Application of geometry in brick decoration of Islamic architecture of Iran In Seljuk period

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Abstract: Islamic architecture encompasses a wide range of religious styles from the foundation of Islam to the present day, influencing the design and construction of buildings and structures in Islamic culture. The principal Islamic architectural types are: the Mosque, the Tomb, the Palace and the Fort. From these four types, the vocabulary of Islamic architecture is derived and used for buildings of lesser importance such as public baths, fountains and domestic architecture. Architecture through the ages, has embraced a wide variety of arts and sciences. By using mathematics, Iranian architecture has achieved a high level of beauty and perfection. It is evident that advanced geometry was used by the prominent architects at that time. Geometry was used not only to solve structural problems, but also in the details of the designs of various structures. These range from the immense high entrances of Friday Mosques in important cities, to entrances of ordinary homes. By reviewing examples of medieval Iranian architecture, one becomes aware of its close relationship to scientific fields such as mathematics, geometry, cosmology, and astrology. This Relationship made it possible to achieve perfection, monumentality and poetic beauty. This paper interest to study about geometry using in Iranian architecture in the seljuk period.
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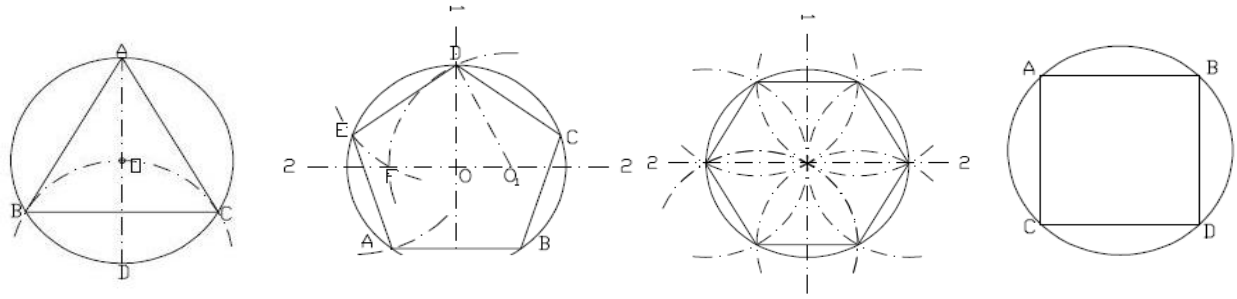
1. Introduction

Architecture of Iran in Seljuk period started in eleventh century and continued until early thirteenth century. Architecture of this period has special position in term of genre and art style and is considered as culmination period of Iran architecture. Also in this period, art of architecture flourished and highly dexterous architects and artists create many valuable and precious works. In architecture this period, there was created great Iranian mosque through combination of 1- four porch yard, 2- round square hall and four arches two factors. And four porch styles became system of religious architect . As well as it was customary in other applications such as building schools and caravansaries.

The architects of this period granted accurate nature and quality to Iranian architecture of this period using architectural elements of the past (Sassanid architecture) like (dome, porch, and yard) and arched style buildings applying precision geometry. And by creation of large and magnificent buildings and stabilize their style whereas Iranian architects seems satisfy with their building style apparently, since then they found their work done and expend their endeavor in building decoration . They used various methods in decoration such brickwork, tile, and tore, muqarnas.

Brickwork of this period has the highest and best function as element of ornament in addition to load-bearing and transfers of various forces such pressure, stretching and cutting that took the place of adobe in religious building gradually. Thus brick surface that were from high quality material and visible and durable were exposed. Use of pattern and geometric forms of bricks in building either pure or in form of mixed with other materials, led brickwork of Seljuk period in Iran to reach the highest degree and full progress. Also most of brick surfaces were created according to geometric principles and rules. And rich designs and brick-covered decoration arches were used in soffits, walls of mosques, schools and minarets. Beauty, grandeur and purity of this the architecture of this period due to observing of proportions and harmonious rates in combination of form and volume and applying of geometric forms in brick decorations. This paper reviews application of geometry in brick decoration and also studies how geometry was used in brick decorations. And finally it will discuss around applied concepts and aesthetic aspects.

