Predicting Fabric Drapability Property by Using an Artificial Neural Network

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ABSTRACT

Drape, one of the most important properties of fabric, has played significant role in providing graceful aesthetic effects in garments. Drapability of textiles is judged subjectively and is dependent on people's skill and experience, which render difficulties during drape comparisons, especially when judged by different people. This work reports the results of a study on predicting the drapability of woven fabric using an artificial neural network. It was established that drapability could be predicted from the mechanical properties of fabric at low-stress.

Keywords: Back-propagation, correlation coefficient, fabric drape, neural network.

INTRODUCTION

Earlier research in textile mechanics mainly focused on understanding the relationship between the mechanical properties of fabrics and yarns as well as fabric structures [1-8]. However, drape is a very important property of fabric particularly from designer point of view as well as end user point of view, as it plays major role in aesthetic appeal of fabric. It is directly related to textile aesthetics, which is important in the development and selection of textile materials in apparel industries and especially for the design of clothes. Drape is the ability of a fabric to fall under its own weight into wavy folds. It plays a significant role in providing graceful aesthetic effects in garments. It is a unique property that allows a fabric to be bent in more than one direction, resulting in a sense of graceful appearance [9-11]. Fabric drape is the ability of a fabric to deform when suspended under its own weight in specified conditions [12-14]. Fabric drape along with luster, colour, texture, etc. defines fabric and garment appearance. Drapability of a fabric is the combined effect of several factors such as: stiffness, flexural rigidity, weight, thickness etc. [15-20].

Fabric drape refers to the fabric shape or profile when held at the edge. Mechanically speaking, fabric drape is the fabric's response towards gravity due to its own weight. However, fabrics with identical mass can show very diverse drape behaviors as determined by the same mechanical properties defining fabric hand. Therefore, it becomes obvious that fabric hand and drape are interconnected. Any difference in overall fabric hand, or in the individual hand attribute, can be used or interpreted as a difference in fabric drape behavior or fabric formability.

The formability is defined as the product of bending rigidity and low stress extensibility. In fact, formability is a measure of the degree of longitudinal compression sustainable by a fabric in a certain direction before the fabric buckles. This parameter was introduced by Lindberg and has been used by various other workers to assess fabric formability [21].

Formability shows good correlation with fabric quality appearance. However, as the appearance of a fabric is dependent of so many other attributes, formability alone cannot explain the phenomenon. Studies were also carried out to understand the dependence of fabric quality appearance on weft formability. From the results it is observed that higher weft formability gives better appearance values for worsted fabrics. However, in general the formability in weft direction is lower as compared to the warp. Weft formability also shows a good correlation with the appearance value for most worsted fabrics. It is observed that for all fabric samples, appearance is dominated by the formability. This may be attributed to the fiber characteristics which are responsible for the bending rigidity and low-stress extensibility of the fabrics.

It is found that the formability has highest influence on appearance followed by creasing and drape respectively. Increasing fabric formability and improved appearance are achieved due to improved low-stress mechanical properties [21-22].

The use of the FAST system as an instrument for measuring low-stress fabric properties to enable them to be correlated with a subjective assessment of drapability is a viable method. The relationships between fabric performance and properties are very difficult to describe quantitatively by traditional mathematical or mechanical means due to the non-linearity of the parameters and the large number of variables involved.

Therefore, this seems to be an ideal situation for application of the artificial neural network (ANN). Attempts have been made in the last decade to apply the ANN technique to textiles. Ramesh et al. used an ANN to predict yarn tensile properties based on yarn processing and material parameters [23]. Pynckels et al used an ANN to determine the spinning performance of fibres from fibre properties [24]. Cheng et al. predicted the strength of yarns according to their constituent fiber properties [25]. The application of ANN in these areas shows great promise because an ANN can deal with nonlinearity, detect patterns and relationships in the data and interpret information from tens or more variables, which is the case in this research.

ANN algorithms have been also used by many researchers for predicting different kinds of fabric properties. Fabric extensibility was predicted by using artificial neural networks [26]. ANNs were also used to predict the tensile and air permeability of the woven fabrics [27-28]. Fabric hand was predicted using artificial neural networks by Hui et al. [29], and Matsudaira [30].

