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Advanced digital applications for the development of personalized models for women's clothing

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ABSTRACT

In the age of digitalization, designers have all the tools they need to create, innovate and develop new styles to attract and retain customers. They can use specialized IT applications (with geometric tools) to develop personalized styles based on integrating the customer's anthropometric measurements and stylistic preferences. This paper presents a new approach to designing personalized women's models using geometric digital applications. Suppose the designer decides to change the values of the initial data, add/delete data or change the structure of the geometric functions of the design script. In that case, all parts of the model designed with geometric functions are automatically changed. In this way, the shape of the model pieces for atypical bodies of customers or several other customers can be created/ drafted accurately and quickly.

Keywords
geometric tools,
personalized garments,
digital patterns

1 Introduction

Everyone wants a good life, surrounded by beautiful objects for personal use (clothes, jewellery, footwear and leather goods, cosmetics, etc.) or in our living and working spaces (furniture, holsters). All of them must be manufactured responsibly and personalized according to every individual's needs and wishes [1-3]. Manufacturers need to rethink their production processes for all the goods that a civilized society needs by developing products with an extended life cycle, made from recycled materials, through environmentally friendly processes and with as little waste as possible [4,5].

Personalized objects can be developed by knowing or predicting consumer preferences regarding models, materials, helpful life, colours, price, etc. [5,6]. Before different items are produced, they must be

sustainably tested to see if they meet the customer's requirements so they do not become unsold. The only way to test a new model is to obtain its virtual counterpart and make it available to the consumer. This can only be done in a virtual environment corresponding to the category of the new product and in which the customer could analyze or test it (if the customer needs to test it, then they must have their virtual avatar to interact with the new product [7-9]. For clothing, footwear and leather goods, which are very diverse, complex virtual platforms have been developed for online shopping. On these platforms, the customer can create their virtual avatar, try on the selected model virtually and register some data to personalize the selected product (in terms of colour, motifs, accessories to be added or product lengths). All customer requirements are "translated" into product-specific dimensions during the design phase. The designer can propose alternative variants of the selected model by using different combinations of materials, colors or accessories and determine the production costs.

Software manufacturers for the clothing industry have developed special applications (2D and 3D) that allow the designer to explore several solutions for developing a personalized variant of the selected model [8,10]. These software programs require specific knowledge, skills, and competencies to determine the model measurements and analyze the shape and size of the client's virtual avatar (in proportions, posture, and conformation) to develop the best design process to achieve the goal [8,11].

This paper presents a geometric development of garment models based on specific blocks for the clothing category to which the model belongs. The size of these blocks is determined with mathematical relations based on anthropometric indicators and garment measurements. The novelty of this software is that the user can visualize how the selected anthropometric indicator is measured and can develop the design scenario using different/unusual categories of such indicators. Any change or adjustment to the design scenario of the blocks is automatically applied to the size and shape of the model pieces.

2 Method

2.1 Theoretical considerations

As customized design allows customers to get exactly what they want or need, it is the easiest way to increase their confidence in the products manufactured by a specific company. For these reasons, more and more people opt for bespoke/customized design as a fantastic, environmentally friendly alternative. In response to consumer expectations, some well-known companies have already started to utilize innovative technologies that enable the development of distinctive clothing and accessories [12,13]; whether referring to a small detail or a fully customized silhouette, a bespoke /customized or personalized garment has a unique quality created just for a specific wearer.

The designer's experience, expertise and knowledge regarding the details of the model, the interactions of the materials in the structure of the garment (which are influenced by the silhouette of the product, the destination and the manufacturing technology) and the customer's body shape all contribute to ensuring that the garment fits perfectly and is balanced on the surface of the body. The model pieces' geometric shapes must consider all this information. If the model needs or the customer wants various adjustments, it is important to interactively change the contour lines of the garment in terms of shape and length. The only method which allows the designer to create a unique and bespoke solution for the customer's model (personalized, tailored or made-to-measure), in which the latter can control the size and details of the model, is by first creating the *2D geometric design* of the garment patterns and then using them to generate the *3D virtual prototype* to check the fit and balance on the corresponding virtual avatar of the wearer.

The principle of the geometric method consists of using different categories of initial data (anthropometric indicators, model measurements and allowances) in mathematical relations [8,14-16]. Using the latter, the designer determines the position of the main points of the contour line of the pattern. These points are then connected with either straight or curved lines to create the shape of the pattern. In the first phase, the shapes of the main elements (front, back and both sleeves) are designed, and later, these elements are modified with respect to the details of the model [8,17].

