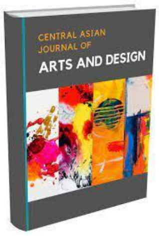

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Article

Methods of Creating Fractals from Geometric Shapes

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Abstract: This article links modern fractal art, which has entered the visual arts, with the science of applied decorative arts, and highlights the presence of fractals in geometric shapes and the methods of constructing them. This paper explores various methods of generating fractals using geometric shapes, including iterative processes, affine transformations, and substitution rules. By examining these techniques, we aim to provide a comprehensive understanding of fractal construction and its applications in mathematics, computer graphics, and natural modeling.

Keywords: Girih, element, composition, pattern, star-shaped, shape, geometric shape.

1. Introduction

Fractals are complex structures that exhibit self-similarity across different scales. They are found abundantly in nature, from the branching of trees to the formation of snowflakes. The mathematical study of fractals has led to various methods of constructing these patterns using geometric shapes. Understanding these methods is crucial for applications in computer graphics, natural modeling, and the visualization of complex systems.

Methodology

Several techniques have been developed to create fractals from geometric shapes. These methods often involve recursive processes and transformations that generate self-similarpatterns. IFS utilize a set of contraction mappings applied recursively to a geometric shape. This method produces self-similar fractals like the Sierpiński triangle and the Barnsley fern. The process involves applying affine transformations, including scaling, rotation, and translation, to generate the fractal pattern (Barnsley, 1988). L-systems are parallel rewriting systems that use string substitution rules to model the growth patterns of plants and other organisms. By defining an initial string and a set of production rules, complex fractal structures can be generated, such as the Koch curve and the fractal tree (Prusinkiewicz & Lindenmayer, 1990). Substitution tilings involve dividing geometric shapes into smaller copies of themselves and arranging them in a non-periodic fashion. Penrose tilings are a notable example, where two shapes, such as kites and darts, are arranged according to specific rules to create an aperiodic tiling that exhibits fivefold symmetry (Grünbaum & Shephard, 1987). This method recursively subdivides geometric shapes into smaller parts, following specific rules. The Sierpiński carpet is created by repeatedly removing the central square from a larger square, resulting in a fractal pattern with a Hausdorff dimension between 1 and 2 (Sierpiński, 1916).

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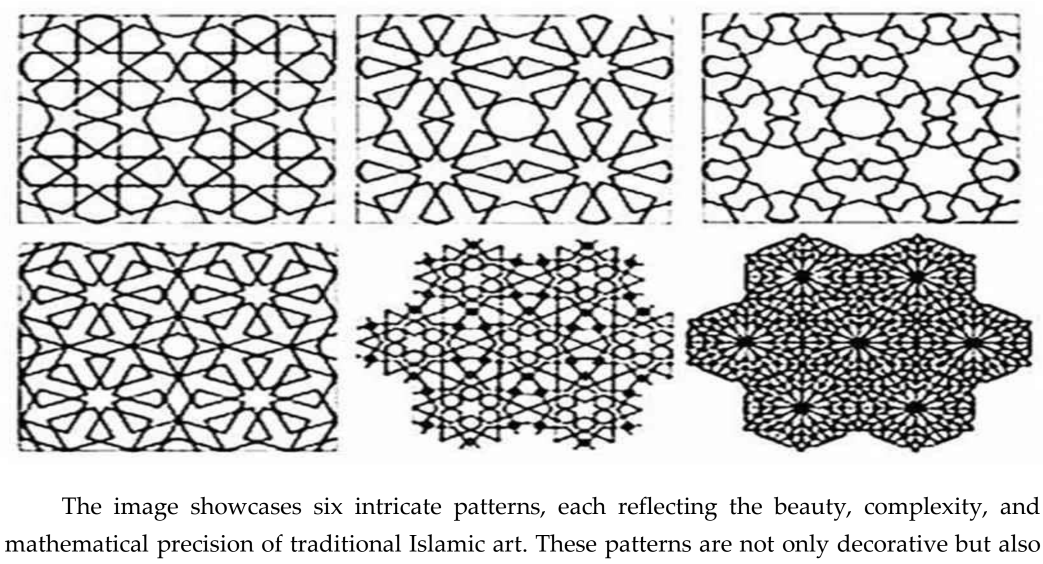
Results and Discussions

Geometric pattern elements consist of four parts: triangles, rectangles, polygons and curved lines. Thousands of patterns can be made using these geometric elements. Like pattern types, geometric elements consist of very simple or complex elements called distributions. A complete pattern composition is created from the repetition of these distributions. There are various unique methods for creating geometric pattern compositions, and we will consider some aspects of drawing a geometric pattern. There are the following methods for creating new geometric compositions.

