosen is greatly exposed to other categories of garment from another class, but is based on the same segmentation of the human body, for example a skirt. This work is also highly remarkable in the field of mass customization, offering the speed and extreme accuracy required due to thefact that the development and testing of virtual models are performed continuously on different software platforms without the data import problem. Among others, an interesting aspect of this process is represented by the analysis and technique used to define the value of spatial parameters of the ease allowance model in 3D. We propose a method to calculate the optimal spatial distance, representing the essential data of the study, to characterise the proper fit of the garment in the static, quasi-static and dynamic phases of fitting. The concept presented used the measurements obtained from inverse modelling of the garment pattern design. The objective of this work is to provide an answer to questions about ease allowance values for a digital garment that is the subject matter for researchers, manufacturers and users of software (for methodology) and software developers (to eliminate technological barriers).

Modelling the garment for ready-to-wear

In our approach, we worked in the field of ready-to-wear to implement the model in a 3D virtual garment. Next, taking into account the strategic needs related to mass production, electronic commerce and digital innovation in the field of manufacturing, we defined a virtual model for the apparel industry and methodology of the design procedure for a virtual garment directly on the 3D adaptive mannequin morphotype model. To explain the general method, we first take basic, classic women’s trousers. In the first part [1] we present our model of the creative process of a garment pattern. This concept is developed in a static mode and transferred into a dynamic mode. Due to the complexity of garment process design, the process proposed represents the MIMO system (multi out multi input).

Many feedback loops are implemented to translate the internal phenomena caused by the man/garment interactions reflecting the notion of appropriate garment fit. The cascade structure of our global model contains three internal models as the human body model, the ease allowance model and the model of the garment. In this arrangement the most important is the ease allowance model, seen as an essential component in the garment modelling process, and its validation. A description of this model is given after each element, specifying which influences the overall process. The garment model incorporates different sub-models depending on the garment product to be made. In the case of trousers, two sub-models are needed. This approach represents an analogy to the structure of basic trousers related to the position of the garment pattern on the human body model. First the sub-model concerns the morphology of the front, while the second represents that of the back with appropriate ease values. These two sub-patterns are strongly combined with each other as a result of feedback from the interdependence between the front and back parts.

To determine parameter values of the ease allowance model, an identification procedure was applied to decrease the numbers of iterations of the fitting test. For that purpose, the superposition of industrial garment patterns and those created in 3D as well as their validation in 3D were made. An observer of the 3D model is used to alter the garment pattern from 3D to 2D. Following the results of the garment pattern modification, we ensure the checking of results coming from the observer by analysis of the fabric deformation whilst the garment pattern flattening process is done. Next an estimator of fabric deformation is used to control the feasibility of the flattening garment pattern process. This helps to guarantee its performance required in relation to the suitable garment model.

2D ease allowance model

When the design of the adaptive model of morphotype is completed, the next step is using the output variables of this model in order to support the ease allowance model (***Figure 1***).

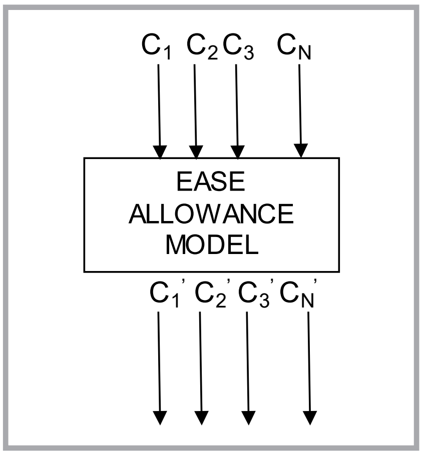

Figure 1. *Ease allowance model.*

We used the morphological shape of the contours coming from the modelling of the human body process as input parameters of the ease allowance model (C_1, $C_{2, \ldots}$). Consequently it can be considered as the core of the virtual garment model. Each alteration of the ease allowance model directly influenced the style of the garment by the existing parametric relationships. In most cases the garment is a combination of different contours that appear in two body segments at least, and the choice of the right morphological contours is very important. For example, for garments such as shirts, the upper limbs and torso are required. A more complex example like a smoking jacket needs three segments. In the case of trousers, the morphological shape of the lower limbs and lower torso expressed the input parameters. Management of the ease allowance model is achieved with the large number of ease inter-correlated parameters. These control parameters are allocated to the relevant contours of the human body through the control points, which are positioned at defined locations on the contours of the human body. Fur-

