GEOMETRICAL DESIGN ALGORITHM FOR KNITTED SKIRTS

Mioara Creţu and Luminiţa Ciobanu
Technical University "Gheorghe Asachi" of Iaşi, Faculty of Textile, Leather & Industrial Management, Department of Knitting and Ready-Made Clothing, Romania
lciobanu@tex.tuiasi.ro

ABSTRACT

Even if the knitted fabrics are considered to be 2D materials, the final products have a 3D geometry, regardless of their application. Knitting on flat machines offers the possibility of producing fabrics with 3D geometry or integral products. The main problem is how to translate the 3D fabric/product geometry into a 2D plan required for the knitting programme. The paper takes into consideration the women skirts as a 3D knitted product and studies the way such a product can be divided into simple 2D basic geometrical bodies (rectangles and triangles).

Key Words: knitted skirt, basic geometrical bodies, gores

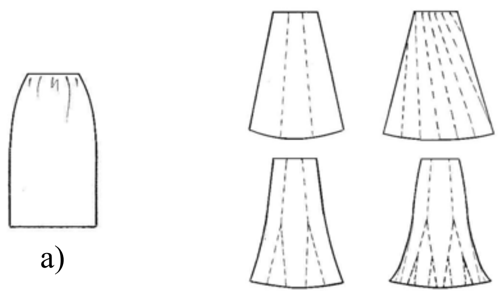
1. INTRODUCTION

The skirt shape is determined by the geometrical specifics of the body part, but also it is influenced by the stylistically fashion characteristics. Different from the skirts made of woven fabrics, where the complex 3D shape is obtained assembling garment parts of preset form and dimensions, the knitted skirts can be produced directly through integral knitting. The knitting of complex 3D fabrics allows eliminating almost completely the cutting and sewing operations.

The paper proposes a new approach to the design of knitted skirts based on the equivalence of the skirt shape with a 3D geometrical body, like cylinder or frustum of a cone. This way, the skirt can be translated in a basic 3D body and subsequently in a 2D shape that can be programmed for knitting. The basic 3D body representing the skirt can also be used as a starting point to diversify the shape of the knitted skirt.

2. SKIRT CHARACTERISATION ACCORDING TO SHAPE

In order to establish a design algorithm for knitted skirts it is necessary to define the shapes possible to obtain through knitting. Figure 1 illustrates the most representative skirt shapes based on cylinder (a) and frustum of a cone (b). The cylindrical skirt shape is elemental, being the closest to human shape of the human body. The skirts with a shape based on the frustum of a cone (Figure 1.b) present different degrees of complexity, according the aesthetic and fashion requirements.



a) b)

Figure 1. Basic skirt shapes and gore geometry

The dotted lines in Figure 1.b divide the skirt surface into gores, thus decomposing the 3D shape into a 2D knitting form to be used for integral knitting. The knitting direction is the most important issue when defining the shape, position and dimensions of the gores. If the cylindrical skirt can be produced without problems regardless of the chosen knitting direction (longitudinal or transversal), the examples of skirts based on a frustum of a cone are knitted transversally.

The shape design for knitted skirts is based on the idea that the skirt gores can be considered made of simple polygons – triangles and rectangles. The gore is obtained by combining these two types of polygon. The skirt shape is controlled using the following parameters:

1. Skirt dimensions – waist perimeter P_w, product length L_{pr} and hem width L_h. The waist perimeter is an anthropometrical parameter, depending on the population specifics, while the other two parameters are variable, according to fashion and type of product.
2. Gore shape indexes – number of gores, n, symmetry degree, f (f = 0 means a symmetrical gore, f =1 means an asymmetrical gore), multiplication degree of waist perimeter, m (m= L_h/P_w) and number of skirt enlargement points, p.

Figure 2 illustrates an example of a gore made of a rectangle and four triangles used to obtain a flared skirt with its shape derived from the frustum of a cone.

