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The Fractal shapes in Islamic design & its effects on the occupiers of the interior environment (case study: El Sultan Hassan mosque in Cairo)

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Abstract:

The Islamic civilization are distinct for using the art of geometry in their creative designs. In the early Islamic period, designs used simple forms like square shape, gradually more geometrical transformations are applied such as; shapes subtraction, addition, subdivisions, branching and rotation. The aim of this study is to show that the fractal geometrical shape, with the feature “self-similarity, infinite number of iterations for shapes with reducing scale, in finite region ”is one of the most influential elements in the Islamic design and consequently has its beneficial effects on the occupiers of Islamic interior environment. This study analyzed the existence of fractal shapes in the Islamic design with finite number of iterations since the old centuries through analyzing El Sultan Hassan mosque in Cairo, Egypt (1356-1362) as a case study. The fractal shapes are used in the Islamic design of the walls, ceiling, doors, domes and floors. The study also suggested a new contemporary Islamic golden and non-golden fractal shapes with large number of iterations to be generated by using the computer technology that can be used in the interior design. The Islamic fractal design acts as a strong stimulus to the brain generating strong emotions in very short time. The study illustrated that the Islamic fractal interior design has an aesthetic as well as healthy effects on their occupiers as, it improve the wellbeing, generates positive emotions and reduces the stress level, induces relaxation, improves the long-term memory, emitting positive energy balancing the negative energy in the space. Thus, create a comfortable healthy interior environment with increasing the vitality & reproducibility of their occupiers.

Keywords:

Fractal shape, Interior environment, self-similarity, Islamic design, Golden shape.

Research problem:

Did the Islamic design use the fractal shapes in its designs? Was the feature; self-similar infinite number of iterations shapes with reducing scale in finite region of the fractal geometric shape satisfied in the Islamic design.

Research objectives:

- Illustrated that fractal shapes are used and are influential elements in the Islamic design.
- Illustrated the effects of Islamic fractal design on the health and comfort of the interior environment's occupiers.
- Suggested new contemporary golden and non-golden Islamic fractal geometrical shapes to be generated using the computer technology and can be used in the interior design.

Introduction:

The Islamic laws of inheritance was the base in the partition and calculation of irregular areas that lead to the presence of fractal geometry. (Jencks 2002, 235) The complexity of the Islamic design derives from the Successive iterations of subdivision which is the fractal feature (Letourneau 1987, 45, Raymond 1994, 3-19). The studies showed that the irregularity of geometry is a sign of high order and complexity (Akbar, 1988; Ben-Hamouche 2004, 2009a,2009b). Fractal is concerned with irregular forms and complex objects that show self-similarity at each scale of magnification when it undergoes a certain process of iteration. Fractal presents a new instrument for analyzing and understanding the complexity of the Islamic design, and thus displaces the Euclidean geometry that have long dominated the studies of Islamic design by non-Euclidean geometry. The geometrical fractal feature, being inspired from the natural fractal feature coined “self-similarity in shapes, with reducing scale, to infinite number of iterations in finite region” (Mandelbrot 1989).

Material and methods:

- This article analyzed El Sultan Hassan Mosque as a case study to show that the existence of fractal geometric patterns in the Islamic design by using the fractal feature “self-similarity, infinite number of iterations for shapes with reducing scale in finite region” as a measure.
- Suggested new contemporary golden and non-golden Islamic fractal geometric shapes with large number of iterations which can use the computer technology in its generation.

I- Fractal in the Islamic design.**1. Fractal forms properties:**

The fractal form is characterized as being a fragmented geometric shape that can split into infinite number of reduced-size copies of the whole form. The self-similarity is a prominent feature of the fractal forms. The similarity is between the smaller scale parts that form the number of infinite iterations constructing the whole shape. The self-similarity is either “complete” with the small parts are completely similar to the whole shape, or “approximate”, with the small parts roughly like the whole shape. Uniformity and harmony exist in any fractal shape. Fractal shape has decimal dimension between 0&1 ,1&2 and 2&3 which represents how fractal fills the space. There are many definitions of fractal dimensions, including: the Hausdrof dimension, Rainey dimension, Box counting dimension (Sala 2003,235-44).

2. The Fractal features that coincide with the Islamic design objectives**- Unity in diversity:**

Unity is considered one of the most important Islamic basis and thoughts. Fractal Islamic design represents unity through the repetition of self-symmetric shapes into smaller scales.

- Recurrence and rhythm:

Achieved by the particular self-similarity, uniform rhythms, and the continuous flux of the whole system components.

- Infinity:

Islamic design expresses the meaning of infinity inspired from their beliefs of the infinite godhead knowledge and the infinite universe. Fractal consists of infinite number of iterations.

3. General analysis of different fractal elements in Islamic design:

Islamic design used the fractal patterns in many various applications as in ornaments, floor, arches, portals, minarets, mihrab, dome. In this context, we analyze some of it in different era to illustrate a different fractal shape.

- Islamic ornaments

The Islamic ornaments used 3 principal modes like :floral ,calligraphy and geometric patterns, which depend basically on repeating the initial shape in self-symmetrical shapes with reduced scales in finite region to reach the overall fractal Islamic patterns (Figure 1,2,3,4,5).

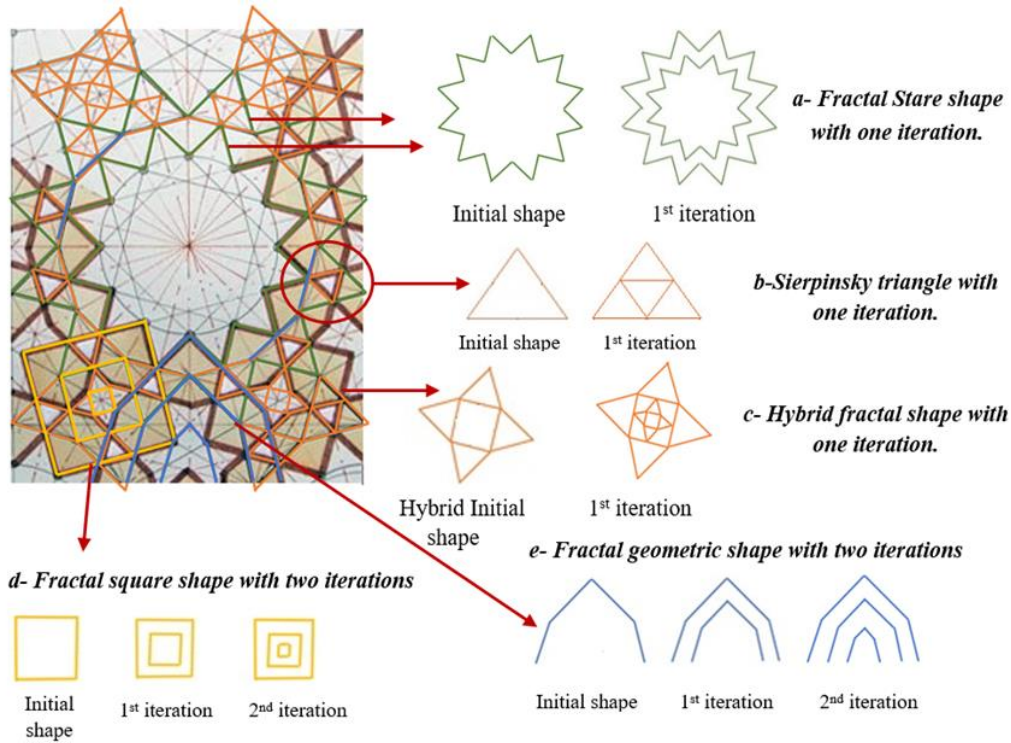


Figure1 : Umayyed Islamic fractal shapes.

Source: <https://fractalpattern.wordpress.com/2011/07/25/islamicgeometricpattern-origin/>



Figure 2: Two different fractal shapes; self-similar iterative shapes with different small scales in finite region.



Figure 3: Floor design using fractal Sierpinsky triangle with one iteration.

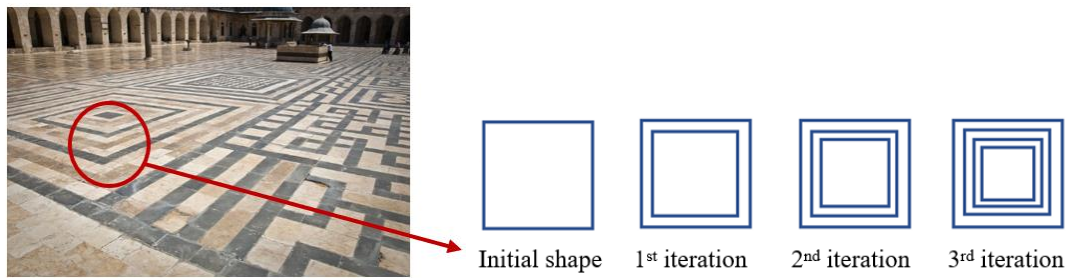


Figure 4: Floor design using fractal Square shape with number of iterations.

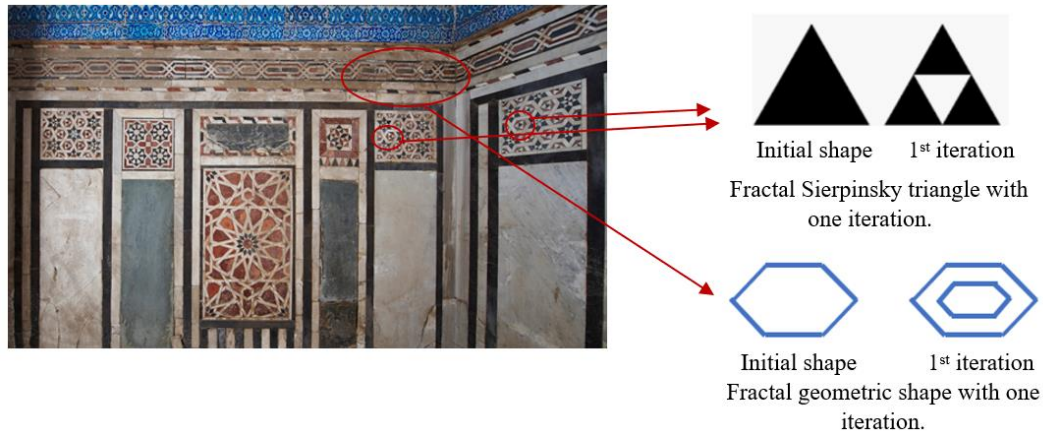


Figure 5: Different fractal shapes in wall design.