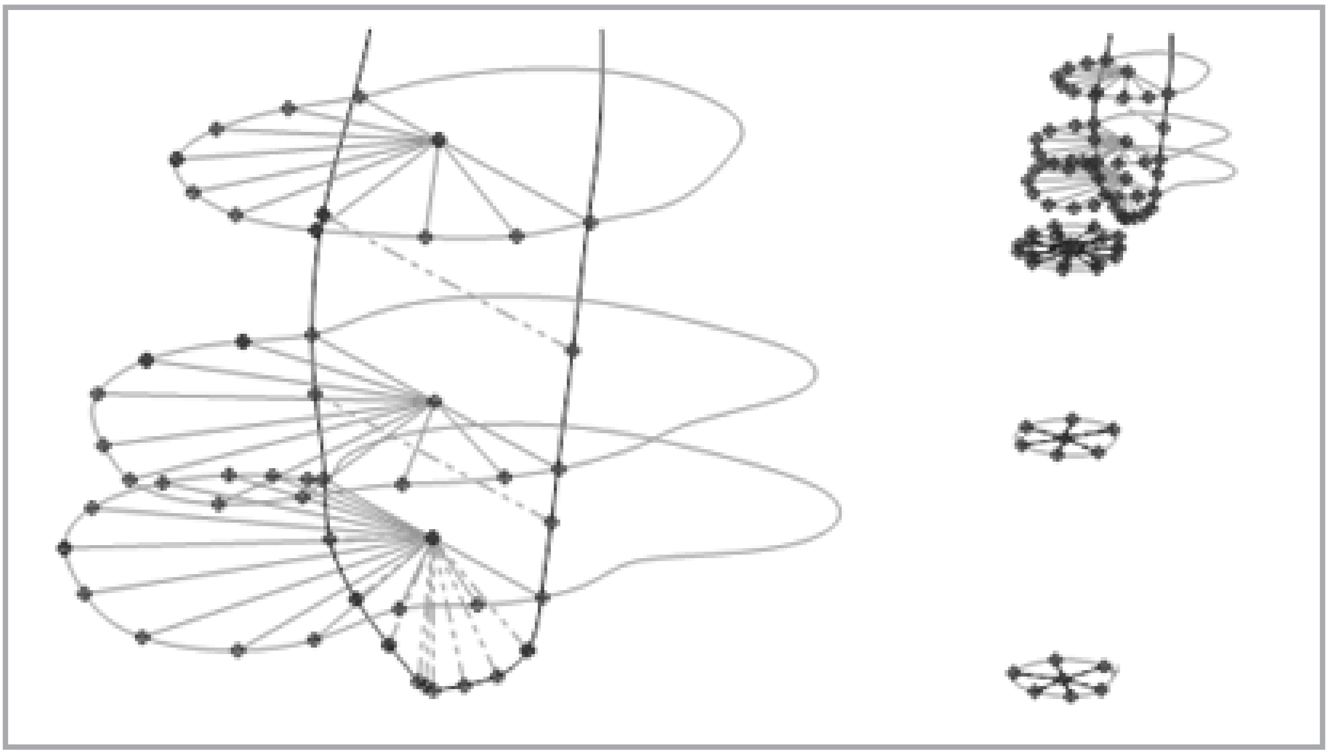

Figure 2. *Distribution of the control points assigned to the morphological contours.*

thermore these control points are appropriate for the fashion model of trousers selected. The distribution of these control points is essential to manage the ease allowance model more easily. The human body represents a set of very complex shapes, causing the placement of more control points in the curvature areas than in flat places. ***Figure 2*** shows an example of linear and spatial distribution of the control points on the morphological contours of the human body.

The choice of morphological contours of the human body is a challenge requiring fashion expert knowledge that explains the contact areas between the garment and the body [5-6]. Moreover in the case of a lack of contact between the garment and body, the fabric draping has to be interpreted and the static position of the final garment should be extrapolated. In the case of trousers, we make the assumption that trouser leg forms follow leg morphological shapes. Conversely the top contours of the trousers are directly obtained from the cross sections of the human body. The 3D scanning process can also influence the final form of the garment pattern, caused by the stringent posture of the human body. In the case of trousers the problem arises at the trouser leg level, hence the virtual human body posture represents a kind of support to the 3D design process of trousers. Furthermore in the fashion design other external factors are involved that must be integrated in the modelling. In our case we include an assumption that the trouser leg falls straight in a vertical direction to the ankle. The morphological contours of the thigh are recopied at the knee and at the ankle levels to ensure the comfort criteria of user as well as the correct fit of the trousers (***Figure 3***).

