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Design and development of an application for the generation of garment patterns based on body measurements using CNN

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ABSTRACT [1]

In recent years, the growing consumption of products and services over the Internet has led companies to take their business models to virtual platforms, so retail fashion companies, such as ateliers, need to adapt to new market trends. Ateliers specialize in making garments to the customer's measurements, so this process requires a high level of time, cost and personnel specialized in taking body measurements and pattern making. There are several technological solutions to obtain body measurements and other solutions to obtain garment patterns, however there are no solutions that integrate both processes. Therefore, we propose an application to produce dress garment patterns tailored to a person from photos, using image processing and convolutional neural networks (CNN). Our proposal starts by obtaining a frontal and a lateral photo of the person, as well as her height, and then processing the images to obtain the body measurements by means of a CNN. Finally, we proceed to adjust the patterns of the garment required with the measurements obtained in order to give as a final result the dimensions of the dress's garment patterns.

Keywords: garment pattern, body measurements, fashion, CNN, application

1. INTRODUCTION

In recent years, clothing consumers have been demanding that garments be tailored to fit their bodies [1]. In order to obtain tailored garments, garment patterns that take into account the customer's body measurements are needed. The body measurements of a person are obtained with a method that consists of measuring different parts of the body with a tape measure, which requires contact between the person and the garment maker in charge of the measurement; however, this physical method is not suitable for e-commerce [2]. On the other hand, a traditional method is used to make garment patterns, which is inefficient because it is time-consuming, and a beginner requires up to five years to become a pattern maker and needs at least 10 years to master pattern making [3].

Currently, the textile industry mass-produces garments to satisfy the high demand of the fast fashion market, on the other hand, consumers demand that garments are tailored to their bodies, however, providing a solution to this demand is complicated, since traditional pattern generation methods do not allow mass production of customized garments [1]. Similarly, it is difficult for women to find a ready-to-wear garment that fits them and their bodies, and this search is too time-consuming [1]. Approximately 49% of female online consumers have this difficulty and more and more clothes are being returned due to dissatisfaction [4].

The pattern making process a tailored garment is complicated and time-consuming. Modifying the pattern of an existing garment can reduce this time; however, this modification requires an expert pattern maker [5]. In addition, although there are specialized software's for the design of garment patterns, when these programs are used for made-to-measure garments, they usually present problems in the fitting of the garments with the customer's body, since these programs are based on generalized bodies and sizes, in order words, aimed at the massive textile industry [3].
There are several research studies that propose methods and solutions to obtain the body measurements of a person, among them is the research conducted by Xia et al. that proposes a mobile application that through a

[1] I would like to thank our professor Daniel Subauste for his support and patience with the peer-editing.

frontal photo, the height and weight of the person, predicts a total of six body measurements using image processing and a linear regression neural network [2]. Foysal et al. proposes a mobile application for the detection and classification of female body shapes [6]. In their next research, Foysal et al. propose a mobile application that, by means of three photos and the height of the person, can obtain only three measures using a linear regression neural network and mathematical calculations according to the body proportions with respect to ISO 8559:1989 [7]. Wang et al. proposed a neural network with radial basis function (ANN-RBF) for the prediction of eight body measurements by receiving the measurements of height, waist circumference, abdomen and hips as input data [8]. However, the number of body measurements provided by these proposals are not enough for a pattern maker to make a tailor-made pattern for various garments.

Among the research on garment pattern generation, it has been proposed to obtain patterns through fashion sketches [9], however, these are limited to jeans and lower body measurements. In another research, it is proposed to obtain the measurements of the garment patterns and adjust them, but this is from 3D patterns [5]. None of them incorporates the process from the taking of body measurements to the generation of garment patterns.

Our proposal is as follows:

- We develop an application that allows to generate the dimensions of the garment patterns according to the client's body measurements.
- We propose to obtain the body measurements from two images (side and front) using a CNN and the dimensions of the patterns will be calculated through mathematical calculations.