Software producers for the fashion and clothing industry have developed special applications (made-to-measure) in which designers can write mathematical relations using unlimited and different categories of initial data. With this geometric and interactive approach, the shapes and sizes of the pieces are automatically generated or modified when the designer changes the initial data (changing values or adding other categories of initial data) or changes the structure of the mathematical relations to obtain the best shape for the patterns of the model. With the following software, the designer can create their scenario (with specific initial data and mathematical relations) in relation to the customer's garment category and body shape: Modaris Expert (Lectra), Made-to-Measure (Gemini – a Lectra company), Seamly (Fashion Design Software), Telestia Creator, Grafis CAD Clothing, etc. The designed patterns (personalized, tailored, made-to-measure or bespoke) are then used to create/generate the 3D prototype of the garment (using the 3D module of a CAD software such as Lectra, CLO 3D, Optitex, etc.) and to check how the sewn virtual product fits on the virtual body representing the customer. In this way, the designer analyses the garment's appearance on the customer's avatar or if there are areas where the garment has problems (tensions, flaws).

2.2 Research methodology

Whether itis a tiny detail or a completely tailored silhouette, a customized or bespoke/personalized garment is unique because it is made just for one wearer.
There are numerous methods of personalizing a garment, including:

- By painting, sewing on a patch or adding embroidery;
- Going to a tailor to have the fit of a garment adjusted;
- Buying a garment from a brand where the customer can determine the finish, fit and size (co-design process).

Creating a garment from scratch, with utmost care and attention to the dimensions of the customer's body and wishes, is what we call bespoke tailoring and personalization.

When developing a personalized/ tailored or made-to-measure garment, there are some essential points that the designer needs to consider, such as [4,14,15]:

- The technical details of the garment model (dimensions, adjustments, position of cut lines, fastening systems, finishing details, presence and position of pockets or other decorative elements, etc.); technological features (decorative stitching, hems, cuffs, etc.);
- The physical characteristics of the materials from which the selected model can be made, colours or motifs;
- The wearer's body shape: the values of anthropometric indicators that provide information about size, natural posture, proportions and conformation.

The third point can cause serious problems with the fit and balance of the garment worn on the wearer's body if the information about the size and shape of their body is not accurately determined and analyzed.

The customer's personal data can be transmitted in the following ways:

- Directly: the customer goes to a company to order the desired model directly. Here, he is measured by a technician or designer to obtain all the information needed to develop the new model and to discuss some of its details. If the company has the necessary equipment (3D body scanner), the customer's body is scanned, and from the resulting images, the designer or technician will get everything they need to know about the customer's body shape and size.
- Indirectly: The customer uses the tutorial of a special app to obtain the virtual 3D shape of their body (the 3D shape is the result of several combined photos taken from different angles). Then, they send the result of this process to the company that produces the required garment model;
- Online: The customer follows a tutorial to measure the main body dimensions. He can write these values in the proper fields, and the platform will generate its proper size, or he can pick / select from the website the closest size of the model, which corresponds to his values of body dimensions. This closest size of his body will be the needed one and sent to the manufacturer.

When the company uses the wearer's data from online platforms, the designer must analyze all the information and find a corresponding size in their database. They then use patterns of the appropriate

size to develop the ordered model. The latter's quality depends strictly on the accuracy with which the customer has measured and provided personal details about the body and the style of the model.

An efficient and sustainable method for developing personalized garment models is to use particular applications of CAD systems to create a database with basic blocks (using geometric methods) for the most frequently required product categories and customer profiles (by age and gender). All necessary information and the structure of the mathematical relations are associated with the particularities of the wearer's body shape and the details of the categories corresponding to the garment [5,6,11]. The shapes of the patterns designed in these blocks (called main or master patterns) directly result from the initial data values and mathematical relations used by the designer to develop the design scenario. The shapes of the master patterns are then altered to obtain the shapes of the components of the selected model.

This paper presents an example of developing personalized designs for women's products using digital geometric applications – *Seamly*. In the first stage are designed the patterns of the main elements of the garment (for example, a dress without sleeves); the main patterns are exported in a 3D environment to check their balance and fit on the virtual correspondent avatar of the customer (Clo3D software). From this point, the checked patterns (with a good appearance and fit) can be used in 2 ways, as follows:

- Import into *Seamly* or any other CAD software (Lectra, Gemini, Assyst, Optitex, etc.) and modify the shape according to the styling details of the selected model (which can be obtained from them);
- Directly modify the shape of the main patterns in a 3D environment to obtain the model pieces.