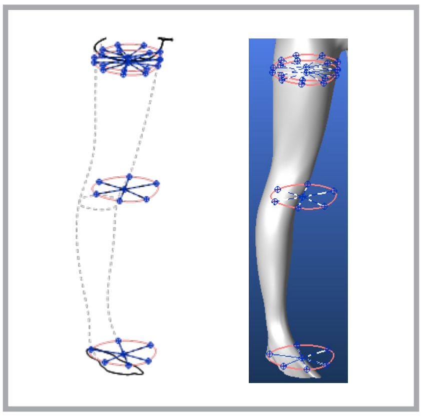

Figure 3. *Trouser leg conception.*

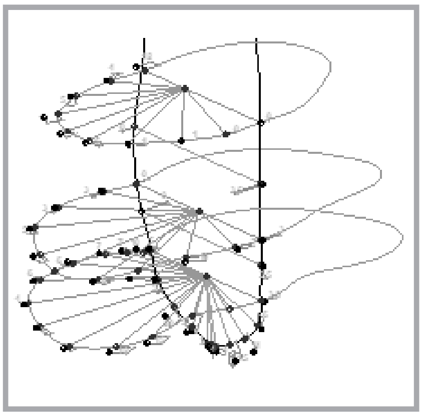

Figure 4. *Proposed ease allowance model of trousers.*

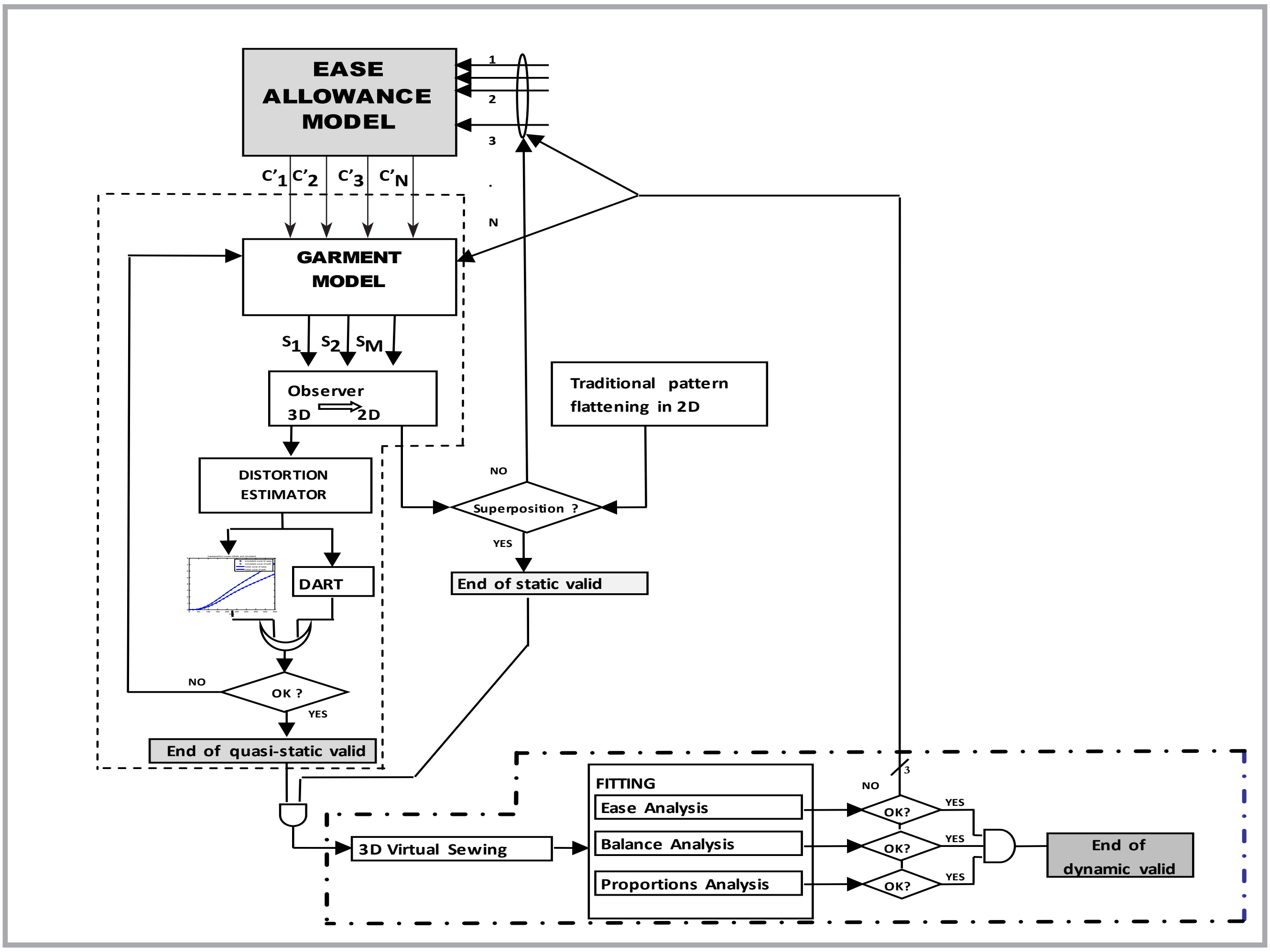

Figure 5. *3D garment model [13].*

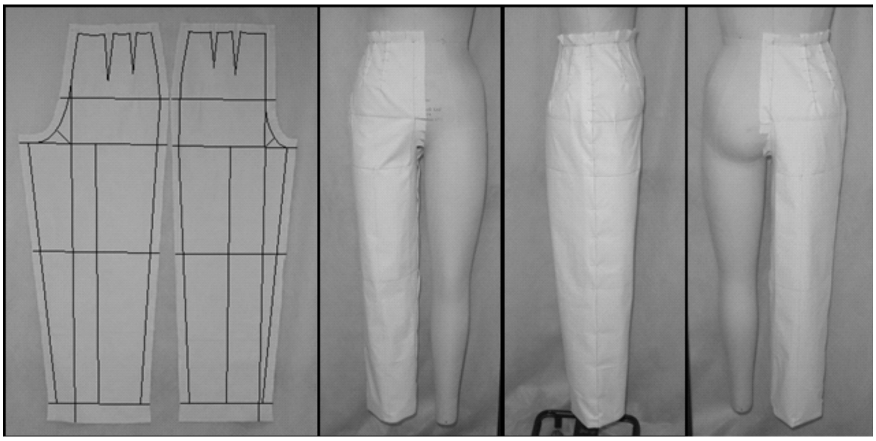

Figure 6. Trouser patterns in 2D and 3D (front, side, back).

