A Shape Grammar Study: Form Generation with Geometric Islamic Patterns

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Abstract

The aim of this research is to present the features of geometric patterns in Islam, to use rules-sets for two and three dimensional form generation and to indicate the potential of mathematics of symmetry and geometry. The study focused on parametrically defined shape grammars of Islamic patterns to generate three dimensional forms in CAAD. The information offered in this paper can be used to generate innovative depictions and to add fresh perspective to architecture. Throughout the history, some simple repetitive patterns were used as a starting point for architectural layouts, landscape designs or urban planning. In this research, Islamic patterns are used as a basis for three dimensional form generation explorations. This study can be accepted as a preliminary step of more complicated forward studies for innovative designs with historical patterns.

Keywords: Islamic patterns, form generation, shape grammars.

1. Introduction

Geometric patterns have been used by different cultures throughout the history. These patterns were used mostly as decoration elements for interior or exterior design of surfaces. When Turks chose Islam, they had developed entirely innovative and unique art field. Geometry is the origin of every art and discipline. Every society has used patterns in different forms. The octagonal interlacing patterns had significant function in Karahanli architectural ornaments. Afterwards, these patterns had been improved with original ideas in Gazneli, Big Seljuk, Anatolian Seljuk and Ottoman cultures.

For almost 30 years, shape grammars are used as a foundation for art and architecture such as Chinese lattice designs [1], window designs of Frank Lloyd Wright [2], traditional Turkish houses [3], ornaments on ancient Greek potteries [4], chair designs of Hepplewhite [5] and paintings of Richard Diebenkorn [6], Georges Vantongerloo and Fritz Glarner [7]. These series of examples point out that shape grammars can be used to produce innovative models on the basis of historical styles. Today, there are various significant research connected to Islamic ornaments and geometric origins of Islamic patterns [8-11].

Roots of Islamic patterns are differentiating in time, according to historic periods and cultures. Two and three-dimensional creative expressions can be seen in Islamic art. Islamic art has three main objectives, which are calligraphy, floral ornaments and geometric ornaments. In general, combinations of these elements are used on the same object. Geometric and floral patterns are the most important ornamental design components of Islamic art, because any depictions of human and human related subjects are forbidden. Art and need of expression lead people to another solution, which is based on geometry and mathematics. Although the main aim of these geometric or floral patterns is decoration, they depict a variety of Euclidean rules and geometric structures. These patterns are used on different kind of materials such as tiling, glass, paper, wood, plaster, metal, stone and brick. Usually, Islamic patterns can be seen on *mihrap*, minbar, window and door shutters, sultan's lodge, fountain fences, tile, stalactites, *rahle*, ceiling and walls.

Architects should try to explore new tools for being able to design in a different and more efficient technique than a conservative approach. The patterns can be spatial elements and be used as a base for architectural, interior or urban designs. This paper is focused on one of the fundamental patterns in geometric Islamic ornamentation; eight-pointed star and innovative form generation explorations with this pattern.

2. Islamic Patterns

According to Stiny, design is calculating with shapes and rules, and shape grammars are mathematics. They let us calculate in algebras of shapes [12]. Geometry is the basis of everything. From the beginning, Islamic patterns were considered as three dimensional and used in different buildings as basis for the domes, plans for minarets, tombs etc. Especially, in the mosques of Architect Sinan, simple patterns are used as underlayers of his design of the mosques [10].

The complexity of shapes is retrospective. It is an artefact of the rules that depends on how they are actually applied. Without rules, there is no complexity. And with rules, complexity varies – up and down- [12]. Shape grammars are the algorithmic systems used to analyze existing designs or create new ones. In spite of using text or symbols to express conceptual representations, shape grammars help to generate innovative designs through computational effort with shapes and rules. Stiny indicates that design is calculating when you do not know what you are going to see and do next. What a shape is depends on what rules are used, and when and how. This can vary for different rules, and, in fact, it changes every time any rule is tried [12]. Numerous probabilities of rule selection and application of these rules may cause emergent design solutions. This research aims to present the characteristics and shape grammar rules of geometric patterns in Islam and to indicate the potential of mathematics of symmetry and geometry. The study focused on parametrically defined shape grammars of Islamic ornaments for form generation in CAAD. The information offered in this paper can be used to generate innovative depictions and to add fresh perspective to architecture.

