Fractal geometry as the synthesis of Hindu cosmology in Kandariya Mahadev temple, Khajuraho

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Abstract

The underlying relationship between Hindu cosmology and fractal theory is manifested in Hindu temple where fractal geometry acts as the language. This paper has analyzed the Kandariya Mahadev temple at Khajuraho as the paradigm of Hindu temples with regard to fractal geometry and describes the syntheses of fractal features of the temple from the Hindu cosmology and philosophy.

Keywords: Cosmic energy; Degree of details; Fractal dimension; Iteration; Self-similar repetitions; Vastu Purusha Mandala

1. Introduction

The properties of self-similar repetitions, abundance of textural details, and cascades of shape in architecture have been characterized by fractal geometry [1]. Coined by Mandelbrot in 1970s, fractal theory has been widely applied for the analysis and synthesis of architectural and urban designs [1–4, 17–20]. The term, ‘fractal,’ comes from the Latin word ‘Fractus’ which means ‘broken’ or ‘irregular’ or ‘unsmooth’.1

Mathematical property for the creation of fractal geometry has been known as iteration. Different rules of iteration create different fractal figures (Fig. 1). The property of endlessness in the process of iteration makes fractal figure as the microcosm of infinity. Due to its never-ending nature, fractal geometry cannot be possible to explain by Euclidian geometry, but be possible by computer-generated programs and computational techniques such as Shape Grammar [21]. In nature there are plenty of fractal-like objects which are not true fractal, but up to certain range of scales they display fractal properties [5].

Although employed in various fields for different roles,2 fractal geometry has been applied particularly, in architecture as a language which translates the beauty of complexity as well as the ideas of architects [6]. It also reflects the process of universe and its energy through the buildings [7]. Hindu temple is one of the best examples of those fractal buildings which were constructed in the past, far before than the birth of fractal theory and manifested the religious cosmic visions [8].

This paper mainly deals with the fractal geometry that performs the key role for transforming or manifesting the Hindu cosmology and philosophy into the divine diagrams (so-called vastu purusha mandala) and then to the structure. First, the Hindu cosmology and philosophy has been briefly reviewed. And then, the divine diagram of vastu purusha mandala and its application to the temple structure has been introduced. Second, Kandariya Mahadev Temple at Khajuraho has been briefly introduced for the further study. Third, a ‘box counting method’ has been introduced for the analysis of the temple with regard to fractal geometry. Lastly, Kandariya Mahadev temple has been analyzed with regard to fractal geometry through the application of Hindu cosmology and philosophy.

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1Mandelbrot and frame. Geometry of self-contacting binary fractal trees. The mathematical intelligencer, 1999. They defined fractal on the basis of binary fractal tree as the recursively by symmetric binary branching.

Fig. 1. Top: development of a fractal figure from a single circle by the iteration having some definite rule. Bottom: development of different fractal figure from the same circle but by the iteration having different rule.

2. A brief review of Hindu cosmology and philosophy

Hindus believe that the universe is created, destroyed, and re-created in an endless repetitive series of cycles where Brahma is the creator, Vishnu is the sustainer and Shiva is the destroyer, and all of them are the trinity of Parameswar, the Supreme Being who is the manifested form of the whole infinity. He is the principal creator of the universe. According to the myth, before each successive series of the creation of universe, a lotus is grown from the navel of Vishnu and then Brahma is born over it as the incarnation of the supreme God. Brahma starts creating the universe in a Brahma-day and destroys it in a Brahma-night and again creates the new universe next day. He repeats this process for 100 Brahma-years until his death. After his death, Brahma is born again and starts the new cycle of creation. A universe takes 4,320,000,000 years to be survived and same years to be destroyed. Hence, a universe is the result of time that follows the cosmic order in which a fraction of moment is the microcosm of biggest time unit.

Another myth says that mount meru is the axis of the cosmos. According to the Mahabharata, gods twisted the mount meru to find their most precious elixir, amrita, which was lost during the terrible flood in the cosmic ocean. During twisting, the ocean became churned and gods found their elixir, and at the same time the every being in the universe was produced.

According to Hindu philosophy, the main goal of man’s life is to achieve the ultimate liberation from the illusionary world where he suffers from his endless rebirth. Krishna says in Bhagavad Gita, if man worships, devotes and meditates to the manifested form of the wholeness of infinity, and sees the truth of its manifestation; he will surpass the confusion of the never-ending cycles of rebirth in this physical world, and finally will assimilate with the God. Hindu calls it moksha. It brings the ultimate peace and harmony in man’s life. But how one, from the physical world, can practice to realize this ultimate truth of the creation? Brihat samhita and Sthapatyaveda give the solution as the temple which should act as the microcosm of the cosmos. It should be the bridge for the man of physical world to the God of divine world.

