MORPHOLOGICAL CODE OF HISTORICAL GEOMETRIC PATTERNS

The digital age of islamic architecture

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Abstract. This study intervenes in the long-standing paradigm that considers compositional analysis as the key to researching the Islamic Geometric Patterns (IGP). The research argues that the compositional analysis of the geometry is not solely sufficient to investigate the design characteristics of the IGP, and the better way of achieving this emerges through a consideration of the design formalism.

1. Introduction

The science and technology of the digital age is revolutionizing architectural practices (Kolarevic, 2004). Digitals, both computerized and computational, advance the design and manufacturing processes. This opens new opportunities to explore complex formal compositions and has recently shifted the focus toward form generation, which challenges the dominant representational logic of traditional architecture (Oxman & Oxman, 2014). Several writings (Greg Lynn, 1993; Migayrou Frederic, 2003; Kolarevic, 2004; Hadid & Schumacher, 2002) of theories of the digital emerged that are centered on procedural processes and mathematical form generation that turn the focus from the curvilinearity and blobby forms of folding toward digital design thinking. These theories emphasize formalism, or the mechanisms that govern the structure of relations within an architectural form rather than formal compositional aspects (Oxman & Oxman, 2014; Kolarevic, 2004). In other words, it is a shift from form 'making' toward form 'finding' (Kolarevic, 2004).

When it comes to the design and research of Islamic architecture, the discipline is still over-dependent on approaches that focus on the formal representation of historical models. However, it has been argued that limiting Islamic architecture to particular compositional characteristics degrades its real value and segregates it from the general architecture of the world (Rabbat, 2004). Instead, the inquiry should concentrate on the understanding of “the emergence and evolution” of architectural forms that reestablish an open-ended search for forms and make Islamic architecture an active contributor to the world’s architecture (Rabbat, 2004).

2.Islamic Geometric Patterns

Islamic Geometric Patterns are a prominent characteristic that demonstrates the diversity of geometric designs in Islamic art and architecture. These simple to complex interlaced geometric forms are made from a variety of materials and cover various architectural and non-architectural surfaces throughout the Islamic world. The earliest attempts at producing geometric designs date to the 9th century during the Abbasids Dynasty (750–1258 CE). Followed by major innovations that occurred between the 10th and the 16th centuries (Necipoğlu & Al-Asad, 1995).

Historically, Islamic art and architecture took advantage from the mathematics of its age. The enormous diversity of complex forms that exist in Islamic art and architecture are products of mathematical and geometrical advancements as discussed in available historic documentation. One such document is *Risâla fimâ yahtâju al-sâni’ u min a’ mâl al-handasa* (On the Geometric Constructions Necessary for the Artisan), by al-Būzjānī, (998). Yet, when it comes to the design and analysis of Islamic architecture, mathematics is mainly discussed in terms of proportion with less focus on the computational nature of form generation that encompasses mathematical and algorithmic thinking.

This paper focuses on the design formalism and presents a method that incorporates mathematics and morphology to construct a shape-code that packs the necessary information to construct a particular geometry and utilizes this code to investigate and design IGP.

3. Precedence

A few studies “breached” the representational approach and its “Orientalist roots,” emphasizing the relationship between mathematics and the historic IGP. The first study that scientifically investigated the IGP was conducted by Edith Muller (Müller, 1944), who analyzed the symmetry of the patterns based on group theory. This research was followed by other publications by Wasma’a Chorbachi (1989), Herash Lalvani (1989), and Sayed Abas and Amer Salman (1995). These later studies attempted to identify a method to mathematically engage the design of the IGP. They acknowledged the important contribution of group theory in studying the patterns, and used scientific notation to identify individual geometric designs in a discrete manner.

Although these studies either examined a particular design (for example, Chorbachi examined interlocking geometry), a particular design feature (such as symmetry in Abas's study), or a small population of designs (Lalvani), all of these methods provide an approach that is concerned with designing a scientific method rather than describing the mere formal qualities. However, none of the above studies have developed methods to capture continuous transformation of design topologies –morphology– or reflected back and analyzed historical designs.

