Resizable Trouser Template for Virtual Design and Pattern Flattening

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Abstract

A novel resizable design platform to execute three dimensional (3D) design and grading as well as pattern flattening of lower-body outerwear is developed. A set of Point-Cloud data, captured by a modern body-scanner, is used as raw material to generate a virtual model, which is further sliced at pre-determined horizontal displacements to extract a set of sectional curves. The extracted curves are modified, made symmetrical as necessary, scaled and programmed to be linked with size databases before using them to generate a new surface, which forms a resizable design platform. It has been found to be possible to use the resizable design platform as a 3D drawing board for the creation of virtual trousers and shorts, and for the execution of 3D grading and automatic pattern flattening within the environment of an available computer-aided design (CAD) system. Hence, the processes of fashion illustration and pattern creation may be combined into a single step. As far as is known, such a resizable design platform for combined virtual design, automatic pattern creation and 3D grading of outerwear has not been previously demonstrated.

Key words: Virtual clothing; virtual mannequin; pattern flattening; 3D grading.

1. Introduction

Although free-form three dimensional (3D) objects can be modelled in space without difficulty, using widely available 3D CAD systems, virtual clothing design usually requires a 3D platform on which to create the garments. Very commonly, a virtual mannequin upon which a design may be created is used to help reproduce the required geometry and anthropometry. Significant advances have been achieved in draping flat pattern pieces on virtual mannequins to create virtual clothing (Fozzard and

Rawling 1991, 1992; Okabe et al. 1992; Chiricota 2003; Fuhrman et al. 2003; Thalman and Valino 2005; Luo and Yuen 2005). As a consequence of such development work, this technology has become sufficiently mature to offer a useful preview of prototype garments. Subsequent commercialisation has resulted in the availability of several clothing CAD systems that include virtual mannequins and drape engines (Sayem et al. 2010). In parallel with this research, efforts have also been made to create virtual clothing panels directly on 3D mannequins and these panels may then be flattened into 2D pattern pieces (McCartney et al. 2000; Kim and Kang 2002; Wang et al. 2002a, 2000b; Sayem 2004; Petrak and Rogale 2006; Petrak et al. 2006; Decaudin et al. 2006; Kim and Park 2007; Fang et al. 2008a, 2008b). However this technology is not sufficiently advanced for both close-fitting and loose-fitting garments. Only a few clothing CAD systems include pattern flattening or unwrapping tools, and these only focus on close-fitting garments (Sayem et al. 2010). An efficient solution for developing virtual outerwear in space and subsequently flattening into 2D pattern pieces is not available yet.

2. Research Problem

Unlike close-fitting garments, outerwear does not and indeed should not assume the exact geometry of the human body at all places. Items of outerwear require only to follow the broad architecture of the human body but are still expected to fit the wearer comfortably; having an appropriate size and shape. Outerwear includes a variable space between the body and the garment commonly known as ease; this may be primarily intended to promote the wearer's comfort and performance, it may be design oriented, or it may be a compromise between the two. It is, however, particularly difficult to specify the level of ease required when developing virtual outerwear. Using a precise virtual version of a human body as a design platform does not work effectively for the development of a garment silhouette which is not body dependant, and it is also ineffective for the incorporation of design ease. As a result, it is still considered appropriate to drape pre-drafted flat pattern pieces on a virtual mannequin when creating virtual outerwear, in the same way as when creating items of intimate clothing, and currently-available 3D clothing CAD systems work mainly on this basis.

3. Proposed solution

In order to develop a sketch-based interface for designers to create 3D outerwear, a modified mannequin has been hypothesised which will be developed based on data scanned from either clothed or unclothed human models; but which will be modified to take into account the structure and silhouette of a particular item of outerwear. For the development of such products, specific 3D templates for upper and lower body garments, such as shirts and trousers, should provide designers with appropriate platforms for 3D outerwear. To incorporate ease directly into 3D designs, it is proposed to vary the fundamental 3D templates by identifying the most important girth and displacement measurement areas so that they may be resized with the help of a size database which includes appropriate functional and design eases. Such a product-specific 3D template should provide an efficient design platform after linking with the size database to integrate appropriate levels of ease, and this will facilitate the development of virtual outerwear using drawing and mesh generation techniques. It will be appreciated that coupling the size database with the 3D template will also provide an option for 3D grading. As the associated CAD system contains a flattening tool, the virtual clothing developed on such a template may be unwrapped into 2D pattern pieces, thus making available the capability of 3D to 2D pattern flattening for outerwear.

This paper describes the development of a 3D template for men's trousers and also demonstrates the '3D to 2D pattern flattening' technique which can be used in the industry.

4. Methodology

A reverse engineering and geometric modelling technique is applied to develop a 3D template for men's trouser. An advanced body scanning system from [TC]^2 (Textile/Clothing Technology Corporation), USA having operational parameters of: point accuracy <1mm, circumferential accuracy <3mm and data density between 600,000 and 1,000,000 points per subject is used for capturing a point cloud of a male subject wearing casual trouser made of thick woven fabric.

[Figure 1 near here]

Reverse engineering and modelling software are used to generate a CAD model (Figure 1) from the scan data of the subject wearing the trousers and then to extract from it horizontal sectional curves representative of the garment shape and size (Figure 2). The sectional curves are imported into an available 3D CAD system that includes tools for 3D modelling and texture mapping, lines and curves drawing, mesh generation from drawn curves, flattening 3D surface into 2D. The following steps describe the method.

a) Nine sectional curves as shown in Figure 2 are extracted by slicing the CAD model at pre-selected girth measurement locations that are found to best represent the shape and size of casual trousers. Looseness control girth 1 (LCG1) and looseness control girth 2 (LCG2), taken between the Seat and Crotch, together with upper thigh girths taken at the crotch point (UTCP) and also mid thigh girths are responsible for giving a variable silhouette and looseness to trousers, unlike the waist and seat curves which do not vary and which suspend the garment so it can hang downwards under gravity.

[Figure 2 near here]

b) As the extracted curves are neither continuous nor sufficiently smooth, modified b-spline curves are drawn, based on them, by smoothing out the irregularities as shown in Figure 3. These modified b-spline curves are further used for scaling and surface generation. To ensure a symmetrical finish to the proposed 3D template, just one half of the extracted curves are utilised.

[Figure 3 near here]

c) For the purpose of scaling, the modified b-spline curves are divided into three groups: body rise dependent curves, neutral curve and inseam dependent curves. The upper thigh girth at the crotch point (UTCP) is considered to be a neutral curve, as it is required to increase and decrease its size only in the horizontal plane (X & Y directions of the 3D coordination system) after scaling. This is not influenced by changes to either the body rise or to the inseam.