Drapability is one of the most complex mechanical properties of fabrics and it is essential in many applications of textile fabrics. In this study, an attempt is made to establish a method using ANN's to predict fabric drapability using fabric mechanical properties (particularly formability) measured by the Fabric Assurance by Simple Testing (FAST) [31-32]

MATERIALS AND METHODS

Experimental Materials

The samples used in this study were medium to heavy-weight woven fabrics of plain and twill weaves currently available in the market.

A total of forty (40) fabric samples were selected randomly from a total of 50 samples that had been chosen for the entire experiment. Details of fabric samples are tabulated in *Table I*.

TABLE I. Details of fabric samples.

Materials	Weave	No. of samples	Tt (Tex)	Threads per cm.		W (g/m2)
				Ecm	Pcm	
Cotton	twill	20	30-45	15-22	14-20	180-220
Linen	Plain	20	40-55	17-25	16-23	270-350

Where:
Ecm : Ends per cm
Pcm: Picks per cm
Tt: Yarn Count in tex
W: Fabric weight

Measuring the Surface Properties of Fabrics

As stated in the introduction, the FAST system is used to measure the surface mechanical properties of fabric and some parameters were derived from these, resulting in eight characteristics of fabric surface. The definitions of the parameters and the statistical values are shown in *Table II* below. The measurements took place under standard laboratory conditions.

TABLE II. Characteristic values of surface mechanical properties of fabrics.

Symbols	Unit	Measured Method	Min	Max	Mean
$E5_{weft}$	%	FAST 3	3,7	4,1	3,8
$E5_{warp}$	%	FAST 3	3,7	4,0	3,7
$E20_{weft}$	%	FAST 3	3,9	4,4	4,1
$E20_{warp}$	%	FAST 3	3,8	4,3	4,1
B_{weft}	µN/m	FAST 2	38	45	40
B_{warp}	µN/m	FAST 2	40	48	42
F_{weft}	mm^2	FAST 2-3	1,07	1,43	1,18
F_{warp}	mm^2	FAST 2-3	1,05	1,41	1,15

Where:
$E5_{warp}$ Extension at a load of 5 cN/cm at warp direction
$E5_{weft}$ Extension at a load of 5 cN/cm at weft direction
$E20_{warp}$ Extension at a load of 20 cN/cm at warp direction
$E20_{weft}$ Extension at a load of 20 cN/cm at weft direction
B_{weft} Bending rigidity at weft direction
B_{warp} Bending rigidity at warp direction
F_{weft} Formability at weft direction
F_{warp} Formability at warp direction

Subjective Testing

The fabric drapability was assigned grades (*Figure 1*) from 1 (low drapability) to 5 (excellent drapability). These five drapability grades were used to define the drapability of a given textile material as represented in *Figure 1*.

Drape shape					
Drapeability grade	**5**	**4**	**3**	**2**	**1**

FIGURE 1. Proposed drape grade.

When evaluating on the basis of pictorial representation, various evaluators expressed different standpoints regarding the pre-determined criteria of quality grade that was evaluated. It is therefore essential for the chosen ranking panelists to have some background and knowledge of textiles to facilitate better understanding of the ranking drape grade. A total of 30 male and female students were trained prior to the actual testing. The students were conversant with textiles and clothing by virtue of their current training in textile-related courses.

Analytical Method

Test Results from the FAST System

The descriptions of the fabric surface characteristics evaluated by the FAST system are given in *Table II* above. The mechanical properties of denim and linen fabric were evaluated by FAST (Fabric Assurance by Simple Testing) according to BS 3356-1961. The FAST variables, namely, bending rigidity, extensibility and formability are drawn from the internal formulae as follows:

$$B = M \times (C)^3 \times k \quad (1)$$

where:

- B: bending rigidity (µN.m)
- M: Fabric mass per unit area (g/m²)
- C: bending length (mm).
- K: conversion factor = 9,81x 10-6

$$F = B \times \frac{E_{20} - E_5}{14.7} \quad (2)$$

where:

- F: formability of the fabric (mm^2)
- B: bending rigidity (µN.m)
- E20 extension (%) under a load of 20 cN/cm
- E5 extension under a load of 5 cN / cm.

These terms have also been defined in *Table II* above. The derived fabric mechanical property most closely related to the aspects of drapability properties under study is fabric formability in the warp and weft direction.

