

ADAPTIVE MODEL OF THE HUMAN BODY  
– A NEW TOOL FOR FASHION DESIGNERS  
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**ABSTRACT**

The new dynamics of global trade demand change in the traditional ways of designing fashion. The new generation of fashion designers is driven by forces of globalization of trade and the corresponding change of pace in global supply chain; changing demographics and body shapes; increasing demand for better fit and sizes; and, faster changes in fashion trends fuelled by emergence of new mediums like internet. One of the consequences is that just about every piece of equipment in any aspect of the clothing and textile world is connected to a computer of some sort. The new age designers will be designing his new ensemble on a virtual mannequin on a computer. As his client may be any shape, size and origin, based anywhere in the globe, he will be working with body measurements captured in a remote body scanning booth & electronically communicated to him by adapting his virtual mannequin to the new measurements.

This paper presents work carried out at ENSAIT on creation of a virtual adaptive 3D mannequin using the actual human body measurement data captured by a 3D body scanner. The first part of the paper discusses the changes in the world trade that are driving developments of new tools for designers, and positions this study in the larger project framework of directly designing clothing on a virtual body in three dimensions. In the second part the representative model of human body developed using various interactive sciences such as anthropometry & biometrics is presented and in the third part the model is adapted in 3D CAD. Simulations carried out to validate the model are also presented.

**1. BACKGROUND**

Last decade and a half has seen tremendous changes in the global trade. The new dynamics of global trade are demanding change in the traditional ways of designing fashion. The new generation of fashion designers will be using completely new designing tools and corresponding skill sets in future. Some changes in global fashion that are driving these developments are :

1. Globalization: As the world increasingly becomes a global village, the location of designers, manufacturers and buyers has ceased to be a constraint. They can all be located in different parts of the world. Information exchange takes place through electronic transfer (internet), which is just not possible when working on a drawing board.
2. Mass customization: The fashion business followed a simple pyramid model earlier-made-to-measure couture on the top, ready-to-wear (often a distillation of couture) in the middle and knockoffs by mass retailers on the bottom. Since the late 1980s, however, as luxury evolved from privately owned family-run houses to publicly traded global conglomerates, couture became an exercise in branding to sell logo-embossed lipsticks, perfumes and handbags to the masses. With skyrocketing prices, the number of women who shopped for made-to-measure suits (starting at \$20,000) has dwindled from several thousand in the 1960s to a mere 200 today. Haute couture seems to be commercially dead.

Couturiers are now designing for the masses. Karl Lagerfeld for H&M, Isaac Mizrahi for Target and guest designers like Hussein Chalayan & Sophia Kokosalaki, and Eley Kishimoto for British retail chains TopShop and New Look respectively. Ready-to-wear has taken over the design lead from couture and by using technology to provide a better fit of garment with higher comfort, is increasingly addressing higher volume of consumers at the middle –upper levels. Designers of Prêt e Porte fashion as well as the designer/luxury brands are at various levels of addressing this need for greater consumer satisfaction. Mass customization is the emerging technology solution that can provide personal garment customization that is cheaper and faster.

3. Faster changes in fashion trends: Fashion trends are changing faster than ever. Retailers not only want more collections per season but also that their offering to the consumer for a particular season should also keep changing through the season. We have now these so-called "fast fashion" or "dynamic collection" companies can deliver new lines of clothes to their stores every four to six weeks, who are displacing traditional high-end ready-to-wear designers as the leading trendsetters, particularly in fashion-conscious Europe.

Since late 1990s, H&M and Zara have opened hundreds of stores across Europe and have speeded up the design cycle with computer technology. Zara uses data from its 426 stores to spot new trends, and offers 10,000 new products a year. TopShop, another newcomer, generates as many as 300 new designs a week. The shelf life of a garment has fallen from six months to a few weeks, creating a seasonless cycle for fashion. Luxury brands are compelled to adopt fast-fashion tactics to compete. Ferragamo has centralized inventory and established computer links to suppliers, cutting the design-to-delivery cycle by 20 percent, to 10 weeks. Many other fashion houses like Escada have come up with "hot fill-ins" that are midseason collections. For designers, this trend implies quicker development and more designs per week.

4. New media: Expensive fashion magazines which earlier used to be the medium for providing the consumer access and exposure to latest fashion trends have been replaced by new mediums like internet and fashion channels on TV which does the same on a daily or rather hourly basis. The collections are on the internet within minutes of their being shown on the various fashion weeks around the world. The trends are quickly spotted and the fast fashion companies have their knockoffs ready in their stores within a couple of days. Internet has also opened the possibility of retailing fashion directly to the consumer anywhere in the world through B2C e-commerce. New skill sets as well as designing and visual merchandising tools are needed by the designers to address the new mediums.

