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# Rare Romanian Ethnographic Textiles—Reverse Engineering of Fabrics for Fashion Trends

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**Abstract:** (1) Investigating, collecting data with specific character, as well as registering and investigating data concerning ornaments and colors, patterns as expressive possibilities of designs of Romanian folk textile are important activities to do. The first goal of the research undertaken was to collect, preserve, and protect knowledge about old patterns and weaving techniques in selected regions of Romania, and the second to use old patterns for the modern needs of folk handicraft weaving and the clothing industry. (2) In the undertaken research, material was obtained from antique textiles, clothes, and paintings on canvas, from selected objects in the Maramureș region and Bihor region. The selection was made by the ReliefF method. The specimens of specification throw weight by the geometry method was used to characterize the types of weaving techniques. Principal component analysis methods were used to reduce the amount of data of the vector of textural features. (3) The research on selected Romanian textiles allowed for the construction of a model of texture features that describes them. The results include the specimens' measurements, analysis of fabric structures, yarn specification, and the reconstruction of the fabrics. Based on the obtained results, a simulation of fashion trends was performed. (4) The analysis of individual components increased the knowledge of weaving techniques in the studied regions and may be an inspiration for contemporary design in local and regional handicrafts as well as in the clothing industry.

**Keywords:** cultural heritage; fabric structure; fashion; heritage textiles; ReliefF method

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## 1. Introduction

Heritage textiles are an important part of many museum or personal collections throughout Europe; the preservation and capitalization of this delicate and fragile heritage being a priority for specialists and not only. Textiles, and more broadly the clothes made of them, are an important element in the assessment of regional and local tourist attractiveness in terms of regional cultural heritage, and in part of the traditional ones in terms of the utility culture of the regions, they still constitute their value in sectors of contemporary tourism such as agritourism [1,2] and cultural tourism.

The issue of sustainable development in many approaches occupies an important place in contemporary scientific research, which is also reflected in the relationship between sustainable development and research, protection, and preservation of cultural heritage [3–5]. Numerous case studies show the real links between cultural heritage and SDGs [6] and the discussion of political guidelines for heritage and development actors [7]. An important role in the relationship between sustainable development and cultural heritage is played by the regulation of forms of participation, the more so despite the wide support for the contribution of participation practices in heritage to a more inclusive and culturally sensitive local development in many different projects [8]. However, most of the research is still focused on the theory and architecture [9], landscape [10], or protection of cultural heritage, examples of traditional craftsmanship, important especially in developing countries [11]. The cultivation and development of these forms of craftsmanship is important for the preservation of heritage and is also an important factor of tourist attractiveness in the local dimension. Additional income generated by tourist traffic is an important element that reduces the level of local poverty and involves residents in economic processes [12].

Similar to the above-mentioned relations between the protection of cultural heritage and sustainable development, there is also the issue of preservation and non-invasive or micro-invasive diagnostic techniques and methods in the conservation of museum objects, based on the example of natural fiber fabrics. The implementation of SDGs in the field of textiles [13] is focused mainly on research on the use of natural raw materials [14] and on economic aspects, including textile recycling [15]. Bearing the above in mind, it should be noted that the undertaken research on ethnographic, rare Romanian fabrics, on the one hand, is part of the preservation of local and regional cultural heritage, and on the other hand, through the restoration and promotion of design, it provides information and tools for cultivating this rare fabric in modern handicraft times.

The added value of the work is also the inclusion of non-invasive research on textiles in a wide spectrum of not only technical analyses of textile materials, but also pointing to the importance of the research conducted for the preservation of cultural heritage thanks to better diagnosis of these textiles, which will enable the implementation of appropriate conservation processes. Through their maintenance, and thanks to the obtained results, it becomes possible to recreate old fabric decorations and restore both natural materials and old patterns to contemporary designers of utility fabrics. It is important because the contemporary fashion industry should take into account the SDGs [16] in its projects and implementations, both in terms of the use of ecological materials and the use of well-known, but often forgotten patterns. The postulated approach, the extensive use of natural materials and old, classic, regional designs may become an important factor in influencing the natural environment and shaping pro-ecological attitudes of consumers.

The aim of the research undertaken is to collect, preserve, and protect knowledge about old patterns and weaving techniques in selected regions of Romania. A utilitarian goal, thanks to the analyses carried out, it is possible to use the old design for the modern needs of creating new designs that can be successfully used in the modern clothing industry (and handicrafts). Due to the richness and diversity of the Romanian cultural heritage, the paper contributes to the documentation and promotion of the Romanian cultural values both at the European and the world level. Non-invasive investigation of several Romanian heritage objects was carried out.

Aged textiles are fragile and quite difficult to handle. The study proposes, by various methods, garments to be restored and stylized using traditional motifs and techniques; the ornamental materials are collected from the series of old Romanian ethnographic textile objects, which currently are stored and, respectively, exhibited either in personal collections or in ethnographic museums; one specimen is a fragment of a degraded canvas wall painting from the wall of a historical wooden church. Heritage textiles, e.g., holiday clothes, usual clothes, and interior decorations are complex in terms of component materials (they are made of natural fibers (protein or cellulose) such as cotton, linen, hemp, silk, etc.) and also from the point of view of the techniques used for their realization [17–23].

Textile materials with a high degree of wear or that are unused can be useful in creating new objects, restoring aged ones, or transposing traditional motifs onto new ones, in order to recycle through the principles of circular economy [24–30]. Complex interdisciplinary tools and strategies support the analysis and experimental research for heritage textiles; we mention in this regard modern techniques such as: X-ray, 3D and laser scans, infrared and UV, imaging analysis obtained by analyzing detailed images obtained through integrated microscopy (such as Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force microscopy (AFM), CytoViva (dark field microscopy)) [22,31–34] on textile historical and cultural objects, which open new paths to diagnosis, monitoring, protection, conservation, and promotion [35,36]. The digitization of the textile cultural heritage is a complex, multidimensional process that can include the reverse engineering component, which in addition to the problem of three-dimensional (3D) digitization of objects, digital content management, representation, and reproduction also provides complex and interdisciplinary documentation about the respective cultural material object [37–39].

