Research On The Construction Of Parametric Islamic Pattern Unit Totem Template And Its Related Product Applications

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***Abstract*—The beauty of Islamic patterns lies in their fusion of order, harmony, and infinity. These patterns, based on geometric shapes, form precise and balanced structures through repetition, symmetry, and rotation. While devoid of depictions of people or animals, they exhibit a pure, abstract beauty, symbolizing the perfection and eternity of God.When appreciating Islamic patterns, we can feel the fusion of mathematical rationality and artistic elegance, creating a tranquil and peaceful aesthetic. Therefore, the beauty of Islamic patterns is not merely decoration, but also an expression of spirit and faith, allowing us to see infinity within rules and feel peace within order. Therefore, this article utilizes the Gresshopper module (GH) of the Rhino software plugin to create various parametric Islamic pattern prototype templates. This allows for the free modification of the geometric features and dimensions of each prototype, and also enables its easy extension to the surfaces of other objects. This will make it easier for those interested in Islamic pattern research or product surface decoration to promote and apply these techniques, thereby creating more exquisite products and ultimately promoting and continuing the aesthetic skills of Islamic culture.**

***Keywords*— Islamic patterns,Paramatric design**

I. Introduction

The development of decorative art is a manifestation of the progress of human civilization. Through historical materials, we can understand that it starts from rock paintings in prehistoric times, to decorative patterns on utensils and even on fabrics and buildings. It is a slow and gradual transformation. It is a record and symbol of human thought and symbols, reflecting people's thoughts and aesthetic concepts at that time. Therefore, even though the emergence and development of many different civilizations have caused changes in the expression of patterns, it has also promoted the diversity of patterns. Patterns are living shapes. From the evolution of patterns throughout history, we can see that patterns reflect people’s depiction of life [1]. The development of decorative art is a manifestation of the progress of human civilization. Regarding the development of decorative art, Ye Liu Tianzeng [2] mentioned that from the perspective of the history of human art and cultural development, decorative art can be said to be the earliest artistic activity and aesthetic display of mankind. The decorative art presented in different periods reflects the thoughts, aesthetic concepts and religious beliefs of the time. From the perspective of historical evolution, human beings have not only created scientific and technological civilization, but also created artistic culture. At the beginning of civilization, people invented and manufactured various tools and utensils to meet their living needs. With the improvement of wisdom and the accumulation of experience, humans became more and more sophisticated in the production of utensils. At first, utensils were made for the need to make a living. With the improvement of production techniques, in addition to practical purposes, aesthetic concepts gradually emerged in the shape. Therefore, the patterns on the utensils also changed from their original practical functions to artistic expressions.

From the evolution of Eastern culture, we know that pattern elements in Western culture entered the Eastern world through activities such as ethnic migration, cultural exchanges, wars and trade, thus increasing the diversity of pattern expression in the Eastern world. Western patterns also have a history and evolution. Compared with the gods, ghosts, religions, mythical beasts, flowers, plants, people, birds, insects, auspicious patterns, auspicious objects and auspicious words in Eastern culture, the patterns of Western culture are mainly plant patterns and geometric patterns in nature; it changes from simple patterns (squares, circles, diamonds, text shapes and curve shapes, etc.) to complex changes. The composition type has evolved from a two-sided continuous composition to a four-sided continuous composition, and can even expand infinitely outward, and has evolved from simple line expression to complex interwoven pattern presentation. Regarding this evolution process, Riegel[3] divided the patterns into four styles: geometric patterns, heraldic patterns, plant decorative patterns and Arabic decorative patterns.

The so-called Arabic decorative pattern is a complex decoration with repeated geometric shapes. It is an important element of Islamic art and is often seen on the wall decorations of mosques. The way its geometric figures are composed must be based on the Islamic worldview. For Muslims, the combination of countless geometric figures means that there is an infinite existence beyond the visible material world. This geometric style of arabesque did not become widely popular in the Middle East and the Mediterranean basin until the Golden Age of Islam. Therefore, geometric patterns and symmetry are the main themes of Islamic artwork, which naturally give rise to the abstract concept of symmetry. Pattern and symmetry are two of the most profound and pervasive concepts conceivable by the human mind, and no other concept unites science, art, and nature as they do. Patterns and symmetries are equally fascinating and meaningful to kindergarten children and physicists constructing complex theories of the universe [4].