Figure 1: Sareben brick minaret



a 2 b2 c 2 d2

Figure 2 : transition of a square into a circle

2- Great Seljuq Empire architecture

Seljuk architecture is the name given to the architecture of the Seljuks. The architecture can be found in the areas where the Seljuks ruled, most of the Middle East and Anatolia between (11th - 13th Centuries). After the 11th century the Seljuks of Rum emerged out of the Great Seljuk Empire, developing their own unique architecture.

The architecture can be found in a vast area stretching from the Hindu Kush to eastern Anatolia and from Central Asia to the Persian Gulf. The homeland of the Seljuk architecture was Turkmenistan and Iran, where the first permanent Seljuk buildings were built. Unfortunately the Mongol invasions and earthquakes destroyed most of these buildings and only a few remain. In 1063 Isfahan was established as capital of the Great Seljuk Empire under Alp Arslan.

The most significant alteration carried out in the early twelfth century was the conversion of the mosque plan into a four-iwan plan mosque. Another mosque-type introduced at this time was the kiosk mosque, consisting of a domed space with three open sides and wall containing a mihrab on the qibla side.The architecture of this period was also characterized by memorial tombs which were usually octagonal structures with domed roofs, called Kümbet or Türbe. An impressive example of tomb architecture is the mausoleum of Sultan Sanjar at Merv, a massive building measuring 27 m square with a huge double dome resting on squinches and muqarnas pendentives.

3. History of Geometry using in architecture

Many researches show the close relationship between mathematics and Islamic Iranian architecture.

"The Study of mathematics had long been an area of original and fruitful research in Islam. translations of Euclid were of course already available in the Abbasid period. While the scientists of Saljuq and Mongol Iran were the best of their age, it has been estimated that it was the Timurid period which saw the apogee of Islamic work in computational mathematics."(Kane, 1995 :35)

The transition of a square into a circle (Figure 2) by using triangles is one of the characteristics of Iranian architecture from the pre-Islamic period. Later, Iranian architects used this process to create more complicated and elaborate form in the design of their buildings. The center point of the square, marked by the intersection of two diagonals, is the most important point of in its transition to a circle process.

This called for a further geometrical solution in the corners in order to create the desired forms and volumes. In order to create the vast varieties of forms which were achieved by the turning, rotating, and twisting of a simple square, the usage of circles and triangles was common and widely used in much of the medieval Islamic Iranian architecture.

It is evident that advanced Geometry was used by the prominent architects at that time. "The techniques of tower construction established in earlier centuries continued and spread under the Saljuq Sultan, their governors, and their neighbors. The cylindrical brick shaft of a variable taper was decorated with brick patterns and inscriptions of varied quality and complexity." (Bloom,1989:157)

Usage of advanced mathematics continued into the Il Khanids period. "Its apparent feature was a more immense scale. The structural load-bearing components of monuments were concentrated. A large ratio of height to the interior width of the chamber was displayed." For example: " the weight of the double shelled dome of the mausoleum of Uljayto in Sultanieya central Iran (45 meter high with

a diameter of 24.5 meter) is concentrated on a small number of supporters, without the use of any shoulder or buttress."(Hejazi , 1997) So it needed to be calculated prior to its construction.

Geometry was used not only to solve structural problems, but also in the details of the designs of various structures. These range from the immense high entrances of Friday Mosques in important cities, to entrances of ordinary homes. The more modest residential architecture conceals private and common-use areas of the houses. The layout of such houses varied according climate, culture, tradition, and aesthetic tastes. In order to satisfy these demands, and the placement of these structures within an urban setting, the architects had to rely on mathematics in order to achieve the best results.

The mastery of advanced mathematics among the architects, and the application of this knowledge in the various aspects of design led to the creation of amazing and admirable architecture1. There is no doubt that only those architects who were acquainted with an advanced knowledge of geometry, algebra and astrology, as well as, poetry and philosophy, could design such architectural elements that protected the structural stability while achieving perfection of beauty characteristic of medieval Iranian architecture in Iran. This level of balance and elegance would not have been attained without the mastery of mathematics by the creators of the work.

The ratio of height to the diameter of the towers or minarets in medieval Iranian architecture shows another aspect of the use of mathematics in architecture. The Tower of Gonbad-I-Qabus near Gorgan (in northern Iran), is a unique example of such a case. While this tower "reaches the amazing height of sixtyone meters, its diameter is only seventeen meters." (Daneshvari,1986:14) This mathematical relationship helped the architect to create the sense of "the ascension from earth toward heaven." This effect is achieved by narrowing the diameter of the tower where the entrance is placed, in comparison to the height of the structure.