Artificial Neural Network Construction

As illustrated in *Figure 2*, a back-propagation network of three layers, namely the input layer, the hidden layer, and the output layer, was used. A total of 20 samples were considered for training of the network. Of these, 7 physical factors shown in *Table III* were regarded as the training input vector, with their drape properties producing the learning target data. The physical factors and sensory factor results pertaining to the last 20 samples served as query inputs and outputs, respectively.

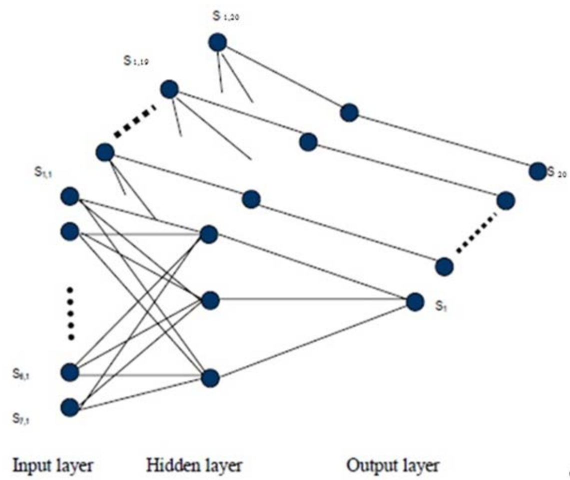

FIGURE 2. Adopted neural network layout model.

TABLE III. Learning data for the back-propagation neural network.

	Li							Lt
S	Te	Tf	E	P	W	Fe	Ff	DP
1	42	55	22	17	268	1.05	1.09	3
2	48	60	27	22	313	1.07	1.05	4
3	45	57	25	20	307.5	1.07	1.06	3
4	50	63	23	19	277.8	1.29	1.25	2
5	47	65	21	18	300	1.08	1.05	3
6	75	59	22	17	320	1.17	1.07	4
7	80	60	23	19	315	1.14	1.04	3
8	79	63	20	20	305	1.15	1.1	2
9	82	59	19	19	325	1.16	1.09	3
10	83	58	21	18	330	1.15	1.08	3
11	45	55	25	21	228	1.15	1.11	4
12	43	60	27	22	248	1.11	1.14	4
13	45	57	25	20	205	1.1	1.15	3
14	50	63	22	17	217	1.16	1.13	3
15	55	56	21	18	216	1.17	1.19	4
16	48	57	22	19	220	1.17	1.14	3
17	50	59	26	20	222	1.1	1.13	3
18	47	61	23	19	228	1.14	1.12	4
19	52	60	25	20	235	1.17	1.18	4
20	53	52	23	22	219	1.16	1.12	3

Where:
Te: Warp count (tex)
Tf: Weft count (tex)
P: Picks per centimeter
E: Ends per centimeter
W: Weight (g/m^2)
Ff: Formability on weft direction in mm^2
Fe: Formability on warp direction in mm^2
DP : grade of the Drapability Property
Li: Learning input
S: Sample number
Lt: Learning target

The non-linear transfer function used is the sigmoid function

$$f(x) = \frac{1}{1+e^{-x}} \qquad (3)$$

The values of the function vary between 0 and 1 for the input layer, while the hyperbolic tangent sigmoid (tagsig) transfer function was used on the hidden layer according to the following formula:

$$tagsig(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}} \qquad (4)$$

In order to attain output values greater than 1, a linear transfer function was used on the output layer. In computing the change in weight between the hidden and the output layers the generalized delta-learning rule was used.

The aim of network learning is to reduce the delta between the target value and the predicted value. The quality of learning, which is the error vector, is evaluated by the following equation:

$$E = \frac{1}{2}\sum (T_j - Y_j)^2 \qquad (5)$$

where E is the error vector; Tj is the output layer target value; and Yj is the output layer prediction value at node j. To minimize the value of the energy function, the steepest gradient descent entry point method was used. The optimal data convergence after network training was obtained under these conditions.

In the supervised network learning process, the degree of convergence can be expressed in terms of the root-mean-square error (MSE) from the following relationship:

$$MSE = [\frac{1}{n}\sum (T_j - Y_j)^2]^{1/2} \qquad (6)$$

where n is the number of units processed by the output. The MSE value varies from 0 to 1. If the MSE converges to less than 0.1, a good result is obtained.