5. Populations have changed: Fashion designers continue to make clothes based on the traditional 8-10 head, hourglass figures. The population size charts and even the mannequins based on them were prepared many decades ago. Population sizes have changed, as has been indicated by the new size surveys conducted by scanning thousands of people in USA, UK, France and many other places. Actual female figures for example differ widely varying from rectangular to pear-shaped to inverted triangles. Hourglass figures are only a fraction. Further, the bodies today fit more closely to 7.5 head scale. That's why the ready to wear garments fit so few a people.

One of the consequences of these changes is that just about every piece of equipment in any aspect of the clothing and textile world from design, production and ordering to the administration and quality control is connected to a computer of some sort. With the new

set of tools that are under development, new age designers will be designing their new ensemble on a virtual mannequin on a computer. As his client may be any shape, size and origin, based anywhere in the globe, he will be working with body measurements captured in a remote body scanning booth & electronically communicated to him by adapting his virtual mannequin to the new measurements. Finished design will be communicated back and once approved, a dedicated ink-jet printer will print out the fabric, an automatic cutter will cut exact patterns already designed by the CAD system and the garment will be sewn and got ready in a matter of couple of days. Many solutions are available from companies like Lectra and Gerber etc.

This paper presents work representing one of the steps required in achieving this goal i.e. creation of a virtual adaptive mannequin which can be adapted by the designers as per the shape, size and origin of his client using only a few simple body measurements.

## **2. INTRODUCTION**

In the sequence from design conceptualization to production of the garment, the stage of patternmaking is perhaps the most critical for getting consumer satisfaction in terms of size and fit. Traditionally patternmaking is carried out in 2D either on a paper or on computer before being tested in 3D (Maubert R. 2003). It would normally take several fit corrections or adjustments before the most optimal fit is obtained. These alterations are indicative of the transfer errors and incorrect interpretation between the 2D and 3D forms. Patternmaking stage is hence considered be to most challenging and expensive stage for the clothing companies.

The development of a virtually adaptive body form has the potential to revolutionize this stage of clothing manufacture by allowing the assembly and the visualization of clothing on a virtual mannequin in 3D. These developments actually form part of a completely new industrial concept for garment manufacture that is being proposed. Figure 1 shows the various stages of the concept (Aussel A., Barjonet C 1985) (Lourdeaux D., 2001).