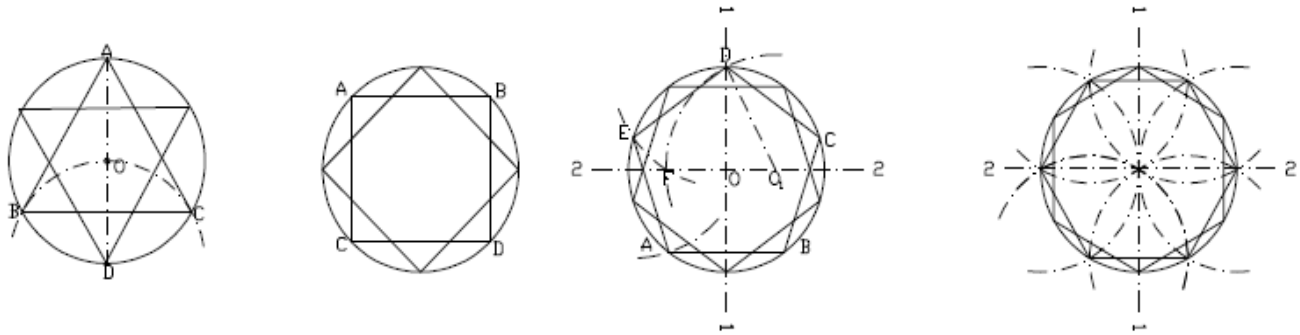
An additional example is the Gonbad-i- Ali Tower at Abarquh, in central Iran. This octagonal tomb consists of a tower of rubble masonry, rather than the traditional brick, and features a "bold three-tiered muqarnas3 cornice, also of rubble, [that] once probably supported a pyramid roof."(Hoag,1977)

Further use of advanced mathematic is evident in medieval Islamic architecture of Iran, especially the period between the Seljuk and the Timur dynasties, in the height of the towers and entrances, and the two shelled domes, used in the mosques of various cities. The "lofty minarets, with their ambitious construction and rich geometric and epigraphic decorations were designed and constructed with immense skill."(Laleh,2001) "Construction techniques have not been studied thoroughly, but the continued ability of these slender towers to resist earthquakes suggests that their builders employed some sophisticated method, perhaps wooden tie beams, to give tensile strength to the structre." (Bloom,2001)

4. Geometry in brickwork decorations

Pattern creation on surfaces in Islamic architect is possible by using circle and creation of regular polygons and dividing circumference to several desired parts. As an example simple polygons are obtained by dividing circle into 3, 4, or 5 parts and connecting them together.

Divisions of circles are increasing by rotating the regular shapes. So that circumference is divided into 6, 8, and 10 in triangle, square, and pentagon respectively. So we have a Star with connecting them together.



(Figure 3)

In Islamic architecture of Iran micro and small models emerge with repetition of a base figure in circle. Basic size is determined by radius of a circle. Divisions of circle (relative to its radius) to 3, 4 or 5 parts or multiple of them specifies order of proportional divisions in repetition of basic pattern. Therefore at first circle circumference is dividing into 4 parts and surrounded square is obtained by

connecting 4 points on circle. And geometric method is obtained for sub proportional divisions of basic pattern area and eventually lattice pattern lines by circumscribing circle in square. When we decorate a surface, we divide one of the sides equally into number of parts that match up with the numbers of basic pattern. Thereupon we will have surface covered with circles (Figure 4). Diameter of circles is equal to component part of surface sides that we would have a surface covered by basic pattern square by attaching them to each other (figure 5).

In each of peripheral and surrounded squares in circles as shown in figure 6, concentric squares are obtained with connecting junction point of lines in each of the squares in surface. For example in figure (6a) the proportion of side of surrounded square ACBD to side of peripheral square abcd is equal to $\frac{AD}{ad} = \frac{1}{\sqrt{2}}$ and also in figure (6b) the proportion of sides of concentric squares is equal to $1:\sqrt{2}$. So the areas being halved respectively (7).

