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DEVELOPMENT AND ASSEMBLING OF TEXTILE PRODUCTS

Creation of databases for a virtual training library in fashion design

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ABSTRACT

A library of knowledge that contains a fabric database, 3D human body models database, and 3D garment database has been developed in the framework of the Erasmus+ project DigitalFashion – "Collaborative Online International Learning in Digital Fashion", which is a collaboration of 6 European partners who would like to strengthen their working together through collaboration in online international teaching. The fabric database contains 49 physical textile fabrics, both woven and knitted fabrics. Each partner provided at least eight fabrics. The library contains also 3D human body models of different sizes (male, and female), and 48 pattern designs for women's and men's garments. The fabric's physical and visual parameters have been determined using known textile standards, including their draping images taken using a Cusick Drape Tester. These fabric parameters have been used to predict the equivalent digital twin fabric based on Lectra digital fabrics, thereby completing the fabric database with their matching digital twin fabric. The digital twin fabrics have been used to simulate the 3D garments for the 3D garment database, based on the selected patterns and styles. To test the robustness of the fabric digitization process, a woman A-line skirt (real) was made by each partner using their fabric. These skirts were then compared with their simulated (virtual) skirts. The investigation has shown that the digital twin fabrics represent the real fabrics well. The virtual training library will support the specially developed training platform for virtual fashion design.

1 Introduction

The field of digital fashion is rapidly evolving, and the fashion industry is witnessing rapid integration of digital technologies in the fashion supply chain, including design, product development, and marketing of finished products [1,2]. Furthermore, following the COVID-19 pandemic, fashion technology has to be made more open to online training. The designers have to be creative and develop fast new models by analyzing and interpreting the customers' demands from virtual platforms, digital body features, and fashion preferences [3-5]. Considering this background, the DigitalFashion project aims to introduce collaborative online international learning in digital fashion that will train higher education students and young professionals in the area of virtual prototyping and virtual garment development to empower them for the future market.

This approach leads to faster garment design cycles, reduction of physical samples, faster time-to-market, efficient interactions between various stakeholders of the fashion supply chain, and mass customization [1,6]. E-learning provides more attractive and rapid access to educational materials and processes from wherever and more so, if it is made inclusive to persons with disabilities or various factors, including the restrictions of COVID-19 pandemics [7-9]. An inclusive training platform requires customization of the support system behind the platform to work with well-known objects in the physical world in their virtual form [10].

Modern clothing design relies on a comprehensive collection of pre-established databases. The selection of fabric for specific garment styles/patterns undergoes modification and refinement through a numerical fitting process, utilizing scanned or digitally generated body models known as avatars (3D human body models). These procedures are entirely conducted in the digital realm, marking a significant shift towards a digitally-driven fashion landscape. Storing the data appropriately enables a consistent method to extract needed parameters of the datasets [11].

There exist digital fabric libraries, e.g. Vizoo [12], and clothing simulation software like u3m [13], with open formats, but their use remains limited to their developers and a small number of experts.

An Erasmus + project DigitalFashion – Collaborative Online International Learning in Digital Fashion is dedicated to e-learning in the wider textile sector, of which the project partnership involves five European countries and six institutions: The National Research and Development Institute for Textiles and Leather (INCDTP), Gheorghe Asachi Technical University in Iasi (both Romania), National Higher School of Arts and Textile Industries (France), Hogeschool Gent (Belgium), University of Maribor (Slovenia) and the Textiles and Clothing Technological Centre – CITEVE (Portugal). The main outputs of the project are: R1. New methodology for a common framework on collaborative online international learning in the field of digital fashion; R2. Library of knowledge (the three databases) for virtual fashion design and technology; R3. Training platform for fashion design through personalized 3D virtual garment fitting; R4. Curricula for collaborative online international learning in the field of digital fashion.

The third and fourth outputs of the project are currently in progress. In the second phase of the project, three databases are being built: (1) 3D human body models of different sizes (male, female), (2) fabric database (49 fabrics), and (3) pattern designs database (48 patterns) for women's and men's garments to develop a digital fashion platform with a knowledge base for 3D virtual garment prototyping. A third project output involved a comprehensive study of textiles digitalization techniques. It was based on image analysis of orthogonal projections of the draped physical textiles using a Cusick Drape Tester and machine learning techniques. The aim of this approach was to identify the digital twin fabrics from the Lectra digital fabrics and integrate them into the fashion design training platform.