Then, in Section II, we will explain definitions of applications related to the process of taking body measurements, the process of generating garment patterns and the relationship between body measurements and garment patterns. In Section III, we will explain our proposal. In Section IV, comparisons will be made with solutions that take body measurements or generate customized garment patterns. Finally, in Section V, we will explain the experiments and results and in Section VI we will present the conclusions.

2. BACKGROUND

Body measurement process

Body measurements are necessary for garment making. Body measurements can be taken in contact or non-contact. The former requires a tape and standardized criteria [10] such as ASTM D5219-09, ISO 8559:1989 [12], ISO/TR 7250-2(2010) [4] and ISO 20685-2010 [11], but this method is not suitable for e-commerce because it would require a face-to-face contact with each of the customers and would be losing the essence of e-commerce of not needing to move to obtain a product [2]. Within the method of taking non-contact measurements are active and passive measurement, the active one uses laser lights or 3D scanners, the latter costing up to $50,000 [2]. On the other hand, passive measurement is ideal for e-commerce due to its fast measurement and low cost, this method includes the use of 2D images for measurement and has high significance for the fashion industry due to the precision of smartphones [2].

Garment pattern generation process

The generation of a garment pattern consists of the pattern maker drawing the construction lines of the garment on paper, then proceeding to cut the paper along the drawn lines to obtain the pieces of the garment that will be used for the cutting of fabrics that make up the final garment [1]. At present, this process is still, for the most part, a manual process, in addition to depending a lot on the pattern maker's experience, which leads to inconveniences such as long production time, inefficiency and inaccuracy in the garment's garment [1].

Relationship between body measurements and garment pattern

According to Gu et al., in the study conducted by Nakazawa, he mentions that there is a relationship between the garment pattern and the human body, exclusively with the body measurements of certain body parts. It is because of this relationship that the dimensions of the pattern can be adjusted to fit the person's body size [4]. The relationship depends on the garment to be made, if it is a shirt, measurements of the chest, waist and hips are needed [11]; while for a pair of pants, measurements of the abdomen, hips, thighs, knees and ankles are necessary [12].

3. RELATED WORK

In the literature review, we found some proposals of applications or models for the calculation and prediction of body measurements using body images.

In the research conducted by Foyzal et al. [6], they proposed a model for the classification of female body shapes using images. The researchers proposed two classification models, the first using the K-Nearest Neighbor technique and the second with a convolutional neural network, of which the second model gave the best results. Likewise, with the best model implemented, they developed a mobile application that by means of photos taken with the device's camera allows the classification of the bodies, thus allowing female users to have easy access to the proposed solution.

Furthermore, in the following research by Foyzal et al. [7] they developed a SmartFit Measurement smartphone application to calculate body measurements such as waist, lower hip and thigh, which are needed to create tailored

pants. The inputs needed are the height of the person, a front view photo, side view photo and a background location photo. Using image processing and the SURF (Speeded up robust features) algorithm, the background is removed from the image to obtain the silhouette. Then, the waist height is calculated using a neural network, the maximum width of the silhouette is used for the hip height, and the ISO standard (at five-eighths of the person's height) is used for the thigh height. Then, with the height of the three body parts, the authors proceed to calculate the horizontal measurements of the two images (front and side view) using pixels and the ellipse perimeter formula is applied to each measurement to give the volume of a human body.

On the other hand, within the proposals for the generation of garment patterns, Liu et al. [9] propose the creation of patterns from jeans fashion sketches, so they analyzed the relationships between a fashion sketch, the pattern and human body dimensions. The relationship between a design sketch and a pattern, and the relationship between pattern and body dimensions was found by linear regression. Finally, formulas were obtained to model the relationship between the sketch, the garment pattern and human body dimensions, whose input parameter is body height, and measures such as waist height, hip height, leg depth, knee height, waist circumference, hip circumference, knee height and opening circumference are calculated.

