THE ALGORITHMIC ANALYSIS OF AL AQSA'S TEN-FOLD ROSETTE PATTERN

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Abstract

Islamic geometric patterns are examined in the context of their mathematical infrastructure. These patterns are usually embedded to the parts of the historical buildings and they require great mastery according to their time periods. In this study, the ten-fold pattern of Al-Aqsa is examined algorithmically with the use of visual programming language. Grasshopper is used for this algorithmic examination. The decomposition of the pattern with the use of codes can help designers to understand the logic of the formation of the pattern as well as creation of the new ones. The pattern code helps designers to create variations of the geometry to some extent.

Keywords: Islamic geometric patterns, Al Aqsa, 10 fold pattern, rosette.

1. Introduction

The essential construction of Islamic geometric patterns lies within the utilization of mathematics and geometry to produce intricate ornamentations (Maddaova, 2019; Broug, 2008; Bonner, 2017). Various studies have been conducted on the mathematical origins and composition of Islamic geometric patterns, providing an analytical ground to better understand their configuration (Agirbas, 2020; Nadyrshine et. al., 2021; Ranjazmay Azari et. al., 2023; Takva and Takva, 2023; Khamjane and Benslimane, 2018). Also, there are studies about the basis of muqarnas which are composed of two-dimensional Islamic geometric patterns (Agirbas and Yildiz, 2021; Agirbas et. al., 2022; Agirbas and Yildiz, 2023). According to Barrios and Alani (2015) studies show that computation of Islamic geometric patterns can aid in enhancing our understanding their original conceptualization; however, parametrically modeling these complex patterns is rather difficult due to their overlapping formations and the lack of a guide on how to design them from scratch. Studying and modeling patterns from eminent monuments such as Al-Aqsa can broaden the scope of understanding of the formation of these geometries.

There are limited applications and studies on the geometric patterns found within Al-Aqsa. Built within the Haram al-Sharif, Al-Aqsa has undergone numerous reconstructions and alterations (Al-Natsheh, 2022). The Islamic geometric patterns that appear within Al-Aqsa are an amalgamation of different styles due to the periodic changes that it underwent. Islamic geometric patterns with 8, 10, and 12-folds can be perceived in numerous locations within the Al-Aqsa Mosque. However, the most prominent one is the ten-fold pattern which is attributed to the Ayyubid period (Reki and Selcuk, 2018). Since there are many different fold orders that can be created using the base of the pattern found within the complex, it can be parametrized using Rhino with the Grasshopper plugin to create a synthesis of their mathematics. The geometric pattern related to this study is located on the Minbar of Salah Al-Din (Figure 1). The original material composition of the minbar consists of walnut wood, ebony, and ivory; however, the minbar was burnt in 1969 and reconstructed in 2007 using similar materials (Abweini et. al., 2013).

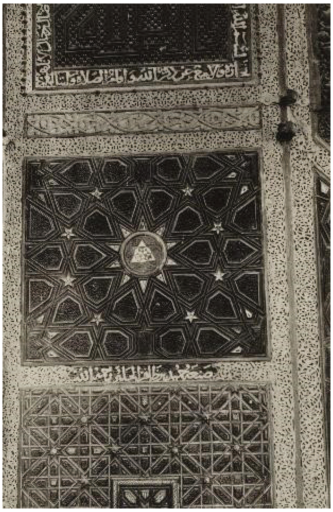


Figure 1. Close up of geometric pattern of Salah Al-Din's Minbar (Creswell, 1921)

2. Methodology

By utilizing plug-ins such as Grasshopper into Rhino, the basis of the geometric pattern can be parametrized, allowing for different configurations to be modelled. However, before initializing the pattern a geometrical analysis needs to be conducted to understand the elements of composition and how it is assembled.

The Mathematics Behind a ten-fold Pattern

As Abdullahi and Bin Embi (2013) mentioned in their paper, ten-fold geometric patterns are developed based on using a simple pentagon on a symmetrical axis and drawing circles according to its edges and central nodes. This provides an elementary outline to ensure the symmetry of the polygon throughout. The second phase of derivation entails drawing circles through each central node on every side and drawing a mirrored (x-axis) pentagon, to create the basis of the tenfold pattern. During the third step, two circles are drawn at each side which give an internal starting point for the tenfold pattern to form. Finally, the geometry is derived from creating symmetrical lines in accordance with the nodes that the circles provided from the previous step.