This research aimed to verify the digitization of textiles using machine learning techniques, which is presented in the methodology. A 3D comparison of real and virtual skirts made of five different fabrics and their virtual twins was performed.

2 Methodology

The creation of databases for the learning platform, the process of digitization of textiles and the process of comparing physical with virtual ones for five selected fabrics are briefly presented to verify the process of digitization of textiles.

2.1 Creation of databases for library of knowledge for training platform

The 3D garment database was created on four selected garments (man shirt, man trousers, woman blouse, woman skirt) collected from the project partners well spread around Europe. Each project partner provided patterns for a women's skirt, a women's blouse, a men's trousers, and a men's shirt. The database contains patterns of 10 different skirts, 10 blouses, 5 shirts, and 8 men's trousers. Furthermore, the database was completed with 2 men's polo shirts, 1 men's short, 1 men's sweatpants, and 1 men's T-shirt. The patterns collected are graded in different sizes for men and women.

The 3D human database is from HOGENT's Smartfit database. Smartfit is a national measurement survey carried out in Belgium and the database contains body measurements of more than 5000 Belgians, both women and men, with ages ranging from 3 years to 85 years. For the DigitalFashion project, avatars of young women aged 18 to 25 years in (Belgian) sizes 38, 42 and 46 were chosen.

The fabric database contains 49 physical textiles, both woven and knitted fabrics. Each partner provided at least two textiles that are commonly used in their region for the selected garments and their respective styles. Therefore, each partner provided at least 8 fabric samples of size 50 cm X 100 cm. Their physical and visual parameters have been determined using known textile standards, including their drapability. The fabric physical parameters were determined according to the following standards, Fabric weight: ISO 3801-1977 – Textiles – Woven fabrics – Determination of mass per unit length and mass per unit area, Fabric thickness ISO 5084-1996 Determination of thickness of textiles and textile products, as well as fabric raw materials, structures and described their finishes. Furthermore, fabrics have been classified according to specific garments, i.e. woman's blouse/skirt and men's shirt/trousers with their corresponding garment styles.

2.2 Procedure of fabrics digitalization

Collected fabrics were defined by their essential parameters required for digitization. These parameters are areal weight, thickness, material composition, structure, bending resistance, stiffness, and the draping image taken using a Cusick Drape Tester, i.e. orthogonal projections of the drapes of textiles were taken using a digital camera. In addition, calculated were the drape coefficients (DC) and the number of nodes using Drape Analyzer software. To quickly find the digital fabric that corresponds to the real one, the Lectra handbook (Swatch book) is involved. For a specific real fabric, a set of similar real samples is first identified in the Lectra handbook by directly comparing the basic parameters (areal weight, thickness, fiber composition) and appearance (weave type, warp and weft structure). Since each real sample in the Swatch book has a digital fabric in the database of Lectra CAD (Modaris 3D Fit), a group of similar digital fabrics can be selected from Lectra fabric database.

To identify the most relevant digital fabric, the drape image of real fabric is compared with the drape images of digital fabrics. The drape image (cf. Fig. 1**Fehler! Verweisquelle konnte nicht gefunden w erden.**) is taken with a resolution of 1296 x 1025 pixels). The support diameter of the drape plate is 18 cm, while the fabric sample has a diameter of 30 cm.

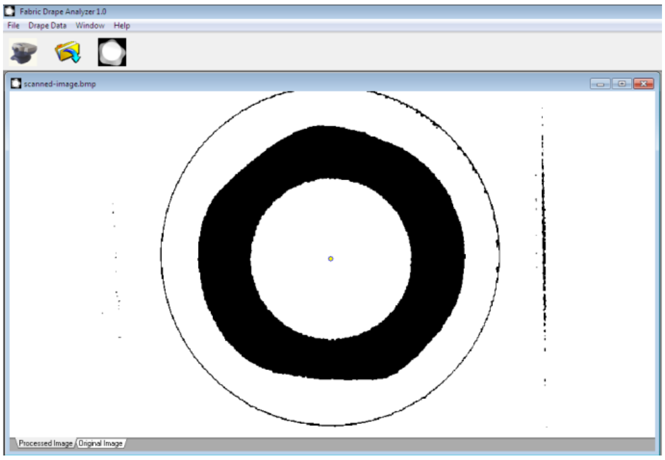


Fig. 1 Fabric drape image (support diameter is 18 cm and fabric sample diameters is 30 cm)

The overall progress includes three main steps:

- Step 1 (drape parameters estimation): A drape image of a real fabric is processed, and five drape parameters (explained in the next section) of the real fabric are estimated by extracting information from the image using image processing techniques.
- Step 2 (clustering): Digital fabrics in the Lectra database are clustered into different groups based on their drape parameters and the number of nodes in the real fabric.
- Step 3 (prediction): A number of classification machine learning models is applied to identify the closest digital fabric based on the output of steps 1 and 2 as well as the areal weight of the real fabric.

