DIGITAL INTEGRATION OF NATIONAL ORNAMENTS FOR CLASSIC FURNITURE

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Abstract: *This scientific article investigates the integration of geometric (girih) and floral (islimi) ornaments - integral parts of Uzbekistan's national architectural heritage - into modern classical furniture design through the lens of digital technologies. The relevance of the study is determined by the need to preserve national identity in the context of globalization and to adapt traditional art forms to industrial production (CAD/CAM, CNC, parametric design). The work analyzes patterns from the Topkapı scrolls and the architectural decoration of the Timurid period, developing a methodology for applying them to the tectonic and ergonomic structures of furniture products. New methods for the symbiosis of complex quasicrystalline grids with classical furniture forms using digital algorithms are proposed. As a result, the possibility of serial production of patterns with accuracy up to 0.01 mm using CNC technologies is substantiated. The study reveals not only the aesthetic but also the constructive and functional aspects of national ornaments.*

Keywords: *Girih, parametric design, classical furniture, digital integration, islimi pattern, ergonomics, tectonics, CAD/CAM technologies.*

INTRODUCTION

In today's global design industry, the priority is to apply high-tech solutions while preserving cultural identity. Uzbekistan's rich architectural and artistic heritage,

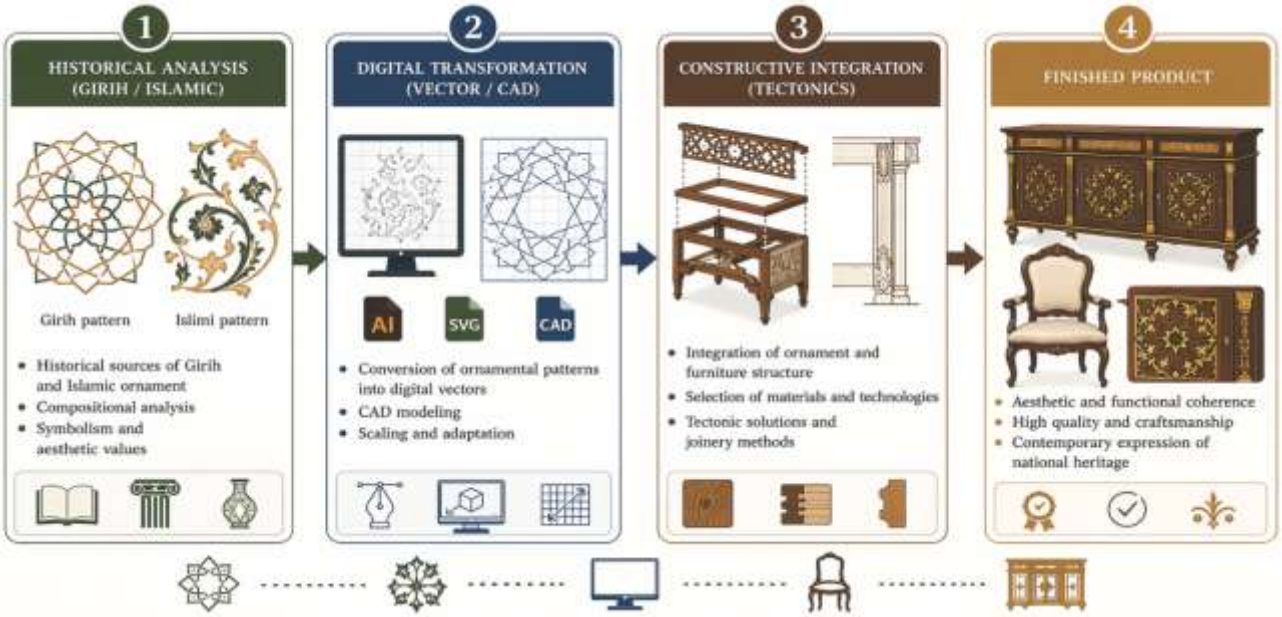

Figure 1. Conceptual scheme of integration of national ornament in classical furniture. Source: developed by the author.

particularly the system of girih and islimi patterns, serves as an inexhaustible source for modern interior and furniture design due to its mathematical perfection and aesthetic appeal. Digital technologies, especially parametric modeling and computer-aided manufacturing (CAM) systems, allow introducing complex ornaments formed over centuries into classical furniture design in a new context (Ziyodullayev, 2023). The relevance of this article lies in the need to transform traditional craftsmanship through digital algorithms and bring them to the modern consumer market as competitive products. The conceptual framework of integration is shown in Figure 1.