4. Methods

This research utilizes mixed methods in two sequential phases. In phase one, simulation modeling is employed to develop a parametric model that describes the formalism of the IGP and construct the representational code of historical designs. In phase two, content analysis is utilized to study the representational codes with consideration to related historical manuscripts on mathematics and geometry.

4.1 ANATOMY OF A PATTERN

In general, the periodic IGP consist of a repeat unit (RU) and a repetition structure. The RU is the minimal region that contains the basic geometrical composition; it is possible to have more than one type of the RU. The repetition structure is the product of systematically repeating RU to fill the space. The shape of the RU affects the type of the repetition structure. The repeat unit itself can be subdivided into several fundamental units (FU). The FU are the minimal compositions within the repeated unit that cannot be obtained by symmetry. Figure 1 shows the process of identifying the fundamental unit of geometry at different levels of geometric complexity.

4.2 THE MORPHOLOGICAL DESCRIPTION

The morphological description provides the minimal amount of numerical information that is necessary to produce a series that refers to a particular historical IGP, and encompasses the possible transformations. In previous paper (Alani & Barrios, 2015) , a description that utilizes absolute values was presented. In this paper, however, the morphological code is based on a relative description of the geometric composition within the FU. The method proposes types of parameters that represent the percentage of how far a point is from a reference point (RP).

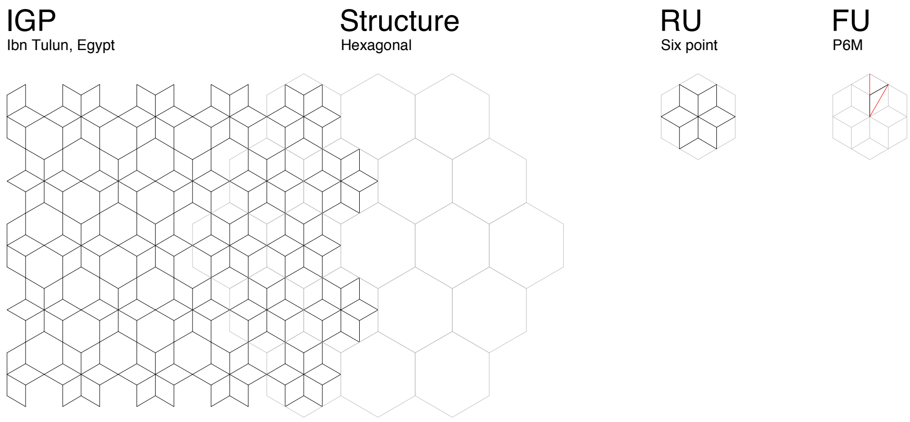

Figure 1. From left to right, the analysis of pattern structure, the repeat unit, and the fundamental unit.

While the RP can be any point in the space, this paper proposes positioning the RP on the outer segment of the FU. The placement of the design elements depends highly on the RP. Each line in the design requires two points, called targeted points (TP), to be constructed. Each point requires two vectors to be defined: the construction vector (CV) and the pointing vector (PV). The CV emits from RP toward a Construction Point (CP). The CP is always the point that lies at the outer border of the FU and is determined by the intersection of this segment with a vector that emits from the center of the RU passing through the TP (Figure 2). The length of the CV is identified as the proportion from the outer segment of the FU. The PV emits from CP toward the center of the RU. The length of the PV is a proportion of the vector constructed from the center of the repeat unit and the CP. The end point of this vector is the TP. Connecting all the TPs creates the basic lines of a geometric composition. Therefore, it is possible to code any geometry using the following parametric model:

Symmetry Type: {TP1 - TP2 - … - TPn}

Where n is the number of TPs in the geometry.

By substituting CV and PV for TP, the above model can be written as follow:

Symmetry Type: {[CV1–PV1] - [CV2–PV2] - … - [CVn–PVn]}

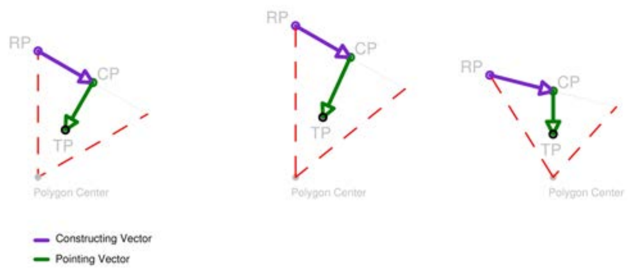

Figure 2. Illustration of the proposed method.

