An algorithm for the analysis of static hanging drape

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ABSTRACT – REZUMAT

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In this paper, an analysis of drape characteristics of textile waste derived from their 2D colour digital images was made. There have been proposed algorithms and procedures for obtaining 3D shapes of real drape. The description of the drape characteristics of fabrics was made by a total of 17 features. The advantages of the proposed methods and tools are that they don't need complicated calculation methods or a lot of time to measure and obtain a three-dimensional model. A predictive model was created from the obtained data for automated prediction of the drape coefficient of textile waste. The proposed methods and procedures can be applied in the analysis of fabric drape on video files obtained after exposure of the textile fabrics at different airflow rates.

Keywords: *textile waste, drape characteristics, algorithms, 3D shapes*

Un algoritm pentru analiza drapajului static

În această lucrare, au fost analizate caracteristicile de drapaj ale deșeurilor textile, derivate din imaginile digitale color 2D ale acestora. Au fost propuși algoritmi și proceduri pentru obținerea de forme 3D ale drapajului real. Descrierea caracteristicilor de drapaj ale materialelor a fost realizată prin 17 caracteristici. Avantajele metodelor și instrumentelor propuse sunt acelea că nu necesită proceduri complexe de calcul și un timp îndelungat pentru măsurarea și obținerea unui model tridimensional. Din datele obținute a fost creat un model predictiv pentru preconizarea automată a coeficientului de drapaj al deseurilor textile. Metodele și procedurile propuse pot fi aplicate pe fișiere video în analiza drapajelor pe fișiere video obținute după expunerea țesăturilor textile la diferite debite de aer.

Cuvinte-cheie: *deșeuri textile, caracteristici de drapaj, algoritmi, forme 3D*

INTRODUCTION

A major problem in the fashion and textile industries is reducing the cost of developing textile garments. The preliminary analysis of textile fabrics through simulation is a way to reduce this type of cost. For such a simulation analysis of the properties of the textile fabric to be sufficiently effective, it is necessary to know its density, extensibility, resistance to bending, and type of textile materials used. In other words, the physical and mechanical characteristics of the textile fabric must be largely known [1–3].

Classical methods for the analysis of the characteristics of textile fabrics are accurate, reliable, and similar, but require particular laboratory conditions, chemical reagents, and qualified specialists. The duration of the analyses, and their labour intensity, make them ineffective in the express determination of the fabric properties. The methods of visual evaluation of the properties of textile fabrics are also subjective and depend on the experience and qualification of the evaluator.

An important feature of textile fabrics is their drape. It is related to how the textile fabric falls, folds, and thus shapes the final look of interior elements, clothing, curtains, upholstery, tablecloths, napkins, blankets, and fashion accessories.

To determine the draping of textile fabrics, the most common methods used in practice are hanging drape, Cusick's drape, and modified Cusick's drape [4, 5]. According to Davis et al. [6], and also Ju et al. [7] the benefit of using a hanging drape is that it is suitable for determining certain physical properties, such as the degree of bending of the fabric.

In addition to the classical method for the analysis of the drapability of textile fabrics, using a round sample, some methods use samples with a rectangular shape [7].

According to Bhat et al. [6] and Bi et al. [8], the simulation analysis of rectangular drape is a complex task because it requires knowledge of many factors that affect the formation of drape. The authors propose an algorithm that can be used to determine the drape characteristics in dynamic mode, based on video file data. The results are compared with those obtained for real clothes such as dresses and skirts. Bouman et al. [9], expand the scope of this type of research by offering a method for analysing hanging drape based on video file data. The study was performed by determining the influence of airflow rate on the properties of textile fabric. The authors give a

comparison of the outcomes produced by their system and those obtained by specialists in the field of textile production.
According to Yang et al. [10] and Maqsood et al. [11], the methods for analysing hanging drape on video clips have the main disadvantage that they require the use of markers, as well as the use of complex algorithms and procedures to determine the characteristics of the drape. In most cases, the research is limited to a specific type of textile fabric. The reported results are more often obtained under specific conditions of video recording, which are difficult to apply to fabrics that the authors did not use. One solution to this problem is to use methods such as neural networks. Duan et al. [12], point out that the physical similarity network (PhySNet), shared with the Bayesian optimization procedure, can determine the drape characteristics, with an accuracy of 34% for textile fabrics and 68% for clothing. The analysis is done after the application of various air movements around textile fabrics and clothing.
According to Rasheed et al. [13], in the analysis of video files of fabrics, it is necessary to take into account their mechanical properties. This thesis has also been confirmed by Santesteban et al. [14], for clothing, with the authors proposing a new self-learning algorithm suitable for this purpose.
It should be summed up based on the examination of the available literary sources that in the simulation analysis of hanging drape, a method of extracting data from video clips is more often used. Because the video file can be divided into individual frames of which it consists, each frame can be considered a static image, the processing of data from this video file is based on the differences between the individual frames. In the analysis of these images, it is necessary to take into account the mechanical characteristics of the textile fabric. It is also necessary to offer algorithms and procedures, as well as predictive models that provide sufficient accuracy of the analysis, without requiring complex and powerful computational tools, requiring long analysis time, and high cost.
In the textile industry, waste is generated mainly during the tailoring stage. Incineration and landfilling should be the last method used for the management of textile waste, after reuse and recycling. One solution to reduce the negative impact on the environment would be to move to a circular textile production and consumption system [15–18]. The circular design of textiles is a significant measure to improve the durability and recyclability of the products and to guarantee the take-up of secondary raw materials in new products.
The paper aimed to obtain 3D shapes from 2D images of fabric drape resulting from textile waste. There were proposed methods and tools for obtaining 3D shapes of hanging drape.
From the textile waste resulting from production, fabric samples with a size of 30×30 cm were prepared. Depending on the percentage of cotton contained, they were divided into three classes. A total of 90 samples were analysed.
To obtain colour digital images, a distance of 50 cm from the camera to the sample was fixed. From the obtained data, a predictive model was created for the automatic prediction of the drape coefficient of some fabrics resulting from textile waste.