The aim of the research is to develop theoretical and practical principles for integrating Uzbek national ornaments into classical furniture design using digital technologies. To achieve this goal, the following tasks were defined: to analyze the mathematical and geometric structure of national ornaments from the perspective of digital modeling; to determine the tectonic connection between ornament and furniture construction; to evaluate the ergonomic and aesthetic capabilities of modern digital manufacturing technologies in furniture design. The object of the study is classical furniture in national style, and the subject is the methods and principles of digital integration of ornaments.

The scientific novelty lies in the fact that for the first time, the quasicrystalline properties of girih patterns and decorative schemes from the Topkapı scrolls are studied in relation to parametric algorithms in modern furniture design (Necipoğlu, 2017). The practical significance is demonstrated by the fact that the developed

recommendations and models can be used by furniture industry enterprises to create innovative products under a national brand.

METHODS

The research was based on the methodology of design theory and architectural history. First, a comparative analysis method was used to study technological differences and harmonies between traditional hand-carved woodwork and modern CNC (Computer Numerical Control) technologies. This method revealed opportunities to increase production efficiency without losing the visual quality of the ornament (Uralov, 2020). Additionally, using grapho-analytical methods, the geometric grids of national patterns were converted into digital vector forms, allowing proportional scaling of the ornament according to furniture dimensions.

Within the case-study method, girih samples from Timurid architectural monuments, specifically the ten-pointed star compositions of the Shah-i-Zinda ensemble and the Bibi-Khanym Mosque, were analyzed (Masson, 1950). These historical samples were processed using digital algorithms and adapted to the facade