2.2.1 Drape parameter estimation

In the drape image, the initial presentation of the extracted contour is in the Polar coordinate system, then the contour signal is transformed into the Cartesian coordinate system to facilitate the analysis, as illustrated in Fig. 2*Fig.*.

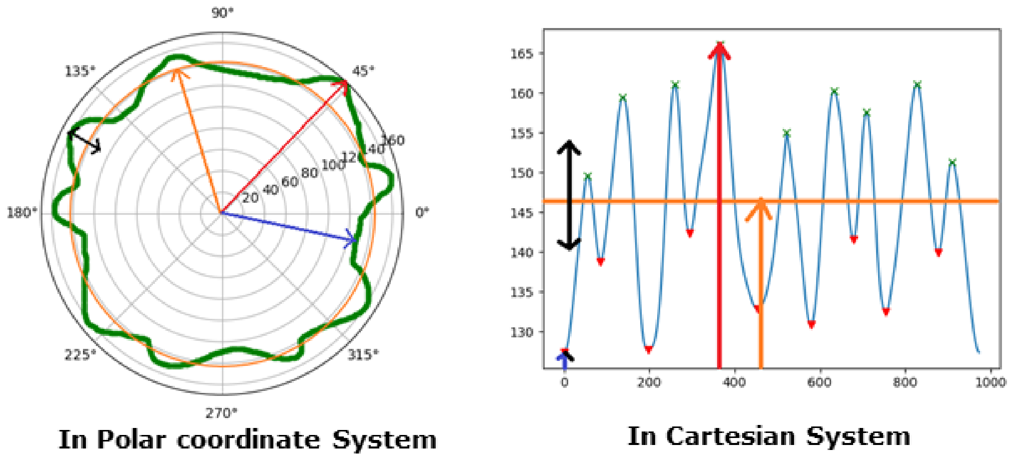


Fig. 2 Contour signal in different systems.

The number of peaks (NoP) in the signal can be determined by counting the number of signal periods, which is equivalent to the number of valleys. Specifically, in Fig. 2**Fehler! Verweisquelle konnte nicht gefunden werden.**, the orange, red, blue, and black arrow corresponds to the average distance (AD), maximum peak (MP), minimum valley (MV), and average amplitude (AA), respectively. MP and MV are the distances from zero to the highest and lowest point, respectively. AD is the average distance from zero or the mean of the contour signal. AA is the average amplitude of each node in the signal. The unit of these parameters is the pixel. The AA and AD from the contour signal to the center point of the circle are computed using Equations (1) and (2), respectively, as follows:

$$AA = \frac{1}{n}\sum_{i=1}^{n}\frac{p_i - v_i}{2} \quad (1)$$

$$AD = \frac{1}{n}\sum_{i=1}^{n}\frac{p_i + v_i}{2} \quad (2)$$

where n is the number of peaks (number of valleys); p_i and v_i are the dimension of peaks and of valleys i, respectively. In addition, the maximum peak and minimum valley are also considered in the dimension of the signal. The process of estimating drape parameters includes four steps, namely pre-processing, peak and valley detection, abnormal elimination, and drape parameter calculation, as depicted in Fig. 3.