The waist, low waist, seat and LCG 1 & 2 are considered to be body rise dependent curves as they are required to change their sizes in the horizontal plane after scaling and are also subject to vertical displacement of their position in either the +Z or the –Z direction if the body rise is increased or decreased respectively.

The thigh, knee and bottom hem curves are considered to be inseam dependent curves as they are required to change their sizes in the horizontal plane after scaling and they are also subject to vertical displacement of their position in either the +Z or the –Z direction if the inseam is increased or decreased respectively.

d) The neutral curve is scaled with one factor based on the scaling point shown in Figure 4. The scaling factor is A'/A, where:

A' = desired value of the curve from size table; and
A = the existing size of the curve.

[Figure 4 near here]

e) The rise dependent curves needed to be scaled with three factors to ensure their size changes appropriately in the $\pm$X and $\pm$Y directions and also the vertical displacement in the $\pm$Z direction with change in rise length. Before that, the rise is defined as a vertical line from the centre of the waist to the crotch, as shown in Figure 5, and is scaled from the centre of the waist with a factor BR'/BR, where:

BR' = desired value of the body rise from size table; and
BR = the existing length of the body rise.

The rise dependent curves are then scaled from the end point of the scaled rise as shown in Figure 5 and with the factor of BR'/BR for the $\pm$Z direction and using B'/B for the $\pm$X and $\pm$Y directions, where:

B' = desired value of the each curve from size table; and
B = the existing size of that curve.

[Figure 5 near here]

f) Similarly the inseam dependent curves needed to be scaled with three factors to accurately define the size changes in the ±X and ±Y directions and the vertical displacement in the ±Z direction in respect of changes to the inseam length. Before that, the inseam line is defined as joining the innermost points of the curves as shown in Figure 6 and is scaled from its upper end with a factor of IL'/IL, where:

IL' = desired length of the inseam from size table; and

IL = the existing length of the inseam.

Then the inseam dependent curves are scaled from the upper end point of the scaled inseam line as shown in Figure 6 and with the factor IL'/IL for the ±Z direction and C'/C for the ±X and ±Y directions, where:

C' = desired value of the each curve from size table; and

C = the existing size of each of that curves.

[Figure 6 near here]

g) In order to link with the scaled curves, a table of size parameters is developed using the Excel program, as the CAD system facilitates Excel-linking of external values with the parameters of geometrical objects modelled in it. The size dataset is presented in Table 1. The values for waist, low waist, seat, body rise, inseam length and leg hem girth are taken from the size chart for trousers for men described by Aldrich (1990) in the second edition of the book "Metric Pattern Cutting for Menswear". The looseness control girths 1 and 2, as used in this work, are not usually included in traditional pattern drafting systems for trousers, thus their values are not available in traditional size charts. Using this 3D modelling technique based on sectional curves, these two curves play an important role in defining the trouser silhouette between the seat and the crotch line. They contribute to the fullness of the trousers from the hip to the thigh area. It is thus assumed that their value would not be less than the value of the seat. Considering this, the same value as the seat is adopted for these two girths as in Table 1.

The values for the UTCP, thigh and knee are taken from the body measurement of the male subject whose scanned data is used in this work. The male subject had a waist measurement close to a trouser size of 90cm, so those measurements for the UTCP, thigh and knee are taken for this size and they are systematically graded for the other sizes.

[Table1 near here]

h) The size table has been further split into sub-sections for individual sizes from 74 to 110 and for functional and design ease allowances, as for example in Table 2 for size 90, which are added to them. It should be noted that there is no definitive rule or formula available to calculate functional and design eases for a particular type of garments (Petrova and Ashdown 2008; Gill and Chadwick 2009). The ease values used in this work are included only for the purpose of testing the proposed 3D template and can be readily changed based on designers' and wearers' requirements.

[Table1 near here]

i) Once all nine curves are scaled and linked with the each of the size databases, a geometric modelling technique with '*curve to curve matching*' and '*parametric synchronisation*' options is applied to generate new surface out of them. Two problems occurred with the attempt to generate new surface out of the scale curves. Firstly, the geometrical differences between the top five curves and the bottom four curves. The top five curves are open B-spline curves, whereas the bottom curves are closed B-spline curves. The modelling tools of the software do not allow the generation of a continuous surface out of these open and closed curves. Secondly, if two separate surfaces are made out of closed and open curves separately, the system also could not merge them seamlessly again for the same reason. To solve these problems, the bottom curves, namely the upper thigh girth at crotch point (UTCP), thigh, knee and bottom hem girth, are split with a distance of 2 mm along the inseam position. This converted the bottom curves into open curves and ensured the generation of a seamless surface in two steps.

[Figure 7 near here]

j) In the first step, a surface is generated out of the top five curves and the UTCP and in the second step, a surface is generated with the lower curves and including the UTCP. In both cases, the UTCP formed a common end contour and thus merged the surfaces seamlessly, as can be found in Figure 7, and formed the left part of the desired trouser template. The left part is then mirrored on the other side to make the complete trouser template that is hypothesised in section 3 (Figure 8).

[Figure 8 near here]

5. Testing

The functionality of the resizable template described in section 4 is tested, based on the following criteria:

a) function as a drawing platform;
b) 3D clothing development and flattening;
c) automatic grading of 3D clothing;
d) resizability.

Using the "region" drawing and the "triangulated surface generation" tools, the 3D design of trousers may be developed on the template. Available rendering tools are used to visualise different fabric designs. Finally the 3D designs are automatically flattened into 2D pattern pieces using the flattening tools. The resizability of the template is checked by linking the developed size databases and also by manual variation of the values of size parameters manually.

6. Results and Discussion

The trouser template, which has been developed within the framework of this research and has been described in section 4, has been found to be fully functional in respect of serving as a 3D drawing board for clothing designers. It allows the drawing of any free-hand curves on its surface. Using 3D drawing tools, it is possible to specify the outline of a 3D design of trousers or shorts on it, as can be seen in Figures 9 & 11. When a new layer of surface is generated, based on the specified outlines of the 3D shape of the template by using the surface generation tools available in the CAD system, a 3D representation of the virtual trousers or shorts is made possible as may be seen in Figures 9, 10 & 11. The virtual clothing developed in this way stays as an adjacent top layer of surface on the 3D template.

