AN ANALYTICAL STUDY OF FIVE-POINTED ISLAMIC FLORAL PATTERNS AND AN EXPERIMENTAL DESIGN USING PENROSE TILING

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ABSTRACT

Islamic floral patterns warrant further research and analysis as they are an important aspect of the cultural heritage of Islamic patterns. These floral patterns are aesthetically inspired by flowers, leaves, vines, and stems and feature characteristics such as symmetry, interlacing, and pattern repetition. This study analysed a five-pointed rose pattern (peony flower) and its elements, such as the curved lines that make up the leaves and flowers. A new floral pattern featuring a botanical motif and curved lines was designed and distributed using kite and dart tiling. The floral pattern was designed using the pentagram reflection of the Penrose tiling method to suit modern design requirements of looking like a Shamsah. The results of the floral ornament and newly designed patterns were then reviewed in order to facilitate the generation of new patterns accurately and quickly through computer design software. Thus, the problem of time and effort in designing Islamic floral patterns was solved. This study also provides suggestions for future studies on Islamic floral patterns.

KEYWORDS

Arabesque; Islamic pattern; Rosette method; Penrose tiling; Floral ornament.

الملخص

تعتبر الزخارف النباتية موضوعًا مهمًا في التراث الثقافي للزخرفة الإسلامية، والذي يتطلب مزيد من البحث والتحليل. نظرًا لأن أنماط الزخرفة النباتية الإسلامية قائمة على القيم الجمالية، ومستوحاة من الزهور والأوراق وفروع وجذوع النباتات، وتتسم بخصائص مميزة منها التماثل، والتداخل، والتكرار. وتهدف هذه الدراسة إلى تحليل أنماط زخرفة الوردة الخماسية (زهرة الفاوانيا أو عود الصليب) وعناصرها المكونة من الخطوط المنحنية التي تتشكل منها أوراق وبتلات الزهرة. ومن العناصر الزخرفية لتلك الزهرة، وخطوطها المنحنية تم تصميم وتوزيع زخارف نباتية جديدة متمثلة في الزخرفة المعروفة باسم الطائرة الورقية والسهم. صممت هذه الزخرفة النباتية باستخدام الانعكاس الخماسي المعروفة باسم فسيفساء بنروز، لتلائم متطلبات التصميم الحدث لتظهر بشكل الشمسة. وبواسطة الزخرفة النباتية والتصميمات الزخرفية المستحدثة منها وفق ترتيب عرضها يسهل استحداث أشكال زخرفية جديدة تتسم بالدقة باستخدام برامج التصميم الرقمية بالحاسب الآلي. وهكذا يتم معالجة مشكلتي الجهد والوقت فيما يتعلق بتصميمات الزخارف الإسلامية النباتية. وتقدم الدراسة كذلك مقترحات جديدة تتعلق بالدراسات المستقبلية للزخارف النباتية الإسلامية.

الكلمات الدالة

أرابيسك؛ زخرفة إسلامية؛ زخرفة الوردة؛ فسيفساء بنروز؛ زخرفة نباتية.

INTRODUCTION

Arabesque art is an Islamic floral motif that uses spiral stems and intertwining branches. Although these motifs vary from one design to another, they are almost always filled with flowers and leaves that cover the entire space of a piece. Islamic arabesque decorations emerged in the ninth century AD. This is evidenced by the artefacts and stucco art used to adorn the walls of Samarra in Iraq (Afif Behansi, 1970). Over the years, Muslim craftsmen have invented and developed two types of motifs. The first relies on geometric polygons to produce new Islamic patterns, i.e., the Islamic star and rose patterns. The second, and more importantly, use the leaves and stems of a plant to simulate nature. Floral motifs use various kinds of plants and trees as inspiration for different abstract and modified elements as well as free formations (Kaplan, 2005). This is characterised by the repetition of elements in infinite circles that mimic the rotation of planets in space. Throughout the ages, Islamic motifs have spread among Muslim artists and are painted differently from one country to another and from time to time. However, despite apparent differences, they all exude an unmistakably oriental Islamic character (Lapidus 1996). These motifs never deviate from the Islamic stereotype and decoration formation concepts. Rotation, which relies on two or more elements alternating periodically, is one of the most prominent types of floral motifs. Other types of floral motifs are symmetrical and asymmetrical. Some floral motif artists use several colours to evoke feelings of joy, beauty, tranquillity, and comfort in the viewer. They also use gilding, which is a golden colour (Islamic Illumination), to give the piece a more luxurious aesthetic (De Hamel and others 1992) Hanash, 2010). The branches and leaves used in plant motifs vary in accuracy, composition, and presentation. This is because artists can use their imagination to draw many plant motifs innovatively by drawing stems and branches that are extremely long, twisted, and winding to give the illusion of growing continuously and permanently. Floral motifs include various floral drawings and roses of various forms. Over the years, artists have innovated how these floral motifs are abstracted and painted. Many amateur and contemporary scholars and designers research and analyse the patterns and geometric techniques developed by ancient artists to inspire them to create newer, more modern techniques and patterns (S. J. Abas & Salman, 1992).

The factors influencing the design of Islamic decorative pattern styles include the location, time period, materials, and environment in which these motifs were developed. In terms of location, the decorative techniques in a country may be adopted and creatively modified to be more Islamic. In terms of the time period, the extension of the Islamic eras and the development of life politically, economically, and culturally influences these designs. In terms of materials used and the environment, artists used whatever raw materials were available, leading to variations in the art produced from one Islamic country to another (Shuraiki, 2012). Islamic plant-based decoration is on the brink of extinction as there is a decline in the number of traditional-style artworks produced. Apart from the cost of raw materials and the production method, the political and economic crises that plague most Middle East countries have resulted in the deterioration of most of the traditional and folk-art techniques. Therefore, this study aims to save Islamic motifs from extinction by documenting, studying, analysing, and reformulating Islamic motifs in ways similar to modern designs. This

is to be accomplished by developing methods of generating new models and simplifying the manual drawing process using the reflection method of Penrose tiling.

This study analysed Islamic floral motifs and created new patterns using the Penrose tiling method. The first chapter of this study introduced floral ornaments, while the second chapter comprises a thorough literature review. The pentagonal flower and its elements are analysed and discussed in the third chapter. The fourth chapter covers transforming the flower, while the fifth chapter discusses the use and design of new patterns. The results of this study are presented in the sixth chapter.

