The Story of Altair Designs and Jules Bourgoin

Roger Burrows

Park City, Utah; rogerburrows@me.com

Abstract

The geometric patterns in Altair Design coloring books can trigger perceptions of regular, sometimes shifting, shapes. Their constructions derived from a drawing made by the 19th century architect Jules Bourgoin of a 14th century window in Old Cairo.

Introduction

Altair designs are geometrical line designs with the peculiar psychological property of triggering perceptions of recognizable shapes that can change as you look at them, see Figure 1. The phenomenon is known as *pareidolia*, which is the tendency for perception to impose a meaningful interpretation on a nebulous stimulus, such as seeing clouds as elephants or birds. But there is more to these line designs than perceptual properties; there is a geometrical logic. The designs create triangular meshes that follow a precise geometrical methodology of straight-line placements overlaid upon an exact arrangement of five close-packing circles within a 45-degree right triangle that is reflected and rotated to form a square tile that is tessellated to cover a design area. Thus, shapes in an Altair design can be perceived in many ways, rotated, reflected, and translated throughout the overall design.

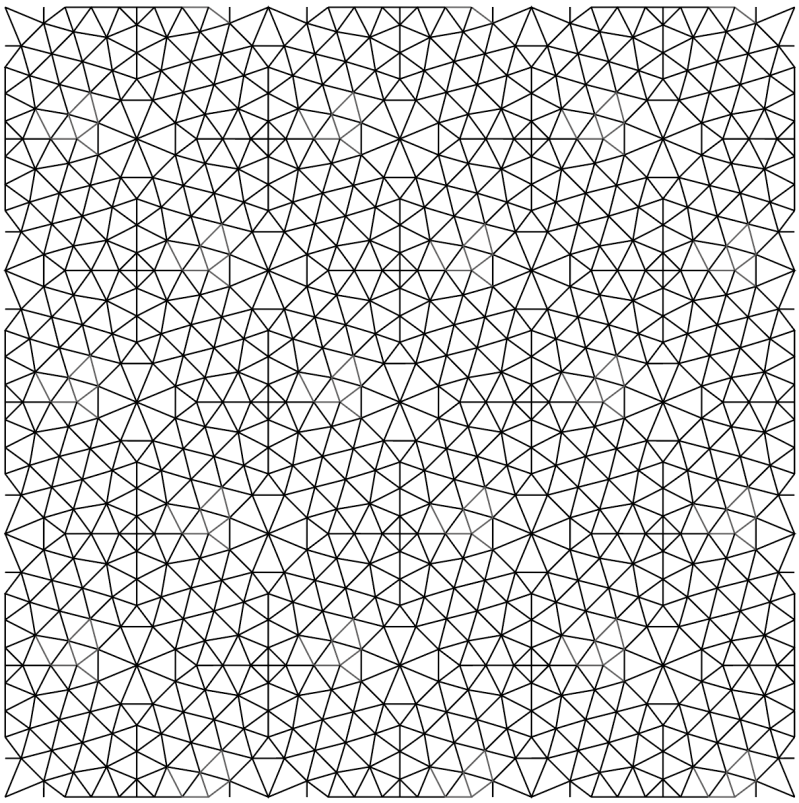

Figure 1: *The Altair design (#1) is composed of circumscribed polygons and radii surrounding the circles of Figure 5, that can trigger perceptions of many recognizable shapes.*

In 1968, I was introduced to Dr. Ensor Holiday, 1903–1988, a chemist who worked on the mass production of penicillin in WW2, a psychologist, and an amateur mathematician. Ensor had been given a copy of *Moorish Remains in Spain*, by Albert Calvert, compiled in 1906, for the King of Spain, Alfonso XIII [6]. Within the pages was a design that had sparked Ensor's interest, on page 571: a design numbered~151. The design was unusual because it contained regular rosettes with 5, 6, 7, and 8 sides—each positioned within five circles that appeared to 'close-pack' with respect to a square tile, and where five of the circles are 'half,' and one a 'quarter,' within that square. Ensor had concluded that close-packing circles formed the basis of design 151's construction, a conclusion that led to his creation of the first Altair designs.

Close packed circles are arrangements of circles in triangular groups that osculate (touch each other without overlap) and such that no circle can be enlarged or reduced, even by the smallest amount, without creating an overlap or a gap, see Figure 5.