With the rapid advancement of Computer-Aided Design related technologies, digital applications have become an indispensable part of design practice. Parametric design has become a popular new design method in this design field, especially in the field of digital architecture in recent years. Different from the 3D modeling software commonly used in product design, the parametric design tool is a design method in which parameters and calculation logic are connected to each other to generate geometric patterns. The changes in the geometric model can be seen in real time through the adjustment of parameters and calculation elements. At the same time, the breakthroughs in digital manufacturing technology in recent years have given designers more new possibilities in design [5].

Like its name, parametric design presents all elements of the design process as data. The geometric shape is no longer determined by the graphics drawn by paper and pen, but by the direct construction of data and shape logic. Its design and construction method is not as in the modeling software that we are familiar with, in the 3D working space with elements such as points, lines and planes, intuitively performing shapes, stacking, stretching and other actions to complete the design methods of geometric modeling. The design is woven with the arrangement and interactive links between data on a blank paper-like operating platform [6].

The application of data gives the definitions and rules behind the natural patterns a suitable stage. The concept of parametric design allows mathematical definitions and even various algorithms to be added to design ideas. Through the combination of data and algorithms, the shapes can be create based on specific logic or mathematical definitions. In the development of digital architecture, there have been many practical cases of algorithms that use natural patterns for design creation. With parametric design techniques, people’s ideas of “real” natural designs seem to be realized [7].

The development of architectural design and industrial design is inseparable. Although parametric design has been widely used in the field of architectural design, the information on industrial design is still extremely limited. Although some works of parametric designs have appeared one after another, but the discussion on the application of the entire design process is still at a relatively inadequate stage, especially in the cultural and creative industry, and no one mentions its application [8][9].

II. ISLAMIC GRAPHIC STYLE FEATURES

Geometric patterns appear in large numbers in Islamic culture. They exist on different materials such as tiles, wood, brass, paper, plaster, glass, etc., and they are particularly prominent on the surface of buildings. Leaving aside the patterns on felt, floral motifs and stylized floral designs, Islamic motifs appear in three specific geometric features. One of the most easily recognizable is the rectangular Kufic letter pattern. They used simple rectangles and squares to create calligraphic designs in a stylized form of Arabic letters. This pattern is most commonly used on building surfaces to add majesty and solemnity. The second special Islamic pattern form is the arabesque, which consists of curved elements that resemble leaves and flowers. In this pattern, the spiral shape continuously winds, undulates and connects, and the sense of periodicity and rhythm is very prominent in this pattern.

The largest category of Islamic patterns uses complex polygonal and, less commonly, circular arcs to enclose areas, with designs in a basic grid repeated over and over again to completely fill an enclosed area. The most striking feature of this type of pattern is the symmetrical form of the "stars" and "constellations". Some Islamic designs do not include stars, but they are quite rare and not very elaborate or complex. Stars with six, eight, ten, twelve and sixteen rays occur most frequently, but stars with other numbers of rays (especially multiples of eight, up to ninety-six) may also be seen. The star shape is not just decorative, but has important psychological and historical reasons.

The fusion of straight and curved elements and Arabic calligraphy shows the most obvious characteristics of Islamic architectural decoration. For Muslims, the poetry of the Quran represents the visible reality of God's word, and its calligraphy enhances its sacredness and inspiration. No other civilization has placed such a high value on pattern and symmetry, and no other civilization has so deeply respected the sanctity of words, that it can be said that "calligraphy is the jewel in the crown of Islamic art."