RESULTS AND DISCUSSION

Correlation Analysis

The use of a correlation analysis will provide a means of drawing inferences about the strength of the relationship between the variables. It is used to get a measure of the degree to which the values of these variables vary and to provide a quantitative index of the degree to which one variable can be used to predict another. A linear correlation, denoted by r, measures the strength of linear relationship between two variables for a sample and is calculated by:

$$r = \frac{SS_{xy}}{\sqrt{SS_{xx} \times SS_{yy}}} \qquad (7)$$

Where the sum of squares SS is defined as follows:

$$SS_{xy} = \sum xy - \frac{(\sum x)(\sum y)}{n} \qquad (8)$$

$$SS_{xx} = \sum x^2 - \frac{(\sum x)^2}{n} \qquad (9)$$

$$SS_{yy} = \sum y^2 - \frac{(\sum y)^2}{n} \qquad (10)$$

The graphs in *Figure 3* are the resultant least square lines or curve-fits constructed using the sets of data on the drapability-formability and on the warp and weft directions, where a polynomial approximation assuming a linear relationship between each of these set groups was used. An evaluation of the correlation coefficient according to Eq (5), on these fitted curves results in the following correlations for the warp and weft directions, respectively:

(a) The correlation between the formability on the weft direction and drapability was 0.892
(b) The correlation between the formability on the warp direction and drapability was 0.886

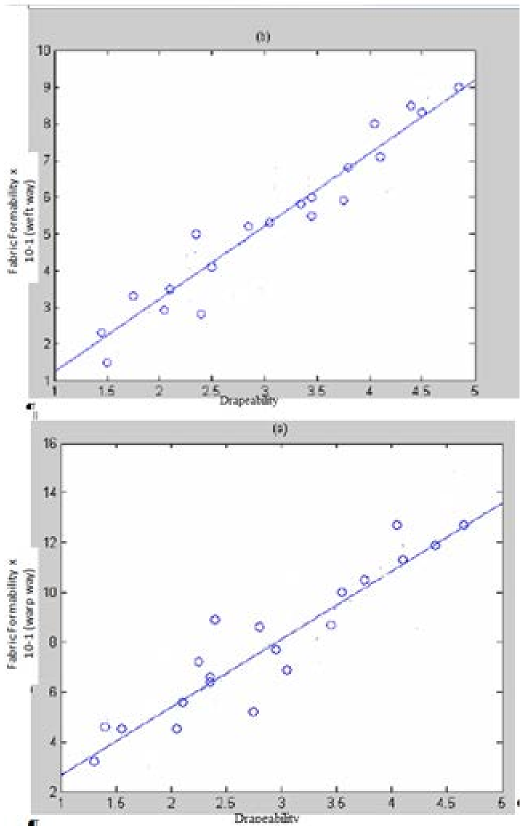

FIGURE 3. Correlation curves between fabric formability properties and fabric drapability.

In general, the above results of the correlation coefficient between the FAST measured fabric surface characteristics and the subjectively analyzed drapability parameters showed that the expected relationship between them exists. A high correlation coefficient between the subjectively determined fabric drapability and the assigned surface characteristics was also observed. From these two correlations curves the inference may be drawn that firm with low formability, whose weave structure is tight, will not bend easily and therefore will have low drapability.

Backpropagation Analysis

A three-layer neural network consisting of a seven-neuron input layer, a fourteen-neuron hidden layer, and a one-neuron output layer was adopted in this backpropagation. The network was trained for a function approximation that is a nonlinear regression and an application of the steepest descent-training function to the neural network, with 0.05 as a learning rate. A momentum term of 0.5 was used. During training, the weights and biases of the network were iteratively adjusted to minimize the performance of the network. The default performance function for feedforward networks is the mean square error (MSE) – the average squared error between the network outputs and the target outputs. The neural network learning model is in accordance with the experimental data of seven inputs and one output, descriptions of which are listed in *Table III.*

A correlation coefficient was designed for better and more objective visualization of the effectiveness of the model.

A plot of the predicted data versus the evaluated values of drapability is shown in *Figure 4.* The correlation coefficient, r, between the predicted and evaluated values is used to judge the quality of the prediction. The value of correlation coefficient was high (r = 0.86) indicating that the predicted data agreed well with the evaluated values.