The authors of the paper [3] propose a pattern design method for jeans based on body dimensions and allows to adjust the generated garment patterns in case the result is not satisfactory after a virtual or real fitting. The method is composed of four parts: the first part refers to the initial input such as height, hip circumference and waist circumference; the second part, adjustable input, allows evaluating the length of the jeans, type of waist height, leg circumference and knee circumference; the third part is the parametric model which determines that the height from waist to hip and inseam are important for the garment patterns. Finally, the output is the garment pattern with the desired style that can be modified if the customer is not satisfied.

Liu et al. [1] proposes an application development method for creating garment patterns with 3D interactive technology called 3D Interactive Garment Pattern Making Technology (3DIGPMT). The proposed method consists of 8 stages that begins with the 3D modeling of the person's body and the garment to be made, then the garment is adjusted to the 3D model of the person. After the fitting is done, the surface of the garment is segmented and then the 3D surfaces are unfolded to 2D and with them a post-processing of these surfaces is performed to finally obtain the garment patterns. The software developed with the proposed method allows users to model a 3D body with the desired body measurements, model a 3D garment from images, fit the 3D garment on the 3D model of the person, flatten the 3D model of the garment and generate the garment's garment patterns.

Wang et al. [13] propose a model for the design of garment patterns using neural networks and fuzzy logic, the proposed model is composed of a series of sub models where each one of them is in charge of predicting a dimension of the pattern by receiving as input data body measurements. Likewise, the authors define a general scheme for the implementation of a garment design and garment making system composed of five phases, where the proposed model is integrated between the first and the second phase. In the first phase of the scheme, people's body measurements, garment style and other preferences are collected; in the second phase, the pattern is designed with the parameters obtained from the proposed model using specialized software; in the third phase, the garment is generated in 3D from the designed patterns to be visualized by the customers; in the fourth phase, the necessary adjustments are made to the patterns; and finally, in the fifth phase, the garment is made using the adjusted garment patterns.

4 .DESIGN AND DEVELOPMENT

General scheme of the application

Prior to the development of the solutions, the general scheme of the proposal was designed. Fig. 1 shows the scheme composed of three parts. The proposed scheme allows to understand the flow of the order of a garment fitted to the customer's measurements, and it also shows the integration of the body measurements and the generation of clothing patterns. Likewise, the general scheme allows to have an overview of the functionalities that the applications must offer.

Data collection and preferences: First part of the general scheme where the necessary information is obtained from the client to make the tailor-made garment. As shown in Fig. 1, in this part the selection of the garment that the customer wants according to their preferences is made, in addition to the capture of body images to obtain body measurements.

Processing of body measurements and garment patterns: In this second part of the general scheme, the body images of the customers are processed to serve as input data for the convolutional neural network (CNN) model that predicts the body measurements of the customer and with them to adjust the dimensions of the base pattern of the garment selected for its confection.

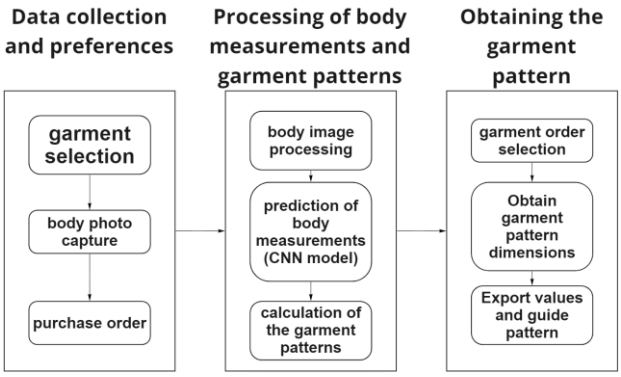

Fig. 1. General scheme.

Obtaining the garment pattern: The last part of the general scheme consists of obtaining the dimensions of the garment pattern according to the customer's body measurements and providing the possibility of exporting these values together with a base pattern guide to make the pattern layout.

