Exploratory Analysis and Dataset Creation of Qajar Carpet Designs and Motifs: A Data-Driven Approach with a Focus on Machine Learning

Siamak Sarbazi[1], Azadeh Yaghoubzadeh[2], Mahdi Sarbazi[3]*

[1]M.A. Student in Carpet Design, Faculty of Carpet, Tabriz Islamic Art University, Tabriz, Iran.

[2]Assistant Professor, Faculty of Carpet, Tabriz Islamic Art University, Tabriz, Iran.

[3]PhD Candidate, Department of Computer Engineering and IT, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran.

Abstract:

This research primarily seeks to conduct an exploratory, data-centric examination of carpet motifs and designs from the Qajar era, employing modern machine learning techniques to achieve this goal. By collecting images of Qajar carpets from renowned museums such as the Victoria and Albert Museum, the Metropolitan Museum of Art, and the Hermitage Museum, a dataset comprising 800 metadata entries (200 original images and 600 augmented versions generated using grayscale, Laplacian, and Gabor filters) was created. The study examines the statistical distribution of carpet designs, visual features, design patterns, dimensions, and weaving regions. The "Seven-Face" classification—Mohramat, Ghabi, Vagirehii, Lachak-Toranj, Mehrabi, and Afshan—serves as the main analytical framework, revealing that Afshan (30%) and Lachak-Toranj (23%) designs are predominant. In comparison, 41% of the carpets incorporate pictorial elements influenced by Western cultural aesthetics. Kerman and Kashan emerge as primary production centers; however, challenges such as missing regional information (28.5%) and incomplete collection data (43.5%) persist. This research demonstrates that integrating computational methods with art-historical studies can deepen our understanding of the evolution of design, stylistic origins, and regional distinctions in Qajar carpets, thereby paving new pathways for interdisciplinary research in the field of Iranian traditional arts.

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1. Introduction

The Qajar dynasty (1789–1925) was a significant period in Iranian history, marked by major socio-political, economic, and cultural changes that strongly influenced the arts and handicrafts, particularly carpet weaving. The dynasty was established after the fall of the Zand dynasty by Agha Mohammad Khan Qajar. Intellectual developments, such as the founding of Dar al-Funun and the spread of print media, introduced Western ideas such as nationalism and democracy, thereby contributing to the Constitutional Revolution. Economically, reliance on foreign powers and treaties, such as the Golestan and Turkmenchay, weakened Iran's national autonomy [1].

Within this context, Iran's carpet industry underwent major organizational shifts. From the 1870s until World War I, both the number of looms and the volume of exports increased dramatically. Prior to this boom, production was conducted in regional workshops in centers such as Kerman, Isfahan, Azerbaijan, and Kashan, funded by aristocrats and merchants. International demand—spurred by world exhibitions and the Arts and Crafts Movement—led to foreign investment and design modifications tailored for export markets. Companies such as Ziegler established domestic weaving workshops in Sultanabad. Qajar carpets possess artistic, cultural, economic, and social significance; pictorial carpets from this era, influenced by photography and Western printmaking, depict scenes from epics and myths with a human-centered realism, symbolizing a transitional moment from tradition to modernity [2, 3].

Design classification of Persian carpets relies on multiple systems—such as medallion, vase, and geometric typologies—but the "Seven-Face" categorization, based on underlying structural layout (Mohrammat, Ghabi, Vagirehi, Lachak-Toranj, Baghi, Mehrabi, and Afshan), is historically grounded from the ancient to the Islamic periods. The composition of the field is defined through symmetry schemes (overall, half, quarter, and sub-quarter symmetry) and size formats (e.g., rug, runner) [4, 5].

Recent advances in digital heritage preservation and smart data analytics have demonstrated significant potential for documenting and analyzing historical artifacts. The integration of advanced security frameworks with IoT systems provides a robust infrastructure for managing large-scale heritage datasets and ensuring data integrity [6]. Complementary research has focused on optimizing computational methods for processing and analyzing complex pattern datasets, including realistic demand modeling and distribution optimization algorithms applicable to historical image analysis [7]. Furthermore, clustering methods and efficient computational techniques have emerged as powerful tools for dimensionality reduction and pattern extraction in large historical image datasets while maintaining analytical accuracy [8].

Collectively, these studies underscore the importance of integrating intelligent data processing mechanisms, clustering algorithms, and optimization techniques to design comprehensive systems for heritage documentation, artifact analysis, and the management of historical datasets that support the preservation of cultural resources such as Qajar-era carpets.

This study compiles a collection of Qajar carpet images from major museums, including the Victoria and Albert Museum, the Metropolitan Museum of Art, and the Hermitage Museum, and applies data augmentation techniques to quadruple the dataset and produce a metadata file comprising 800 entries. The research aims to analyze the distribution of designs, visual features, design patterns, collection locations, dimensions, and weaving regions to illustrate how cultural, economic, and commercial factors shaped the development of Qajar carpet art. Ultimately, the study establishes a foundation for exploratory machine-learning applications in the analysis of historical artworks. A concise review of the research background and theoretical foundations of Qajar-period carpets is first presented; thereafter, the historical context and the cultural–economic significance of Qajar carpets are outlined. The next section explains the pattern classification system ("Haft-Rokh") and the structural components of the carpet field. In the methodology section, the process of collecting images from museums and credible sources, the preprocessing and data augmentation methods (including grayscale conversion, Laplace filter, and Gabor filter), and the construction of the metadata file with approximately 800 entries are described. Subsequently, the labeling procedure and the specifications of the metadata columns are explained, and in the results section, statistical and visual analyses are presented, including the distribution of pattern types, the proportion of pictorial carpets, symmetry patterns, dimensions, and the geographical dispersion of weaving. The discussion then interprets the findings and addresses data limitations, and finally, the conclusion offers suggestions for future research and for the application of machine learning in historical art studies. This structure is designed to create a logical connection between computational methods and art-historical analysis, guiding the reader from the foundations to the results and the research outlook.