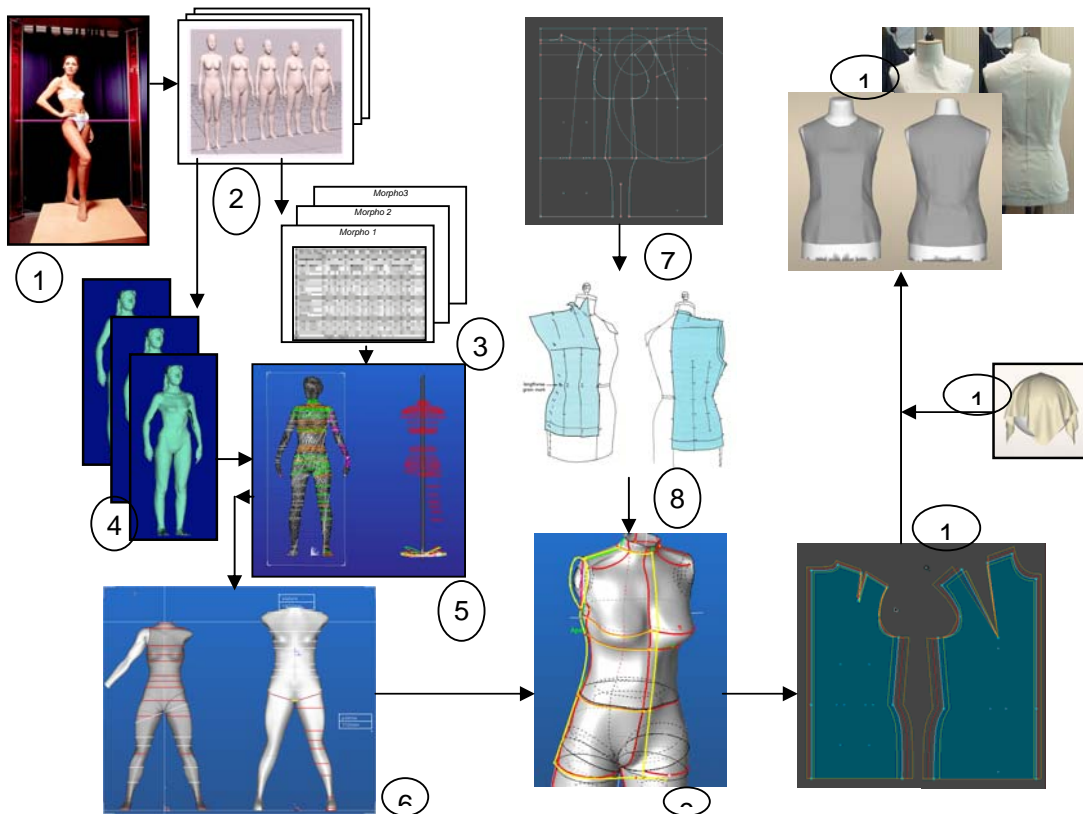


Figure 1. Concept flowchart for assembly and the visualization of clothing on a virtual mannequin in 3D

The first step (stages 1-6), representing this work, is formation of a virtual adaptive mannequin. It comprise of acquiring human body morphotypes using a 3D body scanner (1) (Arquès D., Janey N, 1990) (Shao J 1992) (Dillard T. 2004). The data so acquired is co-related with the pre-determined body shapes (2) and the standard body size-charts (3) of a given population (French in this case) to make a representative morphotype (4). Various dimensions of this morphotype are identified and parameterized (5) to arrive at the adaptive model of human body (6).

The second step (stage 7-9) is creation of an interface for draping clothing on to this virtual mannequin based on use of strategic contours to define the fit of clothing (9). Technical parameters of control in traditional pattern making (7) and draping (8) are applied to the virtual mannequin (6) to arrive at the strategic contours.

In the final step (stage 10-12), the data of style of clothing to be realized (10) is integrated with the data of the mechanical model of fabric (11) and its design/texture/drape characteristics to arrive at the simulated clothing draped on the virtual mannequin (12).

Step 1 of the concept represents the objective of this study.

### 3. PARAMETERS CONTROLLING THE ADAPTIVE MODEL

The adaptive model of human body or a ‘parameterized mannequin’ is creation of an adaptive 3D surface representing a shell around human body on which a piece of clothing shall lie. The surface development of this model is based on the various curves obtained when the scanned human body image is sectioned horizontally. The choice and

the position of these curves, their parameter settings, their relationship with each other and with the standard body shapes and measurements of population are taken into account while developing the model. Amongst other things, this model must be able to interface perfectly with a pattern design digitized in CAD software. The various parameters that control the morphology and dimensions of the model (Soe et al., 2004) are:

- 1) Morphological parameters managing height of the body,
- 2) Morphological parameters managing volume,
- 3) Parameters of control,
- 4) Parameters of volume distribution between the front and the back of the body.

### 3.1 Morphological parameters managing the height

The concept of beauty is related with the analysis of the form, shape and proportions of the human body (Olivier 1967), (Schreider 1937), (Chiappetta, 2000). Concept of beauty is also related to anthropometry, the science of measuring living human individuals for the purposes of understanding human physical variation. The ancient Pythagoreans discovered a curious relation of harmony between two dimensions, called the golden ratio, an irrational number, approximately 1.618 (approx. =  $8/5$ ), that possesses many interesting properties. Shapes proportioned according to the golden ratio have long been considered aesthetically pleasing in Western cultures, and the golden ratio is still used frequently in art and design, suggesting a natural balance between symmetry and asymmetry. Two quantities are said to be in the golden ratio, if the whole (i.e., the sum of the two parts) is to the larger part as the larger part is to the smaller part, or, if the ratio of the larger one to the smaller one equals the ratio of the smaller one to their difference.

Applied to our model of human body representation, many proportions are in the Golden ratio: the stature to the height of the umbilical point, the stature minus the height of the umbilical point to the width of the shoulders, etc (all =  $8/5$ ). The current anthropologists would reverse this ratio and would write  $5/8$  or 62.5%. Nevertheless, proportions of all body parts have been studied and compared with the stature: the head = 13.5% of the stature, the turn of chest = 30.6%, the lower limb measured until the crotch = 51.3%, the length of the foot = 14.9%, the upper limb = 45.5%, the hand = 10.9%. Several of these proportions are the same as the golden ratio. A modern rule based on more scientific studies of the anatomy and the average proportions of the human body was proposed by Charles Blanc in "Le canon des Ateliers" and followed by other anatomists Quetelet (1871), Topinard (1885), Richer (1890).