LITERATURE REVIEW

Islamic art is defined as any art produced in lands where Islam is the main religion and influences its governance. Islamic art is also displayed in museums of Islamic heritage and some international museums in countries such as Turkey and Qatar. Since its inception, Islamic art has been used to decorate palaces and buildings that still stand to this day. It is characterised by the use of rotation, repetition, and intertwining polygonal stars and arabesque designs. This study reviews extant studies on arabesque and geometric Islamic patterns. While analysing Islamic geometric patterns and the traditional method of drawing them, Bourgoin collected more than 190 patterns from the Islamic world and analysed 30 of them (Bourgoin, 1973). Multiple studies have also sought to discover the characteristics of the Islamic decorative patterns, their elements, techniques, and methods of geometric and mathematical drawing, schematic drawings that contain pairs of lines, repetition, and symmetry of design, and more complex Islamic geometric patterns (Bonner, 2017; Bier, 2017; Wichmann & Wade, 2017). Islamic patterns contain lines that continuously delineate through the paths and units of a hierarchical structure (Cromwell 2012). These patterns have been analysed to determine a set of patterns both geographically and historically (A.J. Lee, 2015). As these patterns are similar at times and differ at other times, they have also been analysed and compared in terms of geography and history (Aboufadil et al., 2019), starting with pentagrams, hexagrams, and the most famous, the octagram. These stars are divided into folds, forming the Islamic star, which consists of 12 reflections often seen in Moroccan decorations. Several types of 12-fold rosettes differ according to the geometry of their petals in a cyclic structure of up to 17 overlapping crystal groups. The rosettes overlap by varying amounts, generating new periodic and semi-periodic patterns (Abouf Adil et al., 2019). The Islamic star is distinct due to lines that overlap and contrast each other. A set of rosette patterns is created by doubling the amount of overlap found in a basic star using arithmetic: i.e., six is doubled to twelve, and eight is doubled to sixteen. Therefore, many patterns of the Islamic rose were created (Aboufadil, Thalal, & Raghni, 2013).

Mathematical analyses have found that some ideal star patterns combine a variety of styles, such as nine and eleven points, as well as between thirteen and sixteen points. This produces star patterns by incorporating the repetition of an equilateral triangle template using reflections and symmetry (Cromwell, 2010a; Cromwell, 2010b).

Classical engineering methods based on group theory have been used to develop algorithms for Islamic patterns to efficiently generate crystal repeating patterns using modern computer

graphics (Abas & Salman, 1992; Abas, 2001; Hankin, 1991). Islamic decorations contain polygons with five, six, seven or eight points in a circle. As the geometric shape increases, the circles are divided into points that are equal in dimension and angle. Straight lines are then extended equally between the points that divide the circle. The bifurcation of these inflection circles in the geometric space forms basic geometric shapes, such as pentagrams, hexagrams, heptagrams, and octagrams, which are then doubled to create new innovative patterns. Historical sources of ornamentation have been used to develop mathematical tools that analyse Islamic star patterns according to Hanken's technique of "contact polygons" (Kaplan 2005) to beautifully and geometrically design Islamic star patterns. Traditional design techniques rely on the symmetrical placement of ornaments and the intertwining of straight lines within the circle of the pattern elements. This method for creating a set of decorations can be used to fill in many regular polygons. Star patterns can also be designed to fit the Euclidean plane symmetrically (Kaplan, 2000; Kaplan & Salesin, 2004). The symmetry of Islamic geometric patterns can be classified as either frieze or crystal (Rønning 2009). In Islamic patterns, stars are formed by intertwining lines. Many such methods are based on the symmetry group theory, which is used to construct Islamic star patterns by repeating the decorative shape within a suitable grid (Art & Shephard, 2015; Khamjane & Benslimane, 2018). The Penrose tilings are notable for being non-periodic (i.e., there is no translational symmetry) but well-organized. Their structure, known as quasiperiodicity, can be characterised in various ways, including self-similar subdivisions, tiles with matching rules, and R5 projection of a cubic lattice slice. The tilings are particularly notable for having a large number of local five-fold and ten-fold rotational symmetry centres, which are common in Islamic geometric patterns. This resemblance has sparked comparisons, leading some to believe that classical Islamic designs are antecedents to the Penrose tilings and even proof of quasi-periodicity. (Cromwell 2009) This work observed the use of subdivision in traditional Islamic design systems and overlaid Penrose kites and darts on Iranian designs. The latter paper was widely covered in the press around the world, however some of the coverage exaggerated and misinterpreted the real findings.(Lu and Steinhardt 2007) Even though Islamic motifs have local ten-fold symmetry, they are frequently used as part of a flat periodic pattern with no overall five or ten-fold symmetry. This work incorporates these motifs into patterns based on Penrose tilings. (Rigby 2006)

In this study, Islamic patterns; particularly the arabesque Islamic rosette; and its components are analysed to produce innovative floral patterns using Penrose tiling. This should save craftsmen time and effort to design many endless varieties of decorations.

ISLAMIC FLORAL PATTERNS ANALYSIS

Floral patterns are divided into three categories: curvilinear designs with floral parts, floral motifs and patterns with curved edges, modified leaves, and tendrils, all of which are shown realistically. The bifurcation is flowing and detailed, and the artwork is symmetrical. (Abdellahi 2011) Some painters exaggerate the stems and tendrils' expanse, leaving them so lengthy and knotted that they appear to grow endlessly. Islamic art is inspired by various natural floral patterns, which are used in their innovative and unique designs. Floral ornament

patterns are included for decorating: book pages, ceramics, fabrics, carpets, domes, ceilings, walls and Shamsah, decorative frames, friezes, and decorative angles.

Main Elements of Islamic floral Ornaments

Several elements dominate from the earliest monuments with mosaics of naturalistic motifs, such as the Dome of the Rock and the Umayyad Mosque, to the early 18th Century glazed tiles of Madar-I Shah Mosque, the repertoire of Islamic vegetal ornaments. Egypt has already been exposed to Seljuk skills for developing Islamic floral ornament. By the mid-thirteenth century, buildings such as Sultan Al-Zahir Baybars Mosque (1267) and Mustafa Pasha (1272) in Cairo, built by the early Bahri Mamluks (1250–1382), may be found. (Yeomans 2006) These main elements can be classified according to their botanical and morphological features. Narrowing these features down to the morphological aspects related to abstract ornaments is necessary (see Figure 1).
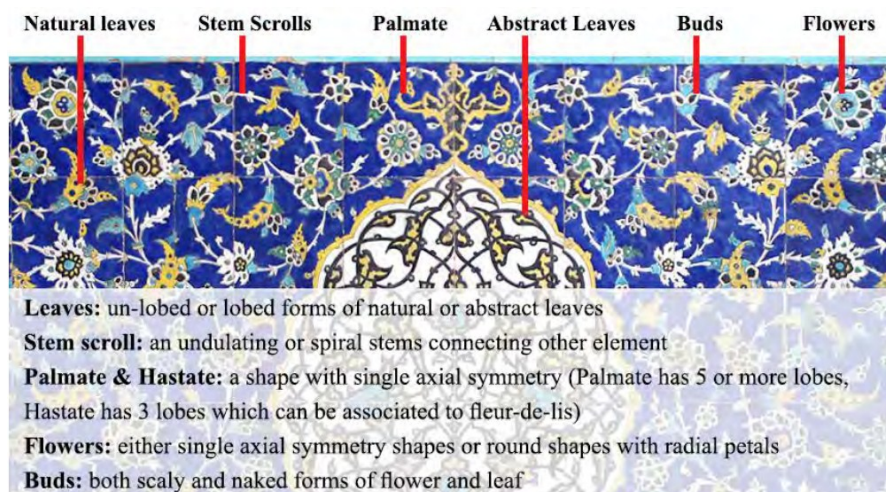
Figure 1 elements of Islamic floral ornament in Sheikh Lutfallah Mosque
(Source: (Abdullahi and Embi 2015)

