https://doi.org/10.59849/aidd.2024.82

One Approach to the Study and Cataloging of Handmade Azerbaijani Carpets

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"Art is a product of the physical condition of a people, on the one hand, and their entire civilization, that is, several hundred of their habits, on the other."

Stendhal

"Genuine, immortal works of art remain accessible and bring enjoyment to all times and peoples."

Hegel

Abstract. The article proposes an approach to studying handmade Azerbaijani carpets, presenting a method for recognizing patterns and ornaments based on three types of decomposition: breaking the image down to its elementary components, analyzing the distribution function of the occurrence of threads of specific colours within the pattern, and representing the carpet in its colour scheme. A reference database of well-known classical patterns and ornaments belonging to the Azerbaijani school is being developed. For carpet recognition, a modular architecture of an intelligent information system has been designed, encompassing systematization, recognition, and evaluation as a sample of the spiritual culture of the people. Cataloguing handmade Azerbaijani carpets is an interdisciplinary task involving specialists from various fields of science and technology.

Keywords: information technologies, pattern recognition, distribution functions, recognition system, center of gravity, symmetries, catalog, petroglyphs

Introduction. Adhering to the principles of conducting a classic scientific study, it is worth noting that the evolution of handmade carpets has been influenced by social, economic, and sometimes political and fashion trends. This phenomenon is characteristic of any country. Moreover, the development of science and technology has played a significant role in this process.

In Azerbaijani handmade carpets, the selection of color palettes is particularly striking, every border stripe is astonishing, and the ornaments are so captivating that one begins to believe in their magical energy.

Europe and Asia have highly appreciated the craftsmanship of Azerbaijani weavers. Luxurious wool and the finest silk carpets adorned prominent homes and palaces. Archaeological findings conducted within the territory of our republic, along with literary monuments, indicate that the art of carpet weaving originated in Azerbaijan in ancient times [5, p. 45].

It is no coincidence that the masters of high art during the Renaissance, when designing interiors for their famous paintings, widely used carpets woven by artisans from the leading Azerbaijani schools. "Medallion" carpets with a star in the center of the main field, known since the mid-15th century, continue to adorn museums, cultural centers, private collections, and more even five centuries later. There are many examples of this, two of which are shown in Figures 1-2.

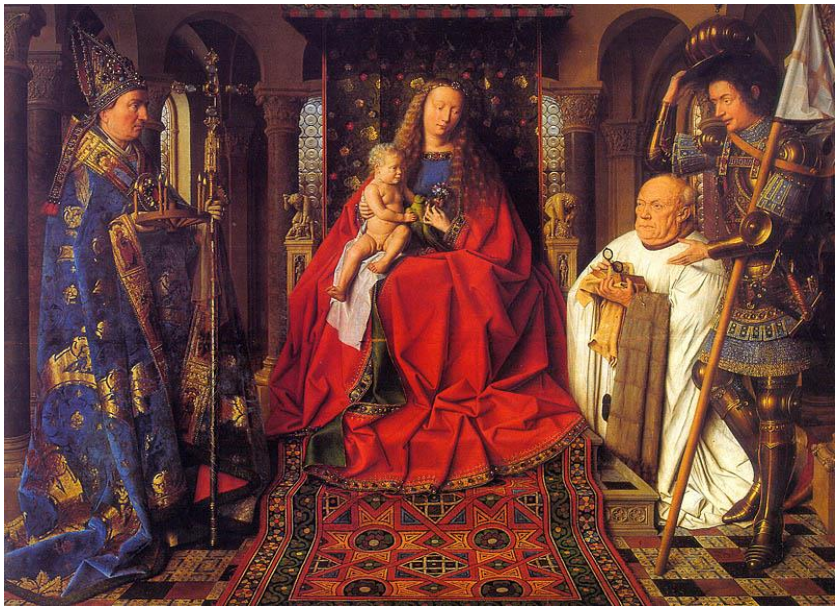

Fig. 1. Altarpiece "Madonna of the Canon van der Paele" by Jan van Eyck (1390-1441), Gruuthuse Museum (Netherlands).