[Figure 9 near here]

[Figure 10 & 11 near here]

Graphical features of the fabrics can also be imparted on the virtual clothing designed on the 3D template with the help of rendering tools. An example is presented in Figure 12. The geometrical properties of the virtual clothing are fully representative to that of the 3D template. Moreover the surface of the virtual clothing generated on the template may be completely developed into 2D by the implementation of a flattening engine, as can be seen in Figure 13. The flattened pieces maintain the exact dimensional properties of the virtual trousers. These can be directly used as the production patterns after addition of suitable stitch and seam allowances. It is noticeable in Figure 13 that the flattened waistband from the virtual trousers of Figure 9 is not straight and rectangular as a traditionally-drafted waistband is expected to be. This indicates that the flattened pattern pieces interpret the 3D shape of the virtual garments and will reproduce it exactly without the necessity of any darts when assembling the fabric together.

[Figure 12 & 13 near here]

The geometry of the virtual clothing generated on the 3D template is dependent on the geometry of the 3D template. As a result, any change in size and shape of the 3D template is automatically reproduced in the virtual clothing developed on it. This provides the opportunity of automatic grading in 3D by resizing the 3D template with the help of the size database developed and interlinked with it. Figure 14 shows the automatic grading in 3D of a simple left-front panel developed on the design template when, for example, the sub-databases of sizes 78, 86 and 106 are individually linked with the 3D template. A variable silhouette can also be produced by altering the size parameters individually or in combination, as shown in Figure 15.

[Figure 14 & 15 near here]

7. Conclusion

Automatic flattening of virtual clothing into 2D pattern pieces offers a number of benefits to the clothing industry. It combines into a single step, creative clothing design and pattern creation, which are traditionally executed by two separate professionals. It not only reduces the manpower involvement, but also shortens the product development lead time. However, this technology cannot be implemented in the industry until an efficient CAD software package with functional 3D design platforms for both intimate wear and outerwear and a flattening module becomes available on the market. The virtual mannequin offers a solution for creating body-hugging garments, but there have not previously been any efficient solution for outerwear. It is proposed that product-specific resizable templates should be used as 3D design platforms for outerwear. In this paper, a process for developing a resizable trouser template by applying reverse engineering and geometric modelling techniques has been demonstrated. The resizable trouser template serves as a 3D drawing board to develop virtual trousers and shorts. Virtual clothing developed on it may be readily developed into 2D using a flattening engine. The template is resizable with the help of eleven size parameters including nine girth measurements and two linear measurements (body rise and inseam). This offers the opportunities for automatic grading in 3D and for the creation of a variable silhouette. The process demonstrated here will serve as a guideline for software developers while developing 3D design interfaces for outerwear, for both men and women, in a 3D CAD environment directed towards pattern flattening.

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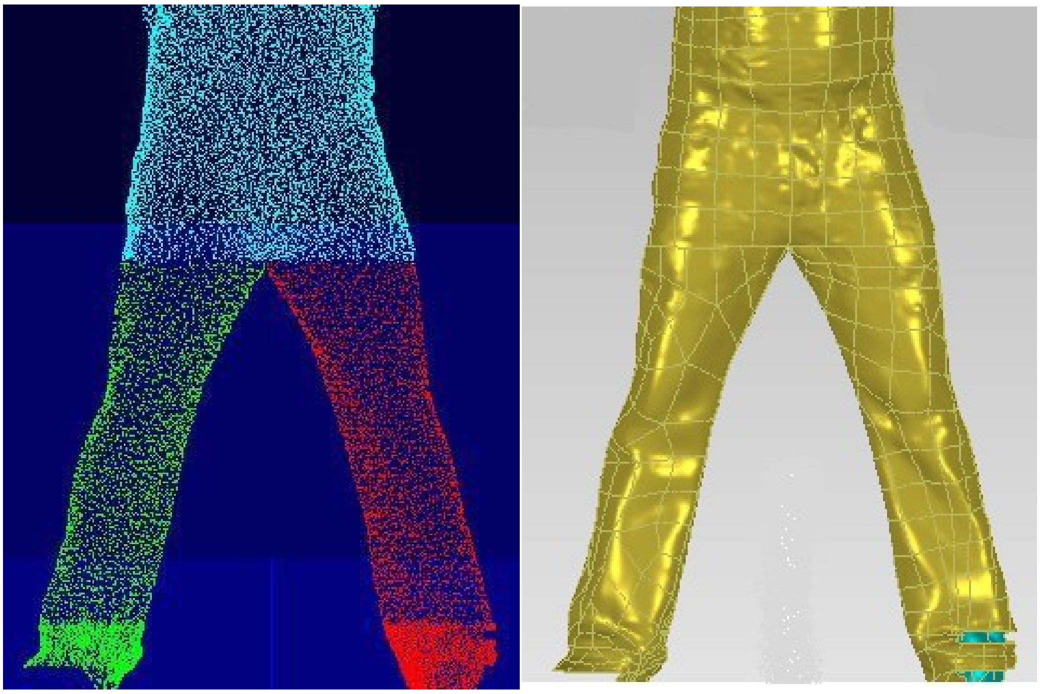