The important concept which emerges from all this discussion is that the human form follows a standardized rule, a standardized ratio. This concept was examined by the famous Italian biologist Viola, who drew the diagram of the body of the average Italian and worked out the precise proportions on these measurements. He noted that the proportions of this morphotype are found in the statues of antiquity. Most perfect is certainly the rule of  $7\frac{1}{2}$  heads. Lysippe, famous for its Apollon de Belvédère, uses like measuring unit the 'addendum', which one finds 8 times in the measurement of the stature of the body. The manufacturers of wood mannequin decided to choose the rule of 8 heads because it has the advantage of simplifying the process of creation of clothing (Cooklin1990),(Bily1991). This old approach is of great interest in deciding the proportions of clothing as it makes it possible to identify "strategic curves" which will be extracted from the body scan and which will model the morphology of a human body.

The strategic curves extraction is further defined by Europe CEN standards under the expression "primary measurements and secondary measurements".

Accordingly, the morphological model of the human body can be managed by two classes of parameters that define the position of strategic contours with respect to height in a body scan:

1) primary parameters related to contours which respect the rule of the golden ratio and its modern interpretations, and which is in relation to the lines of construction of clothing at the time of its creation (NF 2001) (NF 2005) These parameters manage the vertical position of the measurement.

2) Secondary parameters are related to contours which are complementary to the primary parameters characterizing the morphology of each muscle and contributing to the concept of morphotype.

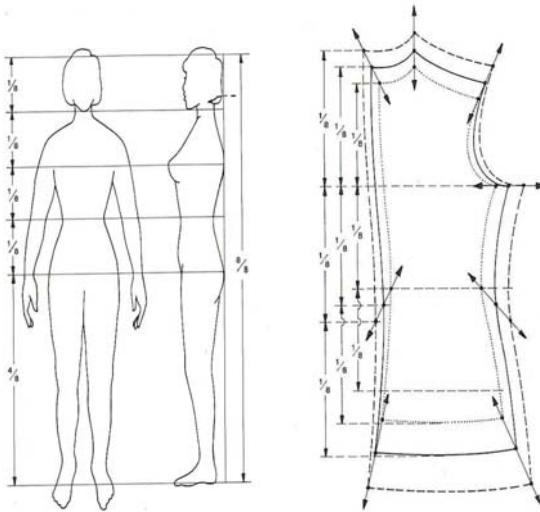


Fig.2 Application of the 8 heads rule to the patterns definition.

### 3.2 Morphological parameters managing volume

The dimensional parameters managing volume must be functions of the pre-determined body shapes and measurement data of the given population so as to control the volume of a human body automatically. Human biometrics (anthropometry) analyzes the measurements made on the human individuals using statistical laws. Two important mathematical laws that are relevant to our study are:

- 1) Law of distribution – the values collected in human biometrics have variable frequencies which are distributed according to various laws of distribution viz. Normal (Gaussian), Poisson etc. In morphology, only the binomial Gaussian law is used.
- 2) Law of correlation - In the human body, dimensions of one body part is often related to that of another. When a dimension increases at the same time as another, it is said that they present a direct positive correlation; on the contrary if it decreases when the other increases, there is direct negative correlation.

It is known that the variation in various dimensional parameters of a body shows a normal distribution indicating a linear relationship between them. Analysis of a table of various girth measurements for example shows a significant correlation between the chest girth and other girth contours taken in the same direction. Thus, a simple relation can be written between them:

$y = A_1 * x + B_1$  where:

$y$  : value of the other parameters (waist girth, hip girth...),

$x$  : value of the chest girth,

$A_1, B_1$  : constants for a given morphotype.

In the case of certain parameters, the relation is not uniformly simple and there are multiple slopes. In such cases the relation can be written as:

$y = A_2 * x + B_2 + A_3 * (P_c - x)$  where:

$P_c$  : value of the chest girth,

$A_2, B_2$  : constant for a given morphotype,

$A_3$  : corrective constant after the break point

### 3.3 Parameters of Control

Considering the large number of parameters defining a human body, it is advisable to setup an adaptive procedure to control the model of prediction using a minimum number of parameters. Broadly speaking, the morphological parameters reveal two types of variables: internal variables and variables of control. The internal variables are definite and correlated according to the rule of the golden ratio and the anthropometric relations whereas the variables of control, (Bily 1991), (Cooklin1991) must follow certain rules of evolution and proportion in the 3D space, i.e.:

- 1) to have the most important dimension in the direction which it control;
- 2) to be placed in two perpendicular directions;
- 3) to be strongly correlated with the parameters which are in the direction of control.