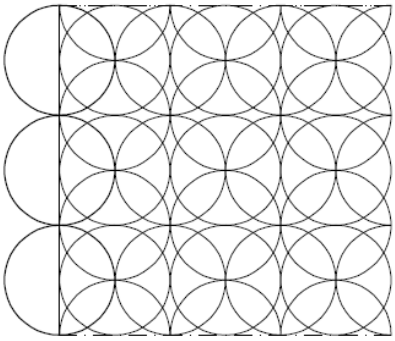


Figure 4

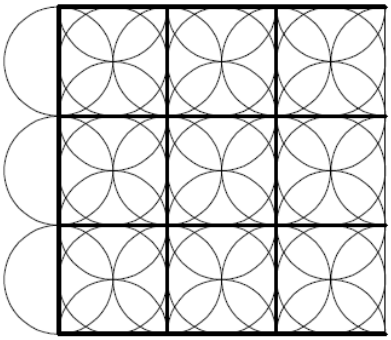
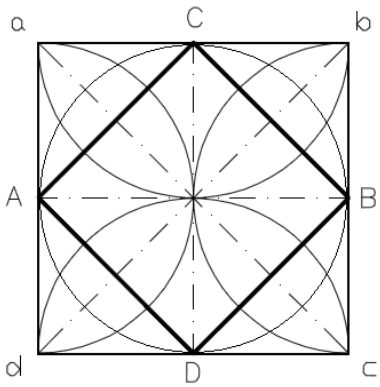
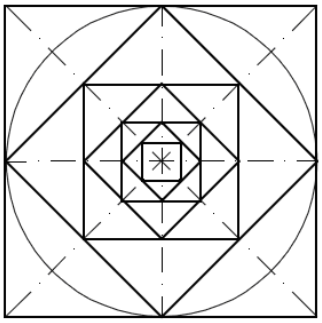
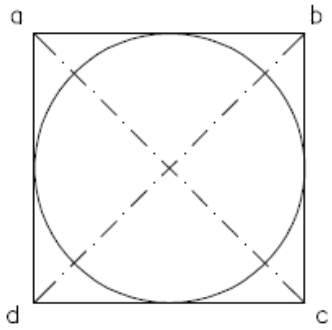


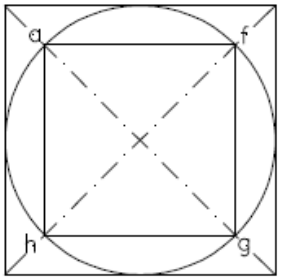
Figure 5

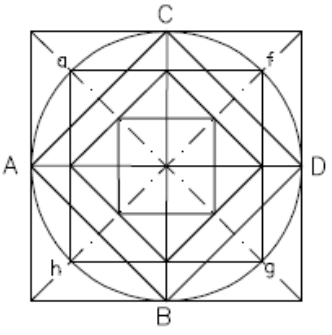




(Figure 6): (6_a) (6_b)





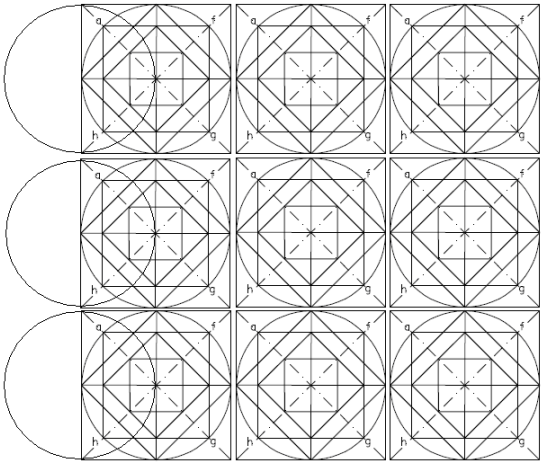


(Figure 7) : (7_a) (7_b) **(7c)**

Also in figure (7a) by drawing diameter of ac and bd from Peripheral Square, the junction points of diameter and circle are connected to each other and square of asfg is obtained. As well as the square of ABCD is obtained by connecting middle points of sides of Peripheral Square (A,B,C,D points) to each other (figure (7b)) . And finally it makes an octagon star through combination with square of afgh (figure 7c). In figure (7c), concentric squares and parallel

consecutive sides with proportion of $1:\sqrt{2}$ are achieved. And it is construct the major lattice of basic pattern.