Islamic art was derived from Greek math that based on pure geometry. According to Pythagoras, everything in the universe can be defined by mathematics. Each number has certain meanings. Cube and square represent world, pyramid and triangle represent fire, and dodecahedron represents the universe. Two-dimensional geometric patterns in Islamic art are compositions of closed polygons. In Islamic art, geometric and floral patterns are generated by some basic geometry rules such as isometric transformations and Boolean operations. Translation, rotation, reflection, repetition are the isometric transformations (also called as Euclidean transformations). Boolean operations are operations like union, intersection, subtraction etc.

Repetition is the most useful and fundamental feature of Islamic patterns. There are few basic shapes in Islamic art, but interlocking design of these basic shapes generate different and complex patterns. Islamic patterns are usually produced by the repetition of triangle, square and pentagon. Star is an important shape in Islamic art. In almost every culture, the star represents the eternity. Each arm of a star has the same distance from its center. Circle does not have starting or ending points. In Islamic art, the circle and the center of the circle represent the creator (*Allah*) and Mecca - the center of Islam. That's why circle is one of the key shapes in Islamic art and architecture. Another important feature of Islamic patterns is *symmetry*. Symmetry, or the series of ways in which a single *motif* can be repeated an exact number of times within a circle, is the most fundamental manifest aspect of Islamic geometric art [11]. It is the main operation in derivation of geometric and floral patterns. Symmetry is used for generating compositions and tessellations. Stylized rose pattern - *gülçe* (rosette) and stellar patterns are the most frequent Islamic ornaments and they are generated with these simple features. Figure-background relationship is another important aspect in Islamic art. Different parts of the patterns can be dominated by figure-background relationship. Colors are essential for figure-background relationship and visual perception, particularly in tiling and engraving. Sometimes, different materials or colors can be combined with others to increase the visual perception.

3. Form Generation with Islamic Patterns

This study is focused on one of the fundamental patterns in geometric Islamic ornamentation; eight-pointed star. The square represents the *earth*, or the physical elements such as earth, air, fire and water. If a square overlaps another, with the second square pointing upwards, eight-pointed star is formed. The eight-pointed star is related to the symbolism of the *eight bearers of the throne*, from Koran and certain cosmological subjects [11]. Different rule-sets are applied to the pattern and these generative rules are based on shape grammar and fractal geometries [13]. Afterwards, the resultant patterns are used as a basis for generating three dimensional forms. Rectangular array (Figure 1) and polar array (Figure 2-10) are applied to the eight-pointed star. Then, each star is extruded to a specific height; in most of the cases, the height of each star is increased from outside to the center of the pattern.

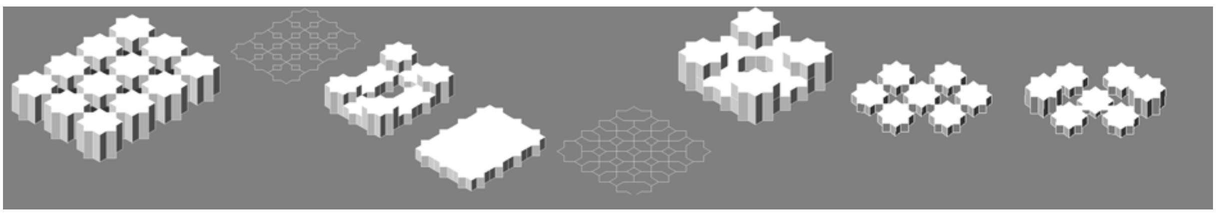

Figure 1. Rectangular array with eight-pointed star.

