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3D Garment Modelling - Creation of a Virtual Mannequin of the Human Body

Abstract
This work presents the modelling and numerical simulation of mannequins as well as clothes in a 3D virtual environment. The paper explains garment modelling, with the objective of defining the development of a 3D body model that is useful and based on the demand of the garment industry. For this purpose a development strategy should be defined. Many scientists are working on the creative process for virtual garment development to create a garment directly on a 3D model of the human body, also called " virtual tailoring".The first strategic issue in this context that we present is that the model must necessarily incorporate the ease garment model associatively. These parameters define the priority concepts that are the draping and proper fit of the garment. The second point is that the transition between the 3D and 2D patterns, known as flattening 3D patterns, must be associative, precise and must take into account the real deformation of the fabric.

Key words: *garment modelling, virtual garment, virtual mannequin, human body.*

Introduction

The simulation of a garment may be one of the most difficult problems in the field of textile engineering. The work of Imaoka [1] highlights the importance of introducing three models (of representation) to perform the simulation of garment design: garment model, human body model and the environment model. This ideology led to the development of the concept of "the human-clothing-environment". Taking this into account, the techniques of development are much better than 20 years ago at the beginning of research in this area. The aim of the first generation of researchers was to show that it was possible to achieve garment simulation. The role of the second generation of scientists was to develop more sophisticated techniques to increase the virtual reality. The Internet and virtual reality are present at each stage of the life of the human-being: shopping, money, games, movies .... For the most part, it requires the virtual dimension of virtual actors - models. Therefore there is a strong demand to design an avatar wearing the garment with the more realism. In areas such as films or games it is possible to present on the screen virtual clothes very close to reality by integrating sophisticated simulators of fabrics. On the other hand it is very difficult to translate the garment and representation of the human body in 3D into the reality of industrial production of a garment, despite a lot of research of numerous teams around the world.

Global aspect

Our research work is a part of a large-scale thematic interface called the "man / garment / environment". The main objective is to contribute scientifically the evolution of the garment industry, whose aim is moving towards a full virtualisation of the concept of creating and selling clothes. ***Figure 1*** shows that the core of this interface is the human being, who needs to be dressed in a garment providing both comfort and well-being.

For this purpose, a first layer of knowledge (human / clothing) should be studied combining two previous disciplines of sensory character: understanding of human morphology and know-how of business clothing. The analysis and development of this interface leads to a cascade of different models of knowledge (morphology, clothing) in an interaction with the concept of comfort and well-being. The second layer represents the interaction with the outside world (garment interface / environment), which can open the study to the type of application of textile fabrics (ballistic protection, integration of sensors / actuators in medicine...), where mass customisation adds value to the product by its precision, or applications on the Web in the case of a virtual sale.

The research presented is part of a reorganisation of the chain of the garment process for the industry. The overall structure modelling of creating clothes based on a methodology for creating software uses adaptive parameters working in a 3D environment. The main objective is to establish a new concept of creating a garment to reduce the time and costs of product development. This concept should help to resolve errors in communication between the designer and pattern maker by acting together in an interactive manner on a digital 3D representation of the dressed body. Among other things, 3D modelling is a perfect way to remember the unique "know-how".

Two industrial markets have been analysed: the ready-to-wear (mass production) and custom-made (made-to-measure) (mass customization). The effects of