Scan data **CAD Model**

Figure 1. Scan Data and CAD Model

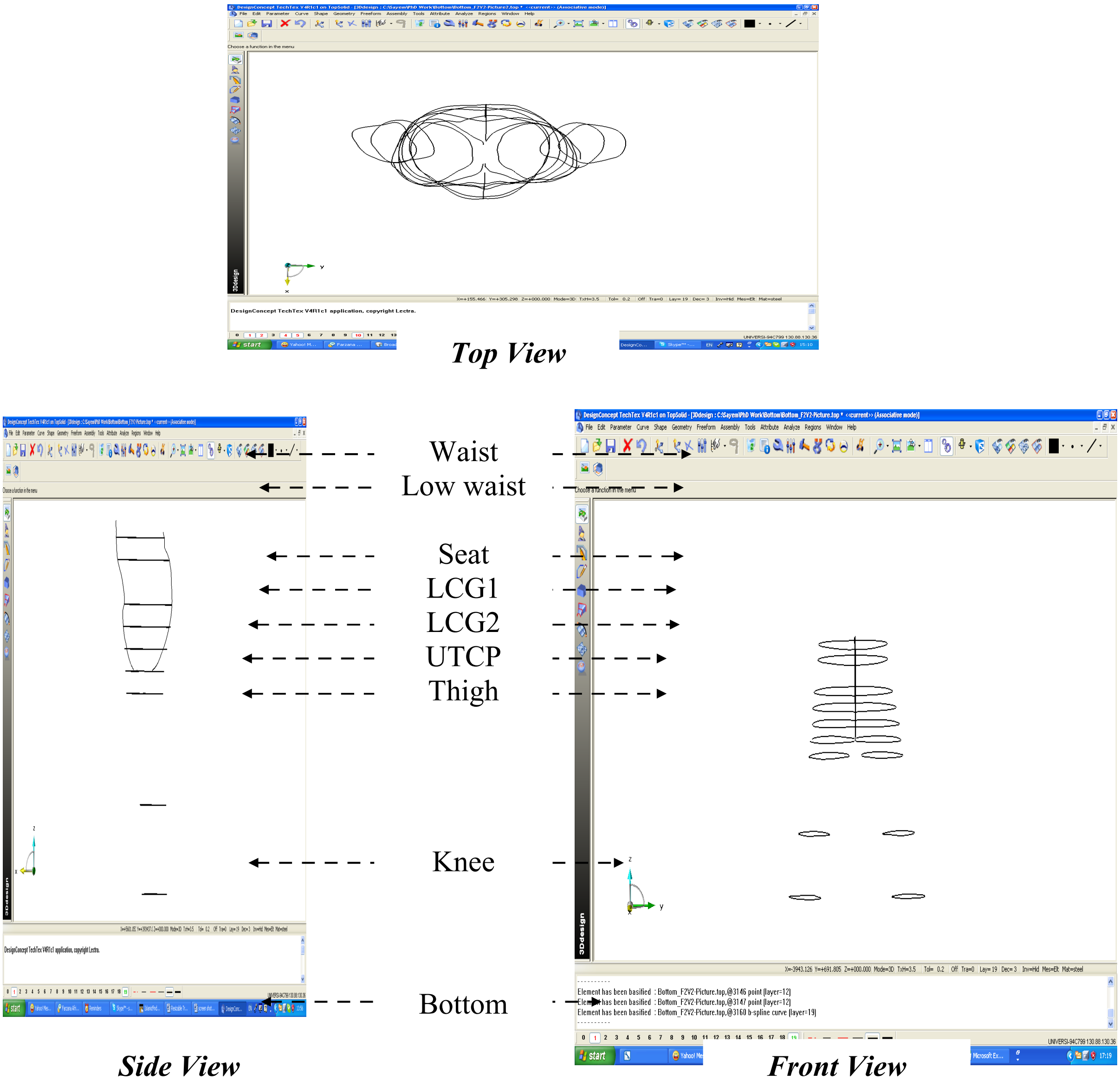


Figure 2. Sectional Curves Extracted from the CAD Model

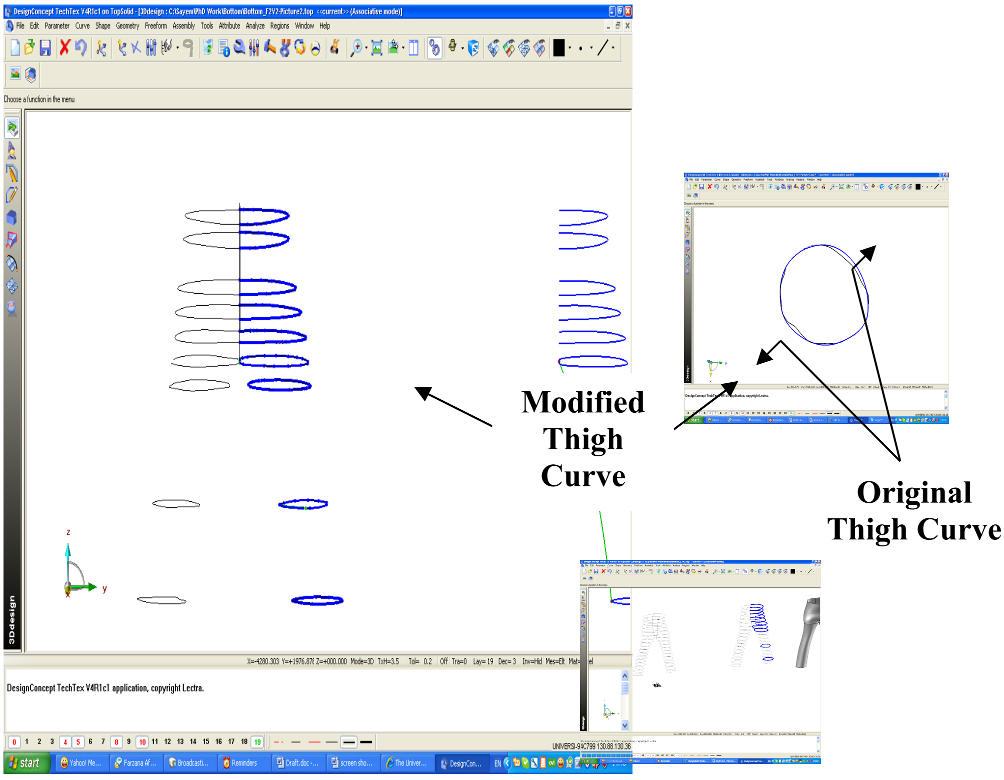