MATERIAL AND METHODS

From the textile waste resulting from production, fabric samples with a size of 30×30 cm were prepared. Depending on the percentage of cotton contained, they were divided into three classes.
Table 1 shows data on the textile fabric samples used.
By using the Cusick method, the drape coefficient (DC) was determined according to the method presented in [19–20].
The thickness of the fabric (*B*, mm) was determined with a micrometre Carbon Fibre Composites Digital Thickness Caliper Micrometre Gauge (Shenzhen Ruize Technology Co., Ltd., Shenzhen, PR China), with a range of 12.7 mm, resolution of 0.01 mm and accuracy 0.1 mm.
The textile fabrics' weight (*GSM*, g/m^2) was determined with a scale Pocket Scale MH-200 (ZheZhong Weighing Apparatus Factory), the maximum determined the mass of 200 g, with a resolution of 0.02 g, according to the following formula:

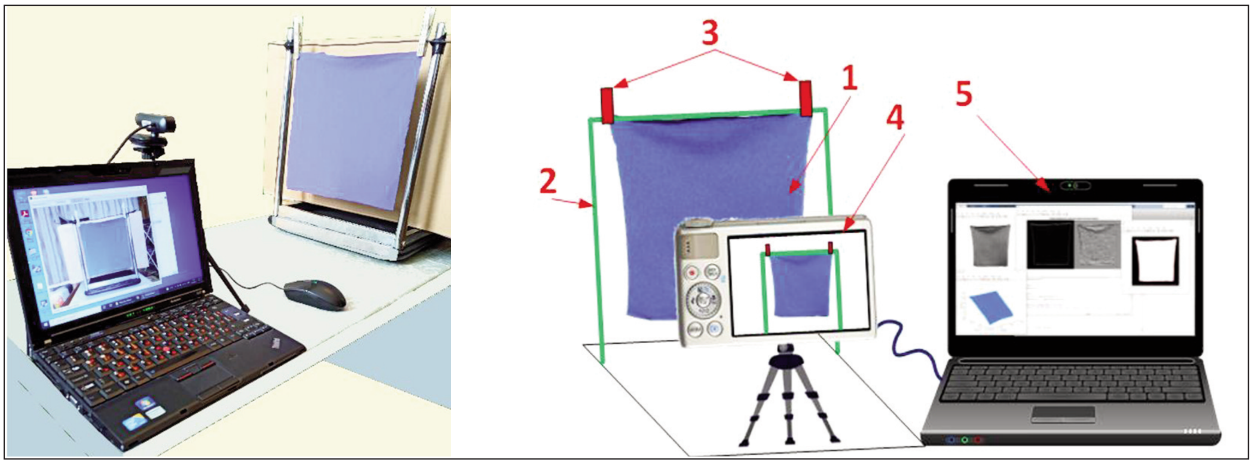
$$GSM = \frac{10000\, W_s}{A_s}, \text{ g/m}^2 \qquad (1)$$

where W_s is the mass of the measured sample, g; A_s – area of the sample in cm^2.

Table 1

DATA ON THE TEXTILE FABRICS USED			
Parameter \ Class	C1	C2	C3
Cotton (%)	100	74.15±15.56	0
Polyester (%)	0	17.85±14.23	66.85±15.9
Elastane (%)	0	8.17±9.09	0
Polyamide (%)	0	0	33.15±15.9

During the preparatory measurements, 3 samples of each type were measured. The scaling factor, the appropriate image capturing distance of the objects and the direction of the stage lighting were determined. Measurements and analyses were made after measuring 30 samples of each type of fabric. A total of 90 samples were analysed. 50% of the data was used to create the algorithms and procedures, and the remaining 50% of them were for their test validation.
Figure 1 shows the experimental configuration used to obtain digital colour images of the drape. As can be seen in the figure on a fixed support (1) is placed the measured sample (2) which is fixed with clips (3). A video camera Rapoo XW180 (4) (Rapoo Europe BV,



a *b*

Fig. 1. Experimental set-up for obtaining drape images: *a* – general view; *b* – principle schematic

GX Bergschenhoek, The Netherlands) was used for recording. The camera has been connected via the USB interface to a personal computer (5) that receives, processes, and analyses drape images.

To obtain colour digital images, a distance of 50 cm from the camera to the sample was fixed. The algorithms and procedures in the present work were created using utilizing the Matlab programming language 2017a (The MathWorks Inc., Natick, MA, USA).

The characteristics describing the drape were calculated according to the mathematical equations derived by Sanad et al. [19] and Alikhanov et al. [21]. The area ratio (*KA*) is determined by the percentage of the area of the textile fabric before placing the test bench and the area after the appearance of the drape. It is determined by the following mathematical dependence:

$$KA = \frac{A_{fs}}{A_d} \quad (2)$$

where A_{fs} is the area of the textile fabric after draping; A_d – the area of the sample.