Design: Although abstract parts of the style have been utilised in mosques or shrines, a little realistic style from early Islamic floral decorations has returned. A distinction between the Fatimids and the Umayyad scrolls is that early Islamic styles had leaves or flowers growing out of the main scroll. In contrast, the Fatimids' style has leaves growing out of other leaves, forming part of the main scroll. Furthermore, leaves are larger, curves have lower radii, and vine scrolls are stockier than early Islamic forms, producing dense and exuberant patterns compared to prior styles. A vertical feature (trees, palmate or bulbous chalice) bisects the surfaces of these motifs, which was a typical approach in Umayyad decorations(Abdullahi and Embi 2015). The overuse of fan-shaped leaves is another feature of these ornaments. In Islamic Floral design, in the case of friezes and borders, leaves grow continually out of the apex of each other to make scrolls. Compared to early Fatimid ornaments, stems and scrolls got thinner over time, while tri-lobed and five-lobed leaves became increasingly common in designs. The Islamic floral ornamentation impacted modern neighbouring kingdoms and empires such as the Qara-Qoyunlu, Aq-Qoyunlu, and the Ottomans. Floral Islamic art and

architecture were carried on by the Safavids in Iran and the Mughals on the Indian subcontinent until the early 16th century (Golombek, Wilber, and Allen 1988).

Color: A defining feature of the style is the transition from monochromic and polychromic blue designs to colourful polychromic tiles (including turquoise, yellow, gold, ochre, red, and green). The popularity of the over-glazing technique in the late 15th century accelerated this change, resulting in more exotic colours and contrast in late floral ornamentation.

Figure 2 shows the types of flowers in the floral decoration, as in the Safavid style. We also see three main types of flowers, the lotus flower, the carnation flower, and the peony flower. The last flower is the five-pointed flower we will analyze in this work, as the other flowers consist of the five-pointed flower in the red circles in Figure 2.
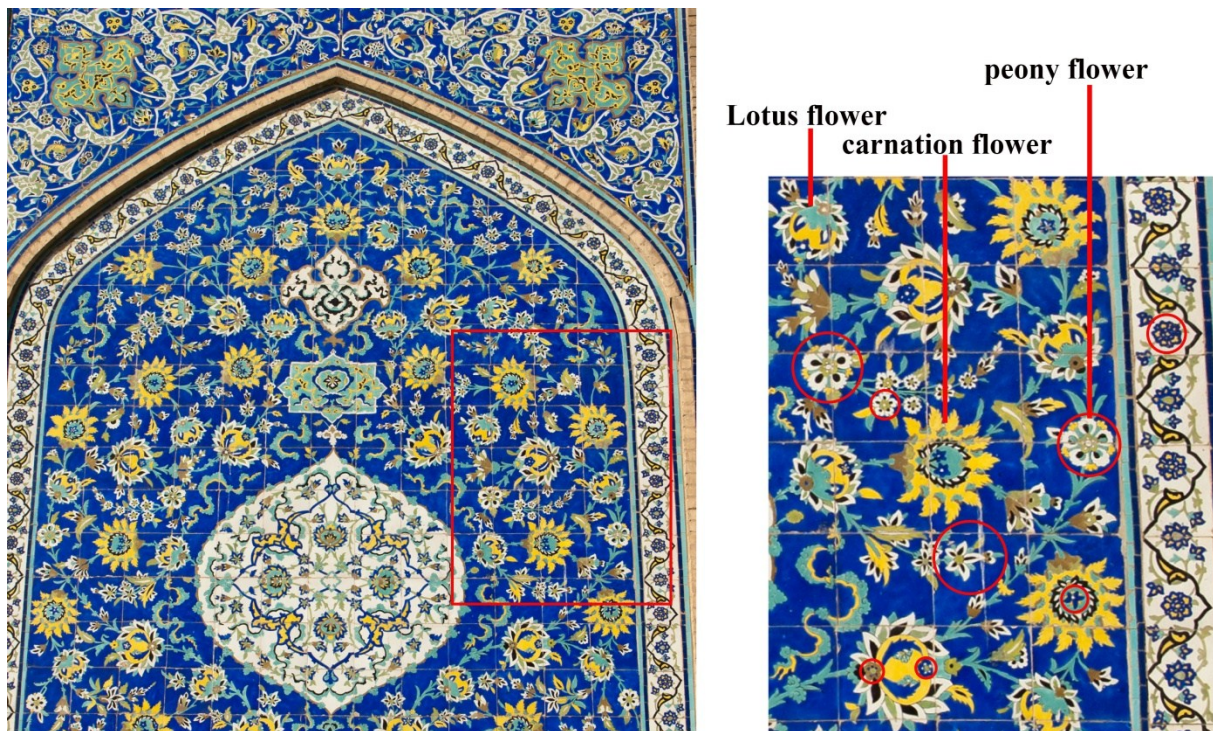
Figure 2 Sheikh Lutfallah mosque 1602-19 Safavid Tiles floral ornament elements (source: www.felickr.com 2010)

The basic rules of Islamic motifs

The motif depends on the artist's and old craftsmen's style and undergoes multiple design stages. The final motif is consistent with its elements concerning dimensions and distances, which are distributed according to similar scales that the artist perceives to be a guide for creating different patterns. The most important design rules are as follows:

- **Repetition** means copying or redrawing a decorative unit or single element multiple times at specific dimensions. Some of the methods of repetition include successive, overlapping, and opposite repetition, usually adjacent horizontally, vertically, or circularly. The element is repeated according to the circle's division into points. An illustration of the types of repetition is provided in Figure 3. The consecutive repetition consists of half a circle successively repeated in a straight line (Figure 3a). Half the circle intertwines, repeated by dividing one half of the circle into two halves

and drawing the other half from the middle of the first circle (Figure 3b). An opposite repetition is created by alternately reversing half of the circle equidistantly along a straight line. (Figure 3c).
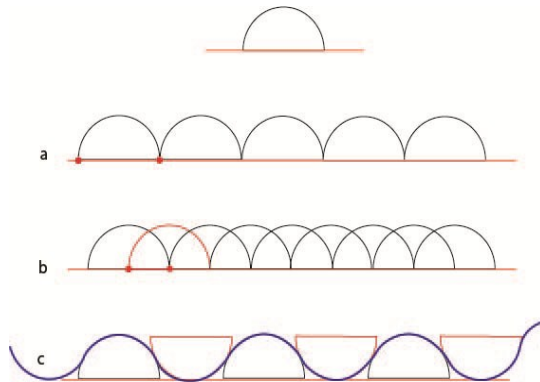