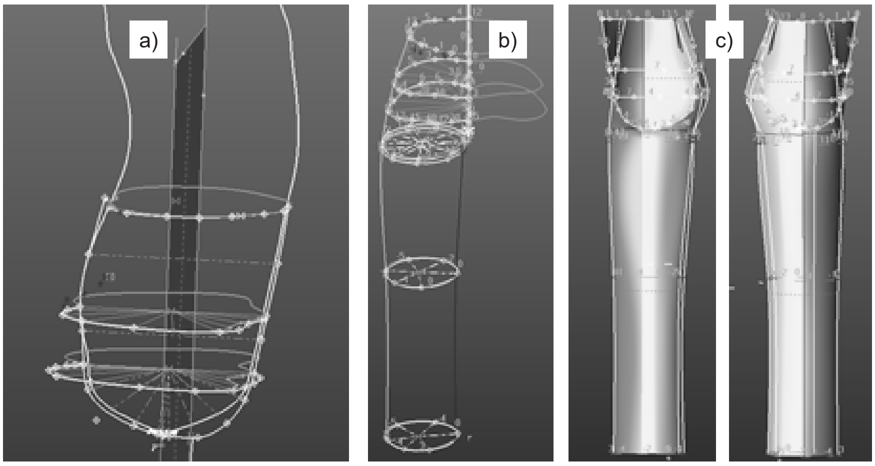

Figure 7. Numeric moulding of trousers.

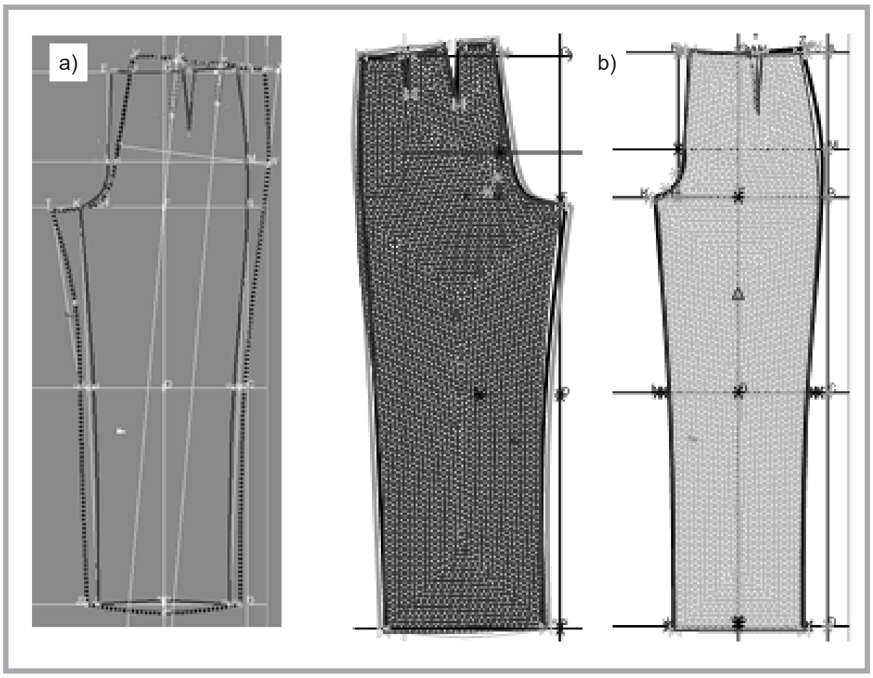

Figure 8. Pattern of adaptive model to control the ease allowance by flattening.

Moreover, the model of ease allowance proposed takes into account the process of design of a garment model incorporating the secondary contours of the human body model. As in the case of human body modelling, in order to respect "the beauty of the human body" (the appropriate curvatures of the human body), we used these secondary contours and their control points. Additional to the basic model of trousers chosen. we have added the additional contours located between the waist and hip as well as at the buttocks area.

Figure 4 (see page 123) shows the ease allowance model of women's trousers proposed. This model consists of ease output points (C_1', C_2', …) obtained by the shift of the control points created on associated morphological contours, whose value offset is managed by ease volume parameters called ease points (EP). Each point is moved independently in the direction defined by itself and the gravity center of the surface of a given contour. The value of ease volume parameters will be changed during the design validation phase in each of the feedback loops. This process could be explained as the moulding of the garment shell volume, which is controlled by adjusting the fabric draping and garment fitting.

3D garment model

The input of the garment model is represented by the ease points of the ease allowance model as a required support to the skeleton of the garment. These new points are used to define the new contours and to control of the ease allowance of the front and back independently. This condition is a priority in the case of robust people. The 3D garment modelling proposed (***Figure 5***, see page 123) uses fabric draping techniques (3D molding) [13] taking into account the positioning of seam lines (in and out seams) and pinching of the waistline associated with the moulding phase, where final identification of control lines defining the garment model is made.

3D garment modelling of trousers adapts the traditional design concept based on 3D moulding employing a canvas, as we can see in ***Figure 6***.

Using the contours created on the EP, we defined the position of trouser seams (***Figure 7***). We used the frontal plane (dividing the body into front and back parts) to find the intersection points of the trouser's contours. Next these new points are used to draw the trouser's seam lines (inseams and outseams). The position of the seam lines is crucial because they strongly influence the morphology of the trouser model. Moreover, taking into account the creativity of designers, it is very important to manage the surface ratio between the front and back parts of trousers [6]. Hu Chung Lo [5] emphasises the influence of seams on the garment taking into account the type, location and shape of the garment when it is draped over the body. Numeric moulding allows to create the surfaces of the front and back supported by the relevant EP, sewing lines as well as additional lines. These additional lines are required to respect the morphology and good looks of trousers in 3D. Furthermore, during the numeric moulding phase, we directly placed the dart on the front and back at the waist level.