The other two characteristics are related to "fluidity" and "infinity", which may not be obvious from isolated patterns, but as in the Islamic patterns mentioned above, the geometric basis used is the replication of the grid, and the pattern can be repeated infinitely to fill the space as much as possible. A concomitant property is that the viewer's eye has no natural focal point. When people look at an unfolded pattern, their eyes will "flow" continuously along the lines, and they will see many complex structures and relationships. This feature is not evident in the geometric designs of other cultures.

III. Parametric Design Principle

Parametric design is a top-down calculation method, using related geometry as the basis, and then through the calculation of various dimensional parameters, as a technology of product design. Compared with traditional design methods based on subjective intuitive judgments, experience and habits, parametric design focuses on the definition of relationships. However, the setting process takes time to understand the logic behind and the choice of information. Zaha Hadid believes that the process of parameter importing design is necessary and can improve the feasibility of the design.

Parametric design uses the parameter rules of each characteristic as the design basis. Each parameter represents an important characteristic, which may be structure, capacity, cost or even some physical characteristics. By designing the interrelationship between the structure and data of each characteristic to generate the basic form required for the design.

In recent years, the application of parametric design techniques has gradually become popular. There are more and more CAD (Computer-Aided Design) software based on the concept of parametric and derivative design. However, most of the parametric derivative design tools are rarely packaged into a single standalone software at present, but mostly in the form of plug-in tools used on a specific CAD platform. For example, the parametric software "Grasshopper" developed by McNeel can be installed in the same company's Rhinoceros3D modeling software. It can be designed with the 3D model constructed by Rhino and can also be designed in Grasshopper. "Genoform" is based on Solidworks. Through Genoform, you can use the 3D model constructed by traditional modeling methods in Solidworks as the basis and parameterize the features of the model, so that you can quickly produce a large number of different types by adjusting each feature The design plan, the latest Genoform can also be linked to Grasshopper and Autodesk's Inventor software. In this study, the Grasshopper application plug-in to the Rhinoceros 3D modeling software was used as a modeling tool for weaving characteristic. The reason is that Rhino itself is easy to operate, and it has been widely used in the field of industrial design for modeling.

A. *Parametric Design Software - Grasshopper*

The Grasshopper is a graphical parametric design tool developed by the McNeel Corporation since 2007. It is installed in the 3D modeling software Rhinoceros produced by the same company in a plug-in form. Grasshopper is currently a software under work in progress, and many functions are often added and adjusted when the version number is updated. Grasshopper is mainly used to create generative algorithms. 3D geometric models are created through the connection, design of parameters and various calculators. The algorithms in the program are not only limited to the use of numbers, but text, video, audio, and touch applications can all be used as calculations or in the form of parameters. As architectural design is currently the most important field of parametric generative design methods, architects and related learners are currently the main users of Grasshopper, but its gradually improved and increasingly perfect graphical user interface and operation methods allow other fields users also began to pay attention to this software and used it as a tool for parametric design.

B. *The Modeling Concept of Grasshopper*

Grasshopper (hereinafter referred to as GH) is a software that uses the graphics programming language (GPL) as its operating method. Simply put, GH uses Rhinoceros to create basic 2D and 3D geometric figures, edits the logic of the subsequent generation of geometric figures through GH, and finally reuses Rhinoceros serves as its platform for presenting calculation results.

For example, in the past, to create a sphere in the Rhinoceros environment, it can be simply divided into several steps. First, draw the section contour line, use the rotation forming command, enter the rotation angle, and finally get the model. The entire construction process is shown in Figure 1(a). But when we need a semicircle, we have to operate the above process again. In the GH environment, we only need to find the most important arithmetic unit in the creation of a spherical surface: the rotating surface. When we understand the parameters required for the rotating surface, the axis of rotation, the section contour, and the angle of rotation, then through the interaction between the arithmetic units, it will automatically construct a complete sphere. The whole construction process is shown in Figure 1(b). Therefore, if we only need a semicircular surface, we can modify the rotation angle parameter immediately [10].