Development of the convolutional neural network

The proposed solution involves the prediction of body measurements, so we developed a neural network because as mentioned by authors [2], [8] the implementation of machine learning and deep learning models in various areas of industries have been shown to improve the efficiency of processes, in addition to other benefits. In the research of Foysal et al. [7] they implemented an application that classifies women's body shapes by developing a classification model with K-Nearest Neighbor and another with CNN, of which the CNN model gave better results. On the other hand, Yan et al. [10] developed a CNN model for the prediction of body measurements that can compete with the 3D scanners. Therefore, we decided to develop a CNN model that can predict the body measurements that are involved in the dimensions of clothing patterns.

Dataset and data cleaning: The data used for the training and validation of the model came from the research conducted by Yan et al. [10], where the authors processed 3D silhouettes from 3D scanners to train their model. This data set has a total of 4149 frontal and lateral images of people, each of them with their measurements calculated by the 3D scanners; however, of the total, only those corresponding to women were used, giving a total of 2646. Once the necessary information was collected, we proceeded with data cleaning by eliminating data containing outliers or null values in body measurements and those lacking at least one lateral or frontal image of the body.

CNN architecture: The architecture designed for our neural network follows the classical architecture of other convolutional neural networks that include a convolutional section, however instead of having a classification section our network contains a regression section to predict body measurements which are continuous values as shown in Fig. 2. In the convolutional section we added four convolutional layers of 32, 64, 128 and 128 filters in each of them with a 3×3 kernel, also between each convolutional layer we added a 2×2 max-pooling layer. On the regression section side, the input layer consists of 516 neurons which receives as input data the values of the last layer of the convolutional section that was previously flattened, then two hidden layers, one of 256 neurons and the second of 128, and finally the output layer composed of one neuron which is the resulting body measurement.

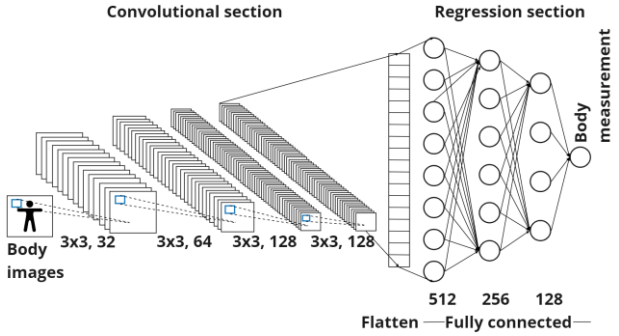

Fig. 2. Convolutional neural network architecture.

Technologies involved: The technologies and libraries used for the development of the neural network were Tensorflow and OpenCV, the first one is a well-known library in the field of artificial intelligence since it speeds up the process of building neural networks, on the other side, the OpenCV library allows the manipulation and processing of the images since prior to the training of the CNN it is necessary to re-scale and normalize the images.

Training and validation: Once the CNN were built, we proceeded with training, for this we divided the data set as follows 80% of the data will be for the training phase, 10% for validation and the remaining 10% for testing. We also used the cross-validation technique with a K factor of 10, i.e., we divided the data set into 10 different training and validation groups. This technique was used in order to improve the training stage of the CNN since the size of our data set is small.

Generation of dimensions of the garment patterns

Once the predicted body measurements are obtained, our proposal proceeds to make the garment patterns. We used a “automatic drafting by pattern formula” method, this adapts the body measurements so that they can be used in the garment patterns as shown in Table I, where L is the full value of the body measurement.

Table I. Adaptations of body measurements.