By taking these remarks in consideration, the adaptive human body model can be controlled using the stature parameter in the vertical direction and by the contour of chest (relating to the size: 34, 36, 38,...) in the horizontal direction .

### 3.4 Parameters of volume distribution between the front and the back of the body

Studies have showed that the mass related to the front of a person is not the same as that carried on the back, and is definable by a law of distribution between the front and the back (Seitz at al, 2000). One plan of distribution indicates that the front accounts for 62.5% of the total volume of the body and that the back accounts for 37.5%. A facial plane is positioned perpendicularly to the horizontal section of the chest dividing the body vertically in these proportions. The intersection of this plan and the symmetry plane of the human body define a homothetic axis which will make it possible to evolve homothecy of various body contours according to the laws of volume distribution managed by the parameters preset in “Morphological parameters managing volume”

## 4. METHODOLOGY OF DESIGNING THE ADAPTIVE MODEL

Digital data for morphotype of a human body is acquired using the 3D body scanner by Techmet and associated software supplied by Human Solutions. Information is imported from the scanner in the form of a mannequin morphotype (figure 3) in Lectra’s data-processing tool Design Concept 3D for developing the model of the human body. This

mannequin determines the general appearance (morphology) of the future adaptive parametric mannequin (Wang 2005) and is representative of the characteristic measurements of the basic size for a given population.



Fig.3 Mannequin morphotype

First step is to define the position of primary contours. A data base of primary parameters of control for the mannequin morphotype is created (figure 4a: foot, ankle, knee...). These parameters define the position of each section according to stature  $h_a$  (figure 4b). Next step is to create the secondary contours. They are oblique in the case of a junction of leg or arm or horizontal where refinement due to a muscle is needed (figure 5a). These parameters are also defined in terms of the stature  $h_a$  (figure 5b: genou1, genou2...). Figure 6 shows the calculated values of various primary and secondary parameters which are used for making the mannequin morphotype. At this stage of the process, the first stage of parametric mannequin morphotype is created by extracting values of various primary and secondary contours using an associative translation (figure 7).

