ETHNIC DESIGNER COMPONENT OF CLOTHES' DECORATION TECHNIQUES USING EMBROIDERY

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Abstract: *The problem of incorporating the embroidery of ethno designer's clothing into the technology of decorating clothes is investigated. The technique of adaptation of the sign system of ornaments to the technological support of machine embroidery is developed taking into account the concept of regional differences in the national costume of Podillya. The mechanism of scaling the size of the report of the cross-member element in accordance with the characteristics of the canvas groups is investigated. A project-design of ribbon ornament compositions on the details of Podillya shirts and modern women's costume using the "Inkscape" program has been developed. It was established that the construction of a geometric ornament according to the laws of symmetry provides technical conditions for the creation and testing of the quality of the embroidery ornament in accordance with the contours of parts of garments in graphic editor of Draw Ltd.*

Keywords: *embroidery technology, ethno design, canvas, ornament report, cruciform element, scaling, embroidery machine, mosaic graph, program editor.*

1 INTRODUCTION

The Ukrainian national costume is a phenomenal thing both for beauty and for bright colors, according to the harmony of forms, regional variety and variety of embroidery ornaments.

The use of the principle of "well forgotten old" as a retro-fashion, national costume does not justify the innovation expectations in the way of design. This is due to the lack of reliability of group preferences of consumers for anthropological reasons, the lack of substantiation of segmentation of the embroidery decoration with the shape of the product, the use of archaic approaches to the time-styling of elements of the national costume to popularize the cultural heritage.

The harmony of the national costume is based on the canonical conception of the ethnic image of a person, which was selected by different generations to create a unique thing. The concept of ethno design requires radical changes in engineering design of modern clothes on the basis of spirituality of the Ukrainian people. Taking this into account, the integration of the heritage of the national costume in the development of the ethno design component by adapting the sign system of ornaments to the morphological structure of embroidery according to the gender-age function in the clothes design is becoming a crucial issue.

2 DISCUSSINS IDEAS

The key information about the rules of behavior of the ethnic group contains not only the conditions and scheme of movements, but also the description of the sign system of the chain of associations of aesthetic quality of the national costume. In particular, it is a form, a line, a color and an ornament [1]. Embroidery in clothing has become a powerful means of self-identification of the people and an integral part of their spiritual life.

The formation and development of the ethnic function of the garment as a piece of clothing and ritual in the evolution of the national costume contains the concept of regional differences in cut, color, decoration, methods of combining and wearing individual elements of clothing [2, 3].

The effectiveness of decorating with embroidery determines the technological support for making the ornaments. An analysis of the technique for embroidery has shown that there is a sufficient variety of perfect embroidery equipment that can be used in the manufacture of sewing products created in folk traditions. Changing of consumer needs and techniques for decoration requires continuous improvement of software. Modern software for decorating clothes with embroidery are developing in parallel with the change of technology. There are many programs for embroidery: Wilcom, Embird, XStitch, Craft Grid, Cross Magic, Pana Vue Image Assembler, PC Stitch, PM Stitch Creator, WIN-Stitch [4, 5]. However, most of them are highly specialized.

None of the modern programs contains a catalog of Ukrainian national ornaments.

The main areas of software development are the creation of programs for managing the embroidery machine (PCMM), which can be

divided into: internal, which are intended for the organization of the equipment and its components; external, which control the process of embroidery decoration. The development of internal PCMs (firmware) is carried out by enterprises manufacturing embroidery machines [6].

Modern software editors for automated filling of arbitrary sections of cross-shaped elements (CSE) lead to the formation of uneven hegemony, which have several unnecessary stitches formed as a result of the transition from one stitch to another. Such CSE impair the quality of embroidery. In connection with this, there is a need for research on filling the embroidery ornament with only even cross-shaped elements.

3 METHODS

The ethno-design component is based on the synthesis of ethnic, archaic, authentic material and modern academic and non-academic forms of culture. It is an effective means of surviving national culture in modern conditions and a basis for a dialogue of modern cultures [7]. The level structure of the authenticity of the sign system of composite means, based on the example of the national costume of Podillya (Figure 1), forms four main components in the first level, among which the component 4M is chosen for researches, and two additional, in particular, technological aspects are considered in 2A.

The choice of composition of clothing ornamentation depends on the technique of decoration and the material type. The network is used as a way of connecting parts with each other. The "bottom" technique provides the product with saturation, so the composition of such products is always easier. Using the "cross" technique, the ornament became more complex and versatile compared to the "bottom", and the technique "flattening" - is the summit of any composite solutions. That is, the composition of the garment is an entire system that combines all the structural and decorative elements of the product. As the technique of "cross" is most often used in Podillia [8, 9], it is chosen for further study of the concept of sign symbols in the design of a modern wardrobe.

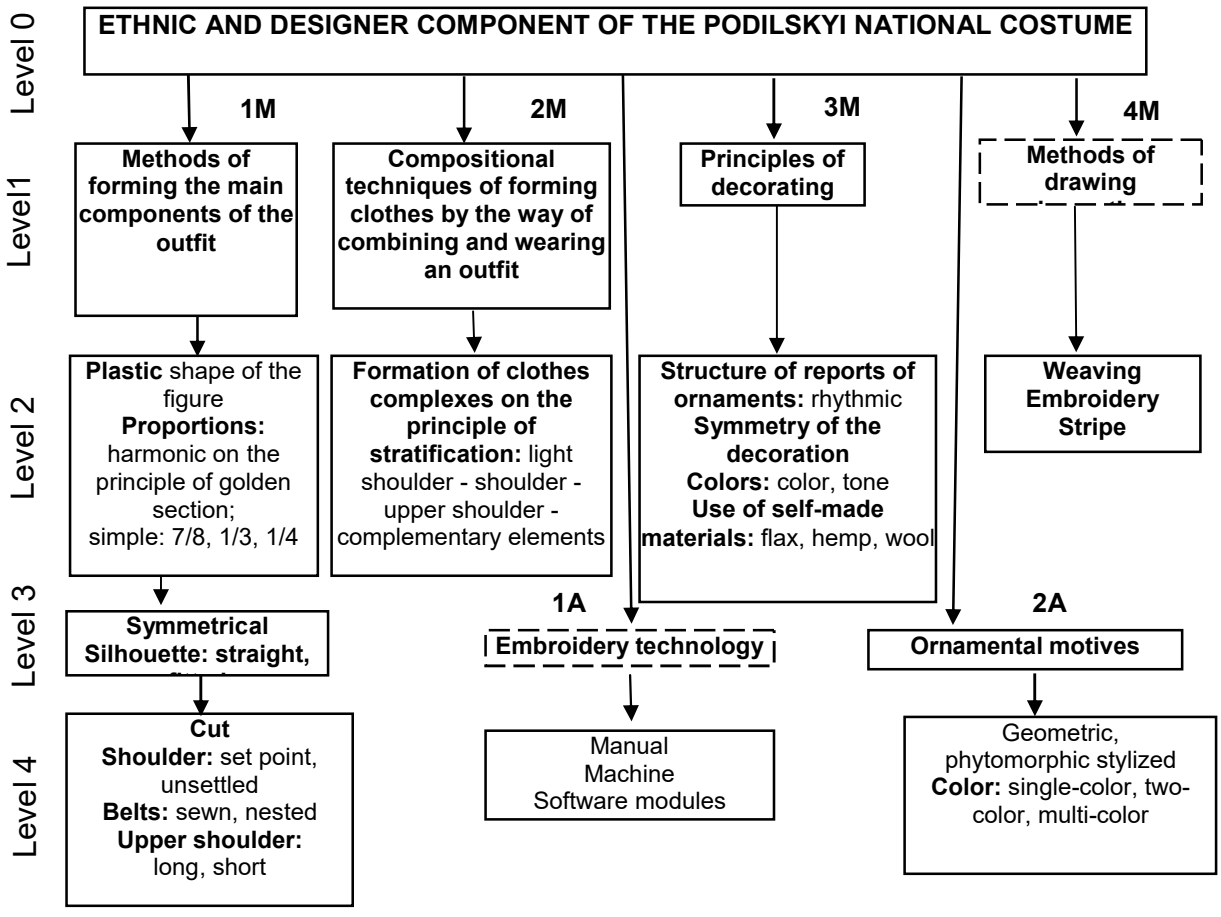

Figure 1 Scheme of ethnic and design component of the national costume of Podillya: M - the main components; A - additional components