2. Related Works

Mohammadzadeh and Panjeh Bashi (2025), in their article "A Comparative Analysis of Design and Color in a Qajar Carpet Preserved in the Iranian Carpet Museum and the Tiles of the Golestan Palace Complex," conduct a comparative examination of the design and visual patterns of a Qajar carpet from the Carpet Museum of Iran with the motifs seen on Qajar-period tiles in the Golestan Palace. The authors highlight the visual similarities and dominant color palette (blue, yellow, pink) shared between the Qajar carpet and tiles, demonstrating that the cultural and artistic interconnectedness of the Qajar era resulted in color and pattern correspondences across these two media [9]. Given the study's focus on analyzing the design and coloration of Qajar carpets, this source is particularly valuable for understanding the structural features of Qajar motifs and comparing them with other contemporary art forms within the broader context of art history.

Rashadi et al. (2023), in their research "An Investigation and Analysis of National Identity Indicators Reflected in Qajar Pictorial Carpets," employ a descriptive-analytical methodology to examine the visual and thematic elements of Qajar pictorial carpets through the lens of indicators of Iranian national identity. By analyzing 79 Qajar pictorial carpets—featuring themes such as portrayals of kings, notable figures, religious concepts, literary inscriptions, and more—the researchers demonstrate that all major cultural and historical dimensions of Iranian identity are represented within these carpets [10].

Soleiman-Moghadam et al. (2021), in a study titled "Using Support Vector Machines in Classifying Lachak-Toranj and Turkmen Geometric Carpet Designs," apply data-mining methodologies to the challenge of pattern classification in Iranian carpets. By extracting immediate grayscale image features from 60 Iranian carpets (Lachak-Toranj and Turkmen geometric designs) and utilizing Support Vector Machine (SVM) algorithms, the authors achieve a high classification accuracy (over 89%) between these two design categories [11]. Although this article does not focus on the Qajar period, it demonstrates the effective application of machine learning to analyze and classify Iranian carpet patterns, serving as a model for operationalizing machine learning techniques on visual carpet datasets.

Ahani et al. (2021), in their study "An Analysis of Power Symbols in Qajar Pictorial Carpets," examine symbols and visual indicators associated with royal authority in Qajar pictorial carpets. The authors argue that Qajar monarchs used both direct imagery (such as portraits of kings) and indirect iconography (such as crowns, parasols, birds, boteh motifs, etc.) to visually articulate concepts of power [12]. This study, which focuses on the symbolism and representations of authority in Qajar carpets, is relevant to iconographic analysis and thematic interpretation of Qajar carpet designs.

Abbasi Shokatabad (2021), in the article "A Comparative Study of Religious Elements in Qajar and Pahlavi Carpets," adopts a historical-analytical approach to examine religious themes and motifs in Qajar and Pahlavi carpets. The author demonstrates that Qajar carpets are rich with Shi'ite iconography and visual narratives related to various religious traditions, whereas Pahlavi carpets generally depict themes centered on the lives of the Prophet and the Imams [13]. This study, by focusing on religious symbolism in carpet design, provides insight into the semantic and symbolic aspects of Qajar carpets—features that can be utilized for semantic feature extraction in data-mining approaches to Qajar carpet imagery.

Additionally, Soleiman-Moghadam et al. (2020), in their research titled "Classification of Iranian Carpet Motifs Based on Quantitative Features Related to Aesthetics," extracted four major visual features—complexity, anisotropy, self-similarity, and the Birkhoff-like features—from images of Iranian carpets categorized into three common patterns (Afshan, Lachak-Toranj, Turkmen). The authors demonstrate that combining anisotropy with Birkhoff-like features enables highly accurate discrimination among these three categories (up to 97%) [14]. This source represents another example of machine-learning applications (SVM) and feature extraction in analyzing Iranian carpet imagery, aligning with the concept of exploratory analysis of carpets within machine-learning frameworks.

Safaran et al. (2017), in their study titled "Re-identification of Kerman Pictorial Carpets (Qajar and Pahlavi Periods)," employ a descriptive method to identify various types of pictorial rugs woven in Kerman Province during the Qajar and Pahlavi eras. The authors, while noting the transformation of Kerman carpet motifs since the Qajar period and the influence of Western naturalism, examine the main visual characteristics of Kerman pictorial carpets—such as high color diversity, rich chiaroscuro, natural floral designs, and Boteh Jeqe [15]. The study concludes that classifying Kerman pictorial carpets based on these features is feasible, suggesting that statistical and comparative analyses of Qajar-period motifs within specific regions (such as Kerman) can inform the development of machine-learning systems for identifying carpet provenance.

Sabbagh Pour and Shayesteh Far (2011), in their research "A Study of Qajar Pictorial Carpets (Held in the Carpet Museum of Iran)," examine Qajar pictorial carpets through descriptive and thematic analysis. In addition to introducing the reasons behind the emergence of pictorial carpets—such

as the influence of Western culture, interest in realism, and the expansion of print and photography—the authors categorize the common themes of these carpets into subject groups: kings, historical figures, Europeans, ancient Iran, literary narratives, religious themes, and others [16].

To date, much of the available information on Qajar carpets has been recorded in scattered, qualitative, and non-structured formats, with few studies adopting a data-driven, exploratory, and analytical approach to understanding the patterns, visual features, and structural similarities of carpets from this period. Meanwhile, recent advances in machine learning and computer vision have enabled the extraction of quantitative features from historical carpet images, thereby enabling the discovery of hidden visual patterns. Such approaches can assist in the classification of designs, identification of weaving regions, stylistic analysis, and even the digital preservation of this heritage. Therefore, the present research—aimed at creating a structured database, labeling it, conducting statistical analyses of design and motif patterns, and facilitating the development of intelligent models—represents a necessary step toward a more scientific understanding of Qajar carpet art and its potential applications in historical studies and artificial intelligence.

3. Materials and Methods

The Qajar era (1789–1925), which began after the fall of the Zand dynasty, emerged when Agha Mohammad Khan Qajar[*] seized the power and control through warfare, strategic maneuvering, and political negotiation. He also unified much of Iran under a tribal leadership system rooted in nomadic origins and earlier loyalties to the Safavids [1]. Socio-politically, the period witnessed a cultural awakening through the establishment of modern schools such as Dar al-Fonun[†] under Abbas Mirza[‡] and Amir Kabir[§], initiating modernization in education, the military, and legal systems. Students were sent to Europe, factories were established, and the press—beginning with the publication of Vaghaye Ettefaghieh in 1253 AH—cultivated an intellectual class and introduced Western concepts such as nationalism and democracy, ultimately leading to the Constitutional Revolution as a response to autocratic rule and foreign influence. Economically, dependence on foreign powers, particularly Russia and European states, led to treaties such as the Golestan and Turkmenchay, which ceded territory and imposed capitulations. These pressures, combined with mismanagement of resources and economic dependence,

weakened national sovereignty and intensified internal instability amid Europe's rapid industrialization [1].

