

## Fractal Geometry and Persian Carpet

seyed Mahmood Moeini  
Department of Architecture  
Malayer Branch, Islamic Azad University  
Malayer, Iran  
E-mail: mmoeini.arch@yahoo.com

Mehrdad Garousi  
Freelance Fractal Artist  
No. 153, Second Floor, Block #14  
Maskan Apartments, Kashani Ave  
Hamadan, Iran  
E-mail: mehrdad\_fractal@yahoo.com  
<http://mehrdadart.deviantart.com>

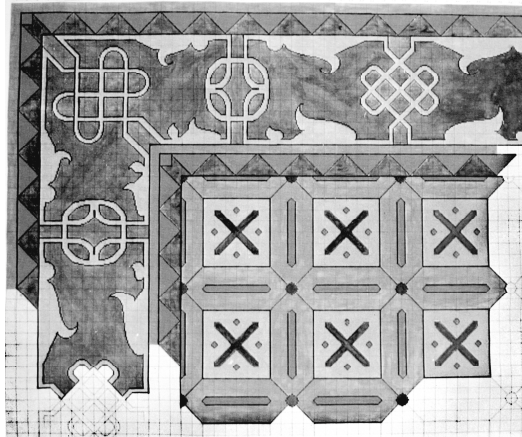
### Abstract

We show that Persian carpets often contain visual patterns with a hierarchical level of structure and detail similar to that found in many fractals.

Persian carpets can be considered as a central part of Iranian life and a world-famous symbol of Iranian culture. Carpets are laid on floors, used in religious ceremonies, while showing a sort of art. Iranians also kneel on carpets to pray [1]. It is difficult to be certain about the early history of carpet weaving in Iran. Due to the fragile nature of the materials from which a carpet is made, not many historic carpets have survived. The earliest remains of carpets from Iran date to the Sasanid period which is strongly thought to be the historical origin of these artistic handicrafts as we know them today [2].

What makes Persian carpets as precious as they have been through millennia is embodied in their patterns, processes of mapping and their weaving. These fields are the authors' focus to uncover properties similar to those in fractal geometry.

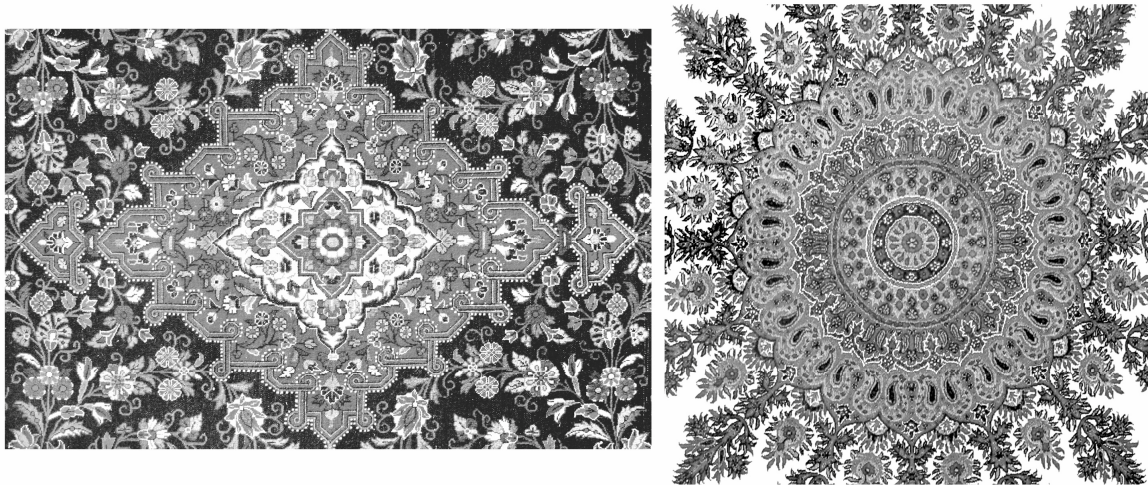
In general, Persian carpet designs have been inspired by nature, history, religion, and myths. They may use flowers, trees, natural scenery, historical and mythological characters, Persian poetry and calligraphy, and religious symbols and stories. These patterns have such origins in history that many motifs, patterns, and traditional colorations found in rugs that are produced in many other countries today have either originated in or been influenced by motifs and patterns used in Persian carpets [2]. What makes these patterns unique is the way they are designed. Everything starts from a graph-paper which is known as the *map* and is made up of thousands of squares, as in Figure 1.