Following this procedure, a validation phase was performed in order to set the right values of EP using the feedback loop of the overall model. In this case, we took into account the industrial (ready-to-wear) pattern of trousers to be coherent with the target population, described precisely in the static validation stage of the garment.

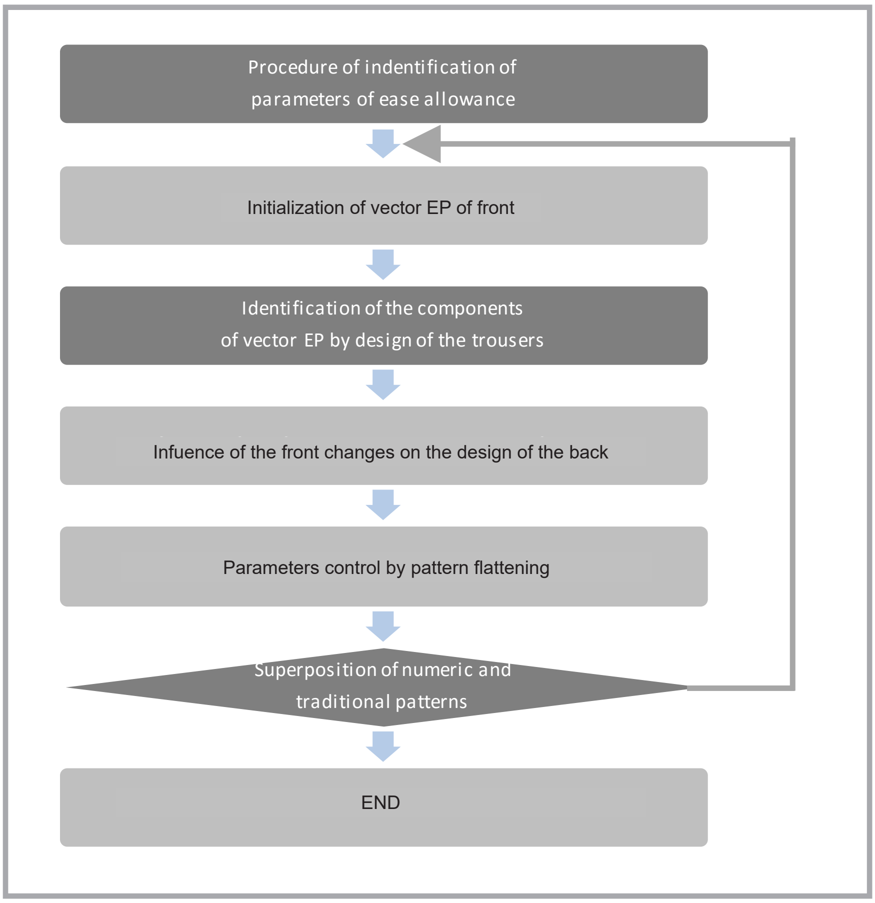

Figure 9. *Indentification procedure of ease allowance model.*

Procedure of static garment validation

A model of the garment was carefully designed to avoid identification of ease problems. The division into front / back sub-models is strategic, not only because it allows identification of the final vector parameter model of the ease allowance, but also due to the specificity of the garment design process. Control of the 3D ease allowance (EP) takes place in the procedure involving several stages.

The first stage is implementation in a 2D of model of the adaptive pattern defined by flattening industrial patterns performed by the International Academy of Technical Cutting PARIS [12]. The result, given in ***Figure 8.a***, shows that it is possible to adjust this pattern by the control parameters (EP) based on measurements of the person scanned. Then we identify the different values of ease allowance for contour after contour by systematic monitoring based on the approximation of patterns issuing from the 3D concept (***Figure 8.b***) associated with the 2D flat pattern (mesh background) and Vauclair method (gray outline). In our case, the identification was carried out in several stages. The first was an identification of parameters of the model on the front of the trousers. The second is the identification of parameters of the model on the back of the trousers.

Alteration at the waist level concerning the value of the EP should be equal to zero in order to take into account its fitting. This phase justifies particular attention. Using the moulding method used, we immediately integrated the darts, where the value of EP is zero.