The parametric model can be used to derive representational codes that refer to particular historical designs. Consider the geometry shown in Figure 3. The description of this geometry can be written using the above model as:

P6M : { [0 – 1] - [0 – 0.5] - [1 – 0] }

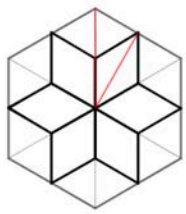

Figure 3. Six-fold star found in the mosque of Ibn Tulun in Egypt from the ninth century.

In this representational code, P6M refers to the shape of the repeat unit and the type of the symmetry. The rest of the code refers to a series of connected points. Each point is coded in the form of CV and PV.

Figure 4 shows the advantage of using relative values in the description. Regardless of the shape of the repeat unit, the description can always fit the composition in the hosting cell unit. Such an approach enables the mapping of an IGP on a variety of surfaces as explained in the 3D printed model shown in Figure 4.

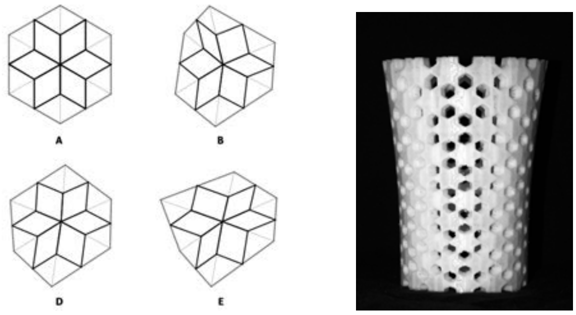

Figure 4. Left: Mapping of the geometry into a deformed CU. Right: 3D printed model demonstrating the mapping of an IGP onto a non-flat surface.

4.3 CODING PROCESS

The parametric model utilized to derive the representational codes of historical designs. Data was sampled from Islamic monuments from various regions from the Islamic world dated between the 9^{th} and the 16^{th} centuries. Each morphological code can be stored with identification information such as the geographical location, chronological information, and the governing dynasty.

4.4 MORPHING

Values within the representational code for historical designs were manipulated, and new codes were derived. The manipulation of data was performed to cover all possible variations; this resulted in continuous transformations of geometry to cover all possible morphological states. Figure 5 illustrates the morphing process of the original geometry of Ibn Tulun mosque.

5. Results

When the results of the morphing process were compared with the representational codes of historic IGP, it was found that some of the newly derived codes exactly matched historic designs. Therefore, three different types of relationships between designs were identified: identity, topological similarities, and morphological similarities.

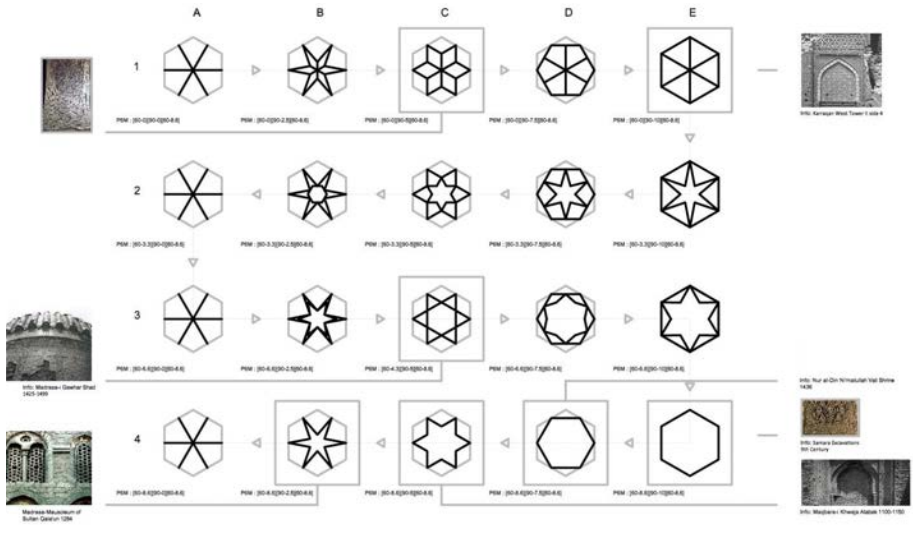

Figure 5. Following the arrow, this figure explains selected transformations of Ibn Tulun geometry through various topological states.