Modelling using Grasshopper

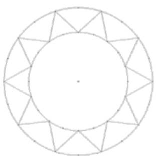
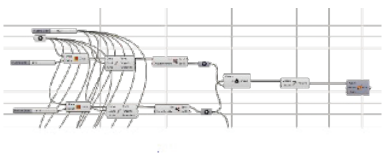
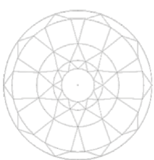
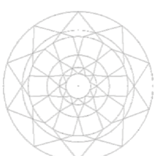
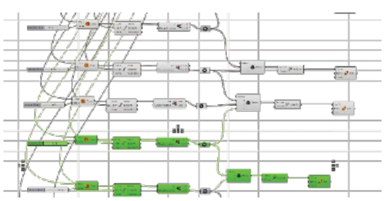
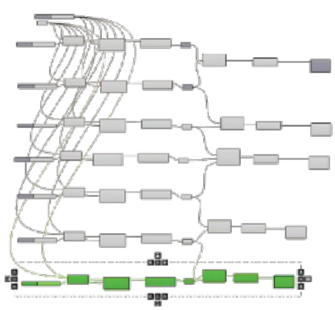
Grasshopper is a coding tool that enables generative modelling and parametric design, by allowing the user to algorithmically manipulate the script. The advantage of using Grasshopper rather than Rhino solely is that it provides the opportunity to control the pattern folds and the spacing between the inner geometries. Based on the mathematical breakdown concluded above, the pattern is comprised of radial configurations and along a symmetrical axis; the primary shape is a pentagon which provides the outline of the overall pattern.

Using the pentagon as a basepoint doesn't allow for the parameterization of the pattern, and rather hinders the sequence of progression as it is limited to a 10-fold parameter. Therefore, the set of rules and codes needed to be revaluated to control the results and thus a new approach was applied.

The first step was to breakdown the pattern into a much simpler form, consisting of circles and points (Table 1). This provides a foundation for the parameterization of the number of points that are contained in the overall geometry, which would alter the fold number. This was achieved by connecting a single number line slider to the divide polygon function. By doing so, the pattern could increase and decrease in folds rather than each component separately.

The overall pattern consists of five circles that are divided by points, then each two would be weaved into one another to create the folds. The first four circles are easy to connect as they weave at a straight line at three points forming a sharp triangular node. The difficulty lies within the connection of the fifth and sixth circle with the first four circles as the points are creating the pattern. For this step a boolean along with an expression of (3*(x/2)) was defined at the fourth circle. The remainder of the pattern follows the same set of rules. Finally, a polyline script connected to each weave node and extruded using the pipe function.

Table 1. Model progression in Grasshopper

Final Form	Script Breakdown	Description
		Creating points on both the first and second circle every other point to create a 10-pointed star
		Draw the third and fourth circle and set expression of (3*(x/2)) at the fourth circle
		Draw the fifth circle and repeat the same code in the first step
		Add a pipe script for each geometric node and bake the result

3. Results and Limitations

The resulting geometric pattern is an interactive and parametric model that can be used to further understand the variations between fold number, radius, and connectivity. By using Grasshopper, the pattern could be altered to portray a variety of different patterns according to the number of folds. This allows for new topologies to be generated and the overall morphology of simple base shapes into intricate patterns. As Agirbas and Basogul's (2021) and Agirbas's (2017) studies, the basic shape of these patterns can be used to produce many different pattern designs.

The main limitation of this study is that most Islamic geometric patterns are seamlessly connected, with some overlapping at certain points. The script created didn't effectively portray this element of geometric design, hindering the transition of the pattern as well as the aesthetic illusion related to smoothness of the transfiguration between each line.

To further improve this study, a more thorough and precise mathematical analysis can be conducted to understand how the geometric strands overlap and form. Moreover, the script can be refined and broadened with more accurate codes as well as new functions that could aid in achieving the desired outcomes. To broaden the scope of study, different variations and fold patterns can be modelled and studied as the script is interactive and parametric.

4. Conclusion

To conclude, the mathematical analysis and modeling of the ten-fold pattern found in Al-Aqsa Mosque plays an important role in our understanding of Islamic geometric patterns and their origins. There are a few studies conducted specifically on the Islamic geometries found in Al-Aqsa Mosque which is rather unfortunate as the mosque is a historic amalgamation of Islamic architecture and geometric patterns. The period of the geometric pattern changes in accordance with the number of folds which sheds light on its mathematical composition and geometry. The mathematics also reveals several attributes about the composition of the pattern; the use of an odd numbered shape like the pentagon to create an even numbered pattern demonstrates the elaborateness of the geometries used and how they are skillfully manipulated. Studying and modeling patterns from eminent monuments such as Al-Aqsa can contribute to sustain cultural sustainability.

Modelling the pattern also uncovered the difference between mathematical analysis, past construction techniques, and the computerization of the pattern.

The mathematical breakdown can reveal the original construction method and derivation of the pattern; however, when it came to using Grasshopper and Rhino, the means of modeling the pattern significantly changed and were rather simplified. Although the limitation of digital modeling is that it is difficult to illustrate interlocking and overlapping elements, it still provides us with a parametric tool for generative designs to better our understanding of the variations that occur relative to the fold numbers.

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