Ensor did not know that Albert Calvert had copied design 151 from a book by Jules Bourgoin, *Les Elements de l'Art Arabe* dated 1879, without acknowledging Bourgoin's authorship and without describing Bourgoin's construction methods [1]. The original design appears in Bourgoin's work as plate 163 with text describing the method of construction, which was not a method relying on close-packed circles.

Jules Bourgoin

Jules Bourgoin, 1838–1908, trained as an architect at the École des Beaux-Arts in Paris and spent several years in the Near East working for the French consulate in Alexandria between 1863 and 1866, mainly in Egypt, with the French Archaeological Mission in Damascus, 1874–1875, and the Committee for the Conservation of Arab Art in Cairo, 1880–1884. Bourgoin was fascinated by Islamic patterns and made thousands of pencil drawings of them, sketching Islamic designs that he found in Alexandria, Cairo, Jerusalem, and Damascus. He was an excellent draftsman and an aspiring mathematician, and determined possible methods of construction for each design he studied. Whether the methods he applied were only of his derivation or from the guidance of others is unknown [2, 3, 4, 5].

In 2015, I learned from Daud Sutton, a specialist in Islamic geometric patterns, that design 151 was a window lattice from the Mosque-Madrasa of Amir Salf al-din, Sargatmish, 1356, in what is now 'Old Cairo,' Egypt [12]. The lattice is of stone and shows signs of repair, but the arrangement of the 5-, 6-, 7-, and 8-sided rosettes is clearly that of design 151, see Figures 2, and 10.

In his text, Bourgoin describes a ray-like method for positioning the rosettes of design 151. He describes them as ray-like because the method is based on the intersections of extended regular polygonal radii, like rays of light emanating from center points. Due to the lack of text in Calvert's work, Ensor Holiday assumed the design 151 method was of close-packed circles that Bourgoin used to surround the rosettes, which do, in fact, close pack, and not Bourgoin's ray-like method, see Figure 5.

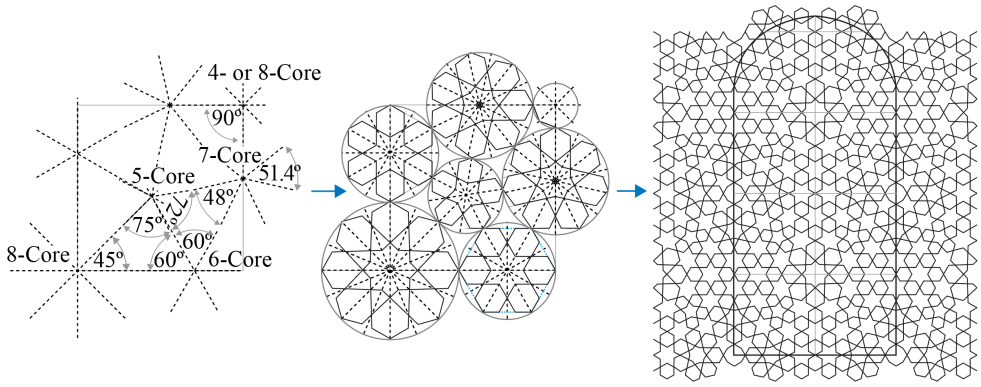

Figure 2: Bourgoin's 'ray' construction of design 151, of the Sarghatmish Mosque-Madrasa window.

It is a fact that close-packing circles do appear in Bourgoin's constructions of other designs in *Les Elements de l'Art Arabe*, as do ray-like constructions, and both can be used to construct design 151. Also, both methods generate Islamic designs that were not studied by Bourgoin, lending credibility to their use as a standard means of construction. A philosophical dimension adds further credibility to their use. Both can create number sequences that might convey meanings through the numerology of the Koran or ABJAD root words. The ray method number sequence for design 151 follows a progression: 8-Core and 6-Core radii intersect at one position to approximately accommodate 5-Core radii, and then an intersection of the 6-Core and 5-Core radii approximately accommodates 7-Core radii. In this case, Islamic meanings might be Surah (chapter) and verses 8:6, 6:5, 5:7. Both ray and circle methods, if applied to design151, create number sets that can match ABJAD meanings with 8,6,5 and 6,5,7. [9, pages 175-178].

A 'Ray' Design Method

A ray-like method appears to have been a valid means of Islamic design construction as it can duplicate many rosette designs created during the Abbasid periods of Kufa, 750–762, Baghdad, 762–836 and 892–1258, Samarra, 836–892, and Cairo, 1261–1517, see Figures 3, and 4.