**Figure 1:** A corner of a half-work map of a carpet on graph-paper, from [5].

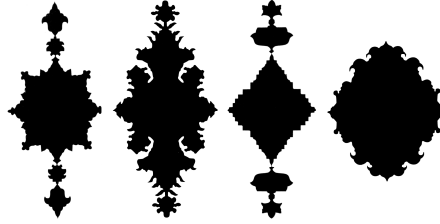
These squares are the very basic units of construction of every shape and pattern, simple or complex. This way of designing is an origin of simultaneous derivation of complexity and order because, no matter how big the final patterns will be, they can still embed very tiny details comprising single basic units or small groups of them. This can play role as a potential for *self-similarity* in carpet patterns and layouts since starting with a basic checkered plane to create large patterns can spontaneously cause *iteration* and combination of similar patterns at different scales resulting in scalability and self-similarity. Repetition of crosses with four squares around them, on a small corner piece of the map shown in figure 1, at different scales introduces such a visual self-similarity in the way that each set of crosses and squares of the previous iteration is placed inside the squares around the larger cross of the latter iteration. Another essential feature of Persian carpet mapping that feeds this is its space-filling nature so that the designer, by means of different symmetry techniques and diverse geometric and ornamental motifs, is always trying to fill the whole map with piles of complex details, but in an ordered manner. The final goal of mapping is, therefore, to fill everywhere with something and thus negative empty spaces are generally avoided. Taking account of these properties of carpets reminds one of the well-known concept of *unity in multiplicity* or *unity of existence*, which flourished vastly in Islamic art [3].

Centers of a large number of central-mapped carpets are composed of numerous symmetric ornamental or geometric shapes repeatedly placed within each other. This behavior is similar to the ability of fractals to reveal infinite structure at any scale. The smaller forms at the centre of carpets are simple geometric shapes like squares or flowers that become more complex with the increase of the number of sides or boundary patterns. As Figure 2 shows, these detailed patterns can continue to expand outwards, beyond the carpet or picture bounds. The perimeters of some of these central closed forms are very similar to perimeters of some fractals. Figure 3 depicts a number of them.

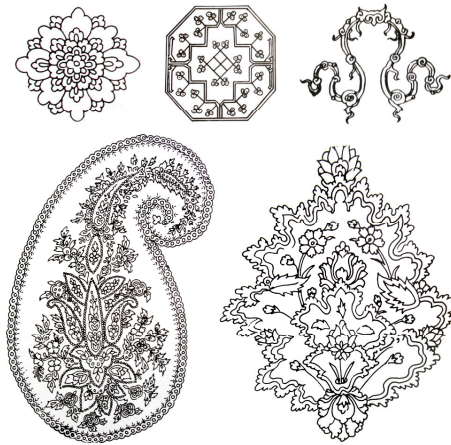


**Figure 2:** *Central areas of two different carpets.*

Surveyed a little closer, another important part of design is the pattern units, usually in curved floral ornaments, used repeatedly in different parts of the map at different sizes and scales. Some of them are outcomes of the repetition of forms and carry considerable amounts of self-similarity. Examples are depicted in Figure 4: the simple pattern in the upper right comprises short pieces of curve articulated together at different scales containing mirror symmetries; the upper left one represents semi-similar views at different places and scales. The lower right sample is more complex and features smaller examples of itself inside, at both the top and bottom of it ; the other examples operate similarly.



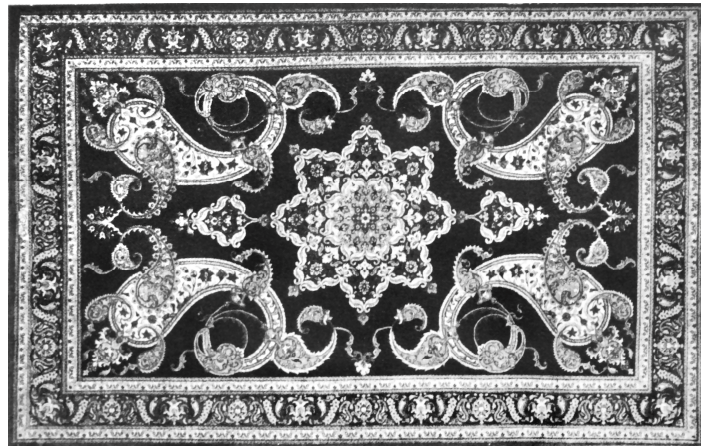
**Figure 3:** Overall shapes of the central areas of four carpets.