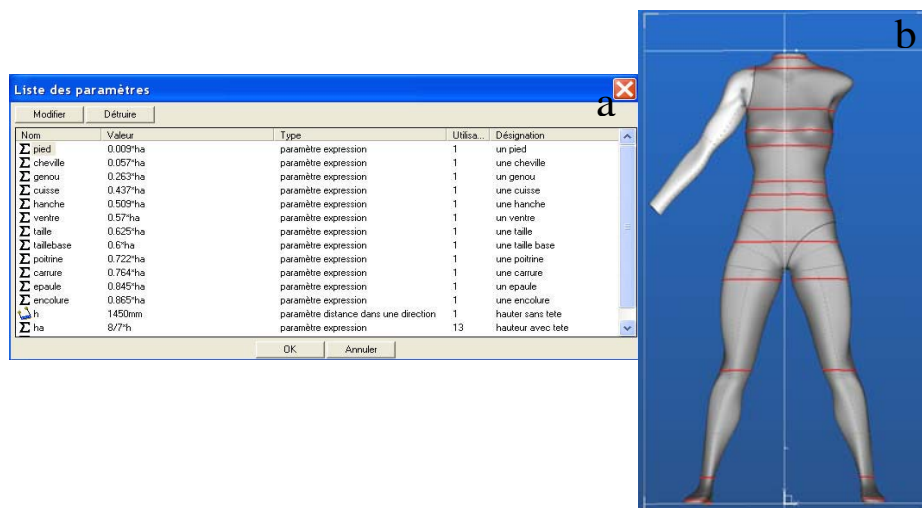


Fig.4. Parameters of order & mannequin morphotype with its primary contours

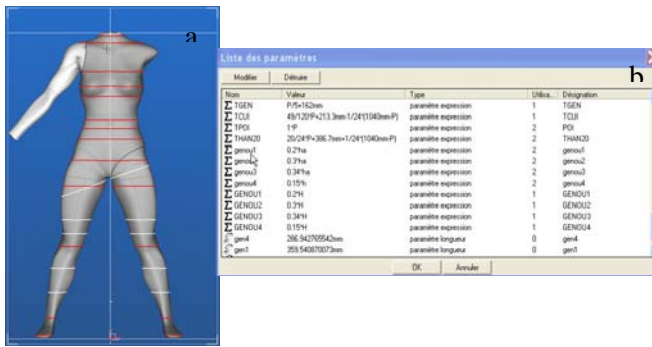


Fig.5. Secondary contours and parameters

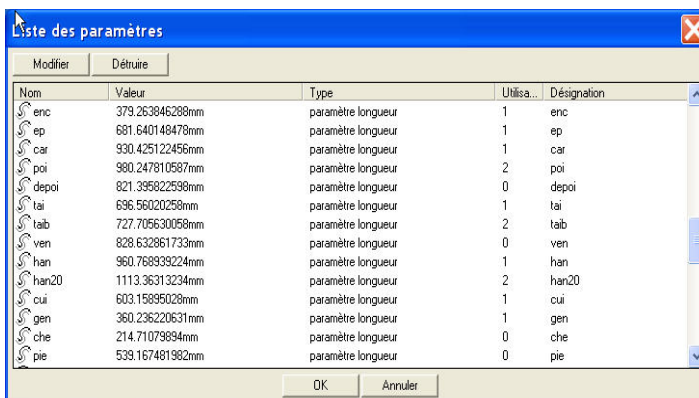


Fig.6. Primary and secondary parameters

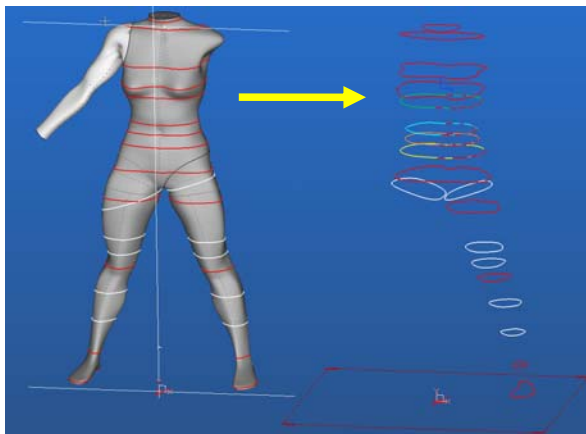


Fig.7. Extraction of primary education and secondary contours by translation

In the next step the mannequin is adjusted for symmetry by use of a judiciously chosen symmetry plane (to correct any directional bias, twist or deformation in the morphotype) and creation of the half contours of each preceding contour (figure 8a). These half contours are then replicated in symmetry on the other half to define new symmetrical contours (figure 8b). This operation is carried out only for the trunk.

Next step is to assemble the members (arms and legs) to the trunk. For legs, oblique secondary contours are used for making the trunk-leg connection (figure 9b). A half

contour is defined from one of oblique contours and two lines of junction binding oblique contours (figure 9a). After applying the symmetry operation on these two new elements, final oblique contour is created (figure 9c).

The distribution of the body volume between the front and the back is defined using the facial plane (Figure 10a) passing through the associated line of distribution. This line of distribution is formed by identifying points on the half contours that divide the contour in the ratio 65(front):35 (back).