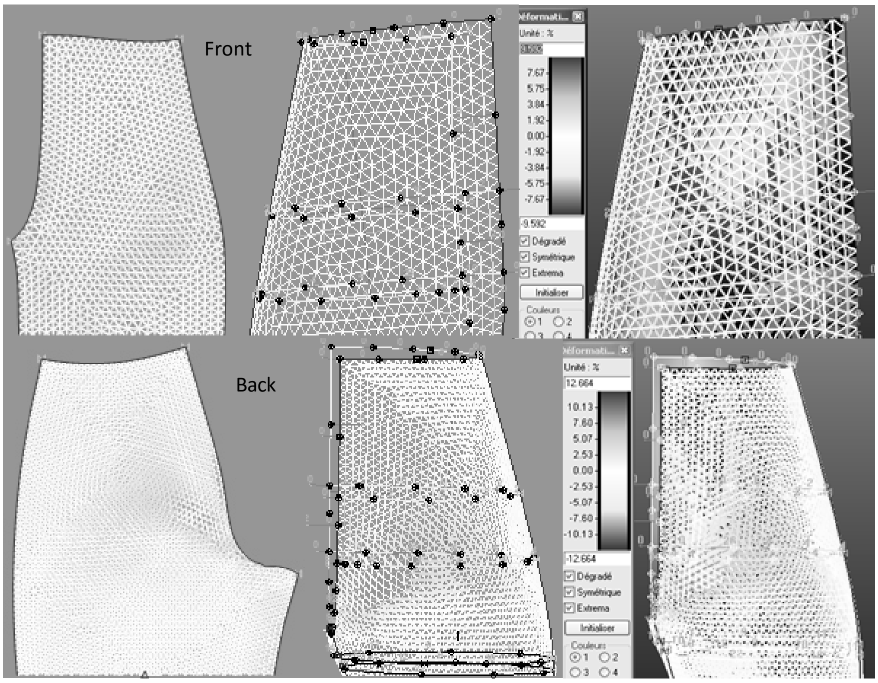

Figure 10. *Deformation analysis of the meshed material at the waistline.*

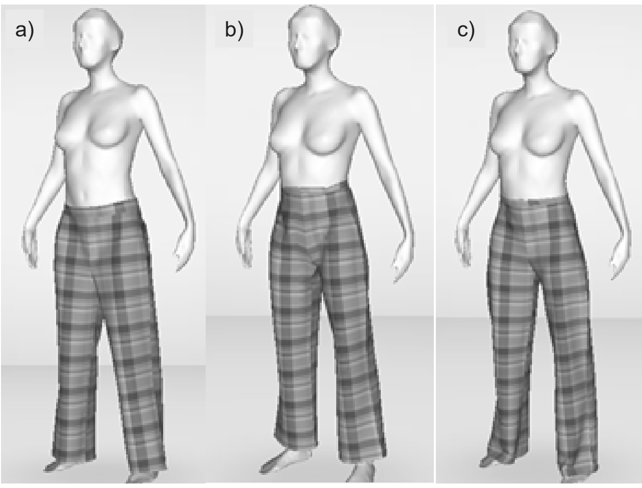

Figure 11. *Drape of trousers from 3 different methods.*

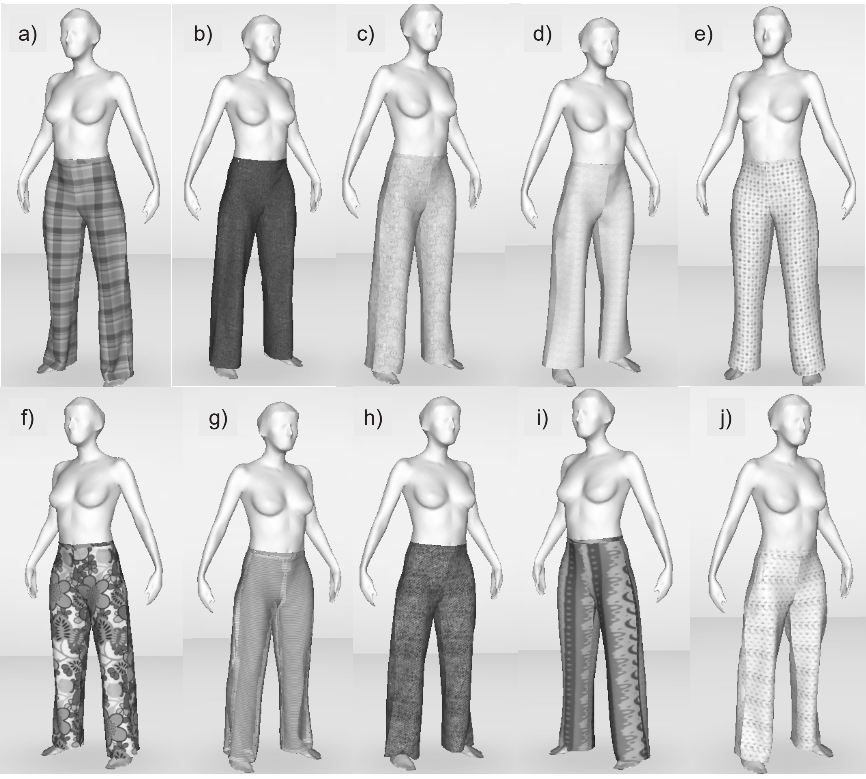

Figure 12. *Trouser pattern tests without the dart for different materials. a) cotton 67% PES 23%, b) worsted 100%, c) viscose 100%, d) canvas cotton 100%, e) flax 100%, f) PES 100%, g) silk 100%, h) denim cotton 100%, i) acryl 50% viscose 50%, j) knitt cotton 100%.*

The diagram in ***Figure 9*** (see page 125) recalls the methodology described to identify the value of ease allowance (EP) parameters:

- Analysis of the front of the garment pattern to prepare a model for the desired design,
- Initialisation of the first vector of ease parameters required to start identification for the front only,
- Design control surfaces of trousers to avoid exaggerated deformations or causing construction impossibilities.
- Design control of back surfaces of the trousers. Because of the correlations between the front and back of the trousers, each change in EP on the front, especially near the internal and side seams, influences the surface of the back of the trousers.
- Checking the parameters of flat patterns. It is recommended to decrease the size of the triangles to refine the mesh and smooth the edges of flattened patterns.
- Superposition of patterns by the Vauclair method [12] and virtual patterns. This test allows us to validate, or not, the virtual garment patterns. In the case of validation, EP values are correct. If the virtual drape of the trousers is not correct, we restart the procedure at the step of initialization the EP vector.
- Analysis of results obtained by the superposition of patterns.