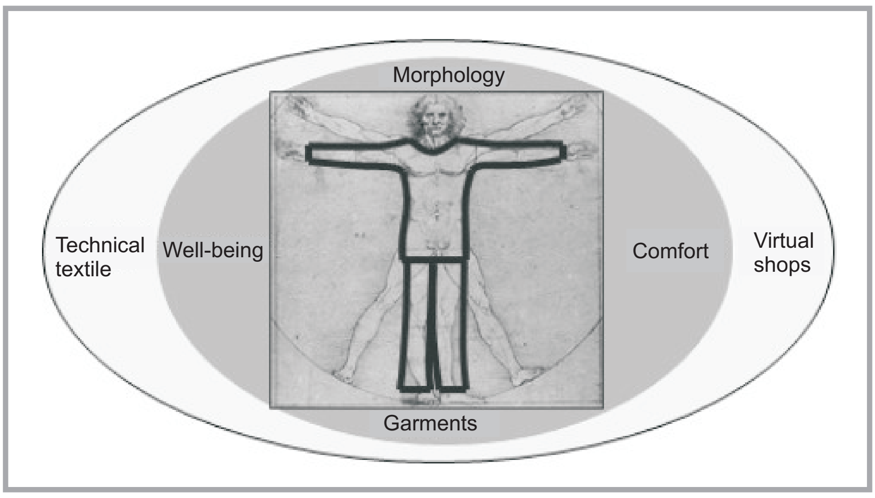


Figure 1. *Interface "man / garment / environment".*

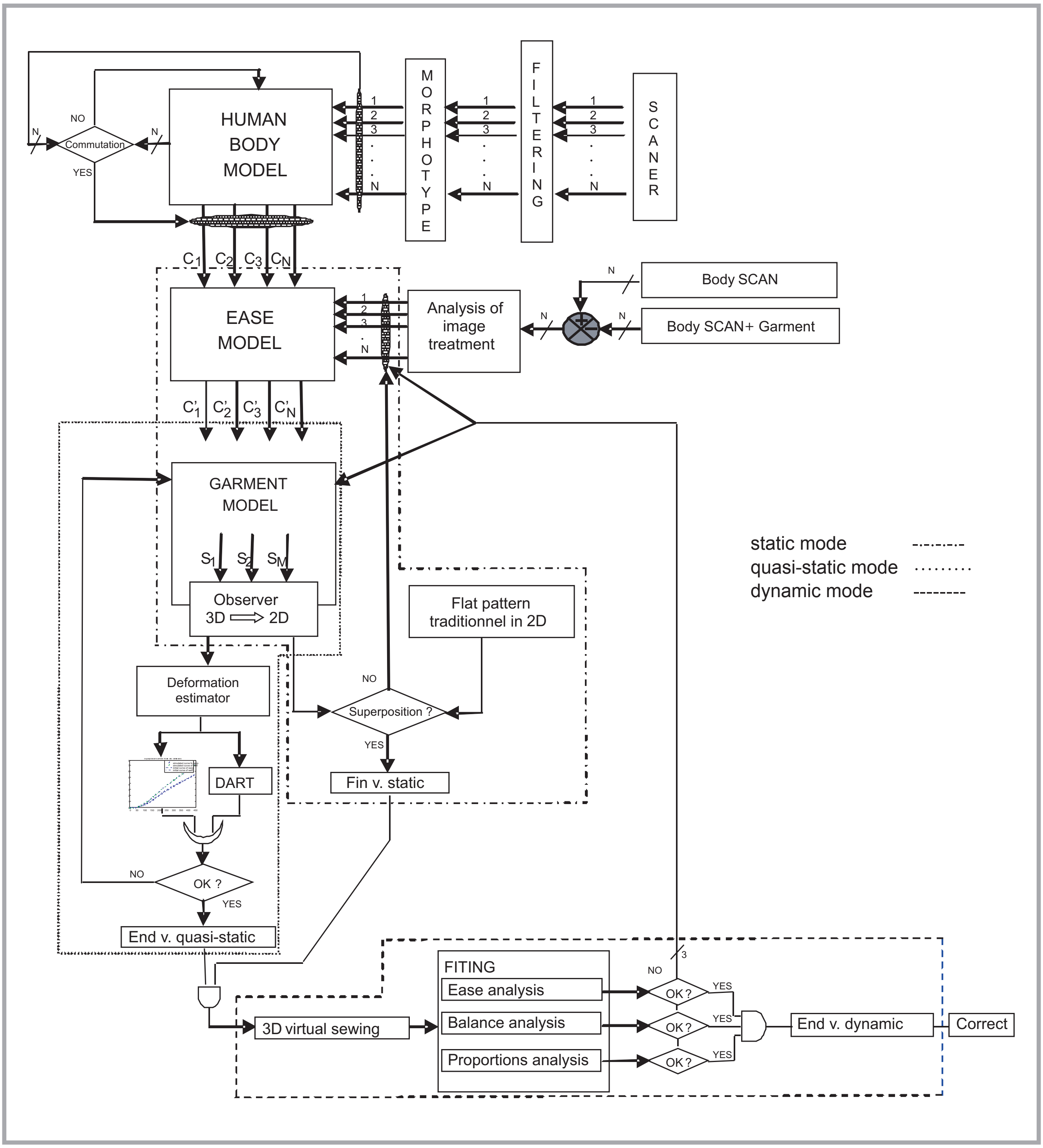


Figure 2. *Global model of the garment creative process.*

globalisation lead to producing quickly to avoid copying and require a constant renewal of collections in a very short time. Production is no longer local; it is now imperative to communicate data through the internet in digital form. Analysis of manufacturing shows the need to evolve to a 3D virtual world correlated with the industrial needs mentioned in international measurement campaigns. The latter advised to work with 3D virtual models respecting the morphology of the human body to prevent the return of unsold clothing. This need has transformed the concept of size in the concept of high morphotype segmentation. To meet all these criteria, the methods of work should be changed; designers should adapt the modern world of 3D over the Internet. For these reasons, the original concept of creating a garment with a virtual 3D model of adaptive morphotypes (garment creative process) is proposed. The diagram in ***Figure 2*** shows a global model of the garment creative process related to the data processing cycle [2].

This concept is developed in a static (---·-·---) and quasi-static (·········) mode, and validated in a dynamic mode (-------). The process represents a multi-input/multi-output model because of the complexity of the problem. Different return loops are implemented to translate the internal phenomena caused by the human/garment reflecting the concept of the best fit. These loops represent a validation. This global model is composed of 3 internal switching ones arranged in a cascade: the human body model, the model of ease and style of clothing. Modelling of the human body is achieved through the development of an adaptive model of morphotypes (on the basis of results of measurement campaigns) representing the avatar of the consumer. This study is based on the anthropometry and biometrics of the human body.

The ease model is the most important because it allows to validate the concept of comfort and correct garment draping by controlling the ease, balance and proportions of the garment, which is essential in the garment modelling process and for its validation.

The model integrates the garment in parallel with the different models influencing the product to be made. For example, in the case of trousers two sub models are needed related to the position of patterns on the human body model. One is associated with the morphology of the front, and second with the back part of the human body, taking into account appropriate values of ease. These two sub patterns are strongly connected to each other, such as the effect of feedback from the interdependencies of patterns – a front and back. Two identification procedures (that can be mixed) have been introduced to minimise the criterion of fit by acting on the ease parameters easily. The first procedure is used to estimate the value of parameters in the real mode from scans of a person wearing and not wearing the garment. The second procedure – the static mode, uses knowledge about the industry in the field of ready-to-wear. The superposition of a traditional pattern with those created for a 3D garment model was checked. To do this, an observer of the 3D model was used for the conversion of 3D patterns into 2D. Following the optimisation of the pattern error, we must monitor the outputs of the observer taking into account the deformation of the material during the verification of patterns. A deformation estimator – the quasi static mode, is then used to check the feasibility of the patterns in order to act accordingly along the lines of the clothing, as we did during trials of patterns using the 2D model. But these return loops only partially validate the patterns in the 3D static mode. The virtual garment, meaning the garment drape on the mannequin or the adaptive avatar, validates the dynamic aspect of garment fitting. In this case, the designer acts on the model of comfort or style of clothing, including the material impact on these models.