1. Creating a pattern composition based on a combination of geometric elements: a) based on a combination of rectangles, b) based on a combination of triangles, c) based on a combination of regular polygons, d) based on a combination of curved lines.
2. By continuing some sides of geometric elements:
3. By adding some elements to the composition.
4. By adding some sides of the pattern elements in the composition.
5. By combining two different girih elements.
6. As a result of removing some parts from some girih compositions.
7. Dividing girih compositions into several independent compositions.
8. Creating various compositions using different grid lines and so on. Girihs are characterized by the number of star edges, which are grid-like and star-like. Floral girih is a complex type of pattern, which is a pattern formed by combining the components of the islimi and girih. Girih has a specific meaning with its structural composition and is called by names depending on the elements from which it is made. If the girih consists of a 5-pointed star, it is called a five-pointed girih. Similarly, if the girih consists of 5 and 6-pointed star-like elements, with a change in the number of edges of this shape, it is called a five-pointed girih. If it consists of 6 and 10-pointed star-shaped elements, it is called a six- and ten-pointed girih. If it consists of 5, 8, and 12-pointed star-shaped elements, it is called a five-, eight-, and twelve-pointed girih, and so on.

This figure depicts complex geometric patterns widely used in Islamic architecture. These patterns are often found in domes, roofs, walls and surface decorations. Within each shape, there are star-shaped, polygonal and complex symmetrical elements. The patterns consist of interconnected shapes, and circles, lines and central symmetries play a major role in their creation.

Figure 1. Collection of Geometric Islamic Patterns



The image showcases six intricate patterns, each reflecting the beauty, complexity, and mathematical precision of traditional Islamic art. These patterns are not only decorative but also deeply symbolic, expressing harmony, balance, and the infinite nature of creation.

Top Left Pattern: This design features a simpler geometric layout, combining circular and rectangular forms. At its center lies a prominent circle, around which symmetrical elements are carefully arranged. The overall composition is balanced and harmonious, making it a gentle yet elegant example of geometric ornamentation.

Top Middle Pattern: Here, the structure is based on hexagons and triangles, creating a dynamic and interlocking design. The pattern demonstrates both internal and external symmetry, giving it a sense of unity and completeness. This type of geometry is common in Islamic architecture, where mathematical order underpins artistic expression.

Top Right Pattern: A beautiful blend of organic and geometric forms, this pattern incorporates flowing, floral motifs with circular shapes. Despite the complexity of the surface design, the elements are arranged according to a hidden geometric structure, reflecting the Islamic artistic tradition of combining nature-inspired forms with mathematical order.

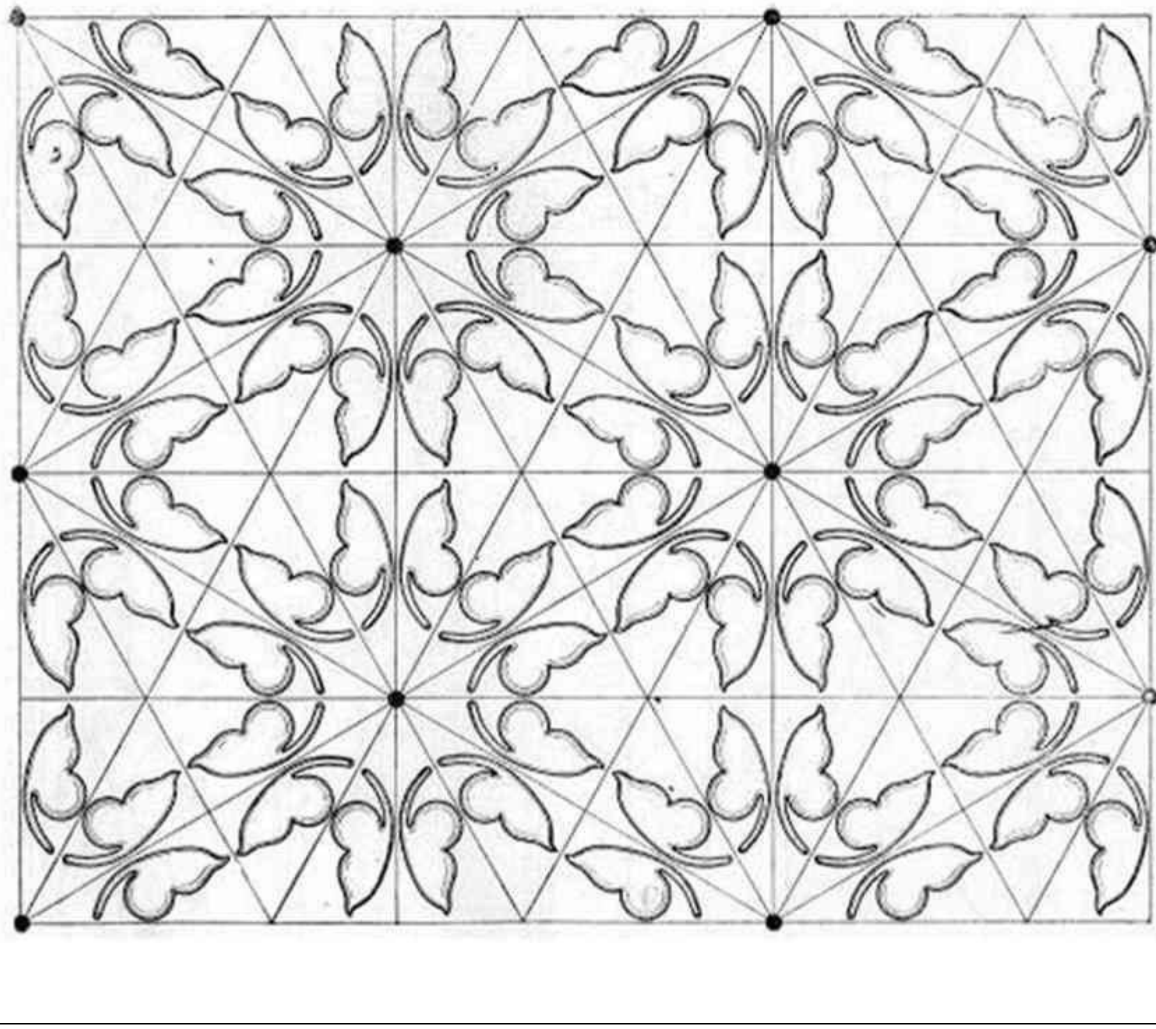
Bottom Left Pattern: This pattern is built on a rectangular grid system and features tightly interlocking star shapes. The stars are arranged so closely that they seem to support one another, creating a strong sense of cohesion and stability. This interconnectedness is a hallmark of Islamic design, symbolizing unity within diversity.

