Media Archiving Tradition: Algorithmic Analysis and Preservation of Geometric Patterns in Historical Architectural Monuments

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Abstract

This article proposes that examining the algorithmic structure analysis of geometric patterns with computational methods has a significant role in preserving and restoring various examples found in architectural structures of historical importance. Using computational methods, researchers can accurately analyze the intricate details of geometric patterns and detect any damage or deterioration in artworks. This information can then be used to develop effective conservation and restoration strategies, ensuring that these architectural structures are preserved for future generations to appreciate. Through systematic examination of geometric patterns, we gain insight into these structures' craftsmanship and cultural significance and create a digital archive that can aid long-term preservation efforts. The article conducts a structural analysis of six distinct geometric pattern examples that are present within the traditional context. It employs a combination of applied mathematical and empirical approaches to propose form-specific methods for computationally generating significant motifs passed down through tradition. Adopting this approach makes it feasible to transfer patterns that are defined algorithmically to future contexts, regardless of the medium used. This approach also provides a means to mitigate the risk of technological obsolescence.

Keywords

Geometric Patterns, Algorithms, Preservation, Architecture, Coding

Introduction

The preservation and documentation of historical architectural monuments have long been pivotal in understanding the rich cultural heritage of civilizations spanning centuries. Among the myriad facets that contribute to the uniqueness of these monuments, geometric patterns hold a particularly significant place. These patterns, often intricately woven into architectural designs, serve as visual narratives of cultural, mathematical, and artistic expressions. However, the challenge lies in their preservation, especially in the face of natural wear and tear, vandalism, and the passage of time. Traditional methods of documentation have played a crucial role, but recent advancements in technology, particularly in the realm of algorithmic analysis and media archiving, have opened new horizons for the study and preservation of these geometric patterns. This paper delves into the fusion of tradition and technology by exploring the application of algorithmic analysis in the preservation of geometric patterns found in historical architectural monuments, shedding light on the potential benefits and challenges of this innovative approach in safeguarding our global cultural heritage.

The preservation of geometric patterns within historical architectural monuments holds profound significance in our understanding of cultural heritage and architectural evolution. These patterns serve as a bridge connecting us to the aesthetics, symbolism, and mathematical prowess of past civilizations. They encapsulate the intricate design philosophies, religious beliefs, and societal values of bygone eras, offering valuable insights into human history's artistic and technical achievements. Geometric patterns are not mere embellishments; they represent a universal language transcending linguistic and temporal boundaries. By preserving these patterns, we safeguard the collective memory of our global civilization, allowing future generations to appreciate and learn from the masterful craftsmanship of our ancestors. Moreover, the preservation of geometric patterns is essential for the continued study and interpretation of architectural history, aiding architectural historians, archaeologists, and conservationists in unraveling the secrets concealed within the walls of these monuments. As we delve into algorithmic analysis and media archiving to preserve these patterns, we embark on a journey to bridge the gap between tradition and technology, ensuring that our shared architectural heritage remains accessible, interpretable, and revered for generations to come.

The significance of preserving geometric patterns in historical architecture becomes even more pronounced when considering their role in the Islamic Enlightenment Period, a pivotal era in the history of science, art, and architecture. During this flourishing period of Islamic civilization, spanning from the 8th to the 13th centuries, geometric patterns were not merely ornamental; they were a manifestation of profound intellectual pursuits. Islamic scholars made substantial contributions to mathematics, particularly in the field of geometry, and these achievements found vivid expression in the architectural marvels of the time. The intricate geometrical designs adorning structures like the Alhambra in Spain and the Shah-i Zinda in Uzbekistan are emblematic of the intellectual and artistic synergy of the Islamic Enlightenment Period.

Figure 1. Shah-i Zinda in Uzbekistan

These patterns showcased the application of advanced mathematical concepts, such as tessellations and symmetries, reflecting a deep understanding of geometry's aesthetic and spiritual dimensions. Preserving these patterns allows us to unlock the legacy of this enlightened period, providing valuable insights into the interplay of science, culture, and architecture and how it shaped the architectural landscapes that continue to inspire awe and admiration today. These patterns not only served as decorative elements but also symbolized the harmony between the physical and metaphysical realms, emphasizing the holistic approach to knowledge and understanding during that time.

Approaches to preserving and documenting architectural heritage

The origin and specific techniques employed in the creation of these intricate geometric patterns remain largely unknown. However, it is indisputable that these patterns arise as a result of an iterative process aimed at producing symmetrical arrangements utilizing compasses and rulers. Oftentimes, these patterns encompass geometric forms, which are carefully organized to produce intricate designs. The visual appeal and aesthetic qualities of geometric patterns stem from their precise construction and adherence to mathematical principles. These patterns have been found in various cultures throughout history, such as Islamic art and ancient Greek architecture. The mathematical principles behind these designs allow for a harmonious balance between symmetry and complexity, captivating the viewer's attention and creating a sense of order and beauty. This design tradition is difficult to categorize due to its diversity and complexity, and no systematic method of comprehensive classification has been established [1][2][3].