Circularity (*C*): this is a descriptor of the complexity of the form and its sharpness:

$$C = \frac{4\pi A_{fs}}{P_{fs}^2} \quad (3)$$

where A_{fs} is the area of the drape; P_{fs} – drape perimeter.

K is the coefficient that describes the object's form. It is a relationship between the drape shape and its dimensions.

$$K = \frac{P_{fs}^2}{A_{fs}} \quad (4)$$

where A_{fs} is the area of the drape; P_{fs} – drape's perimeter.

Eccentricity (*E*): illustrates how the drape's shape deviates from an ideal circle:

$$E = \frac{D_{fs}}{d_{fs}} \quad (5)$$

where d_{fs} is the major axis of the drape; D_{fs} – drape's small axis.

AR-Coefficient of the minimum rectangle that reveals how close the object (drape) is to its minimum rectangle.

$$A_{mr} = d_{fs} D_{fs}\,; \quad AR = \frac{A_{fs}}{A_{mr}} \quad (6)$$

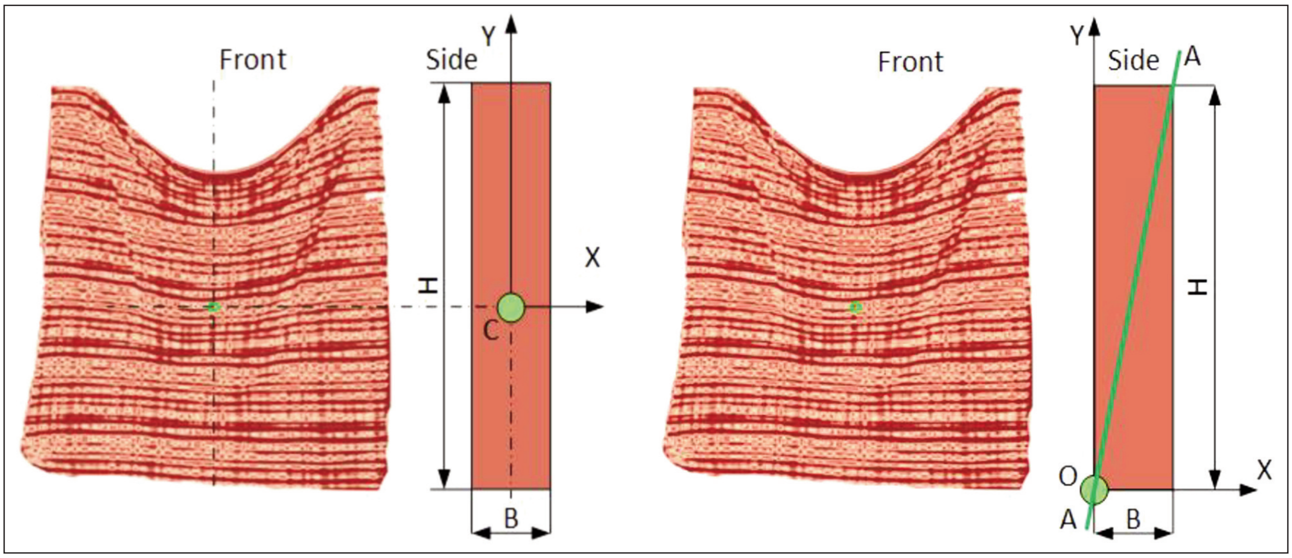
where A_{mr} is area of the minimum rectangle outlined around the drape; D_{fs} – large axis of the drape; d_{fs} – small axis of the drape.

Calculation of moment of inertia (Area moment of inertia, m^4) was used to determine changes in drape. The moment of inertia (*I*) is a characteristic that describes the ability of a textile fabric to withstand bending. This factor is determined by the vertical or horizontal axis of the sample. The centre of the sample or its lower-left corner can be taken as the origin of the coordinate system.

Figure 2 shows the two options for determining the moment of inertia of a textile fabric, with a different origin in the coordinate system.

The variables used to calculate the moments of inertia include the thickness of the textile fabric (*B*), and its height (*H*). There were calculated the following parameters: the moment of inertia along the *x* (I_x) axis; a moment of inertia along the *y* (I_y) axis; the moment of inertia on both axes (I_{xy}); drape moment of inertia (I_D). In the case of the variant with the origin of the coordinate system in the left corner of the textile fabric, the moment of inertia along section A-A (I_{AA}) was also determined.

The moments of inertia in the case of the variant with the origin of the coordinate system – the centre of the textile fabric and those with the beginning of the lower-left corner were determined by the following mathematical dependences [6]:



a *b*

Fig. 2. Variants for determining the moment of inertia of textile fabric, with different origins of the coordinate system: *a* – centre of fabric; *b* – left corner

Centre of fabric

$$I_{x1} = \frac{BH^3}{12} \quad (7)$$

$$I_{y1} = \frac{B^3H}{12} \quad (8)$$

$$I_{xy1} = 0 \quad (9)$$

$$I_{D1} = \frac{BH}{12}(B^2 + H^2) \quad (10)$$

Left corner

$$I_{x2} = \frac{BH^3}{12} \quad (11)$$

$$I_{y2} = \frac{B^3H}{12} \quad (12)$$

$$I_{xy2} = \frac{B^2H^2}{4} \quad (13)$$

$$I_{D2} = \frac{BH}{3}(B^2 + H^2) \quad (14)$$

$$I_{AA2} = \frac{B^3H^3}{6(B^2 + H^2)} \quad (15)$$

There were developed algorithms to determine the drape characteristics. The first algorithm serves to determine the drape characteristics, and the second for its three-dimensional visualization. Drape was scaled using the scale parameter, expressed as pixels per millimetre (pix/mm).