The preservation and capitalization of this delicate and fragile heritage is a priority for specialists and the public. Due to the richness and diversity of the Romanian cultural heritage, the work contributes to the digitization and promotion of Romanian cultural values. A series of non-invasive investigations on several Romanian heritage textile objects was carried out.

## 2. Materials and Methods

### *2.1. Methods and Tools*

#### 2.1.1. Regression Model

The regression prediction model of the type Z = f (X, Y) was used to determine the extent to which textural features reduced to two main components can be used to predict which region of Romania a textile element is from. A polynomial source model of the second order is used, which consists of a dependent variable—specimen, and two independent variables—the first and second principal components. Insignificant coefficients from the model that have a p-level greater than the significance level $\alpha$ were removed. The model was estimated by: root mean square error (RMSE); sum of squired errors (SSE); critical Fischer coefficient (Fcr); coefficient of determination ($R^2$). Data were processed at a level of $\alpha = 0.05$.

#### 2.1.2. Software Tools

Matlab 2017b software system (The MathWorks Inc., Natick, MA, USA) was used to process the experimental data. Visualization of accessories and elements of fashion design was made. The tools of the online simulation Design Lab [40] were used for this purpose.

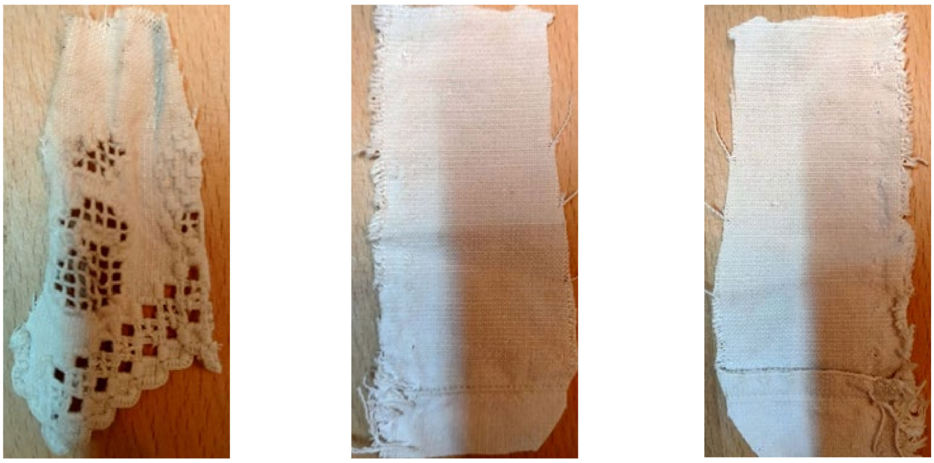
### *2.2. Materials*

Women's or men's shirts represent an important piece of Romanian folk costume. Textile objects, Specimen no. 1 (Section 2.2.1) and Specimen no. 2 (Section 2.2.2) represent the traditional shirt for females (called "ie") from the Maramureș region. The investigated heritage object, Specimen no. 3, is stored in an ethnographic museum the Beiuș area, Romania, and it is a men's shirt, about 80–100 years old, made of cotton cloth, made at home, by hand weaving war. Specimen no. 4 (Section 2.2.4) represents a traditional Romanian pillow ornament with motifs specific to the Beiuș area, Romania; Specimen no. 5 represents a painting degraded fragment on canvas, from a wall of a historical wooden church, the Boianu Mare, Romania, dating to the 1710s. Specimen no. 6 is another sample of fabric that also belongs to Specimen no. 2.

Fabric samples were investigated using the "GX microscope, UK model No. 111085", Department of Geology, Faculty of Science, Kaferelsheikh University, Egypt.

#### 2.2.1. Specimen 1

The Specimen no. 1 (Figure 1a–c) represents an aged women's shirt, Maramureș County, Romania (source: personal collection).



(**a**) (**b**) (**c**)

**Figure 1.** Specimen no. 1, aged women's shirt, Maramureș County, Romania (source: personal collection): (**a**) Handmade crouches; (**b**) Woven fabric of plain weave 1/1 face; (**c**) Woven fabric of plain weave 1/1 back.

Analyses of the fabric structure of Specimen no. 1 (Figures 1 and 2) by microscope tools. Details of microstructure photos of sprang with needle lace and loop braided lace at the bottom and the last seven rows approaching the center of the sprang worked by interlinking four warp threads of two pairs of sprang, as found with ties knotted and ties unknotted.