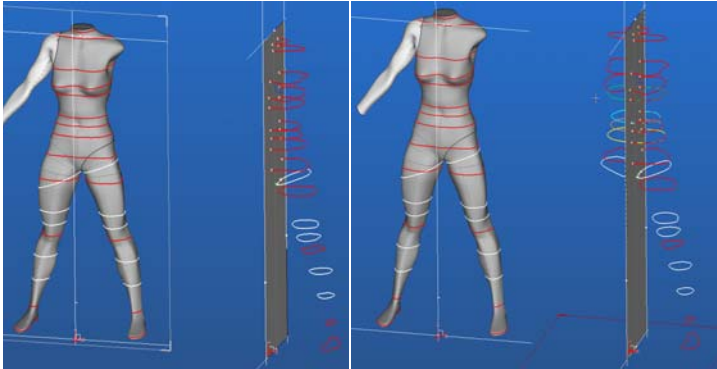


Fig.8. Half contours and symmetric contours of the trunk

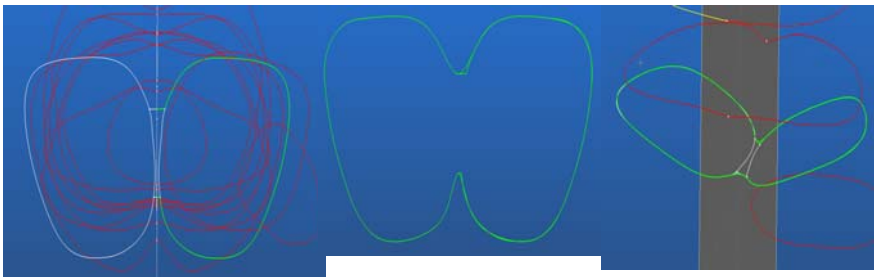


Fig.9. Creation of secondary contours

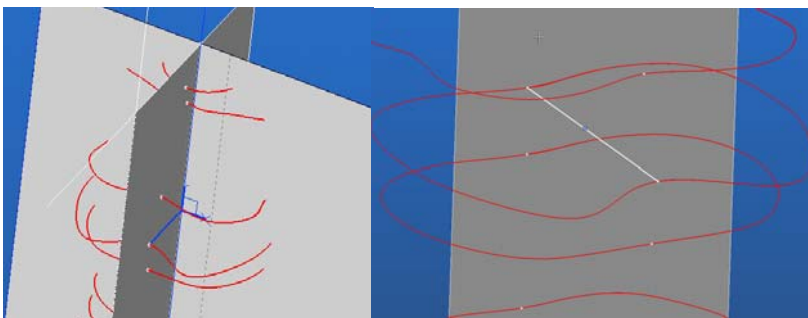


Fig. 10. Distribution back/ front

In the final stage, to move from the mannequin morphotype to a totally adaptive parameterized mannequin, all the parameters are valued zero so that all useful contours are relocated to the horizontal plane (Figure 11a) in zero position. They are then repositioned according to the new table of parameters of control (figure 11b) managed by the new stature H. Figure 12 shows the original contours resulting from the mannequin morphotype and new contours of the mannequin parameterized by a stature H different from ha.

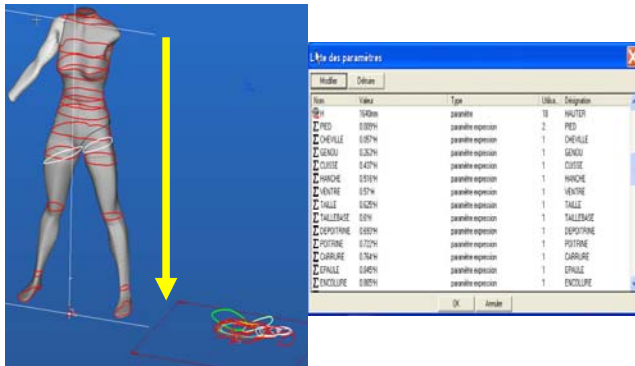


Fig. 11. Parameterized dissociation of mannequin morphotype

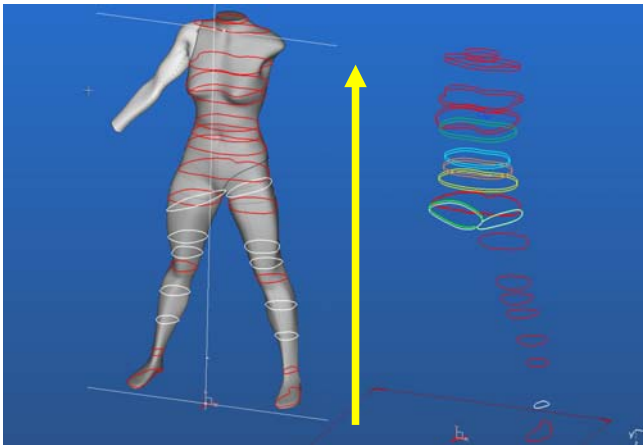
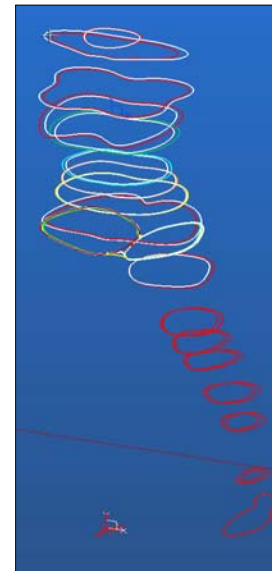