To connect the physical world with the divine world and to reflect the truth of creation, the layout of cosmos was copied graphically in the foundation of temple. Here, a mythical incident was interwoven where a formless being covered the sky and was, immediately, arrested down to the earth by the creator Brahma and other gods. This supernatural fact was depicted graphically by vastu purusha mandala, where vastu refers to physical environment, purusha refers to energy, power or cosmic being, and mandala is the diagram or chart. Central portion of the mandala represents the place of Brahma and other portions symbolize the other gods according to their capability. By laying down this metaphysical diagram in the foundation, various supernatural forces are captured beneath the temple whereas its centre is the source of cosmic energies. The basic shape of the vastu purusha mandala is a square.
which represents the earth [11]. Its four sides depict the four cardinal directions. It also symbolizes the order, the completeness of endless life and the perfectness of life and death [10]. According to Hindu philosophy, our mundane life is controlled by the number four—four castes, four stages of life, four great epochs or mahayugas, four heads of Brahma, the four Vedas etc. [12].

There are various types of vastu purusha mandala, which are nothing but the squares grids, produced from the basic shape; namely, a square which is known as sakala mandala. Each smaller square within the grid is called one pada. The number of pada may vary from 1, 4, 9, 16, 25 and so on up to 1024, where it follows the geometric progression of 1, 2, 3, 4, 5, 8, 16, 32 of common ratio 2. The mandala having even numbers of pada in its grid known as yugma squares mandala whereas the mandala, having odd numbers of pada known as ayugma squares mandala. Vastu purusha mandala is also known as different distinctive names according to the numbers of pada within the grid. The mandala having 1,4,9,16,25 and 36 numbers of pada within the grid are known as sakala mandala, pechaka mandala, pitah mandala, mahapitah mandala, manduka chandita mandala and para-masayika mandala, respectively.\(^\text{14}\)

3. Kandariya Mahadev temple, Khajuraho, 1030 A.D.

Kandariya Mahadev temple at Khajuraho sets the benchmark of Hindu art in India. This temple was constructed in the middle of 11th century when Hindu temples had attained the highest point of matured design. During the period, all kinds of Hindu art including sculpture, music and dance, were intermingled in temple designs [22]. Kandariya Mahadev temple has height about 31 m. It is elevated above a lofty plinth which makes the temple structure sanctity and monumental. The structure is 30.5 m long and 20 m wide, faced to the east to welcome the first rays of sun. The whole structure consists of four major parts (Fig. 2):

1. Garbhagriha, i.e., sanctuary where the main deity has been kept.
2. Pradakshina path, i.e., circumambulatory path having three sides balcony bringing ventilation and light to the interior.
3. Mandapa, i.e., columned assembly hall having two sides balcony.
4. Artha mandapa, i.e., entrance porch.

Kandariya Mahadev temple stands out from other temples of the region due to its grand scale with elaborated building design as a whole and ornamentation. The well-controlled zigzag plan of the temple creates the vertical visual rhythm, accentuated in the elevation through its sharp recessions and projections, whereas the horizontal friezes on the elevation create the horizontal rhythmic growth upward (Fig. 3).

The most distinctive part of the temple is its lofty curved towers above the sanctuary. It is known as shikhara. Shikhara is crowned by an amalaka,\(^\text{15}\) a ribbed circular motif, and a pot finial, known as the kalasha, a sacred pot in which the most precious elixir amrita had been kept. Here in the shikhara, the amalgamation of the form of lotus blossom and that of mountain has been frozen into the form of multiple recursive archetypes. Replicas of the towers are the most distinctive character in the Kandariya Mahadev temple.

Like exterior, interior of the Kandariya Mahadev temple is elaborated with ornamentation. At exterior it has more than 646 numbers of figures whereas 226 numbers of figures were sculpted in interior. There is no boundary between interior and exterior in terms of ornamentation and detailing.

\(^\text{14}\)For more information regarding vastu purusha mandala, its history and application to the Indian traditional architecture in deep, see V. Chakrabarti. Indian Architectural theory and practice; contemporary uses of vastu vidya. Routledge Curzon, 1999.

\(^\text{15}\)Amalaka is a kind of fruit available in north part of India. According to Hindus amalaka is a sacred fruit. In most of the Hindu temples, amalaka was adopted as the finial on shikhara.