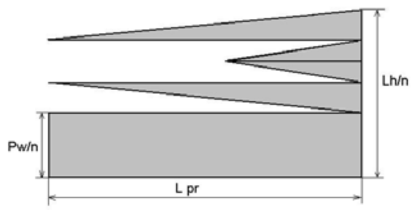


Figure 2. Aspect of a knitted gore for a flared skirt
Pw = 78 cm, Lpr = 62 cm, n = 6, m=2.85, f = 1, p = 2

The shape of knitted skirts can be designed using an algorithm based on the equivalence of the skirt shape with a basic 3 D geometrical body and the decomposition of this body into gores, made of triangles and rectangles. This way the control of the skirt shape is done through simple parameters related to the skirt shape and dimensions.

3. DEFINITION OF THE KNITTED SKIRT SHAPE

The garment shape represents one of the main elements of creativity in fashion design stage. The garment shape diversification is not justified only by the need to dress the human body, but also it has other aesthetic and social motivations that are sufficient reason for creativity in this direction.

As stated above, in the case of knitting a skirt, the knitting direction is paramount to the way the fabric is programmed and the knitting techniques used for it. A skirt can be knitted along its length (starting from the waist or from the hem line) or along its width. Each knitting direction has its peculiarities regarding the way the skirt shape is conceived and designed and subsequently the knitting programme. It also influences the skirt aspect and behaviour due to the direction of the knitted fabric in the skirt.

The knitting direction along the skirt width presents the following advantages: the knitting process is simpler and it there are much more the possibilities of developing different and complex skirt shapes. The paper considers the only this type of skirts, produced width wise.

The 3D skirt shape is obtained by repeating a 2D element called a gore on the skirt surface. A gore can be designed using a preset number of basic elements, simple geometrical polygons –

rectangles and triangles. The rectangles correspond to the support zones of the skirt and ensure the minimum product width at the hem line. The triangles have the following functions:

- They give a supplementary width along the hem line;
- They adjust the skirt along the waist line (similar to the darts role in the case of woven skirts);
- They control the product silhouette line.

The gores are placed repeatedly on the skirt surface. They are produced by using the knitting on selected needles technique, according to the shape of the gore. The carriage has variable strokes and therefore, there are needles missing a certain number of cycles. This way there zones in the fabric where there are more stitches compared to the rest that will determine the shape of the skirt.
Such complex 3D shapes can be knitted only on electronic flat machines with take-down sinkers and presser foot that allow missing a higher number of cycles.

When programming such a fabric, the gore dimensions are translated into stitch rows and wales, so the stitch density must be known. The horizontal stitch density depends mostly on the machine gauge - yarn count correlation, while the vertical density is controlled through the quality stitch cam position, the yarn tension and the take-down force. It must be underlined that it is preferable to have a higher vertical stitch density because it improves the fabric dimensional stability and its mechanical behaviour.
For rectangles, the carrier has a complete stroke, while for triangles, the stroke is variable. The number of needles selected for each variable stroke depends on the triangles hypotenuses. According to the triangle position the number of selected needles will increase or decrease progressively. The number of selected needles is determined with:

$$N_n = \frac{d}{A} \qquad (1)$$

Where: N_n – number of selected (working) needles
d = horizontal dimension for the triangle
A = stitch pitch = $D_w/10$ (mm)
D_w = horizontal stitch density (wales per 10 mm)
The height of rectangles and triangles is determined based on the vertical stitch density (stitch height) and the calculated height of the gore:

$$H = \frac{h}{B} \qquad (2)$$

Where: H = triangle/rectangle height (rows)
h = triangle/rectangle height (mm)
B = stitch height = $D_r/10$ (mm)
Dr = vertical stitch density (rows per 10 mm)

4. DEVELOPMENT OF KNITTED SKIRTS WITH COMPLEX SHAPES

Five examples of knitted skirts are chosen for discussions in order to underline the use of basic elements (rectangles and triangles) in designing the 2D gores and subsequently the 3D skirt. They begin with the most common and simple skirt model and go on with examples characterised by an increasing degree of shape complexity. These models illustrate the extended range possibilities of combining basic elements.