Modelling of the human body

The human body has been one of the most absorbing and most explored objects for many ages. Before designing a garment adapted to the human body, intimate knowledge of its morphology is necessary to meet the final style successfully. The human body consists of a head, neck, torso, two arms and two legs. The average size of an adult human is largely genetically programmed. The body type and composition are influenced by factors such as postnatal diet or exercise. Characteristic variations in the shape of the human body are fundamentally important for many applications ranging from animation to the style of product [2]. To respond quickly to customer needs for a garment guided by fashion, it is necessary to accelerate the process of garment production. Since the 70s, a growing trend in the field of CAD for garment production has been observed. Although in this period industrialists have focused on improving the design of patterns using computers, their target is always the same - "customer satisfaction". Modelling the human body has become possible and is required by new perceptions of shopping, i.e. e-commerce. For this purpose, knowledge of human morphology is a priority. Anthropometry, derived from anthropology and related to the measurement of human individuals, is a science for understanding the evolution or the physical change of the body. Today anthropometry plays an increasingly important role in industrial and garment design, ergonomics, and architecture, where statistical data like the distribution of body size in the population are applied to optimise products. Changes in the lifestyle, nutrition and ethnic composition of populations lead to changes in this distribution (e.g. obesity), requiring more regular updating of anthropometric data collections.

As a part of modeling the human body, two major directions have been developed. The first is dedicated to mass customisation with the introduction of a non-adaptive model – such as a complete process of creating a virtual body (male or female) based on a generic reference model, as we can see, for example, in the work of the N. Magnenat-Thalmann team [3]. The work of Ju et al. [4] is oriented towards creating a realistic animation of the model, whose body geometry looks like a very refined human body, as well as an important project - CAESAR [5]. In [6] the authors manage to create a correspondence between data from the scanner and a virtual model of the human body, for which they convert the polygonal mesh representing the surface of the scanned body into a volumetric representation, thus aligning the 3 - D mesh within a volume that represents a set of voxels. Paquet and Viktor [7] propose a method to calibrate virtual models of an anthropometric point of view using measurement data of the human body from the CAESAR project. They argue that the modelling of a large number of morphological characteristics are interdependent, such as knees, head circumference, hips, ... but it can lead to non-specific anthropometric virtual models that do not reflect reality, but a quality sufficient for commercial use.

The second direction in the field of ready-to-wear taken by other authors is the adaptive model, which is able to adapt its volume to chart sizes or tables of measurement. Among others, Cho et al. [8] describe the development of an interactive model of the human body that can be modified with different contours of the body, which could be useful for 3D digital models, where the advantage is its ease of controlling the shape of the silhouette and calculating lengths and associated perimeters. Kim and Park [9] identified three issues in CAD for the garment industry: Each size change requires a new model of the digital human body and a large amount of processing necessary to face collision with a male model, and a scanned model consists essentially of a series of triangular elements. They then propose a model of a parametric body with specific sections for certain parts of the 3D model, or the shape and size of the model can be modified either by the reorganisation of each section or changing the vertical position thereof. The work of Wang [10] is based on a parametric approach to the human body directly from the cloud of unorganised points. The configuration consists of a semantic feature extraction technique that is applied to the construction of the wired functionality of the human body in 3D. Some of these authors (for example T. Seo & N. Magnenat Thalmann [11]) completed their study by virtual fitting moving towards 2D/3D technical assemblies. Their contribution includes a new compact and effective representation of the body model and geometry from a scalable database using a network type transformation - RDF (Radial Basic Function). From the assumptions of Grob, Fuhrmann & Volker [12], a method can be established for the automatic pre-positioning of a virtual garment that can be used in a virtual shop. During simulation of the pre-positioned clothing, a geometric positioning algorithm makes up several pieces of garment automatically and simultaneously around the human body.

In the article of Wanga [13] automatic 3D technical solutions for tailor-made clothing are presented. Free-form surfaces are adopted to represent the complex geometry models of clothes. In the design of a complex surface, abstractions are fixed in association with the models using non-manifold structure data.

A CAD system was developed to create garments in an automatic mode with the prediction of the drape's final form designed on the human body [14, 15].

The aim of our study was to adapt the process of creating a garment to move it towards a 3D environment allowing to obtain industrial garment patterns. Moreover with the intention of checking its correctness directly whilst trying on the 3D garment, it was attempted to execute the whole procedure employing industrial CAD solutions. It is important to begin to define exactly the various anthropometric points on the virtual human body relevant to this new concept in order to help to manage the size of the adaptive mannequin according to the sizing chart. Such a database of adaptive mannequins could be a very interesting point for the 'ready-to-wear" as well mass-customisation segments.

Morphological analysis of the human body

This paragraph is devoted to the study of the human body, which requires introducing some basic notions related to the morphology thereof. It should be remembered that the design of a garment has to be proceeded by knowledge of the human body, with its characteristic features and proportions related to the nature (female and male). The discipline of 'anthropology' (the original Greek "anthropos" - the human being, "logos" - science) represents all studies on humans from different aspects of their life taking into account their evolution, family formation, and differentiation of race. Thus analysis of the human body is more efficient in the textile and garment industry. Manufacturers have used anthropometry as representing a branch that contains anthropological methods of measurement specific for the human group. Measurement of the human body and analysis of the position of anthropometric points are also used in other disciplines such as criminology, medicine and engineering applications.

