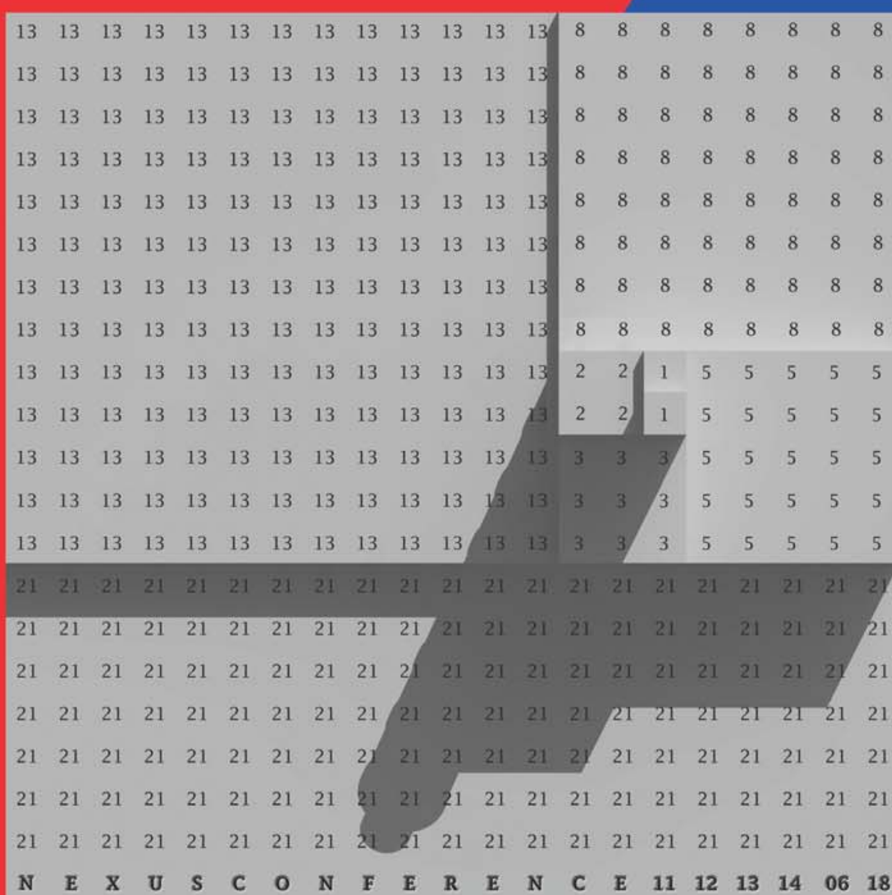
NEXUS 2018

Architecture and Mathematics

Conference Book



KIM WILLIAMS BOOKS

Dipartimento di Ingegneria dell’Energia, dei Sistemi,
del Territorio e delle Costruzioni
University of Pisa

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edited by

Kim Williams and Marco Giorgio Bevilacqua

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ALGORITHMIC DECOMPOSITION OF GEOMETRIC ISLAMIC PATTERNS: A CASE STUDY WITH STAR POLYGON DESIGN IN THE TOMBSTONES OF AHLAT

Asli Agirbas[1]

Introduction

In this study, mathematics was used to analyze an existing monument. The mathematical design rules of the star polygon shape in the selected monument were determined based on the shape grammar theory. According to the shape grammer theory (Stiny and Gips, 1972; Duarte, 2005; Stiny, 2006; Ozkar, 2011; Knight and Stiny, 2015) (in other words rule-based design), forms are created using certain rules. The probable rules for the creation of the star polygon shape in this study were produced simultaneously in the computer environment using a visual programming language (in the Grasshopper program that works as a plug-in to the Rhino program) and a 3D algorithmic model of the shape was created.

The Research

The monument, a part of the pattern of which was analyzed, is a tombstone in the cemetery of Ahlat (Fig. 1). The cemetery of Ahlat is located in Ahlat, a district of Bitlis Province in Turkey's Eastern Anatolia Region. Ahlat hosted many different civilizations from the past to the present. The cemetery, which takes place in the tentative list of the World Heritage Convention of the United Nations Educational, Scientific and Cultural Organization (UNESCO), dates back to the 12th and 15th centuries. The historic area, now used as an open-air museum, is 200.000 square meters and contains more than 6000 tombstones. These tombstones, which have high-quality artistic values, contain carved designs that require great mastery. Although the tombstones are generally similar to each other in material, form, decoration and writing character, they are different from each other, especially ornamentation in detail. The tombstones, which are generally in the shape of rectangular, are 40-70 cm wide and 1-5 m high. The material used in these tombstones is ignimbrite, Ahlat's local construction material. It is locally called 'Ahlat Stone' (Isik et.al. 2015). Ignimbrite, a volcanic stone, is formed in the end of volcanic eruptions. It is a light and easily shaped stone. Thus, the masters could easily shape this stone (Baykara and Isik, 2016).