2.2.1 General presentation of Seamly

Seamly (Fashion Design Software) has two modules, *Seamly2D* (for pattern drafting) and *SeamlyMe* (for body measurements), which allow pattern makers and tailors to create custom-fit digital sewing patterns [18]. The user selects and opens the corresponding icon SeamlyMe to create a *New* file or open one that has already been created (*Open individual*). The file will be saved as a ".vit" file. If the user chooses *New*, he has to select the *Measurement type*, the *Unit*, the *Base size*, and the *Base height* and then close this window by selecting the *OK* button (Fig. 1). After that, the user selects Add known, this opens another window in which the body measurements are grouped, described, coded, and visualized (Fig. 2). The user selects the dimensions, the corresponding code (id) is then automatically shown, after which they can enter their values or formulae. The measurements are grouped from A to P for the human body and Q for pattern making. After the user selects the *OK* button, the measurement is added to the design list (Fig. 2).

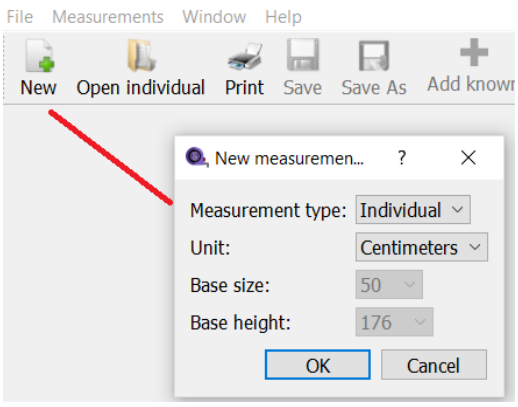


Fig. 1 Create a new file.

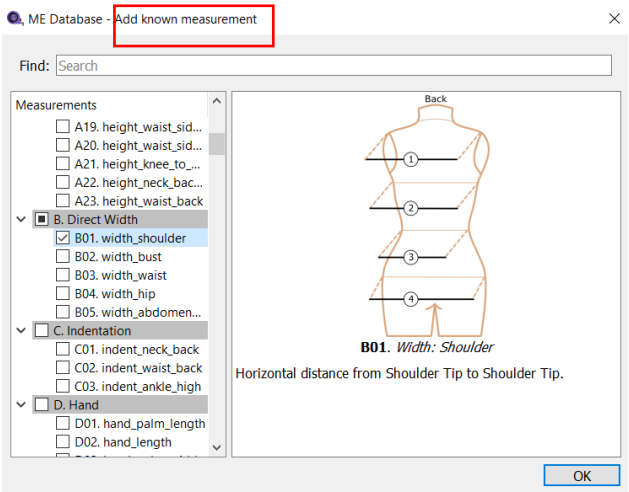


Fig. 2 Visualise the selected measurement.

The user can type the value (Fig. 3) or a formula for the selected measurement. In order to write a formula, the user selects

and then they have to write it using values or by selecting the data displayed.
When the user has to introduce a different type of dimension, which is not listed by the software, they must select, which makes another window pop up (Fig. 4), in which the user provides the following information:

- The new dimension appears in the “a” field;
- The user writes an ID or a code in the “b” field;
- The user writes a value (in the “c” field) or selects the “d” field to write a formula;
- The user writes the full name of the new datum in the “e” field;

The user can describe the new datum in the field “f”.The user now selects 

and fills in the name of the new block and chooses the measurement units (Fig. 5). In order to draft the pattern, and the designer has to open the file containing the list of initial data (the file created in SeamlyMe and saved as a “name.vit” file).

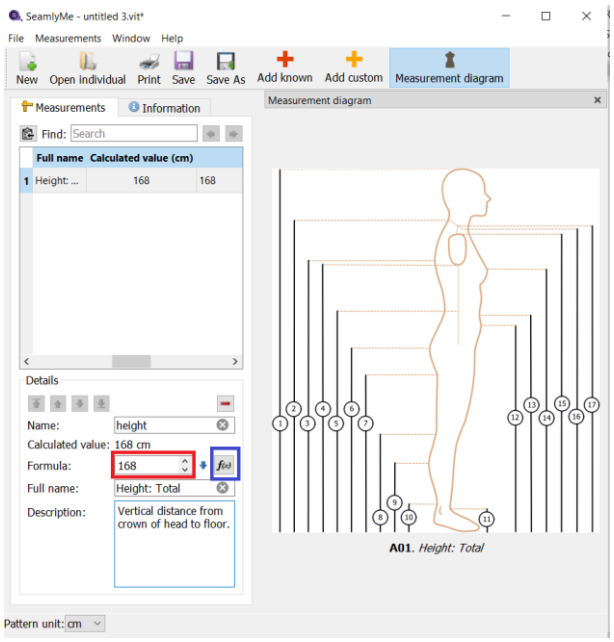


Fig. 3 Measurement field.