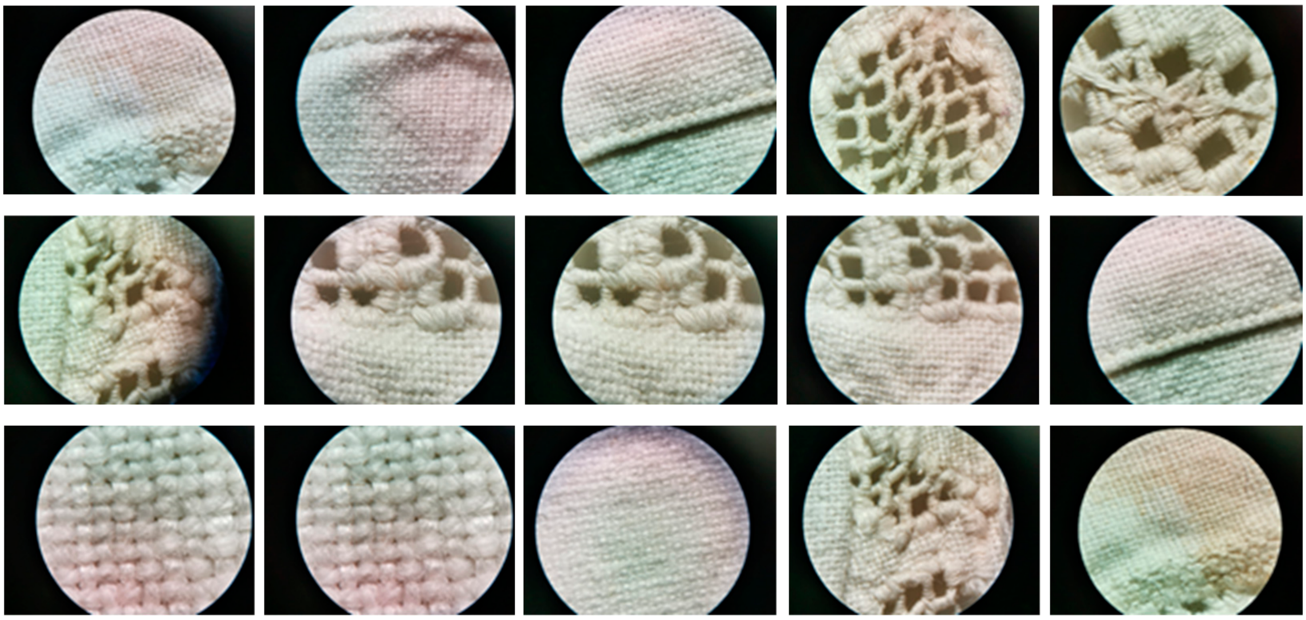


**Figure 2.** Microscope images, Specimen no. 1.

Textile fragment made of fabric with exquisite detail, made of white flax (Linen) cloth with a variety of decorative elements in flax (Linen) thread [41].

These decorative elements include needle lace and loop braids. Since the original function of this textile could not be determined with certainty by merely investigating the extant garment, analyses were attempted in order to produce a copy. Several flax (Linen) garments have been identified by Elnashar [42,43]. Some of these garments feature more than one type of decorative needlework or thread manipulation technique, including needle lace, finger loop braiding, and sprang, as shown in the results analysis of the specimens' specification throw weight by the geometry method by Elnashar [44,45]. There are three sprang fragments all made of undyed, z-spun, S-plied two-ply thread, with diameters ranging from 0.02991 cm to 0.0334 cm and featuring hole designs in patterns. The largest sprang piece is quite elaborate and is still attached to a plain-weave, undyed flax (Linen) fabric woven in z-spun threads with a fabric density of sixteen threads per centimeter (forty-one threads per inch). With a warp count of 41 threads per inch (= sixty loops), the sprang design is not entirely symmetrical.

2.2.2. Specimen 2

Represents an aged long women's shirt, Maramureș County, Romania (source: personal collection) (Figure 3a–c).

(**a**) (**b**) (**c**)

**Figure 3.** Specimen no. 2—long women's shirt, Maramureș County, Romania (source: personal collection): (**a**) Back; (**b**) Ornamental yellow tassel; (**c**) Face.

Analyses of fabric structure of Specimen no. 2 by microscope tools.

The lace and loop braid at the clothes' lace connecting the main section to the tie of lace. The analyses of construction for the reconstruction of the garment made using materials and methods that approximate those of a hundred years ago; only with the help of the construction was simulation trial wearing possible (Figure 4).

**Figure 4.** Detail microstructure pictures of needle lace, textile ethnographic object, no. 2, aged long women's shirt, Maramureș County, Romania.

Antique hand-woven natural flax "Linen" from Romania with a fabric density of sixteen threads per centimeter was used for the side panels and ties, and hand-spun plied flax (Linen) thread within thae range of the thread diameters of the extant clothes was used for the sewing thread, needle lace, and sprang. It is very easy to find tightly spun and plied commercial flax (Linen) thread with a spin/ply angle of 45° twill woven fabrics, so flax "Linen" thread was commissioned from a spinner, who spun the flax "Linen" on a spinning wheel and finished it by hand.

2.2.3. Specimen 3

Details of the ornament and fabric of the man's shirt, Beiuș area, Bihor County, Romania, aged 80–100 years (source: personal collection) (Figures 5a–c and 6).

(**a**) (**b**) (**c**)

**Figure 5.** Specimen no. 3—man's shirt, Beiuș area, Bihor County, Romania (source: personal collection). (**a**) Colored ornament lower part of the sleeve (face); (**b**) Sample back side; (**c**) Colored ornament lower part of the sleeve (back).

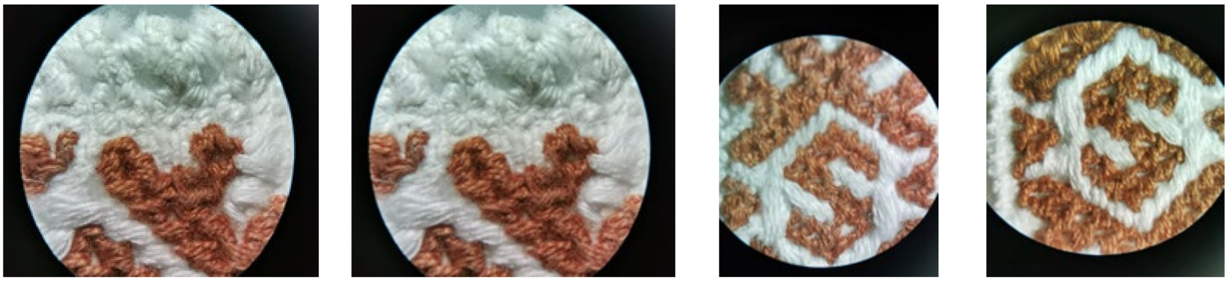


**Figure 6.** Details of the microstructure pictures of several fragments with loop-braided lace and needle lace on the edges from a range of garments. Specimen no. 3, man's shirt, Beiuș area, Bihor County, Romania (aged 80–100 years), personal collection.

Analyses of fabric structure of Specimen no. 3 by microscope tools.

The edging seems to be simply decorative in some cases, while providing grip and structure in others. The clothes edge is decorative, made along the neckline, and appears to serve no other purpose. The loop-braid and needle lace edges on two fragments thought to be supportive garments may have also provided necessary grip to hold them in place, and perhaps also kept them from rolling up along that edge. One garment of still undetermined use features a loop braided lace only; the pattern of the decorative edge in the lace probably served the same purpose.