Formalizing the method: A ray is a radius of a regular polygon that radiates out from a point. A ray-core comprises all the radii that divide a regular polygon's sides and vertices. There are, therefore, as many rays, called the ray core value, as there are sides to the polygon. The ray methodology starts with aligning radii from two ray cores with the lines of symmetry of a tessellating grid, such as squares or regular hexagons. Then, the intersection angles of the two ray cores are determined, where angular 'near' correspondences to other regular polygons, and the underlying tessellating grid can serve as center points for new ray cores. For design 151, see Figure 2, the tessellating grid is squares. The first ray core is that of an octagon, the second a hexagon, the third a pentagon, the fourth a heptagon, and the fifth a square or octagon that lies at the upper right corner of the containing square grid. The centers of ray cores define the positions of regular rosettes sized to touch each other where possible. Gaps between rosettes are filled with petal shapes.

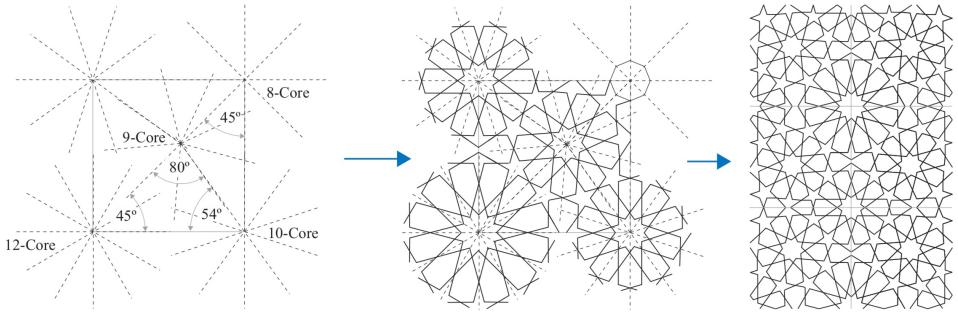

Figure 3: *Wall relief Alay Han Mosque, Akseray-Kayseri Road, 1192, Turkey. Ray construction.*

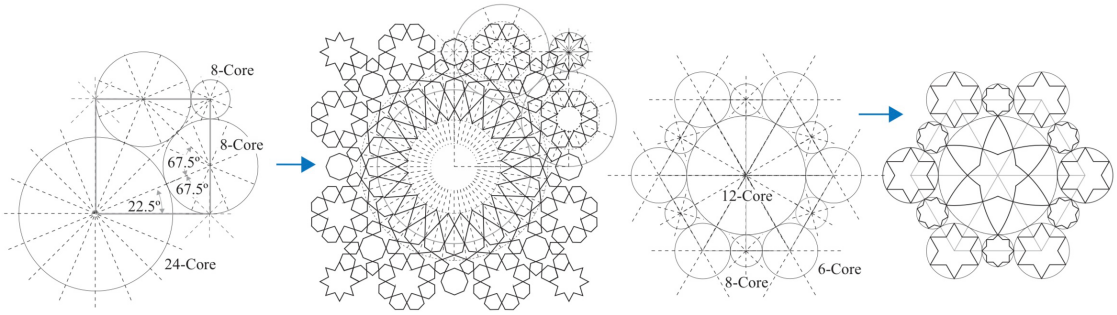

Figure 4: *Bourgoin [4] pages 150 and 96. Ray method with close-packing circle correspondence.*

A Close-Packing Circle Method

Because Ensor Holiday perceived the method of design 151 as based on five closely packed circles, see Figure 5, we both thought we could use other close-packing arrangements to create other Altair designs, [7, 8]. The technique generated all sorts of close-packing arrangements of circles and spheres filling two- and three-dimensional space, see Figures 6, and 7. The method is dynamic, where circles and spheres incrementally change size and position within various tessellating forms, such as squares, hexagons, cuboids, or tessellating prisms until they all touch in triangular groups. There are multiple start points and arrangements for generating close-packing sequences using the method, and each generated close-packing arrangement has its unique structure and proportion, like molecules transforming through various energy states.