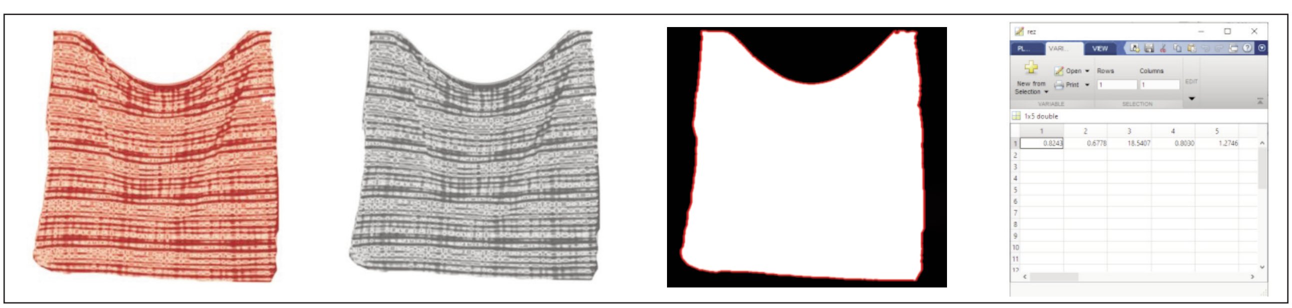
The algorithm for determining the drape characteristics is presented in figure 3: Stage 1. Load the original RGB image; Stage 2. Convert to grey levels with *rgb2gray* function; Stage 3. Define the contour of the drape in the image; Stage 4. Calculation of the drape coefficients according to the mathematical formulas is presented above.

The algorithm for three-dimensional visualization of the drape is shown in figure 4: Stage 1. Load the original RGB image; Stage 2. Convert to grey levels; Stage 3. Defines the gradient of the image with the *imgradientxy* and *imgradient* functions; Stage 4. Find the coordinates of the pixels that have a gradient higher than 1. Calculate the coordinates of the 3D graphics of the drape. The pixels of the drape in the image are detected by [*x, y*] = *find*(*L*=1). The gradient of these pixels is determined by *z* = *find*(*Gmag*>5).

Prediction of drape coefficient (*DC*). According to Hunter et al. [5], the draping coefficient can be predicted by the degree to which the textile fabric is folded (R_B), the mass of the fabric (*W*), the moment of inertia (I_D), and the coefficient of stretching (*Y*).

$$DC = f(R_B, W, I_d, Y) \quad (16)$$

To select the informative features describing the drape characteristics of textiles waste, as well as the reduction of their number, methods of continuous improvement of the meaning of the features were used: ReliefF, FSNCA and SFCPP [21]. Features



a *b* *c* *d*

Fig. 3. Algorithm for determining the drape characteristics: *a* – Stage 1; *b* – Stage 2; *c* – Stage 3; *d* – Stage 4

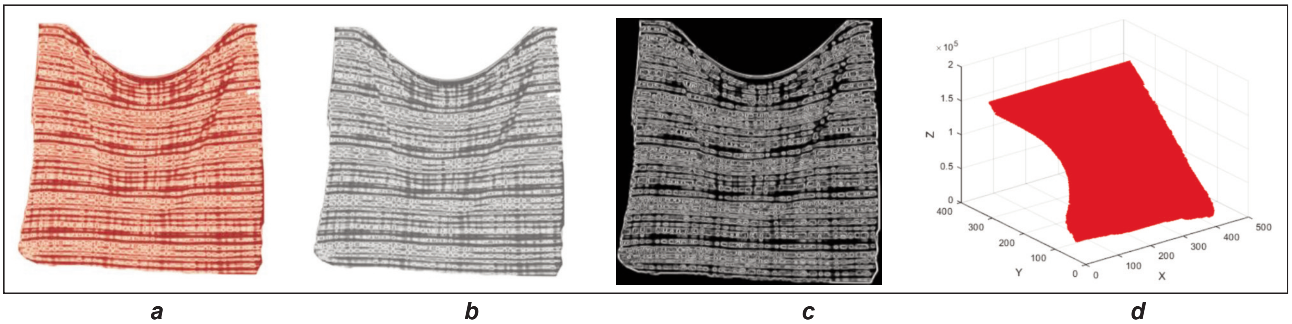


Fig. 4. Algorithm for 3D visualization of drape: *a* – Stage 1; *b* – Stage 2; *c* – Stage 3; *d* – Stage 4

with weights greater than 0,6 were selected as informative. A vector of features was created from them, through which the drape coefficient (*DC*) is predicted after reducing its data volume.

The data in the resulting vector of traits are reduced by the methods of latent variables and principal components [22–24]. A second-order model was used. It describes the relationship between reduced data from drape characteristics and *DC*. In general, the model has the form:

$$z = f(x,y)$$

$$z = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 \quad (17)$$

where "b" is the coefficients of the model; "x" and "y" are the independent variables; "z" is the dependent variable. Depending on the p-value, the non-informative coefficients are removed from the regression model. The accuracy of these models was assessed by the criteria: coefficient of determination (R^2); F-criterion; Standard error (SE); p-value. The differences between the actual measured values and those of the model are estimated by the residuals.