According to the purpose, materials for embroidery are divided into two types: 1) the basis on which embroidery is performed - a fabric or a canvas; 2) the embroidered material - threads, ribbons, cords, beads, etc. [9]. The modern textile industry produces fabrics specially designed for cross-stitch embroidery. The criteria by which fabrics are classified into one or another group are the composition of the material, the method by which the fabric is woven, as well as its use [10]. As the main fabrics for making clothes with embroidery, the ones made of fibers of natural origin are usually chosen. These are hemp, linen, silk and woollen fabrics. Especially technologically qualitative materials are considered to be natural fabrics of factory production: cotton, percale, colophon, batiste, china, muslin and silk. Do not overlook the home-made fabric (Table 1).

Those of these fabrics, which have a clearly defined fabric of linen weave, are used as a basis for embroidery. On fabrics with a very small weave structure or poorly traced, the embroidery is performed on a temporary canvas or on a water-soluble net. Or they perform the embroidery on a permanent canvas with a clearly distinguished weave of the required density, which then tune in to parts of the details. Threads take the dominant place among the embroidered materials. They come in color, quality and thickness. Threads that have different composition and structure are used for embroidery on fabric and on canvas. As for composition, they are divided into three groups: 1) natural - linen, silk, wool, cotton, hemp; 2) artificial - staple, viscose; 3) synthetic - fervor, linen fabric, metal, gold and silver [11].

By structure all threads are divided into 2 groups – divisible and indivisible. Divisible threads can be separated into several threads and can be used as one at a time or in a combination with other threads to make them thinner or thicker. Indivisible are those which are not divided by structure. To increase the bulk you can use several folded threads of the different length (Table 2).

The most popular manufacturers of embroidery threads are DMC (France), Anchor and Madeira (Germany), Ariadna (Poland), Belka (China) and Gamma (Russia).

Manufacturers of threads for embroidery develop a variety of palettes, which have more than 1000 shades of colors. Each color has its name and its shades are indicated by the corresponding numbers (Table 3).

Table 1 Classification of fabrics used for the manufacture of embroidered products

№	Raw material composition	Names of fabrics
	Natural fabrics	
1	flaxseed	Marquisist, Batista, Homespun, Plain-Dyed
2	Hemp	Homespun harsh, acid, semi-white, and plain-colored
3	Cotton	Chittish, beard, madapolam, various types of canvas, velvet, lamuth, percale, batiste, reps, satin, marquis, mittal, muslin
4	Silk	Atlas, Repts, Crepesatin, Toal, Crepesine, Georgette
	Artificial, synthetic and mixed fabrics	
5	Artificial	Staple, acetate fiber, krepedeshin, krepsatin, lizeta
6	Synthetic	Twist, lavsan (terlene, dactron, tergale, tetheron), nitron, kapron, casmillon, silon
7	Mixed	Flax with lavsan, wool with lavsan

Table 2 Characteristics of threads for embroidery

№	Raw material composition	Characteristics of the main features
1	Cotton	In the rush or twisted, muline, crunchy, iris, flask
2	Cotton and paper	Muline, bleached and non-bleached threads of different thicknesses
3	Silk	Aartificial silk, natural twisted or in a single thread of the most diverse colors from bright to light - pastel shades, as well as silk muline
4	Linen	non-bleached, thin and rough torsion or in the ridge
5	Stained	Embroidery threads in big coats or on bobbins of different shades
6	Viscose	Embroidery viscose of different thickness, twisted in coils or on bobbins
7	Woolen	Volatile, gas, twisted wool, wool in one thread or in a band
8	Mixed and synthetic fibers	Acrylic, semi-cotton, braid, soutiques, lurex, metallized
9	metallic	Spools, tinsel plated, golden and silver cord, spruce, spiced

Table 3 The numbering of the main colors used for the manufacture of nationally-designed clothing

Color's name	The company-producer of threads			
	Gamma	DMC	Anchor	Madeira
	Numbers of color shades			
black	0420	310	403	black
red	0012	600-606	31-46	206-210
yellow	3192, 0042	307	289-298	103-114
green	0209, 0210, 0319	702-703	226-238	1306, 1307
orange	3195, 3196	721-740	303-316	201, 202
blue	0082, 0308	791-798	131-178	904-912
sky-blue	3121, 0023, 0304	996	130, 1090	1103, 0907
burgundy	0062, 0708, 3211	347-356	1014-1025	401-407
dark brown	0217-0219	300-304	351-359	2602, 2005
light brown	0054	437	360-364	2011, 2012
dark green	3158, 0212, 0213	518	923	2704
orange-red	0044	946	332	207
grey	3179, 0917	611-613	831, 898	1902, 1903

The development of engineering and technology makes it possible for the sewing industry to use a high-speed personal computer, which greatly enhances the possibility of mass production of clothing with embroidery. In most cases, the bearers of information are CDs or DVDs distributed by embroidery machines manufacturers that contain patterns with embroidery patterns [12]. The main characteristics of industrial embroidery machines include: the rate of execution of decorating with embroidery; number of heads; number of needles (heads); size of the working area or maximum size of the shoulder; the memory of the machine and the information carrier (Table 4).

Table 4 The main characteristics of industrial embroidery machines

The name of the characteristics of industrial embroidery machines		Range of variation
The speed of embroidery making [st/min]		1200-1400
Number of working heads [unit]		1-24
Hoop	flat [mm]	Hoop
	cylindrical [mm]	
Number of needles [unit]		1-12
Information carrier [kilobite]		256-800

In existing software editors, there are two ways to create CE (Figure 2).

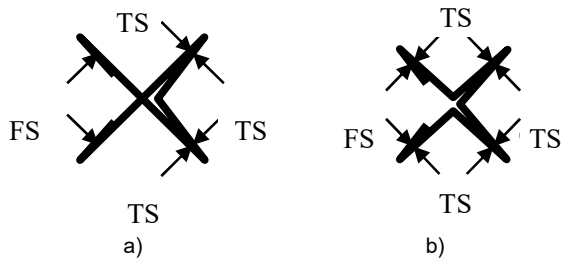

Figure 2 Schemes of existing methods of machine embroidery of CE, stitches: a) of different lengths; b) of the same length

In the first method of embroidery, fastening stitches (FS), which length is twice the size of the transition stitches (TS), and in the second - the length of the FSs and the TSs is the same FS=TS. However, it is evident that in both ways there is TS for another FS, which cannot be avoided, even in simple patterns of embroidery ornamentation. That is, regardless of the methods of formation, existing cruciform element (CEs) are uneven. Especially it is visible on the diagonal with CEs, formed by stitches of different lengths (Figure 3).