### 2.2.4. Specimen 4

Pillow ornament, Beiuș ethnographic museum (100 years old), Bihor County, Romania (Figrues 7a,b and 8). Handmade tapestry woven fabric structures, from colors of red, white, and gray, were used as pillow ornament. The analysis of construction of the reconstruction of the garment was made using materials and methods that approximate those of a hundred years ago. Antique hand-woven natural flax "Linen" from Romania with a fabric density of sixteen threads per centimeter was used for warp and the number of weft per centimeter was 12, of flax (Linen), and hand-spun plied flax (Linen) thread within the range of the thread diameters of the extant clothes was used for the tapestry woven fabric structures. It is very easy to find tightly spun handmade tapestry woven fabric structures, plied commercial flax (Linen) thread with a spin/ply angle of 45° twill woven fabrics, so flax "Linen" thread was commissioned from a spinner, who spun the flax "Linen" on a spinning wheel and finished it by hand.

(**a**) (**b**)

**Figure 7.** Specimen no. 4, pillow ornament, Beiuș ethnographic museum, Romania (source: ethnographic museum). (**a**) Back; (**b**) Face.

**Figure 8.** Detail microstructure photos of the pillow ornament, Beiuș ethnographic museum, Romania.

Analyses of fabric structure of Specimen no. 4, by microscope tools.

2.2.5. Specimen 5

Canvas painting, Boianu Mare historic wooden church, Romania (Figures 9a,b and 10).

(**a**) (**b**)

**Figure 9.** Specimen no. 5, Canvas painting, Boianu Mare historic wooden church, Romania (source: Boianu Mare heritage wooden church). (**a**) Back; (**b**) Face.

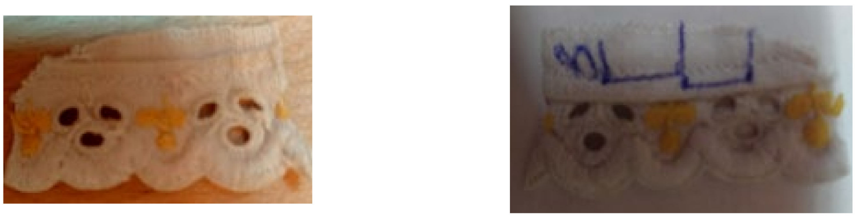
Canvas painting of woven fabric structures. The analysis of construction of the reconstruction of the garment was made using materials and methods that approximate those of a hundred years ago. Antique hand-woven natural flax "Linen" from Romania with a fabric density of twelve threads per centimeter was used for warp, and the number of weft per centimeter was 12 wefts of flax (Linen), and plied flax (Linen) thread within the range of the thread diameters of the extant clothes was used for the woven fabric structures—-plied commercial flax (Linen) thread with a spin/ply angle of 45° twill woven fabrics. Flax "Linen" thread was commissioned from a spinner, who spun the flax "Linen" on a spinning wheel and finished it by hand in Egypt.

Analyses of fabric structure of Specimen no. 5 by microscopic tools.

**Figure 10.** Detail microstructure photos of a narrow strip of sprang, possibly for the paneled canvas painting, Boianu Mare historic wooden church, Romania.

2.2.6. Specimen 6

Needle lace and/or loop-braided laces as edging, in extant textiles, kept them from rolling up along that edge. One garment of still undetermined use features a loop-braided lace only. The pattern of the decorative edge from the lace probably served the same purpose. The sample belongs to Specimen no. 2, aged long women's shirt, Maramureș County, Romania (source: personal collection) (Figures 11a,b and 12).



(**a**) (**b**)

**Figure 11.** Specimen 6—long women's shirt, Maramureș County, Romania (source: personal collection). (**a**) Back; (**b**) Face.

**Figure 12.** Details microstructure photos. The pattern has holes worked in five rows combined with holes of twice the length worked in seven rows of interlinking, the second sprang strip and pattern. Specimen no. 2, aged, long women's shirt, Maramureș County, Romania (personal collection).

Analyses of fabric structure of Specimen no. 6 by microscope tools.

With a non-stretched width of 3.2 cm (1.28 inch) and a preserved length of 10 cm (4.0 inches), it was made with a slightly finer plied thread of 0.5 mm in diameter. It too was worked in a hole pattern with forty-eight warp threads (=twenty-four loops), the holes arranged in the shape of a flower again worked in seven rows. The exact purpose of these two narrow sprang fabrics cannot be determined, but considering that the large sprang is part of a garment, and one of the two narrow sprang pieces was clearly sewn to a woven fabric, their stretchy properties could have been used to accommodate various sizes and quantities.

*2.3. Analysis of Fabric Structures Yarn Specification Reconstruction of Fabrics*

Some main parameters of the specimens are determined. They include the diameter of fiber, material weight, and full weight of the cloth. The diameter of fiber $d$ is defined as indicated in the following equation [Elnashar] [44,45]:

$$d = 4.44\sqrt{\frac{N_T}{D}} \quad (1)$$

where $N_T$ is Tex count; $D$—fiber density.

The weight $W$ of fiber, can be defined as [Elnashar] [44,45]:

$$W = \frac{\pi d^2}{4} L \cdot N_{WT} \quad (2)$$

where $d$ is cross section of fiber; $L$—length of fiber; $N_{WT}$—number of threads in 10 cm length of fiber.

The full weight $CW$ of cloth can be calculated as [Elnashar] [44,45]:

$$CW = \sum W_{cp} \quad (3)$$

where $W_{cp}$ are weights of cloth parts. For example, $W_{warp} + W_{weft} + W_{embroidery}$.

Fabric analysis is used to study the construction, properties, features, orientation, and dip of particles within a fabric. This analysis is implemented for: identification of face and back side of the fabrics; identification of warp and weft threads; fabric weight and yarn density; fabric structure. Fabric structure is analyzed using microscope.