**Figure 4:** Examples of separated pattern units of Persian carpets.

All explained aspects of carpets above are related to the pre-weaving process of mapping which causes whatever complexity, geometry, symmetry, and curvature that can later be seen in them. However, the weaving process is itself a unit-based and scalable process. The very basic units of carpet weaving are knots that are produced by passing the crosswise strings of weft under and over the lengthwise strings of the warp. A basic factor in determining the quality of a carpet is knot density: the number of knots per square inch. More knots indicate more details, finer work, better quality, and a higher price [2]. These knots are put one by one on each other and grow up row over row to create patterns of the map square by square. Very fine Persian carpets may even have as many as 800 knots per square inch [4].

There are below some examples of carpets that show more fractality in their overall view. Note the repetition of *Bote-Jeghe* forms on each other in the corners of the carpet depicted in Figure 5, the strange pattern at the center of Figure 6 which resembles a Julia set fractal and the space filling spirals surrounding it, and finally the iterative reproduction of rhombuses in the carpet of Figure 7.



**Figure 5:** A carpet with a pattern known as *Bote-Jeghe* in Iran, from [6].

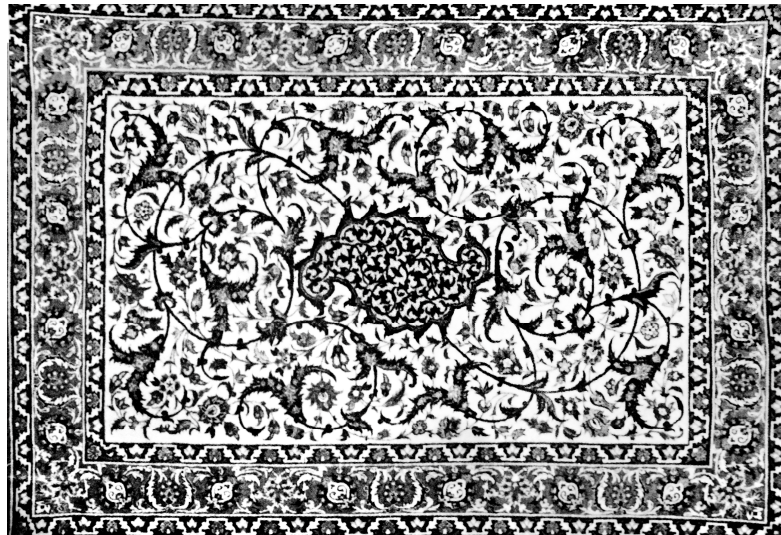


Figure 6: This carpet is a very good example of the evocation of the complexity of fractals, from [7].

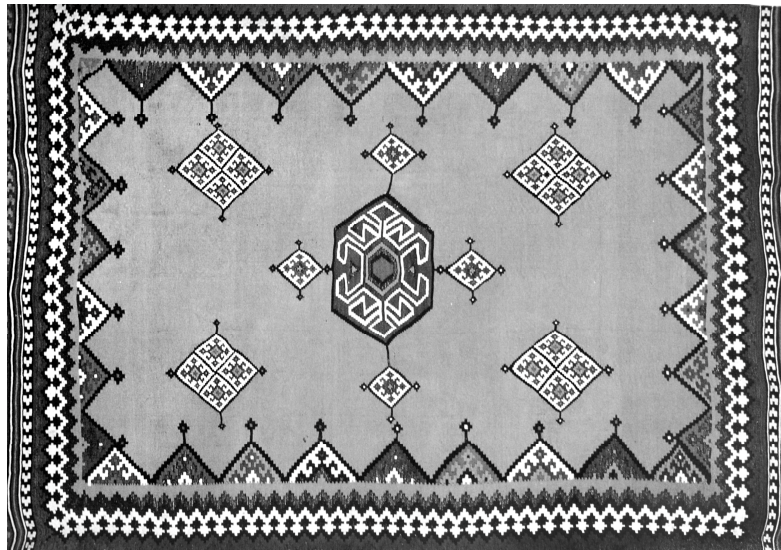


Figure 7: A carpet with a simple and clearly fractal-based design, from [8].

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