3-1   The Significance and Value of Carpets in the Qajar Period

The growth of the carpet market during the Qajar era was driven by international demand arising from world exhibitions, museums, the Arts and Crafts movement, and the increasing purchasing power of the Western middle class. However, local capital was insufficient to meet rising demand; therefore, investments came from Iranian wholesalers, merchants, bankers (Sarraf), and Western importers who expanded the international carpet trade. Local producers initially reorganized production toward export-oriented models, adjusting dimensions and designs to suit Western tastes. Foreign companies, such as Ziegler, which operated in Sultanabad (Arak) from the 1870s onward, established domestic workshop networks to standardize production [2].

The value of Qajar carpets as symbols of Iranian art and culture is rooted in their artistic, economic, and social dimensions. As one of Iran's ancient cultural industries, carpet weaving represents a defining emblem of Iranian artistic identity and carries profound cultural and national importance. It serves as a medium through which local artisans express their beliefs, emotions, and worldviews. Qajar pictorial carpets, which emerged in the late eighteenth century, constitute a major category of carpets from this era. Influenced by artistic innovations such as printed images and photography, these carpets introduced new modes of visual expression into the medium of weaving. They reflect the cultural, social, political, and artistic dynamics of the Qajar period. The rise of these carpets was shaped by factors including the impact of Western art and culture, a growing inclination toward realism, human-centered ideas, and the introduction of photography and print—all of which enhanced their artistic and innovative significance [3].

From an economic perspective, the carpet industry in Kerman—despite the region's peripheral political position within the Qajar Empire—grew into a global enterprise. Competition among Kerman's leading families encouraged the development of cotton, opium, and carpet production, elevating the economic value of carpets as drivers of local and national transformations up to the Constitutional Revolution of 1906. These carpets formed part of Iran's economic integration into global networks and played a key role in enabling local elites to navigate political, economic, and social changes [17]. In Qajar royal paintings, carpets appear as courtly floor coverings, functioning as symbols of

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[*] The first king of Qajar era
[†] Dar al-Fonoun (also written Dar ul-Funun, Dar al-Fonoon) is the name of the first modern school in Iran, founded in 1851 by Amir Kabir during the Qajar era.
[‡] Abbas Mirza (1789–1833) was the Crown Prince of Iran and the son of Fath-Ali Shah Qajar. He was also the governor of Azerbaijan.

[§] Amir Kabir (1807–1852) was one of Iran's greatest reformers and the prime minister of Naser al-Din Shah Qajar. He founded Dar al-Fonoun, the first modern school in Iran, and made wide-ranging reforms in the military, government, economy, and justice system to modernize the country and reduce corruption. His strong, progressive policies angered powerful courtiers, leading to his dismissal, exile to Kashan, and eventual assassination in the Fin Bathhouse.

luxury and royal furnishing—thus revealing their symbolic value within court culture. Alongside carpets, felt and silk fabrics were also used as floor coverings, influencing the material and stylistic character of woven carpets [18].

Their presence in Western museums highlights the collectible and historical value of Qajar carpets. Georgiana, during her 1894 travels through Isfahan, Yazd, and Shiraz, collected 85 Qajar objects—including carpets and textiles—which she donated to the Holburne Museum in Bath. This collection became part of Britain's museum heritage and demonstrates the cultural value of Qajar carpets within Western trade and tourism contexts. Robert Murdoch Smith similarly contributed to the expansion of the Victoria and Albert Museum's collection of Qajar art, including carpets, thereby elevating their historical and artistic status [19]. Qajar-era commissioned carpets with royal insignia—such as the carpets bearing the "White Eagle" emblem produced in Kashan-Isfahan (seventeenth–eighteenth century examples later serving as models for Qajar designs)—are of high diplomatic and historical value [20].

4. Classification of Carpet Designs and Motifs

The design and motif structure of Iranian carpets, along with their color schemes, constitute some of the most significant aesthetic components of this art form. These elements play a central role in distinguishing between various carpet styles and regional traditions.[4] Design may be understood as the overarching architectural layout or the overall image formed by motifs arranged within the carpet's field. Motif refers to the individual decorative element whose characteristics embellish and articulate the design [21].

Arthur Dilley categorized Iranian carpet designs into groups such as medallion-based, hunting-ground, animal motifs, pictorial, Isfahan carpets, vase designs, Polonaise, and prayer-rug patterns [22]. Ali Hossein classified carpet designs into prayer rugs, medallions, vases, animals, baghi, ghabi, and geometric patterns [23]. Cecil Edwards initially divided Iranian carpet designs into two general styles—curvilinear and rectilinear—and then listed categories such as Herati, pine or palm motif, boteh, crab design, corner-and-medallion, Mina Khani, Shah Abbasi, willow tree, Henna-flower, and Sparkling flower* motifs [4, 21]. Azin also classified designs into Herati (or Mahi), Paisley, corner-and-medallion, Shah Abbasi, forest (weeping-willow), Sparkling flower, and crab patterns, and added motifs such as the vase, Mina Khani, Henna-flower, Haj Khanami, Afshan, Mehrabi, Mostowfi, and Chevron [4]. The Iran Carpet Company categorized carpet designs into nineteen groups, including designs inspired by ancient monuments and Islamic architecture, Shah Abbasi, Islimi, Afshan, derivative patterns, repeat patterns, boteh, tree, Turkmen, hunting-ground, Gol Farangi (European floral), panel, vase, interlaced fish (Mahi Darham), Mehrabi, Moharamat, geometric, tribal/nomadic, and composite designs [4, 21]. G. Ford divided carpets into three major groups—universal patterns, geometric patterns, and floral patterns. The universal category includes boteh, Herati, Mehrabi, tree, vase, baghi, and pictorial designs; the geometric category consists of geometric Afshan, repeat patterns, plain-field medallion, and Afshan-medallion compositions; and the floral category includes floral Afshan medallion and Afshan-medallion patterns [24]. Toraj Jooleh introduced the nineteen-part classification of the Carpet Company, pointed out its variations—from expansions to 20 or 25 groups to reductions into two or three primary categories (such as nature-inspired motifs versus human-made patterns)—and then proposed a new classification based on Golestan motifs, corner-and-medallion motifs, striped motifs, hunting-ground motifs, Herati motifs, boteh motifs, Gol Farangi motifs, derivative motifs, pictorial motifs, and Mehrabi designs [25].