The magnificent carpets, remarkable for their quality and craftsmanship, woven centuries ago in Shirvan, Karabakh, Absheron, Guba, Kazakh, Ganja, Mughan, and Talysh, now adorn the largest museums in Europe and America. It is important to note that 90% of the carpets known worldwide as "Caucasian," especially pileless ones, are Azerbaijani carpets [5, p. 78].

The exquisite carpets woven on Azerbaijani territory were mentioned in the records of the Venetian traveler Marco Polo (13th century), the English traveler Anthony Jenkinson (16th century), and the Dutch navigator Jan Struys (17th century). Numerous descriptions of carpets can also be found in the works of Nizami, Khagani, and others.

We will not enumerate all the cultural centers where Azerbaijani carpets and carpet products are currently preserved. Unfortunately, the global market is rife with counterfeits, and it is our duty to protect the name and origin of the Azerbaijani carpet.

Fig. 2. The Ambassadors, Hans Holbein (1497 – 1541).

The first impetus for our research into this process was the Law "On the Protection and Development of Carpet Art" issued by the President of the Republic of Azerbaijan, I. Aliyev, on December 7, 2004. The seriousness of the issue was further confirmed by the State Program on the Preservation and Development of Carpet Weaving in the Republic of Azerbaijan, adopted on February 28, 2018.

Task formulation. Modern science and information technologies, with their vast resources, can provide significant assistance in addressing the tasks arising from the Law, corresponding decrees, and the State Program. Based on this, we will consider the process of developing an intellectual information system for the recognition and identification of patterns and ornaments of Azerbaijani handmade carpets. To achieve this goal, a number of sub-tasks need to be addressed, including the following:

- Systematization of carpets by regions, schools, and masters;
- Decomposition methods;
- Recognition and identification methods;
- Quality assessment methods;
- Development of the system as the basis for future cataloging.

In any field of decorative applied art, for its in-depth study and proper analysis from both a scientific and artistic perspective, as well as the understanding of the origin, content, form, construction, and composition of the ornament, it is essential to first master the "alphabet" of the latter, i.e., to be able to recognize the forms of its elements. In addition, it is also necessary to know the technical characteristics of this particular field of decorative art. The patterns of traditional Azerbaijani carpets, like those from other regions of the world, have evolved over the centuries, but the main motifs and symbols have remained the same.

The elements of Azerbaijani carpet ornamentation are divided into ornamental features of pileless and pile carpets. Based on their technical and artistic characteristics, pileless and pile carpets of Azerbaijan are classified into types that represent various schools and groups. The composition of carpets typically consists of two parts: the central field of the carpet and the border. Similarly, the ornamentation of carpets is divided into two groups of elements: the first group consists of elements of the ornamentation of the central field, and the second group consists of elements of the border ornamentation. Thus, the decorations of all types of Azerbaijani carpets are divided into two main groups. The first group includes elements of the decoration of the central field, while the second group includes elements of the decoration of the border. The elements of the central field, based on their position within the carpet composition, should be further divided into two groups: 1. filling and auxiliary elements; 2. main elements.

Filling elements, in terms of their content and form, can also be divided into four main groups:

1. Depictions of living beings;
2. Depictions of household objects;
3. Elements of various forms;
4. Plant elements.

Materials and methods of research. Narrowing the search space when recognizing complex images is one of the main challenges in the theory of pattern recognition. This issue also arises when recognizing carpet patterns and ornaments – figures of complex constructions. The number of patterns in Azerbaijani handmade carpets is measured in the hundreds. To recognize them, it is necessary to highlight informative and significant features that characterize a particular pattern. Based on the research, the following attributes were identified: type, name, school, time, author, shape, base material, knot density, pile height, thread material, number of border stripes, number of central patterns, thematic basis of the pattern, number of colors in the pattern, etc. In total, the number of parameters provided by the expert and identified in the process of researching the task was 128. Among them, 41 parameters were found to be informative and significant.