Identity refers to historic IGPs that have the exact same code. Although some identical designs may look different because of using different embellishments for each design, these geometries still have an identical geometric composition.

A topologically similar IGP refers to a design that has the same "spatial relations" of the composition and is less concerned with "spatial distinction." For instance, Geometries 4B, 4C, and 4D in Figure 6 are topologically equivalent.

Geometry 4B: P6M : { [1 – 0] - [0 – **0.75**] - [1 – 0.33] }
Geometry 4C: P6M : { [1 – 0] - [0 – **0. 5**] - [1 – 0.33] }
Geometry 4D: P6M : { [1 – 0] - [0 – **0.25**] - [1 – 0.33] }

Morphologically similar IGP refers to all designs that can be derived from a particular IGP regardless of the topological transformation. For instance, all designs in Figure 5 are morphologically equivalent. Figure 6 explains how new relations can be established between historic IGPs based on morphological similarities.

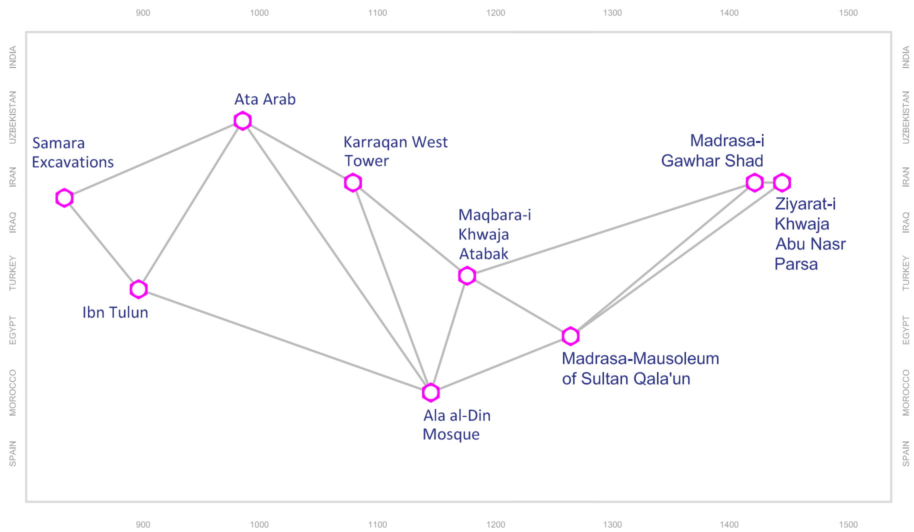

Figure 6. morphological relations between historical designs

6. Conclusion

Mathematics is essential for understanding IGPs. The identification of design formalism of the IGP enables the construction of databases of representations of design singularities, which can be an extensive source of information. These representations are useful not only to the archiving of information but also to investigate and empirically analyze the morphology of historical designs for possible correlations. As this study found, the relationship between various historic designs goes beyond formal relations to a deeper structural level.

7. Discussion

The goal of this research is to provide a different understanding of the historical IGP that is based on mathematics and morphology as an alternative to the conventional formal understanding, aiming at establishing a new platform to engage the research and design of the IGP.

The significance of developing the parametric description is also to establish a lower level interaction with the methodology that grants designers complete control of the model’s components and its mathematical structure. Such an approach enables exploration beyond known historic designs, or what is intuitively obvious, to search for new, uncharted forms. One practical implementation of the parametric description is to control the form of the geometry in responsive pattern system through direct manipulation of the PVs.

Although the focus of this research is on the IGP, the underlying goal is to provide a method to actively engage the design of Islamic architecture, based on mathematics and morphology, to construct a version of history that represents the digital age through incorporating innovative computational tools into the design process. Eventually, this will reduce the gap between the contemporary world's practice of architecture and Islamic architecture by allowing the latter to contribute to current design practices.

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