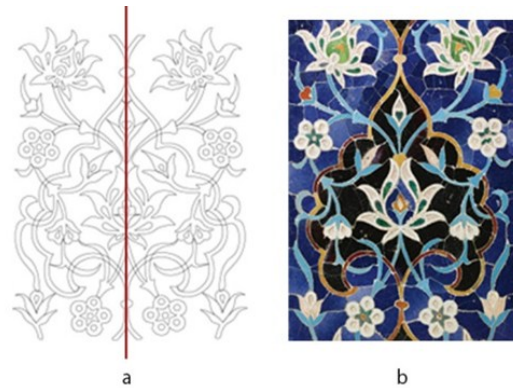Figure 3 Illustrates types of repetition.

Figure 4 Illustrates symmetry (4-a) A monumental Timurid Mosaic Tile panel with lotus blossoms, Transoxiana, 15th century (4-b) source: patterninislamicart.com

- ▪ **Symmetry** means that half of the decoration matches and balances the other half. This is measured by drawing a straight line that divides the decoration into two halves. If the designs in the two halves are equal, they complement each other. The decorative elements are in the first half as well as the second half (Figure 4).
- • **The bifurcation** is divided into four sections (Figure 5):

  (1) Bifurcation from a single point. The lines of a decorative unit emerge from one central point towards the outside or to the four sides (Figure 5a), depicting the method of drawing a circle and dividing it into four parts. Each section in the circle is then divided into two halves to create an eight-section rosette. This rule is often used in plant-based and floral-based Islamic designs. The number of bifurcation lines within the circle can be multiplied by dividing each part of the circle into two equal halves, as in the historical Islamic patterns of 6, 8, 10, 12, 14, and 16.

  (2) Bifurcation from a single line. The unit branches from straight or curved lines from one side (Figure 5b) or both sides (Figure 5c). This type of bifurcation is common in decorative bars, frames, and friezes so that all the foundations need not exist in one pattern.
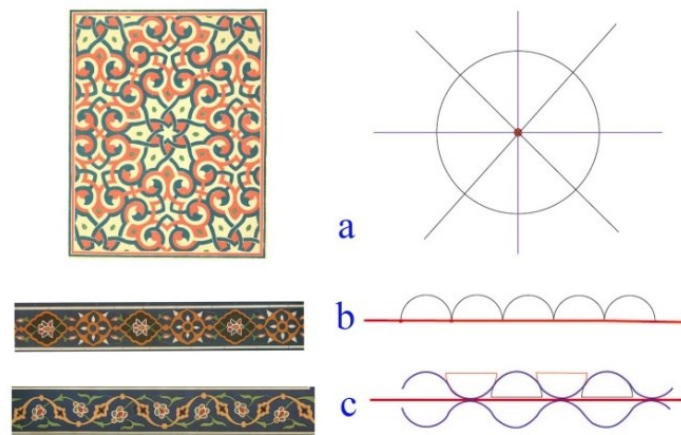
Figure 5 Illustrates Bifurcation L'art de l'Asie Centrale, N Simakoff,1883. source: patterninislamicart.com

1. FIVE-POINTED ISLAMIC FLORAL TRANSFORMATION

- Footage and analysis of the steps and method of drawing the Islamic rose:
- Two circles are drawn. The smaller circle is half the size of the larger circle.
- A third circle is drawn to divide the design into *n* partitions (n>5) (Figure 6a).
- To convert the middle circle into a rosette, the centre of the middle circle is divided into five equal sections. A circle is drawn on each point before the intersections of the five circles are deleted to create a star in the centre (Figure 6b).
- The straight lines within the third circle are replaced with curved lines (Figure 6c).
- Curved lines that complement the simple leaf shape are drawn (Figure 6d).
- Zigzag lines with several bends or in the shape of a leaf are drawn to make the flower design more complicated (Figure 6e).
- Islamic decorations have shapes filled with colour, and shapes which are hollow, and the leaf was filled with two branches in black to highlight the shape of the leaf. (Figure 6f).
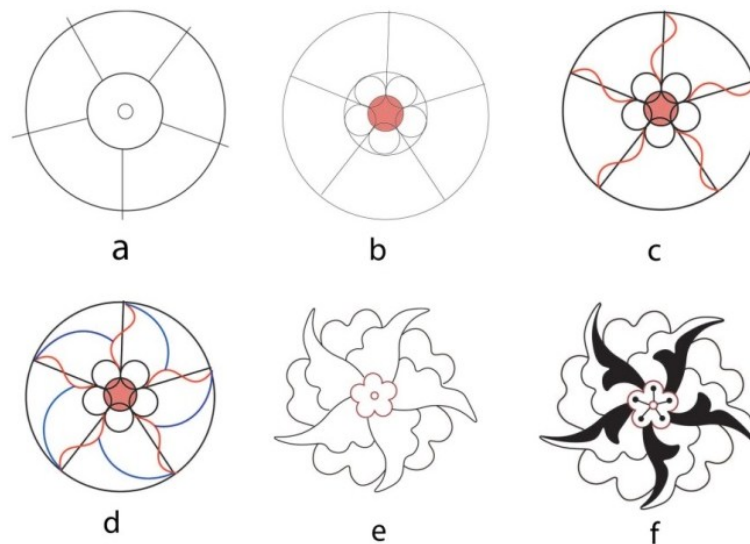

Figure 6 Illustrate the construction of peony flower rosette and its transformation.

Table 1 Evolution of peony flower Elements of Islamic Floral Ornaments

Ottomans (1290-1923)	Safavids (1501-1736)	Mughals (1526-1858)

Models of the five-pointed peony flower pattern in different historical periods table 1.