- **Muqarnas:** one of the most unique and accurate decorative elements, that reflects the fractal growth in Islamic design and is used to decorate the area between the wall and the dome (Burckhardt, 2009). The steps of fractal muqarnas creation from the small basic line (arc) till the final form is given in (Figure 6a). Different types of fractal muqarnas is given in (Figure 6b)

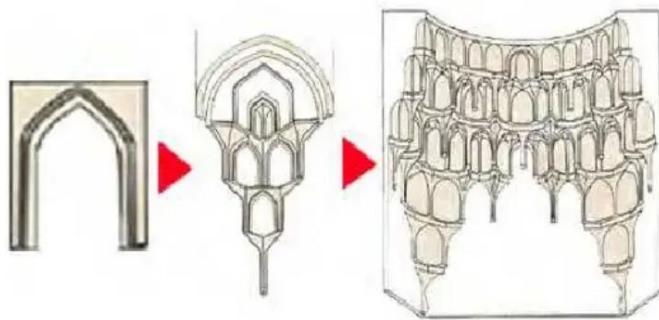


Figure6a: Fractals main steps of muqarnas
Source: Elgohary 2019,

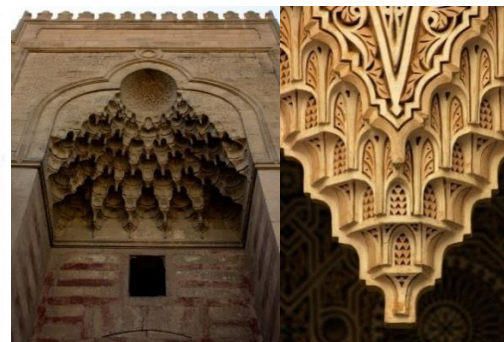


Figure 6b: Different types of fractal muqarnas.

- Portal and arays:

We analyzed the fractal shapes of mosque “al-Nasir Muhammad Ibn Qalawun cairo” using the fractal feature self-similar iterated shapes with small scale in finite region.

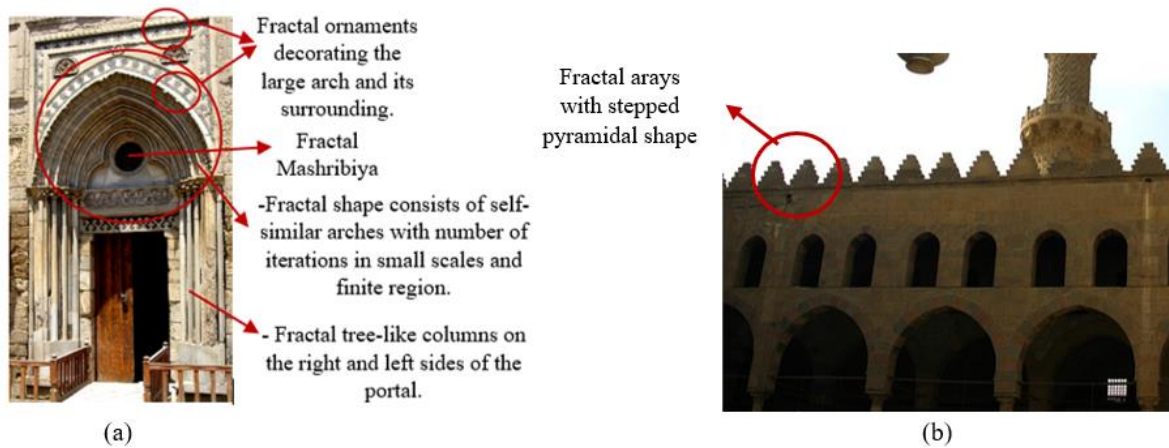


Figure 7a, b: Fractal design in “al-Nasir Muhammad ibn Qalawun” Mosque Cairo.

- **Minarets:**

Three different types of Minarets that achieved the fractality feature: on each minaret three self-similar successive etages were built from large to small scale, the middle one decorated with fractal Muqarnas (Figure 8).

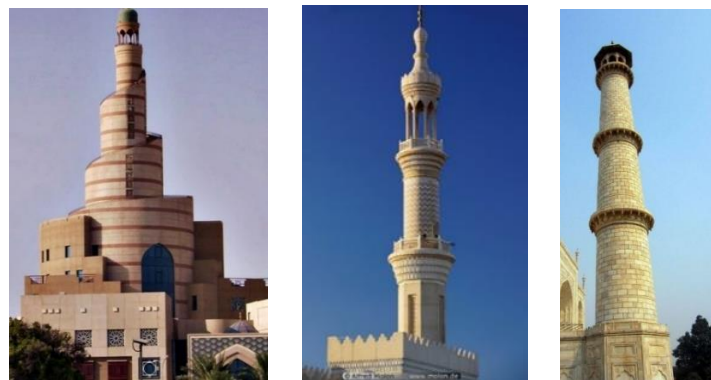


Figure 8: Three fractal minarets

II- Analysis study of Islamic fractal design in “El Sultan Hassan mosque”:

In this section we analyzed the mosque of sultan Hassan in Cairo to present that the fractal feature “self-similar iterative shapes from large to small inside a finite region” is existed in its Islamic design.

The sultan Hassan mosque was built in Cairo in 1361 A.D. It is the most famous mosque from the Mamluk Era (Figure 9a). The building housed madrasa and his mausoleum. The mosque of sultan Hassan consists of a square central courtyard with four great Iwans. The largest of the Iwans is a prayer hall behind which is the domed mausoleum of sultan Hassan (Figure 9b) (Abouseif 2007) .



(Figure 9a) The sultan Hassan Mosque.



(Figure 9b) Plane of the Sultan Hassan Mosque.

Source: (Adel 2010, 97)

Figure 9: The sultan Hassan Mosque and its plane.

1. Analysis of Exterior Islamic fractal patterns:

A. The facades:

The façades of the mosque are mostly composed of stone interlaced with marble.

- The four facades of the mausoleum.

There are 3 exterior facades and the 4th is interior. The top edge of the three exterior facades is decorated with fractal shape arrays. (Figure10,13) *The top of the four facades* is crowned by a thick cornice of “fractal” muqarnas projecting 1.5 m over the rest of the wall. Each facade is divided in two longitudinal identical each one has upper and the lower windows. Each upper window consists of 3 different ‘fractal’ shapes, *the first*, is the recesses crown with fractal muqarnas that are in turn surmounted by a shallow conch. *The second*, is a rectangle shape decorated with irregular fractal stripes. *The third* is the window has approximate fractal shape with two self- similar iterations (Figure 11,13). The two upper windows are separated by a fractal bull’s-eye- like medallion (Figure 12,13). The lower window; have a stepped pyramidal profile ‘fractal geometrical shape’ (Figure 13). The openings in both upper and lower windows are covered by ‘fractal mashrabiya’.

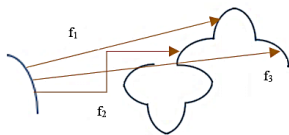


Figure10: The fractal shape of the arched windows.

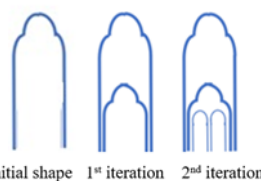


Figure11: The upper window is totally approximate fractal shape with two iteration.

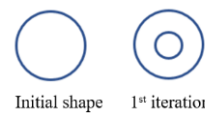


Figure12: The center part.

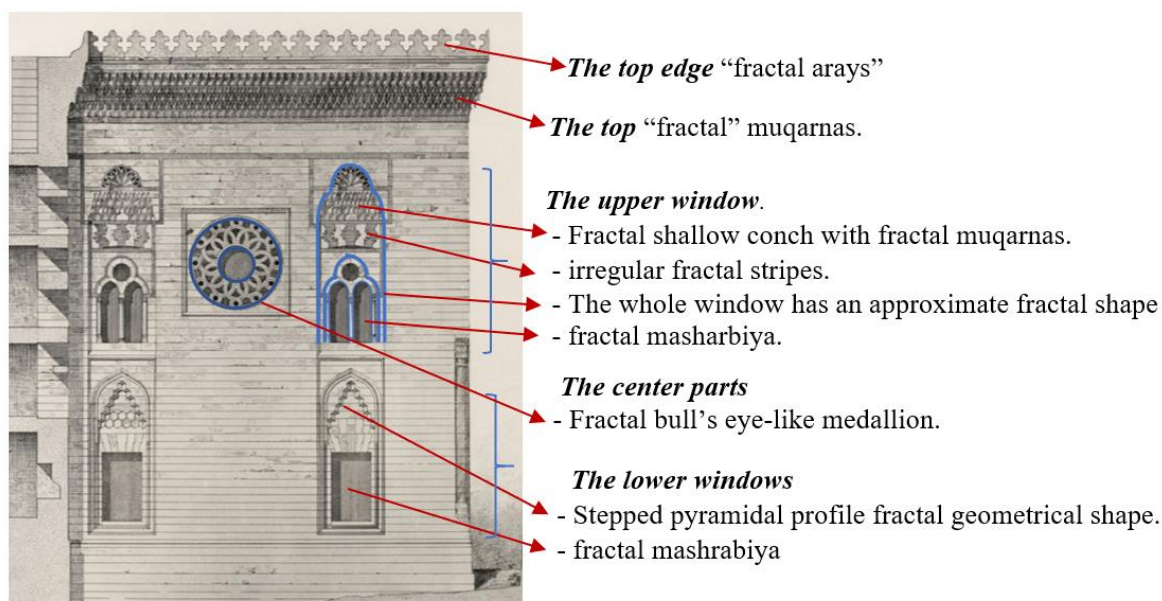


Figure13: The analysis of different fractal geometrical shapes in the exterior facades of the mausoleum

Source : <https://books.openedition.org/inha/4898>

- **The southern and northern facades:**

Each façade has eight horizontal rows of windows. Each window consists of two successive small and large parts. The openings of the windows are covered by fractal mashrabiya. The vertical column ended by fractal muqarnas cornice running along the top of its walls (Figure 14).