4. Fractal dimension and box counting method

In fractal geometry, fractal dimension is the quantity which measures the fractalness of an object. For any fractal object fractal dimension is always non-integer, i.e., unlike integer-dimensional objects (zero-dimensional point, one dimensional line, two dimensional square and three dimensional cube) fractal object is a fractional-dimensional which may be in between one dimensional and two dimensional object, or in between two dimensional and three dimensional object. For in between one-dimensional and two-dimensional fractal object fractal dimension ‘D’ is always more than 1 and less than 2 (i.e., 1 < D < 2), whereas for in between two- and three-dimensional fractal object the fractal dimension ‘D’ is always more than 2 and less than 3 (i.e., 2 < D < 3).

There are various methods to evaluate the fractal dimension, among which the ‘box counting method’ is suitable for measuring the fractal dimension of the elevation of buildings, mountains, trees or any objects which are not true fractal. Albeit, ‘self-similarity dimension method’ is very common for calculating the fractal dimension, but the method is only applicable for the true mathematical fractals where self-similar structures are found at all zooming scales.

Fractal dimension calculated by ‘box counting method’ measures the fractalness of an image on the basis of roughness or textureness or the amount of details. Images having fractal dimensions 1.1–1.5 indicate less roughness and details they have, whereas images having fractal dimension 1.6–1.9 but less than integer value 2, exhibit high textureness and abundance of details. Roughness of the images having fractal dimensions 1.21–1.25 or the dimensions 1.81–1.86 are visually not so much distinguishable by naked eyes. But naked eyes can easily distinguish the images having fractal dimensions 1.1, 1.2, 1.3,..., 1.8 and 1.9, separately.

To evaluate the fractal dimension of an image by ‘box counting method’, firstly a squares grid is overlaid on the image where the size of each grid box, let ‘S’, determines the scale of the grid. Then the boxes, having any mark or line of the image within the grid, are counted; let it is ‘N’. After repeating the same process on the same image by changing the box size, fractal dimension ‘D’ of that image can be obtained by transforming the results of ‘S’ and ‘N’ into the log–log graph. The slope of the resulting line of the log–log graph determines the fractal dimension of the image.

There are various software that can directly calculate the fractal dimension of an image by following the basic process of ‘box counting method’. In this paper, the software of ‘Box Counting Demonstration’ has been employed for counting the marked boxes. For the analyses, all parts of the temple have been taken as two-dimensional images by keeping the information about image sizes and their resolutions.

For example, by taking the box sizes or grid sizes 24, 12, 6 and 3 of a squares grid for a fractal image of 60 mm × 43.5 mm with resolution 80 pixels/cm, marked boxes are counted by the ‘Box-Counting Demonstration’ software (Fig. 4). Then by taking the log of grid sizes (S) on the X-axis and log of marked boxes (N) on the Y-axis following results have been obtained as shown in Table 1 (Graph 1).

Slope of the resulting line in log–log graph shows the fractal dimension of the image is 1.55. The resulted points lied on a smooth straight line in the graph indicate the uniformity of details of the image in different scales. Here fractal dimension 1.55 confirms that the level of details of the fractal image is medium.

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16 Other well known methods include ‘measured dimension method’ or ‘structured walk method’ which is only applicable for the overlapping curves, while the other methods (like box counting and self-similarity dimension methods) cannot include the part of overlapping curves. Self-similarity dimension is believed to be the standard fractal dimension of a pure fractal object and equivalent to Mandelbrot’s fractal dimension. But ‘box counting method’ measures the fractal dimension of those objects which are not true mathematical fractal. This method basically measures the rate of roughness or detail-ness of an image, but not an object itself. Accordingly, ‘box counting method’ is the suitable and preferable method to calculate the fractal dimension of the images of buildings, mountains, trees or any objects which are not true fractal. Box counting dimension is also equivalent to Mandelbrot’s fractal dimension. For more details, refer to Lorenz [13].

17 The software of ‘Box-Counting Demonstration’ was developed by Martin Nezadal, Institute of Physical and Applied Chemistry, Brno University of Technology, Brno, Czech Republic for determining the fractal dimension of an image through box counting method.
5. Analysis of Kandariya Mahadev temple

5.1. The foundation and floor plan

In the foundation of any Hindu temple, cosmos is embodied by laying down the diagram of vastu purusha mandala on a selected ground. This divine diagram reflects the image of cosmos through its fractal qualities. In the diagram, squares are repeated within a square and other squares within another square and so on. Each newly born square perhaps depicts the birth of new universe in which the centre of mandala is the source of creation of each square, i.e., each universe. Apart from this, as the fractal properties in vastu purusha mandala, each yugma mandala (even numbers of squares grid) is the result of fractal iteration of four-squares grid, i.e., pechaka mandala, whereas each ayugma mandala (odd numbers of squares grid) is the iteration of nine squares grid, i.e., pitah mandala. For example, pechaka mandala produces maha-pitah mandala (16 squares grid), and manduka chandita mandala (64 squares grid), and pitah mandala produces paramasayika mandala (81 squares grid) in an iterative way. ‘Fig. 5’ shows the fractal characteristics of different mandalas and their iterations from the sakala mandala.