The greatest characteristic of the analyzed pattern in this study is that it is in the form of carving and is in a knotted structure. Therefore, when the rules of analysis for this pattern were done, the pattern was considered 3-dimensionally. In the pattern examined in this study, it is obvious that the star-shaped polygon takes place in a hexagon. However, unlike many other star-shaped Islamic patterns (Bodner, 2012; Sarhangi, 2012), the end points of this star do not intersect with the hexagon.

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Fig. 1. Tombstones from Ahlat Cemetery and selected star-shaped pattern for the analysis

The parts, which intersect with hexagon, are the knots at the end points of the star. Therefore, while this star-shaped pattern was being analyzed in the hexagon, the star was handled with its knots in the end points. According to this, when the knotted star shape in a hexagon was analyzed as three-dimensionally, 3 L–shaped pieces knotted into each other were defined. And in the hexagon, 4 pieces of each L–shaped pieces were determined.

The possible series of rules for creating this pattern was determined (Fig. 2) and transferred to the algorithms in the same rules of framework (Fig. 3). Accordingly, a circle was first created for the creation of this pattern. The 'circle' component was used to create a circle in Grasshopper. The size of the circle can be parametrized by the 'number slider' parameter connected to the radius value of the circle component. Afterwards, this circle was divided into 6 equal pieces.

Six point outputs were obtained as a result of this process using 'divide curve' component. This value can easily be parametrized by the number slider placed in the 'number of segments' input of the divide curve component. A polygon (hexagon) was created with combining these points using 'list item' and 'line' components (Rule Series 1). Then, a circle was created in the centroid of the hexagon with the help of 'area' and 'circle' components. With the aid of a divide curve component, this inner circle was divided into 24 equal pieces. With the aid of the list item component, 3 points with equal distance were selected from the parts in ¼ of this inner circle (Rule Series 2).

Then, with the help of 'evaluate curve' component, 20%, 70% and 80% parts of one edge of the hexagon (that was created in Rule Serie 1), and 30% part of the other edge of the hexagon and 30% and 80% parts of another edge of the hexagon were determined.