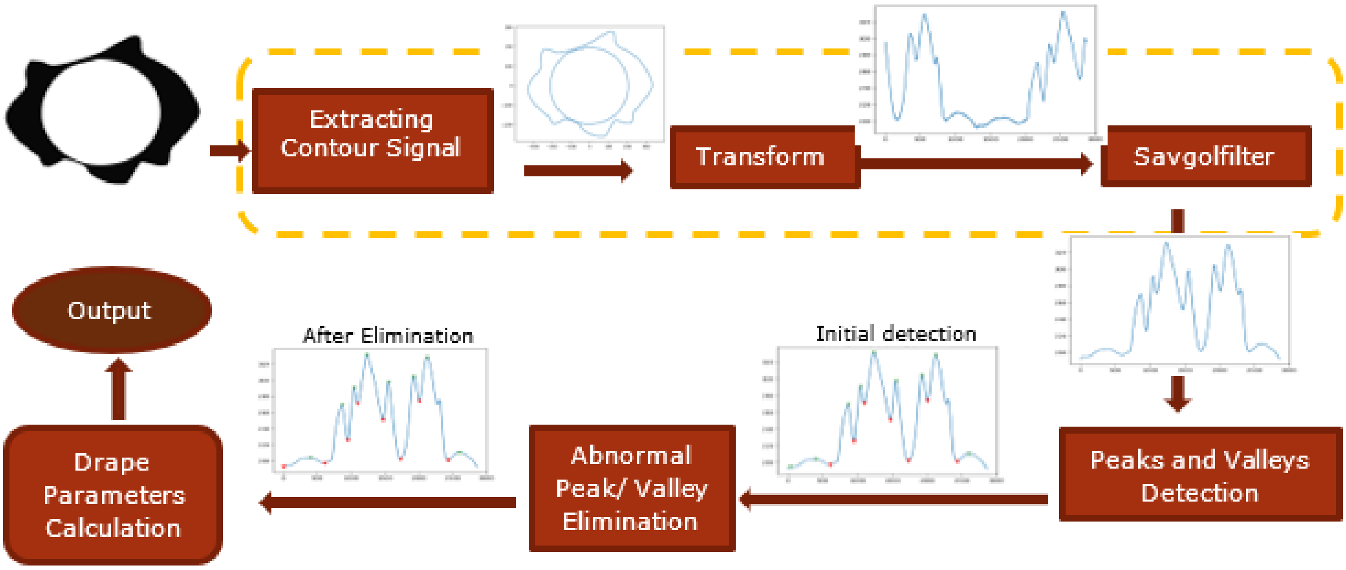


Fig. 3 The process of drape parameter estimation.

2.2.2 Clustering Process

The next step is to cluster the existing digital fabrics into different clusters based on the similarity of their drape parameters to identify the group that is the closest to the real fabric (closest group), as shown in Fig. 4. The digital fabrics are clustered using the K-means algorithm and principal component analysis (PCA). K-means is an unsupervised machine learning algorithm that divides data into a specified number of clusters, where it partitions a set of fabrics based on the four attributes, namely AA, AD, MP, and MV. The selection of an appropriate value for the number of clusters (k) is crucial in K-means clustering, and the "elbow method" is commonly employed to determine the optimal value of k. An elbow visualizer is a tool that aids in the identification of this optimal k value. Due to the limitation of the number of fabrics in the database, it is necessary to determine the ideal number of clusters.

In addition, to facilitate visualization of the clustering results, we applied PCA to reduce the data of high dimensions to a plan before applying K-means. Then, the selected digital fabrics are clustered into different k groups. After the clustering, the closest group of digital fabrics can be obtained by comparing the distance between the centroid of each cluster with the real fabric based on its estimated drape parameters (predicted in step 1).

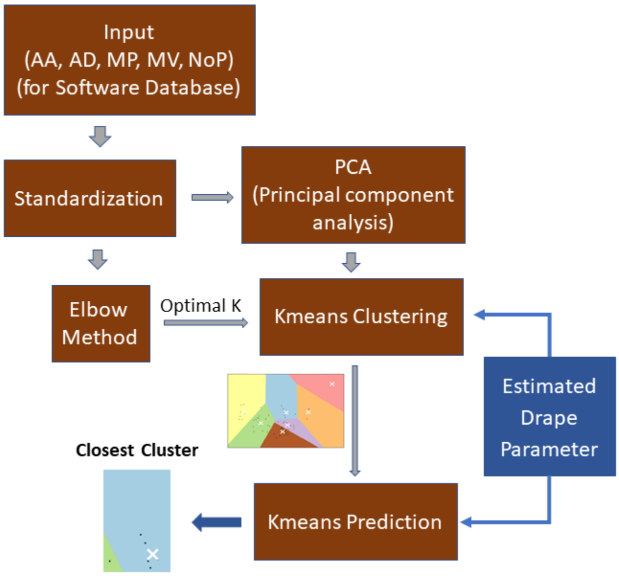


Fig. 4 The process of clustering digital fabrics.