Figure 3. Drawing Modified b-spline Curves

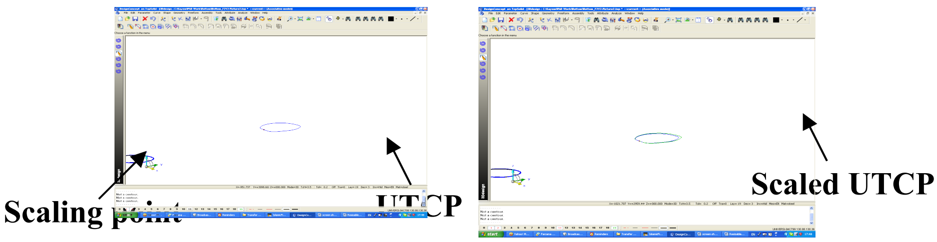


Figure 4. Scaling the Neutral Curve

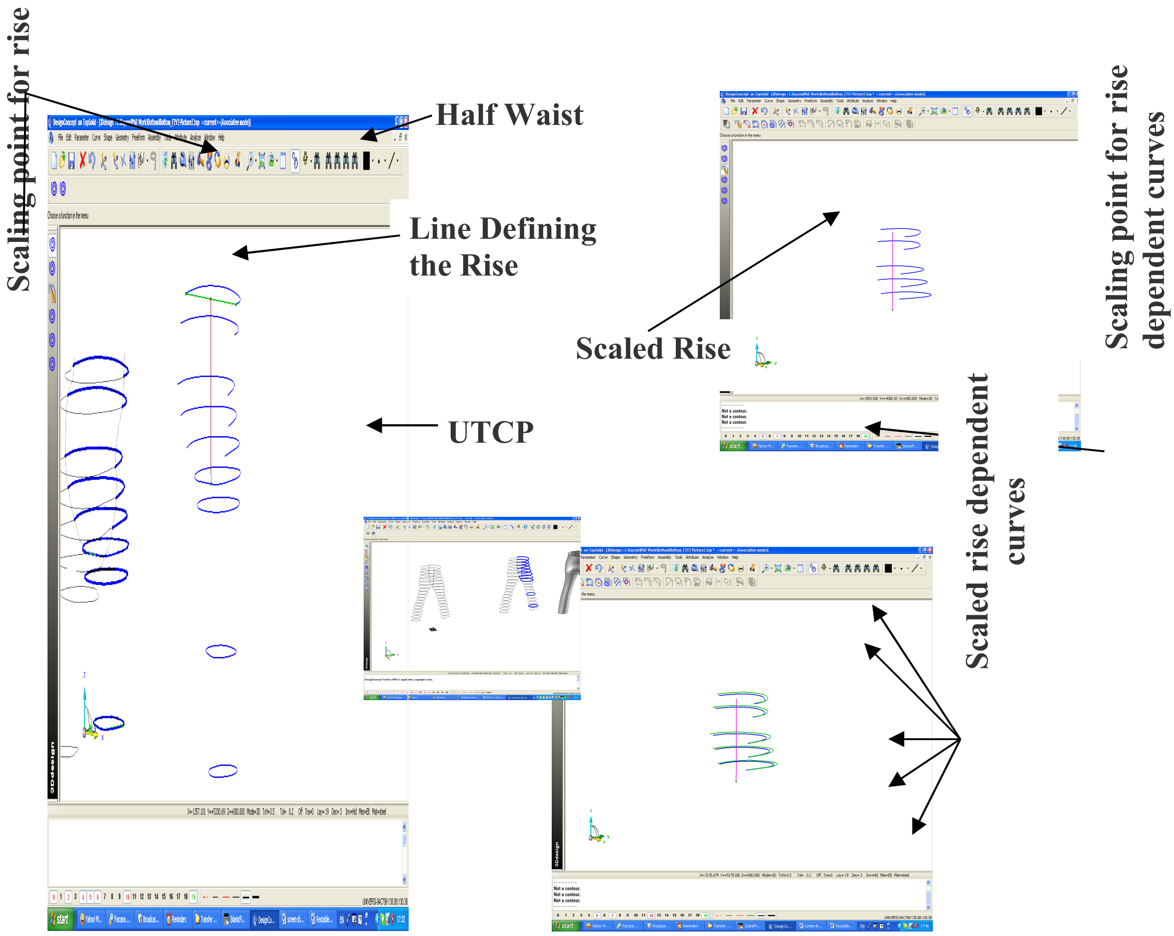


Figure 5. Scaling Rise Dependent Curves