The softwares used for obtaining and processing data are Matlab 2017b (The MathWorks Inc., Natick, MA, USA) and Statistica 12 (TIBCO Software Inc., Palo Alto, CA, USA).

All data were analysed with a significance level of 0.05.

RESULTS AND DISCUSSION

As a result of the measurements and calculations, the values of the characteristics of the drape were determined. They are presented in table 2 by standard deviation and their mean.

The results of the selection of informative features that describe the drape are shown in figure 5. It can

Table 2

OBTAINED DATA FOR THREE CLASSES OF TEXTILE FABRICS

Parameter \ Class	C1	C2	C3
DC	33.64 ± 6.88	28.52 ± 9.1	36.28 ± 3.25
GSM (g/m^2)	139.29 ± 25.18	182.74 ± 19.21	194.18 ± 14.74
B (mm)	0.36 ± 0.1	0.51 ± 0.1	0.63 ± 0.06
KA	0.82 ± 0.11	0.82 ± 0.17	0.82 ± 0.09
C	1.75 ± 0.42	1.12 ± 0.59	1.53 ± 0.51
K	5.87 ± 0.42	4.55 ± 0.41	3.42 ± 0.3
E	0.9 ± 0.07	0.69 ± 0.07	0.5 ± 0.05
AR	0.51 ± 0.01	0.55 ± 0.01	0.58 ± 0.01
I_{x1} (mm^4)	881.4 ± 301.64	1324 ± 661.73	1437.65 ± 711.03
I_{y1} (mm^4)	0.1 ± 0.02	0.29 ± 0.14	0.65 ± 0.37
I_{xy1} (mm^4)	0	0	0
I_{D1} (mm^4)	881.5 ± 301.66	1324.3 ± 661.85	1438.3 ± 711.37
I_{x2} (mm^4)	881.4 ± 301.64	1324 ± 661.73	1437.65 ± 711.03
I_{y2} (mm^4)	0.1 ± 0.02	0.29 ± 0.14	0.65 ± 0.37
I_{xy2} (mm^4)	28.43 ± 7.85	58.49 ± 27.89	91.11 ± 47.27
I_{D2} (mm^4)	3526 ± 1206.65	5297.18 ± 2647.4	5753.2 ± 2845.48
I_{AA2} (mm^4)	0.21 ± 0.05	0.58 ± 0.28	1.29 ± 0.75

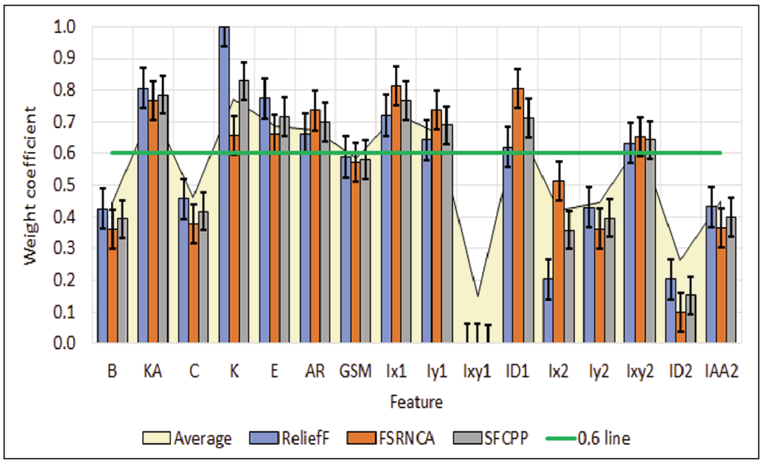


Fig. 5. Results of selection of informative features

be seen that the most informative are the geometric features describing the shape of the drape. Then, there are those obtained from the inertial moments of textile fabrics.

After the selection, the number of traits is reduced by half. The following generalized vector of nine traits (*FV*) was obtained:

$$FV = [KA\ K\ E\ AR\ GSM\ I_{x1}\ I_{y1}\ I_{D1}\ I_{xy2}] \quad (18)$$

The data from the feature vector is reduced to two principal components and two latent variables. They describe the variance in the experimental data as over 95%.

Regression prediction models for the draping coefficient (*DC*) by principal components and latent variables have been developed.

The principal component model $DC = f(PC_1, PC_2)$ has a coefficient of determination $R^2 = 0.71$. According to Fisher's criterion $F(3, 86) = 35.44$, which at these degrees of freedom has a critical value of $F_{cr} = 2.71$. The standard error of the model has a value of $SE = 0.072$. The level of significance is $p < 0.01$.

The model for latent variables $DC = f(LV_1, LV_2)$ has a coefficient of determination $R^2 = 0.74$. According to Fisher's criterion $F(3, 86) = 46.43$, which at these degrees of freedom has a critical value of $F_{cr} = 2.71$. The standard error of the model has a value of $SE = 0.07$. The level of significance is $p < 0.01$.