2.2.3 Prediction Process

The main concept behind the prediction process is to analyze the characteristics of both real fabric (based on its drape parameter – calculated in Step 1) and the digital fabrics in the closest group or cluster derived in Step 2 (they are taken as learning data for prediction), in order to identify the most similar fabric existing in the digital Lectra database. The prediction task is carried out using the Min Euclidean Distance technique and five machine learning techniques based on the previous learning data, including K-Nearest Neighbors (KNN), Random Forests, Naive Bayes, and Decision Tree.

Finally, the most relevant digital fabrics are in the closest and their technical parameters are then input into the 3D garment software to generate the corresponding 3D garment and fitting effects.

2.3 3D virtual try-on

A women's A-line skirt in size 38 was chosen to make the first simulations of the 3D garments on the 3D body model of size 38 and to compare the results with the physical garments. Figure 5 presents pattern pieces of the A-line skirt and Fig. 6 the virtual prototype of the A-line skirt. Simulations of skirts were performed for digital twins of physical fabric selected by each partner.

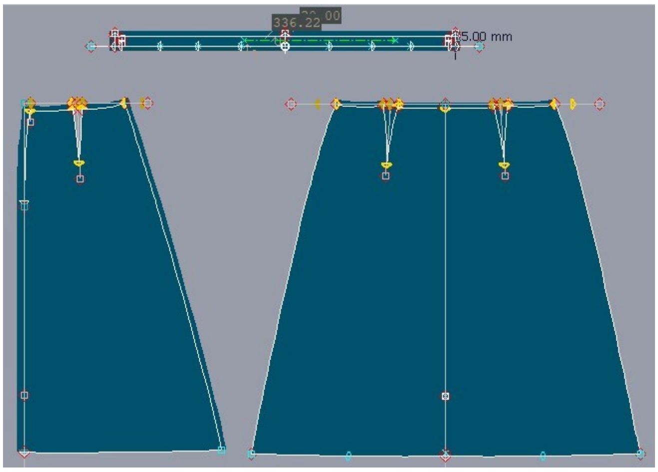


Fig. 5 Patterns pieces of the A-line skirt.

Fig. 6 Virtual prototype of the A-line skirt.

2.4 3D real try-on

Five physical garments of women's A-line skirts were made using the provided patterns in garment size 38, but with different types of fabrics selected by the partners from the created fabric database. All the skirts made were dressed on the tailor's dummy with the same dimensions as the 3D human body model of size 38. The physical garments were first evaluated visually in terms of aesthetics, appearance (draping) and fit. Each skirt was compared with its 3D simulated digital garment and the shape and fit were analyzed. The shape and fit of the garments were observed from the front side, left side, and right side. The back side was not considered in this analysis. The similarities and differences between the physical garments and their representative garments were also observed.

3 Results

3.1 Digital fabrics

In total 49 different types of fabrics with different visual appearance, feel, and touch from different material compositions and different fabric constructions were collected in the fabric database. This is a true representative of all possible diverse fabric characteristics/parameters that a designer may need to work with. The collected fabric was filled into a database according to the garment type. The fabrics in the database are identified according to the numbers given by the project (F1-F49) and according to the identities given at the source (partner numbers). Additional datasets of the fabrics are the fabric image, color according to Pantone or RGB code, material exact composition, type of weave/knit, the density of the yarns in the weave/ knit, areal weight of the fabric, thickness (mm), transparency – yes or no, the feel/touch – rough or smooth, and the drape image.

All the collected fabrics turned out to be from conventional material compositions, as shown in Table 1. The difference between the fabrics was in the material mix composition and the fabric construction (the woven/knitted design, the yarn size, and the finishes: printed (multicolor) or even colored), which differentiated them. Variation in any of the listed parameters brings a completely different fabric look/feel. These fabric parameters contributed immensely to the visual appearance, feel, and areal weight of the fabric.

Table 1: Summary and the properties of the collected fabrics.