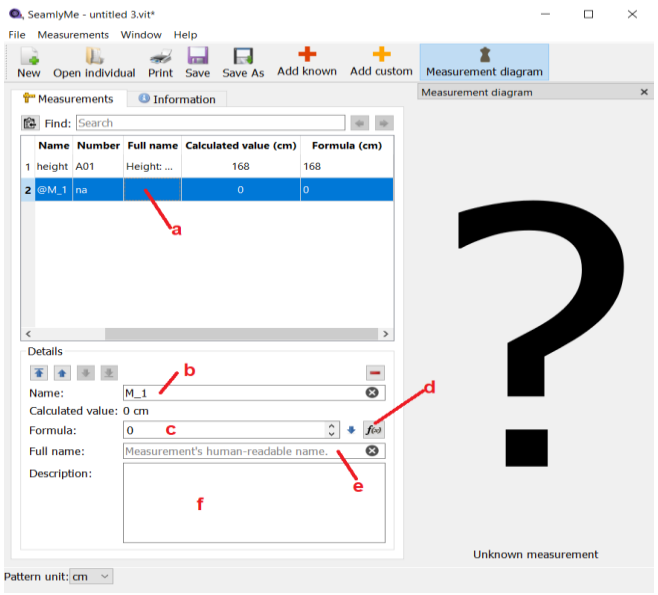
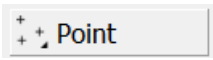
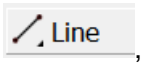
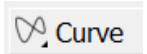


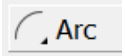
Fig. 4 Define a new dimension.

After starting a new work session, the drawing and piece tools are activated, and the design (A) starting point is automatically displayed and positioned within the workspace.

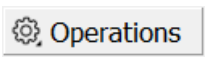
The drawing tools used to draft the patterns are: *Point* 

, *Line* 

, *Curve* 

, and *Arc* 

, each of which has different options.

The pieces can be altered by using the following tools: *Operations* 

and *Piece* 

.

The procedure for designing a new pattern consists of the following steps:

- establishing which initial data are required;
- choosing the design solution (determining the mathematical relations);
- measuring the dimensions of the customer’s body and establishing the range of sizes;
- creating the measurement file in *SeamlyMe*;
- drafting the main patterns and pieces of the model;
- creating the layout of the pattern to be printed or exported.

2.2.2 *Design with Seamly*

The software allows personalized and customized 2D development of garment patterns in a geometric network. The network uses a combination of different geometric tools (see section 2.2.1) to establish the position of different points on the pattern outline contour. By accessing geometric tools, the user has to fill some fields with numeric values or data selected from the measurement file and/or mathematical relations. At any time in the design scenario, the user can make changes regarding initial data or the way of determining the position of the contour points on the pattern outlines [14-16,18].

The user selects *SeamlyMe* to create the measurement file (Fig. 6), which is saved with a declared name by the user and a particular extension from the software ("name.vit).