After excluding the insignificant coefficients from the basic model, regression equations were obtained, describing the relationship between *DC*, the principal components and the latent variables, to which the feature vector *FV* was reduced. These models have the form:

$$DC = f(PC_1, PC_2)$$

$$DC = 33.61 + 10.01PC_1 - 9.03PC_1^2 + 8.18PC_2^2 \quad (19)$$

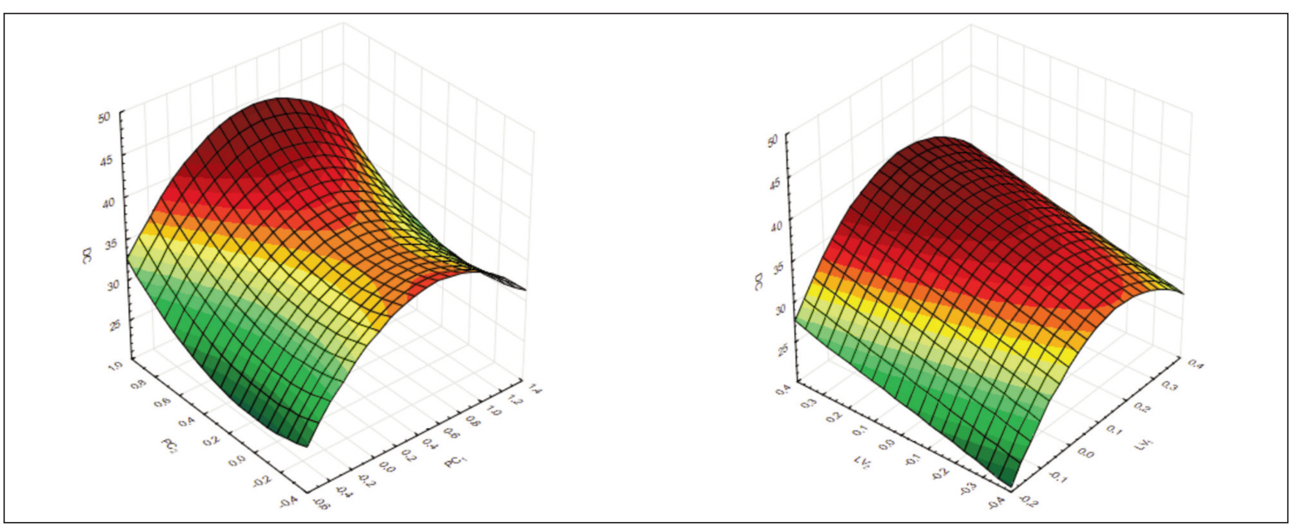
$$DC = f(LV_1, LV_2)$$

$$DC = 33.81 + 30.46LV_1 + 8.79LV_2 - 80.78LV_1^2 \quad (20)$$

In general, the obtained models are presented in figure 6. Independent variables are the first two main components and the first two latent variables. In both cases, the dependent variable is the drape coefficient (*DC*). In both graphs, it can be seen that the prediction will be with the highest accuracy when the *DC* values are in the upper levels.

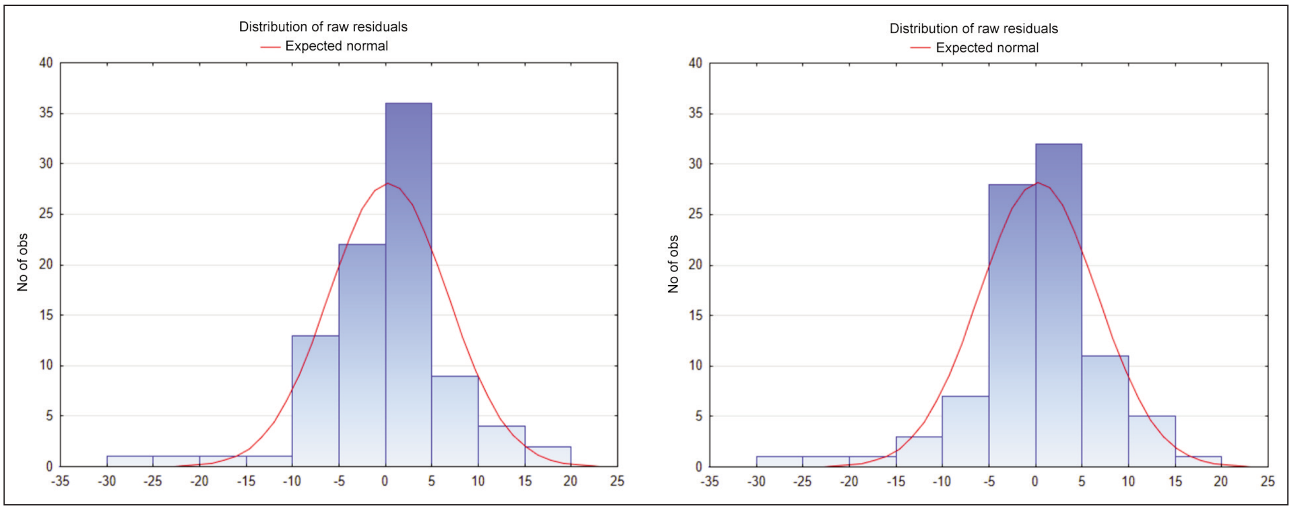
Figure 7 shows the distribution of the residuals of the obtained models. The graphs show that in both models the distribution of residuals is close to normal. This analysis shows that the obtained DC prediction models are adequate and describe the experimental data with sufficient accuracy.