Garment	Styles	Material Composition	Fabric Structures	Areal weight (gm^{-2})	Thickness (mm)	Finishes
Man shirt	21	Cotton, polyester, Viscose, wool, and in mixed percentage composition	Knitted/Woven	75 - 200	0.2 - 0.6	Stripped, checked, and plain colours, light fabrics, easy iron and easy care
Man trouser	24	Cotton, polyester, Viscose, wool, and in mixed percentage compositions some with elastane	Knitted/Woven	206 - 447	0.3 - 1.8	Mostly plain, dyed in dark colors, visual and feel effect brought by fabric construction
Woman blouse	21	Cotton, polyester, Viscose, wool, tencel, lyocell, and in various percentage composition	Knitted/Woven	60 - 145	0.1 - 0.3	Mostly plain fabrics in different shades of white. Additional bright-colored printed fabrics, easy iron, easy care
Woman skirt	28	Cotton, polyester, Viscose, wool lyocell, denim, and in mixed percentage composition	Knitted/Woven	114 - 404	0.3 - 1.6	Fabrics with multiple visual effects, single colored, multiple colored

The digital fabrics of all the physical fabrics were identified according to the Lectra fabric numbers in the Swatch book, which are included in the fabric database as 'Lectra best match'. Thus, a complete representative fabric database with both physical and digital fabrics was created that will be linked to the training platform. The customization of the fabric database will allow the partners to use their digital twin fabrics for the online training platform and use the result on the real fabrics.

The corresponding numbers of fabrics and styles are shown in Table 2. The overall number of fabrics in this table is 53, meaning that some fabrics could be used in more than one garment item.

Table 2: No of items in the developed databases.

Garments	Total No. of Styles	No. of fabrics	Patterns for selected styles
Woman blouse	28	18	15
Woman skirt	21	13	15
Man trouser	24	11	10
Man shirt	21	11	8

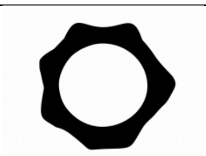
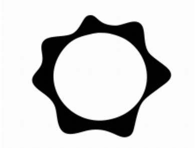
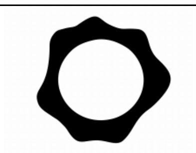
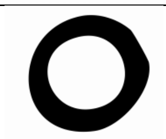
3.2 3D real vs. virtual Try-on

All the A-line skirts were confectioned in high-quality standards with the visual result presented in Fig. 7 (five physical skirts) and Fig. 8 (virtual skirts).

The skirts were sewn from fabrics chosen by the project partners. Table 3 shows the fabrics selected by the project partners accordingly for the production of physical skirts (Fabric ID) as well as their orthogonal draping projections, determined using the Cusick Drape Tester, analyzed draping coefficients and node numbers. The project fabric number is a number between 1 and 49 given to the fabrics in the project fabric database, while based on the fabric digitization process, predicted fabrics from the Lectra (digital twin fabric) are marked as Lectra fabric match number.

It can be observed that the first three fabrics have a similar drape coefficient between 0.628 and 0.647 and the same number of nodes (7 nodes), while their orthogonal projections are also quite similar. The fourth fabric has the lowest drape coefficient (0.378) and also seven nodes among all analyzed fabrics, while the last fabric has the highest drape coefficient (0.791) and 12 very shallow nodes, indicating a high bending rigidity of this fabric. Consequently, this fabric after the digitalization process was predicted to differ from others in terms of draping properties (Lectra fabric match = 100), while the prediction for the other four fabrics having the same number of nodes (7) predicted the same fabric (Lectra fabric match = 30). Based on these two fabrics, we carried out simulations of the draping of 3D skirts and their comparison with physically sewn skirts.

Table 3: Selected fabrics for real and virtual try-on.

	Women skirt				
Fabric ID	**Orthogonal projections of the draped fabrics**	**Drape ratio**	**Number of nodes**	**Digital fashion project fabric database no.**	**Lectra fabric match no. (digital twin)**
MARIBOR_F05		0.647	7	**F27**	**30**
TUIASI_F08		0.378	7	**F32**	**30**
INCDTP_F11		0.628	7	**F29**	**30**
CITEVE_F01		0.629	7	**F26**	**30**
HOGENT F2		0.791	12	**F34**	**100**

Since different types of fabrics are used to produce the A-line skirts, there was a slight difference in the draping and appearance of the skirts, as can be seen in Fig. 7. The number on each image of the physical skirt is the fabric number in the projects' fabric database (Table 3). Five physical fabrics were converted into two digital twins fabrics (Lectra match No. 30 and 100) using a digitalization process. Each skirt was compared to its simulated skirt based on the selected digital twin fabric.

Fig. 7 Representative physical A-line skirts on the mannequin.