Fig. 12. contours paramétrés par H

Nom	Valeur	Type	Utilisa...	Désignation
P	900mm	paramètre	11	POITRINE
TENC	$P/6+210.7mm+1/60*(1040mm-P)$	paramètre expression	1	TENC
TEP	$0.86*P$	paramètre expression	1	TEP
TCAR	$P/4+135mm+0.7*P$	paramètre expression	1	TCAR
TDEPOI	$0.83*P$	paramètre expression	0	TDEPOI
TTAI	$25/24*P-293.3mm+1/24*(1040mm-P)$	paramètre expression	1	TTAI
TTAIB	$10/12*P-26mm-1/11*(1040mm-P)$	paramètre expression	2	TTAIB
THAN	$20/24*P+266.7mm+1/24*(1040mm-P)$	paramètre expression	1	THAN
TGEN	$P/5+162mm$	paramètre expression	1	TGEN
TCUI	$49/120*P+213.3mm-1/24*(1040mm-P)$	paramètre expression	1	TCUI
TPOI	$1*P$	paramètre expression	2	POI
THAN20	$20/24*P+386.7mm+1/24*(1040mm-P)$	paramètre expression	2	THAN20
genou1	$0.2*ha$	paramètre expression	2	genou1
genou2	$0.3*ha$	paramètre expression	2	genou2

Fig.13. Anthropometry relations

Fig.14. Contours associated with a new size



Anthropometric parameters (figure 13: TENC, Mtoe...) are now integrated into the design using the central homothetic line of intersection of distribution and symmetry planes for creating contours associated with a new size managed by the value of turn of chest P (figure 14). Surfaces of representation of the adaptive mannequin are pressed on the curves of contours of the trunk and the leg separately using an adaptive surface

function (gauge) to define the volume of the mannequin. The leg is duplicated symmetrically (figure 15). The problem of the shape of crotch is regulated by creating a surface limited by contours of separate crotch and total contour exit of these two contours (figure 16)

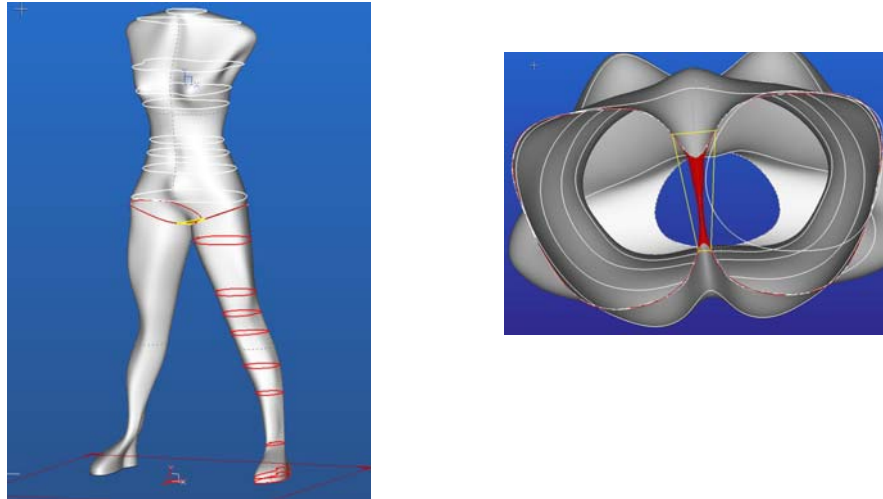


Fig. 15. Adapted surface function (gauge)

Fig.16. creation of contours of the crotch

## 5. RESULTS OF SIMULATION

Figure 17 shows us some results of simulation of this adaptive human body morphotype. Simulations were carried out for various values of stature (1657, 1657, 1750, 1800), of the turn of chest (950, 1000, 1000, 1100) and combination of these two parameters. It was noticed that the morphology of the mannequin created is rather close to original morphotype in spite of the strongly imposed variations.

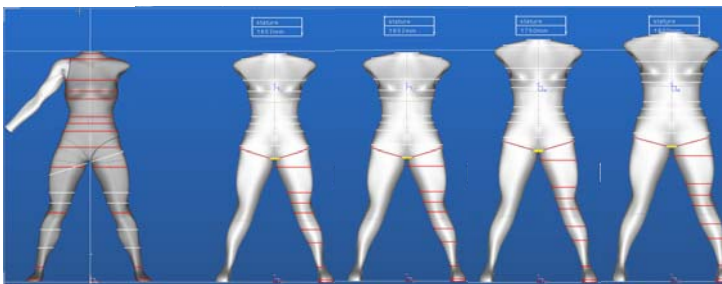


Fig. 17. Mannequin morphotype parameter

## 6. CONCLUSIONS

This paper presents the methodology of making a virtual parameterized (adaptive) mannequin. Results show that a virtual model of human body close to the real morphotypes can be created by this principle of creation. The anthropometric relations can be easily adapted to the measurement data of various populations. The rest of parameters for making the mannequin are definable in terms of two simple measurements of stature and turn of chest. The mannequin can thus be easily adapted by a designer to his requirements. Next stage of development is to integrate the mannequin with the pattern making process.

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