At the same time by laying down the diagram of mandala in the foundation of temple, cosmic energies were grasped beneath the structure. The center of mandala is the source of all energies which are radiated outwards to the physical world. The square shape of mandala significantly implies to maintain the energy equilibrium. Arnheim [14], in his book, ‘Art and Visual Perception’, finely describes the hidden ‘field of forces’ within the square where each side of the square applies the force towards the center. Thus, the center of square applies equal force towards its each side (Fig. 6a).

Similarly, in the case of nine-square grid, each side of the nine-square grid applies the equal forces to the center which is itself a square and to make a balance, this central square also applies the equal and opposite force to each side of the grid. Accordingly, within the nine-square grid ‘field of forces’ becomes higher, because, as Arnheim described, within the grid each square itself has its own ‘field of forces’ (Fig. 6b). Thus, the increasing numbers of squares in a mandala help the diagram to arrest the (cosmic) energies more concretely where the ‘field of forces’ is increased in a fractal manner. These restored energies in the mandala radiate out to the physical world eternally from the center (Fig. 6c).

Although the mandala is primarily square, it may be turned into different shapes for applying to the foundation of temple. But the final shape must evolve out of the square, because of its essence in all Hindu architecture. As time goes the final shape of mandala was turning into complex through some transitional stages. In these stages, plans of some earlier temples evidence that the fact of radiating cosmic energy took the main role for amending the basic shape of mandala. Surprisingly, it is turned out in some special cases that the process of amendment is nothing but the fractal iteration of mandala.

To begin with, the evolutionary stages of temple plans are to be discussed. In the early ages, plans of Hindu temple were nothing but the direct copy of vastu purusha mandala. Parvati temple at Nachna, constructed in 6th century A.D., is one of those temples in which the grids of mandala and its overall shape was directly applied to foundations, especially to the foundation of sanctuary (Fig. 7a). After then this square and grid plan of the temple was modified by bumping up each side outwards to the four directions depicting the radiation of cosmic energies. This time, the shape of temple plan is the visual expression

Table 1

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<tr>
<th>Step</th>
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<th>Marked boxes (N)</th>
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<th>Log (N)</th>
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</tr>
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</table>

Graph 1. Fractal dimension 1.55.

of energy radiations whereas in the plan of Parvati temple it was only the symbolical expression. In the sixth century to the seventh century A.D. Hindu temples were usually constructed on this modified plan by following the same grids of mandala. Vishnu temple at Deogarh, constructed in the late sixth century, is the example of this type of temple (Fig. 7b).

As time goes, the shape of Hindu temple plan became more complex where each sides of the square of mandala bumps up twice. By repeating the same process, i.e., by iterating, each side of the square of mandala attains a fractal like pattern in which this time it expresses the directions of radiating cosmic energies more clearly. This pattern was employed on the plan of Surya temple at Modhera in the 11th century (Fig. 7c). In this temple the developed pattern was overlapped by the self-similar pattern towards the east direction at the same axis leading the entrance to the sanctuary and got the final outcome.

Lastly, during the 11th century, the plan of Hindu temple had attained its final shape as the result of third fractal iteration of mandala. This modified and matured plan was widely adopted in the North Indian temples; among those Kandaraiya Mahadev temple at Khajuraho is the most remarkable (Fig. 7d). Evolution of this temple plan is the process of fractal iteration. Here the iteration was lead by the cosmological events as well the symbolic geometries and sacred proportions. There are two hypotheses about the geometric operations of mandala to evolve the final plan of Kandariya Mahadev temple.

According to the first hypothesis, pitah mandala, i.e., nine-square grid is considered as the primary shape for the geometric operation to evolve the plan of Kandariya Mahadev temple. In this geometric operation one smaller square within the grid of mandala, i.e., one pada has been taken as one unit. The outward energies generated from the center of mandala have bumped up the middle of each side one unit along the four directions (Fig. 8a) as the first iteration. Then all the newly born outer corners have been filled with meandering elements which are developed from...
the quarter of one \textit{pada}. Each meandering element is the combination of a golden rectangle and a square born from the same rectangle. After filling the outer corners, it has got the fractal pattern which is overlapped with a self similar pattern, planned for the \textit{mandapa}, along the axis of entrance to the sanctuary. Lastly, by projecting the entrance part along the same axis, it has attained the final shape (Fig. 8b).