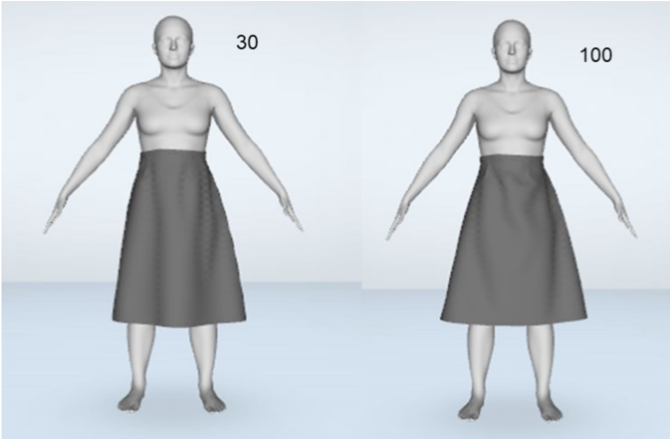


Fig. 8 The simulated virtual skirts from digital twins fabrics Lectra match 30 and 100.

The physical vs. the virtual skirts are compared in terms of the shape of the skirt: front side, left side, right side, the hemline (draping), and presence of folds within the skirt. The assessment scale used in these comparisons ranges from excellent, good, satisfactory, and bad to very bad.

Table 4 represents results of the comparison in addition to the twin digital fabrics match used in the simulation of the virtual skirts. The rating "good" indicates that there was no significant difference in the shape and fitting between the virtual and the physical garments.

Table 4: Comparison of the real try-on to the virtual try-on.

Fabric No.	Fabric source	Lectra fabric match	3D garment match	Front side	Left side	Right side	Hemline
Fabric F27	MARIBOR	30	Good	Satisfactory	Good	Good	Good
Fabric F32	TUIASI	30	Good	Good	Excellent	Satisfactory	Good
Fabric F29	INCDTP	30	Good	Excellent	Excellent	Good	Good
Fabric F26	CITEVE	30	Good	Good	Good	Good	Good
Fabric F34	HOGENT	100	Good	Excellent	Good	Good	Excellent

From this case study, it was concluded that the identified digital twin fabrics represent well the behavior of the physical fabrics manifested in the virtual and real skirts, respectively. This is in line with the values of the drape coefficients of the fabrics.

4 Conclusions

A representative library of knowledge containing 49 fabrics, 3D human body models with 3D simulated garments, and 48 graded patterns has been created in the project framework. The fabrics have diverse origins, thus a true representative of the various possible physical characteristics and visual and feel effects of fabrics that a designer may need to work with in creation of the selected garments. The fabric database contains the fabrics with their physical properties that determine their visual appearance, feel, and fit and their digital twin fabric predicted using the fabric physical parameters and their drapability parameters. The library contains also 3D human body models of different sizes (male, female), and 48 pattern designs for women's and men's garments. The fashion database contains 10 different skirts, 10 blouses, 5 shirts, and 8 men's trousers have also been created including their 3D Garment database. Furthermore, the database is complemented with 2 men's polo shirts, 1 men's short, 1 men's sweatpants, and 1 men's T-shirt. The patterns collected are graded in different sizes for men and women. The 3D human database is a selection of avatars of young women aged 18 to 25 years in (Belgian) sizes 38, 42 and 46, selected from HOGENT's Smartfit database.

The digital twin fabric selection procedure from Lectra based on the fabric parameters and drape parameters has been elaborated. To validate the digital fabric selection process, a woman A-line skirt (real) was made by each partner using their fabric. These skirts were then compared with their simulated (virtual) skirts. The investigation has shown that the digital twin fabrics represent the real fabrics well. The library of knowledge developed will be mounted into the training platform, where partners could use their real known fabrics in the virtual training platform. The databases need to be expanded to contain more fabrics, garment types, and patterns of the remaining styles.

Author Contributions

Sheilla Odhiambo: formal analysis, writing – original draft preparation; Alexandra De Raeve: formal analysis, investigation, resources, validation; Cosmin Copot: formal analysis, investigation, writing – original draft preparation; Ion Razvan Radulescu: project administration, funding acquisition; Andreja Rudolf: validation, formal analysis, investigation; Tadeja Penko: validation, formal analysis, investigation; Xianyi Zeng: conceptualization, software, validation, formal analysis; Xuyuan Tao: conceptualization, validation; Thu-Ha Do: writing, software; Alexandra Cardoso: formal analysis, investigation, validation; Irina Ionescu: visualization, supervision, validation; Joris Cools: software, investigation, formal analysis, validation. 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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