Model 1

The skirt is made of 6 to 10 gores. The product silhouette is gradually enlarged starting with the waist line, introducing a new flaring line between the hip line and the hem line (p = 2). The gore is made of 7 basic elements (3 rectangles and 4 triangles) that can be distributed differently, as presented in Figure 3.b and 3.c. The positioning of the basic elements within the gore influences the skirt aspect. In the first case, the line between the gores is slightly inclined and the gores are no longer straight in the skirt. In the second case, the lines between the gores and the gores themselves will be placed vertically in the skirt.

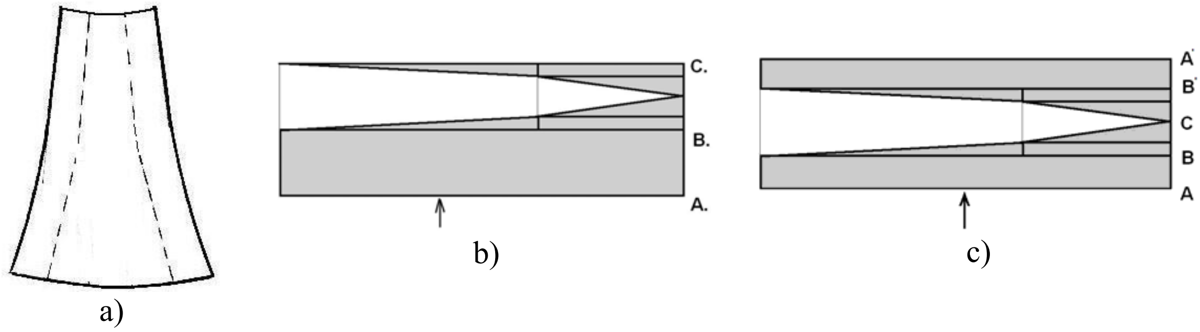


Figure 3. Model 1
a) Skirt aspect; b) Asymmetrical gore - Pw = 66 cm, Lpr = 75 cm, n = 10, m=2, f = 1, p = 2
c) Symmetrical gore - Pw = 66 cm, Lpr = 75 cm, n = 10, m=2, f = 0, p = 2

Model 2

The skirt has a combined silhouette – cylindrical in the upper part and conical in the bottom (Figure 4.a), the value of the p parameter being p = 1. The gore is made of 3 basic shapes, one rectangle and 2 triangles. The dimensions of the basic shapes are determined considering the intended difference between the upper and bottom part of the skirt. A smaller rectangle and higher triangles generate a skirt with a bigger difference between the two parts. The gore shape can be symmetrical or asymmetrical (see Figure 4.b)

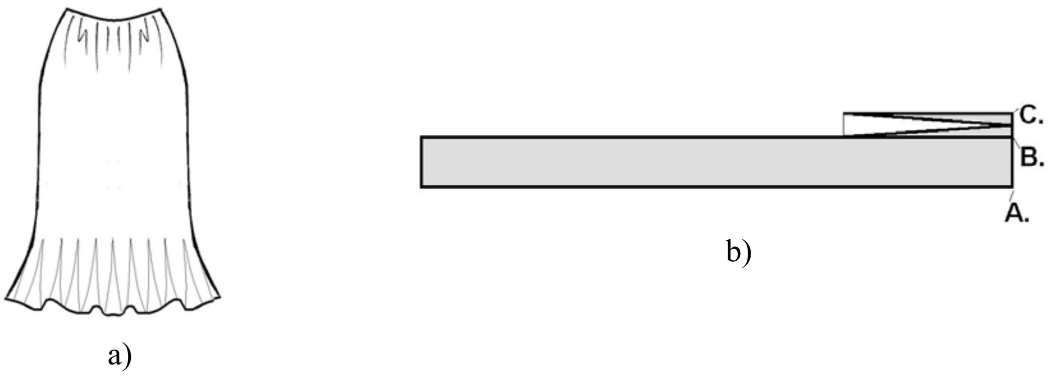


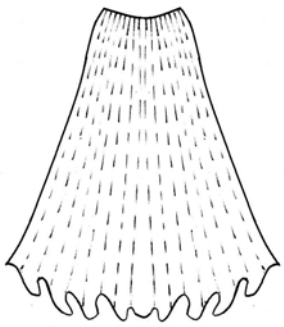
Figure 4. Model 2
a) Skirt aspect; b) Gore
Pw = 66 cm, Lpr = 75 cm, n = 20, m=1.4, f = 1, p = 1