Calculating the exact sizes and positions of close-packing circles or spheres of different sizes requires successive numeric approximations or complicated polynomial equations such as, for design 151's r_4: $(2-\sqrt{2})x^6 + (2-6\sqrt{2})x^5 + (15-5/\sqrt{2})x^4 + (16-2\sqrt{2})x^3 + (-8-12\sqrt{2})x^2 + (6+4\sqrt{2})x^1 + (-1-\sqrt{2}/2)x^0 = 0$, where x is r_4 and calculates to 0.3236945… when the containing square side length is 1 unit. The (x, y) coordinates for the center of r_4 are calculated to (1,0.54281…). Deriving equations for the five design 151 radii involves tangency conditions, boundary constraints, radii interrelationships, and the square's side length.

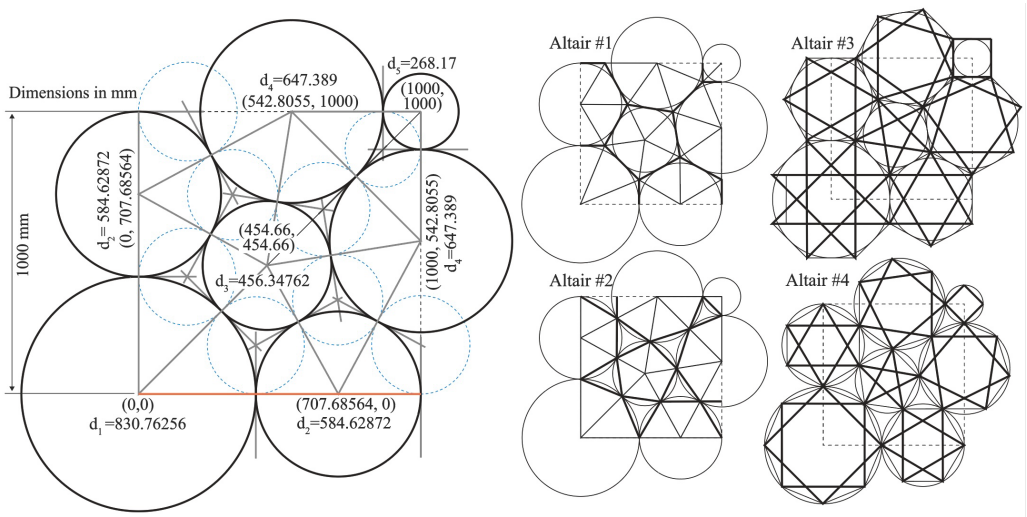

Figure 5: *The circle-packing of design 151 based on the above calculations. Altair's close-packing circles are sized and positioned (x, y) for circle centers and circle sizes $d_n = 2r_n$. Altair designs are created by connecting intersection points.*

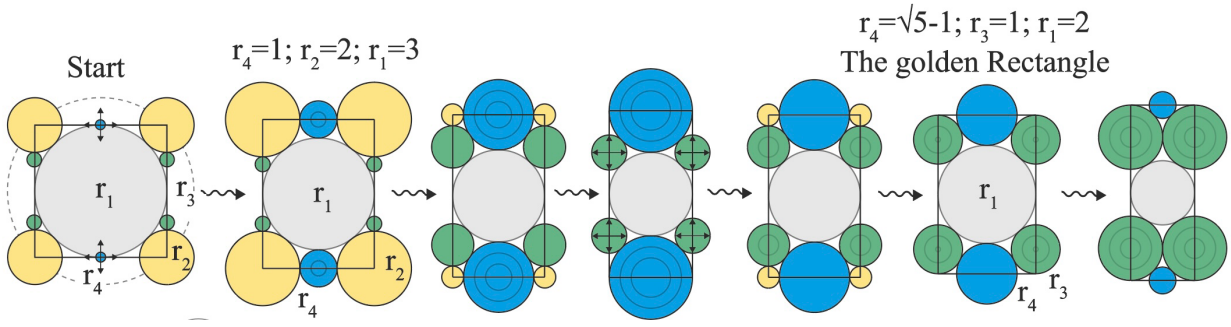

Figure 6: *This is the first close-packed sequence developed in which the constraining rectangle symmetry is also allowed to change. The blue circles have the priority of growth, followed by the green. The transitions between close packings are not shown but are represented by the wavy arrows.*