Ultimately, the Haft Rokh (Seven-Face) classification has been adopted. This system, grounded in the dual axes of design and motif, includes Moharamat, Ghabi, Vagirehi, Lechek-Toranj, Baghi, Mehrabi, and Afshan patterns [4]. These are elaborated below.

4-1   Haft Rokh Classification in Carpet Design and Motifs

The Haft Rokh classification is proposed through an analytical comparison of existing systems (e.g., the Iran Carpet Company's nineteen-part taxonomy and Western models, such as Ford and Edwards). These previous models often exhibit inconsistency in naming and definition, combining diverse criteria—such as geography, motif name, or designer—without a unified framework. In contrast, Haft Rokh focuses on design as the foundational structure (composition and layout) and motifs as the decorative elements. The design establishes the overall face of the carpet, while the motifs—primary (e.g., geometric, Khatai, Islimi) and secondary (e.g., boteh, vase, animals)—decorate it [4].

This model is layered: First, the designer selects one of the seven structural patterns; next, motifs are added; finally, secondary designs may be combined (e.g., lachak-toranj with Moharamat). This approach classifies carpets on a logical basis and allows for expansion to new design types [4].

4-3   Introduction of the Seven Structural Patterns (Haft Rokh)

Each pattern is described in terms of its historical background (from the ancient to the Islamic eras) and structural characteristics. These patterns form the foundational framework of traditional Iranian carpet design, within which motifs are arranged.

1- Moharamat (Striped Patterns)

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* It is also called "Jowshghani" flower design in persian.

Parallel bands of equal width (horizontal, vertical, or diagonal), filled with continuous motifs and separated from one another. It is the simplest structural pattern, with roots in antiquity (such as the Elamite Lady Plaque from Susa). The motif appears in Achaemenid reliefs, in Behzad's illustrated manuscripts (diagonal lines on tents), and in carpets of Fars province [4]. (Figure 1)
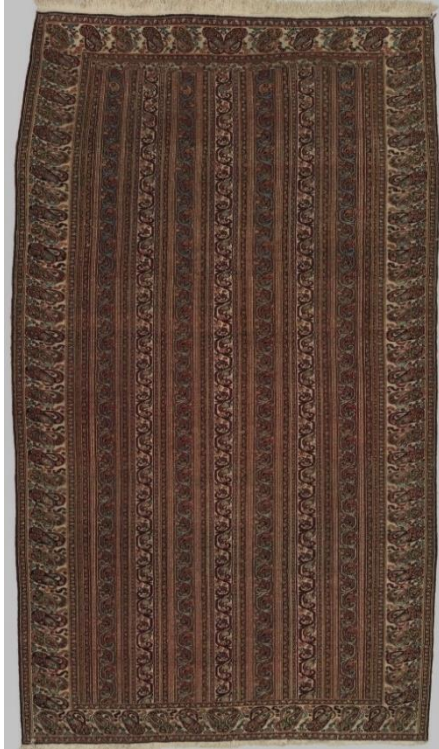

Figure 1: A Qajar carpet featuring the Moharamat design [26]

2- Ghabi Design

Motifs (either single or composite) are placed within geometric frames (square, lozenge, or "kheshti"), creating homogeneous compartments. Sometimes the negative spaces between the frames generate additional shapes. This structure appears from Shush pottery (2500 BCE) and Luristan reliefs (1300–1100 BCE) to Bakhtiari and Tabriz carpets [4]. (Figure 2)

Figure 2: A Qajar carpet featuring the Ghabi design [27]

3- Vagirehi Design

Repetition of motifs (derived from a small unit—quarter or half of the design) along vertical/horizontal axes without a specific orientation. The elements may be single motifs (such as the fish or boteh) or composite ones. Its roots trace back to Parthian-Sasanian reliefs (spirals) and the Qal'eh Qarah Eizheh site, continuing through Kashan carpets with repeating boteh motifs [4]. (Figure 3)
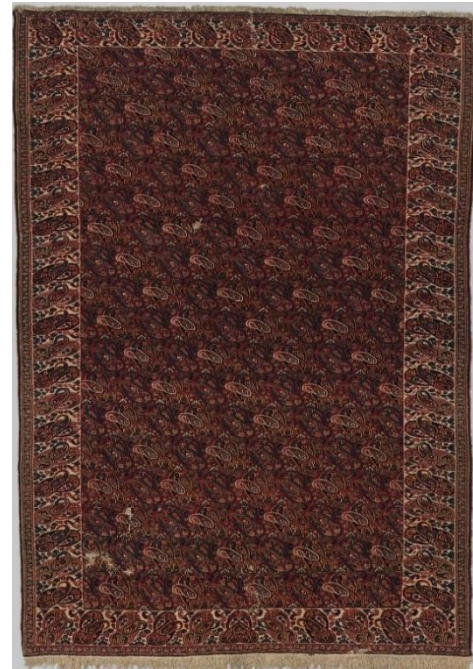

Figure 3: A Qajar carpet featuring the Vagirehi design [26]

4. Lachak–Toranj Design

A central Toranj (round or lozenge-shaped) accompanied by corner pieces (similar or varied) placed in the four corners; the field is designed separately. Variants may omit either the Lachak or the Toranj. This composition appears from Chogha Zanbil tiles and the tomb of Darius (Naqsh-e Rostam) to Islamic bookbinding and "Mowj-e Darya" carpets [4]. (Figure 4)

Figure 4: A Qajar carpet featuring the Lachak–Toranj design [27]