Model 3

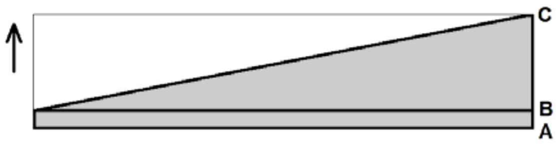
The gore shape presented in Figure 5 is used for circular or semicircular skirts (in the 2D decomposition the hem line is a circle or half circle). This skirt model (Figure 5.a) requires the use of trapezoidal gores that are made of a rectangle and a triangle with the acute angle toward the waist line (Figure 5b). The hem line is practically a polygon line that can be considered circular if the number of gores is high enough (n = 30 – 40).

The rectangle width and the corresponding number of stitch rows are very small because the high number of gores required by the circular hem line and it is:

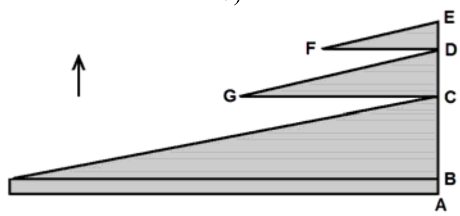
$$AB = P_w/n \qquad (3)$$



a)



b)



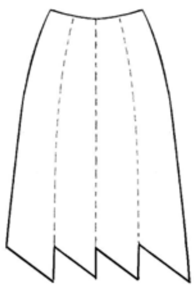
c)

Figure 5. Model 3
a) Skirt aspect; b) Trapezoidal gore - Pw = 66 cm, Lpr = 75 cm, n = 40, m=8.3, f = 0, p = 1
c) Modified gore - Pw = 66 cm, Lpr = 75 cm, n = 40, m=16.5, f = 0, p = 3

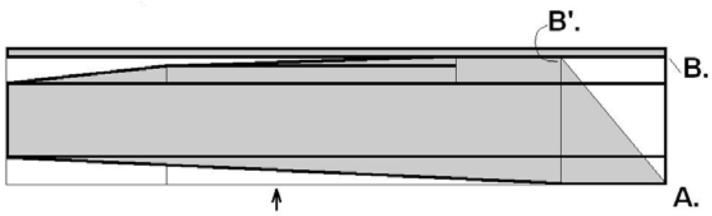
In this case, the shape development can be carried out by introducing new enlargement points at the hem line. The new points can be intended only to modify the hem line and/or to modify the product silhouette. The gore in Figure 5.c controls the length of the hem line as well as the silhouette shape.
The fabric surface within the skirt depends on the value of parameter p. The fabric surface increases with p parameter (p = 3). One problem that arises from the higher amount of fabric included in the skirt is its aspect and behaviour (the fabric deformability under its own weight). This situation can bring some limitations to the number of enlargement points and the triangles dimensions.

Model 4

Figure 6 illustrates especially the aesthetic diversification possibilities for knitted skirts. The gore shape is more complex so that it ensures the proper balance between the gore assembly lines and the hem line shape. The model can be produced with a limited number of gores (n = 8-10).
In this case the gore is based on a rectangle for which the AB straight line is transformed into AB' inclined line using the narrowing technique. The slope will be determined by the number of narrowing, based on the segment length, number of rows and stitch dimensions (height and pitch).
The inclined AB' ending line gives the skirt a corner effect. This effect can be enhanced through special knitted patterns (miss stitches, lace patterns) that modify the fabric normal geometry.



a)



b)

Figure 6. Model 4
a) Skirt aspect; b) Gore
Pw = 66 cm, Lpr = 75 cm, n = 8, m=1.8, f = 0, p = 3

Model 5

The skirt from Figure 7 represents a particular case for which the gore is built using only rectangles. The gore shape will determine a skirt with ruffled creased effect placed on a line between the waist and the finishing lines. The ruffle effect is generated by the smaller BCDE rectangle.