The first phase of the study is to define the three main planes used in anthropometry that divide the human body (presented in ***Figure 3***) in the following way:

- The median sagittal xy plane, which separates the body symmetrically into two parts (half right and half left) through the cervical spine and mid-sternum.
- The median frontal vv plane, which divides the body by the longitudinal axis perpendicular to the frontal plane and "cuts" the body into a front and back.
- The median transverse TT plane, which goes through the waist horizontally and perpendicular to the frontal and sagittal planes.

The plane identifies the human body as two upper and lower parts. The intersections of these planes help to define the three axes of the Cartesian coordinate system of the human body including:

- The vertical axis created by the intersection of frontal and sagittal planes,
- The transverse axis created by the intersection of frontal and transverse planes,
- The sagittal axis created by the intersection of sagittal and transverse planes.

Various 3D scanning technologies to scan the different surfaces composing the human body for many people provide much richer information on the body shape than traditional anthropometric measurements. These technologies provide the possibility to extract new measurements relating to the body shape.

But the real problem which makes the design of a garment difficult is the lack of rules and common international standards, for example for European citizens.

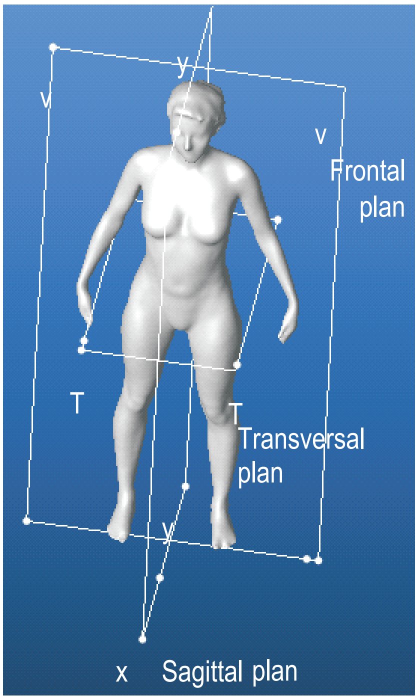


Figure 3. *Principal planes of the human body.*

Winks [17] presents a study on the measurement of a garment and its international standardisation. He analyses the anthropometric aspects to distinguish the dimensions of the human body. This led to a part of an entire study on the population. However, he realises that the average body proportions are similar for the majority of people. A group of average proportion for all populations requires corrections based on the morphology of the different bodies. He noted that ready-to-wear technology is consistent with results with a reasonable degree of acceptability. The manufacturer can reasonably rely on data for 80% of the population; 20% of them belong to the extreme sizes and are not covered. The degree of fitting also depends on intermediate sizes that determine the number of changes in the sizes in the tables.

This conclusion was confirmed also by the results of a measurement campaign carried out in France in 2006. The results of the National Campaign were announced on February 2nd, 2006 [18], showing that the morphology of the French has evolved over the past 30 years. The objective of this campaign was not only to recognise these changes in the population, but especially to notify the apparel sector to produce clothes in accordance with the new morphologies of the French population. The campaign noted that the French population had grown since the last analysis performed in 1987. The same study was conducted in England by Pycock & Bowers [19]. In the early 1990s, the English company conducted its own investigation based on key measurements with 710 women. They found significant differences between the shapes and dimensions of their samples since their last data from the 1950s. The analysis was focused primarily on standards, particularly in terms of the size, inseam length and height of the human body. The survey was confirmed by unsold items, for example, suits with too long sleeves. These observations may be relevant to the apparel industry by offering more accurate size references.

Measurement technique of the human body

The techniques for taking anthropometric measurements are (with advantages and disadvantages) traditional - manual and numeric - and scanning methods. Among the skills, it is necessary to acquire knowledge of the human anatomy, particularly the ability to accurately identify the anthropometric points. The main objective of the measurement technique of the human body is to have a more accurate approximation of the dimensions of a person and to be able to design a garment from this data. The creation process must be closely related to the standards that represent the set of rules to be respected in the measurement phase. These rules define the essential tools used during the measurement, the conditions for taking measurements on the body posture such as the position of the legs, head, etc., and the definitions of specific locations, where measurements must be performed. Measurements of the human body were made in a Human Solution cabin used for the French measurement campaign. The accessibility and format of data output allowed to move to the next stage of the design of an adaptive parametric model and consequently to a generation of digital garments by a 3D approach.

Adaptive model of the human body

A parameterised model of the morphotype is based on a model surface representation defined by many sections of curves derived from the human body scanned. The concept of a set model of the morphotype occurs in the choice and position of these curves, their settings, and the relationship between them and the data from the measurement campaign. Among other things, this model must be operated together with digital design methodology.

The model is managed by different types of parameters directly related to the curves controlling the mannequin's surface. These parameters are intended to manage the morphology of the 3D model and its size. This morphology may vary according to:

- morphological parameters of the limb length or height of the avatar,
- morphological parameters of the volume ,
- control parameters,
- parameters of volume distribution between the front and back of the avatar.

Morphological parameters of height

Analysis and implementation of the morphotype requires knowledge about both forms and human body proportions. In our approach, taking into account the assessment of morphology, the human body model is defined by two classes of parameters defining the position of the strategic contours of the body scanned:

- primary parameters related to the contours that respect the golden rule and the modern canon, which is related to the construction lines of the garment, when it is created. These parameters manage the vertical position of measurement,
- secondary parameters related to the side contours representing complementary morphology and contours reflecting the beauty of the model concept. These parameters characterise the morphology of each muscle as well as contribute to the concept of the morphotype. They depend on the previous settings.

Morphological parameters of volume

These dimensional parameters must be directly related to the data of the measurement campaign and to control of the volume of the human body automatically. Human biometrics (anthropometry) is a part of biology that studies measurements of humans from a statistical law point of view. Two important laws of mathematics dominate in this problem and are the source of many practical applications:

- law of distribution,
- law of correlation.