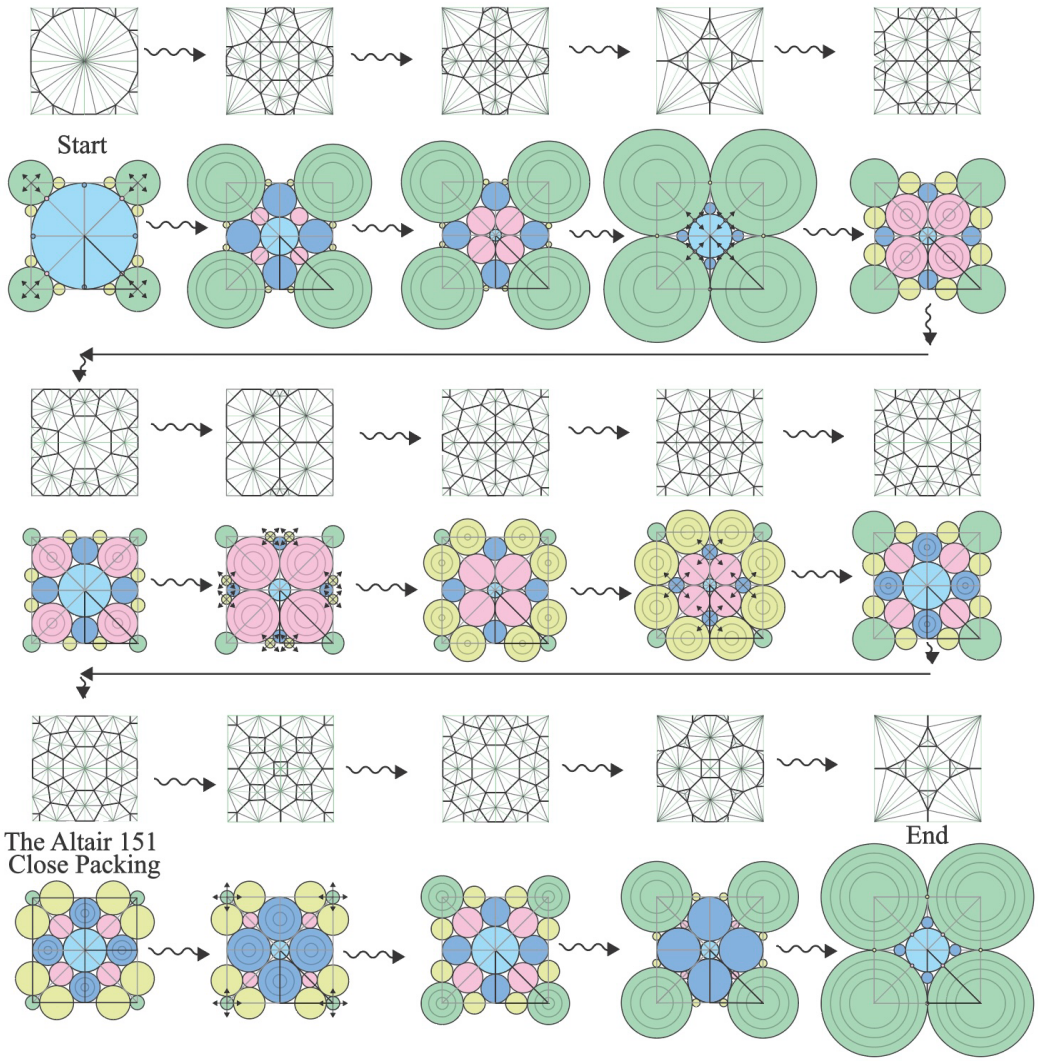

Figure 7: *The method to generate 5-circle close-packings within a square symmetry. Circles change size and position as they move from one close-packing to another, breaking circle contact as they transition. The transitions are not shown but are represented by the wavy arrows. The crossed arrows show circles given the priority of growth up to their maximum size.*

Children and Altair Designs

Developing Altair design variations was not so easy in the 1960s. The period was before computers were easily accessible. So, calculations of circle sizes and positions involved polynomial equations, successive approximations, and log tables. Given Ensor's not-so-good eyesight, I drew the design variations by hand on drafting film. Some of the designs were extraordinarily complex and time-consuming to complete. One wrong move could ruin a design and days of work. But we were both captivated and wanted to push the envelope, so to speak, and didn't mind the challenges. We made many prints of the designs; eventually, some found their way into children's hands. We found that children and adults loved coloring the designs, and we were amazed by the diversity of their imaginations. The same design might be seen as a landscape by some, a flock of birds by others, or as abstract patterns, faces, wild animals, flowers, etc. The designs were eventually published under the name "Altair Designs" by Longmans Press, London, in 1973. At the time of publication, the London Times ran a national competition using the designs with beautiful results. Altair designs had arrived on the scene and became a #1 bestseller! The designs and many variations are still in print after over fifty years.