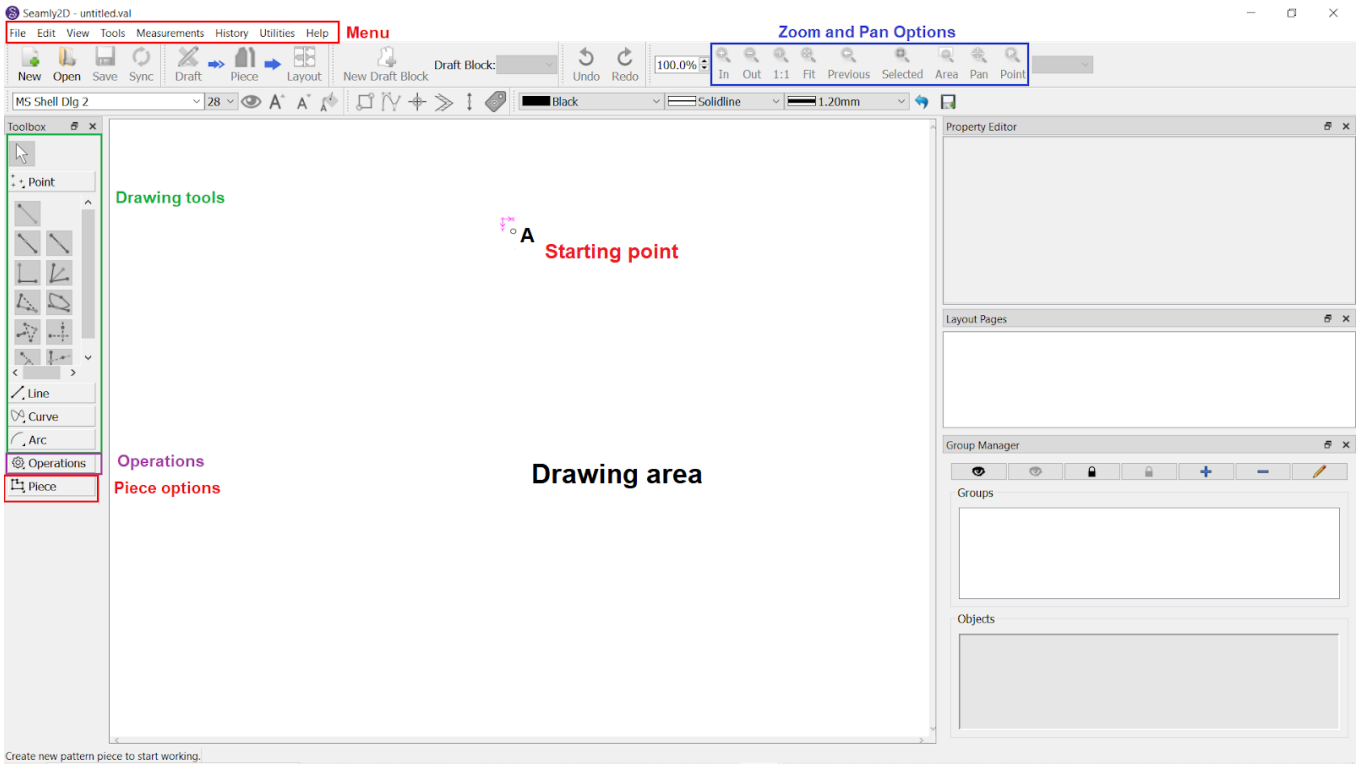


Fig. 5 Working interface of Seamly2D.

This file will be automatically linked with the design scenario created in *Seamly2D*; this file can also be accessed from Seamly2D to make changes if needed. The initial data can be numeric values or results of formulas (Fig. 6).

The next step is to open *Seamly2D* and start the design process. The starting point “A” is automatically positioned in the drawing area and can be moved anywhere. The file is saved as “name.val” (the suffix “.val” is generated by the software). The user decides the procedure by which they will obtain the network and the shape of the main elements (the back and the front patterns for a dress without sleeves).

Table 1 presents some design steps for the selected product category, and Fig. 7 shows the front and back patterns of a dress without sleeves.

Table 1. Design steps (selection)