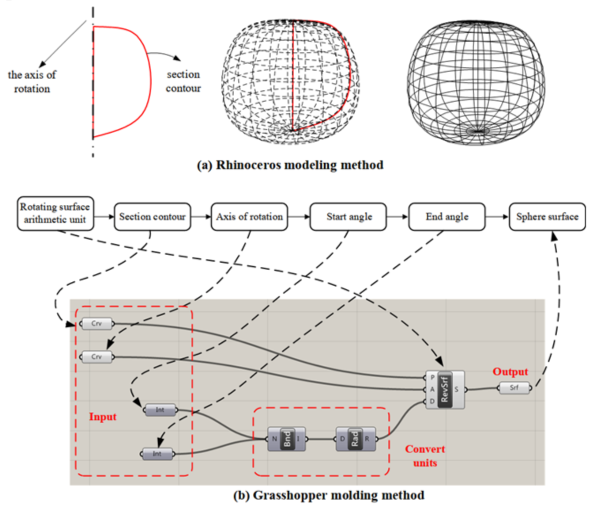

Figure 1 Differences and correspondence between Rhino and Grasshopper construction models.

Taking the gradual change of the sphere as an example again, set the required number parts, and then use the arithmetic progression as the change of the radius parameter to complete the model as shown in Figure 2. When you want to change the requirements, you can quickly generate a new parameter model by adjusting the starting radius of the parameter and increasing the value.

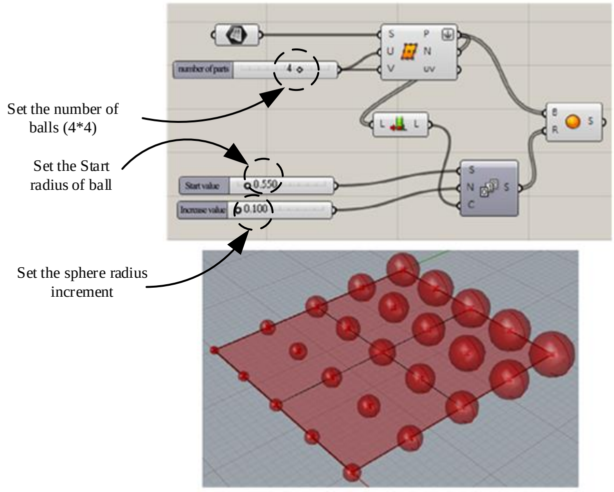

Figure 2 The Grasshopper's construction of gradient sphere model

C. *The Redesign Method of Grasshopper Operator Construction*

Parametric design and its open design operation platform makes the methods of constructing models very diverse. Designers can apply traditional modeling methods to construct various geometric modeling actions like piles of wood. Appropriate algorithms can also be added as an aid to produce various shapes. This derivative design method is the biggest feature and charm of parametric design.

This paper is to highlight the design change features of parametric modeling. Therefore, the size parameters that can be adjusted flexibly must be designed in the modeling process, and in the process of parameter adjustment, the appropriate relevance required by the modeling command must still be maintained. The following is an example of extruding 6 quadrangular pyramids from the 6 faces of a primitive cube in their respective normal directions to illustrate the GH operator construction flowchart, as shown in Figure 3. And Figure 4 is an example of the different results generated by inputting the extrusion height of 20, 30 and 40mm respectively.

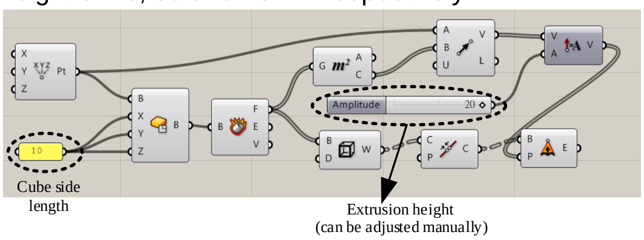

Figure 3 The Redesign method of GH operator construction flowchart

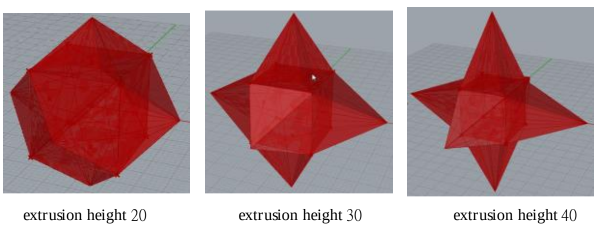

Figure 4 The different results generated by inputting the extrusion height of 20, 30 and 40mm respectively.