Body Measurements	Adaptations of body measurements (front pattern)	Adaptations of body measurements (back pattern)
Neck circumference	$L/4-1$	$L/4-1$
Bust circumference	$L/4+1$	$L/4-1$
Waist circumference	$L/4+3.5$	$L/4+2$
Hip circumference	$L/4+1$	$L/4-1$
Bust height	Same body measurement	
Front length	Neck height – Trouser waist height front	
Shoulder length	Same body measurement	Same body measurement
Across front	$L/2+1$	
Bust to bust	$L/2$	
Back length		Neck height – Trouser waist height back
Across back		$L/2+1$
Side height	Front length – Back length	Front length – Bust height
Hip height	Same body measurement	Same body measurement
Dress length	55 cm (to the client's preference)	50 cm (to the client's preference)

Table II and Table III shows the relationship between the dimensions of the patterns and the client's body measurements that will finally allow the generation of the front and back garment patterns. For example, for the front pattern, Fig. 3, the AC line must measure according to the bust circumference adaptation table, in other words, if the client's bust circumference is 100, applying the formula $L/4-1$ $(100/4-1)$ results in 24, then the AC line measures 24 cm.

Table II. Front pattern dimensions.

Dimensions	Dimension value
A-C	Bust circumference$/4+1$
A-B	Front length
A-E	Neck circumference$/4-1$
A-F	2 cm
C-G	4 cm
E-H	12 cm
D-I	21 cm
J-K	Back length$/\mathbf{2}+\mathbf{1}$
K-K1	2.7 cm
B-M	Hip height high
M-N	55 cm (to the client's preference)
M-M1	Hip circumference$/4-1$
N-N1	Hip circumference$/4-1$
B-O	Hip circumference$/4+2$
B-P	(Hip circumference$/4+2)/2$
P-Q	14 cm

Table III. Back pattern dimensions.

Dimensions	Dimension value
A-C	Bust circumference$/4-1$
A-B	Back length
A-E	Neck circumference$/4-1$
A-F	2 cm
C-G	4 cm
E-H	12 cm
D-I	21 cm
J-K	Back length$/2+1$
B-M	Hip height high
M-N	55 cm (to the client's preference)
M-M1	Hip circumference$/4-1$
N-N1	Hip circumference$/4-1$
B-O	Hip circumference$/4+2$
B-P	(Hip circumference$/4+2)/2$
P-Q	14 cm

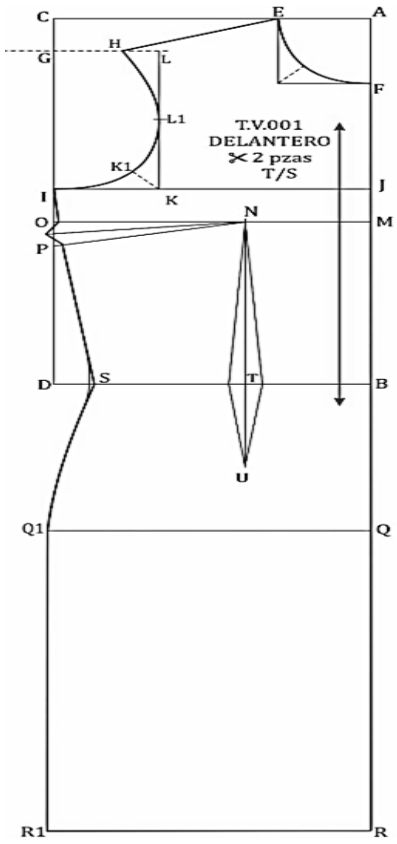

Fig. 3. Front pattern.

Mobile application development

- Guide for taking body measurements: The application shows the client the four aspects to consider to take body measurements correctly in order to improve the accuracy of the measurements, which are first, the use of tight clothing, second, the proper position to take the measurements is with arms and legs slightly open as shown in Fig. 4, in addition, as a third aspect should be considered to take care that the background does not have so many objects and, fourth, 2 images should be loaded as shown in Fig. 5.

- Taking body measurements: In Fig. 6, the client takes a photo of herself in front and side position, then the application proceeds to calculate the body measurements. Afterwards, a screen is displayed with the result of the 4 main measurements and a table with 23 body measurements including the 4 main ones.