5- Baghi Design

Aerial or frontal depiction of the Persian garden (paths, waterways, and trees) based on garden architecture. Its origins lie in Chogha Zanbil and Pasargadae and continue to the Safavid era, where it represented an ideological interpretation of the ancient concept of Pardis [4]. (Figure 5)
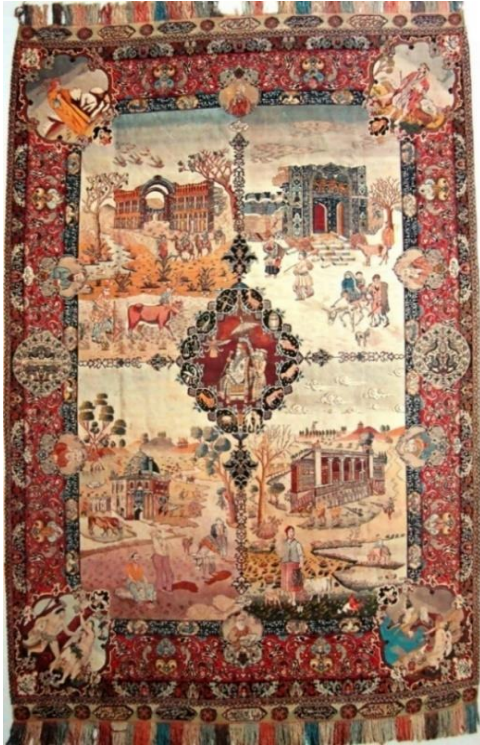

Figure 5: A Qajar carpet featuring the Baghi design [27]

6- Mehrabi Design

Two symmetrical arches in the upper half symbolize a Mehrabi. It includes prayer rug variations (with lamps and columns) and decorative versions (with trees, landscapes, or figural scenes). Its roots trace back to Mithraism (Mithraic caves) and fire temples, and in Islamic contexts to mosques and tombstone carvings [4]. (Figure 6)

Figure 6: A Qajar carpet featuring the Mehrabi design [28]

7- Afshan Design

Structure: scattered motifs with no fixed repetition or orientation (free-flowing movement), without additional structural elements. Background: from Sasanian plates (hunting, coronation scenes) to Safavid carpets with narrative themes and Qajar carpets featuring human figures [4]. (Figure 7)

Figure 7: A pictorial carpet featuring the Afshan design for Qajar period [27]

4-4   Pictorial Carpets of the Qajar Period

Pictorial carpets of the Qajar period (19th century) represent one of the most significant innovations in Iranian carpet art, marking a shift from traditional abstract and floral compositions toward realistic and narrative imagery [3]. Often woven in the royal workshops of Tabriz and Kashan, these carpets were influenced by Western cultural, social, and artistic developments, including photography, printmaking, and diplomatic relations with Europe. They depicted scenes from epics, mythology, hunting, court life, and personal portraits with meticulous detail and vivid coloring [3, 29]. The emergence of this style in the late 18th century coincided with artistic transformations in Iran and reflected a human-centered, realistic worldview, elevating carpets from functional objects to symbolic artistic creations [3] (Figure 8).

In Qajar court paintings, carpets appear as elements of royal furnishings, often combined with floor coverings such as felt and silk textiles. This integration influenced the texture of pictorial carpets and turned them into tools for displaying power and cultural identity [18]. Their themes primarily

Figure 8: Qajar pictorial carpets (1. Mehrabi, 2. Lachak–Toranj, 3. Afshan, 4. Ghabi) [30]

drew from Iranian epic and mythological literature—especially the Shahnameh—portraying pre-Islamic and Islamic characters with compositions inspired by photographic and printed frames. Such iconographic and cultural influences contributed to the formation of this genre, making the Qajar carpet a symbol of the transition from tradition to modernity. [3, 18, 29]

5. Field Design of Carpet and Its Components

In carpet design, the field occupies the largest portion of the surface and contains the main composition. Accordingly, field-design layouts are categorized as full-pattern (1/1), half-pattern (1/2), quarter-pattern (1/4), and sub-quarter (repeating) patterns (Figure 9) [5]. The following outlines each pattern:

1- Full (All-over) Pattern
The entire composition is drawn across the carpet. A common example is the Afshan hunting design.

2- Half Pattern (Longitudinal or Transversal)
Design elements are drawn with longitudinal or transverse symmetry and then duplicated by reflection to complete the carpet. Mehrabi designs are typical examples.

3- Quarter Pattern
Only one quarter—usually the upper right section—is drawn. The complete design is formed by reflecting and repeating it in the other three quarters. Lachak–Toranj designs are the most recognized examples.

4- Sub-quarter Patterns
In these patterns, the entire composition of the carpet is created through the repetition and multiplication of a Vagirehi or bands of eslimi and khataei motifs. Among the most well-known designs in this category are the Mahi-dar-ham (Interlaced Fish) pattern and the Mina-Khani pattern.
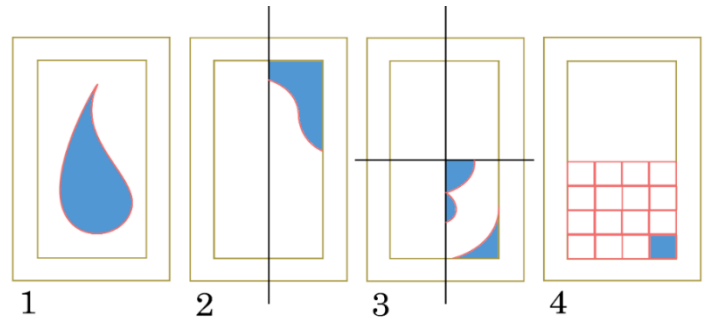

Figure 9: 1. Full Pattern 2. Half Pattern 3. Quarter Pattern 4. Sub-quarter Patterns

5-1   Rug Dimensions

Carpets are produced in a wide variety of dimensions and formats. The most common shapes include rectangular, square, circular, and oval forms. In rectangular carpets, the length and width, and in circular and oval carpets, the diameters, follow specific proportional standards [5]. (Table 1) presents the approximate dimensions of rectangular carpets available on the market.