Texture features. To describe the microscopic images of textile fabrics from the six specimens investigated, the textural characteristics presented in [46] were used. Those texture characteristics that are informative about the studied objects are selected. The selection was made by the ReliefF method [47]. As a result of the selection, a total of 13 textural features were obtained (Table 1). The selected texture characteristics are described in general terms with their formulas, where $\mu_x$, $\mu_y$, $\sigma_x$, $\sigma_y$—mean values and standard deviations of $p_x$ and $p_y$—function of the partial probability density; $_x$ and $_y$ are coordinates (rows and columns) of a common matrix; $p_x + y(i)$ is the probability of the joint matrix; HX, HY—entropy of $p_x$ and $p_y$.

**Table 1.** Textural features obtained as a result of the selection [46].

| | | | |
|---|---|---|---|
| $T_1 = \sum_i \sum_j (i-j)^2 p(i,j)$ | (4) | $T_2 = \sum_i \sum_j \left(i+j-\mu_x-\mu_y\right)^4 p(i,j)$ | (5) |
| $T_3 = \sum_i \sum_j \left(i+j-\mu_x-\mu_y\right)^3 p(i,j)$ | (6) | $T_4 = \sum_i \sum_j \lvert i-j \rvert p(i,j)$ | (7) |
| $T_5 = \sum_i \sum_j p(i,j)^2$ | (8) | $T_6 = -\sum_i \sum_j p(i,j) \log(p(i,j))$ | (9) |
| $T_7 = \sum_{i,j} \frac{p(i,j)}{1+\lvert i-j \rvert}$ | (10) | $T_8 = \sum_{i=2}^{2N_g} i p_{x+y}(i)$ | (11) |
| $T_9 = \sum_{i=2}^{2N_g} (i-T_3)^2 p_{x+y}(i)$ | (12) | $T_{10} = \sum_{i=0}^{N_g-1} i^2 p_{x-y}(i)$ | (13) |
| $T_{11} = \frac{HXY-HXY_1}{\max\{HX,HY\}}$ | (14) | $T_{12} = \sqrt{1-e^{-2(HXY2-HXY)}}$ | (15) |
| $T_{13} = \sum_i \sum_j p(i,j)^2$ | (16) | | |

Data reduction. The principal component analysis (PCA) methods were used to reduce the amount of data of the vector of textural features. The task of PCA is to divide the variables into uncorrelated orthogonal variables, in the form of linear combinations [34]. It has been experimentally found that two principal components are needed to reduce the amount of data in the feature vector.

## 3. Results and Discussion

### *3.1. Results from Specimens' Measurements*

The results from measurements of the main characteristics of specimens are presented in Table 2.

**Table 2.** Results of main measurements of specimens.

| Specimen | Fiber Density, g/cm$^3$ | $N_T$ | | Fabric | | | | | | | | Embroidery | | | | $CW$, g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $L$, cm | $NWT$ | $d$, cm | $W$, g | $CW$, g | $L$, cm | $NWT$ | $d$, cm | $N_T$ | $d$, cm | $L$, cm | $W$, g | |
| | | Warp | Weft | Warp | Weft | Warp | Weft | Warp | Weft | Warp | Warp + Weft | | | | | Warp + Weft + Embroidery |
| 1 | 1.3 | 59 | 59 | 10.8 | 10.8 | 160 | 160 | 0.029 | 0.029 | 1.21 | 2.43 | 6 | 0.029 | 16.7 | 0.7 | 3.13 |
| 2 | 1.3 | 59 | 59 | 10.8 | 10.8 | 160 | 160 | 0.029 | 0.029 | 1.21 | 2.43 | 6 | 0.029 | 16.8 | 0.7 | 3.17 |
| 3 | 1.3 | 59 | 59 | 10.8 | 10.8 | 160 | 160 | 0.029 | 0.029 | 1.21 | 2.43 | 6 | 0.029 | 16.8 | 0.8 | 3.17 |
| 4 | 1.3 | 74 | 74 | 10.8 | 11.4 | 160 | 120 | 0.033 | 0.033 | 1.51 | 2.71 | - | - | - | - | - |
| 5 | 1.3 | 74 | 74 | 10.8 | 11.4 | 160 | 120 | 0.033 | 0.033 | 1.2 | 2.71 | - | - | - | - | - |
| 6 | 1.3 | 59 | 59 | 10.8 | 10 | 160 | 160 | 0.029 | 0.029 | 1.21 | 2.43 | 65 | 0.029 | 10 | 0.04 | 3.17 |

### *3.2. Results from Analysis of Fabric Structures*

The term textiles as fabric structures are applied to all products that result from interlacing threads made from different fibers, mainly to woven fabrics, but also to other structures obtained by weaving, braiding, looping, knitting, lace making, netting, chenille yarns and chenille woven fabrics, sometimes composite structures, or nonwoven fabrics. It also includes twines, cords, tassel, ropes, and materials such as nonwoven, obtained by a process other than spinning.

Fabric structures of Specimens no. 1, no. 2, no. 3, no. 5, and no. 6: the structure is 1/1 plain woven fabric structure 1/1.

Fabric structure of Specimen no. 4, the pillow ornament in the ethnographic museum in Beiuș, Romania: the specific structure of this specimen was analyzed. Figure 13b shows the structure of the specimen.