A Way to Perceive or Create Images and Patterns in Altair designs

Firstly, choose an Altair design, relax your vision and look at it without staring. Try rotating the design and see how it visually appears to change. As you look at a design, try not to fixate on any shape or image—let your imagination roam. You might see large or small shapes. Some people see faces, animals, complete scenes, or abstract patterns. Any shape you see can be found repeatedly, the same way up, but also rotated and reflected. If you see a bird, you might look or create an image of a tree, find the same bird in another place, or maybe create an image of a cat. If you see a shape you like, you will find it repeatedly. The same design can trigger a different perceptual response each time you look at it. Some people have copied their perceived designs onto fabric, wood, or canvas, often enlarging them, see Figure 8.

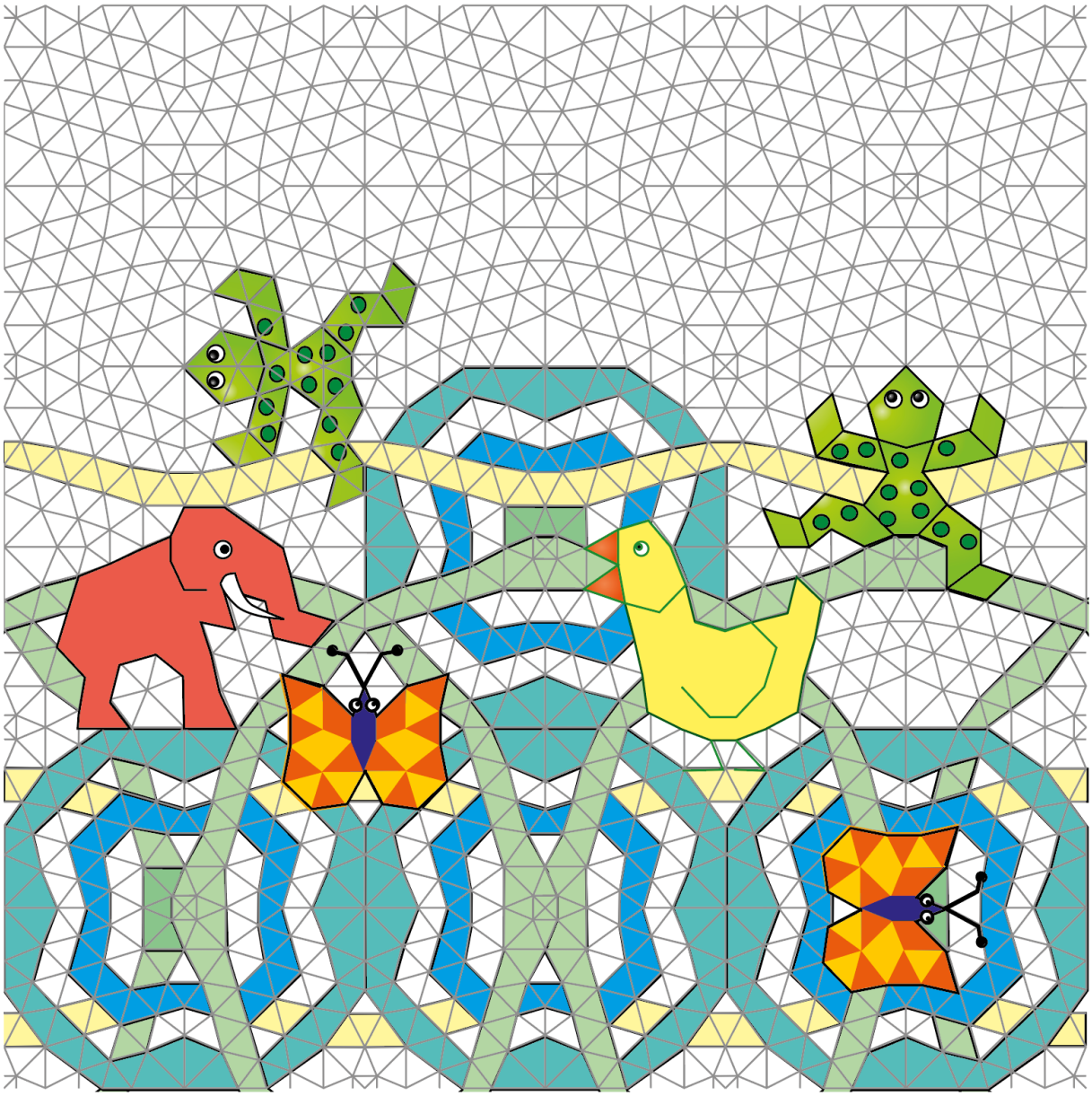

Figure 8: *Examples of perceived images in Altair design #2 based on Figure 10.*

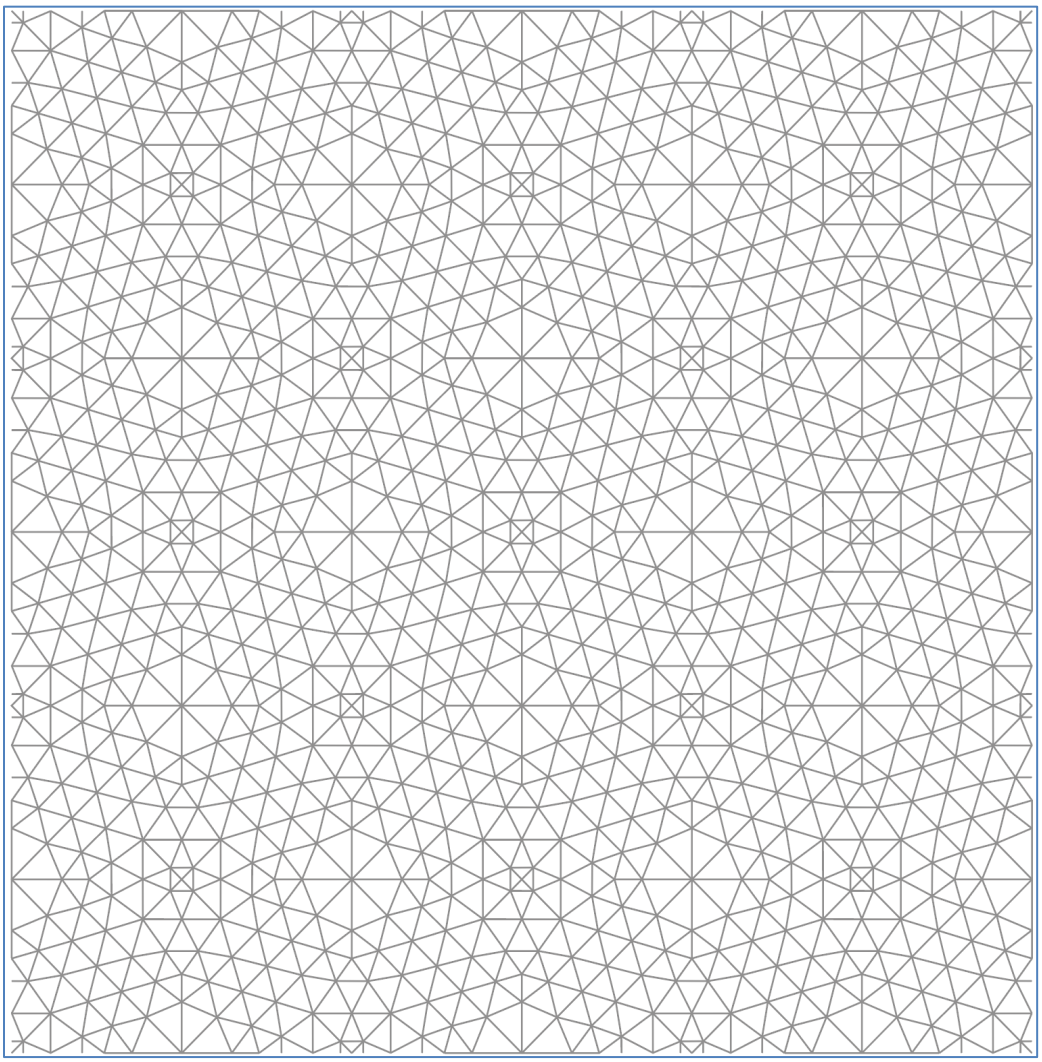

Figure 9: *Altair design #2 inscribed polygons and radii within the close-packing circles of Figure 5.*

Summary and Conclusions

Altair designs may have been the first books of geometric patterns to create the phenomenon known as *pareidolia*. Their development was based on a misinterpretation of a design drawn by Jules Bourgoin, which shows that misunderstanding can be a great source of inspiration. The designs are still in print and, to this day, help teachers of mathematics introduce spatial geometric concepts—and teachers of art to help children develop their visual imaginations. Altair designs inspired the development of many geometries and a broader task to explore the development of visual thinking concerning art and architecture.