Fig. 4. First and second aspects to be considered in the body measurement guide.

Web application development

- Generate pattern dimensions: When selecting the "Generate pattern" button in the order detail view, a new view shows the images of the patterns and a table for each pattern, whose contents are the dimensions of each garment pattern modified according to the customer's body measurements. See Fig. 7 and Fig. 8.

Fig. 5. Third and fourth aspects to be considered in the body measurement guide.

Fig. 6. Taking body measurements.

- Download garment patterns: Pattern data can be downloaded as a PDF file; each file contains the values of the pattern dimensions and the pattern image. See Fig. 9.

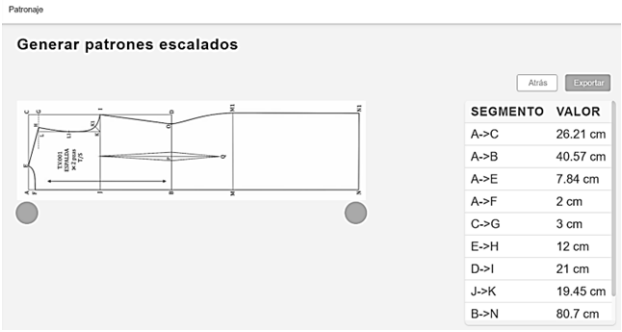

Fig. 7. Generate back garment pattern dimensions.

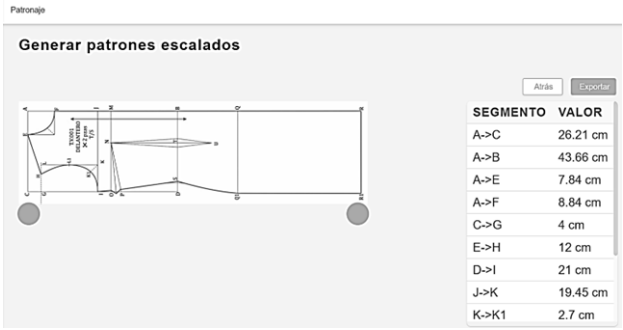

Fig. 8. Generate front garment pattern dimensions.

5. EXPERIMENTATION AND RESULTS

During the development of the CNN model, tests were performed to help find the best accuracy of the calculation of body measurements. Therefore, two experiments were performed: in the first one, 5 models were trained, which calculate 5 body measurements each; in the second experiment, one model was used for each body measurement, a total of 25 models. Table IV shows the comparison between the two experiments.

We conducted satisfaction surveys of the mobile and web applications to two groups with the following characteristics:

- For the mobile application, 10 women between 20 and 35 years old and who consume custom garment services will be selected.
- For the web application, 2 professional experts in garment making and pattern making will be invited.

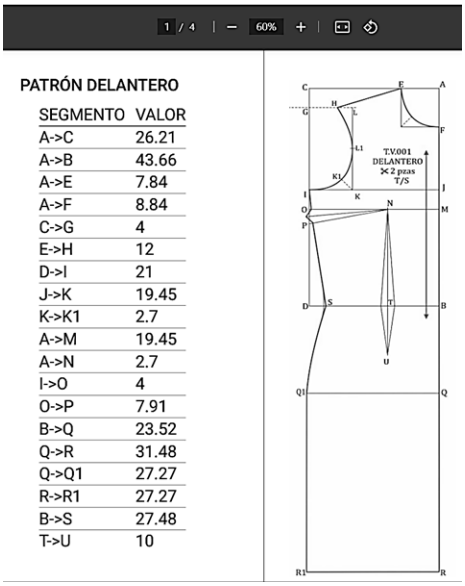

Fig. 9. Generate pattern dimensions.