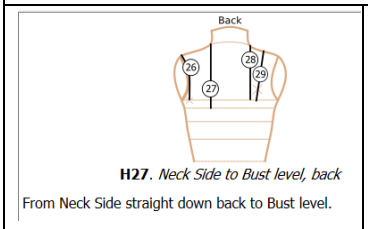
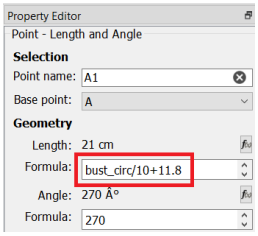
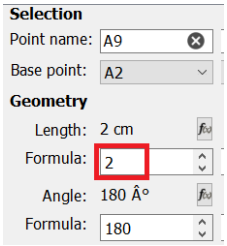
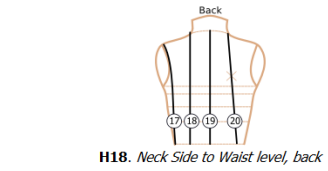
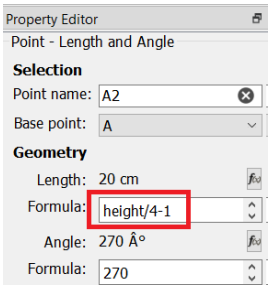
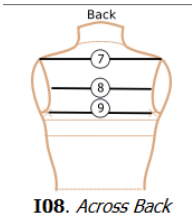
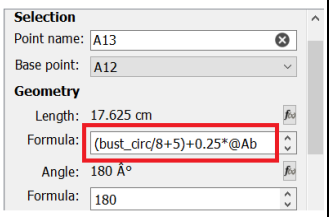
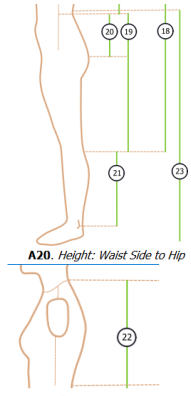
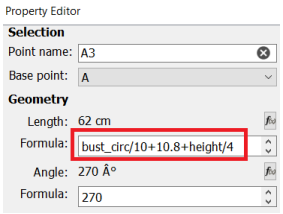
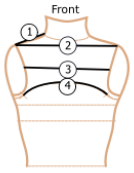
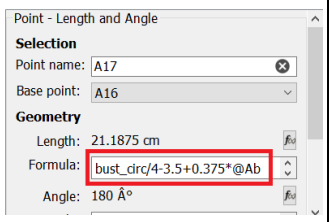
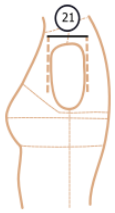
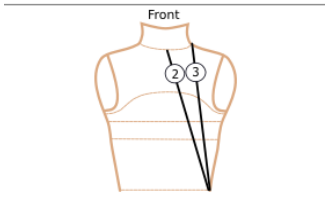
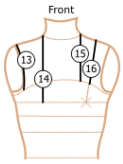
Screenshots from the software			
Anthropometric measurement	Mathematical relation	Anthropometric measurement	Mathematical relation
Positioning the bust line:		Positioning the back middle line	
 **H27**. *Neck Side to Bust level, back* From Neck Side straight down back to Bust level. H27+constructive allowance for this dimension		 **C02**. *Indent: Waist Back* C02+constructive allowance for this dimension	
Positioning the waistline		The back width (on the bust line)	
 **H18**. *Neck Side to Waist level, back* From Neck Side straight down back to Waist level. H18+ constructive allowance for this dimension		 **I08**. *Across Back* 0.5*I08+constructive allowance for this dimension	
Positioning the hip line		The front width (bust line)	
 **A20**. *Height: Waist Side to Hip* **A22**. *Height: Neck Back to Waist Side* A20+A22 constructive allowance for these dimensions		 **I03**. *Across Chest* 0.5*I03+ constructive allowance for this dimension	

Table 1 (continued). Design steps (selection)

<table>
<tr><td colspan="2">Back and front armscye width</td><td colspan="2">The level of the highest point of the front pattern</td></tr>
<tr><td> 

L21. Armscye: Width
L21+ constructive allowance for this dimension</td><td>Back
Selection
Point name: A14
Base point: A13
Geometry
Length: 8.16667 cm
Formula: 2*(bust_circ/8-1.5+0.5*@Ab)/3
Angle: 180 Â°
Formula: 180

Front
Selection
Point name: A16
Base point: A15
Geometry
Length: 4.08333 cm
Formula: (bust_circ/8-1.5+0.5*@Ab)/3
Angle: 180 Â°
Formula: 180</td><td> 

K03. Neck Side to Waist Side, front
K03+constructive allowance for this dimension</td><td>Selection
Point name: A42
Base point: A17
Geometry
Length: 25 cm
Formula: Line_A_A1+4
Angle: 90 Â°
Formula: 90</td></tr>
<tr><td colspan="4">Positioning the vertex (apex) of the bust dart</td></tr>
<tr><td> 

H16. Shoulder center to Highbust level, front
H16+constructive allowance for this dimension</td><td colspan="3">Point - On Line
Selection
Point name: A44
First point: A17
Second point: A16
Geometry
Length: 9.7 cm
Formula: bust_circ/10+0.5

Point - On Line
Selection
Point name: A49
First point: A46
Second point: A44
Geometry
Length: 27.8333 cm
Formula: height/16+bust_circ/6+2</td></tr>
</table>

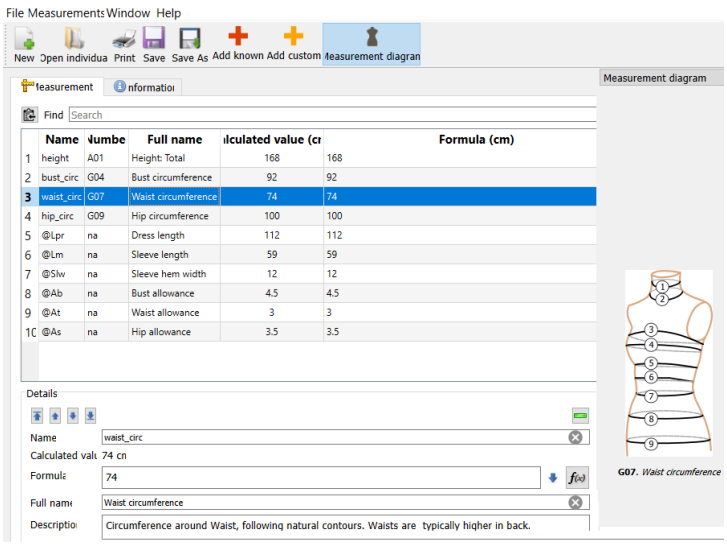


Fig. 6 Creating measurement file.

