

DIGITALIZATION AND MODERN APPLICATION OF ISLAMIC PATTERNS.**S.Egamnazarova**

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Abstract. There is currently a trend towards the use of Islamic geometric patterns (IGPs) as important identity and cultural elements of building design in the Middle East. This article reviews the latest knowledge of IGPs, surveys the main principles, presents the status, and identifies gaps in recent research directions. Finally, future perspectives are discussed by focusing on different aspects of the principles in accordance with the accumulated evidence obtained the review.

Keywords: Islamic patterns, digitization, geometric patterns, cultural heritage, digital archive, contemporary design, statistical analysis, computer vision, architectural decoration, traditional art.

Introduction. Patterns, an integral part of Islamic art and culture, have been one of the main elements of architecture, applied decorative arts, and artistic production for centuries. Although the history of Islamic patterns dates back to the 7th century, their development and spread have had their own characteristics in different periods and regions.

According to historical data, Islamic patterns first appeared during the Umayyad Caliphate (661-750) and were further improved during the Abbasid, Fatimid, Seljuk, and Ottoman periods. [1] These patterns are divided into geometric, floral, and epigraphic types. Geometric patterns are especially important, as they are created on the basis of mathematical laws and represent a symbol of divine order and chaos. [2]

With the development of modern technologies, the methods of preserving, analyzing, and processing Islamic patterns have also changed. The digitization process has made it possible not only to preserve traditional patterns, but also to reinterpret them and apply them in modern design areas.

Nowadays, the digitization of Islamic patterns is gaining relevance due to several factors:

Preservation of cultural heritage - many traditional patterns are disappearing over time

Education and research - the opportunity to study and analyze patterns in digital format

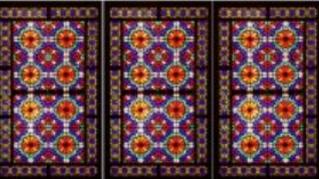
Contemporary design - the application of traditional patterns in new materials and contexts

Global exchange - the distribution of patterns in digital format worldwide while respecting copyright

One of the most distinctive and promising fields of Islamic art—the world of patterns—is gaining new interpretations and applications in the era of modern digital technologies. While Islamic patterns have played an important role in architecture, applied decorative arts, and artistic production for centuries, today they are acquiring new life through digitalization. This article explores the digitization of Islamic patterns, their analysis, preservation, and opportunities for use in modern design fields.

Nowadays, there is a trend of using traditional elements in contemporary Middle Eastern buildings [3]. Islamic geometric patterns are considered one of the main features of Islamic architecture in many cultural traditions of Islamic countries [4,5,6]. Patterns borrowed from Byzantine and Sassanian periods became part of Islamic design during the 7th century, expanding significantly in the 8th–9th centuries in the Middle East, Iran, and Central Asia, due to remarkable growth in science and technology [7,8]. Islamic geometric patterns represent a unique idiom, characterized by interconnected networks of stars and polygons, as well as various forms of high-level symmetry and repetition at both local and global scales [7]. They include many simple forms within the most complex and multilayered designs that appear in both two-dimensional and three-dimensional patterns. As shown in Figure 1, Islamic Geometric Patterns

(IGPs) have been used for centuries as program-based purposes that encompass aesthetics, stability, and structure.

Application		Where	Figures			
Aesthetic-based	Aesthetic-based	Walls, ceilings, <i>muqarnas</i> , <i>yazdi bandi</i>	Shah Ne'matollah Vali shrine, Mahan, Iran		Shah Mosque, Isfahan, Iran	
	Sustainable-based	Entrance and window separators, orosi and mashrabiya	Nasir al-Mulk Mosque, Shiraz, Iran.		Hasht Behesht, Isfahan, Iran	
	Structural-based	<i>Karbandi</i> , scalastic vaults, <i>muqarnas</i>	Timcheh Mozaffariyeh, Tabriz, Iran.		Jameh mosque, Isfahan, Iran	

Due to their fundamental principles, Islamic Geometric Patterns (IGPs) can offer multiple sources of topologies and geometries that may be explored in developing initial designs through computer science and creative technology tools. Recently, discussions on IGPs have largely revolved around widely recognized and symbolic architectural examples in Islamic countries, designed by renowned architects such as Jean Nouvel, Zaha Hadid, and Norman Foster. In these cases, IGPs are incorporated into building envelopes with formal inspiration, primarily for aesthetic and sustainable purposes, and only rarely for structural objectives. To discover new patterns, exploration must go beyond existing examples and examine the “emergence and evolution of architectural forms” [8]. Such an approach opens new research opportunities and revives open inquiry that positions Islamic architecture as an active contributor to global architecture. To achieve this, it is necessary to understand the fundamental principles of IGPs and their potential in relation to new design developments.

To the best of the authors' knowledge, there is still no comprehensive review in the literature that synthesizes research, design, and development efforts on IGP principles. This article aims to fill that gap by thoroughly reviewing and analyzing both their traditional applications and new developments. The study establishes a proper definition of IGP principles by carefully examining previous research and classifying them in terms of their applications in aesthetic, sustainable, and structural directions. Subsequently, it provides an overview of modern trends in these principles within computer science and related technologies. Furthermore, the review highlights the knowledge gaps regarding program-based principles that need to be addressed in order to enhance the potential of IGPs for widespread application in contemporary architecture. Finally, this article proposes several important recommendations for future research.