The two groups used the applications and on the side of the users of the mobile application, the results of the surveys were as follows:

- 20% are totally satisfied with the result of the body measurements and 50% mentioned that they were very satisfied.
- Regarding the aspects that have a positive impact when using the application, 100% of the users consider that it increases satisfaction when buying clothes because it is in accordance with their body, 90% consider that it helps in the knowledge of their body measurements and 40% of the users consider that it has an impact on the time incurred in requesting a tailor-made garment, that it decreases the probability of return and increases confidence when wearing the garments.

Table IV. Comparison between 5 body measurement models and 1 body measurement models.

Body measurements	5 body measurement per model			1 body measurement per model		
	Predicted	Real	RMSE	Predicted	Real	RMSE
Bust_Circ	0.9649	0.9718	0.0279	0.9726	0.9718	0.0209
Trouser_Waist_Circ	0.8697	0.8645	0.0301	0.8691	0.8645	0.0219
Natural_Waist_Circ	0.8345	0.8347	0.0217	0.8398	0.8347	0.0163
Hip_Circ	1.0120	1.0204	0.0174	1.0214	1.0204	0.0142
Hip_2_Circ	1.0208	1.0398	0.0236	1.0396	1.0398	0.0100
Neck_Height	1.4659	1.4309	0.0439	1.4357	1.4309	0.0114
Trouser_Waist_Height_Back	1.0228	1.0289	0.0224	1.0235	1.0289	0.0137
Trouser_Waist_Height_Front	0.9844	0.9807	0.0190	0.9820	0.9807	0.0097

SideNeck_to_Bust	0.2890	0.2810	0.0266	0.2816	0.2810	0.0144
Hip_Height	0.8390	0.8443	0.0139	0.8447	0.8443	0.0090
Hip_2_Height	0.7730	0.7682	0.0236	0.7696	0.7682	0.0082
Bust_to_Bust	0.1843	0.1888	0.0191	0.1869	0.1888	0.0148
Across_Back	0.3541	0.3486	0.0209	0.3506	0.3486	0.0182
Across_Front	0.3812	0.3603	0.0456	0.3623	0.3603	0.0239
NeckBase_Circ	0.3685	0.3747	0.0302	0.3684	0.3747	0.0369
Shoulder_Length	0.1326	0.1196	0.0273	0.1188	0.1196	0.0116
Shoulder_to_Wrist	0.5642	0.3957	1.0039	0.5680	0.3957	1.0528
Bicep_Circ	0.3054	0.3058	0.0119	0.3084	0.3058	0.0084
Wrist_Circ	0.1560	0.1569	0.0087	0.1571	0.1569	0.0061
Inseam	0.7737	0.7691	0.0133	0.7693	0.7691	0.0117
CrotchLength_Front	0.2845	0.3021	0.0262	0.3039	0.3021	0.0103
Crotch_Length_Back	0.3601	0.3636	0.0222	0.3643	0.3636	0.0121
Thigh_Circ	0.5950	0.5848	0.0311	0.5852	0.5848	0.0141
Calf_Circ	0.3627	0.3666	0.0091	0.3677	0.3666	0.0083
Knee_Circ	0.3719	0.3789	0.0117	0.3796	0.3789	0.0128

- 20% of the users consider that they are totally satisfied with shopping for custom-made garments through the mobile application, 50% are very satisfied and 20% consider their satisfaction neutral.
- Regarding the words they would use to describe the application, 90% considered it to be innovative, 80% considered it to be useful, 60% as attractive, and 30% considered it to be intuitive.
- 40% rated the mobile application experience as excellent, another 40% as very good, and 10% as good.