The superposition of pattern contours shows (***Figure 8.2***) that the design process proposed is not only coherent with the techniques used in the ready-to-wear process (method Vauclair), but is also close to ~~a~~ the process of mass customisation.

The second validation phase consists of the quasi-static mode, namely fabric deformation, of the fabric when it is flat. In this case, we use a post treatment to control deformations caused by the transition 2D-3D.

Procedure of quasi-static garment validation

The observer's purpose is to consider the material mechanical constraints whilst 3D patterns are flattened out into 2D ones. In our case, we control the compression of the fabric during waistline fitting by the mechanical post-processing. This control allows to check whether to put the dart in the given place in the case of loose fabric or if there is an area of tension, where the choice of material is required to support this elongation.

Figure 10 (see page 125) shows that the front does not need the dart at the waistline (white colour at the waistline - without shadow zones), defining a state of compression/elongation equal to zero. Similarly the back pattern leads to the same result.

Procedure of dynamic garment validation

This step was to validate the ease allowance model in the dynamic mode of garment draping. We used a feedback loop between this model and the dynamic phase of the garment draping and fitting. ***Figure 11*** compares various techniques of pattern making. The first technique (***Figure 11.a***) comes from the garment industry, where one can notice errors of patterns because of consumer morphology, i.e., the waistline is too low, making folds at the front, which leads to some extra fabric in the hip area. The second technique (***Figure 11.b***) comes

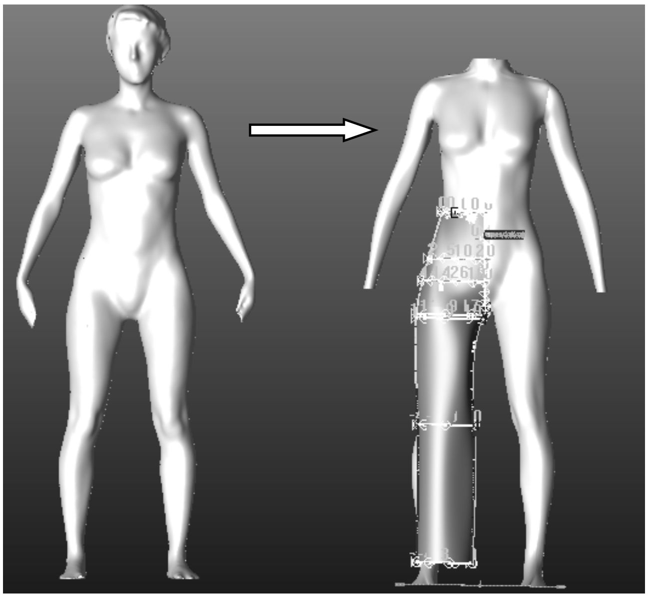

***Figure 13**. Automatic garment during the evolution of the adaptive model morphotype.*

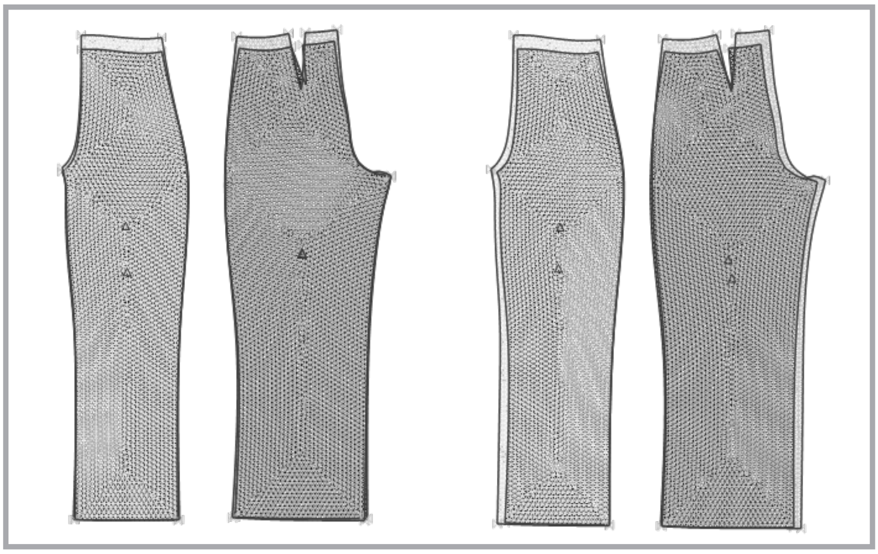

***Figure 14.** Auto-grading of trouser patterns.*

from our 3D design process, where we found some problems as we tried to get closer to the first method. For this reason we set the ease allowances parameters equal to zero, and we imposed darts. In ***Figure 11.c*** the look of the trousers is better, even we did not put the dart. This assumption was justified by the previous validation process detecting deformations during the flattening pattern process seen in the quasi-static procedure. In our case, fabric deformation did not occur during this process, hence there was no need to create the dart for this model, this type of fabric nor for the consumer morphology.