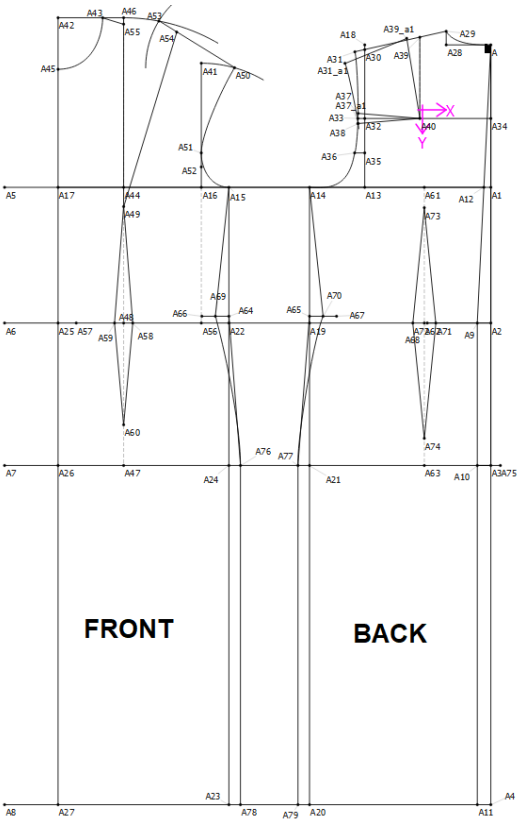


Fig. 7 The main (master) patterns of a dress without sleeves.

The file is saved as “name.val” and then exported as a .dxf file to be used in a 3D environment (Clo3D) for evaluating the fit and balance (appearance) of the main (master) patterns on the correspondent virtual avatar (the avatar has precisely the exact dimensions as those declared in the measurement file and used in the design process), see Fig. 8 and 9 [19].

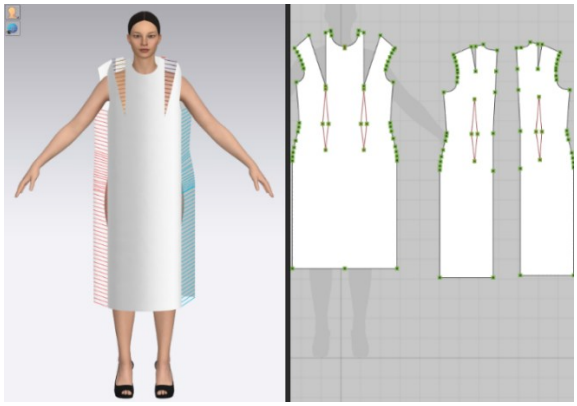


Fig. 8 Simulation in Clo3D (declare seam lines)

a) b)

Fig. 9 (a) Front view; (b) lateral view

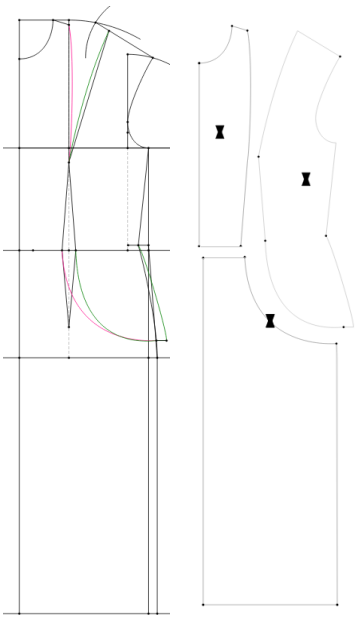
In 3D, the designer evaluates the appearance of the main (master patterns) by analyzing:

- the garment width: The patterns have to be well-dimensioned, not tensioned or with folds;
- position of the hemline (front and back): it has to be horizontal and parallel to the floor;
- position of the back middle line;
- position of the sideseams: these have to be vertical and perpendicular to the hemline;
- position of the darts: scapula dart (back pattern), bust dart (front pattern) and waist dart (front and back);
- the position of the shoulder line and the neckline (front and back): the shoulder lines have to be placed on the upper part of the scapula region, and the neckline has to be well positioned compared to the neck base contour line.