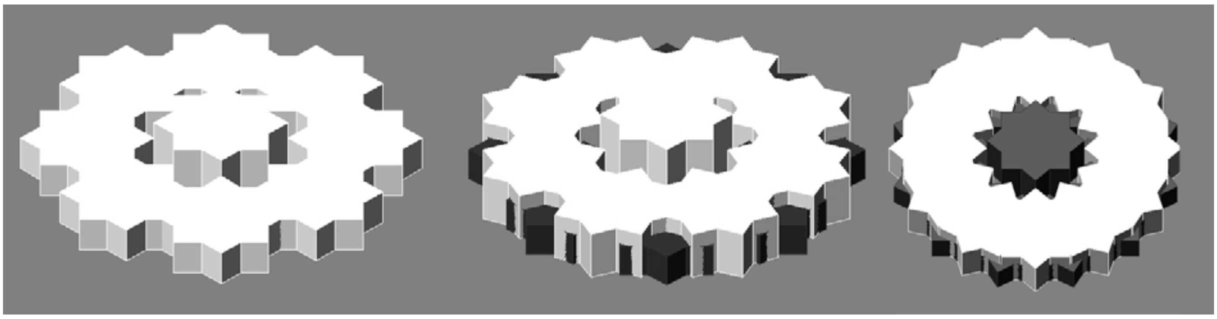

Figure 2. 3D representation of the polar array with 8, 16 and 32 stars.

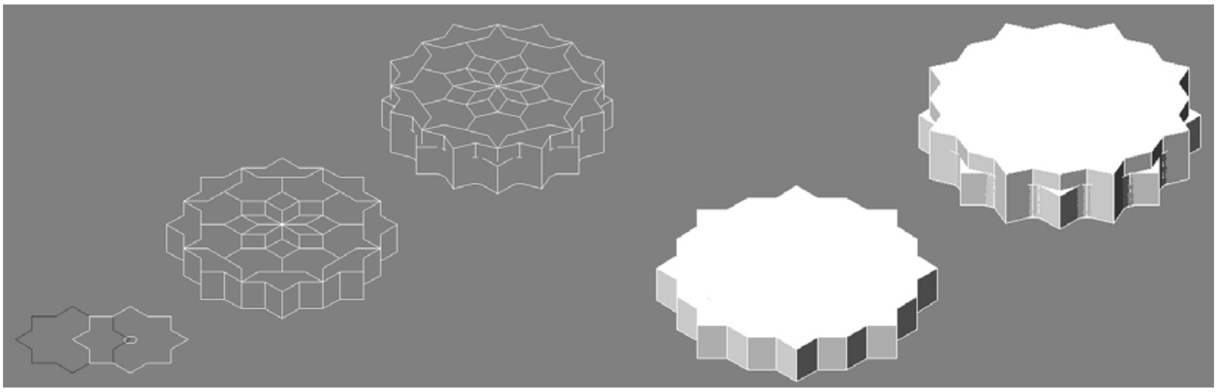

Figure 3. Initial shape and 3D representation of the polar array with 8 and 16 stars.

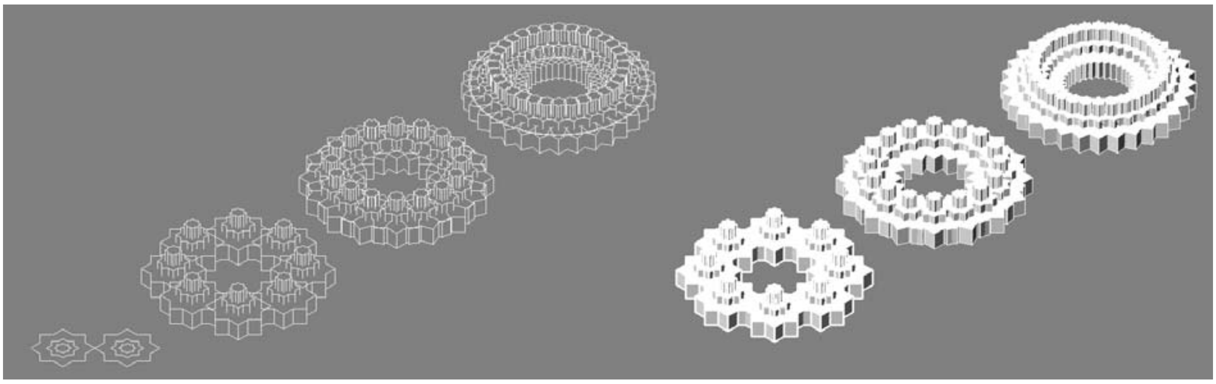

Figure 4. Initial shape and 3D representation of the polar array with 8, 16 and 32 stars.