The problem of recognition should be approached systematically. An art historian views the ornament's image from an artistic and emotional perspective, evaluating the beauty and aesthetics of the work as a whole. For an information technology specialist, this ornament is a physical, static, complex object with a number of geometric parameters, colors, pixels, etc. In other words, the information technology specialist, in order to recognize this ornament, must perform a computer spectral analysis of the colors, distribute the patterns along the contours at the boundaries, identify

informative features for recognition, and determine the mathematical methods necessary to solve the problem. The informative features of carpet patterns are divided into the following categories:

• Features obtained from the expert (technical and technological indicators, artistic analysis, carpet history, restoration, etc.);

• Features obtained through decomposition methods (number of contours in the pattern, color palette, etc.);

• Features obtained using statistical analysis methods (univariate, bivariate distribution functions);

• Features characterizing expert assessments for pattern identification (determining affiliation with a specific school);

• Features based on calculated parameters of the center of gravity of the entire pattern and its individual components (symmetry and asymmetry of the pattern).

For conducting the work using computing technology, special attention is given to the selection of technical means for presenting information. Modern computing technology has sufficiently high technical and software characteristics for the rapid processing of various parameters of graphical images. The accuracy of this processing directly depends on the quality of the image. We used a desktop color flatbed scanner HP Skanjet-4370 with an optical resolution of 3600 dpi and a Canon PowerShot A-570 camera with a resolution of 7.1 megapixels. The primary feature on which the decomposition will be based is color, which creates a contour at the boundary of different colors. The attributes of color include hue, brightness, contrast, saturation, and color temperature.

Solution. If the pile height of the carpet is not considered, it should be viewed as a two-dimensional complex image, consisting of numerous ornaments and patterns in the internal fields, enriched with both complex and simple elements of the border stripes. Therefore, the problem should be approached systematically, i.e., it should be considered from different perspectives.

Azerbaijani carpet patterns are categorized by schools, such as Ganja-Qazakh, Shirvan, Baku, Karabakh, Guba, Tabriz, and others, while the decorations are grouped into 32 subclasses [1, 2, 3]. Regarding regions, it is important to note the significant fact that, despite their geographical proximity, each region, except for the national ones, has its own school, customs, and traditions, which are strictly adhered to and skillfully reflected in the created works of all types of applied art, including carpet weaving. The line where one thread color transitions to another will be referred to as the contour. Mathematically, this can be expressed as follows:

$$F = \{g_k(x_i, y_j);\ f_p(x_q, y_l);\ A_k;\ B_p\}$$

$$\tilde{F} = \sum_{k=1}^{K}\left(\sum_{i=1}^{N}\sum_{j=1}^{M} A_k g_k\left(x_i, y_j\right)\right) + \sum_{p=1}^{P}\left(\sum_{q=1}^{N}\sum_{l=1}^{M} B_p f_p\left(x_q, y_l\right)\right),$$

$$g_k\left(x_i, y_j\right) = \begin{pmatrix} x_1y_1 & x_1y_2 & \dots & x_1y_M \\ x_2y_1 & x_2y_2 & \dots & x_2y_M \\ \dots & \dots & \dots & \dots \\ x_Ny_1 & x_Ny_2 & \dots & x_Ny_M \end{pmatrix} \qquad f_p\left(x_q, y_l\right) = \begin{pmatrix} x_1y_1 & x_1y_2 & \dots & x_1y_L \\ x_2y_1 & x_2y_2 & \dots & x_2y_L \\ \dots & \dots & \dots & \dots \\ x_Py_1 & x_Py_2 & \dots & x_Py_L \end{pmatrix}.$$

where g(x,y) – coordinates of the pattern's contour, f(x,y) – coordinates of the internal field, Ak , B_p – number of patterns on the carpet.