By repeating of this basic pattern on surface side by side and connecting their lines to each other, following pattern will be achieved (Figure 8).



(Figure 8)

5. Geometry in brick decoration of Seljuk architecture:

Architects of Seljuk era began to decorate buildings after achieving to creation of great and magnificent monuments. And brick was used as a decorative element and there was created some wonderful designs with the help of geometry and using brick material skillfully that in this article we will examine two of them.

5.1. **Geometry of brickwork in minaret of mosque of saveh:**

This brick minaret has been built in 504 A.H that diameter of this cylindrical minaret is 3.5 m and its height is about 14 m. and has beautiful decoration with geometric forms related to Seljuk period. Repetition of geometric forms using brick and shadow and created light gave a beauty appearance to building. In this building in addition to geometric forms, there are three brick prominence kufic inscriptions in form of long legs and bangle. That inscription in bottom of minaret is arranged by hollow two edges letters and two inscriptions in bangle is in kufic outstanding script. The lines and geometric designs which are used in, all of them are brick and have been decorated outstanding style and it is considerable in term of technical.

5.2. Geometry of double towers brickwork of kharaghan:

These towers are in the kharaghan near the city of ghazvin. And are the tombs of related to Seljuk period. Also are called kharaghan towers because of their position. These towers would be considered as the oldest double covered domes of Iran. The height of towers is close to 13 m and diameter is about 11 m. map of the tower is 8 sides and in the corners there has been circular holder column. Construction date of these towers is second half of fifth H.A century according to inscriptions.

These towers are considered as a one of the most beautiful towers due to valuable brick decoration. And it is considered as a masterpiece of Seljuk period architecture. And its brick decoration has beautiful geometric designs.

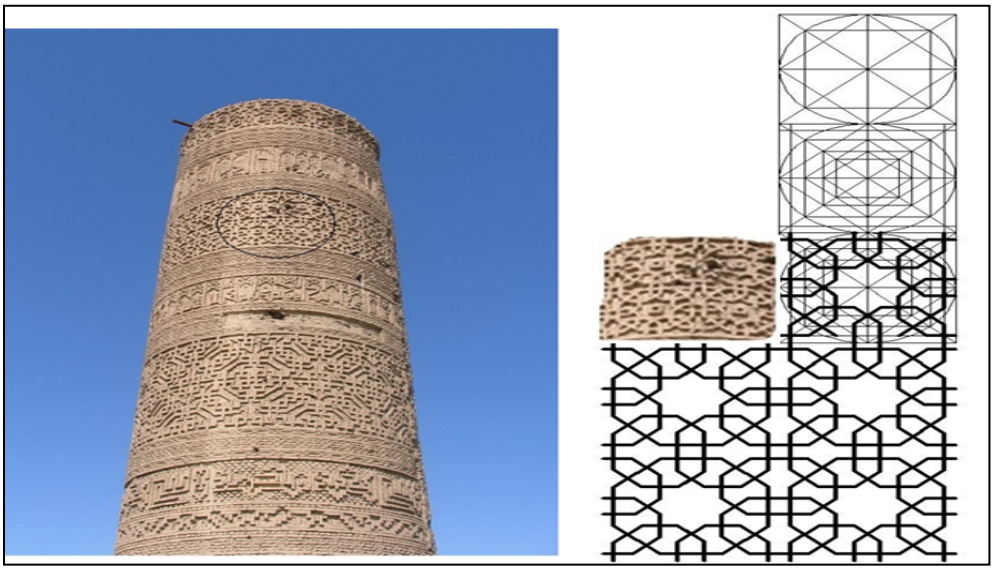


Figure 9: Brick minaret of saveh mosque

5.3. **Brick patterns used in towers view:**

According to the picture in this pattern there is obtained vertices of hexagonal by dividing circle into six parts and connecting the junction points to each other alternately. Also the desired pattern will achieve using other auxiliary lines and selecting some of the obtained lines and connecting them to each other according to following geometric shapes. Geometric forms are obtained by repetition of the shapes alongside one another and connecting their lines each other. This forms and patterns can be seen in the walls of kharaghan double towers by using brick.