IV. GH Construction Process of Parametric Islamic Pattern

This paper utilizes the Gresshopper (GH) plugin for Rhino software to create parametric Islamic pattern prototype templates. This allows for easy modification of the prototype's geometric features and its easy extension to the surfaces of other objects. This will make it easier for those interested in the study of Islamic patterns to apply these techniques and create more exquisite products, thereby promoting and continuing the aesthetic and technical beauty of Islamic culture. The following uses a common Islamic pattern (Figure 5) as an example to illustrate the research methods and steps of this paper:

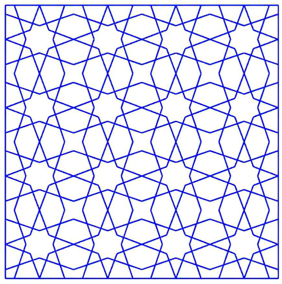

Figure 5 Islamic pattern

Step 1: Analyze the prototype graphic of the pattern.

Islamic patterns are usually derived from a single prototype and extended infinitely, so the first step is to identify the prototype. See Figure 6.

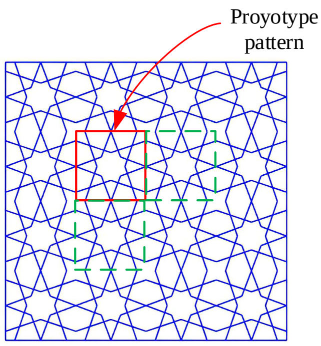

Figure 6 prototype pattern

Step 2: Analyze the geometric relationships of the prototype graphic.

Islamic patterns typically exhibit geometric symmetry. Therefore, analyzing the geometric relationships of symmetry before constructing a prototype graphic will facilitate the subsequent construction process. For example, the symmetry of this pattern is shown in Figure 7.

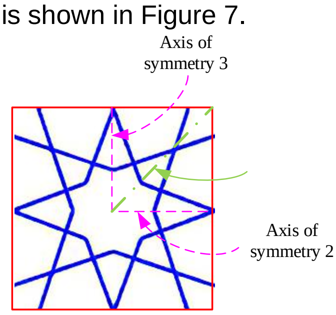

Figure 7 the geometric relationships of the prototype graphic.

Step 3: Construct a unit rectangle and decompose it.

After analyzing the geometric relationships of the prototype graphic, we can begin to construct the graphic using the GH module. First, using the "Rectangle" and "Explode" modules, we construct a unit rectangle and decompose it. This will give us the line segment data B0, B1, B2, and B3 of the four sides of the rectangle, as shown in Figure 8.

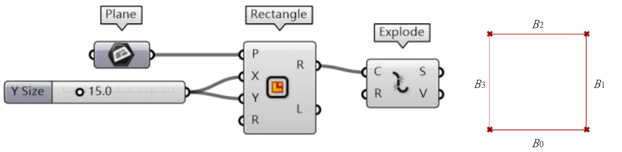

Figure 8 Unit rectangle and the relationship between line segments

Step 4: Construct the L0 line segment within the prototype graphic

Next, the L0 line segment within the prototype graphic is constructed. The method is to use the “List Item” and “Point On Curve” batteries to extract the B0 and B2 line segments respectively, and set the corresponding parameter points P0 and P2 on them respectively. Then, the L0 line segment is constructed using the “Line” battery, as shown in Figure 7.