Table 1. Common Carpet Dimensions in the Market [5]

Type	Approximate Size (cm)
Pushti (Cushion Rug)	60 × 90
Zarochark (1.25 cubits)	80 × 120
zaronim (1.5 cubits)	100 × 150
Ghalicheh (Small Carpet)	150 × 225
Parde (Panel Rug)	200 × 300
Nine meters Rug	250 × 350
Carpet	300 × 400
Large Carpet	350 × 525, 400 × 600, 500 × 800

In the market, carpets whose length-to-width ratio exceeds 250 cm are classified as Kenare-type carpets. In this study, the carpet dimensions have been determined approximately based on practical requirements.

5-2 Data Pre-processing

The following discusses the data augmentation method used in this research.

Before feeding the information into the system, the original dataset was expanded using data augmentation techniques to four times its initial size. These filters do not damage the structural integrity of the rug data (Figure 10). In this research, the emphasis is on improving data quality. By applying three specialized processing methods—Gray-style, Laplacian, and Gabor—the key visual features of carpets, including texture, edges, and patterns, are extracted and enhanced independently. This approach enables the model to achieve higher classification accuracy by accessing a wider range of information. The primary advantage of this method is the significant reduction in computational load, enabling fast execution on resource-constrained devices while maintaining classification accuracy.

Converting images to grayscale eliminates color-dependent variables, allowing the model to focus on the carpet's structural and morphological features; it also reduces color noise resulting from variations in lighting and photographic conditions. The Laplacian filter, by applying a second-order derivative to the image, highlights areas with rapid intensity changes and accentuates the edges and geometric details of the carpet pattern [31]. This two-dimensional isotropic filter helps the model better distinguish the geometric characteristics specific to each carpet type. The Gabor filter, as a powerful tool for texture analysis, identifies directional and repetitive patterns in the spatial–frequency domain. A subtle combination of this filter with the original image preserves overall clarity while enhancing the detectability of fine textures [32].

The results show that intelligent data processing can effectively replace the increased complexity of the model.

Figure 10. Data Augmentation: 1. Original Image 2. Gray-style 3. Laplacian 4. Gabor

5-3 Collecting and Labeling Method of the Data

In this study, the data collection process (focused on images of Qajar carpets) was designed systematically and step by step to construct a comprehensive and analytically reliable dataset suitable for machine-learning applications [33]. (Table 2)

First, the original carpet images were obtained from diverse, reputable sources. Since many carpets from this historical period have been lost over time due to factors such as aging, wars, and other causes, and only visual documentation remains, extensive searches were conducted across the official websites of major international and national museums. Examples include the Victoria and Albert Museum in London, the Metropolitan Museum of Art in New York, the State Hermitage Museum in Saint Petersburg, the Carpet Museum of Iran in Tehran, as well as institutions such as Astan Quds Razavi and several private collections. In addition, authoritative reference works on Persian art and carpet history were consulted as complementary sources to obtain high-quality images accompanied by historical descriptions. This initial stage relied on precise keyword searches—such as "Qajar carpet"—to ensure that selected images accurately represented carpets of that era. Although the number of available original images was limited due to restricted access, every effort was made to capture a wide range of designs, weaving regions, and stylistic variations.

After collecting the original images, data augmentation techniques were applied to address the limited dataset size, a common challenge in machine learning. These techniques were selected to increase the diversity and quantity of the images while preserving their historical authenticity. Three main augmentation methods were employed: 1. Grayscale conversion, which removes chromatic information and emphasizes structural and geometric patterns; 2. Laplacian filtering, which enhances edges and structural details and is particularly effective in identifying intricate motifs; 3. Gabor filtering, which extracts directional and textural features and is well-suited for analyzing the woven textures of carpets. Overall, the data volume was increased fourfold. This expansion not only multiplied the dataset size but also improved the robustness of machine-learning models against variations in lighting, viewpoint, and image quality—an essential requirement for applications such as design classification or regional attribution.

In the labeling stage, a comprehensive metadata file was created to organize the dataset and prepare it for analysis. This file functions as an information bank in which the attributes of each image were recorded with precision. The main columns include:

Name (image file name); Augmentation status (TRUE for augmented images, FALSE for originals); Augmentation type (Original, Gray-style, Laplacian, or Gabor); Carpet design type (lachak-toranj, Afshan, Mehrabi, Moharamat, Ghabi, Vagirehi, Baghi); Picture-carpet identification (is_picture_carpet: TRUE for carpets depicting human, animal, or landscape imagery, FALSE otherwise); Design symmetry pattern (e.g., 1\1 for full symmetry, 1\2 for half

symmetry, 1\4 for quarter symmetry, or Repetitive for carpets with repeating Vagirehi units where the pattern unit is smaller than one-quarter but repeats continuously); Storage location (such as specific museums or unknown when the exact repository could not be identified—a common issue for many lost carpets); Length and width measurements (in centimeters, based on source).

Table 2. Data Collection and Annotation

	Column Name	Column Description	Example
1	file-name	The image file names are placed in this section.	001.jpg
2	is_augmented	Whether the image has undergone data augmentation or not.	True , False
3	augmentation_type	The image model or type is specified.	Original, Gray-style, Laplacian, Gabor
4	design_type	The classification of the carpet's design and pattern is specified.	Lachak-Toranj, Afshan, …
5	is_picture_carpet	Whether the carpet data is in image form or not.	True , False
6	symmetry	The textual design pattern of the carpet is specified.	1\1,1\2 ,1\4 , Repetitive
7	storage_location	The storage location of the carpet is placed in this column.	The Victoria and Albert Museum, The Metropolitan Museum of Art, …
8	length_size_cm	In this column, the carpet's length (in centimeters) is specified.	291
9	width_size_cm	In this column, the carpet's width (in centimeters) is specified.	150
10	Carpet_size	In this column, the overall dimensions of the carpet are indicated.	Ghalicheh, Zaronim, Parde, …
11	region_of_weaving_1	The probable region of the carpet's weaving is included in this column.	Tabriz, Isfahan, No_information, …

The metadata file contains information for 800 rows, each corresponding to a single image (200 original images and the remainder augmented) [33]. All labeling has been clearly assigned and will be used for subsequent analyses. Collecting and Labeling Method of the Data not only structures the dataset but also facilitates data processing and allows researchers to perform advanced analyses, such as

information); Carpet size category (e.g., ghalicheh, kenare, carpet, large carpet, parde, zaronim, zarochark, nine meters rug); Weaving region (e.g., Kerman, Kashan, Kurdistan, or No_information when unspecified). This annotation process was conducted manually based on expert examination of the sources to ensure high accuracy. The metadata file serves as a supporting document for the research.

automatic design classification or geographical distribution studies. Ultimately, it contributes to a deeper understanding of Qajar carpet art.