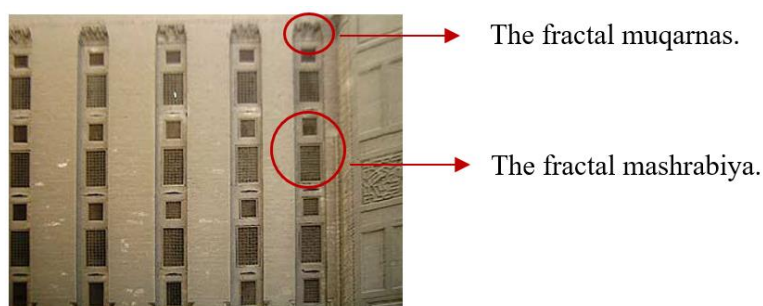


Figure14: The southern and northern facades.

B. The portal

The portal is considered a masterpiece of fractal Islamic art design. It has the same height of the facades and shifting 17° from the northern façade, it can be seen when approaching along the street. The portal is divided in different parts; *the highest part* is decorated by a cornice of fractal muqarnas; *the upper part* dominated by a successive of dripping fractal muqarnas surmounted by the ‘fractal half dome structure shape’ (Figure15a). *The middle part:* has a small window decorated from upper part with fractal muqarnas, where the opening of the window is covered with fractal mashrabiya (Figure15b). *The two side parts* on the right and left of the portal there exists a narrow-carved panel, similar to the portal decoration with fractal dome and muqarnas, surrounded by a series of geometrical fractal shapes. Two fractal trees -like columns are decorating the right and left side of the panel. (Figure15c).



Figure15 a: The upper part of the portal decorated with fractal muqarnas and fractal half dome structure shape.

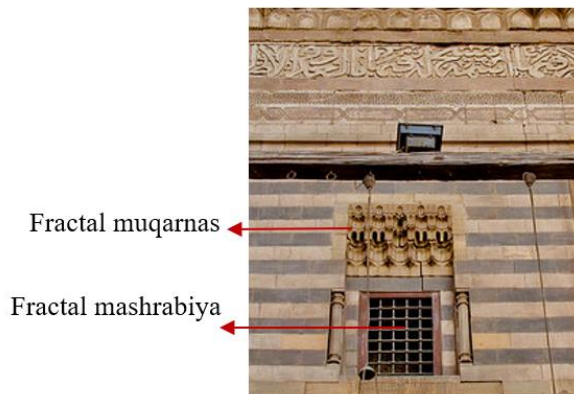


Figure 15b: The small window decorated from the upper part with fractal muqarnas and the open part of the window covered with fractal mashrabiya.

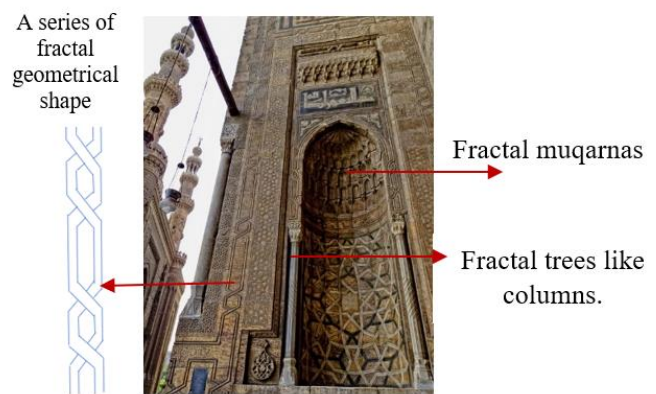
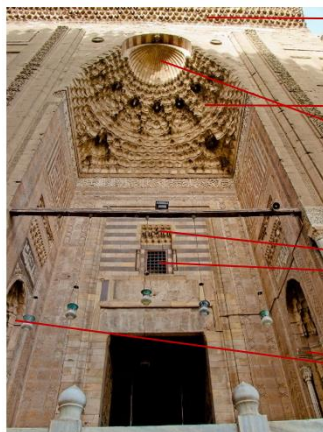


Figure 15c: The carved panel decorated from the top with fractal dome shape and fractal muqarnas structure and two fractals tree-like columns, the whole panel surrounded by geometric fractal shapes.

Figure 15: the fractal portal.



- *The higher part*
- Fractal muqarnas.
- *The upper part*
-Fractal muqarnas beneath the fractal half dome.
- *The middle part*
- The upper part with fractal muqarnas.
-The open part covered with fractal mashrabiya.
- *The two side parts.*
-Fractal dome and fractal muqarnas.
-Two-fractal tree like columns on both sides of the panel.

Figure16: The portal of Sultan Hassan Mosque.

The portal as a whole is decorated from both sides by a series of fractal geometrical shapes (Figure 17a, b). On each side of the portal near the stairs exist two circular ornamental fractal eye-like shapes surrounded by the same series of fractal geometric shapes.

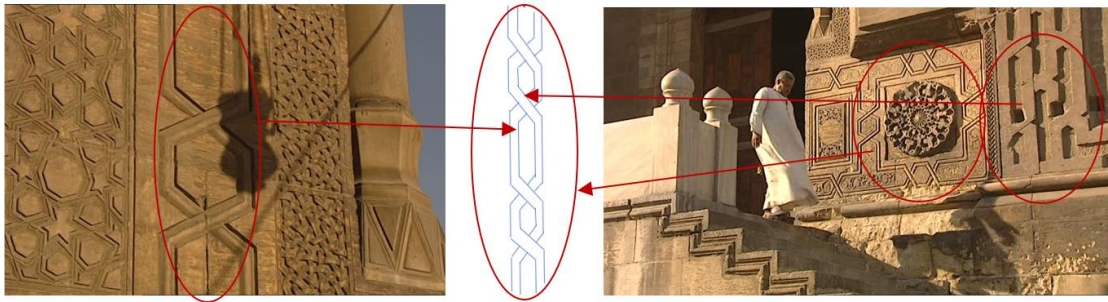


Figure 17a

Figure17 b

Figure17: The whole portal is decorated from around by large series of fractal patterns.

The two sides of the portal stairs have fractal shapes as stepped pyramidal profile (Figure 17b,18). Above the basement port exists a fractal colored stripes (Figure18a). On both sides of the portal exists two fractal tree-like columns (Figure 18a). The flat large area in front of the entrance, the floor is decorated with fractal shape with four iterative circles (Figure18a).

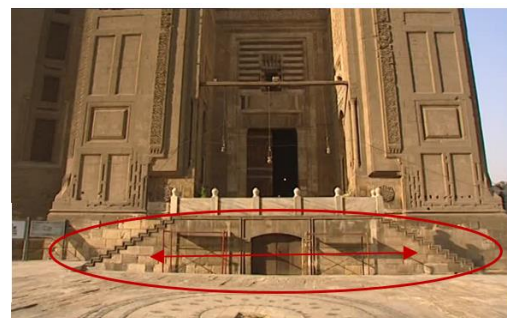


Figure 18a: A fractal shape with four iterative circles in smaller scales on the floor in front of the entrance.

Figure18b: The portal stairs have a stepped pyramidal profile giving a fractal shape.

Figure18: the lower part of the porter.

C. Minarets: The mosque has two minarets one is large and the other is small. Both minarets have fractal shape since they respectively have 3 and 2 self-similar etages with successively smaller sizes, also each etage is decorated with fractal muqarnas (Figure 19).

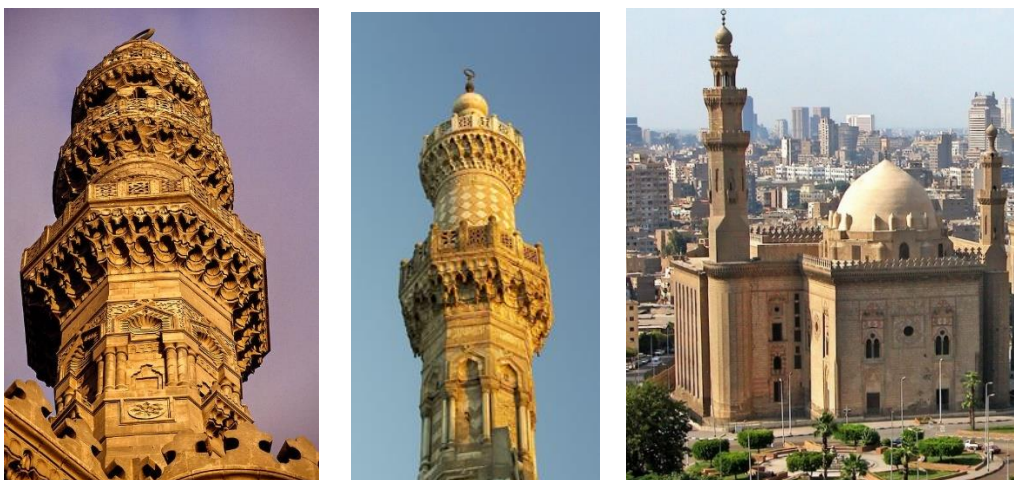


Figure19: The two fractal minarets of El Sultan Hassan mosque with fractal muqarnas.

2. Analysis of the interior Islamic fractal patterns:

A. The Mihrab and the Minbar:

The mihrab is the prayer nich and the minbar is the stepped pulpit, the place where the imam prays with the peoples. Both the Minbar and the Mihrab are among the lavishly fractal examples.

The mihrab and minbar wall: It has a paraboloid shape self-similar with the two smaller paraboloid shapes windows; the wall satisfies fractality feature (Figure 20).