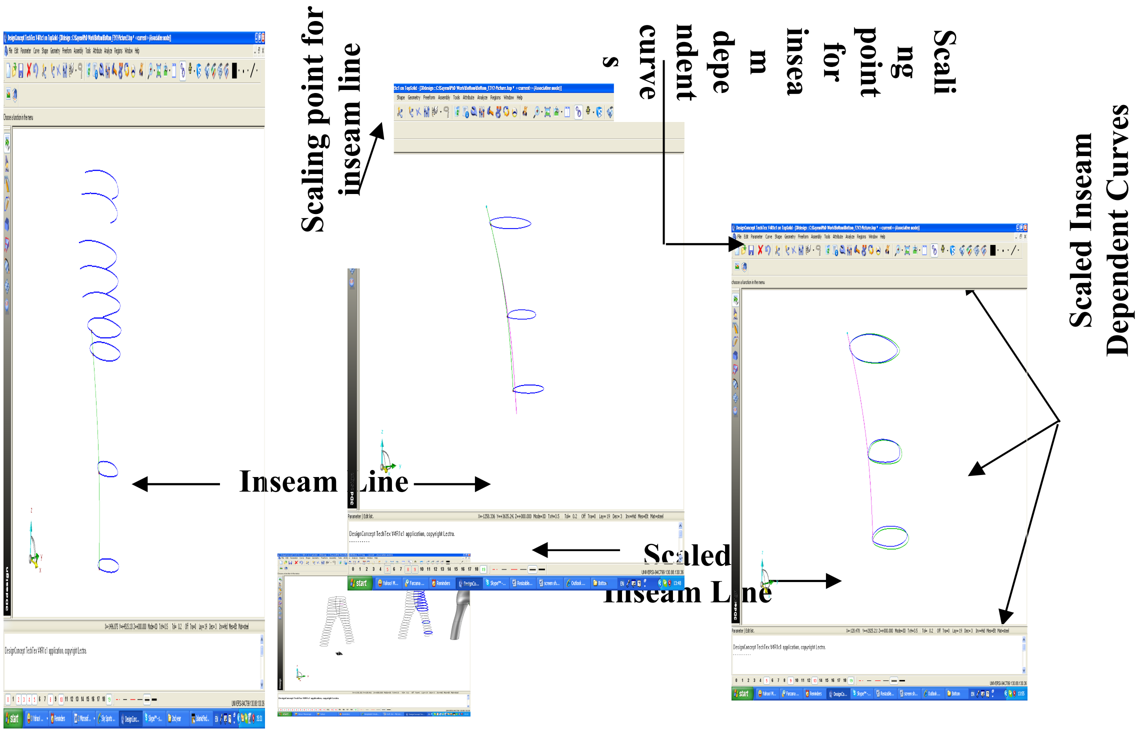


Figure 6. Scaling the Inseam Dependent Curves

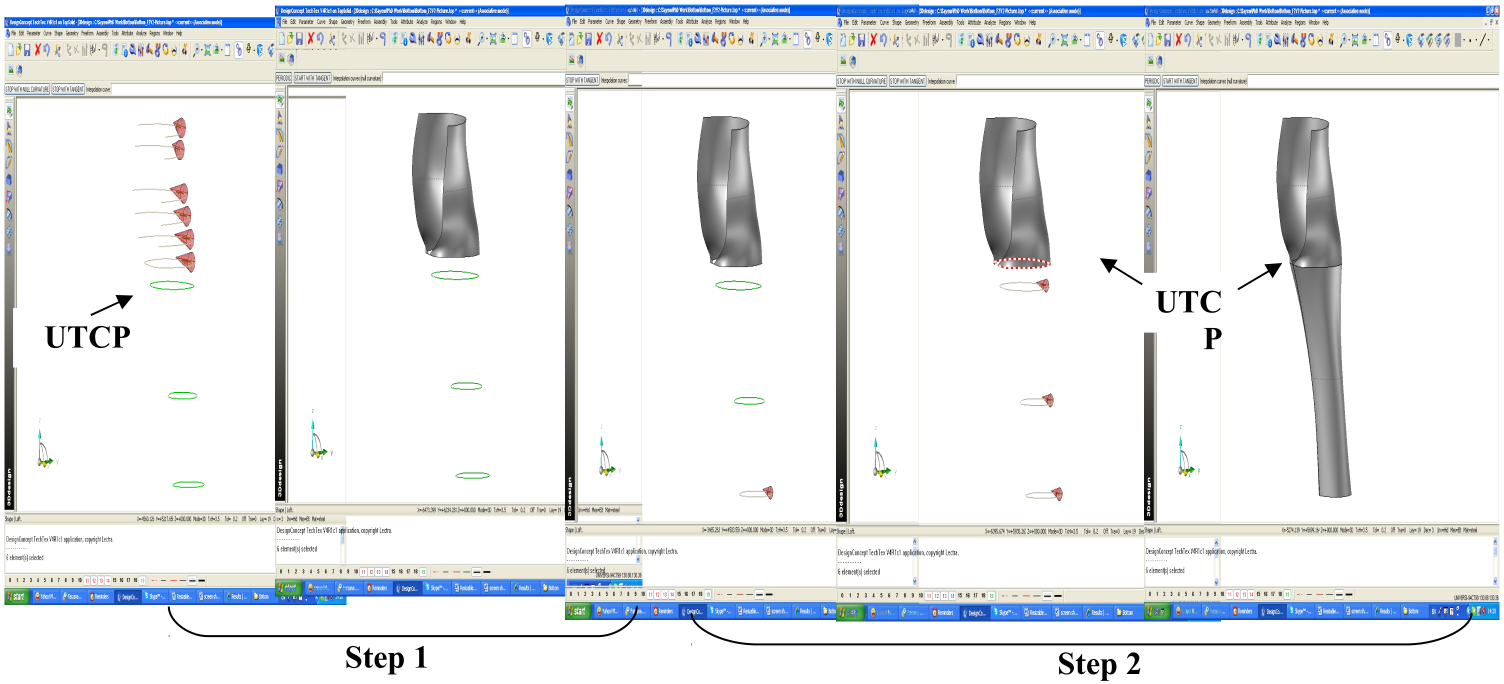
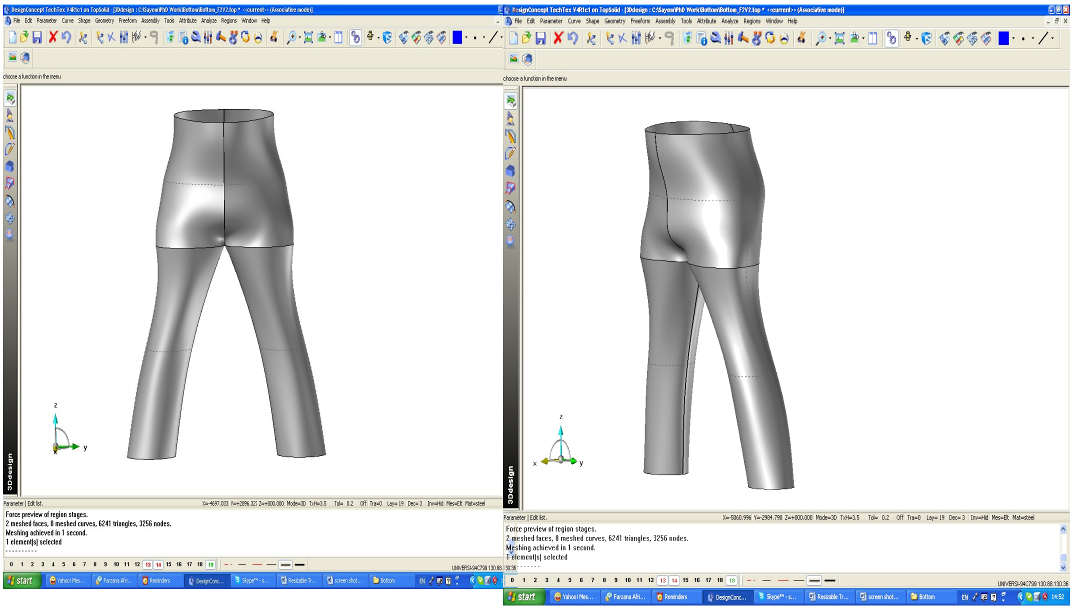
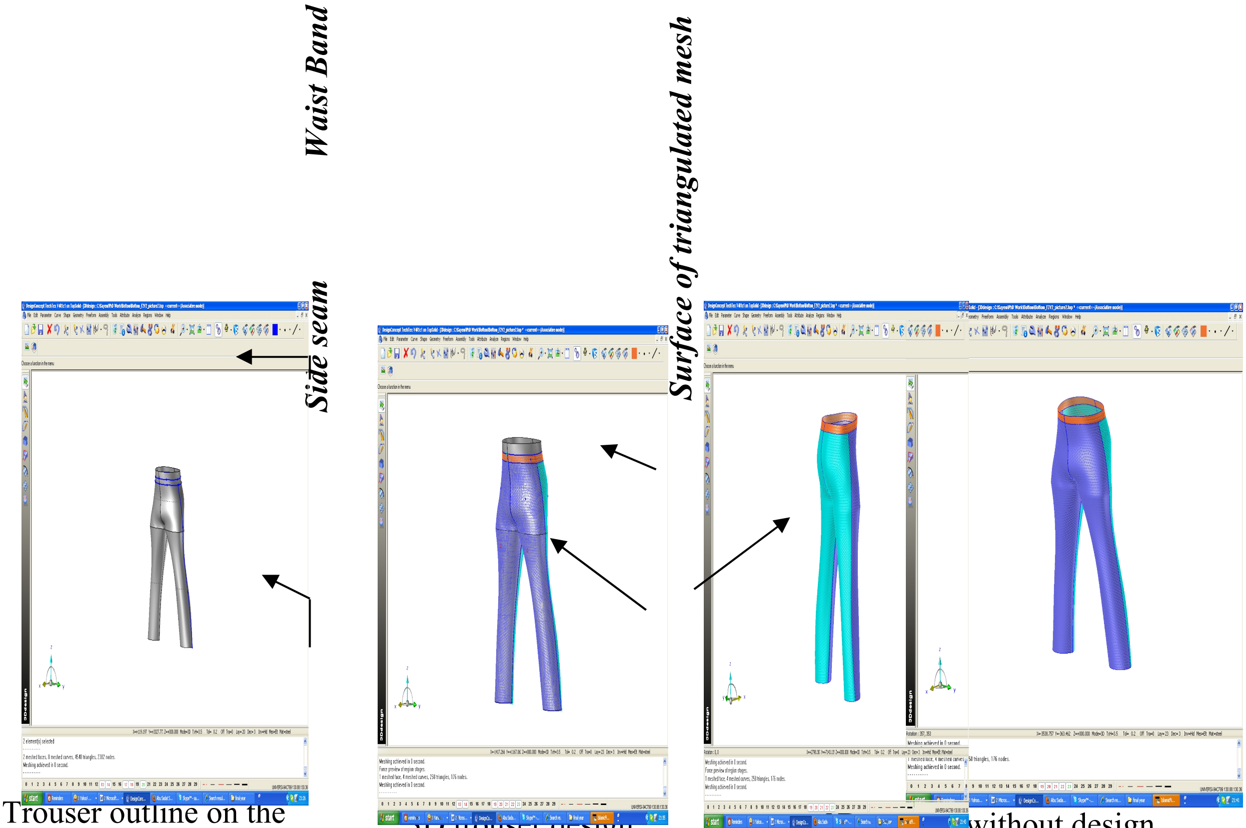