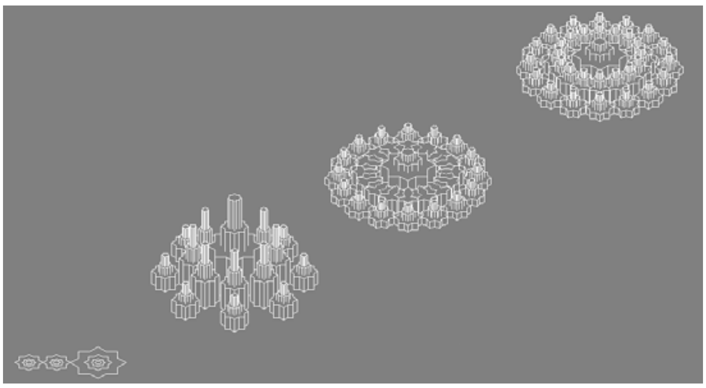

Figure 5. Initial shape and 3D representation of the polar array with 8, 16 and 32 stars.

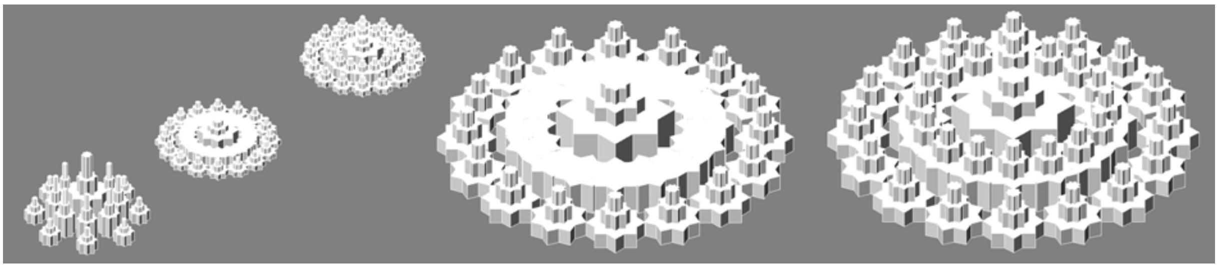

Figure 6. 3D representation of the polar array with 16 and 32 stars.

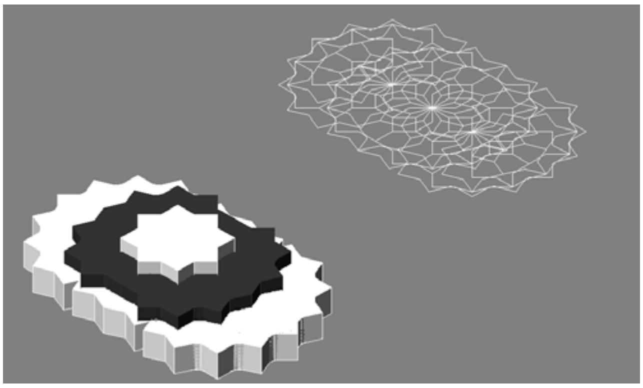

Figure 7. 3D representation and the base pattern.