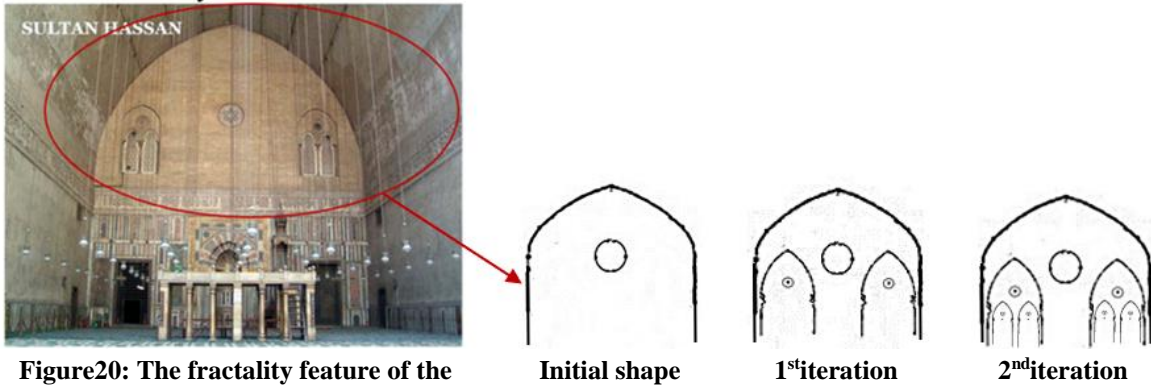


Figure20: The fractality feature of the Mihrab and minbar wall.

- The Mihrab:

It has two iterative arches with self-similar shapes, different in scale, in finite region, giving the fractal shape. It is decorated and surrounded with irregular fractal shapes where both are painted with gold, blue and orange colors (Figure 21a). The self-similar iterative triangles with small scales inside the mihrab satisfy the feature of a fractal shape (Figure 21b). The decoration inside the mihrab include stepped pyramidal fractal shapes (Figure 21b). Four fractal tree-like columns [column=trunk +knot:(transition from the trunk to the branches) +branches crown] hold the mihrab by the large tree-like branching crowns (Figure 21a,c).



Figure 21a: Two 'self-similar arch shapes with different scale in finite region gives fractal shape.



Figure 21b: Self-similar iterative triangles with small scales giving fractal shape. Also stepped pyramidal fractal shapes for decoration.



Figure 21c: Fractal tree-like

Figure 21: the different fractal shapes in the mihrab.

-The Minbar situated next to the Mihrab. It has two decorated self-similar rows with fractal shape arrays (Figure 22a). The Minbar door; is particularly interesting made of bronze inlaid

with silver and gold. Above the minbar door two fractal tree-like columns one in each side of the minbar door (Figure 22a). The top of the door is decorated with *Fractal Muqarnas* and irregular fractal shapes (Figure 22a, b). The design of the door surface decorated with different fractal ornaments shapes (Figure 22c). The door beside the minbar is covered with fractal masharbiya (Figure 22a).

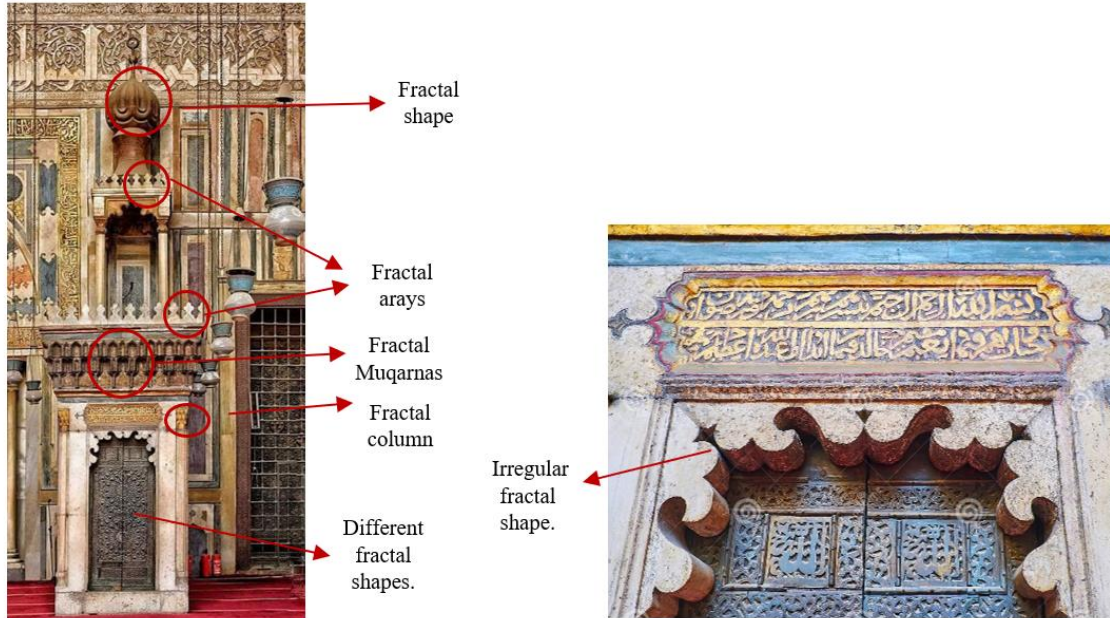


Figure 22 a: The Minbar

Figure 22b: the top of the door.

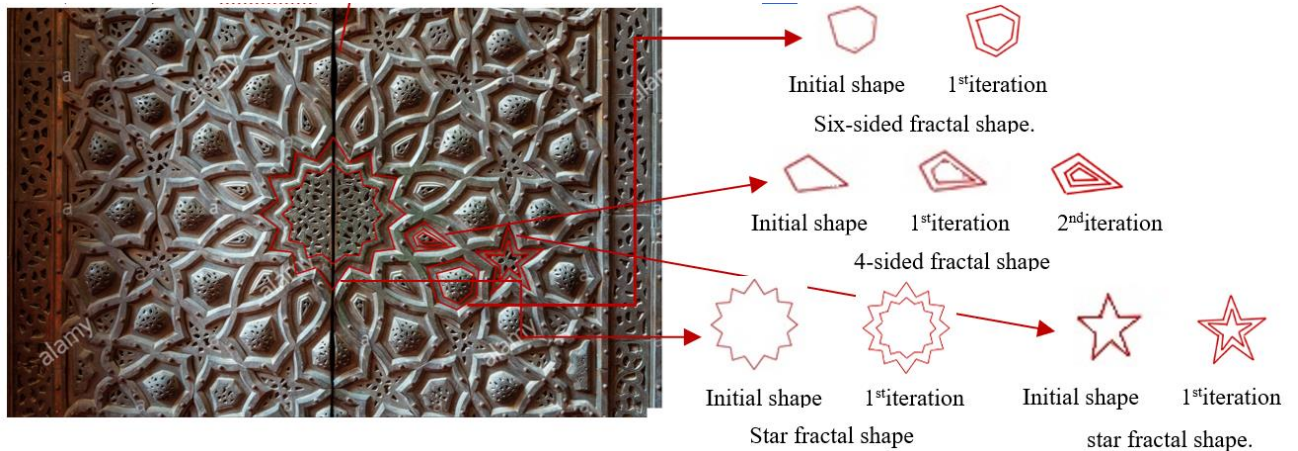


Figure 22c: Details of fractal shapes on the surface of the door in Sultan Hassan Minbar .

Figure 22: The different fractal shapes in the Minbar.

B. The mausoleum

The high dome of the mausoleum is supported and decorated by the four corners with fractal muqarnas shapes lavishly gilded (Figure 23a,b). The decoration of the muqarnas and its fractal shadow on the ceiling has a fractal pyramidal profile (Figure 23a,b). There are many small windows in the ceiling decorated with fractal masharbiya to allow the light and fresh air to move about the mausoleum (Figure 23a,b). The body of sultan Hassan is surrounded by a small carved wooden fence with different fractal shapes (Figure 23a). Behind the tomb is another Mihrab with fractal shapes (Figure 23c).

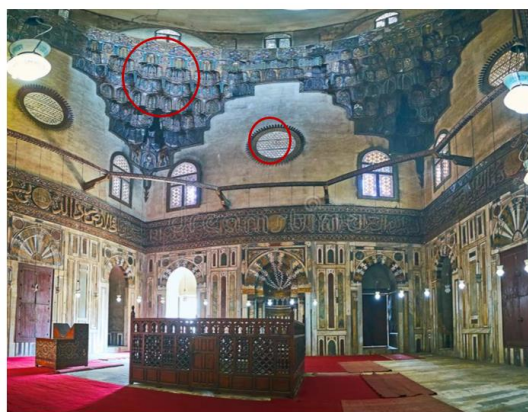


Figure 23 a: the decoration of the muqarnas and its pyramidal profile shadow on the ceiling both have a fractal shape.



Figure 23 b: The four corners with four fractal muqarnas shapes.

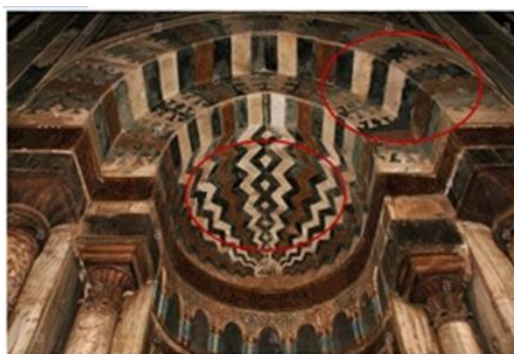


Figure 23 c: The mihrab is decorated with fractal shapes.

Figure23: The different fractal shapes in mausoleum room.

C. The courtyard; This courtyard is a vast square space surrounded by four monumental [iwans](#) (Figure 24). An arch with 2 self-similar with small scale iterations in finite region, achieving the feature of the fractal shape (Figure 24). The shape of ablution fountain illustrated the fractal feature by using the self-similar octagonal shape with 3 iteration with different scales in finite region (Figure 24,25).

The floor of the courtyard; Two-dimension plane is divided into nine sectors labeled A1, A2, A3, B1, B2, B3, C1, C2, C3, B2 is the center of the floor. The patterns in each sector classified under symmetrical groups. This stage revealed the commonalities and differences among various sectors as well as the unique character of each sector. The analytical process can be outlined as follows (Figure 25).



Figure24: A different fractal shape in courtyard.