Acknowledgments

Dr. Ensor Holiday's geometric ideas were inspirational [9, 10]; he was my mentor and friend. Jules Bourgoin's work is a treasure chest of 2D approaches to Islamic-inspired lattice works and a starting point for new 2D and 3D ways of thinking. Thanks to Daud Sutton for finding the design 151 Old Cairo window and to Robert Coleville, University of London Computer Center, for the first close-packing sequence animation, [13].

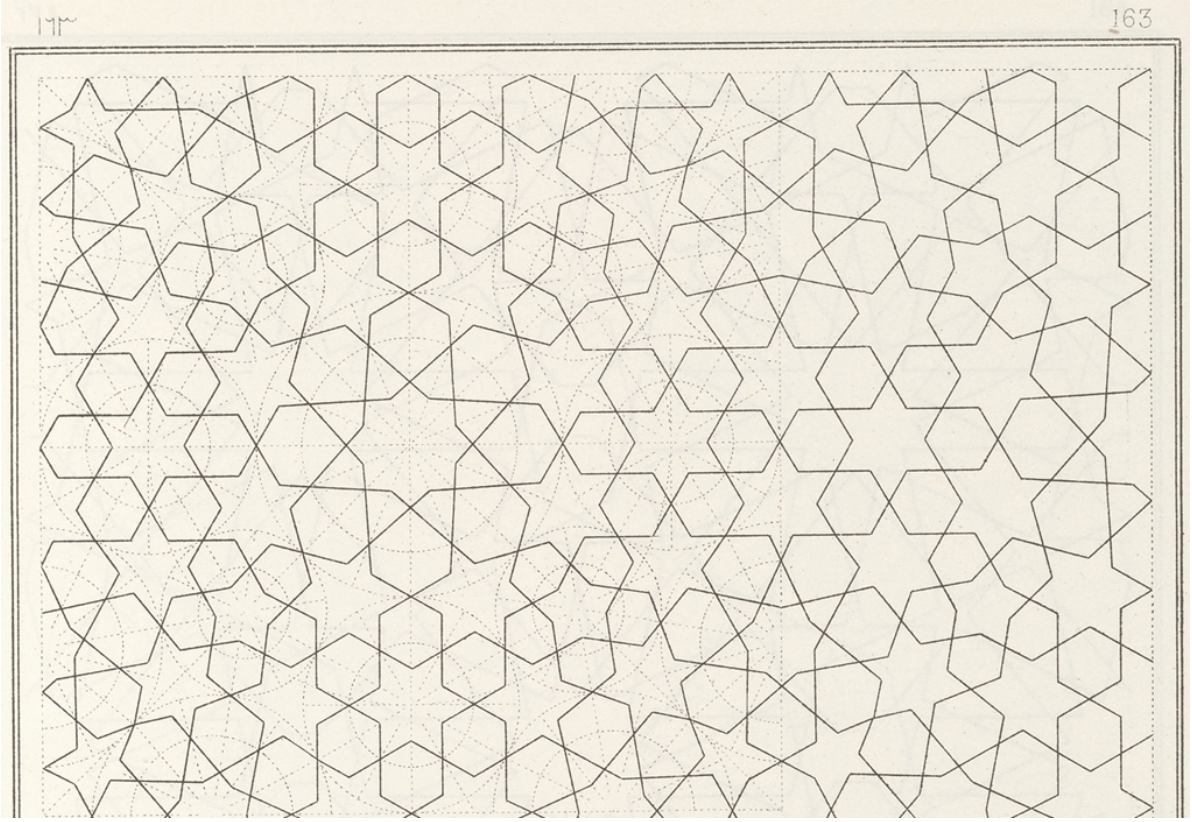

Figure 10: *Cropped view of Plate 163 from Les Elements de l'Art Arabe by Jules Bourgoin 1890-1892.*

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