Despite the lack of a comprehensive classification system, significant efforts have been made to preserve these artifacts in the future. Commonly, the preservation and documentation of architectural heritage relied heavily on traditional methods such as photography, sketches, and written descriptions. While invaluable in their time, these approaches often presented limitations in accurately capturing the intricate details of geometric patterns and architectural elements [4]. Drawings and photographs, for instance, might not fully convey the three-dimensional complexity of a structure or the subtle variations in geometric motifs. As a result, there has been a growing need for more comprehensive and technologically advanced methods that can capture, analyze, and archive architectural heritage with higher precision. With the advent of 3D scanning and imaging technologies, architectural preservation and documentation entered a new era. Laser scanning, photogrammetry, and LiDAR (Light Detection and Ranging) have revolutionized the field, allowing for highly detailed and precise 3D models of historical monuments [5][6]. These technologies enable researchers to capture not only the geometric patterns but also the spatial relationships between architectural elements. Nevertheless, these technologies are burdened by high costs, intensive data processing, and integration issues. Despite these challenges, the benefits of using these technologies in architectural research are undeniable. They provide a more comprehensive understanding of the built environment, allowing for more accurate analysis and design. Additionally, advancements in technology and data processing are continuously improving, which may help alleviate some of the current limitations.

In addition to the previous methods, recent efforts such as machine learning algorithms, computer vision techniques, and pattern recognition software have been applied to process large volumes of data efficiently and automatically identify geometric patterns [7][8]. This shift offers the advantage of both scalability and accuracy, making it possible to analyze extensive datasets of architectural heritage more comprehensively and in less time. Algorithmic analysis also promises to uncover hidden patterns and correlations that may not be apparent through manual observation alone, enriching our understanding of architectural history and aiding in the preservation of cultural heritage for future generations.

Media archiving plays a crucial role in the preservation of cultural heritage by serving as a custodian of diverse forms of documentation, including photos, videos, 3D data, interactive maps, audiovisual narratives, immersive experiences, and more [9][10][11][12]. This process involves managing and storing overwhelming amounts of data, contributing to the broader domain of heritage preservation. In the context of architectural heritage, media archiving becomes a crucial tool for capturing not only the physical attributes of historical monuments but also the intangible aspects of cultural significance, historical narratives, and artistic expressions embedded within them. By digitally archiving these diverse media forms, we ensure that the multifaceted stories of our heritage are not lost to the ravages of time.

Nevertheless, media archiving addresses the critical issue of the long-term preservation of heritage assets. Digital formats, when properly managed and backed up, can provide a reliable means of safeguarding heritage materials against physical deterioration, natural disasters, and other threats. Archiving also allows for the creation of multiple copies stored in diverse locations, reducing the risk of total loss. Furthermore, as technology evolves, digital archives can be updated and migrated to new formats, ensuring the continued accessibility and integrity of heritage materials over time. In this way, media archiving not only serves as a proactive strategy for mitigating risks but also as a dynamic and adaptable tool in the ongoing effort to preserve our architectural heritage for future generations.

Algorithmic Analysis in Geometric Patterns for Heritage Documentation

Algorithmic analysis in geometric patterns for heritage documentation refers to the application of computational algorithms and techniques to analyze, process, and extract information from data related to cultural heritage sites, artifacts, or monuments. This approach combines digital technology, computer science, and heritage conservation to achieve various objectives, including documentation, preservation, and analysis. This method is based on the assumption that geometric patterns can be reproduced by applying specific algorithms. By applying algorithmic analysis to geometric patterns for heritage documentation, researchers and conservationists can precisely capture and represent the intricate details of designated patterns. The information sought for preservation purposes is undoubtedly information on how the pattern can be reproduced in terms of its geometric form content. Because this method allows for the accurate replication of geometric patterns, it guarantees that geometric compositions will be available to generations in the future. This method aims to preserve the pattern by considering the drawing methods, as opposed to proposing a preservation strategy that is faithful to the geometric pattern's material properties. By focusing on the geometric form content and replication techniques, this preservation method ensures that the essence of the pattern is captured and can be recreated even if the original materials deteriorate over time. This approach allows for a broader accessibility to these patterns, as it is not reliant on specific material properties that may be difficult to maintain or reproduce in the future.

In this method, there are several steps to proceed sequentially in the development of a particular algorithm.