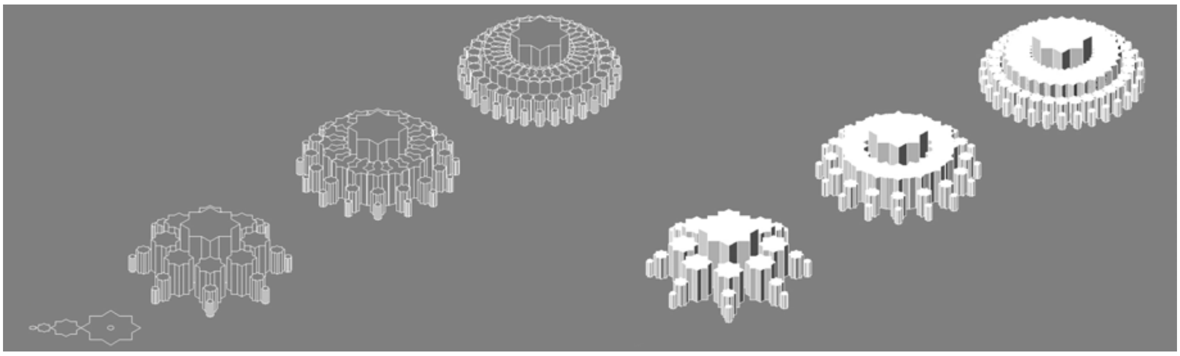

Figure 8. Initial shape and 3D representation of the polar array with 8, 16 and 32 stars.

One of the patterns is generated with scripts (Figure 9). In the near future, the main aim is to improve and transfer all of the rule-sets and the measurements to a programming language and generate a computer implementation to study further design innovations with different patterns and rule-sets in two and three dimensions.

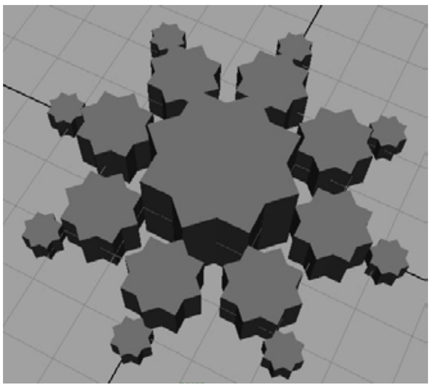

Figure 9. Script-based generated form.

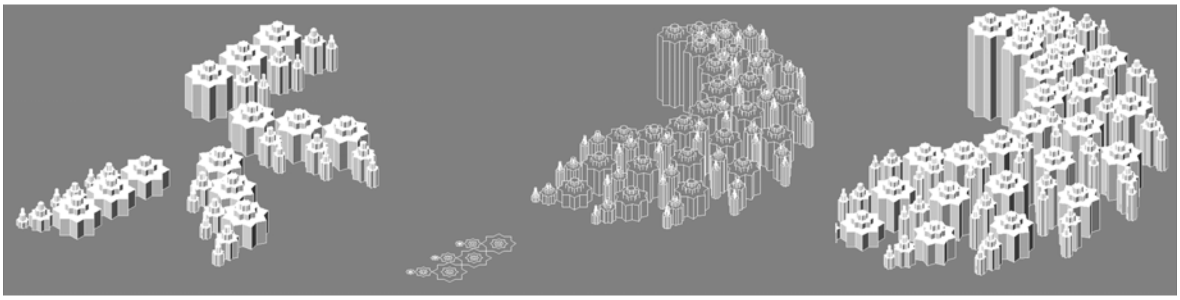

Figure 10. 3d representation of partially polar array with 4 and 8 stars.

Throughout the history, some simple repetitive patterns were used as a starting point for architectural layouts, landscape designs or urban planning. In this research, generic patterns from previous study used as a basis for three dimensional form generation explorations [13]. In the future, structural aspects, columns - beams and interior spatial organizations are going to be considered and resultant forms are going to be improved to respond to these necessities.

4. Conclusion

In Islamic art, there are both floral and geometric patterns. In this study, the grammar rules for geometric Islamic patterns are used as a basis for form generation methods. These geometric patterns are the origin of Islamic art. The stylistic features are correlated with structural framework and social, material, and individual forces. Today, there are CAD programs to help designers to explore innovative design potentials. The resultant forms from this study can be used in the conceptual phase of the designs of restaurants, hospitals, libraries, art galleries, hotels, houses and religious buildings, landscape designs and even in urban planning layouts. This is a preliminary study to design three dimensional forms with pattern grammars and Islamic patterns. The resultant forms are simple, but very inspirational. In the near future, the main aim is to improve and transfer all the rule-sets and the measurements to a programming language and generate a computer implementation to study further design innovations with different patterns and rule-sets in two and three dimensions. This study can be a starting point of more complicated forward studies for innovative designs with historical patterns.

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