Similar to the steps of forming the Islamic rosette above, the method of creating an Islamic pentagonal rose can be deduced. Figure 7a illustrates a hexagonal rose and the process of dividing the circle equally. This is represented by the red lines, while geometric shapes, such as triangles, are denoted in pink while the hexagons are highlighted in blue. The following is the bifurcation method in drawing Islamic patterns, the technique of repeating the elements, and the geometric Islamic flower drawn with straight sides. Figure 7b shows an octagonal Islamic rose. Its' Islamic culture is characterized by the several repeated patterns used in mosques and palaces. These designs have been studied as they are closely related to symmetrical engineering. As seen in Figure 7c, the Islamic flower with floral decoration consists of curved lines. Most decorative elements are duplicate leaves intertwined with each other, like a Shamash. This will be discussed later in this study. Figure 7e shows the method of building Islamic patterns. Notably, they are composed of the same forked style from one point. The circle in the middle is the bifurcation point of the Islamic rose pattern. The decorative elements inside the circle are duplicated to represent the final representation of the Islamic rose pattern. The same process is used in creating hexagonal and octagonal Islamic stars. As seen in Figure 7f, the design of a symmetrical rose has four sides. In Figure 7g, the red circle at the top of the figure contains floral ornament elements that are entirely different from the circle below the shape. However, the construction method was the same, as one element is repeated in the circle to create a beautiful Islamic flower. Figure 7h depicts the completed pattern. The colour was filled within the lines. The design was noted to bifurcate, rotate, and symmetrical patterns with a repetition of floral ornament elements in each of the circles in an integrated manner. Upon analysis of the floral ornament, the method of dividing the rose, and the types of repetition, this study attempted to develop a new pattern with elements of Islamic botanical decorations using the Penrose tiling method.
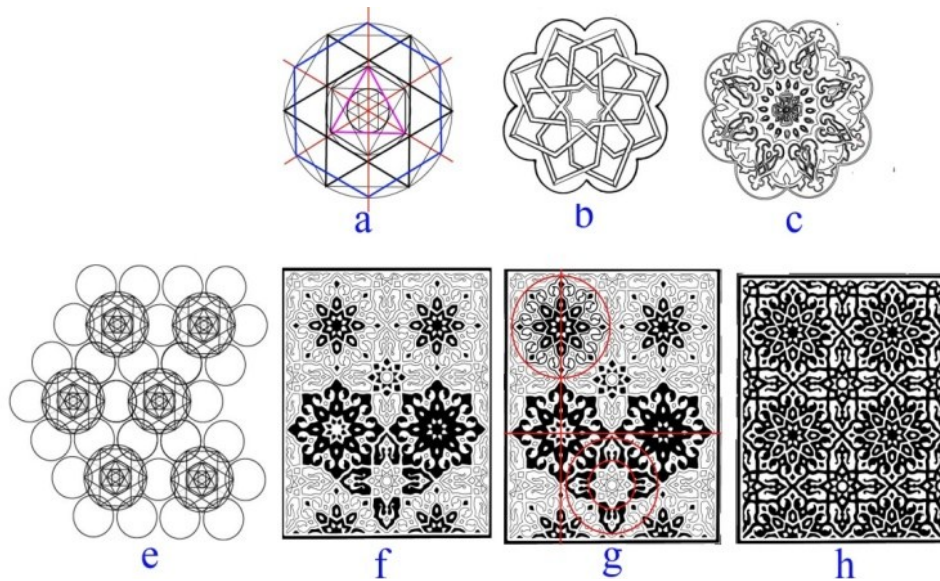
Figure 7 Illustrates the hexagonal, and octagonal Islamic flower and its drawing method

METHOD

This method of constructing new Islamic patterns using Penrose tiling is discussed in this section. One decorative element was identified and then used to build new patterns. The following is a simple explanation of the Penrose tiling method and its use in creating Islamic decorations.

Penrose Tiling

Penrose tiling was developed by British physicist and cosmologist Roger Penrose in the nineteen thirties. This tiling is non-periodic and is comprised of the golden ratio (φ) (Arthur, 1996).

The regular construction of a pentagon is relatively easy. After a regular pentagon has been constructed, its diagonals are created. These diagonals form a second and smaller regular pentagon. The diagonals of the pentagon are assembled as well. The rhombus above can be created using consecutive aspects of the unique pentagon. Examples of periodic tiling include normal tessellations, which use the handiest congruent polygons 2D.

This study constructed an Islamic rose pattern using the φ of the Penrose method.

Kite and dart

The Islamic decorative elements developed using the original Penrose group consisted of three prototypes called the φ. These rules can be described as using vertices or edges. As seen in Figures 8a and 8b, four angles indicate that the figure was quadrilateral with four different angles. The polygon was found to contain two small darts. The area marked in red colour indicates the vertex, the head of the kite and the dart.

As seen in Figure 8c, the kite can be divided into a dart and two kites, a dart at the head of the kite and two kites with heads in the opposite direction of the darts. Figure 8e illustrates the method for constructing a pattern using kites and darts in Penrose tiling. After the shape is reflected at a 72° angle five times, the final pattern is formed (Figure 8f). The darts are shaded light blue, while the kite is denoted by pink.
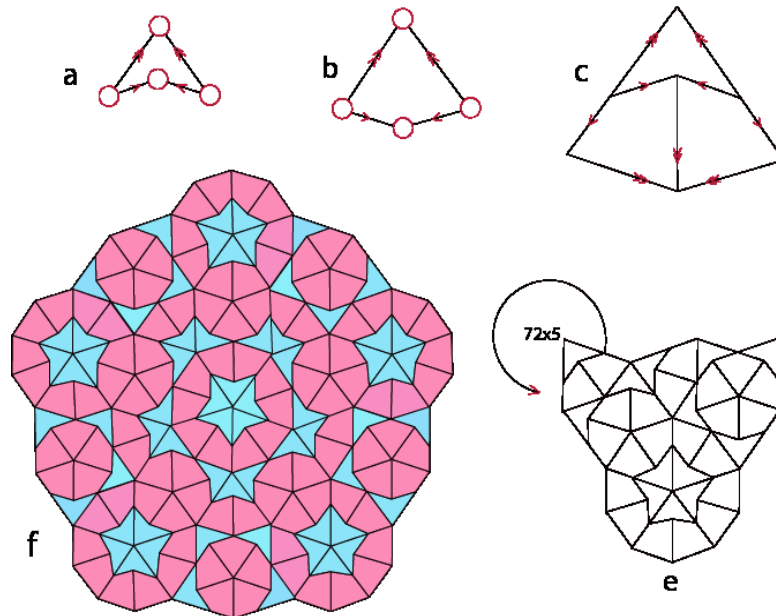
Figure 8   Illustrates the vertices and edges of the arrow and kite using Penrose Tiling, and how to construct the pattern

As seen in Figure 9a, a pentagon was created. A 1:1 line (indicated in red) was drawn on both sides to obtain an equilateral rhombus inside the pentagon. This is highlighted in grey. Kites and darts consisting of two triangles are called Robinson triangles, after observations by Robinson in 1975 (Gummelt, 1996). The kites and darts are shown in detail in Figure 9b. It consisted of two quadrilaterals formed separately by the rhombus at the corners. The kite is a quadrangular shape whose four interior angles are 72°, 72°, 72°, and 144°. The kite can be split along the symmetry axis to form a pair of sharp Robinson triangles with angles of 36°, 72°, and 72°. The dart is a quadrilateral without a convex. Its four interior angles are 36°, 72°, 36°, and 216°. The dart can be divided along the symmetry axis to form a pair of obtuse Robinson triangles with angles of 36°, 36°, and 108°, which are smaller than the acute ones.