Figure 8 displays the outcomes of visualizing the drape's 3D shape. They are obtained by an image processing algorithm. The deviation from the dimensions of the drape is 3–5 mm. The time for obtaining and processing the data, as well as calculating the



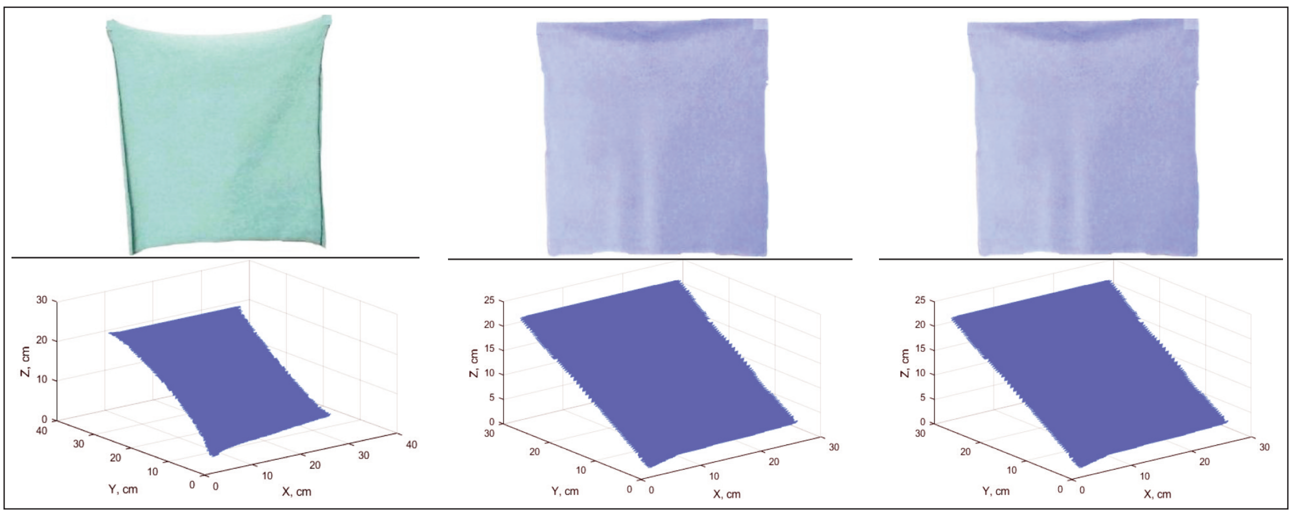
a *b*

Fig. 6. General view of DC prediction models: *a* – $DC=f(PC_1,PC_2)$; *b* – $DC=f(LV_1,LV_2)$



a *b*

Fig. 7. Distribution of residuals of the obtained models: *a* – $DC=f(PC_1,PC_2)$; *b* – $DC=f(LV_1,LV_2)$



a *b* *c*

Fig. 8. 3D shapes of drape: *a* – Sample 1; *b* – Sample 2; *c* – Sample 3

parameters for visualization is up to 5 s. When validating the obtained regression models, an accuracy of 68–70% was achieved. This is close to that obtained in their creation.

The results obtained improve those of Bhat et al. [4]. Methods and tools for simulation analysis of rectangular drape are proposed. The proposed procedures do not require complex computational procedures, such as those proposed by Duan et al. [12]. The significant factors that influence the formation of the drape are selected. In addition to the mechanical properties as proposed by Rasheed et al. [13], in the analysis of rectangular drape of fabrics, the present dimensions and coefficients describing the relationship between them are taken into account in the present work.

CONCLUSIONS

An analysis of the characteristics of drape from textiles waste extracted from their colour digital images was made.

Methods and tools for obtaining 3D shapes of hanging drape have been proposed. These approaches have the benefit of not requiring complicated calculation procedures and a long time to measure and obtain a three-dimensional model. It is possible to obtain 3D shapes from 2D images of drape, as the dimensions of the objects in the image are known, as well as the conditions under which they were taken.

A predictive model has been created for automated prediction of the drape coefficient of textile fabrics from textiles waste. To create the model, there were used geometric characteristics reduced by principal components and latent variables and features obtained by calculating the moments of inertia of the textile fabric.

The findings in the literature have been improved upon. The developed software tools were used in the study of hanging drape from textile waste. In further research, we can look for other factors that influence the construction of a 3D contour of drape, on their two-dimensional images.

The proposed methods and procedures can be applied in the analysis of drape on video files obtained after exposure to textile fabrics at different airflow rates.

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REFERENCES

[1] Spahiu, T., Shehi, E., Piperi, E., *Personalized avatars for virtual garment design and simulation*, In: UNIVERSI – International Journal of Education, Science, Technology, Innovation, Health and Environment, 2015, 1, 3, 56-63

[2] Spahiu, T., Fafenrot, S., Grimmelsmann, N., Piperi, E, Shehi, E., Ehrmann, A., *Varying fabric drape by 3D-imprinted patterns for garment design*, In: IOP Conference Series: Materials Science and Engineering, 2017, 254, 172023, 1–6, https://doi.org/10.1088/1757-899X/254/17/172023

[3] Moskvin, A., Wijnhoven, M.A., Moskvina, M., *The equipment of a Germanic warrior from the 2nd–4th century AD: Digital reconstructions as a research tool for the behavior of archaeological costumes*, In: Journal of Cultural Heritage, 2021, 49, 48–58, https://doi.org/10.1016/j.culher.2021.03.003

[4] Bhat, K., Twigg, C., Hodgins, J., Khosla, P., Popović, Z., Seitz, S., *Estimating cloth simulation parameters from video,* In: Proceedings of the 2003 ACM SIGGRAPH/Eurographics symposium on Computer animation (SCA '03), Eurographics Association, Goslar, DEU, 2003, 37–51