In our study, two cases were studied: The first one considers the chart size tables, while the second follows the law of proportionality controlled by the chest contour. Turner and Bond [20] recommend the use of default tables of measurements rather than mathematical formula interpolation of sizes dedicated to the custom pattern. According to them, the computer system that produces the custom pattern should have the ability to automatically determine the missing measurements of customers in a specific data entry.

Control parameters

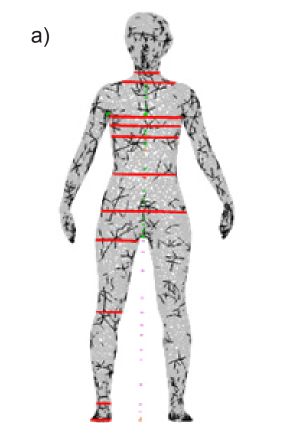
The large number of parameters is required to implement an adaptive procedure to control this prediction model with the minimum number of input parameters. Somehow the morphological parameters show two types of variables: internal and control variables. Internal variables are defined and based on the golden section and the anthropometric as control i.e. two of them must follow certain rules of evolution and proportion in the 3D space, i.e.:

- to have the biggest dimensions in the given directions,
- to be located in two perpendicular directions,
- to be strongly correlated with those parameters which are in the direction of control.

Taking into account these remarks it can be said that the human body can be controlled by the adaptive parameters of height in the vertical direction and the setting of the chest contour (relative to sizes 34, 36, 38, ...) in the horizontal direction.

Distribution plan

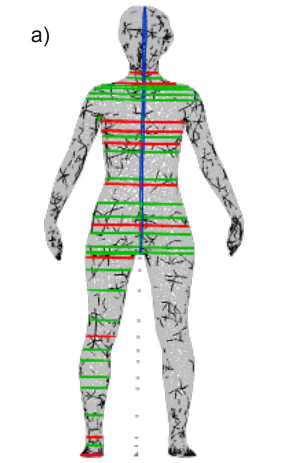
The volume distribution in the front of the human body is not the same as on the back, causing that a new dividing plane is created. This plane ensures that the front represents 62.5% of the total volume of the body and the back - 37.5%. Calculations are performed on the chest contour. The frontal plane is positioned perpendicular to the horizontal section of the chest in accordance with these proportions. The intersection of this plane and the plane of symmetry of the human body defines the homothetic axis. This axis allows to evaluate the different contours of the body in a homothetic manner according to the laws of the distribution volume, which are managed by the respective morphological parameters. ***Figure 2*** shows the concept of modelling the adaptive model morphotype, in which the input variables relating to the real body follow the particular morphology. The input variables are from the scanning process after filtering the data by Rapidform



b)

Parameter	Formula	Code
H	1640	height
hip	0.5294×h	hip
waist	0.6088×h	waist
crotch	0.45×h	crotch
knee	0.248×h	knee
ankle	0.0443×h	ankle
belly	0.5907×h	belly
chest	0.7186×h	breast
armpit	0.75×h	armpit
shoulder	0.8205×h	shoulder
underbust	06953×h	underbust

Figure 4. *Model of morphotype ith primary contours and control setting examples.*



b)

Parameter	Formula	Code
belly1	0.5166×h	bellyl
neck1	0.8463×h	neckl
neck2	0.858×h	neck2
hip1	0.5534×h	hipl
hip2	0.39"h	hip2
knee2	0.2768×h	knee2
calf	0.2×h	calf
fit	0.0047×h	fit
fit2	0.0174×h	fit2
neck3	0.8689×h	neck3
armpit1	0.79×h	armpitl
hip25	0.4112×h	Np_angle
hip15	0.4334×h	hipl 5
belly15	0.469×h	bellyl 5

Figure 5. *Model of morphotype with secondary contours and control setting examples.*

software. During the implementation of the adaptive model of the morphotype, it is necessary to check the monitoring, which is managed by the morphological variables discussed above. For this, the virtual model created during the modelling process is compared with the native model of the real basic morphotype. This feedback loop allows to look for procedural errors and validates the new adaptive virtual model. The scanning tool used to extract relevant data from the human body allows to transfer it to the 3D tool of the design concept, where the process of surface modelling of the adaptive mannequin morfphotype starts. This model determines the general shape (morphology) and parametric model of the future population of human beings. It means that it has been selected from a set of human avatars respecting measurements of basic sizes for a given population.

Modelling of the torso and legs

To define the position of primary contours, it is necessary to set up a database in which the control parameters of the morphotype model (***Figure 4.b***: hip, waist ...) are included. These parameters represent the position of each part of the body depending on the height h, which correspond to the stature of the human body scanned (***Figure 4.a***)

In order to respect the morphology and beauty of the human body, additional, secondary contours must be created. Moreover these contours are also needed for an image of clothing. They are close to an articulation in the case of the joint of a leg or arm, or between two primary contours in order to refine the representation of muscles (***Figure 5.a***). The parameters are also controlled by the height h (***Figure 5.b***: neck1, neck2 ...).

It means that a parametric model of the morphotype can be created when input data important from the point of view of the model management are defined. The next step represents the extraction of primary and secondary contours. (***Figure 6***).