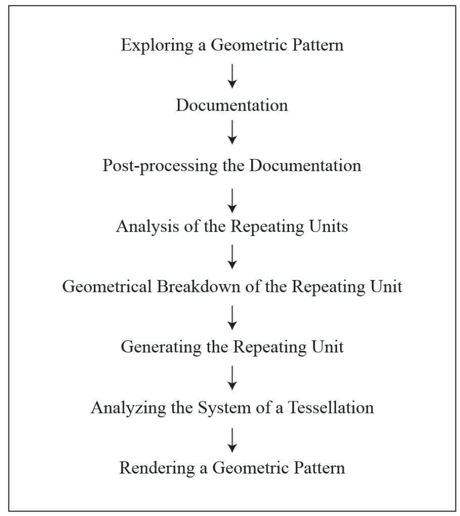

Figure 2. Process Diagram

Exploring a Geometric Pattern: Site visits or investigating the visual corpus of documentation materials
Documentation: Photographing a geometric pattern in situ or referencing a previously taken photograph
Post-processing the documentation: Editing the documented photo in a digital photo editing tool to improve its perspective quality
Analysis of the repeating units: Analyzing symmetry, proportions, and angular relations within a pattern
Geometrical breakdown of the repeating unit: Observing, breaking down, and quantifying its repeating elements to reveal its composition
Generating the repeating unit: Developing computer codes to render a repeating unit with the use of its vertex points
Analyzing the system of a tessellation: Using the repeating units for further analysis on calculating their tessellation relations with each other
Rendering a geometrical pattern: Developing computer codes to render a tessellation and matching its visual similarity with the original pattern

Case Study: Karatay Madrasah Pattern

Established in 13th century, the Karatay Madrasah is a historical architectural marvel situated in Konya, Turkey. Renowned for its exquisite Seljuk architecture and intricate tile work, which showcases breathtaking geometric and floral designs, this madrasah has been meticulously preserved. Originally constructed as a theological school by Seljuk Sultan Aladdin Keykubad I, it is a symbol of the region's abundant architectural and cultural heritage. Presently, the Karatay Madrasah functions as the Karatay Museum, an architectural marvel that highlights an extraordinary assemblage of Islamic art, ceramics, and artifacts; it is a Konya landmark of historical and cultural significance.

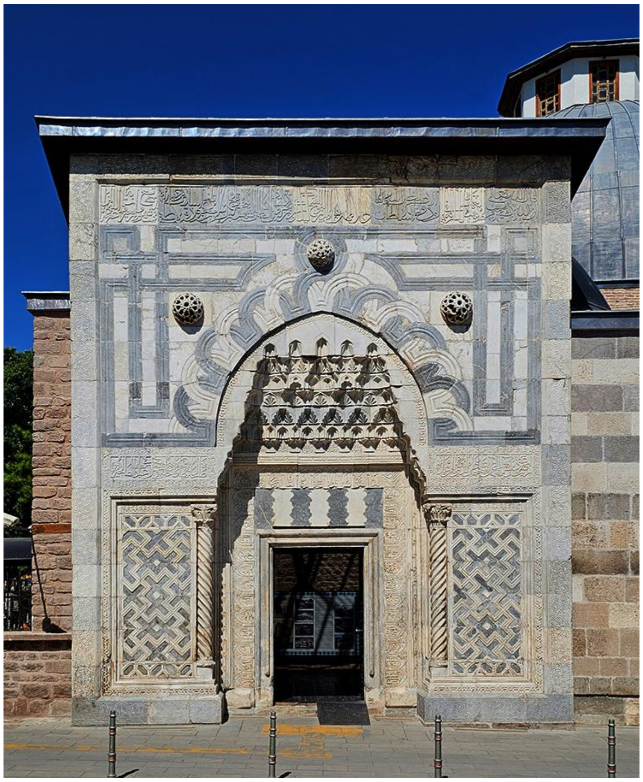

Figure 3. Karatay Madrasa in Konya, Türkiye

This monumental edifice is adorned with an assortment of geometric patterns that exhibit elaborate intricacies. Although the majority of the visual content has been preserved, certain patterns have been significantly impaired, necessitating additional conservation and restoration efforts. The impaired patterns require careful analysis and expertise to accurately recreate them, ensuring the preservation of their original beauty for future generations to appreciate. There is a unique geometric pattern within the halls that necessitates additional care during restoration. Upon examination of the geometric pattern present on the remaining component, it becomes evident that the missing parts can be rebuilt. This can be achieved by employing skilled artisans who specialize in traditional craftsmanship techniques. By carefully studying the existing geometric pattern and utilizing historical references, these artisans can recreate the missing parts with precision and attention to detail. This meticulous restoration process will not only revive the original beauty of the halls but also contribute to the preservation of their cultural significance.