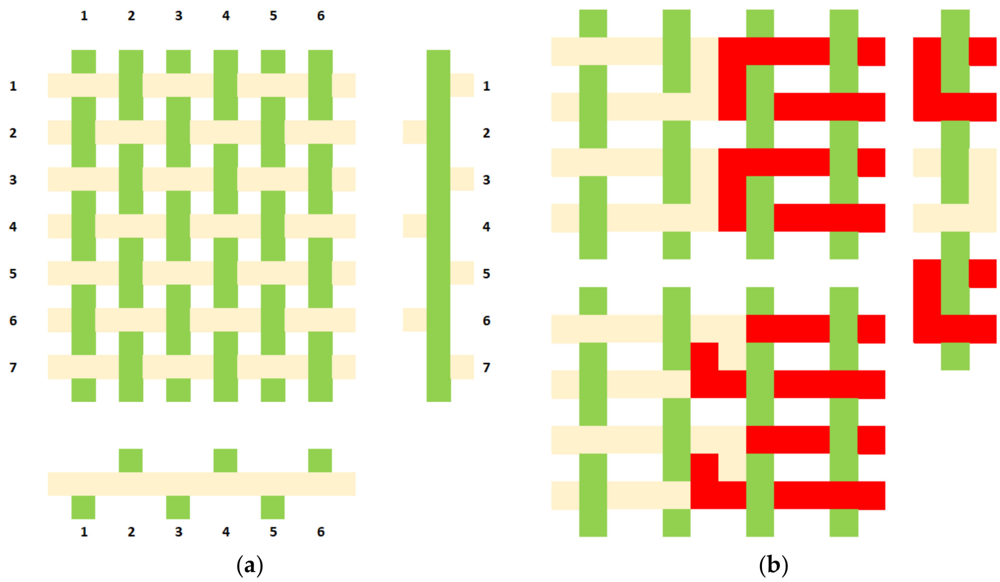



**Figure 13.** Tapestry woven fabrics structures: (**a**) Specimens 1, 2, 3, 5, 6; (**b**) Specimen 4.

### *3.3. Results from Yarn Specification*

The results for yarn specifications are presented in Table 3. Flax (Linen) is presented in English count: 300 yd lengths per lb.

**Table 3.** Results of main measurements of specimens.

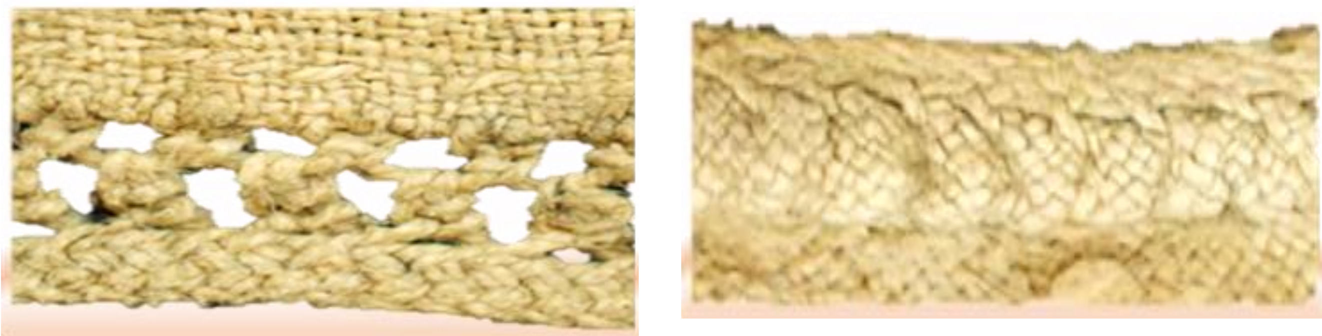
| Specimen | Material Types of Yarns | | | Count of Yarns | | | Yarn Density, g/cm$^3$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Warp | Weft | Embroidery | Warp | Warp | Weft | Warp | Weft | Embroidery |
| 1 | Flax (Linen) | Flax (Linen) | Flax (Linen) | 20/2E (59 Tex) | 20/22E (59 Tex) | 20/22E (59 Tex) | 14 | 14 | 9 |
| 2 | Flax (Linen) | Flax (Linen) | Flax (Linen) | 2E (59 Tex) | 2E (59 Tex) | 2E (59 Tex) | 16 | 16 | 6 |
| 3 | Flax (Linen) | Flax (Linen) | Flax (Linen) | (59 Tex) | (59 Tex) | (59 Tex) | 16 | 16 | - |
| 4 | Flax (Linen) | Flax (Linen) | Flax (Linen) | 16/2E (73.75) | 16/22E (73.75) | - | 16 | 12 | - |
| 5 | Flax (Linen) | Flax (Linen) | Flax (Linen) | 16/2E (73.75) | 16/22E (73.75) | - | 12 | 12 | - |
| 6 | Flax (Linen) | Flax (Linen) | Flax (Linen) | 16/2E (73.75) | 16/22E (73.75) | - | 12 | 12 | - |

The sprang and the warp threads made the pattern slightly off-set, so that the design is not centered. Decorative sprang, needle lace, and finger loop braids figures consist of four pieces of plain-weave natural flax “Linen”. The main side sections measure approximately 3 cm, “1.2 inches”, long, with the width tapering from 5 cm, “2.0 inches”, at the widest point near the mid-crown to 7.5 cm, “2.9 inches”, wide at the point connecting to the ties. One of the panels is ripped away nearest the needle lace, 3.5 cm, “1.37 inches”, from the fabric edge. These panels are connected with a large central section of patterned sprang, also in natural flax “Linen”, measuring 3 cm, “1.6 inches”, in length, which makes up the center panel of the clothes and creates an attractive effect. The sprang pattern resembles a tree of “s” model “pattern”, repeated one and a half times. The last seven rows approaching the center were worked by interlinking four warp threads (two pairs), where the sprang was cut and sewn with rough stitches to prevent unravelling, thus narrowing the fabric towards the back of the garment form. An almost identical tree of “s” model is embroidered in drawn thread work using blue and white flax “Linen” thread on an Antependium. The ties, which were still together when the garment was connected to the main cloth of the two different needle lace patterns, form both the main piece and the ties using the selvedges of the fabric, from the selvedge to which the needle lace is sewn to the torn and narrow ends, with a width of 5 and 6.35 cm, “2 and 2.5 inches”. A simple decorative loop braid.