1.1 The Golden ratio and pentagonal symmetry

Penrose roofs' many common properties and features use $\varphi = (1+\sqrt{5}) / 2$ (approximately 1.618). This is the ratio of the hypotenuse lengths to the side lengths of a regular pentagon. It satisfies $\varphi = 1 + 1 / \varphi$.

The larger and smaller Robinson triangles were found to be obtuse in the pentagon on the left side, i.e., larger triangles at the top - the two halves of the thicker rhombus - had linear dimensions that were increased by the φ, unlike the smaller 1:1 ratio at the base. As such, the ratio of the area increased to 2:1.

The kite was also divided into a dart in the middle, forming two kites (Figure 9d). As seen in Figure 9c, one shaded dart was taken and then repeated at a 72° angle to form a decagon. A single-shaded kite was chosen and duplicated at a 72° angle. A geometric shape with five sides was then formed (Figure 9d).
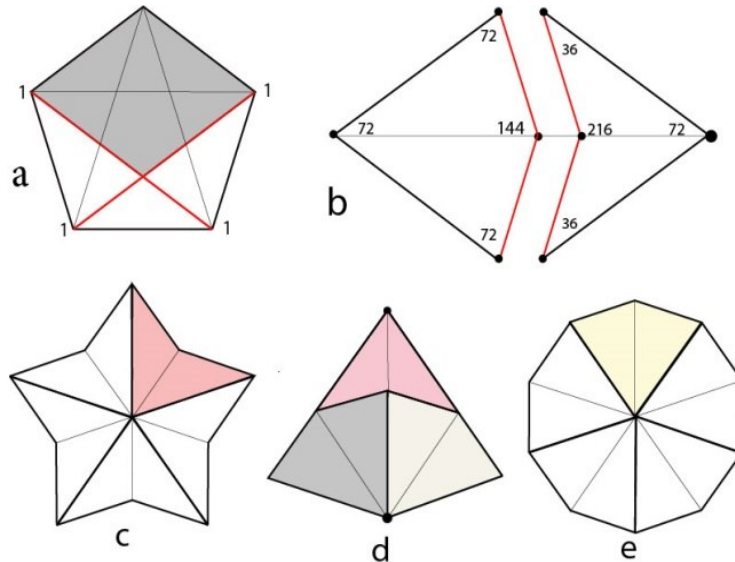
Figure 9 Illustration of the polygon geometry of Penrose Tiling.

RESULT AND DISCUSSION

One floral ornamental element was selected and then drawn in the kite. Repetition was used on the kite (Figure 10e) according to the angles defined in Figure 10b. As seen in Figure 10a, the dart was reflected five times, forming a star and incorporating an Islamic floral ornament. The shape in the middle and its response to other branches was noted. As seen in Figure 10b, the kite was drawn, showing its split into a dart and two kites. The ornamental elements inside were then used according to the theory of the Penrose tiling method. As seen in Figure 10a, the dart reflections with the ornamental detail were repeated five times. This is indicated in red, along with the star in the middle of the Islamic rose, which comes together as the darts are brought together to form a circle. The kite seen in Figure 10b was created from two kites and a dart in the middle, beneath the kites. A floral element was chosen for the two kites.

Regarding darts, the same elements were attached to the five kites and brought together into a circuitous patten (Figure 10c). This study managed to create an Islamic rose using one Islamic floral element. The element was repeated five times, forming an integrated and aesthetic ornament. Figures 10d and 10f, depict the new patterns created in this study. The patterns on the right (Figures 10e and 10g) were created using a similar ornament without the guideline, showing the floral motifs branching out from one central point to form the Islamic rosette.

Various ornamental elements were designed to create more aesthetically pleasing and complex Islamic floral patterns using kite and dart shapes. New patterns using the five-pointed reflections of the kites and darts, as well as new patterns that can be used in textile and clothing, such as hand embroidery or silk printing etc., to create new Islamic designs.

The first pattern consisted of curved lines and simple leaf designs taken from Islamic decorations. It consisted of curves and crowns in each kite that contained curved lines and some leaves (Figure 10b). The dart at the top of the kite consists of four leaves balanced on the sides of the dart and a pivoting leaf in the middle of the dart.

In the first process, when the dart was reflected from a point in the centre, a star formed (Figure 9a). This star design contained an overlapping and innovative floral ornament in the middle and branches of the design.

In the second process, when the kite was reflected from a point in the centre, a star shape also formed in the middle with the last rose, coloured red. Also, the repetition of the plant decoration on the inside of the kite looks like a Shamsah (Figure 10c).

The innovative patterns above were constructed from darts and kites. It is evident that the star in the middle is a result of the repetition of the dart and the motifs within it. The pentagon around the star was repeated five times, a repetition of the kite and its decoration. Reflecting the decorative elements on the left of the guidelines produced botanical patterns, as seen in Figures 10d and 10f.

When the guidelines were deleted, a new decorative pattern that consisted of the vegetal motif appeared (Figures 10e and 10g). The aesthetic of the new Islamic botanical designs, with and without guidelines, was noted. The second style of Islamic floral ornament, the kite, seen in Figures 10b and 10b1, depicted a floral decoration that consisted of an Islamic leaf with some arcs and zigzag lines on either side of the leaf (Figure 11b1). After dividing the kite into two kites with a dart in the middle, the ornament chosen on the kite was the same as that seen in Figure 11b. As for the ornament within the dart, the Islamic floral ornament was chosen and repeated in reverse with some zigzag lines.

When it was reflected five times around the centre point, the dart produced a pentagram ornament. The Islamic five-pointed rose in the middle consisted of leaves and curved lines, as seen in Figures 11a and 11a1. When the two kites and the dart in the middle were reflected five times from the midpoint, the pentagram in the middle, with the Islamic botanical rose, produced a look like a Shamsah, Figure 11c1 in the method of Penrose tiling. The following shapes devised new patterns characterized by repetition and symmetry.

The new patterns shown in Figures 11d, 11e, 11f, and 11g were bifurcated from a single point in the centre. The kite and darts were reflected in a thoughtful fashion, mainly in the pentagonal pattern, with or without guidelines.