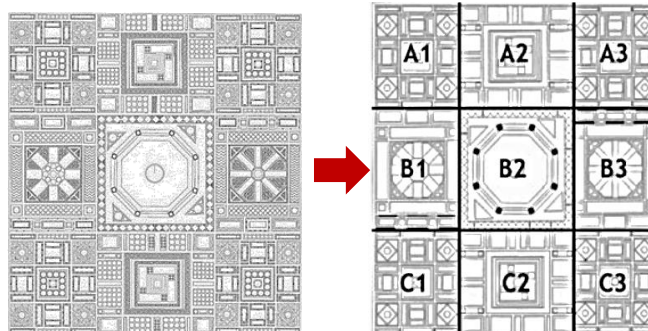


Figure25: Dividing the floor of the courtyard in 3 rows and 3 columns.

Source: (Haider, Moussa 2004.)

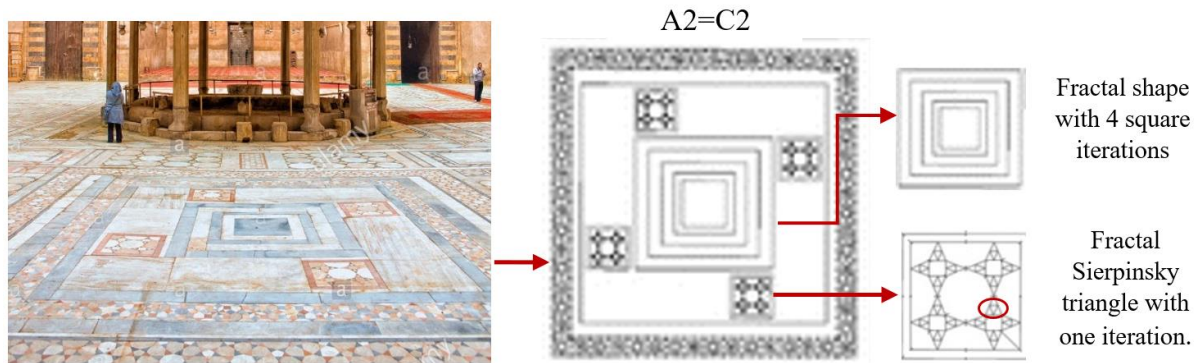


Figure26: Analysis of some fractal geometric patterns in A2, C2.

Source: (Haider, Moussa 2004.)

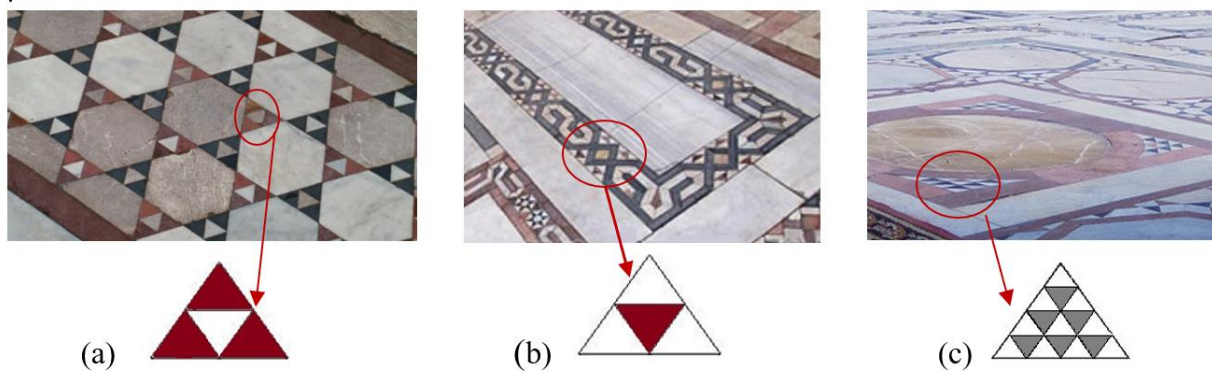


Figure 27: Fractal Sierpinsky triangle with one iteration in the floor design.



Figure 28: Series of Fractal shape with one iteration.

Figure 29: Fractal shape with one iteration

A. The vestibule chamber of Sultan Hassan mosque:

The ceiling is almost covered with fractal muqarnas structure. The middle dome is covered with fractal triangular shapes.

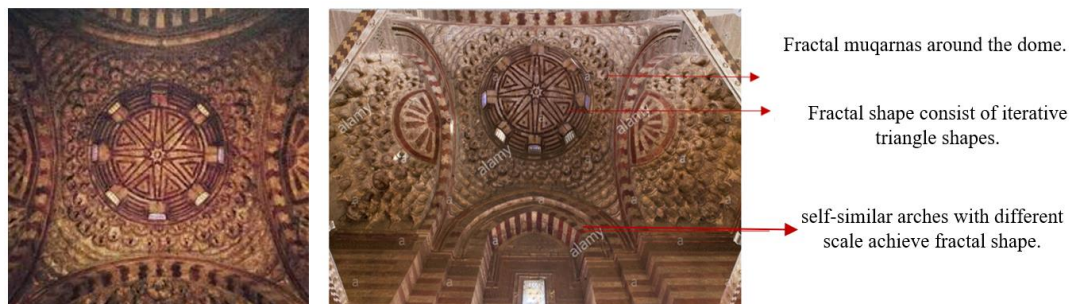


Figure 30: The vestibule of sultan Hassan mosque with fractal muqarnas vaulting, as well as fractal arch.

III. The different effects of Islamic fractal design on the occupiers of the interior environment:

The occupiers of the interior environments are in constant active interaction with the Islamic fractal design surrounding which give the following effects on their health:

1- Lower the human body stress:

Living in an interior environment inspired from the nature lowers the level of stress. (Thompson et al, 2012). Fractal is inspired from nature; therefore, the human bodies respond positively to any fractal structure because the different body systems are constructed in fractal manners like the nervous system, the circulatory system, the brain system and the respiratory system. Thus, a harmonious cognition is generated between the human body and the natural fractal geometrical shapes. Using the same concept in Islamic fractal design in interior environment the human body will dampen its response to stress induced by intensive tasks and reaction to external forces (Taylor 2006,245-51). This explains why the Islamic interior environment induces positive emotions to the human beings.

2- Emit positive energy:

The positive energy in the interior space is the positive effect that appears and affects the space user as a result of using design elements with specific characteristic. Fractal shape is a biogeometrical shape which has the advantage of emitting positive energy, thus will help in balancing the harmful negative energy resulting from the electrical and electromagnetic fields in the interior spaces (Attia 2012,38-39). Hence, using the Islamic fractal shapes in the interior environment will generate positive energy raising the human being's vitality and creating a healthier, vital and reproducible environment.

3- Improving the long- term memory:

The brain is organized in fractal patterns that spontaneously recognize the fractal shape in designs creating an intense mutual positive effect that it engraved in the long-term memory (Dileva, et al,2013). When confronting an Islamic fractal design for the first time, a strong brain stimulus is generated and is archived in the long-term memory. Upon exposure for the second time a rapid stimulus is generated and creates a harmonious emotion with the human body. (Chabot et al.,1976)

4- Environmental therapy.

The people who are subjected to restrictions on their health or cognitive ability cannot always adapt the environment to their specific needs. Therefore, they are more dependent on their interior environment (Marquardt, Schmiege 2009). To solve this problem their interior environment should be designed in a way to meet both their specific needs and also the normal people needs. Using the Islamic fractal design in their interior environment promotes the well-being with suitable physical and psychologically support in order to manage the major stress accompanying illnesses, including relaxation, improving long-term memories, generating positive emotions and thus, promoting non-pharmacological environmental therapy.

5-An Aesthetic effect:

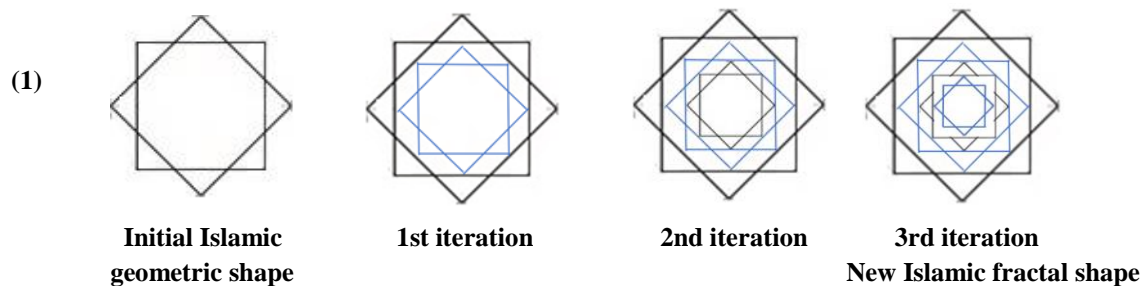
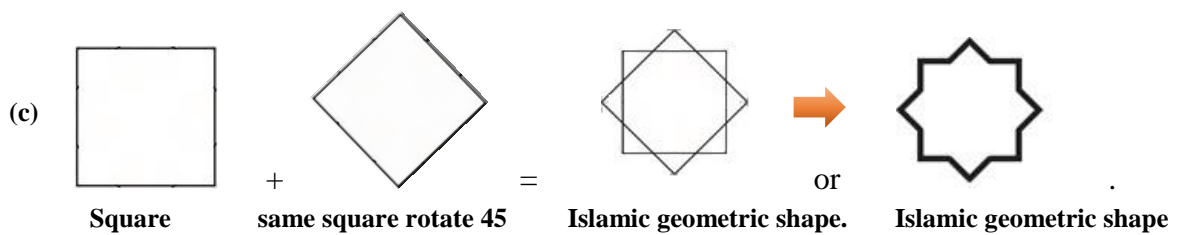
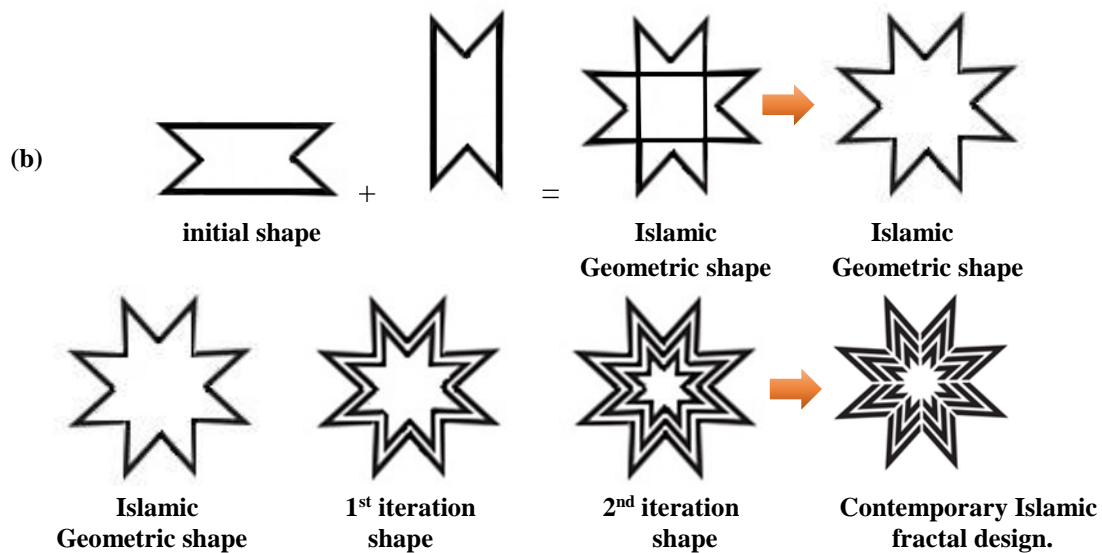
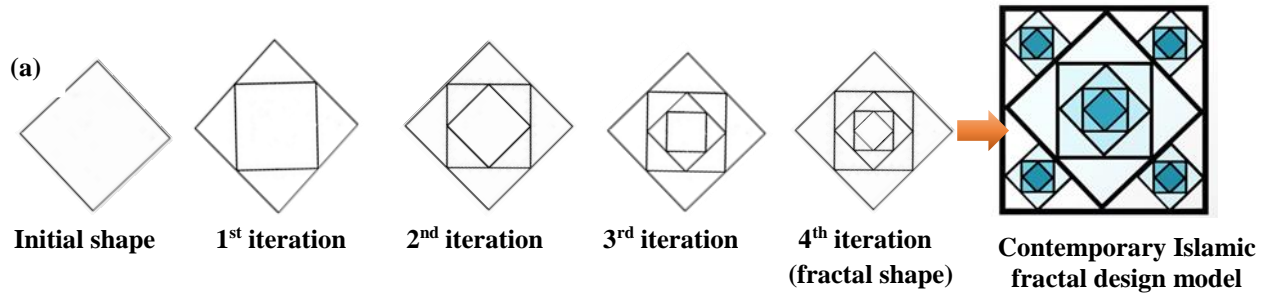
Putting the conventional simple geometric shapes together in unconventional ways creates a new meaning of aesthetic within the whole (Venturi 1966). Accordingly, Fractal shape being organized in a self-similar geometrical shape with smaller scale infinity number of iterations in

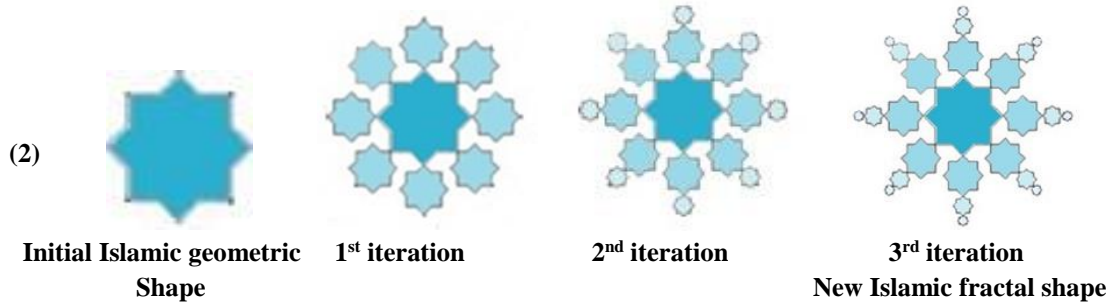
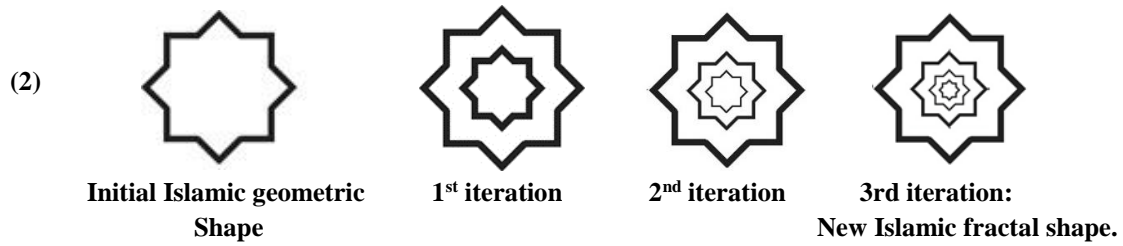
a finite region which is unconventional way, so it is an aesthetic with in the whole. Therefore, the designs complexity achieved by the Islamic fractal geometry give the aesthetic in its designs (Spehar et al. 2003, 813-20)

IV. Suggested New Contemporary Islamic fractal patterns:

1. Simple Islamic fractal pattern.

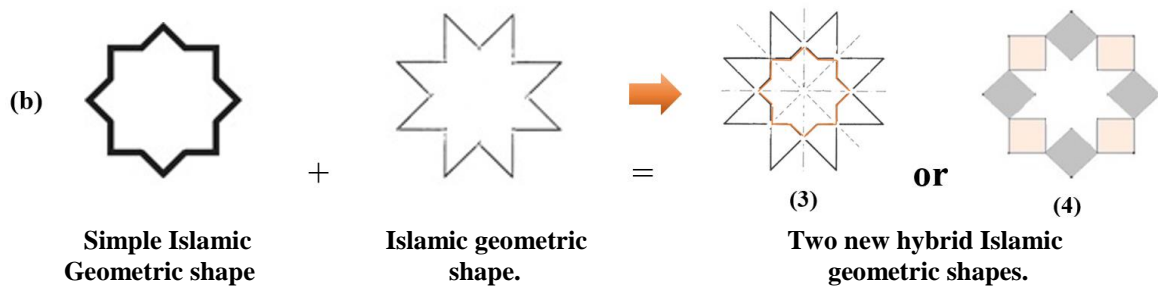
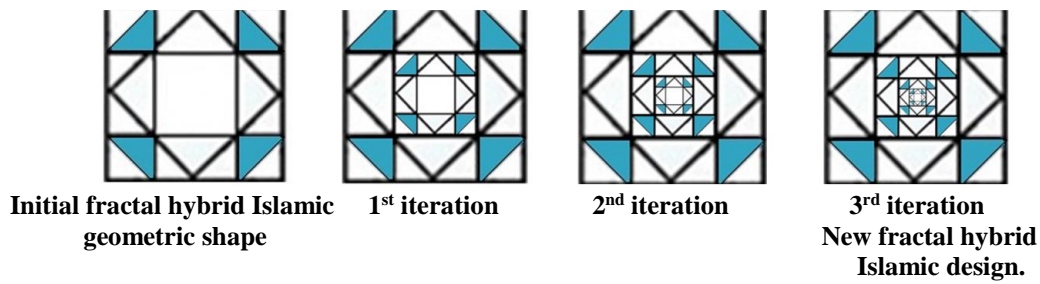
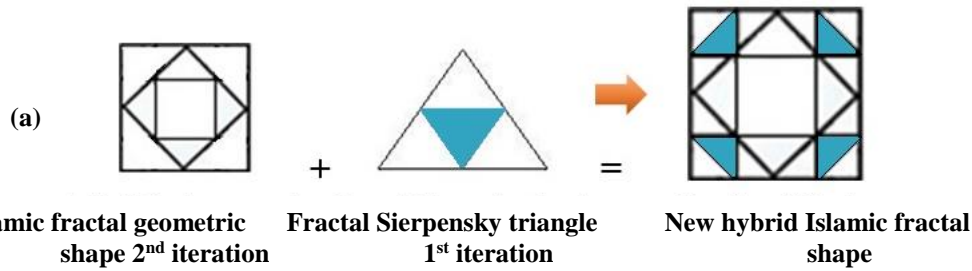
We suggest a new varieties of fractal islamic patterns generated from initial islamic shape using the computer technolgy to be used in interior design and furniture .