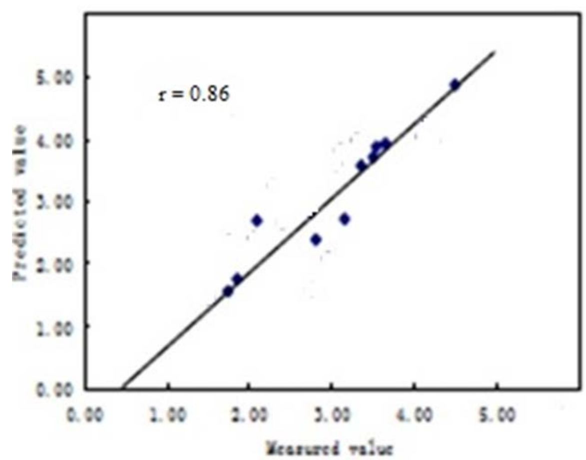

FIGURE 4. Fabric drapability.

CONCLUSION

In this study, fabric drapability is predicted by using neural network based on surface mechanical properties at low stress, particularly fabric formability. On the basis of the above relationship, it is possible to obtain quantitative information on changes in fabric drape by measuring changes in the relevant fabric properties using the FAST system and fabric mechanical properties. The correlation analysis revealed a strong correlation between subjective drape properties and measured formability. It is therefore concluded that a promising application of neural network for predicting one of the aesthetic properties from the physical factors of fabric has been presented. From the above analysis it was found that the physical factors of medium to heavy woven fabrics can be used to predict drapability property of the fabric. It is therefore concluded that a neural network model that has been developed which can predict this drape characteristic of aesthetic. The developed intelligent system can be used in engineering predictions and designing high-quality garments, while at the same time it offers important data required to obtain the desired garment appearance.

REFERENCES

[1] Msahli, S., Hadj Taieb A., Sakli, F., A new approach for predicting the knit global quality by using the desirability function and neural networks, *Journal of the Textile Institute*, 2006, Vol.97, N°1, (2006), 17-23.

[2] Hadj Taieb A., and Msahli S., Optimization of the Knitted Fabric Quality by using Multicriteria Phenomenon tools", *International journal of fiber and textile research*; 3(4); (2013); 66-77.

[3] Gazzah, M, Jaouachi, B. and Sakli, F. Study of the friction effects on residual bagged Denim Fabric Behavior, *The journal of textile institute*, 2; 2014, 95-96.

[4] Gazzah, M, Jaouachi, B. and Sakli, F. Effect of frictional parameters on the residual bagging behavior of denim fabrics, *International Journal of Applied Research on Textile*; Vol. 3 ; Issue 1 ; October 2015 ; 32-43

[5] Gazzah, M, Jaouachi, B, Schacher, L., Adolphe, D., and Sakli, F., Study of the influential inputs on the bagged denim fabric behaviors using the Principal Component Analysis method" ; *International journal of clothing science and technology*, Vol. 27; Issue 6; 2015, 922-939 .

[6] Halleb N., Sahnoun, M., and Cheikhrouhou, M., Evaluation of sensitivity and discriminative performance of tactile sensory panel; *International Journal of Applied Research on Textile*; Vol. 2; Issue 1; April 2014; 30-42

[7] Kheder F., Dhouib S., and Sakli F., The Effect of Seaming on Cloth Shrinkage During Finishing Treatment of Denim Garments, *Research journal of textile and apparel* ; Vol. 17; No. 4; 2013; 90-102

[8] Zaouali R, Msahli S., and Sakli, F., A Nonlinear Viscoelastic Model for Describing Fabric Wrinkle recovery behavior; *International Journal of* Applied Research on Textile; Vol. 2; Issue 2; August 2014; pp. 22-32

[9] Itagi, A. A., Basu, A. Drape Behaviour of Silk Apparel Fabrics with Radial Seams, International Journal of Engineering, Research and Technology", Vol.1, Issue-8,Oct 2012.

[10] Behera, B.K. Pattanayak, A. K.,Measuring and modeling of drape using digital image processing, International Journal of Fibre Research & Textile Research, Vol 33, Oct 2008, 230-238.