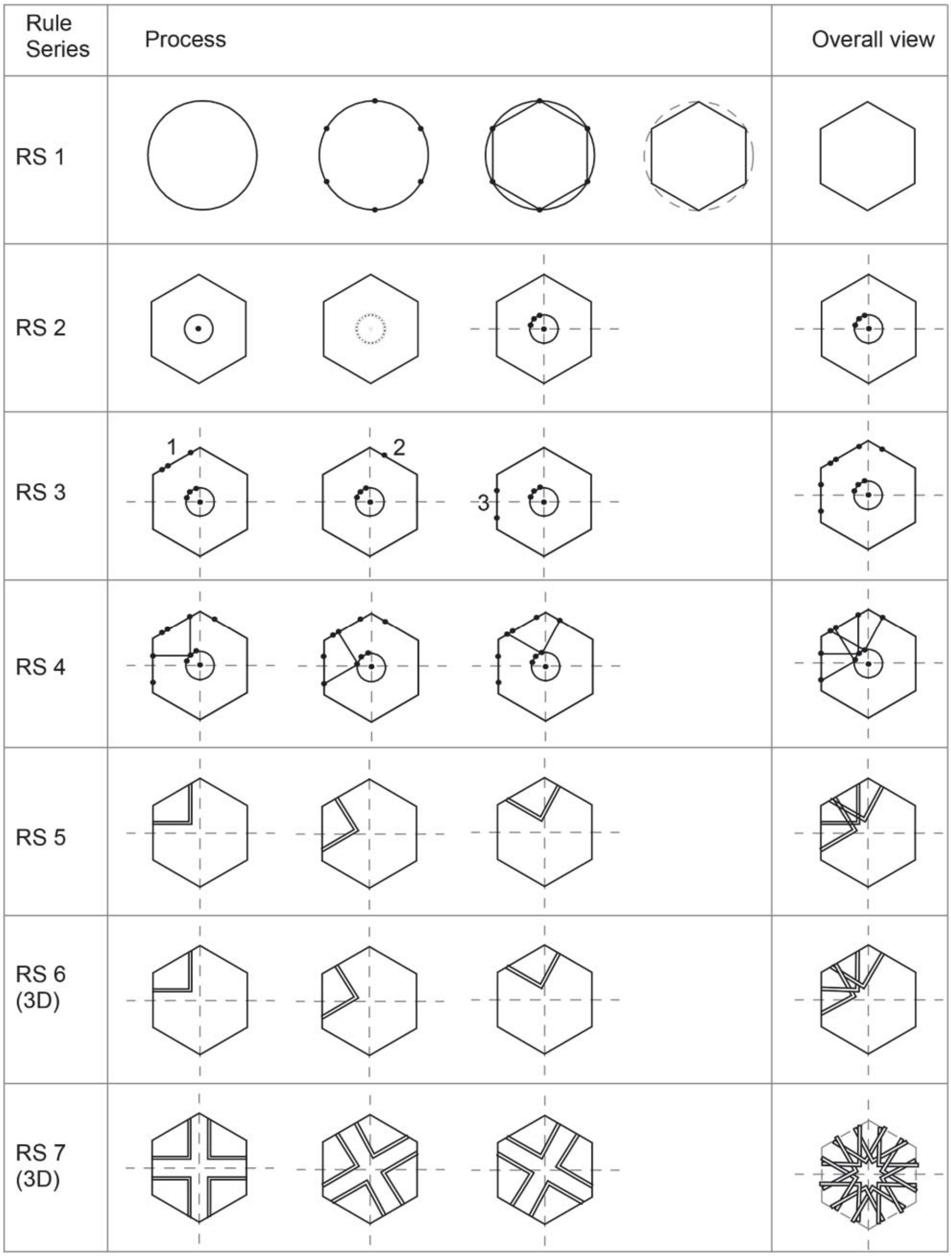

Fig. 2. Set of rules for pattern analysis

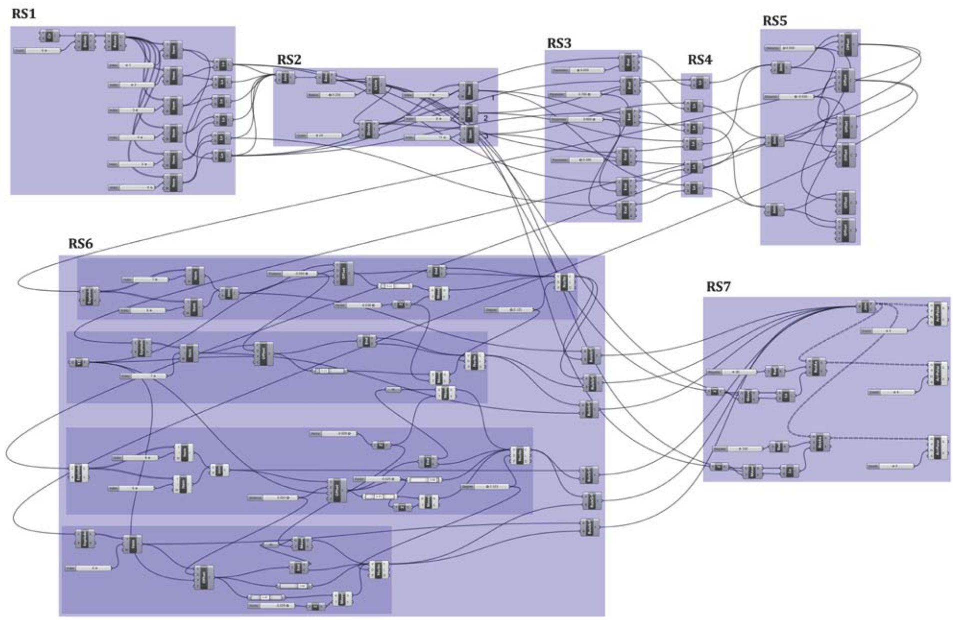

Fig. 3. Transfer of the rules to algorithm

In addition, these ratios can easily be parametrized by number sliders connected to the evaluate curve component (Rule Series 3). With the aid of the 'line' component, three types of L-shaped curve were created in 2 dimensions, combining the 3 points in the inner circle and the corresponding points on the edges of the hexagon (Rule Series 4). With the aid of the 'offset curve' component, the first L-shaped curve, the second L-shaped curve and the third L-shaped curve, which were created in 2D, were taken their offset to double side to create a base area for 3 dimensions. Again, with the number slider connected to the offset component, the offset value can easily be parametrized (Rule Series 5). At the next stage, the form was brought to 3D. The offsets of L-shaped curve in 2D were offset along Z axis to bring to the third dimension. Three points were determined above the last offset curve (along Z axis). From tree points, one point is the starting point of the curve, one is the ending point, and one is determined in between the points (somewhere between the start and end points). This midpoint is determined with the help of the 'point on curve' component and can be easily parameterized horizontally. Then, this point in the middle was moved up or down in the Z axis (vertically) according to the knot structure. Again, this ratio can easily be parametrized. Afterwards, a curve from these 3 points was obtained with the aid of the 'nurbs curve' component. The first created 2D curve and the curve created later in the third dimension were converted to the surface with the aid of the 'ruled surface' component. The other 2 L-shaped form was actually understood to be the rotated version of the first L-shaped form created. The interesting point here is that the mirror image look in 2D disappeared when the shape was analyzed in 3 dimensions. Generally, these types of Islamic patterns are shaped by taking the mirror images of the forms. However, in the analyzed shape of this study, it can be seen that the pattern was created with the circular repeat of L-shaped form. Therefore, with the aid of the ‘rotate axis’ component, this 3-dimensional L-shaped form was rotated in such a way that it overlies the other 2 L-shaped curves seen in two dimensions (Rule Series 6). With the aid of the ‘arraypolar’ component, each 3-dimensional L-shaped form, individually, each to be 4 in total, was copied circularly (Rule Serie 7) (Fig. 4).