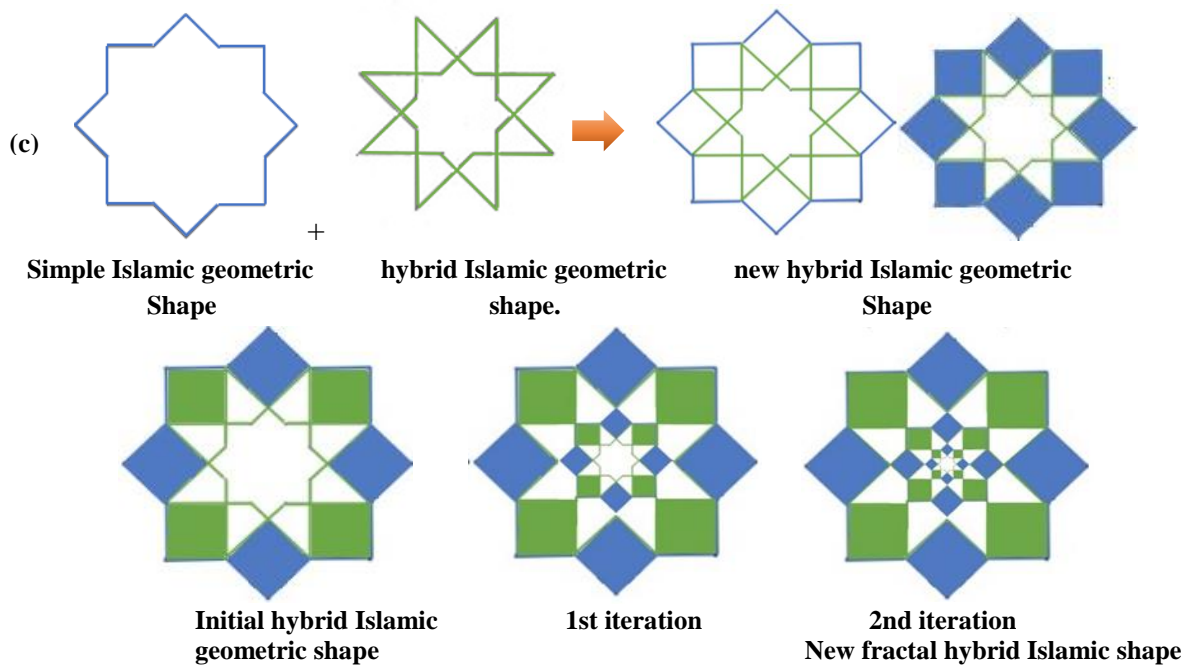
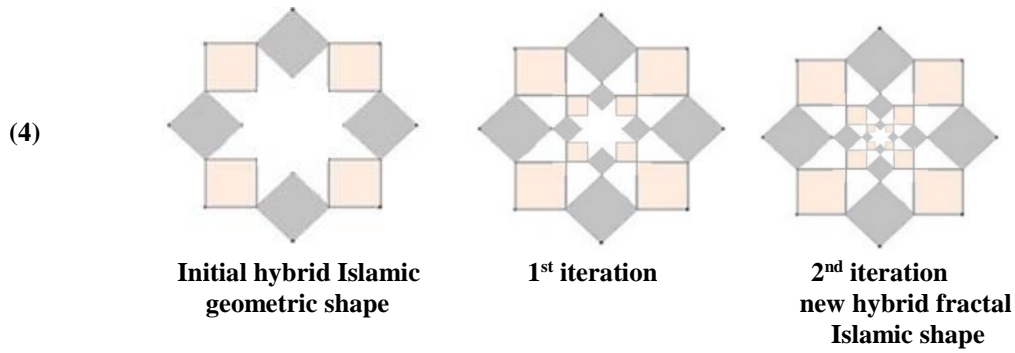
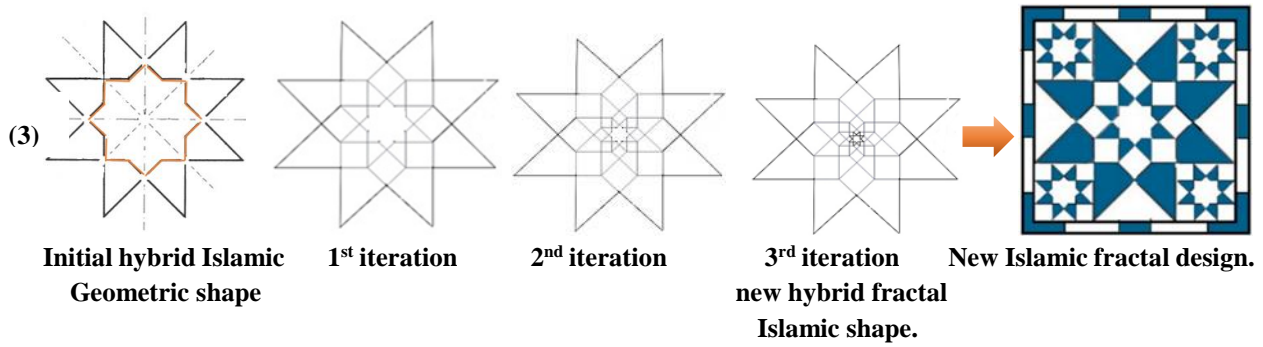




2. New Contemporary Hybrid Islamic fractal patterns;

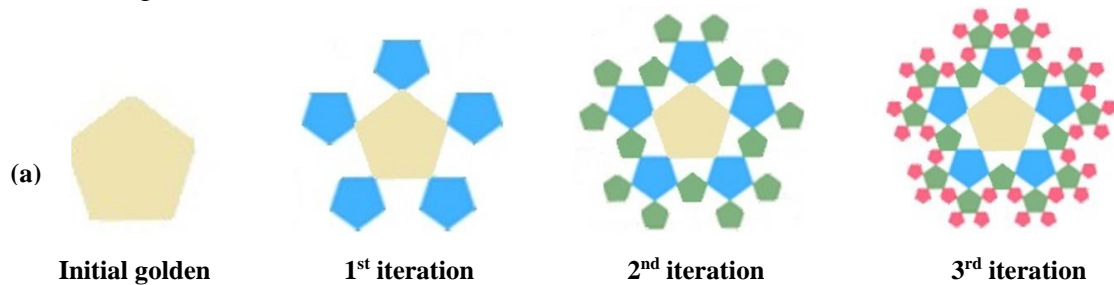
New varieties of hybrid fractal islamic shape are suggested .

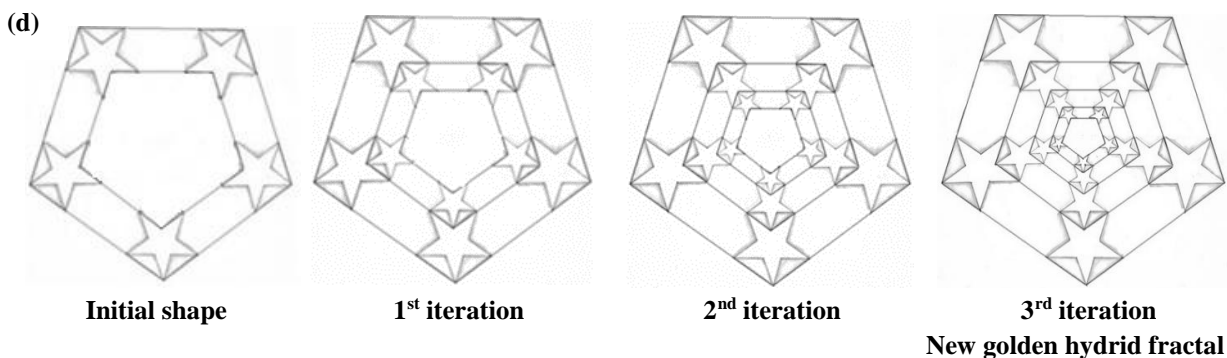
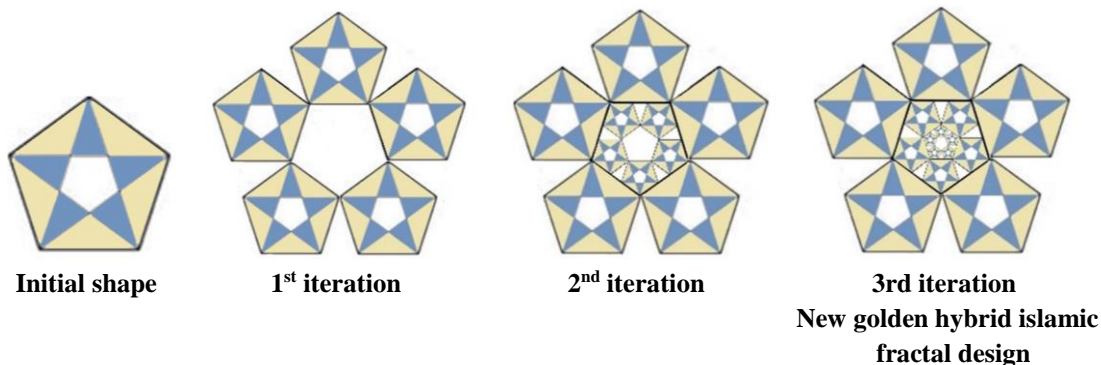
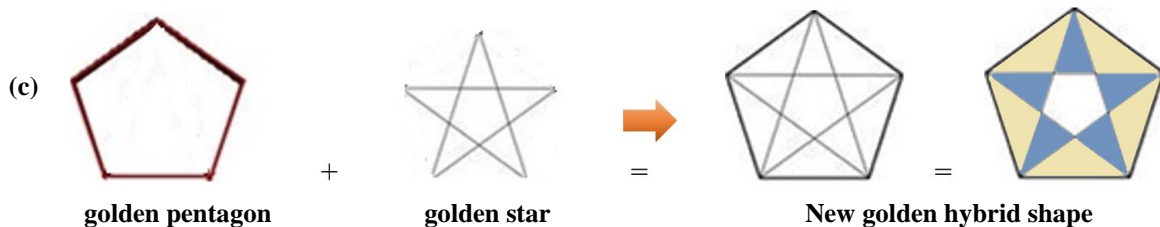
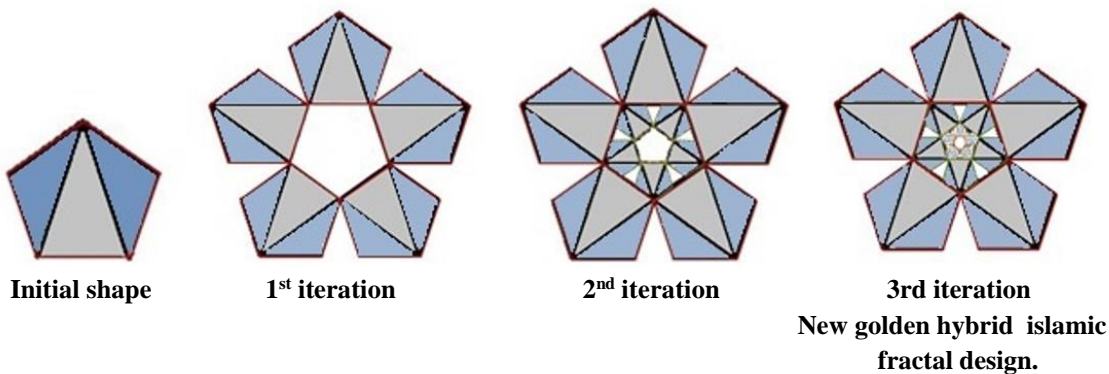
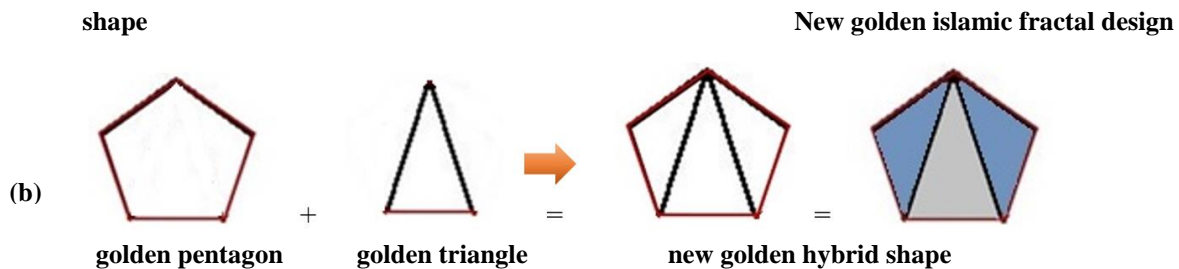