An additional step was choosing the virtual fabric. Different fabrics of variable stiffness were tested with these customised patterns without darts (***Figure 12***). This choice enabled virtual verification of the impact of the fabric on the final rendering of the trouser model and showed both the great difficulty of predicting the final drape of the garment proposed and, consequently, the responsibility for the best fabric choice with respect to the model designated.

In our case the fabric that seems to be the most suitable for our trousers is made of flax, because it has the appropriate draping, which validates the choice of values for ease of assuring wearing comfort. Moreover subjective evaluation proves the need to step up in the final product. The virtual fitting eliminates many real fitting loops needed to validate patterns depending on the morphology of the consumer and fabric used, often found in the industry.

To prove that our strategy in 3D garment modelling represents additional value, we need to consider the adaptive model of the mannequin morphotype. ***Figure 13*** shows that the height modification of the adaptive model of the mannequin morphotype has the impact on the increase in length of the trousers simultaneously. Moreover these new patterns have the advantage of being ready for manufacturing by importing CAD to other compatible modules.

Consequently different variants of the garment model designed in this way will be able to fit the body of a model with size change. ***Figure 14*** shows that our idea leads to pattern auto-grading according to the stature (left), volume and stature (right).

Conclusions

This study presents general ideas of 3D garment modelling and shows the difficulty of conceiving it in 3D, because we must take into consideration many model validation criteria. The implementation of various control feedback loops is essential. We remarked that the ease allowance model with EP was the most difficult to set because of the mutual interaction of different patterns. Among other things, the concept of design is involved in the validation process, which is done by a subjective test. Moreover fixed parameters are set for each type of individual body evolving its morphology. An additional value coming from this idea gives the possibility of pattern auto-grading.

References

1. Cichocka A, Bruniaux P, Frydrych I. 3D Garment Modelling - Creation of a Virtual Mannequin of the Human Body. *Fibres and Textiles in Eastern Europe* 2014; 22, 6(108): 123-131,
2. Imaoka H. Three models for garment simulation. *International Journal of Clothing Science and Technology* 1996, 8, 3: 10-21.
3. Majchrzak A, Chang T, Barfield W, Eberts R and Salvendy G. Human *Aspects of Computer Aided Design*. Taylor and Francis, Philadelphia, PA and London, 1986.
4. Wilson JR. Critical human factors contributions in modern manufacturing. *International Journal of Human Factors in Manufacturing* 1991, 1, 3: 281-97.
5. Hu J, Chung S and Lo M. Effects of seams on fabric drape. *International*

Journal of Clothing Science and technology 1997, 9, 3: 220-227.
6. Torques E, Cani M-P and Hughes JF. *Sketching garments for virtual characters*. EUROGRAPHICS Workshop on Sketch-Based Interfaces and Modelling, 2004.
7. Chiricota Y, Cochaux O and Provost A. Geometrical modelling of garments. *International Journal of Clothing Science and Technology* 2001 13, 1: 38-52.
8. Magnenat-Thalmann N, Soe H and Cordier F. *Automatic Modelling of Animatable Virtual Humans – A survey (3DIM'03)*. IEEE Proccedings of the Fourth International Conference on 3D Digital Imaging and Modeling, pp. 2-10, 2003.
9. Cordier F and Magnenat-Thalmann N. Real-time animation of dressed virtual humans. *Computer Graphics Forum*, Blackwell Publishers, 2002, 21, 3: 327–335.
10. Volino P, Magnenat-Thalmann N, Jianhua S and Thalmann D. *The Evolution of a 3D System for Simulating Deformable Clothes on Virtual Actors*. MIRALab Copyright Information 1998.
11. Carigan M, Ying Y, Magnenat–Thalmann N and Thalmann D. *Dressing animated synthetic actors with complex deformable clothes*. Proceedings of the 19th annual conference on Computer graphics and interactive techniques, pp. 99-104, 1992.
12. Methode de tracés vêtements féminins classique, éditions Vauclair, Système de l´Académie Internationale de Coupe de Paris, ISBN 2-923395-14-4, 1999.
13. Tao X and Bruniaux P. Toward advanced three dimensional modeling of garment prototype from draping technique. *International Journal of Clothing Science and Technology* 2013, 25, 4.
14. GangLuo Z and Yuen MMF. Reactive 2D/3D garment pattern design modification. *Computer Aided Design* 2005, 37: 623-630.
15. Wang Z, Newton E, Ng R and Zhang W, Wang Z, Newton E, Ng R and Zhang W. Modelling of cross-sectional shape for women's jacket design. *SEN'I GAKKAISHI* 2007, 63,4.
16. Wang Z, Newton E, Ng R and Zhang W. Study on the relation between garment style and ease distribution. *Journal of Donghua University* (En. Ed.) 2004, 21, 6.
17. Gupta S, Bruniaux P and Koncar V. Adaptive model of the human body. A new tool for fashion designers, *8th International Foundation of Fashion Technology Institutes Conference (IFFTI): Fashion in the Digital A*, Raleigh, USA, June 20-22, 2006.
18. Cichocka A and Bruniaux P. Adaptive model of the human body. Methodology of design of the morphotype mannequin. *ISC'2006, 4th annual International Industrial Simulation Conference*, Palermo, Italy, June 5-7, 2006.

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