Figure 4. A pattern in detail at the Karatay Madrasa

By applying algorithmic analysis to the pre-existing pattern, it is possible to generate its mathematical structure with impeccable accuracy. A recurring motif featuring a six-pointed star is evident in this instance. The light blue extensions encircle the star shape in an even distribution. Despite the precise craftsmanship and material utilization employed by the masters to create geometric patterns, the geometric forms they produce can only partially represent the absolute form of the design. Therefore, when performing geometric angle analysis on existing patterns, it is necessary to estimate the angular values within the limits prescribed by traditional methods, as opposed to measuring the angles. In this motif, the star in the middle is formed by the union of two equal-sided triangles, so each angle on the sides will be assumed to be 60 degrees.

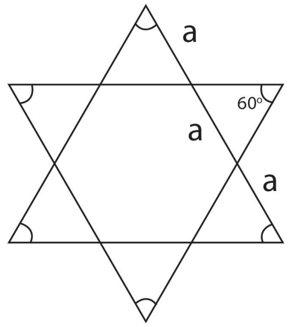

Figure 5. Centered star shape with its angular analysis

These intersecting triangles form a scale set for triangular polygons that will span the entire geometric structure. As seen above, this small convex polygon, formed by the intersection of two equilateral triangles, is another equilateral triangle, one side of which is defined as "a" unit. This scalar will determine both the overall motif and tessellation dimensions. Based on this polygon structure, it is possible to define the extensions around the star shape in the center. By extending the small convex polygon, we can create additional equilateral triangles that will fit together to form other shapes. The angles of these extended triangles will be the same as the angles of the original intersecting triangles, ensuring a consistent geometric structure throughout the entire design. Using the identical triangle polygons, the tentacles around the star shape are constructed below.

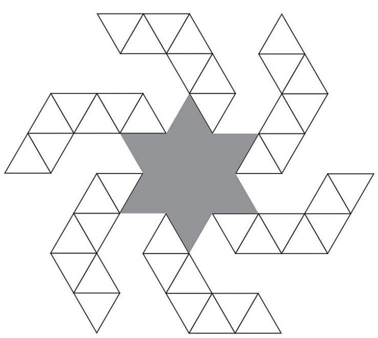

Figure 6. Tentacles placed around the star-shape

Following the identification of the fundamental unit comprising the entire structure, the subsequent course of action entails an examination of the interplay between these motifs as they generate tesselation. Although it is very easy to place the motifs side by side due to their six-fold structure, a horizontal shift is required for each following row. This horizontal shift ensures that the motifs align perfectly and create a seamless geometric pattern.

Figure 7. Code generated tessellation

Nevertheless, it is evident that the tessellations generated through this approach, which employs computer codes and geometric analyses to generate a preexisting pattern, do not adequately represent the pattern's physical material properties. The preservation objective advocated by this approach is the maintenance of the pattern's abstract formal content. It is certainly important to note that the preservation of physical material properties is crucial in accurately representing a pattern. This method aims to be a complementary factor rather than offering an alternative solution to existing conservation measures. By focusing on the abstract formal content of a pattern, this approach allows for a deeper understanding of its underlying structure and design principles.

Conclusion

In the past, geometric patterns were established by employing rulers and compasses in the absence of a protractor. Upon closer examination, the correlation between these patterns and mathematics becomes less apparent. Nonetheless, due to the fact that the analysis of shape relationships can yield expressions in angles, these patterns may also give rise to certain geometric challenges. The approach highlighted in this article utilizes geometric analysis to determine the fundamental components of these patterns. By breaking down the patterns into their fundamental geometric elements, such as angles and lines, it becomes possible to understand the underlying mathematical principles at play. This approach allows for a deeper exploration of the connections between mathematics and these intricate patterns, shedding light on their inherent beauty and complexity.

This method proposes that using computational methods to examine the algorithmic structure analysis of geometric patterns may aid in the preservation and restoration of various examples found in historically significant architectural structures. Researchers can accurately analyze the intricate details of geometric patterns and detect any damage or deterioration in artworks using computational methods. This data can then be used to create effective conservation and restoration strategies to ensure that these architectural structures are preserved for future generations to enjoy.

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Author Biography

Selçuk ARTUT's artistic research and production focus on theoretical and practical dimensions of human-technology relations. Artut's artworks have been exhibited at Sonar Istanbul (2023), AKM (Istanbul, 2022), Dystopie Sound Art Festival (Berlin, 2018), Moving Image NY (New York, 2015), Art13 London (London, 2013), ICA London (London, 2012), Art Hong Kong (Hong Kong, 2011), Istanbul Biennale (Istanbul, 2007), and received coverage at Artsy, Creative Applications, CoDesign, Visual Complexity, CNN GO. He holds a Ph.D. in Media and Communications from European Graduate School, Switzerland.

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