The following results were obtained from the survey of garment and pattern making experts:

- In terms of satisfaction with the calculation of the dimensions of the garment pattern, 100% responded that their satisfaction was neutral.
- Regarding the possibility of downloading a pdf file with the values of the calculated dimensions and the base pattern as a guide, 100% responded that they found this functionality very useful.
- 50% responded that it is very useful and the other 50% that it is totally useful to be able to visualize the body measurements of the clients.
- Regarding the catalog of garments, 50% considered it very useful to offer their custom-made products through a mobile application and the other 50% considered it totally useful.
- Regarding the positive impact of using the web application, 100% responded that they would obtain more clients, 50% considered that it would generate more income, and lastly, 50% responded that it would positively affect the garment making time.
- 50% of the respondents described the application as attractive and 100% described it as innovation and useful.
- 100% rated the experience of using the pattern making web application as very good.

In addition, comparisons were made between the measurements taken with a tape measure and the measurements obtained by our application of the group of 10 users. The RMSE was used to obtain the model errors for each body measurement, as shown in Table V, and on average our model presents a difference of 5.57 cm.

The table presents 23 final body measurements that will be shown to the user, of which the Back_Waist is calculated by the subtraction between Trouser_Waist_Height_Back and Neck_Height, and the Front_Waist is the difference between Trouser_Waist_Height_Front and Neck_Height.

Table V. Accuracy of body measurements of 10 users.

Body measurements	AVG of real measurements	AVG of predicted measurements	RMSE
Bust_Circ	99.1	94.13	6.70673
Natural_Waist_Circ	94.4	95.9	2.63584
Hip_Circ	96.2	102.73	8.16776
Hip_2_Circ	102.9	98.5	5.35594
Back_Waist	39.7	37.75	4.45845
Front_Waist	42.1	45.83	6.1709
SideNeck_to_Bust	26.1	28.96	3.10715
Hip_Height	88	80.37	8.56891
Hip_2_Height	84.8	75.11	12.40256
Bust_to_Bust	19.5	18.85	1.24297
Across_Back	39.8	36.13	6.06498
Across_Front	40.3	38.18	8.34807
NeckBase_Circ	39.5	37.79	3.13975
Shoulder_Length	12	11.75	0.99978
Shoulder_to_Wrist	55.6	60.59	5.5599
Bucep_Circ	30.4	34.44	4.4967

Wrist_Circ	15.4	17.15	1.82423
Inseam	70	75.26	7.29087
CrotchLength_Front	24	31.99	8.36909
Crotch_Length_Back	32	38.2	6.39621
Thigh_Circ	54.3	61.13	7.32049
Calf_Circ	36.3	40.24	4.38072
Knee_Circ	42.6	43.17	5.28023

6. CONCLUSIONS

Our proposal is an application that allows the production of dimensions of garment patterns tailored to a person from photos, using image processing and convolutional neural networks (CNN). The application incorporates the garment making process from the taking of body measurements to the generation of tailor-made garment patterns, which allows fashion companies to reduce time and costs when making tailor-made garments, also allows them to adapt to new market trends. Our proposal starts with obtaining a frontal and a lateral photo of the person, the height, and then process the images and obtain the body measurements by means of a CNN. Finally, we proceed to adjust the patterns of the garment required with the measurements obtained in order to give as a final result the dimensions of the garment's garment patterns.

The survey of the mobile application revealed that 100% of the users consider that the application increases satisfaction when buying clothes because it is in accordance with their body, 90% consider that it helps in the knowledge of their body measurements to make future online purchases. Regarding the result of the body measurements, 20% are satisfied with the result and 50% mentioned that they were very satisfied. Finally, 40% rated the mobile application experience as excellent and another 40% as very good.

The web application survey showed that 100% of the users remain neutral regarding the calculation of the garment pattern dimensions, 100% responded that they would get more customers by using the application, 50% considered that it would generate more revenue and reduce garment making time. In addition, 50% of the respondents described the application as attractive and 100% described it as innovation and useful. Finally, 100% of respondents rated their experience using the pattern-making web application as very good.

In future work, the proposal could be adapted to generate patterns of various garments such as dress suits and could also increase the age range of women to whom the garments will be tailored. Finally, the accuracy of body measurements could be improved by obtaining more data and photos of women.

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