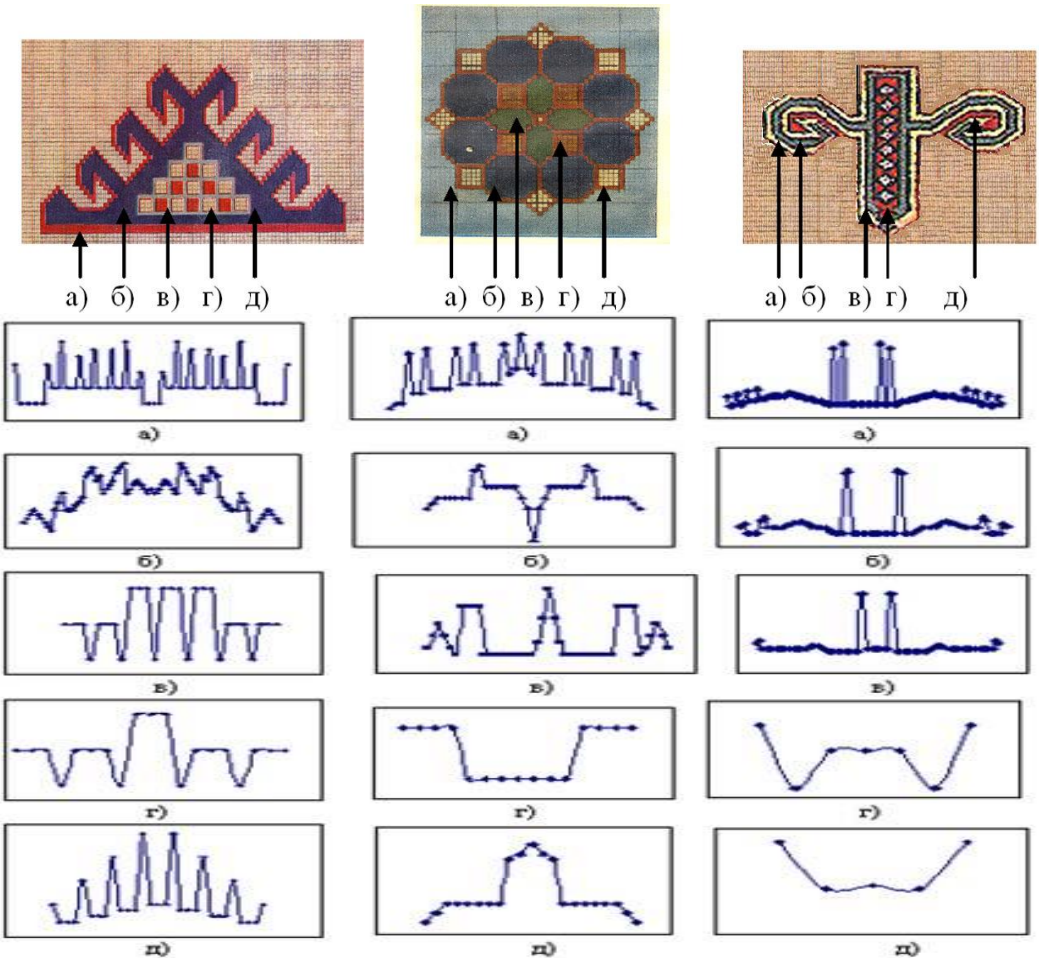

Fig. 3. Distribution function of different color contours.

For example, the frequency of occurrence of contours (color distribution function) for the figures is shown in Fig. 3. The architecture of the pattern and ornament recognition system has been developed based on three types of decomposition. To evaluate the carpet, the rules of the Golden Ratio and Fibonacci numbers were applied, and the center of gravity of the pattern (2D image) was calculated. Over 1,000 decorative samples have been studied. Information about the decorative samples allows us to determine which carpet is characterized by a specific pattern and its school affiliation.

The development of the catalog is an interdisciplinary task that involves the collaboration of specialists from various fields. The approximate structure of such a creative collaboration is presented in Table 1.

Table 1

Institute of Control Systems	**The cataloging and research of rare Azerbaijani carpets stored in museums within the country and abroad, as well as those at risk of being lost.**
Institute of Linguistics	The preparation of a terminology dictionary related to carpet weaving.