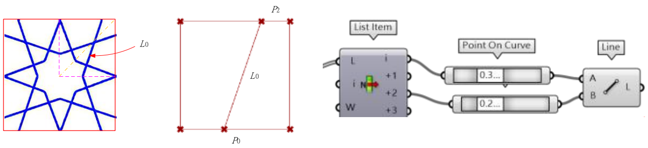

Figure 9 L0 line segment within the prototype graphic

Step 5: Construct the L1 line segment within the prototype graphic

The steps to construct the L1 line segment within the prototype graphic are as follows: Extract the endpoint data of V0, V1, and V2 using the “List Item” battery, construct the L02 line segment using the “Line” battery, set the corresponding parameter point P02 on it using the “Point On Curve” battery, and finally construct the L1 line segment using the “Line” battery, as shown in Figure 10.

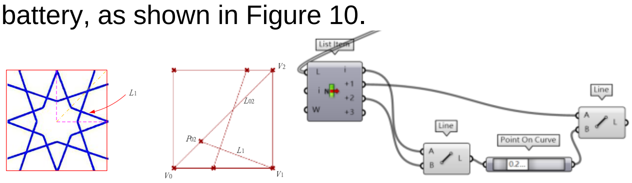

Figure 10 The L1 line segment within the prototype graphic

Step 6: Construct the mirror planes L1 and L0 within the prototype graphic.

The mirror planes L1 and L0 within the prototype graphic can be constructed using a "Construct Plane" cell. The vector passing through V0 and V2 ("Vector 2Pt") serves as the "X" axis input value for the "Construct Plane" cell, while the unit vector of the Z axis ("Unit Z") serves as the "Y" axis input value. This completes the required mirror plane, as shown in Figure 11.

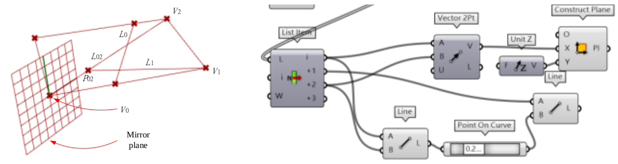

Figure 11 Mirror planes of L1 and L0 within the prototype graphic

Step 7: Execute L1 and L0 mirroring

The "Mirror" battery can be used to mirror the line segments L1 and L0 based on the mirror plane constructed in the previous steps, while hiding the line segment L02, as shown in Figure 12.

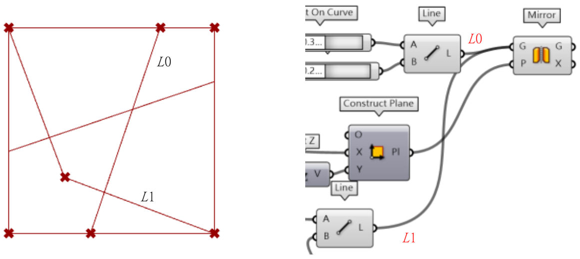

Figure 12 Mirroring of L1 and L0 within the prototype graphic

Step 8: Execute a circular array of relevant feature segments

Next, using the "Polar Array" battery, with point V0 as the center, perform a circular array operation with 4 objects in a 3600-degree radius, including L1, L0, and the line segment mirrored in the previous step. At the same time, hide the unit rectangle. The result of the single original graphic is shown in Figure 13.

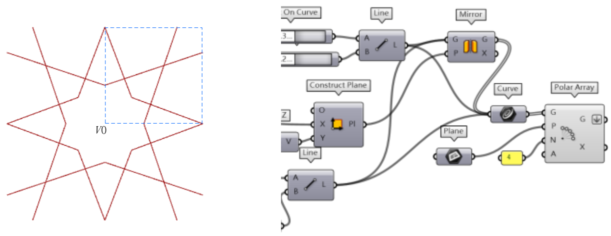

Figure 13 Single original graphic

Step 9: Rectangular arrays of single primitive graphics

To achieve the flexible expansion of this single original graphic, we must first use the "Bounding Box" battery to determine the boundary size of the single original graphic, which will serve as the offset basis for the "Rectangular Array" battery operation. Here, the result of offsetting 3 times in both the X and Y directions is shown in Figure 14.