### *3.4. Results from the Reconstruction of the Fabrics*

A construction of the garment form was made using materials and methods that approximate those of the fifteenth century. Only with the help of the reconstruction that made trial wearing possible, could the original use be determined as clothes. Antique hand-woven natural flax “Linen” from Romania with a fabric density of seventeen threads per centimeter, forty-three threads per inch, was used for the side panels and ties, and hand-spun plied flax “Linen” thread within the range of the thread diameters of the extant clothes was used for the sewing thread, needle lace, and sprang. It is very easy to find tightly spun and plied commercial flax “Linen” thread with a spin/ply angle of 45° twill woven fabrics, so a woven fabric of flax “Linen” thread was commissioned from a spinner, who spun the flax “Linen” on a spinning wheel.

The raw edges of the fabric were turned under twice to the inside of the fabric, and sewn using stitches to the narrow hem. The needle lace between the main body of the headwear and the ties pattern was created by the stitches along the main headpiece and working them from left to right back and forth, turning the piece over for each row and in order to keep the stitches uniform in the direction of the warp threads, the lace on each was whip stitched to the ties. The needle lace along the face edge of the pattern was a simple one-row pattern worked right to left and whip stitched to an almost flat five-loop loop braid, which in cross-section has one rounded face and one flat face. The form of pattern for the braid is called a broad lace of five loops, and it is a quite simple and quickly made braid. Six threads of needle lace and/or loop-braided lace edging on other garments use loop-braided lace and needle lace on the edges, such as on supportive garments. The edging seems to be simply decorative in some cases, while providing grip and structure in others. The clothes' edge form is decorative, made long, and appears to serve other purposes. The loop-braid and needle lace edges on two fragments thought to be supportive garments may have also provided necessary grip to hold them in place, and perhaps also kept them from rolling up along that edge. The clothes of still undetermined use feature a loop braided lace only (Figure 14a,b).



(**a**) (**b**)

**Figure 14.** Tapestry woven fabrics structures: (**a**) Specimens 1, 2, 3, 5, 6; (**b**) Specimen.

The embroidery pattern resembles a tree of "s" model "pattern", repeated one and a half times. The last six rows approaching the center were worked by interlinking four warp threads of two pairs, where the sprang was cut and sewn with rough stitches to prevent unravelling, thus narrowing the fabric towards the back of the clothes and forming an almost identical tree of "s" model embroidered in drawn thread work using blue and white flax "Linen" thread on an Antependium. The form of ties, which were still knotted together when the clothes were connected to the main part of the clothes in two different needle lace patterns, with both the main piece and the ties using the selvedges of the woven fabrics from the selvedge to which the needle lace is sewn to the torn and narrow ends, with a width of 4 to 6.35 cm. A simple decorative loop braid and needle lace form is added to the edge of the main panels. The somewhat mysterious placement of needle lace sewn to the selvedges of the fabric between the main part of the clothes and the ties may indicate a limited fabric width simply to add more decorative elements.

*3.5. Analysis of Texture Features*

Table 4 shows the mean values and standard deviations of the textural features used in this work. As can be seen from the table, after only informative features have been used, they have minimal overlap of their values.

**Table 4.** Results of main measurements of specimens.

| Specimen Texture Feature | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| T1 | 1.37 ± 0.11 | 1.51 ± 0.13 | 1.4 ± 0.19 | 1.04 ± 0.14 | 1.65 ± 0.31 | 1.3 ± 0.18 |
| T2 | 921.33 ± 78.41 | 686.9 ± 156.99 | 682.47 ± 52.66 | 471.38 ± 72.07 | 528.42 ± 128.99 | 753.86 ± 128.54 |
| T3 | 73.15 ± 11.05 | 52.51 ± 17.56 | 7.46 ± 11.67 | 19.09 ± 10.37 | 7.68 ± 30.6 | 52.74 ± 9.1 |
| T4 | 0.59 ± 0.06 | 0.63 ± 0.05 | 0.69 ± 0.08 | 0.56 ± 0.05 | 0.77 ± 0.08 | 0.55 ± 0.05 |
| T5 | 0.13 ± 0.02 | 0.11 ± 0.01 | 0.08 ± 0.01 | 0.12 ± 0.02 | 0.1 ± 0.01 | 0.13 ± 0.01 |
| T6 | 2.6 ± 0.15 | 2.69 ± 0.08 | 3.11 ± 0.1 | 2.79 ± 0.1 | 3.01 ± 0.1 | 2.67 ± 0.12 |
| T7 | 0.78 ± 0.02 | 0.77 ± 0.03 | 0.74 ± 0.03 | 0.78 ± 0.02 | 0.72 ± 0.02 | 0.8 ± 0.01 |
| T8 | 9.43 ± 0.26 | 9 ± 0.49 | 8.24 ± 0.12 | 6.88 ± 0.37 | 7.54 ± 1 | 8.9 ± 0.35 |
| T9 | 76.49 ± 4.7 | 65.62 ± 7.2 | 53.29 ± 1.81 | 35.06 ± 3.58 | 44.07 ± 12.39 | 66.49 ± 6.16 |
| T10 | 1.37 ± 0.11 | 1.51 ± 0.13 | 1.4 ± 0.19 | 1.04 ± 0.14 | 1.65 ± 0.31 | 1.3 ± 0.18 |
| T11 | 0.38 ± 0.03 | 0.36 ± 0.06 | 0.39 ± 0.03 | 0.41 ± 0.02 | 0.33 ± 0.04 | 0.42 ± 0.02 |
| T12 | 0.84 ± 0.02 | 0.83 ± 0.04 | 0.88 ± 0.01 | 0.88 ± 0.01 | 0.83 ± 0.03 | 0.87 ± 0.01 |
| T13 | 0.98 ± 0 | 0.98 ± 0 | 0.98 ± 0 | 0.99 ± 0 | 0.98 ± 0 | 0.98 ± 0 |

After reducing the vector from textural features to two principal components, a regression prediction model of the type *S* = f (PC1, PC2) was created. After removing the insignificant coefficients, F (3,32) = 163.38 is greater than Fcr (3,32) = 2.9. A high value of the coefficient of determination (R2 = 0.93) and low values of the errors SSE = 0.74 and RMSE = 0.44 were obtained. This shows that the model describes the experimental data with sufficient accuracy. The resulting model has the form:

$$S = -2.17 + 32.04PC_1 + 17.47{PC_1}^2 + 5.03PC_1PC_2 \quad (17)$$

Figure 15 presents in general form the model describing the relationship between the region of Romania and the first two principal components of the vector of textural features. The "x" indicates the first principal component. The "y" indicates the second principal component. The two principal components are the independent variables in this model. The dependent variable "Specimen" is marked with "z". An analysis of the residuals and their location around a normal line and from a normal probability graph was made. According to this criterion, the requirements of the regression analysis are met.