The succeeding step consists of a model symmetrisation. Using the symmetry plane chosen, the contours of each half of

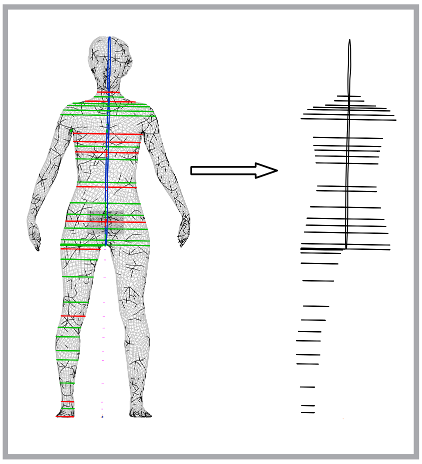


Figure 6. *Extraction of elementary & secondary contours by translation.*

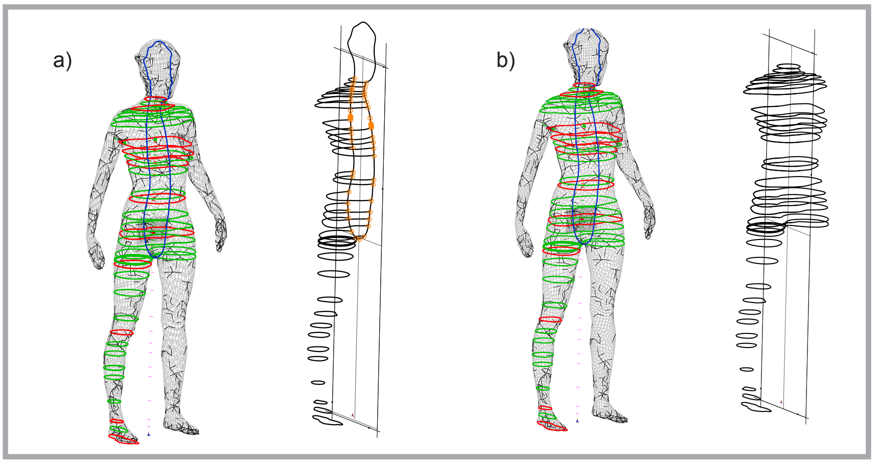


Figure 7. *Semi-symmetrical shape & contours.*

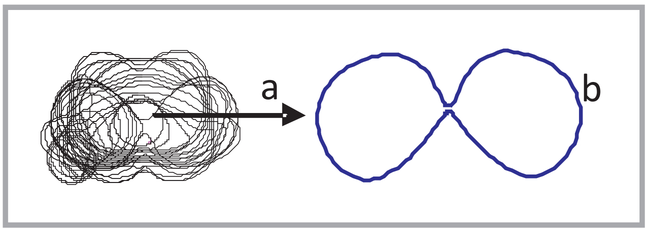


Figure 8. *Creating contours of secondary junction.*

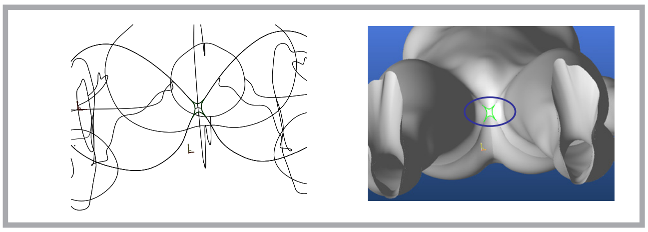


Figure 12. *Creation of crotch contours.*

the primary and secondary contours are created (***Figure 7.a***). These are then symmetrised and sewn in order to define new symmetric contours (***Figure 7.b***). This operation is performed only for the torso. The subsequent phase concerns the join of legs with the torso. Relying on two contours: torso and legs, the final oblique outline defining the connection between the lower and upper part of the human body is created (***Figure 8***). In order to separate the model of the parametric mannequin from the mannequin morpho-

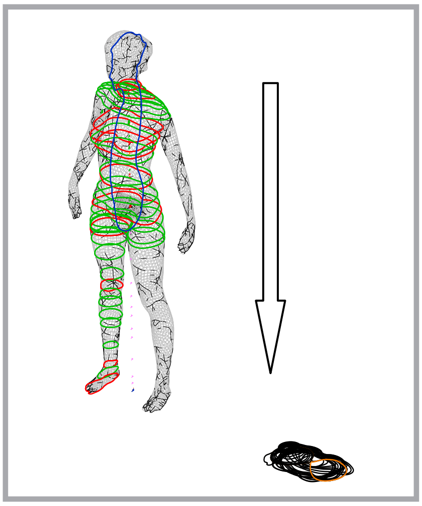


Figure 9. *Parametric dissociation of the morphotype model.*

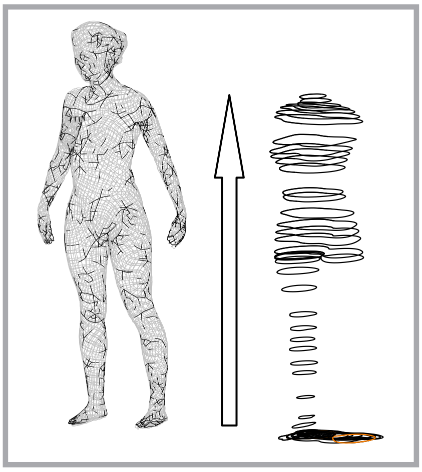


Figure 10. *Contours parameterised by height H.*

type, it is necessary to translate all contours on plane 0, which is at the bottom (***Figure 9***). This procedure allows for the location of contours in the vertical direction as previous control contours managed by height H.

Figure 10 shows the contours of a model parameterised by a new height H representing the mannequin's stature. At this stage of the design, we can integrate the anthropometric parameters in the form of rules. Employing the homothetic translation, we created contours associated with the new size managed by the chest measurement. It became possible to change the mannequin size according to the given chart size and surfaces of adaptive mannequin are generated on these contours. The same procedure is done separately on the contours of the torso and leg. These last ones are duplicated symmetrically with respect to the symmetry plane (***Figure 11***). The problem of the crotch is solved by creating a surface bounded up with the contours, as is seen in ***Figure 12***.