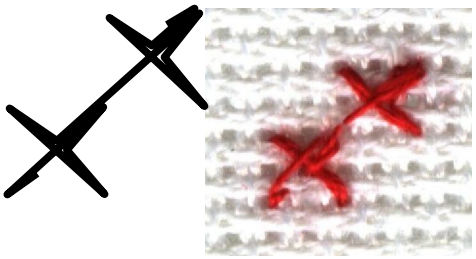

Figure 3 Scheme of existing CEs, arranged diagonally and formed by stitches of different lengths

This leads to deterioration in the appearance of the embroidery. The number of TSs depends on the complexity of the shape of the element of the ornament, the place of the beginning and the end of the embroidery. Existing software modules for editors for embroidery machines use an algorithm for forming FSs that leads to a chaotic formation of the TSs during the embroidery process. A new way to fill the embroidery ornaments with double cruciform elements (DCEs) allows embroidering any form of ornaments without the formation of TSs, since the transition and consolidation are carried out at the expense of the stitches included in the DCEs (Figure 4) [13].

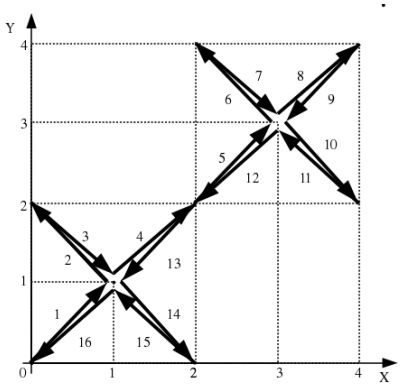

Figure 4 Diagram of DCEs arranged diagonally

Each of the stitches is marked with a serial number, which increases with the performance of several DCEs. The beginning and the end of the system of two DCEs coincide.

4 EXPERIMENTAL

The technology of manual embroidery takes into account the selection of rational parameters of the ornament according to the parameters of density. The mechanism of using a grid in machine embroidery is based on the principle of scaling the dimensions of CE canvas.

The development of a method for selecting rational parameters of the canvas density relative to the parameters of the ornament consists of selecting such density, which allows getting a multiple number of repetitions of a report on a given area of decoration. For this purpose, the size of the design part to be decorated is compared with the size of the ornament that is applied to it. The parameters of the ornament are calculated based on the amount of CEs, which are contained in the given decorating area with the selected canvas type and the size of the CEs, which are planned to be embroidered.

The 15 samples (Table 5) were selected for research on modern types of canvas, for each of them the density (number of CEs per 10 cm of canvas) was determined according to the base and the abb (Table 6). For each sample of the canvas, *lx* is calculated, which is the value of the base (minimum) of CE, which takes one cell on a warp and one cell in a weft. Accordingly, the number of basic CEs in 10 cm canvas corresponds to its density. The range of variation of this indicator is divided into three groups:

small (30-35 CEs per 10 cm) with l_x = 0.10-0.19 cm;

medium (40-60 CEs) with l_x = 0.20-0.29 cm;

high (60-100 CE) with l_x = 0.30-0.35 cm.

Table 5 Photographical pictures of modern types of canvas

№ of a canvas	№1	№2	№3	№4	№5
general look					
№ of a canvas	№6	№7	№8	№9	№10
general look					
№ of a canvas	№11	№12	№13	№14	№15
general look					

Table 6 Characteristics of groups of canvas according to linear density of basic CEs

№ of canvas sample	**name of canvas**	**density of canvas**	**The number of basic CEs per 10 cm canvas**		**measurement of a basic CE *lx* [cm]**	
			on the base	**on the abb**	**on the base**	**on the abb**
3	Hardanger	high	90	87	0.11	0.10
13	Davosa 18		61	65	0.17	0.14
4	Davosa 22		70	68	0.15	0.15
6	Stramin		85	40	0.15	0.23
2, 11	Aida 16		61	60	0.17	0.17
1, 15	Aida 14	medium	53	54	0.20	0.2
7	Floba 14		56	52	0.21	0.2
10, 14	Aida 11		52	43	0.20	0.24
5, 8	Hardanger	small	46	46	0.25	0.25
9	Aida 8		35	36	0.32	0.32
12	Vienna		40	38	0.33	0.32

The basic dimensions of CEs are output (minimum) for a certain type of canvas and can be increased both in warp and in the weft, but no more than to a size of 0.30 cm, as recommended for embroidery [14, 15]. The magnitude of the increase in CEs in relation to its basic sizes is characterized by the scaling factor - *n*. Accordingly, their number in 10 cm will be reduced by the value of *n*. In the range of clothing, this indicator varies within *n* = 1-3 (Figure 5). The higher the canvas density, the higher the *n* factor = it can be 2-3, for the low-density canvas we recommend using *n* = 1-2.

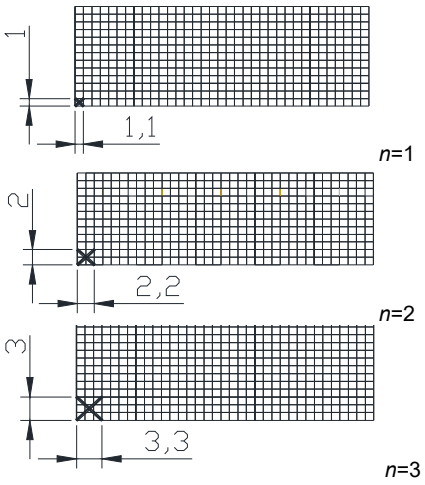

Figure 5 Variants of parameters of CEs at different values of the scaling factor

The amount of CEs in the decoration area is calculated taking into account the basic sizes for each type of canvas and the sizes of the decorating areas of the clothes designs (Equation1):

$$k = \frac{l_d}{l_x \cdot n}, \quad (1)$$

where, *k* is the number of CEs in the decoration area; l_d are the sizes of the decoration area; l_x are basic dimensions of CEs; *n* is a coefficient of scaling of CEs.

Taking into account the inter-dimensional range of variation of decorating zones [16] (at the bottom of the product - 2.0 cm; in the length of the collar - 1.0 cm; in the length of the cuff - 0.5 cm) and the basic sizes of CEs for each canvas one can determine the permissible deviation of their number, within which the length of the ornament can be adjusted throughout the part of the detail. The allowed quantity of CEs, which may enter the boundary of the interval spacing, is calculated (Equation 2):

$$\Delta k = \frac{\Delta}{l_x \cdot n}, \quad (2)$$

where, Δk is the quantity of CEs in the segment of inter-dimensional interval; Δ is the value of the inter-dimensional interval.

To determine the scaling factor of a CE, it is necessary to compare the height of the ornament, calculated for a particular type of canvas, with the parameters of the decoration area. In the sleeve, cuffs and riser collars, the height of the ornament is compared with the width of these details. The height of the ornament is calculated using the following equation (Equation 3):

$$l_r^b = k \cdot l_x, \quad (3)$$

where, l_r^b is the height of the pattern within one report; *k* is the number of CEs in the report in height; l_x are basic sizes of CEs [mm].

If, as a result of the test, it is established that the height of the ornament exceeds the height of the decoration area, then a choice of canvas of lower density is performed for it and a re-check the conformity of the height of the ornament to the dimensions of the part is conducted. If the height of the ornament is half that of the details, then they take *n* factor = 2, if they are three times, then take n which is equal to 3.