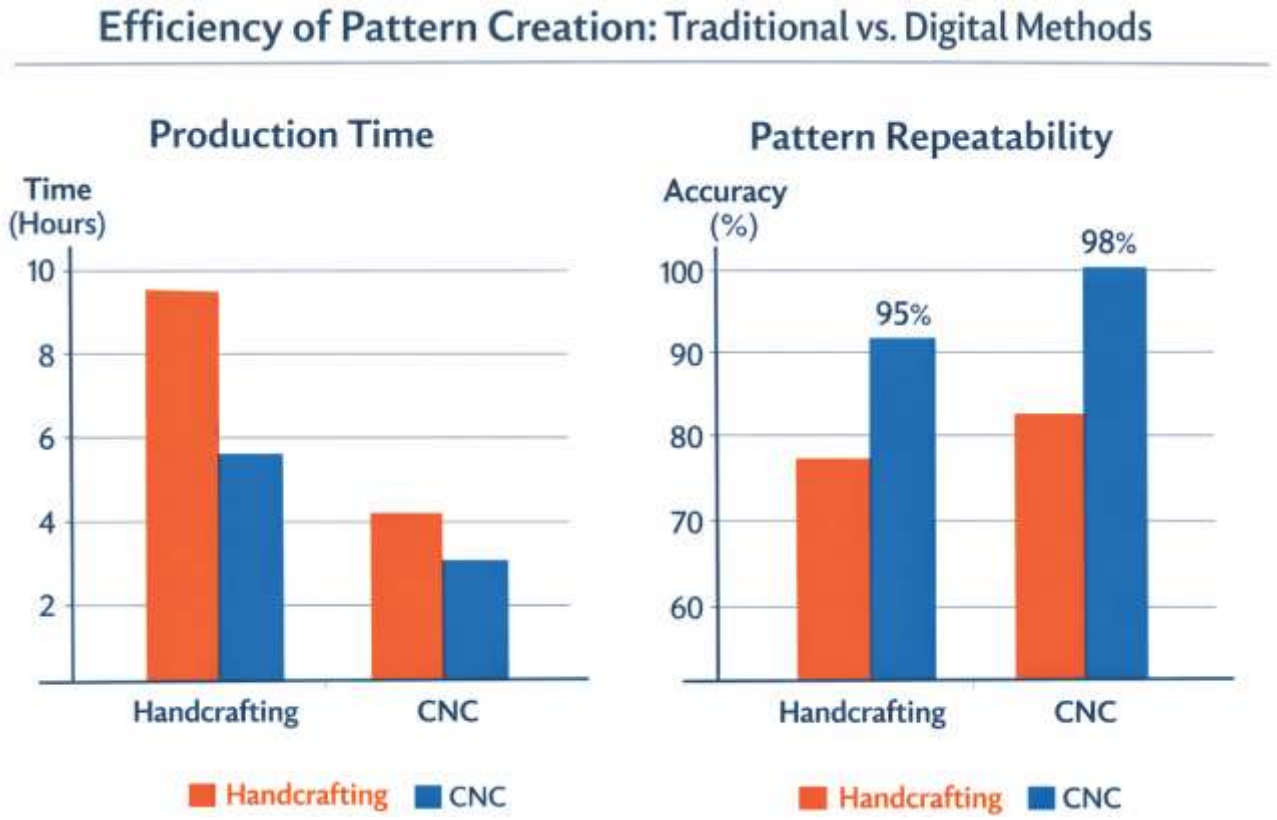

Figure 2. Efficiency Diagram of Pattern Creation Using Traditional and Digital Methods. Source: developed by the author.

and structural parts of furniture products. The main role was played by the design modeling method. A three-dimensional model of classical furniture (e.g., a chair or buffet) was created using modern CAD software, and parametric girih grids were integrated onto its surfaces. This method allowed visualization of not only aesthetic but also ergonomic indicators (Subachev, 2021).

The research methodology focuses on viewing ornament not merely as a decorative element but as a part defining the architectonics of furniture (Pugachenkova, 1950). The relationship between the physical properties of materials (walnut, oak, MDF) and the depth of digital processing was also considered. It is known that material is the main factor determining the designer's activity and product shape. Therefore, the study specifically analyzed the impact of digital technologies on material priority (Mukhamadiev et al., 2017). The efficiency diagram of pattern creation using traditional and digital methods is shown in Figure 2.

RESULTS

The conducted research revealed several regularities for applying national ornaments to classical furniture design. First, it was confirmed that girih patterns consist of five standard shapes (Tabl, Shesh band, Sormeh dan, Torange, Pange) and that their mathematical symmetry fully corresponds to aperiodic grids (Penrose tiling) in digital design (Lu & Steinhardt, 2007). This allows creating compositions of complex girih on furniture surfaces that are infinitely repeatable but have a unique rhythm.

As a result of digital modeling, a parameter table was formed regarding the degree of "stylization" of islimi patterns and their harmony with curved parts of classical furniture (e.g., cabriole legs) (Toshqo‘ziyeva, 2022). It was found that the