Modelling of the arms

Modelling of the arm represents the last phase of our mannequin conception process, because it depends on changes in the torso and complicates the work procedure. Our work begins with the extraction of the different primary and secondary contours of associative morphological contours of the arm from the "real" mannequin morphotype scanned (***Figure 13***). Then the relative positioning of arm contours on the torso lead us to control three types of spatial evolution: in the transverse direction, in the vertical direction and in the direction called "the height of the arm".

For these two last developments, one additional point needs to be created and positioned at three reference points required for moving the arm, when checking the torso. This is a very important anthropometric point: the acromion (***Figure 14***). The first landmark (note 1) allows to divide the arm to "divorce" the upper segment from the whole body; the second (note 2) manages the evolution of the arm length in the direction of it, and the last (note 3) contributes to positioning the arm in the vertical direction when the model of the mannequin morphotype changes its height. Following the chart size and the parameters measured for calculating the distance between the contours of the arm and plane, the contours are projected on the same plane as the arm line tilted e.g. 20 degrees (on the plane with landmark note 1). In this condition, it is possible to take into account anthropometric rules defining the volume of the arm by employing the procedure of homothetic transformation. Additional opposite displacement (***Figure 15.a***) following the direction of "landmark note

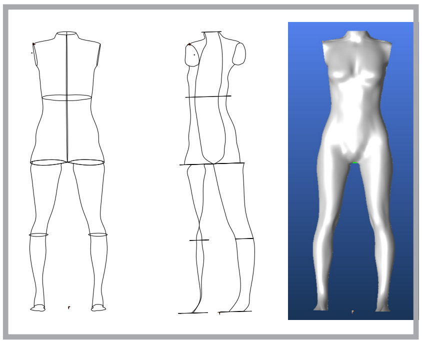


Figure 11. *Surface modelling the mannequin.*

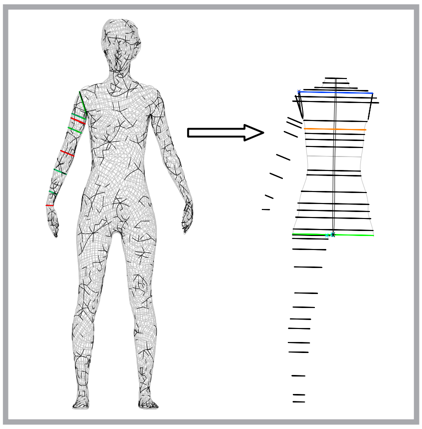


Figure 13. *Extraction of primary & secondary arm contours.*

2" is then performed on these contours, in which their new position is redefined taking into account the control parameters managed by length R, representing the length of the arm. The next stage of the study takes into account the evolution of the arm in the vertical direction. For this, a movement (***Figure 15.b***: t1) of arm contours in the vertical direction with projection on the plane with landmark note 3 is performed. In order to readjust the position of these arm contours (***Figure 15.b***: t2), they are shifted regarding variations in the height H, representing the adaptive mannequin's stature.

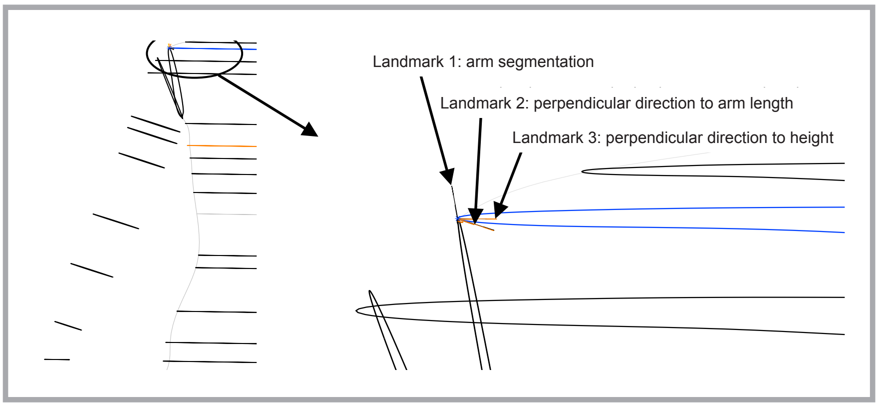


Figure 14. *Landmark changes in the process of acromion creation.*

Results

Finally, the surfaces of mannequin adaptive morphotypes are generated on these contours (***Figure 16***). The left arm is obtained using the symmetry function the same as for the leg. Finally, all surfaces of mannequins morphotype are stitched. The results of adaptive model of morphotype are shown in ***Figure 17***. It is noticed that according to the height H in mm (1640, 1800, 1800 and 1640), the respective circumferences of chest in mm (910, 910, 1000 and 1000) are controlled by the creative process. The morphology of mannequin of morphotype follows the morphology from the scanner, although the large deformations were imposed to the initial human body.

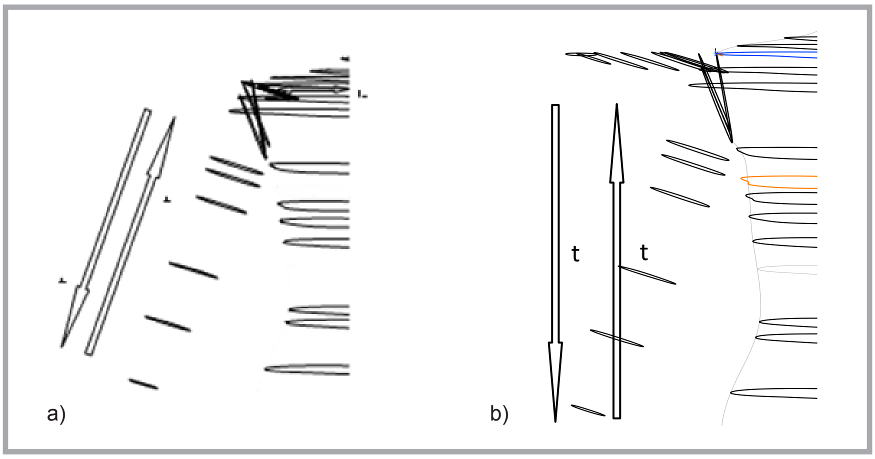


Figure 15. *a) Control settings of the manager of arm length R, b) control settings of the manager of arm length in the vertical direction.*

This model is dedicated to the ready-to-wear garment sectors except the clothing, which is very tight to the body (ease allowance = 0 or negative) as corsetry, because in this particular case it is necessary to consider the evolution of the women chest.