Scope and Methodology. As integral aspects of Islamic visual aesthetics, three forms of art can be recognized: floral patterns, calligraphy, and geometric patterns. This review focuses on studies related to Islamic abstract geometric patterns, particularly in connection with developments in computer science and their applications through relevant technologies.

The preliminary analysis of the selected articles led to the use of certain taxonomies for their review: aesthetic, sustainable, and structure-based applications are regarded as the primary representations of IGPs in contemporary architecture. Moreover, the initial evaluation of the selected papers highlighted that the objects discussed in the literature reviews correspond to the

main taxonomy criteria, encompassing program-based purposes of aesthetics, sustainability, and structure.

Following the literature survey, all principles—drawn from the sources, including primary references—were extracted. Two-dimensional and three-dimensional IGPs can be regarded as symbols of aesthetics through proportions, ratios, symmetry, variations, scales, fabrication methods, and multilevel features. On the other hand, principles such as natural lighting, thermal performance, and visual comfort are classified as sustainability-based applications. Finally, structure-based applications are classified according to principles such as load distribution, self-supporting capacity, material properties, and others.

The classification according to these criteria was refined and established during the data collection process; therefore, the categorization of each criterion is itself a result of the study. As became evident after examining all articles related to the principles, sub-taxonomies cannot initially be identified due to the presence of undefined principles.

Classification of Informatics and Related Technologies

All the works examined in the modern section should fall under the category of computer science and related technologies. Recent developments in this field provide new opportunities for generating novel Islamic Geometric Patterns (IGPs). The foundations for the relevant categories are outlined below.

Numerous modern approaches for restoration and reconstruction—such as photogrammetry and laser scanning techniques (López et al., 2018)—are classified as *digital measurements*. New fabrication tools such as robotic manufacturing, 3D printing, and 3D projection are classified as *digital fabrication*. Text-based programming languages such as Python, Visual Basic, C#, and Rhino Script, along with visual programming tools like Grasshopper, Revit, and others, are classified as *digital modeling*. Contributions also come from advanced computer science and digital modeling domains, including formal grammar, graph theory, virtual reality technologies, augmented reality, optimization, and machine learning.

These advancements are also evident in software development, enabling efficient—often semi-automated—processing of source data and the creation of various ready-to-use outputs, categorized as software tools.

The digitization of Islamic patterns not only allows for their preservation and analysis but also provides opportunities for reinterpretation. In digital format, patterns can be easily adapted to different scales, recolored, and applied to various materials. This expands the potential applications of traditional patterns in modern design and architecture. However, preserving the spiritual and symbolic meanings of the patterns during digitization remains a critical challenge. Research has shown that in some cases, the meanings of patterns are lost when only their visual appearance is digitized.

Conclusion. The digitization of Islamic patterns represents a vital step in bringing this traditional art into a new era. With digital technologies, the processes of analyzing, preserving, and reinterpreting patterns can become significantly more efficient. Nevertheless, it is essential to account for the cultural, spiritual, and symbolic dimensions of the patterns during this process. In the future, it would be appropriate to explore the possibilities of using artificial intelligence and machine learning technologies to automatically analyze Islamic patterns and generate novel ones.

References

1. Abas, S. J., & Salman, A. S. (1995). Geometric and Group-Theoretic Methods for Computer Graphics Studies of Islamic Symmetric Patterns. *Computer Graphics Forum*, 14(1), 43–53.
2. Kaplan, C. S. (2000). Computer Generated Islamic Star Patterns. *Proceedings of Bridges: Mathematical Connections in Art, Music, and Science*.
3. Lu, P., & Steinhardt, P. J. (2007). Decagonal and Quasi-crystalline Tilings in Medieval Islamic Architecture. *Science*, 315(5815), 1106–1110.
4. Özdural, A. (1995). On Interlocking Similar Polygons and Curved Figures in Islamic Geometric Ornament. *Muqarnas*, 12, 191–211.

5. Python Software Foundation. (2025). Python Documentation. <https://www.python.org>
6. Qizi, E. S. X. (2025). INFOGRAFIKA: TA'LIM JARAYONIDA VIZUAL MA'LUMOTLARNI YETKAZISHNING ZAMONAVIY USULI. *Al-Farg'oniy avlodlari*, 1(2), 23-28.
7. Qizi, E. S. X., & Qizi, R. F. X. (2024). TA'LIMDA INFOGRAFIKA: MA'LUMOTLARNI CHIROYLI KO'RSATISH SAN'ATI. *Science and innovation*, 3(Special Issue 33), 389-394.
8. Egamanazarova, S. X., & Siddiqov, I. (2023). ZAMONAVIY TA'LIMDA SCRIBING INTERAKTIV VIZUAL ALOQA VOSITASI SIFATIDA. In *E Conference Zone* (pp. 62-69).
9. Sevaraxon, E. (2023). NEW INNOVATIVE TECHNOLOGIES TO ENGAGE STUDENTS IN THE LEARNING PROCESS. *Gospodarka i Innowacje*, 41, 469-475.