With different densities of the canvas and with different values of CEs, the size of the ornament within a single report will be different (Figure 6). According to the selected scaling factor, their magnitude is calculated on the warp and on the weft (Equation 4):

$$l_r = l_r^b \cdot n, \quad (4)$$

where, *n* is the factor of scaling CEs.

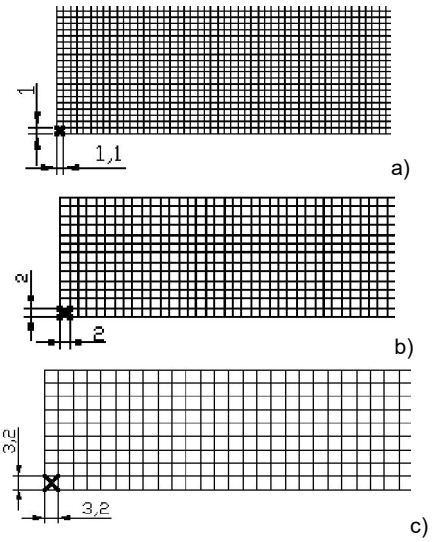

Figure 6 Parameters of CEs on different types of canvas: a) canvas № 3; b) canvas №1; c) canvas №9

To determine the multiplicity of the repeat of the report on the entire part of the detail, one should determine the natural size of the ornament within a single report (Equation 5):

$$l_r = k_r \cdot (l_x \cdot n), \quad (5)$$

where, l_r is the length of the ornament within a single report [cm]; k_r is the number of CEs in the report [units]; l_x are basic sizes of CEs [cm].

Multiplicity of a repeat of a report on a decorating area is calculated (Equation 6):

$$k_{r.r} = \frac{l_d}{l_r}, \quad (6)$$

where, $k_{r.r}$ is a coefficient of multiplicity of the repeat report; l_d is the size of the detail area [cm]; l_r is a report size [cm].

To ensure a clear coincidence of the beginning and the end of the ornament with the outside of the decoration area, the multiplicity of the repeat of the report should be equal to the whole number. Taking into account the number of CEs that are within the reporting range and the multiplicity of its repetition, the number of CEs in the ornament is counted (Equation 7):

$$k_0 = k_n \cdot k_r, \quad (7)$$

where, k_o is the number of CEs in the ornament [the unit]; k_n is the number of CEs in the report [units].

Then we determine the difference between the amount of CES contained in the decoration area of the part and those contained on the ornament area (k-k_o). The obtained figure is compared with the permissible deviation of the number of heights lying within the inter-dimensional interval. If it does not exceed the permissible limit k-$k_o \leq \Delta k$, then the selected report is considered rational. Otherwise, we should choose a new canvas and re-perform calculations.

One of the important characteristics of the ornament is the size measurement, which should be compared with the size of the details. The size of the report depends on the size of the cross and the number of crosses k on the warp and on the weft that are within the report. This parameter is chosen as the main one for characterizing the size of the ornament. In each group of typical reporting chart schemes (Figure 7), the range indicators of crosses on the warp and on the weft were investigated. Since the decorations of the insert (chemisette) and the collar (cuffs) use different patterns in the pattern of the ornament, their sizes have been determined separately.

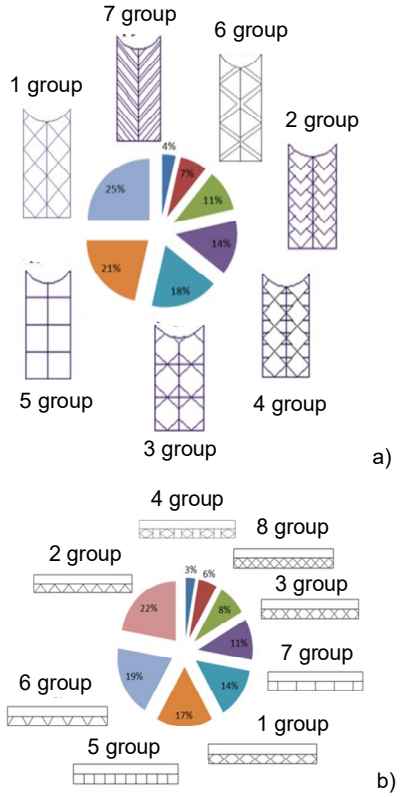

Figure7 Typical reporting frameworks: a) legacies; b) collar and cuffs

The analysis of the size of the report indicates that there is a similarity between the different groups of the typical schemes of insertion (chemisette) and collar (cuff), despite the fact that the range itself is quite large. In this case, the schemes considered within one group of ornaments, are characterized by a different filling area, which is clearly and visually observed (Figure 8). Characteristics of the size of the report are given on the example of chemisette and collar (Table 7). Variants of sizes of ornaments indicate the visual difference of the area of filling the report, (Figure 9), so when choosing an ornament, you must take into account the size of the parts and the size of the product itself.

Table 7 The number of crosses in the report

№ of report group	Number of crosses in the report [pcs]					
	Report Size Groups, chemisette			Report size groups, collar and cuff		
	small	medium	large	small	medium	large
1	16 - 25	26 - 35	36 - 44	5 - 9	10 - 14	15 - 18
2	16 - 26	27 - 38	39 - 49	6 - 9	10 - 12	12 - 15
3	16 - 30	31 - 44	45 - 59	5 - 12	13 - 20	21 - 28
4	16 - 30	31 - 46	47 - 62	5 - 10	11 - 16	17 - 21
5	16 - 32	33 - 49	50 - 64	9 - 12	12 - 15	15 - 19
6	30 - 39	40 - 49	50 - 60	9 - 13	14 - 18	19 - 23
7	38 - 44	45 - 51	52 - 58	10 - 14	15 - 18	19 - 22

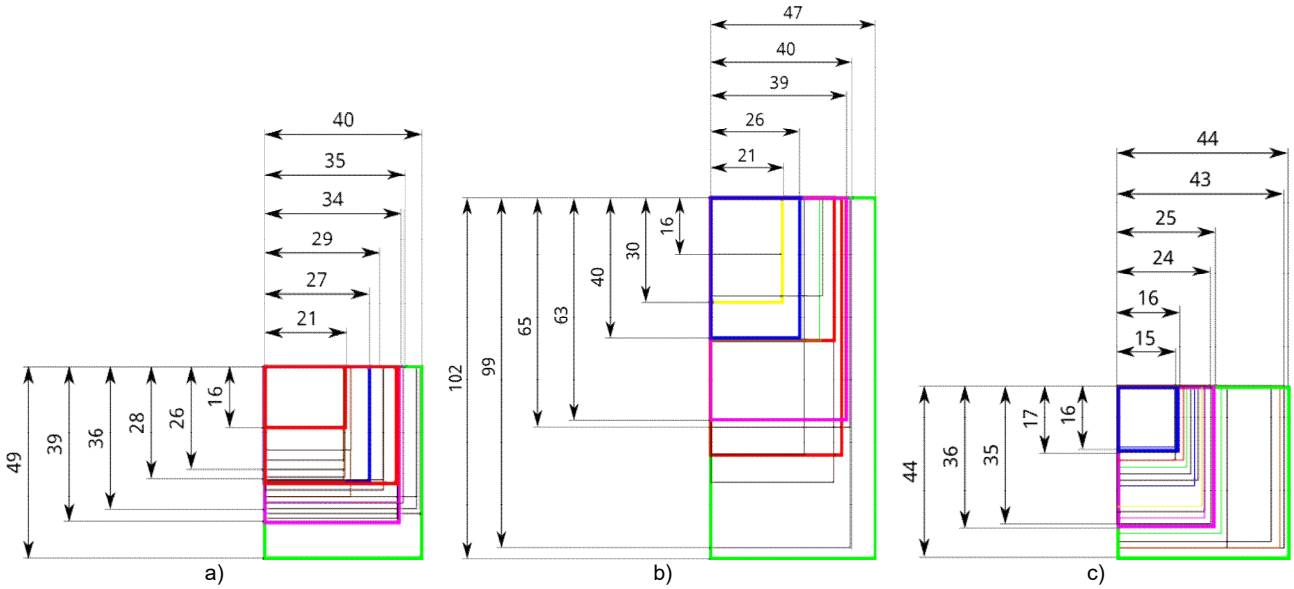

Figure 8 Graphic diagrams of reporting boundaries: a) group 1; b) group 3; c) group 5