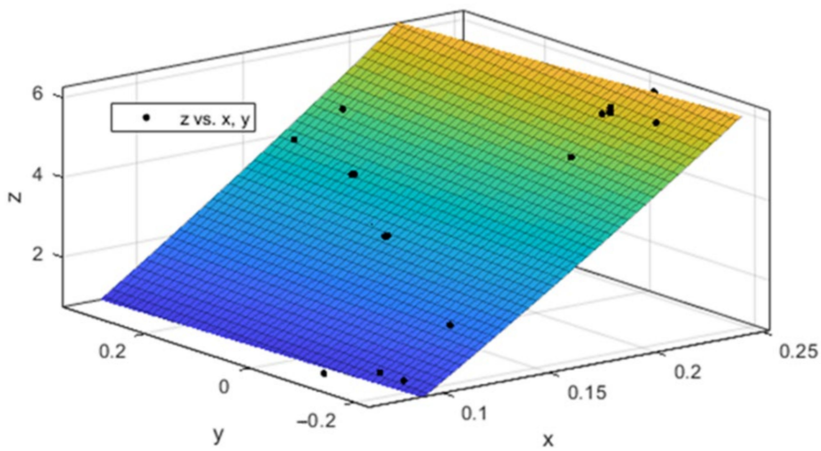



**Figure 15.** Model of the type *S* = f (PC1, PC2)—general view.

### *3.6. Simulation in Fashion Trends*

In creating the clothing models, Pantone® colors for 2022 were used. Colors similar to those of the original folklore elements were selected. The Flare dress model is simulated by a fine smooth fabric. It is in a U-shaped inverted silhouette. A stylized element of Specimen no. 6 is used to decorate the bust and neck. The yellow belt is decorated with an element of Specimen no. 3. At the bottom the band is also yellow, with the addition of a two-tone element of Specimen no. 4. The Bodycon dress model is in an X- figurative silhouette. The pattern is simulated on micro-knitted fine-smooth fabric. Strips with a Specimen no. 3 element are lowered from the shoulders to the center of the belt. The belt itself is decorated with repeating Specimen no. 6 elements. At the bottom, a Specimen no. 3 element is used again, but this time with a half-drop repeat. The last model is a yoga legging. It is simulated on a stretchy fabric, which would practically provide freedom of movement and comfort. The waist has a high strap, which improves flexibility. The elements with which the leggings are decorated are from Specimens no 3, no 4, and no 6. They are placed on squares with different backgrounds.

## 4. Conclusions

The yarn analysis made it possible to determine the characteristic parameters of the weft and warp, the number, density, and texture features of the yarn. Measurements of the samples allow for the identification of slight differences in the weft and warp of the tested fabrics. The differences result from the variety of analyzed fabric samples and are of a natural character related to their production, confirming their individual character. The structure of the fabrics indicates the use of two types of weaves. Plain weave (Figure 13a) was used in the fabrics sample 1, 2 and 4, 5 and 6, while for the weave in sample 4, taken from a pillow ornament, a more complicated weaving technique was used (Figure 13b). The fabric density is defined by the number of weft and warp intersections per unit area, which means that the higher the density, the higher the basis weight of the fabric [48]. However, in addition to the number of strands, the weight is also influenced by the thickness of the yarn. Therefore, with the tested samples (1, 2), it is clearly visible (Table 2) that with a similar number of threads in the embroidery, thinner yarn was used than in the fabric.

Interesting results were obtained thanks to the reconstruction of the textiles.

The works performed with the use of natural linen, a material typical of the 15th century, allowed for the reconstruction of the fabric and confirmation of its utilitarian purpose—-a women's shirt decorated with lace and braids (Figure 1). The embroidery made resembles a tree pattern, and the applied pattern was repeated one and a half times on the fabric. An additional decorative loop braid with needle lace added to the upper edges increases its decorative value.

Taking into account only two main components (Table 4), the created model shows a high value of the coefficient of determination (R2 = 0.93) with a low value of errors, which means that the created model describes the experimental data with sufficient accuracy. The simulation of fashion trends allowed emphasizing the utilitarian nature of the research undertaken. The models created (Figure 16) show possible ways of using colors, patterns, including repeated traditional elements typical of the Romanian regions of Maramureș and Bihor. They are used in two types of dresses, but it is also possible to use recurved motifs in other types of clothing, such as in the example of yoga leggings.

The undertaken research made it possible to achieve the goals set in the work. The obtained results broaden the knowledge of ancient weaving techniques and the structure of materials produced in Romania. The methods of statistical analysis used in the work allow for a new methodological approach to the studied issue and for the construction of a mathematical model that describes the experimental data with sufficient accuracy.

The interdisciplinary work contributed through analytical and experimental research of cultural objects, to the sustainable preservation and conservations of cultural heritage [35] and emphasizes, thus, the benefits for sustainable development. Heritage conservation and the sustainable development goals (SDGs) maximize the impact on a global scale and contribute to the mitigation of the cultural impact on globalization [49–52].

(a) (b) (c)

**Figure 16.** Contemporary clothes using Romanian folk motifs: (**a**) Flare dress; (**b**) Bodycon dress; (**c**) yoga leggings.

However, the undertaken research has a number of limitations, the first of which is the choice of materials, limited to two regions, for the analyzed material. Another is the sheer number of samples, sufficient to try to build a model of texture features, as well as describe techniques and material structure. It is similar to the indication of new patterns and patterns decorated for the needs of the textile industry or handicrafts. However, it is far from being sufficient to fully describe ancient Romanian textiles.

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