[5] Hunter, L., Fan, J., *Measurement and Prediction of Fabric and Garment Drape*, In: Textile Learner, 2008, 7–25

[6] Davis, A., Bouman, K., Chen, J., Rubinstein, M., Durand, F., Freeman, W., *Visual vibrometry: Estimating material properties from small motion in the video*, In: Proceedings of IEEE Conference of Computer Vision and Pattern Recognition, 2015, 5335–5343

[7] Ju, E., Choi, M., *Estimating cloth simulation parameters from a static drape using neural networks*, In: IEEE Access, 2020, 8, 195113–195121

[8] Bi, W., Jin, P., Nienborg, H., Xiao, B., *Estimating mechanical properties of cloth from videos using dense motion trajectories: Human psychophysics and machine learning*, In: Journal Vision, 2018, 18, 5, 1–20

[9] Bouman, K., Xiao, B., Battaglia, P., Freeman, W., *Estimating the material properties of fabric from video*, In: Proceedings of IEEE International Conference of Computer Vision, 2013, 1984–1991

[10] Yang, S., Liang, J., Lin, M., *Learning-based cloth material recovery from video,* In: Proceedings of IEEE Internation Conference of Computer Vision (ICCV), 2017, 4383–4393

[11] Maqsood, E., Chen, H-L., Abdulrahman, N., *The impacts of different woven fabrics on three draping techniques*, In: International Design Journal, 2019, 9, 2, 147–155

[12] Duan, L., Boyd, L., Aragon-Camarasa, G., *Learning physics properties of fabrics and garments with a physics similarity neural network,* In: Pattern Recognition Letters, 2021, arXiv:2112.10727, 1–7

[13] Rasheed, A., Romero, V., Bertails-Descoubes, F., Wuhrer, S., Franco, J., Lazarus, A., *A visual approach to measure cloth-body and cloth-cloth friction*, In: IEEE Transactions on Pattern Analysis and Machine Intelligence, 2021, 1–13, https://doi.org/10.1109/TPAMI.2021.3097547

[14] Santesteban, I., Thuerey, N., Otaduy, M., Casas, D., *Self-supervised collision handling via generative 3D garment models for virtual try-on*, In: IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2021, 11763–11773

[15] Ilieș, D.C., Lite, M.-C., Indrie, L., Marcu, F., Moș, C., Ropa, M., Sturzu, B., Costea, M., Albu, A.V., Szabo-Alexi, P., Sambou, A., Herman, G.V., Caciora, T., Hodor, N., *Research for the conservation of cultural heritage in the context of the circular economy*, In: Industria Textila, 2021, 72, 1, 50–54, http://doi.org/10.35530/IT.072.01.1807, WOS: 000627567800006

[16] Tripa, S., Indrie, L., *Households textile waste management in the context of a circular economy in Romania*, In: Environmental Engineering and Management Journal, 2021, 20, 1, 81–87, ISSN:1582-9596, eISSN:1843-3707 WOS:000620353800009 IF 0,916

[17] Albu, A., Caciora, T., Berdenov, Z., Ilies, D.C., Sturzu, B., Sopota, D., Herman, G.V., Ilies, A., Kecse, G., Ghergheles, C.G., *Digitalization of garment in the context of circular economy*, In: Industria Textila, 2021, 72, 1, 102–107, http://doi.org/10.35530/IT.072.01.1824

[18] Tripa, S., Indrie, L., Zlatev, Z., Tripa, F., *Customized clothes – a sustainable solution for textile waste generated by the clothing industry*, In: Industria Textila, 2022, 73, 3, 275–281, http://doi.org/10.35530/IT.073.03.202112

[19] Sanad, R., Cassidy, T., Cheung, T., *Fabric and garment drape measurement – part 1*, In: Journal of Fiber Bioengineering and Informatics, 2012, 5, 4, 341–358

[20] Spahiu, T., Manavis, A., Kazlacheva, Z., Almeida, H., Kyratsis, P., *Industry 4.0 for fashion products – Case studies using 3D technology*, In: IOP Conference Series: Materials Science and Engineering, 2021, 1031, 1, 012039, 1–9

[21] Alikhanov, J., Penchev, S., Georgieva, Ts., Moldazhanov, A., Shynybay, Z., Daskalov, P., *An indirect approach for egg weight sorting using image processing*, In: Food Measurement and Characterization, 2017, 12, 1, 87–93

[22] Mladenov, M., *Complex assessment of the quality of food products through visual images, spectrophotometric and image analysis hyper-spectral characteristics, Monograph*, University publishing Center of Rousse University "A. Kanchev", Rousse, 2015

[23] Spahiu, T., Zlatev, Z., Ibrahimaj, E., Ilieva, J., Shehi, E., *Drape of Composite Structures Made of Textile and 3D Printed Geometries,* In: Machines, 2022, 10, 587, https://doi.org/10.3390/machines10070587

[24] Indrie, L., Affandi, N.D.N., Díaz-García, P., Haji, A., Ilies, D.C., Zlatev, Z., Taghiyari, H.R., Grama, V., Farima, D., *Mechanical and Morphological Properties of Cellulosic Fabrics Treated with Microencapsulated Essential Oils*, In: Coatings, 2022, 12, 1958. https://doi.org/10.3390/coatings12121958

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