Figure 10:

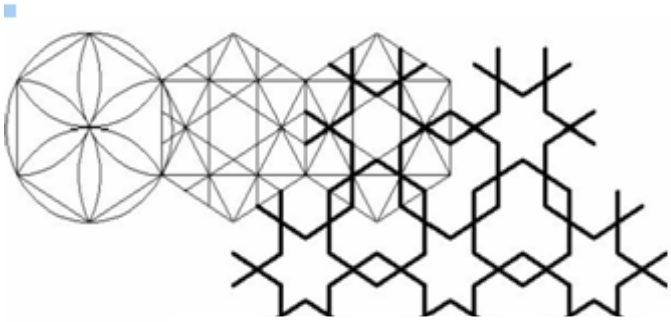
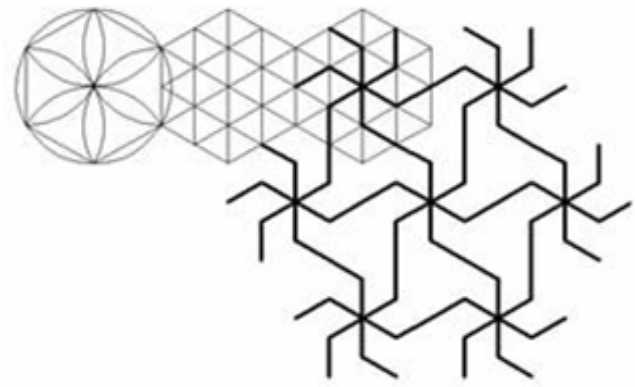


Figure 11

(Geometry of picture 11)

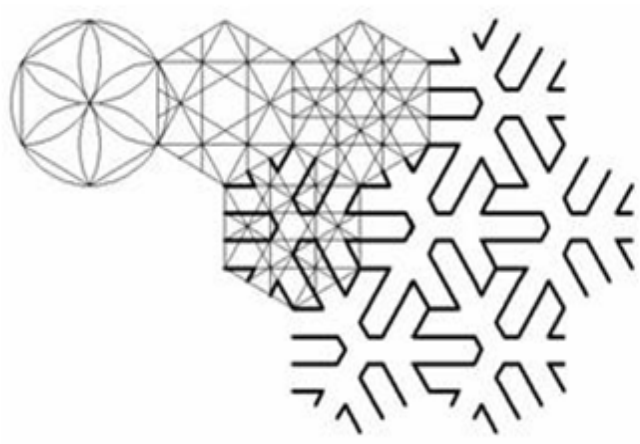
(Picture 11)



(Geometry of picture 12)

(Picture 12)

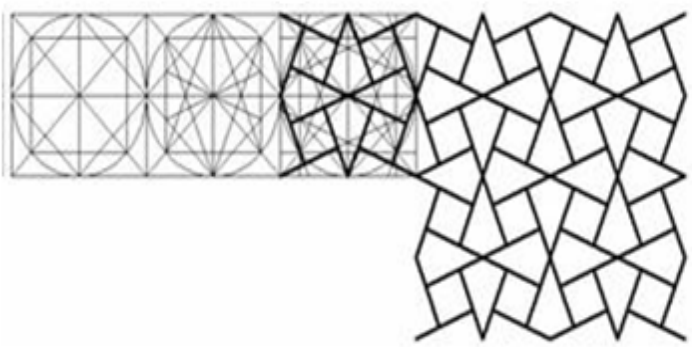
Figure 12



(Geometry of picture 13)

(Picture 13)

Figure 13



(Geometry of picture 14)

(Picture 14)

Figure 14

6. Conclusion:

In Islamic architecture of Seljuk period, brick decorations were used using geometric shapes. Geometric patterns have regular combination and creativity by combination of geometric shapes. Base of shapes and geometric patterns is on the circles. And regular polygons which gradually changing to form of dominate and pleasant stars are obtained by using circle. In other hand there is seen coordination and connection in different shapes such as triangle, square and regular inscribed pentagon in form of comprehensive combination on building include flat and round surfaces and also existence of discipline in form of systematic set of principles such as axis, symmetry, balance, rhythm, repetition and hierarchy of created lines and shapes is observed. As well as the geometric shapes used in building of this period architecture have concept of heaven. Base of these geometric shapes is on the circles that is the incarnation of perfection and led to appearance of regular polygons because there are divided equally so have logical criterion and are joining to perfection.

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