For the third pattern that used an Islamic floral design (Figure 12), the same method was used but with different elements of the pattern. Unlike the previous pattern, a slightly more complex floral piece was chosen this time, the Islamic leaf pattern. The third pattern was constructed using the overlapping method (Figure 12a). The Islamic floral pattern was identical on both sides. When the dart was repeated five times from the centre point, the Islamic pentagonal flower was produced in the star formed by repeating the darts, as in the previous patterns. The pattern shown in Figure 12a1 is an extension of the floral ornament on the corners of the darts. Repeating the dart five times from the centre point was found to make the Islamic pentagonal rose more aesthetically pleasing, with the interlacing of leaves filled with the solid black elements in the design. The kite seen in Figure 12b shows that the decorative element in its centre was symmetrical from the left and right sides. As seen in

Figure 12b1, the kite was divided into two kites with a dart in the centre. The element was divided symmetrically. Figures 12c and 12c1 depict the kite reflected five times which looks like a Shamash. The pentagonal rose in the middle was mixed with entirely different patterns. When this was applied at a 72°line from the centre, it resulted in the Islamic ornament patterns seen in Figures 12d, 12e, 12f, and 12g.

The patterns depended on the bifurcation of one point, with or without guidelines, to form a pentagonal pattern.
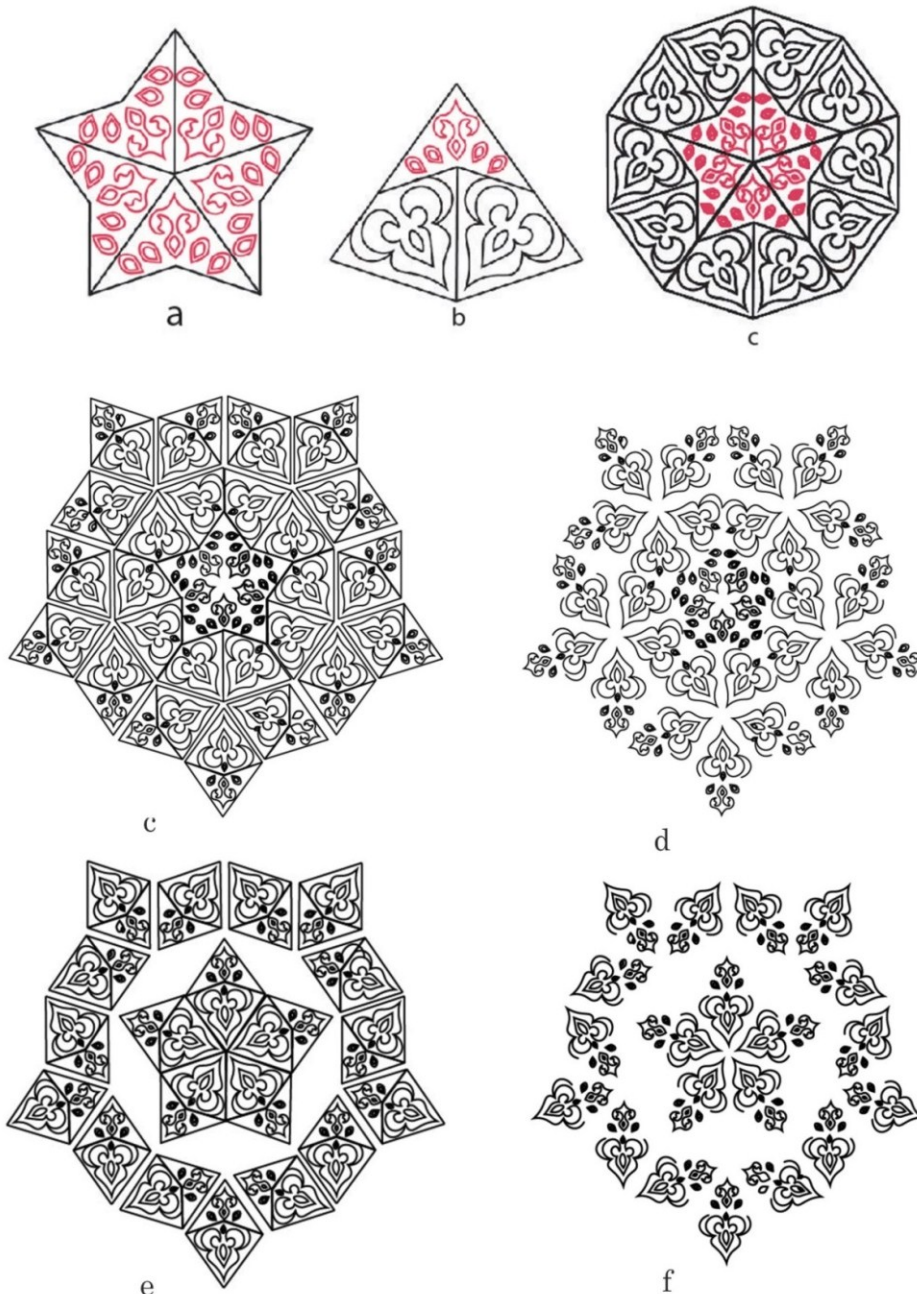

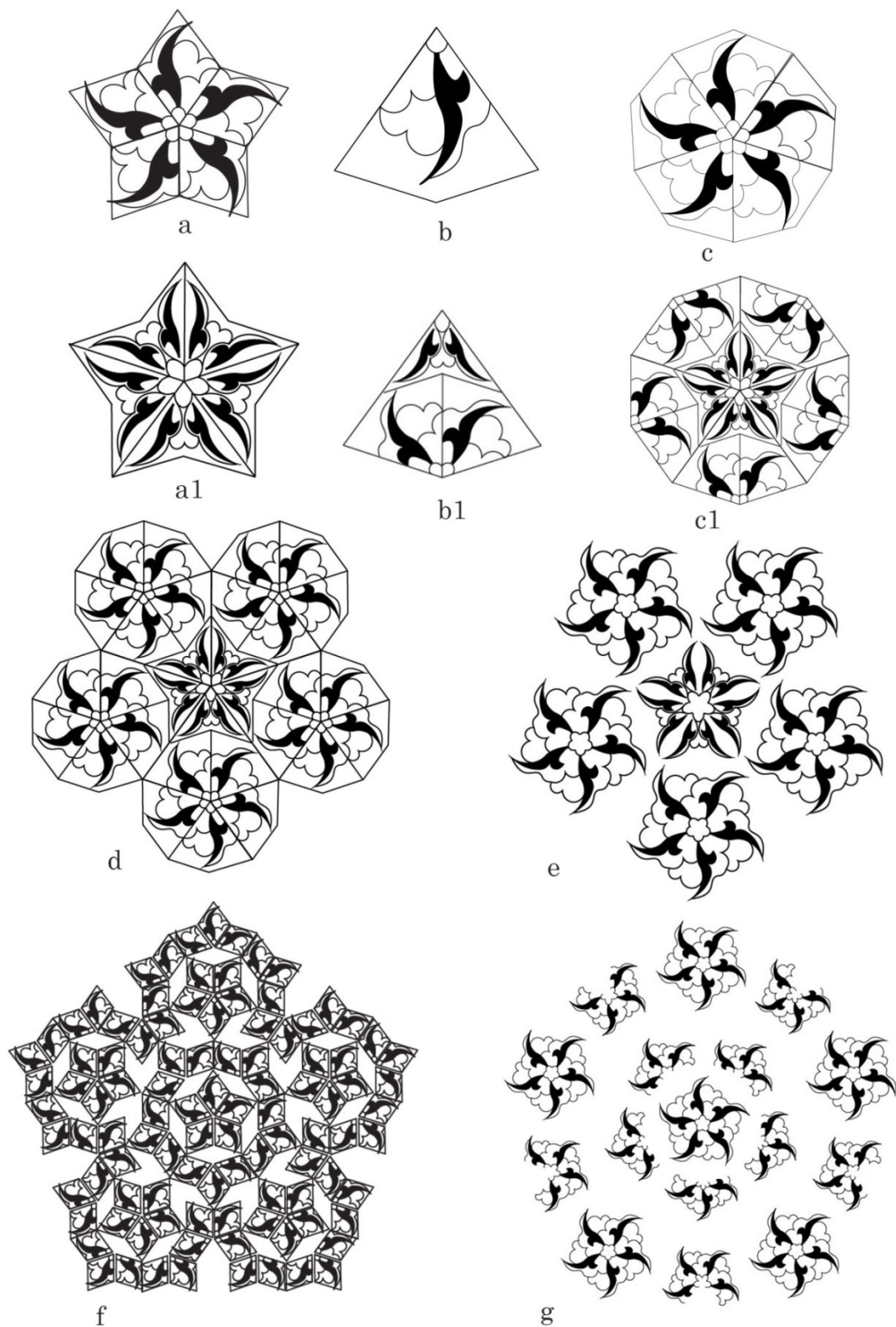Figure 8 Illustrates the first model in applying, the new Islamic patterns of kites and arrows.