[11] Behera B.K., Mishra, R., Effect of crease behavior, drape and formability on appearance of light weight worsted suiting fabrics, IJFTR, Vol. 32, ,Sept 2007, 319-325.

[12] British Standards Institution. Textiles. Test methods for nonwovens. Determination of drapability including drape coefficient. London: BSI; 2008.

[13] British Standards Institution. Textiles - Test methods for nonwovens - Part 9: Determination of drape coefficient. London: BSI; 1998.

[14] British standards Institution. Method for the assessment of drape fabrics. London: BSI; 1973.

[15] Kanade, P. S., Agrawal S. Studies on Drape Time Dependency and Relating It to Other Fabric Properties A., International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 4, April 2014, ISSN: 2319-8753 10911-10915.

[16] Tuigong, D. R., Xin, D. The Use of Fabric Surface and Mechanical Properties to Predict Fabric Hand Stiffness Research Journal of Textile and Application 9 (2), 2005, 39 – 46.

[17] Hedfi, H., Ghith, A., Bel Hadj Salah, H., Study of dynamic drape behavior of fabric using FEM Part I: Model Formulation and Numerical Investigations, International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462 Vol. 3 No. 8 August 2011, 6554- 6563.

[18] Vasile S, Ciesielska-Wróbel IL, Van Langenhove L. Wrinkle Recovery of Flax Fabrics with Embedded Superelastic Shape Memory Alloys Wires, FIBRES & TEXTILES in Eastern Europe 2012; 20, 4(93), 56-61.

[19] Cusick, G.E., The dependence of Fabric Drape on Bending and Shearing Stiffness, Journal of the Textile Institute, 65, (1965), 596-606.

[20] Hamdi T., Guith A., Fayala, F., Study of drape parameter using image analysis, International Journal of Engineering Science and Technology, ISSN : 0975-5462 Vol. 5 No.07 July 2013, 1456- 1464.

[21] Lindberg, J., Waesterberg L., and Svenson. R., Journal of Textile Institute, 1960, 51, TI475.

[22] Minazio, P. G., "FAST – Fabric Assurance by Simple Testing", International Journal of Clothing Science and Technology, Vol. 7, N°23, 1995, 43-48.
[23] Ramesh, M.C. The prediction of yarn tensile properties by using artificial neuron networks', J. Textile Inst., 86 (3), 1965, 459-469.
[24] Pynckels, F., Kiekens P. Use of neural nets to determine the spinnability of fibers', J. Textile Inst., 86 (3), 1995, 425-437.
[25] Cheng, L. and Adams D.L. Yarn strength prediction using neural network', Textile Research Journal, 65 (9), 1995, 465-500.
[26] Rolich, T., Šajatović A. H. and Pavlinić, D. Z. Application of artificial neural network (ANN) for prediction of fabrics' extensibility, Fibers and Polymers, September 2010, Volume 11, Issue 6, pp 917–923.
[27] Çay A., Vassiliadis S., Rangoussi M. & Tarakçıoğlu I. (2007). Prediction of the Air Permeability of Woven Fabrics using Neural Networks, Int. J. of Cloth. Sc. & Techn. Vol. 19, No 1, pp 18-35.
[28] Abou-Nassif , G. A. Predicting the Tensile and Air Permeability Properties of Woven Fabrics Using Artificial Neural Network and Linear Regression Models, J Textile Sci Eng 2015, 5:5 http://dx.doi.org/10.4172/2165-8064.1000209 Textile Science & Engineering
[29] Hui CL, Lau TW, Ng SF, Chan KCC (2004) Neural network prediction of human psychological perceptions of fabric hand. Text Res J 74: 375-383.
[30] Matsudaira M (2006) Fabric handle and its basic mechanical properties. J of Textile Engineering 52: 1-8.
[31] Kawabata, S. (1982), 'Developments of the objective measurement of fabric hand', Objective Evaluation of Apparel Fabrics, in Proc. First Australia-Japan Joint Symposium, Text. Mac. Soc. of Japan, 31-60.
[32] De Boos A. G. and D. H. Tester. The FAST Approach to Improved Fabric Performance, CSIRO, Division of Wool Technology, Australia, Textile Objective Measurement and Automation in Garment Manufacture, ed.

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