Institute of Folklore	As a folk art form, the artistic qualities, compositional features, and ethnic characteristics of Azerbaijani carpets.
Institute of Chemistry	The development of the art of dyeing.
Institute of Botany	The development of the art of dyeing
Institute of Zoology	The history of livestock breeding and wool production, its current state, and the opportunities and development prospects related to carpet weaving.
Institute of Economics	The economic aspects of carpet production and sales, as well as the socio-economic characteristics of carpet production workshops.
Institute of Physics	Deepening knowledge about carpet patterns in relation to the fields of astronomy and optics.

The catalog was developed in stages: concept presentation, material preparation, filling in the catalog blocks, and development of the electronic version.

The structure of the catalog represents a distributed database of the following type: image of handmade carpets; physical characteristics (length, width, ovality, weight, border width, etc.); technological parameters (wool, cotton, pile height, weave density, etc.); chemical parameters (synthetics, number of colors, chemical dyes, dye production technology, etc.); natural dyes (color, plant or mixed technology, etc.); ornaments and patterns; folklore; history of creation; origin of names, etc.

A comparative analysis of carpet images with rock drawings is of interest, for example, the image of a man (Fig. 4).

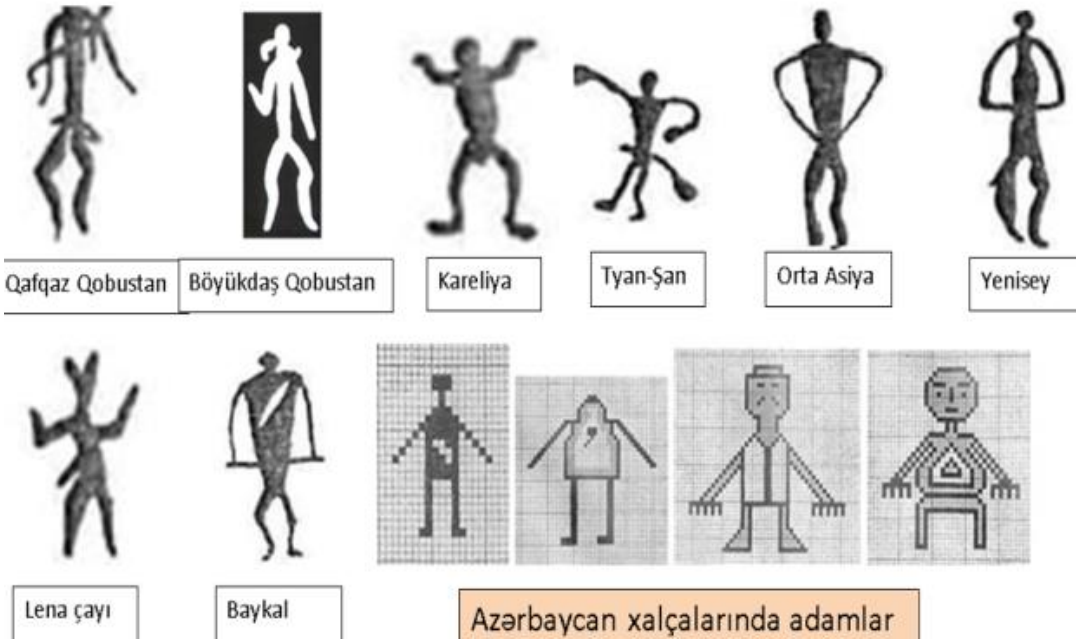

Fig. 4. Petroglyphs and men on carpets

Equally interesting are the images of tools and animals (Fig. 5-6).

Fig. 5. Images of animals on carpets and petroglyphs of Gobustan.

Fig. 6. Ancient Azerbaijani carpets and rock carvings.

To date, more than 1,600 carpets and carpet products have been studied. The development of the catalog, along with the recognition of carpet patterns and ornaments, provides extensive information not only about the carpet but also about the time of its creation. The database includes information of historical and literary content. It offers both a journey into the past and the possibility to experiment with new ornaments.

The capabilities of this module, which include the addition of new samples of carpet products and decorative elements, border strips, etc., form the foundation that will allow for the future creation of a registry of Azerbaijani carpets and the further development of a multimedia library.

We believe that the approach proposed in this work can serve as a prototype for the development of an electronic encyclopedia of handmade Azerbaijani carpets.

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