Figure 9   illustrates the second model in applying the new Islamic patterns of kites and arrows.

a

b

c

c

a

b

c

a 1

B 1

C 1 | C 1
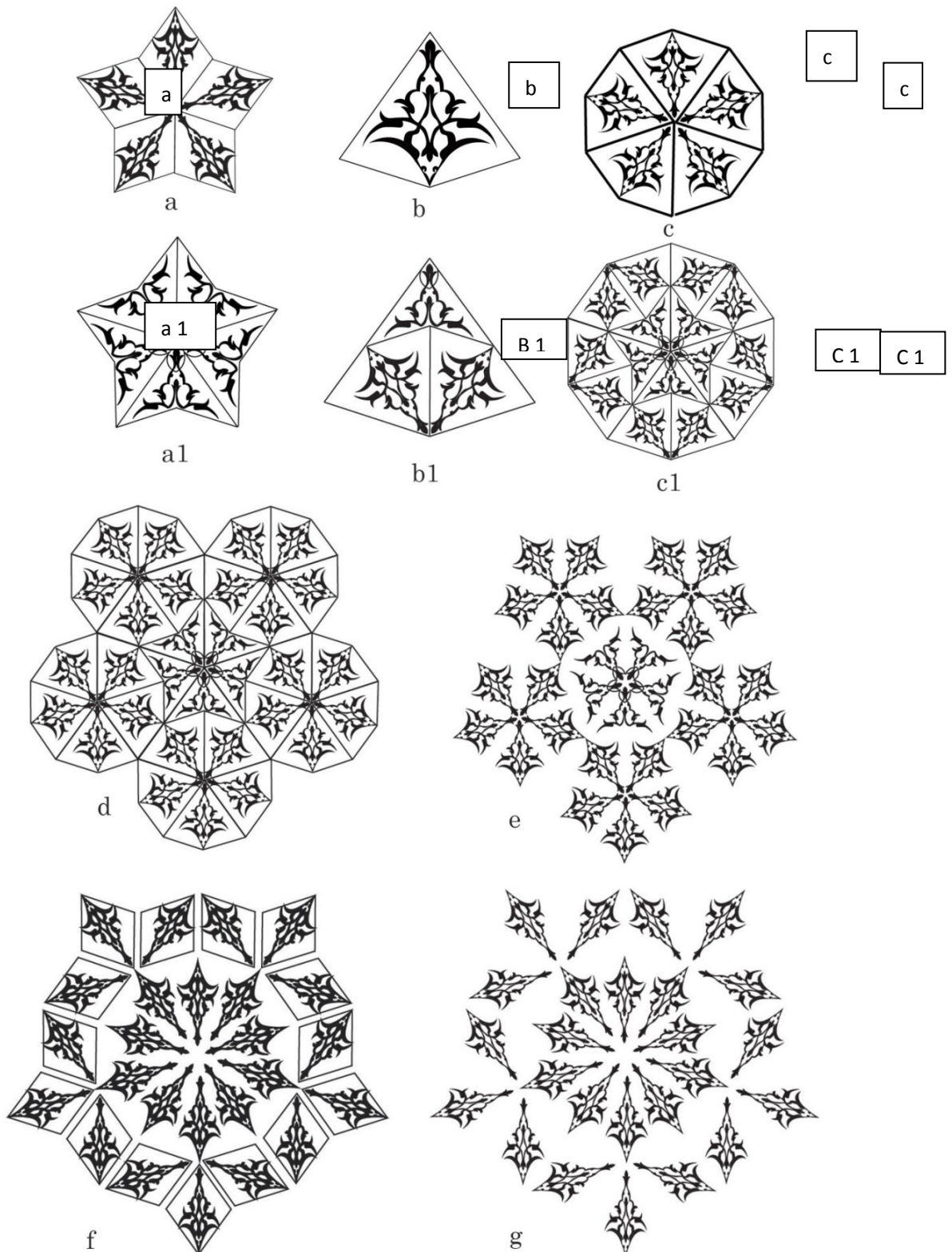
a1

b1

c1

d

e

f

g

Figure 10   Illustrates the third model in applying, the new Islamic patterns of kites and arrows.

CONCLUSION

Islamic floral patterns are an ancient form of Islamic art that is on the verge of extinction. These floral ornaments consist of flowers, leaves and curved lines that can be obtained using standard geometric or irregular methods. This study presented an analysis of the five-pointed Islamic flower (peony flower) and created patterns for new Islamic flowers regularly and geometrically according to the Penrose tiling method. Three innovative floral motifs were designed from one motif, then reflected five times in the kite and darts from one point in the centre. The Penrose tiling method helped construct a floral ornament using only one motif with the pentagram symmetry of the Penrose tiling method. Therefore, the issues of the time and effort required to create Islamic floral patterns and the possibility of generating endless patterns were addressed. The results of the proposed designs showed that new patterns were characterized by repetition, reflection, and bifurcation from a single point. These features were prevalent in the new patterns, with or without general planning guidelines. As the elements of the floral patterns were centred on the centre point, they can be drawn in other ways to create many Islamic floral motifs that look like a Shamsah.

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