To determine the proportionality of ornament parameters with details of clothing, the size of the report must be determined in units similar to the size of the design. For this, it is necessary to take into account the basic size of the cross for each canvas (Table 8) and the number of crosses in the report. According to these indicators, for each type of canvas, the basic reporting sizes (Equation 8) were calculated:

$$l_r^b = k \cdot l_x \cdot \tag{8}$$

where, l_r^b – the basic size of the report; k – number of CE in the report; l_x – basic dimensions of CEs [mm].

The results of calculating the baseline reports based on the warp and on the weft allow you to quickly navigate in determining the natural parameters of an arbitrary report on a given type of canvas.

Analyzing the existing assortment of canvas kinds [17, 18], it has been determined that for large reports it is expedient to use a canvas with a density of 100-70 cells per 10 cm that allows to obtain a CE size of 0.1-0.14 cm, for medium-sized reports - canopy density 65-50 cells per 10 cm with the size of CE 0.15-0.19 cm, for reports of small size - a canopy with a density of 30-50 cells per 10 cm with a size of CE 0.2-0.32 cm. So, the larger the number CEs in the report, the more dense canvas has to be selected for embroidery. This allows you to balance the natural sizes of various ornaments in a constant range of values, which is important for the range of clothing of a certain size-group and age-group.

Taking into account the above recommendations, the ranges of the ornament for the garment details, which are most often to be decorated (chemisette, collars and cuffs) (Table 8), are calculated.

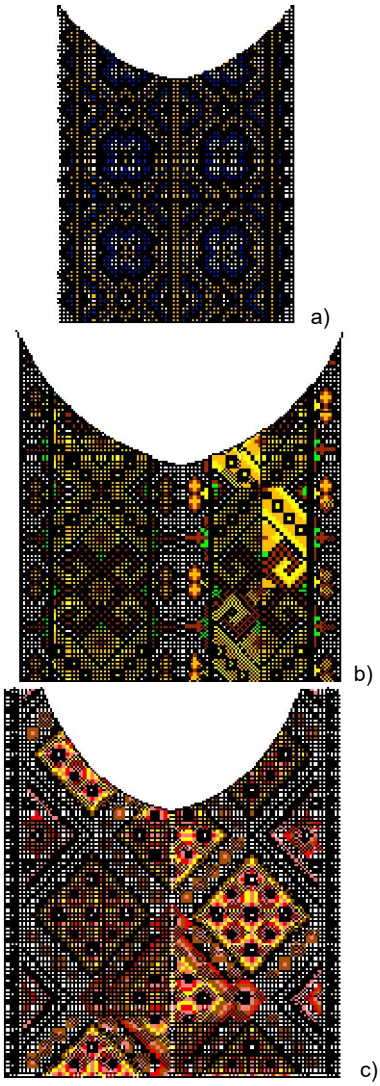

Figure 9 Variants of report sizes: a) small; b) medium; c) large

Table 8 Characteristics of the size of the report and the ornament

Report and Pattern Indicators	Number of CEs in the report [pcs]					
	chemisette			collar and cuff		
	Report Size Groups			Report Size Groups		
	small	medium	large	small	medium	large
Report size, quantity of CEs	15-25	25-35	35-45	10-15	15-25	25-30
Size of a CE [cm]	0.32-0.2	0.2-0.14	0.14-0.11	0.32-0.2	0.2-0.14	0.14-0.12
Ornament size [cm]	4.8-5.0	5.0-4.9	4.9-5.0	3.2-3.0	3.0-3.5	3.5-3.6

The basis of the formation of the configuration of the embroidery ornament is the affine transformations on the area [19]. Some of them are such transformations as displacement, tension-compression, turning. Affine transformations of an object on an area are described by a pair (Equation 9) provided that (10):

$$\begin{cases} X = A_x + B_y + C, \\ Y = D_x + E_y + F, \end{cases} \quad (9) \qquad \begin{bmatrix} A & B \\ C & D \end{bmatrix} \quad (10)$$

where *A*, *B*, ... *F* are constants; *x*, *y* are the coordinates of the transformation; *X*, *Y* are the new coordinates of points of objects.

The affine transformation called the direct shift (Figure 10) is described by the following equation (Equation 11).

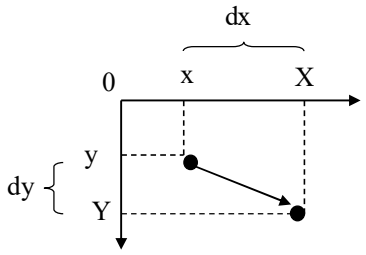

Figure 10 Affine transformation, shift

The inverse transformation allows you to calculate the previous coordinates of the points of objects by known new coordinates (Equation 12):

$$\begin{cases} X = x + dx, \\ Y = y + dy. \end{cases} \quad (11) \qquad \begin{cases} x = X - dx, \\ y = Y - dy. \end{cases} \quad (12)$$

In the matrix form, direct transformation (Equation 13), inverse (Equation 14):

$$\begin{bmatrix} 1 & 0 & dx \\ 0 & 1 & dy \\ 0 & 0 & 1 \end{bmatrix} \quad (13) \qquad \begin{bmatrix} 1 & 0 & -dx \\ 0 & 1 & -dy \\ 0 & 0 & 1 \end{bmatrix} \quad (14)$$

Stretching - compression (Figure 11). This transformation can be called scaling.

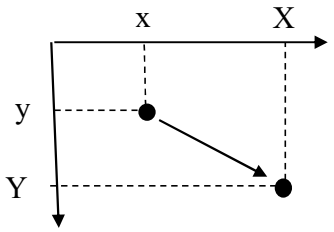

Figure 11 Affine transformation, tension – compression

Straight transformation (Equation 15), inverse (Equation 16):

$$\begin{cases} X = k_x x, \\ Y = k_y y. \end{cases} \quad (15) \qquad \begin{cases} x = X/k_x, \\ y = Y/k_y. \end{cases} \quad (16)$$

In the matrix form, straight transformation (Equation 17), reverse (Equation 18):

$$\begin{bmatrix} k_x & 0 & 0 \\ 0 & k_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (17) \qquad \begin{bmatrix} 1/k_x & 0 & 0 \\ 0 & 1/k_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (18)$$

The rotation around the center of the coordinates (0.0) can be straight (Figure 12a) or inverse (Figure 12b).