Figure 07 Steps of Surface Generation out of Scaled Curves



Front view *Angular side view*

Figure 8. Resizable Trouser Template



Trouser outline on the design template

3D trouser design as mesh surface

3D trouser without design template

Figure 09. Designing Trouser on the Resizable Template

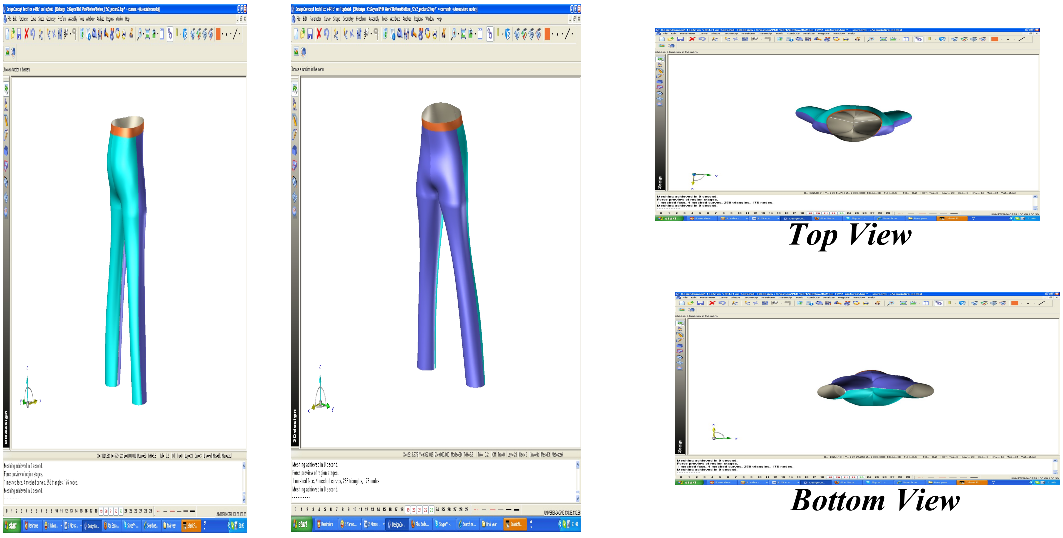


Figure 10. Virtual Trouser after Solid Surface Rendering

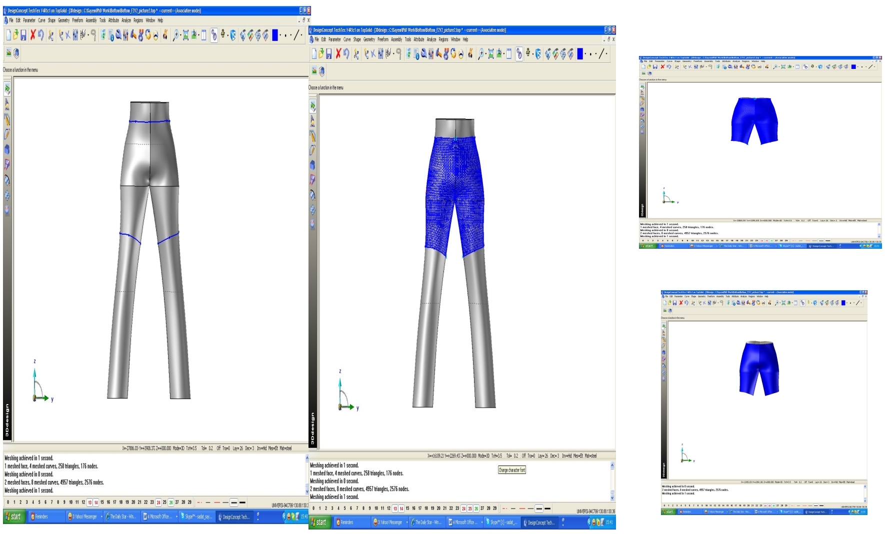


Figure 11. Designing Shorts on the Resizable Template

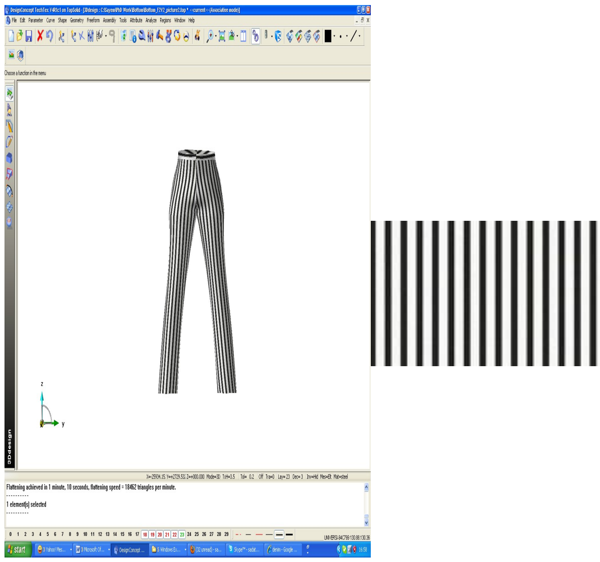


Figure 12. Virtual Trouser Rendered With Black and White Stripe

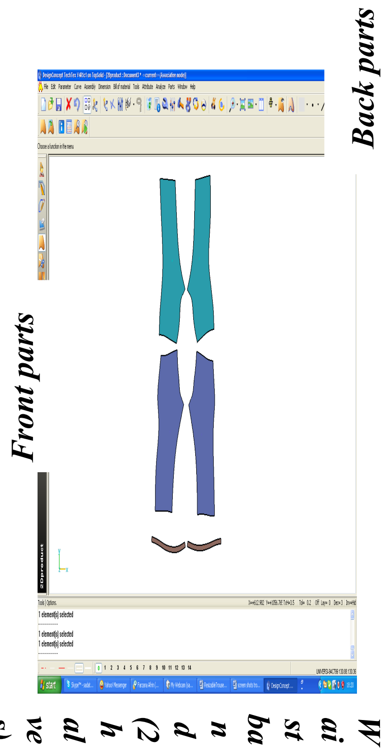


Figure 13. Flattened Pattern Pieces

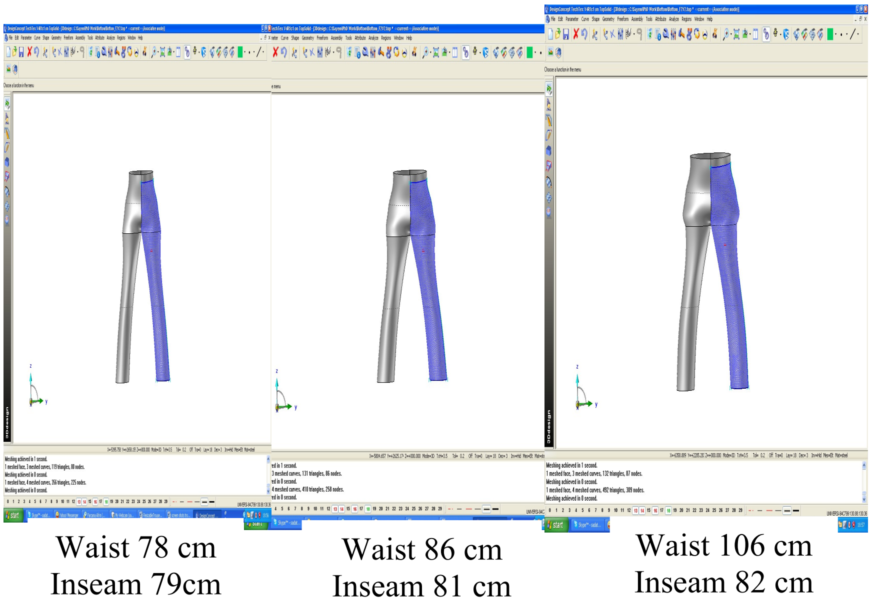


Figure 14. Example of Automatic Grading in 3D

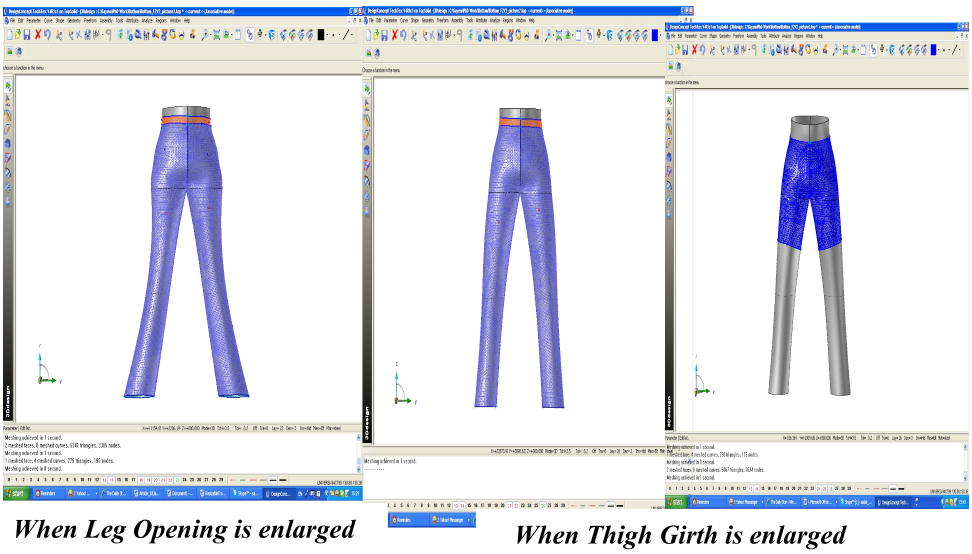


Figure 15. Variable Silhouette by changing the Girth Measurements

Table 1. Size Table for Men's Trousers

Measurement positions	Measurements for Men's Trousers without Ease (in cm) *(Waist used as size designation)*								