3. contemporary golden Islamic fractal shape

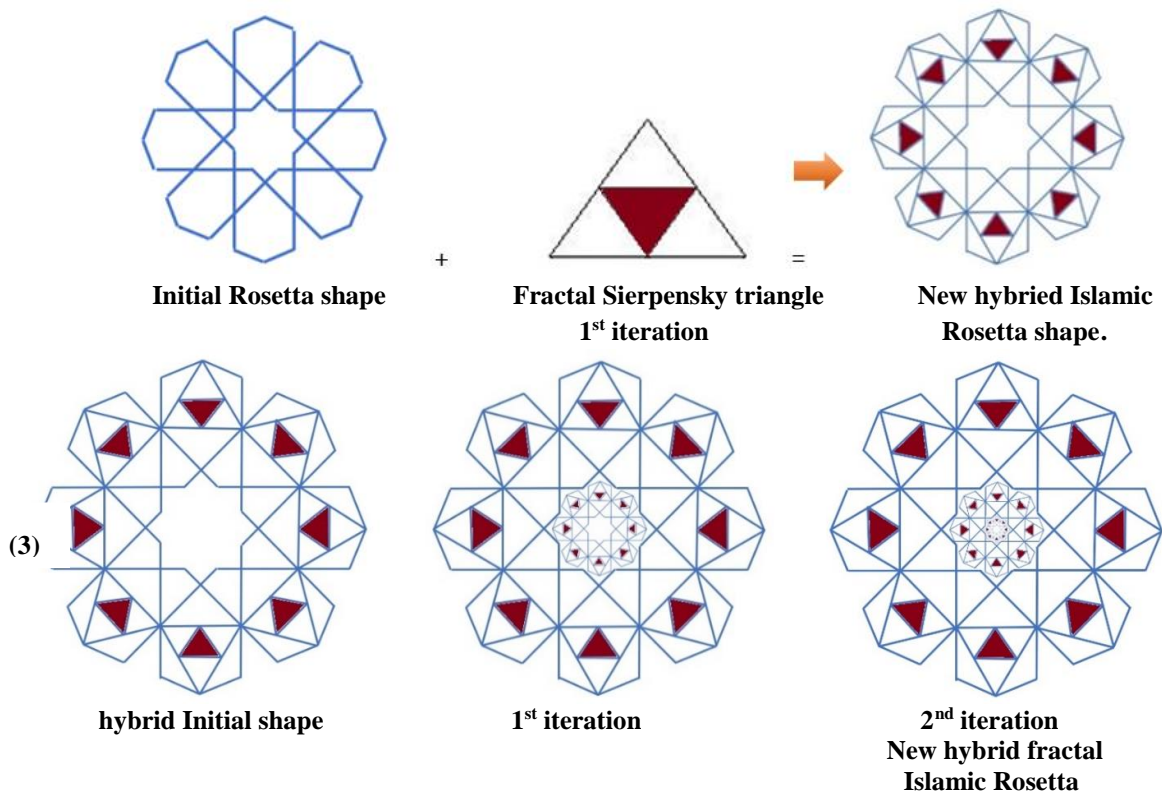
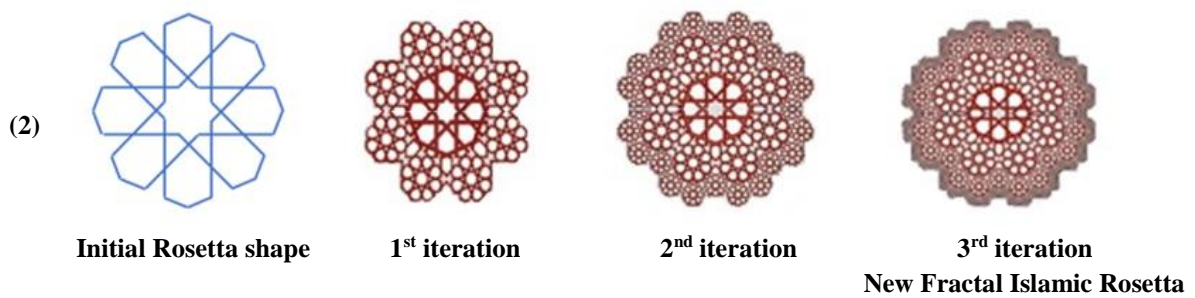
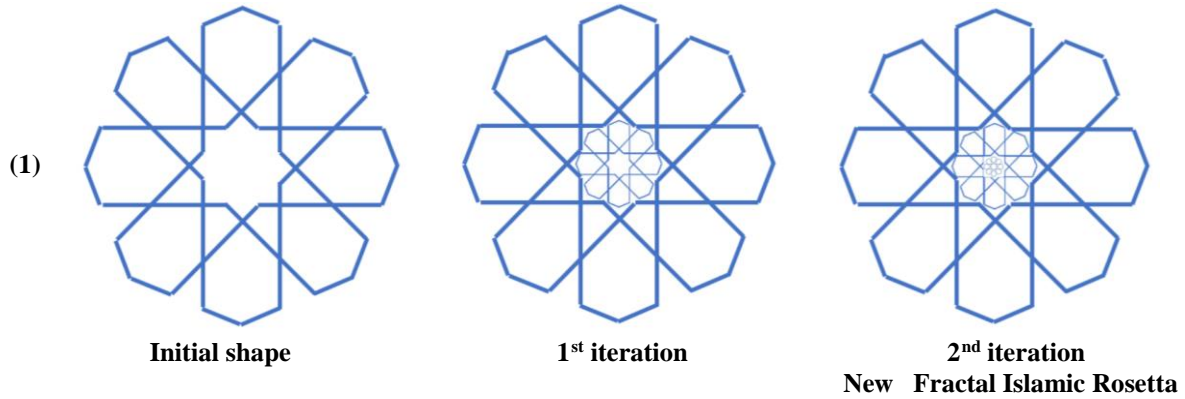
New golden islamic fractal patterns which generated from goldens shape that can be used in interior design and furniture .

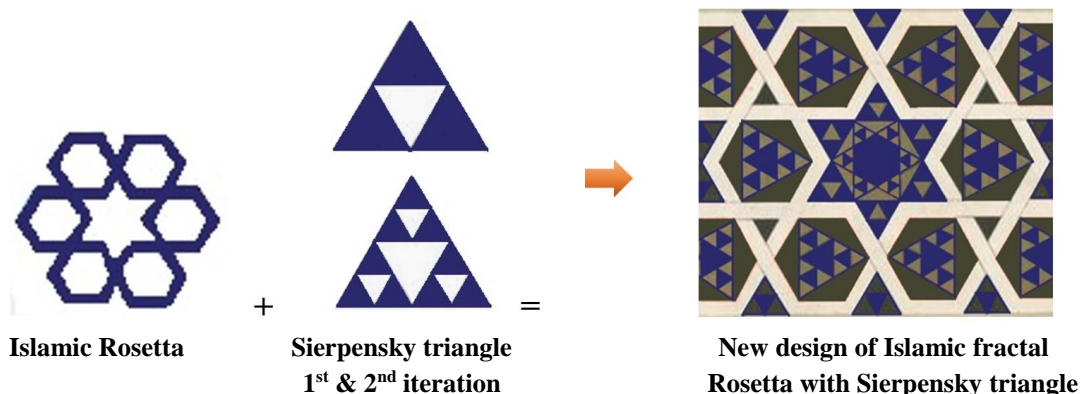




4. New contemporary Rosetta fractal Islamic shapes:

We suggested a new different fractal islamic rosetta obtain from the old one.





Results:

- The analysis revealed that the basic feature of the fractal geometric shape “self-similarity, large number of iterations with different scale shapes” are clearly visible and assessable in most Islamic fractal design.
- The study showed that fractal patterns in the Islamic design existed since the ancient eras of Islam with small number of iterations. It is used in the design of the walls, ceilings, doors, domes, floors.
- The contemporary Islamic fractal patterns can be designed in explicit form with large number of iterations using the digitalization which will emphasize exploring the beauty underlying the Islamic fractal design styles. It enhances the Islamic fractal designs through connecting the Islamic style attributes with the principles of visual complex composition.
- This study suggested a new contemporary Islamic golden and non-golden fractal patterns generated by the computer technology that can be used in the interior design.
- The Islamic fractal design has positive effects on the occupiers of the interior environment including improving the wellbeing, reducing stress, improving the long-term memory, emitting positive energy, balancing the negative energy in the space. Thus, increasing the vitality and reproducibility of the occupiers.
- Knowledge of the basics of fractal helps the interior designer to explore more designing skills and the development of new innovative forms that can be used in the field of interior design.

Conclusions and recommendation:

- The Islamic fractal design acts as a strong stimulus to the brain, generating strong emotions in very short time and improving the long- term memory.
- Interior environments with the Islamic fractal design possess features that can be considered as a non-pharmaceutical environmental therapy: defined as comfortable interior environment with restorative feeling and raising the attention in the space , therefore, reducing stress, fatigue and anxiety and consequently , improving the vitality and reproducibly and emit positive energy creating healthy spaces.
- The Islamic fractal design can be used in different interior environment like homes, offices, educational spaces, hospitals, Mosques, as it affects the human being in a positive way, reduces stress, frustration and anger.
- Using the fractal patterns in Islamic design give a new approach to contemporary Islamic design and can be influential in conveying Islamic philosophy and concept.

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