6. Discussion

Based on a comprehensive examination of the metadata file—which includes 801 rows (800 valid rows related to the images and one additional row presenting average dimensions)—the dataset demonstrates significant diversity among Qajar carpets. Statistical analysis using Pandas shows that the dataset contains 200 original images and 600 augmented images, indicating that data augmentation has been effectively implemented for machine-learning applications. The following presents an analytical overview of the file [33].

The Afshan design, with 240 samples (30%), exhibits the highest frequency, reflecting the popularity of dispersed, floral compositions during the Qajar period. It is followed by Vagirehi designs (196 samples, 24.5%) and Lachak-Toranj patterns (184 samples, 23%), both of which highlight traditional Iranian motifs. Less common categories such as Mehrabi (116 samples, 14.5%), Ghabi (36 samples, 4.5%), Moharamat (16 samples, 2%), and Baghi (12 samples, 1.5%) indicate lower representation. This distribution suggests that Qajar artisans emphasized central-medallion and repeating-unit compositions, possibly influenced by European market demands. (Figure 11)
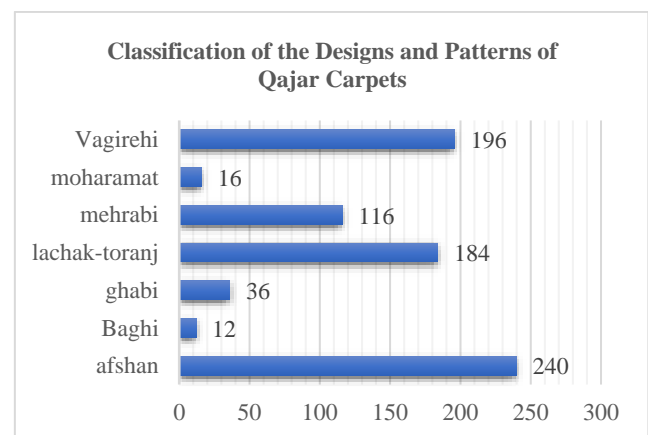

Figure 11. Classification of Qajar Carpets

Regarding pictorial carpets, approximately 41% (328 samples) are pictorial (TRUE), while 59% (472 samples) are non-pictorial (FALSE). Cross-tabulation analysis indicates that Afshan (204 pictorial out of 240) and Mehrabi (64 pictorial out of 116) designs show a greater tendency

toward pictorial elements—such as human figures, animals, or landscapes—while Vagirehi-based and Moharamat patterns are entirely non-pictorial. These findings may reflect the influence of Western art during the Qajar period, when pictorial carpets were often designed for export. (Figure 12)
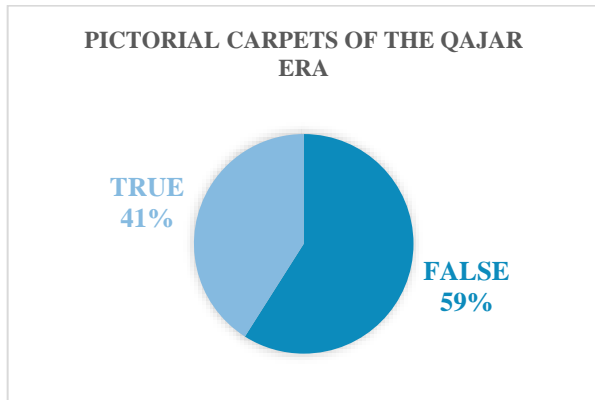

Figure 12. Percentage of Pictorial Carpets in the Qajar Era

In field-design symmetry, 1\1 symmetry (full symmetry) is dominant, with 308 cases (38.5%), frequently observed in Afshan (200 cases) and Mehrabi (56 cases) designs. Repetitive symmetry (repeating Vagirehi units or "brick-like" modular layouts smaller than one-quarter of the field) appears in 244 cases (30.5%), primarily associated with Vagirehi (196 cases) and Ghabi (28 cases) designs. 1\4 symmetry (156 cases, 19.5%) and 1\2 symmetry (92 cases, 11.5%) are more common in central medallion carpets such as Lachak-Toranj (144 cases in 1\4). These symmetry patterns highlight advanced weaving techniques in the Qajar era, enabling the scalable repetition of patterns in larger carpets. (Figure 13)
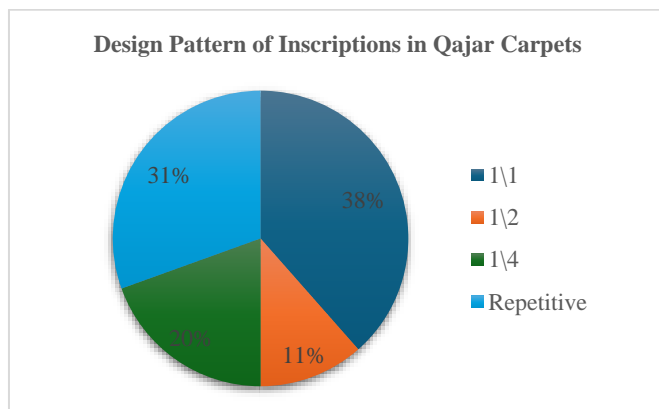