Waist	**74**	**78**	**82**	**86**	**90**	**98**	**102**	**106**	**110**
Low waist	77	81	85	89	93	100	104	108	112
Seat	92	96	100	104	108	114	118	122	126
Looseness control girth 1	92	96	100	104	108	114	118	122	126
Looseness control girth 2	92	96	100	104	108	114	118	122	126
Body rise	26.8	27.2	27.6	28	28.4	28.8	29.2	29.6	30
In seam length	78	79	80	81	82	82	82	82	82
Upper thigh at crotch point	58	59	60	61	62	63	64	65	66
Thigh	49	50	51	52	53	54	55	56	57
Knee	36	37	38	39	40	41	42	43	44
Leg girth at hem	41	42	43	44	45	46	46	46	46

Table 2. Size Parameters with Ease Allowances for Size 90

Size Parameters	Measurements in cm	Functional Ease	Design Ease	Final Trouser Measurement	Linking Value for Scaled Curves
Waist	90	5	0	95	47.5*
Low waist	93	5	0	98	49*
Seat	108	5	1	114	57*
Looseness control girth 1	108	5	3	116	58*
Looseness control girth 2	108	5	5	118	59*
Body rise	28.4	1	0	28.4	28.4
In seam length	82	0	0	82	82
Upper thigh at crotch point	62	5	3	70	70
Thigh	53	5	2	60	60
Knee	40	5	2	47	47
Leg girth at hem	45	-	0	45	45

*Note: * half of the final trouser measurements has been used.*