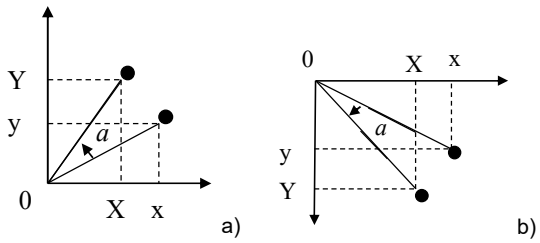

Figure 12 Affine transformation, turn of the object: a) straight; b) inverse

Formulas for the inverse transformation can be obtained if you imagine the rotation of the point with coordinates (*X*, *Y*) at the angle (-*a*).

Straight transformation (Equation 19), inverse (Equation 20). I_n a matrix form, a straight turn (Equation 21), an inverse (Equation 22).

$$\begin{cases} X = x\cos\alpha + y\sin\alpha, \\ Y = x\sin\alpha + y\cos\alpha. \end{cases} \quad (19)$$

$$\begin{cases} x = X\cos\alpha + Y\sin\alpha, \\ y = X\sin\alpha + Y\cos\alpha. \end{cases} \quad (20)$$

$$\begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (21)$$

$$\begin{bmatrix} \cos\alpha & \sin\alpha & 0 \\ -\sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (22)$$

The considered variants of principles of creating embroidery ornaments allow to develop graphic schemes of their construction and to structure the composition of the ornament from its largest to the smallest parts and elements. The highest rank of the division is the composition of the ornament - the methods of arranging elements and modules (motives) on the area. Strapped rectilinear, curvilinear, carpet and other ornament compositions can be seen. The line composition has three variants: horizontal, vertical, and oblique (Figure 13) [20].

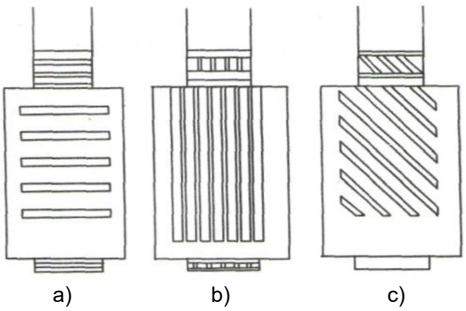

Figure 13 Line composition of the ornament on the sleeves of women's shirts: a) horizontal; b) vertical; c) oblique

In addition to line ornaments there are ornaments that fill the entire area, for example, a lattice ornament. It is placed on a conditional lattice with different forms of cells. In Ukrainian national clothes, lattice ornaments were used with certain restrictions. This is due to the structure of the fabric or canvas, which could not be located at an angle to the base and abb (Figure 14).

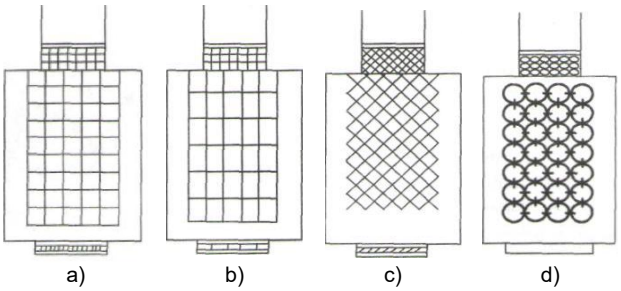

Figure 14 Systems of nodes of simple ornamental lattices on the sleeves of women's shirts in Podillya region: a) square; b) rectangular; c) rhombic; d) hexagonal

Simple lattices of ornament differ in the system of knots [21]. Accordingly, the patterns with the lattice structure of the composition can be grouped into types (Figure 15).

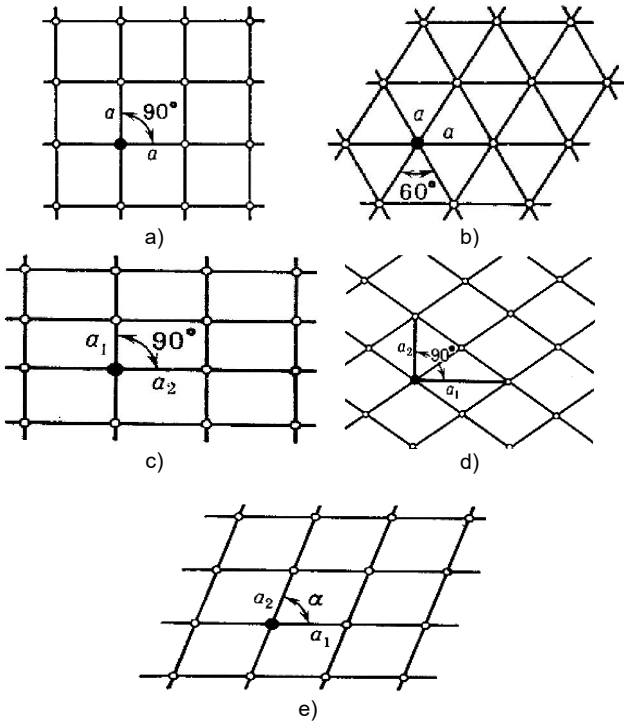

Figure 15 Types of two-dimensional lattices (grids) Brave: a) square; b) hexagonal; c) rectangular; d) rhombic; e) an oblique parallelogram

Different types of symmetry are used when creating line and lattice ornaments. In total there are 7 types of symmetry [22]. To create them we can use the following transformations: parallel transfer; mirror symmetry with vertical axis; mirror symmetry with horizontal axis and rotational (central symmetry) (Figure 16).

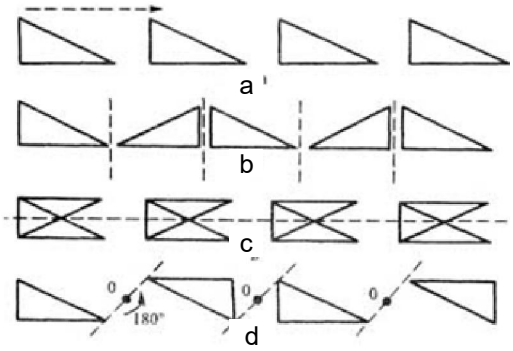

Figure 16 Conversion diagrams for creating line ornaments: a) parallel transfer; b) mirror symmetry with a vertical axis; c) mirror symmetry with a horizontal axis; d) rotating (central symmetry)

Of the 17 groups of symmetry of lattice ornaments [22], only 12 groups (Table 9) are used in Ukrainian national clothes.

5 RESULTS

Analysis of the internal filling of the typical basis of the pattern of the embroidery ornament indicates that within the base there is a repetition of the shape of the outer contour in smaller shapes that fill the foundation. On the basis of the similarity of the combination of the external and internal contours of the ornament, seven groups of typical patterns of decoration of the chemisette (Figure 17a) and 8 groups - the typical schemes of decoration of collar and cuffs (Figure 17b) are allocated.

The use of the method for selecting the dimensions of the CEs to the size of the parts, taking into account the size of the report, ensures a clear positioning of the beginning and the end of the ornament on the decoration area (Figure 18).