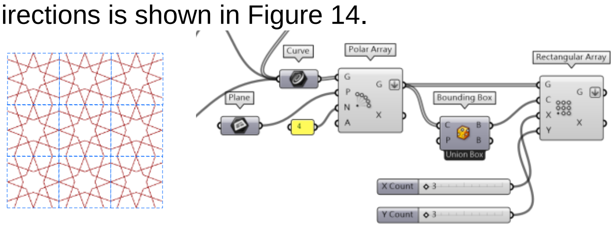

Figure 14. Expanded result of the original graph

Step 10: Complete the final boundary contour drawing

Finally, the "Bounding Box" and "Brep Wireframe" batteries can be used to complete the final boundary outline, as shown in Figure 15.

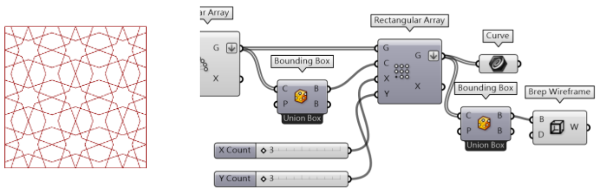

Figure 15 Final boundary outline

Therefore, the complete relational diagram of the GH construction in this example is shown in Figure 16.

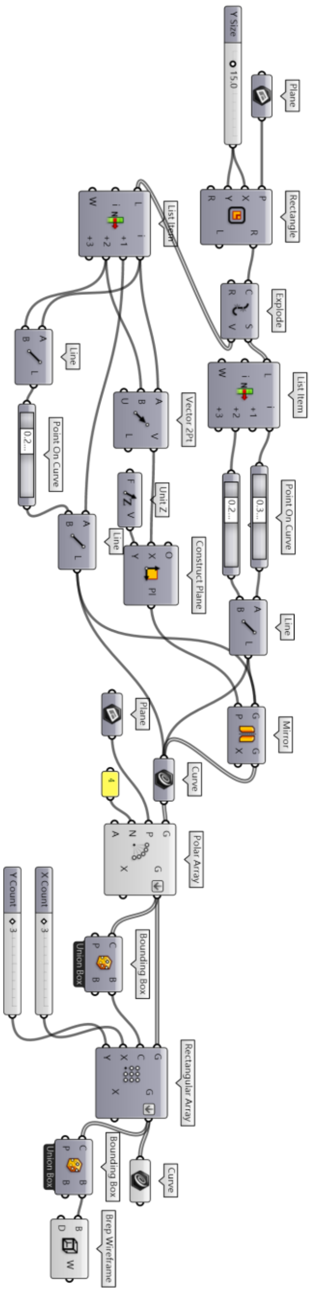

Figure 16 Relationship diagram of the complete GH construction in this example

Figure 17 shows various Islamic graphics obtained by setting different corresponding parameter points P0 and P2 on line segments B0 and B2, which demonstrates the practicality of this project for future research in this field.

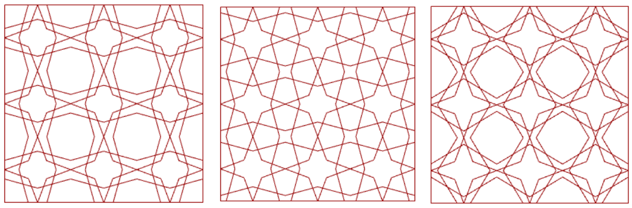

Figure 17 shows various Islamic graphics obtained from different corresponding parameter points.

V. Conclusion

This article utilizes the Gresshopper module (GH) of the Rhino software plugin to create various parametric Islamic pattern prototype templates. This allows for the free modification of the geometric features and dimensions of each prototype, and also enables its easy extension to the surfaces of other objects. This will make it easier for those interested in Islamic pattern research or product surface decoration to promote and apply these techniques, thereby creating more exquisite products and ultimately promoting and continuing the aesthetic skills of Islamic culture. Figure 18 shows a simulated image of a nightlight displaying Islamic patterns in a product design.

Figure 18 Simulation of the night light display with Islamic patterns

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