If something is noticed not to be correct, the user has to make the necessary changes in the design scenario (Seamly) and then re-check the new shape of the main (master) patterns in 3D software (for example, Clo3D).

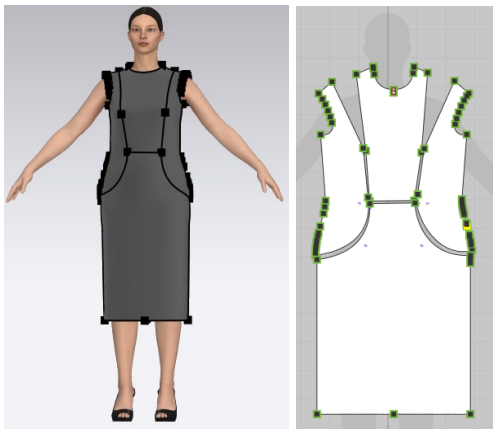
Afterwards, the checked patterns are used to design a dress model without sleeves. The user has the following options: design the model patterns in Seamly with geometric functions, like the master patterns had been designed [18], or directly design the model pieces in a 3D environment with specific tools [19].

Figure 10 summarises the main stages for designing the front model patterns of a dress (*Seamly software*) by applying technical modelling principles (cutlines). If the designer can draft the model lines directly in the 3D environment (Fig. 11) on the imported model, the software automatically generates the model pieces.



a) b)

Fig. 10 Design stages in Seamly software (a) ½ Front pattern modelling; (b) Front pieces (1/2)



a) b)

Fig. 11 Design stages in Clo3D (a) Using 3D Styleline; (b) 2D Front pieces (automatically generated)

3 Conclusions

It is well known that the lifecycle of a fashionable garment depends on the following factors: the style of the model and its integration into fashion trends, the quality of all the materials and accessories used to make it and, above all, how it looks and feels when the customer is wearing it. Nowadays, every customer is willing to pay more if the desired item is made just for them, considering their styling suggestions and the peculiarities of their body shape (proportion, conformation, and posture).

Customized and personalized/ bespoke or tailored garments have become more and more of a necessity nowadays for the following reasons:

- To reduce the number of garments (unpurchased garments) which are wasted because they do not fit any customer in order to protect the environment;
- To increase the satisfaction degree of the customer by offering them products with a high level of quality from all points of view (fitting and balance, materials and manufacturing quality);
- To produce only the required models, if possible (“fashion on demand”) by integrating the customer information in the design process of the new model (the proposed model is developed and promoted in the online platforms, where the customers can visualize them);
- To produce sustainable models using sustainable digital technologies and materials.

This paper presents a solution for developing personalized garments using advanced digital technologies that allow complete control over the size and shape of the garments. The following benefits can be highlighted:

- See the description and measurement of an extended list of anthropometric body characteristics (very well grouped and structured) that can be used either as initial data or to calculate the values of some anthropometric indices. The latter can be used in mathematical relationships to elaborate a customized design scenario (especially for very close-fitting garments);
- The use of specific measurements for pattern making (e.g. darts), which are not common data but very useful for designing complex shapes of 2D patterns for fitted garments;
- Design the shape of the main (master) patterns geometrically and develop them carefully considering the information about the client’s body and the general measurement category of the garment;

- Elaborate patterns for atypical human body shapes (asymmetrical, posture, proportions) by integrating specific anthropometric indices (e.g. posture indices) into mathematical relationships to determine the position of the main points of the contour lines;
- The ability to export the patterns in a compatible format to other software programs that have 3D tools to create the virtual 3D prototype dressed on the client's corresponding avatar;
- Various geometric tools (working exclusively with mathematical relationships) are used to develop the shape of the model parts.

The master patterns (or main patterns) are generated automatically when the designer makes some changes to the values of the initial data (to generate new parts using the new customer information) or by changing the structure of the mathematical relationships if the new customer has a different conformation or posture than the previous one.

This method can only be used by designers who are familiar with analyzing the customer's body shape (proportions, physique, posture) and developing patterns for different product categories. They must also select, combine and use special IT tools to design the best shape and size of the desired item.

This software, or any other with the same advanced module, allows complete control over the shape of the garments, as these shapes result from the application of geometric functions (based on mathematical relationships). In addition, the designer can develop different blocks for different product categories, which can then be modified to develop new collections in response to customer requests with different model details and levels of complexity.

Author Contributions

M. Avadanei: conceptualization, methodology, investigation, writing – review and editing; A.D. Vatra: methodology, validation, writing – original draft preparation; M.I. Rosca: conceptualization, formal analysis, writing – original draft preparation. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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