Bottom Middle Pattern: One of the most elaborate in the collection, this pattern is composed of numerous small shapes arranged meticulously around a central, symmetrical star. The use of star polygons and various polygons creates an intricate visual effect, drawing the viewer's eye toward the center. It reflects the high level of craftsmanship and deep understanding of geometry typical of Islamic artisans.

Bottom Right Pattern: This highly refined design is based on a heptagonal star—a rare and complex shape in traditional pattern design. The pattern is filled with delicate lines and detailed internal symmetry, making it especially suitable for sacred spaces. Historically, such patterns have often adorned the domes and mihrabs (prayer niches) of mosques, symbolizing spiritual depth and divine order.

Together, these six patterns illustrate the remarkable depth. Each design is a testament to centuries of knowledge, craftsmanship, and a worldview that finds beauty in symmetry, repetition, and infinite complexity.

Figure 2. Butterfly Ornamental Pattern



The butterfly ornamental pattern is a captivating fusion of natural inspiration and geometric precision, often featured in textiles, wallpapers, and architectural designs. This motif harmoniously blends the organic elegance of butterflies with structured geometric frameworks, resulting in a design that is both aesthetically pleasing and symbolically rich.

At the heart of this pattern lies the butterfly—a symbol of transformation, grace, and the ephemeral beauty of nature. Incorporating butterfly motifs infuses the design with a sense of vitality and movement, echoing the delicate flutter of wings and the intricate patterns found in natural forms. This approach aligns with the principles of Art Nouveau, where artists drew heavily from natural elements to create flowing, dynamic designs.

The structural backbone of the butterfly ornamental pattern is often a tessellation of equilateral triangles. This geometric grid provides a disciplined framework within which the organic butterfly forms are arranged. By rotating and positioning each butterfly within these triangular cells, designers achieve a rhythmic and harmonious composition that balances order with natural fluidity. Such geometric arrangements are reminiscent of Islamic geometric patterns, where complex designs emerge from the repetition and interlacing of simple shapes.

Symmetry plays a crucial role in the butterfly ornamental pattern. Each butterfly is meticulously placed to ensure balance and coherence across the design. This symmetrical arrangement not only enhances visual appeal but also instills a sense of tranquility and order, making the pattern suitable for various applications, from interior decor to fashion textiles.

The versatility of the butterfly ornamental pattern allows it to transcend cultural and stylistic boundaries. In interior design, it can adorn wallpapers, upholstery, and decorative panels, adding a touch of elegance and nature-inspired beauty to spaces. In fashion, the motif graces fabrics and accessories, offering a blend of sophistication and whimsy. The pattern's adaptability also extends to digital media and graphic design, where it can be employed to create visually engaging compositions.

Beyond its aesthetic appeal, the butterfly ornamental pattern carries cultural and symbolic meanings. In various traditions, butterflies represent transformation, freedom, and the soul's journey. By integrating this motif into design, creators not only enhance visual interest but also imbue their work with deeper significance, resonating with audiences on both visual and emotional levels.

Conclusion

Fractals created from geometric shapes demonstrate the profound connection between mathematics and the patterns observed in nature. By employing methods such as iterated function systems, L-systems, substitution tilings, and finite subdivision rules, we can generate intricate patterns that mirror the complexity of the natural world. These techniques not only deepen our understanding of mathematical concepts but also have practical applications in technology, art, and science.

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