Summary

To develop our model of the human body, we started from segments of the torso and legs. Initially we positioned the primary

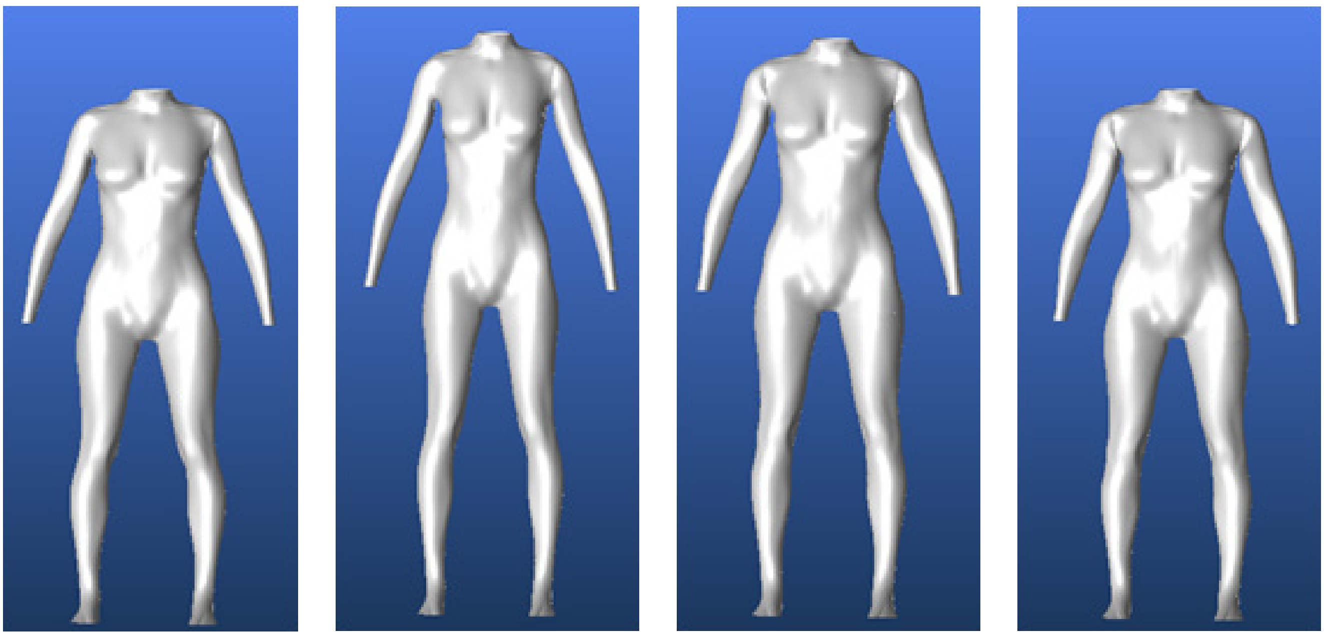


Figure 16. *Parametric mannequin of morphotype.*

(representing the waist, chest, etc.) and secondary contours (respecting the beauty of the human body) associated with the control parameters, and we measured the different contours on the mannequin morphotype. Then we extracted the primary and secondary contours to obtain the half contours compared to the sagittal plane, which allowed us to symmetrise the contours of the torso mentioned to make a symmetric adaptive model. The next step was to separate the contours of the mannequin morphotype to create an adaptive model. We conducted a translation of different contours based on control parameters related to stature h of the mannequin morphotype. Then a new translation upwards was established, thanks to the new parameters of control, for the new height H of the adaptive model. Then we changed the volume of the adaptive mannequin model by applying linear anthropometric rules. It was necessary to create a segmental link to the junction between the torso and legs to respect the continuity of the surfaces. For modelling the arm segment, we use a similar technique. Primary and secondary contours of the moprhotype were extracted, where parametric dissociation of contours of the mannequin morphotype is no longer done on the floor but at the anthropometric point called the acromion. Then we put on it the various landmarks of evolution to perform the work of the volume and length of the arm of our adaptive mannequin model. Finally a final surface model with different values of the contours of the chest and stature is made that will allow us to proceed to the modelling of the garment and work on the interface: man / garment in 3D.

Conclusions

Until now, the creative process of garment conception has been conducted by many repetitive and precise adjustments at the stage of draping on a mannequin or wooden mannequin, which required the manual expertise of experts. However, the increasing demand for the uniqueness of product development for the rapid reduction of responsiveness has led to the development of new software and hardware for these new fashion markets.

Our results have shown that our adaptive mannequin morphotype model follows the human body morphology from the scanner, although large deformations were imposed on the initial human body during the creation process presented. The study proposed can be considered as a new methodological concept, available to any user, that leads to the development an appropriate industrial pattern of a garment in 3D based on a parametric mannequin of the morphotype. Our future work will present the results of our research in the field of the modelling and numerical simulation of a garment in a 3D virtual environment. The strategic point of our study is that the numerical parametric mannequin of the morphotype model integrates the garment model by association without difficulty. On the other hand the flattening of 2D and 3D garment patterns needs to be associative and accurate, and to impose existing fabric deformation linked with the garment drape.

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