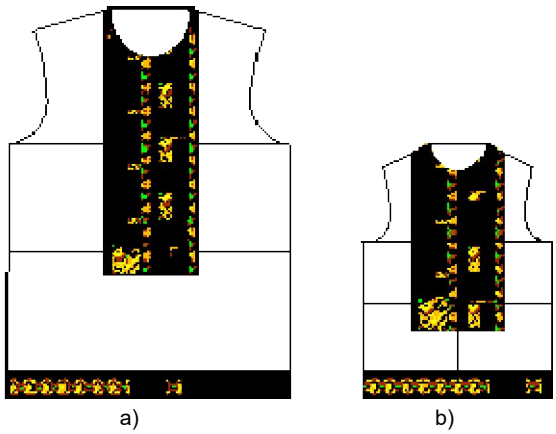

Figure 18 Positioning of the ornament on shirts-embroidered shirts: a) male; b) children's

Table 9 Symmetry groups of embroidery ornamentation taking into account Ukrainian national traditions

Code	Symmetry group	Code	Symmetry group
p1	Simple displacement	p2	Rotating to 1800
pm	Reflection	pg	Reflection with a shift
cm	Reflection + reflection and shift	pmm2	Reflection + reflection
pmg2	Reflection + rotating to1800	pgg2	Reflection with a shift + rotating to 1800
cmm2	Reflection + reflection+ rotating to 1800	p4	Rotating to 900
p4mm	Rotating to 900+ reflection to the angle of 450	p4gm	Rotating to 900+ reflection to the angle of 900

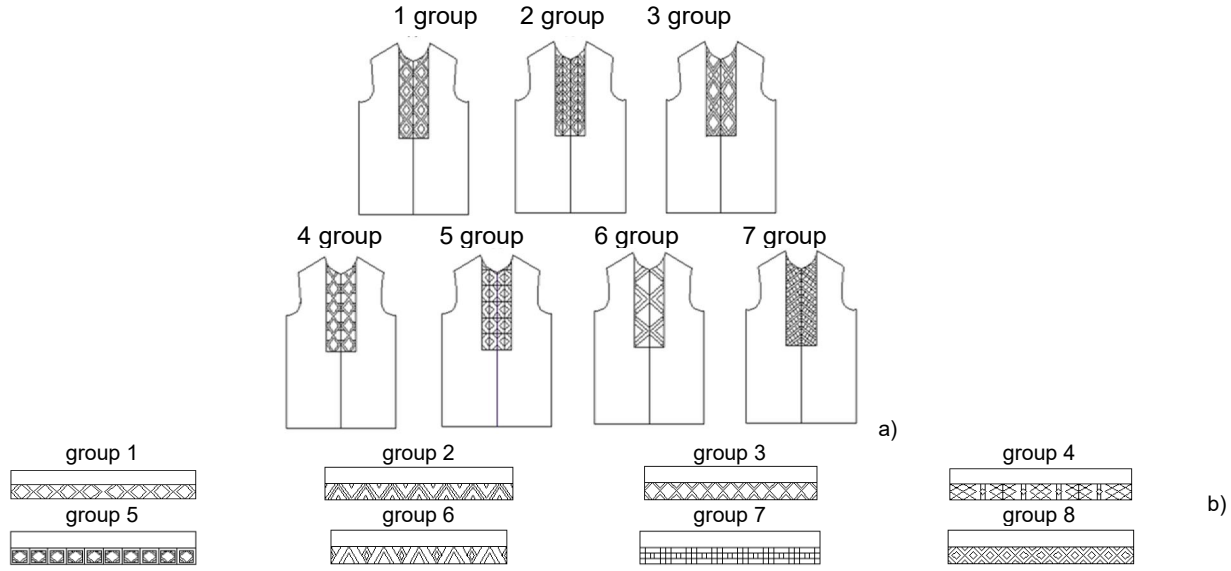

Figure 17 Typical structure of the base of the geometric ornaments of a man's shirt: a) chemisette; b) collar and cuffs

To fill the 3×2 ornament area (Figure 19), a graph *G* has been developed that contains n(*G*)=49 vertices and m(*G*)=48 edges. Figure 19 shows that (as in the case of one or two DCEs) the degree of all vertices (except the vertices of the beginning (*S*) and the end (*E*)) of the graph *G* is equal to two, since adjacent to each of them there are two vertices (located on the edges incident with it). This applies to all the graphs *G*, which can be formed, regardless of the number of DCEs and their relative position on the ornamental site [13].

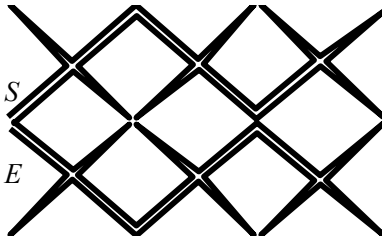

Figure 19 Scheme of rectangular area filling 3×2 DCEs

Proceeding from the definitions of Euler [23], if the graph has only two odd knots (the degree of vertices of the beginning graph (*S*) and the end (*E*) is equal to one), it can be traversed along a route that begins at one of these knots and ends in another (a route that starts in a paired knot cannot cover all knots). That is, it is theoretically possible to fill the arbitrary area of the DCE, (Figure 19). The roundabout can be done in one of two directions (depending on the location of the start of the roundabout). However, the beginning (end) of the bypass can be located in any of the corners of the square, which is described around an arbitrary DCE. If each of the centers of a DCE is denoted by one point and connected by ribs, the received subgraph *P* of graph *G* will be the graph of the machine (Figure 20). This graph allows to simplify the filling of the DCE of any part of the embroidery ornament.

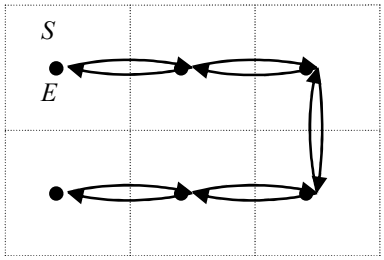

Figure 20 The graph of the machine for filling the rectangular area 3×2

Let us consider the Euclidean space, which is a two-dimensional Cartesian coordinate system and an integer-lattice Z^2 in it. Elements (*x, y*) of the Z^2 set are marked with *v*. We will call the number $\rho(v, v')=|x-x'|+|y-y'|$ - the distance between *v=(x, y)* and *v'= (x', y')*. We call the elements *v* and *v'* adjacent if the distance between them corresponds to the inequality $1\geq\rho(v, v')<2$. Let *B={e, k, l, m, n, r, s, w}* be the alphabet of the arc marks (Figure 21).

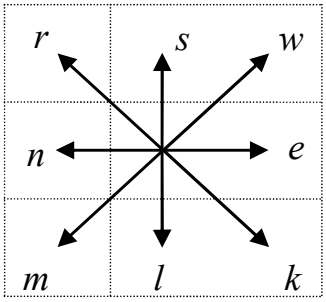

Figure 21 Marking the arcs of a mosaic graph in accordance with their direction

The graph *L=(V, E, a, b)* (Figure 21) is called a planar non-oriented finite bound graph in which the set of vertices *V* is a subset of Z^2, *E* is the set of arcs, $a:v\in V\rightarrow a\in A$ - vertex markup function, $b:(v, v')\in E\rightarrow b\in B$ - arc markup function. Through |*L*| the number of vertices of the graph *L*. is denoted. For any vertex *v, E(v)* denotes the set of all arcs output from it. A circle with a center at the vertex *v* is called the set $K1(v)=\{v'|v'\in Z^2,\ 1\geq\rho(v,v')<2\}$. The domain *O(v)* of the vertex $v\in V$ is called the set of vertices adjoining it with $K_1(v)$. The arcs (*v, v'*) and (*v', v*) of the marked graph are called opposite.

The graph *L* is mosaic, its arcs can be parallel or at an angle of 45° to the coordinate axes. Only neighboring peaks can be connected by arcs, the vertices of the top contain marks of all arcs coming out of it (Figure 22).