The two rectangles can have equal or different height, the height value influencing the degree of ruffle effect on the skirt. The height of the smaller rectangle (BC or DE) is given by the number of rows knitted on the selected needles (on the EB line) and depends on the machine and the yarn characteristics. More rows will determine a bigger ruffle.

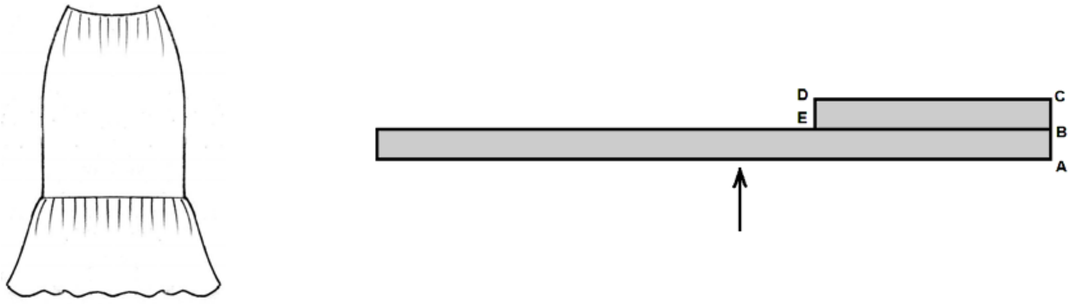


Figure 7. Model 5
Pw = 66 cm, Lpr = 75 cm, n = 25, m=2, f = 0, p = 1

5. CONCLUSIONS

The hypothesis that knitted products (in this case women skirt) can be considered with a determined geometrical shape (cylinder or frustum of a cone) leads to the idea of a product design based on a parametric algorithm.

The 3D geometry of the product can be translated into 2D basic geometrical bodies that form a gore and can be programmed for knitting. This original approach to gore geometry allows an accurate control of the product shape from the design stage, based on the type of basic elements used to construct the gore, their number, their dimensions and positioning. The final product shape and appearance is determined through certain parameters (number of gores, n, symmetry degree, f, multiplication degree of waist perimeter, m and number of skirt enlargement points, p).

The paper proposes the algorithmic approach to knitted skirt design, exemplifying the large range of possibilities for creating different shapes by using simple basic elements that are easy to programme for knitting.

The use of 2D gores and its decomposition into simple bodies and parameterisation can be extended for other types of knitted products.

6. REFERENCES

1. Brackenbury T., *Knitted Clothing Technology*, Blackwell Science Ltd, London, 1996
2. Power, J., Knitting Shells in the Third Dimension, *Journal of Textile and Apparel, Technology and Management*, Vol. 3, No. 4
3. Anon., *The Machine Knitting Magazine ZAZA*, No. 2/2005 Japan

Acknowledgements
This paper is published under the research project PN II ID_589, no. 376/2007, financed by the Romanian Government.

Author(s) Information

1. Mioara Cretu

Faculty of Textile, Leather & Industrial Management, Associate Professor,
53, Mangeron Bd., 700050, Iasi, Romania, mcretu@tex.tuiasi.ro, phone +40 232 278680 ext 1129, fax +40 232 230491, www.tuiasi.ro/facultati/textile

2. Luminita Ciobanu

Faculty of Textile, Leather & Industrial Management, Lecturer,
53, Mangeron Bd., 700050, Iasi, Romania, lciobanu@tex.tuiasi.ro, phone +40 232 278680 ext 1526, fax +40 232 230491, www.tuiasi.ro/facultati/textile