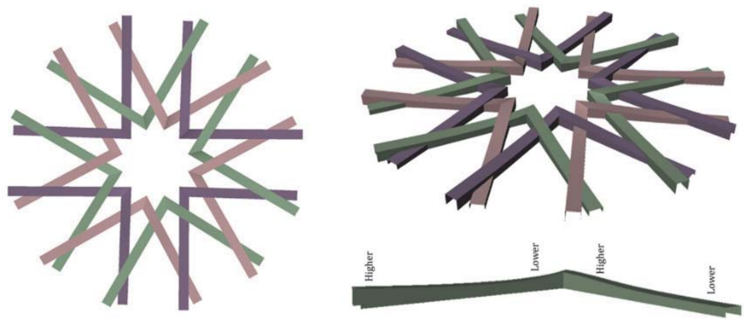

Fig. 4. A 3-dimensional shape of the pattern produced by algorithms

There is no single mathematical set of rules to create this type of forms. The same type of forms can be created with different rules. In addition, while creating the form with algorithms, the creation of rules in detail with well-defined steps provides great convenience for both the design analyzer and the designer. Because, in parametric definition, desired changes can easily be made by returning to a specific part. Along with this, the important benefit of parametric design tools is that the numerical values specified in the parametric definition can be changed very easily. Thus, many different variations, which can be done with the same rules series, can be created easily.

The 3-D form produced in this study can be transformed into a complete mesh that passes each other by the same principle. In addition, as the next step in this study, the knot details of the interlocking star shapes can also be analyzed mathematically and transferred into algorithms

Conclusion

Generally, geometric patterns are analyzed by specifying shape grammar rules. The next step of this, again under shape grammar theory, with determining the rules of the form, it may be analyzed based on algorithms. The use of constructivist methodology with well-defined steps, could be one of the answers to an up-to-date problem of designers' reasoning on dataflow programming. Because, the rules become break points in the definitions, and these break points form the backbone of the designs. As in this study, the patterns, which were transferred into algorithms by using parametric design tools, can be easily modified by changing the parameters in the algorithm and this can create an infrastructure for the future designs. With this method, for the artifacts containing various patterns that cannot be read, various variations can be produced in a short time and many alternatives can be obtained.

Various complex forms containing knots can be analyzed by algorithm-based software more easily, especially in 3D.

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