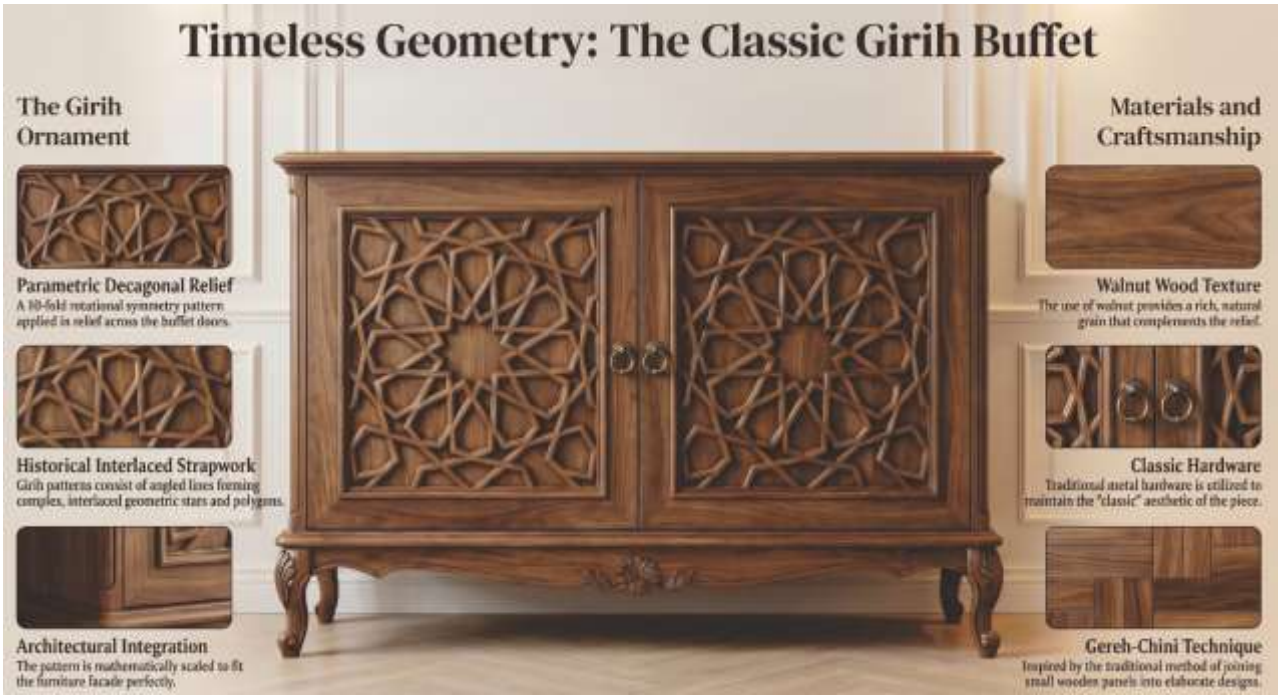

Figure 3. Classic Buffet with Girih Pattern (Project Visualization). Source: developed by the author.

accuracy of carved patterns obtained using CNC technologies reaches up to 0.01 mm compared to handwork, minimizing errors in serial production of complex compositions.

Design experiments showed that the concept of "rapport" plays a central role in integrating ornament into furniture. In a digital environment, dynamic changes in the repeating unit (rapport) relative to the overall scale of the furniture impart visual lightness and compositional balance to the product (Mukhamadiev et al., 2017). According to design conclusions, in classical furniture design, national ornaments should serve not only as surface decoration but also as elements ensuring the constructive integrity of the product. For example, lattice girih on cabinet doors can perform both decorative and ventilation functions (Voronina, 1950). A visual example of such a solution is shown in Figure 3.

As a result of the study, a final principles model for the digital integration of national ornaments into classical furniture was developed. This model rests on three pillars: geometric rigor (girih logic), plastic softness (islimi aesthetics), and technological precision (CNC capabilities).

DISCUSSION

The digital transformation of national ornaments also occupies an important place in the context of international design research. For example, the discoveries of Peter Lu and Paul Steinhardt regarding Islamic geometric patterns open new perspectives for our local furniture industry (Lu & Steinhardt, 2007). While foreign researchers view girih as a mathematical algorithm, our approach focuses on synthesizing it with the "architectonic language" of classical furniture (Kaplan, 2021). In this process, it should be noted that digital technologies should not replace the craftsman but rather expand their capabilities (Matniyazov & Bo'ronov, 2025).

A controversial aspect is that patterns obtained through CNC milling may sometimes lose the "lively" effect of handwork (Zasypkin, 1950). However, this problem can be overcome through the multi-layer and combined processing methods proposed in our study. Foreign experience, particularly the methodology of Italian designers in harmonizing antique and modern styles, encourages us to present national ornaments not only as historical elements but also within the framework of the modern "neo-classical" concept (Bonner, 2017). The final model developed based

Figure 4. Principles of digital integration of national furniture design (Final model). Source: developed by the author.

on these discussed principles is summarized in Figure 4.

Limitations of the work include the fact that digital technologies cannot produce all types of complex reliefs (e.g., deep pargar style) with the same quality. Nevertheless, parametric design allows ergonomically adapting ornaments to the user, for example, simulating the effect of a pattern on a chair back on the human lumbar region using a computer (Subachev, 2021). This, in turn, requires a functional and medical approach to classical design.

CONCLUSION

Based on the conducted research, the following conclusions were formulated:

1. Uzbek national ornaments (girih and islimi), due to their geometric algorithms, have the ability to fully integrate with modern digital technologies. The mathematical logic of girih serves as a basis for creating complex and unique parametric models in CAD/CAM systems (Lu & Steinhardt, 2007).

2. In classical furniture design, ornament integration should derive from the tectonic and functional characteristics of the product. Ornament should appear not

just as decoration but as a system ensuring ergonomic comfort and structural strength (Mukhamadiev et al., 2017).

3. Digital technologies (CNC, 3D scanning) serve to adapt national heritage samples to serial production while preserving their artistic value and ensuring scalable flexibility (Ziyodullayev, 2023).

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