Figure 13. Design Pattern of Inscriptions in Qajar Carpets

In terms of storage locations, the largest proportion of carpets (348 samples (43.5%)) have unknown repository information, likely due to loss, private ownership, or incomplete records. The State Hermitage Museum holds 204 samples (25.5%), followed by the Carpet Museum of Iran with 96 samples (12%), reflecting substantial Qajar-period holdings in Russian and Iranian collections. Western museums, including the Victoria and Albert Museum (56

samples) and the Metropolitan Museum of Art (28 samples), are also represented, but to a lesser extent. Cross-tabulation with weaving regions shows that carpets labeled as No_information often appear under unknown storage categories (228 samples), highlighting historical challenges in provenance documentation. (Figure 14)
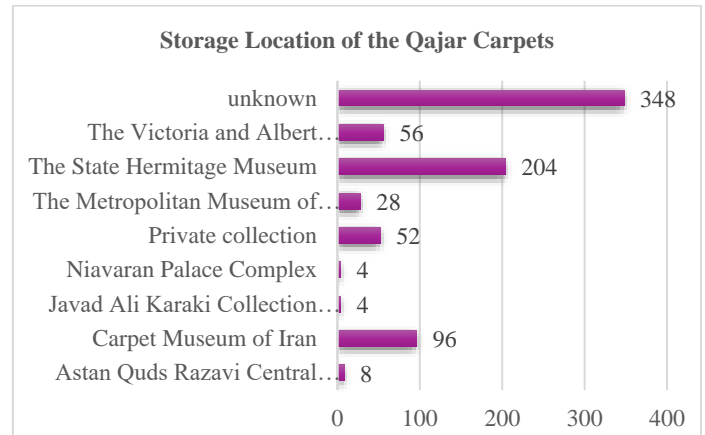

Figure 14. Storage Locations of Qajar Carpets

Regarding carpet dimensions, the dataset shows a predominance of Ghalicheh-size carpets (448 samples, 56%) with an average overall size of 273.6 × 171.7 cm. Larger carpet types—such as large carpets (56 samples) and nine-meter carpets (28 samples)—are less frequent. Group analysis indicates that Ghabi designs exhibit the largest mean dimensions (453 × 302 cm), while Mehrabi carpets tend to be smaller (191.7 × 137.3 cm), possibly reflecting their ritual or domestic functions. (Figure 15)
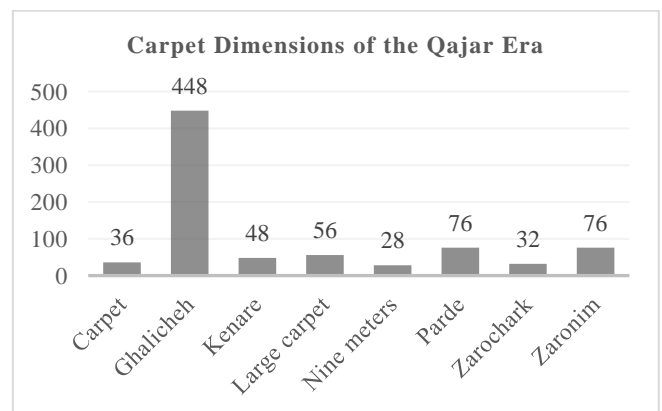

Figure 15. Carpet Dimensions of the Qajar Era

In the weaving regions, 228 samples (28.5%) lack regional information. Kerman (16.5%; 132 samples) and Kashan (14%; 112 samples) are the leading centers, reflecting their prominence in carpet production during the Qajar era. Other regions, such as Bakhtiari (44 samples) and Kurdistan (32 samples), are also represented. Cross-tabulation by design shows that Kerman specializes primarily in Afshan (48 samples) and Vagirehi (32 samples) patterns, whereas Tabriz demonstrates strength in Baqi (12 samples) and Ghabbi (8 samples) designs. Average dimensions also vary: Bakhtiari carpets show the largest mean size (333.7 × 253.8

cm), whereas Malayer carpets exhibit the smallest (164.2 × 108.5 cm). (Figure 16)
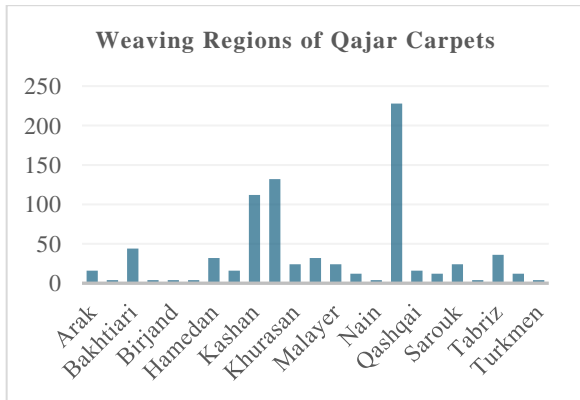

Figure 16. Weaving Regions of Qajar Carpets

These findings highlight the evolution of Qajar carpet art shaped by economic, cultural, and commercial factors. The relationships between variables—such as the association of pictorial carpets with Kerman and Kashan—can provide valuable insights for machine-learning models.

7. Conclusion

Based on a comprehensive analysis of the metadata file—including 800 rows of data on images of Qajar carpets (200 original images and 600 augmented versions)—this study presents a clear depiction of the diversity and complexity of carpet weaving during this period. The key findings reveal a strong emphasis on traditional designs, such as Afshan (30%) and Lachak-Toranj (23%), and a notable use of pictorial elements (41%), reflecting Western influence and commercial motivations. Symmetry patterns such as 1\1 (38.5%) and Repetitive/brick-like arrangements (30.5%) demonstrate advanced technical capabilities, while Kerman (16.5%) and Kashan (14%) emerge as major production centers. However, 28.5% of the samples lack regional information, underscoring challenges in historical documentation. Furthermore, 43.5% of the carpets have unknown storage locations, underscoring their dispersed presence across global collections, including the Hermitage Museum (25.5%).

These findings illuminate the development of Qajar carpet art as a bridge between Safavid traditions and modern influences while emphasizing its economic significance in trade networks. The existing informational limitations emphasize the importance of modern analytical approaches—such as machine learning—for future research.

8. Statements & Declarations

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AI-Assisted Technology Declaration: This manuscript

preparation was assisted by AI-powered language tools (ChatGPT 5.0) solely for language editing, grammatical correction, and translation of technical terms. No AI tools were employed to generate, modify, or interpret scientific content, analytical procedures, results, or their interpretations. All research methodology, data analysis, findings, and conclusions are entirely the product of the authors' scholarly work and expertise. This research was translated in Azar 1404 (December 2025) with the assistance of the ChatGPT 15.1(GPT-5) artificial intelligence model.

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8-3 Author Contributions

Siamak Sarbazi contributed 50% of the work, including the primary research, data analysis, and manuscript preparation. Azadeh Yaghoubzadeh contributed 30% through supervision, methodological guidance, and critical revision of the manuscript. Mahdi Sarbazi contributed 20% by providing advisory support, assisting with data interpretation, and reviewing the final version of the manuscript.

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