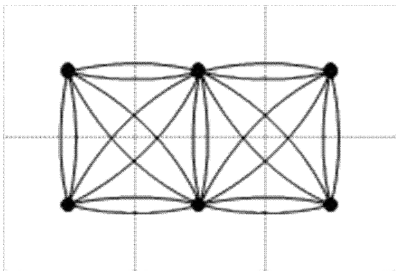

Figure 22 A mosaic graph for a fully filled area of 3×2

The symbol *b* from the mark of vertex *v* of the mosaic graph *L* indicates *v'* to the vertex *v* from the set Z^2 if the vertices *v* and *v'* can be connected by an arc with the direction *b*.

The mosaic graph *L=(V, E, a, b)*, in which the vertex is a plurality of marks of all the arcs coming out of it, is called a graph of a labyrinth or labyrinth.

In searching for route *p*, numerical coding is adopted. Then, *B*={1, 2, 3, 4, 5, 6, 7, 8} is an alphabet of arc marks, and the route *p*

corresponding to the graph of the automaton *P* (Figure 19) can be written *p*=5, 5, 3, 1, 1, 5, 5, 7, 1, 1.

For the development of programme module (PM) and automation of the process of decorating with ornaments of embroidery, a mathematical model with the use of graph theory has been developed.

The creation of ornamental stripes was done using the Inkscape program. Each symmetry group is associated with its visual perception, which is illustrated in the example, the application of a single elementary figure according to Table 9 (Figure 23).

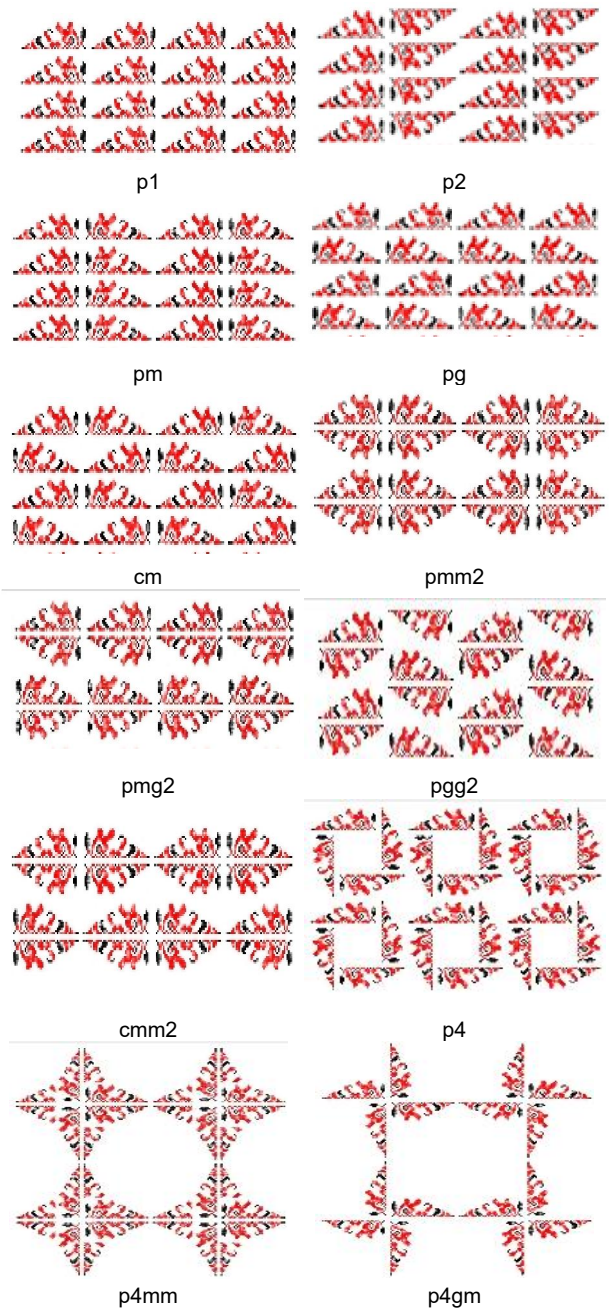

Figure 23 Types of lattice ornaments created with the help of PM "Inkscape" taking into account Ukrainian national traditions

Photographic images of embroidery ornaments are shown on Figure 24.

Figure 24 Photographic images of embroidery ornaments made DCEs

6 CONCLUSIONS

In determining the effectiveness of the methodology for calculating the parameters of the ornament (a group of reports, decoration areas, symmetry laws, the route of a mosaic graph), which flows from the levels of the ethno design component (Figure 1), it is logical to use software engineers in the machine embroidery that use the algorithm for filling ornamentation of DCEs without stitching transition. It should be noted that this method does not explain the mechanism of selecting rational parameters of the density of the report in repetitions in the area of decorating. In this sense, it is advisable to employ a method for selecting rational parameters of the canvas density relative to the parameters of the ornament. To prove this assertion, a method for scaling the CEs according to the characteristics of the canvas groups is proposed (Table 6). The description of the segmentation of the size of the ornament by the reports groups in the channel of the canvas density gives the possibility of affine transformations of the ornament on separate parts of the product on the principle of a triptych. This does not diverge from the practical data known from the works [14, 16, 24], which correspond to the transformation schemes in the symmetry groups. The optimal compositions of ornaments (Figures 13 and 14), in contrast to the results of studies published in [25-27], allow the following to be stated:

- the main regulator of choosing the parameters of the ornament for decoration of parts is not so much the complexity of the composition, as the density of the canvas, as a prototype of the grid;
- for a large group of reports, it is expedient to use canvas № 25-32, for medium-sized reports - canvas № 16-22, for reports of small size - canvas № 8-14. This allows you to balance the natural sizes of various ornaments in a constant range of values, which is important for the range of clothing of a certain size-age purpose.

The structuring of the outer contour through the internal contour of the report on the principle of parallel transport for the formation of a lattice kind of ornament has a substantial influence on the internal filling of the typical basis of the embroidery ornament.

In some types of ornament, the construction of its basis is performed by parallel displacement of the same report along the transfer axis; in other ones a parallel transfer with a stretch of report along the transfer axis is used.

Such conclusions can be considered expedient from a practical point of view, as they allow to reasonably approach to the choice of graphic editor of the software module of embroidery.

Graphic editor of Draw Ltd. allows you to create and check the quality of the location of embroidery ornaments, contours of which correspond to contours of parts of garments.

From a theoretical point of view, using a mosaic graph of filling an ornamentation area [23], which depends on the location of the DCEs, their number and location of the beginning (end) of the roundabout of the graph of the graph is difficult to accomplish without automation since it is necessary to perform certain actions clearly: to determine the size and forms of arbitrary sections filled with one color; formation of DCEs clockwise; the transition between isolated DCEs (which do not bind to each other at one point) and others.

The proposed technique of the technological aspect of embroidery involves the possibility of obtaining the parameters of the ornament with the prediction of their conformity to the parameters of the parts or separate areas of decorating directly before the process of embroidery. This greatly reduces the time spent on the production of original patterns of clothing and increases its aesthetic quality in general.

However, it is impossible not to claim that the principle of the triptych in the information function of the emblem symbolism depends on the sex-age characteristics of the product and indicates the ambiguous effect of the scaling of the report. Such uncertainty imposes certain limitations on the use of software modules, which can be interpreted as a lack of this study. Potentially interesting direction of further research can be focused on the capsular approach to the design of assortment complex in the wardrobe of an ethnically oriented group of consumers.

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