According to second hypothesis, the plan of Kandariya Mahadev temple is the result of third iteration of \textit{pitah mandala} (36-squares grid). Here the \textit{pitah mandala} is rest within the \textit{mandaka chandita mandala} (100-squares grid) on the same grids. The iteration of each side is guided by the gridlines and a circle which touches the corners of \textit{pitah mandala}. The circle depicts the endless cycles of times, the wholeness and the consciousness due to its never-ending shape\textsuperscript{18}. The sides of another square, placed diagonally by touching its corners to the outer edges of the \textit{manduka chandita mandala}, indicate the iteration points.

Each iteration starts from the intersection between a side of the diagonal square and the last iterated line, and stops at the intersection between grid line and the circle. Finally, the iteration stops at the corners of the diagonal square (Fig. 9). The elongations of the last iterated forms depict the four cardinal directions. On the temple structure, these last projected parts are open verandas, symbolizes the cardinal directions.

This fractal operation of the plan of Kandariya Mahadev temple makes it fractal in terms of roughness and irregular shape. Not only the outer plan but also the plan of central sanctuary is also the offset of outer plan, which makes whole the plan as fractal. For analyzing the roughness of the plan of Kandariya Mahadev temple, ‘Box-Counting Demonstration’ software has been employed on the image of plan by taking its size 50 mm \(\times\) 70 mm having resolution 80 pixels/cm and grid sizes 24, 12, 6 and 3 (Fig. 10). It gives the following results (Table 2 (Graph 2)).

From the slope, shown in Graph 2, it is obtained that it has fractal dimension 1.70 which depicts its high degree of roughness or details. The smooth curve as a straight line in the graph describes the uniformity of its roughness. This degree of roughness or details of plan has been accentuated in the structure to make the whole structure complex and textured.

5.2. Elevation

Hindu cosmology, manifested in the plan of Hindu temple two dimensionally, was also manifested in its elevation but three dimensionally and more symbolically. For the elevation too, \textit{sthapati}\textsuperscript{19} took the fractal as a medium to visualize the manifested form of cosmos and to make the pilgrims meditating for spiritual journey. To apply the fractal as a tool for constructing the temple, perhaps, \textit{sthapati} did not use any mathematical fractal theory or formulae, but he influenced by the nature where God himself create mountains, trees, leaves, etc. as the examples of fractal\textsuperscript{5}.

In the structure of almost all Hindu temples, \textit{sthapati} took the mountain as a model of fractal object where

\textsuperscript{18} According to Kumar, “the circle is logically the perfect metaphor for heaven since it is a perfect shape, without beginning or end, signifying timelessness and eternity, a characteristically divine attribute.” (see [12]).

\textsuperscript{19} In \textit{Brihatsamhita} and \textit{Sthapatyaveda}, architects of Hindu temples and residences were called as \textit{sthapati}. It’s a Sanskrit term comes from the ancient Hindu scriptures.
self-similar mounts are repeated and recurred, pointing towards the sky. They made the rising towers, *shikhara* on the temple structure by copying the form of mountain which dominates on the earth, and the replicas of soaring towers on *shikhara* depict the series of repetitive universes [15]. Even the literal meaning of *shikhara* is also mountain. Besides, mythical *mount meru* was also the aim to adopt the form of a mountain in the structure of Hindu temples to manifest the cosmic events. Especially in the case of Kandariya Mahadev temple, the mountain form of *shikhara* has further significance which depicts the *mount kailash* where (according to Hindu beliefs) the Lord *Shiva* dwells, because this temple was dedicated to the Lord *Shiva*. Though the appearance of *shikhara* in all Hindu

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**Table 2**

<table>
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**Graph 2.** Fractal dimension 1.70.
temples are mountainous, but they are unique from each other regarding the styles of repetition of towers, ornamentations on tower facades, tower slopes and their geometric structures.

In the case of Kandariya Mahadev temple, the main tower above the sanctuary is repeated at its four sides and the same process of repetition is continued in each newly born smaller tower, and again this process repeated in the last newly born smaller tower (Fig. 11a). At the same time smaller towers are repeated on the body of main tower in which the whole tower attains such an arrangement where one can easily feel the whole in a part within another part. Above the assembly hall, i.e., mandapa the main tower is repeated within its own body and at the same time its whole body is repeated along the axis of mandapa to the entrance. This arrangement of repetitive towers above the mandapa (assembly hall) and arthamandapa (entrance porch) is such that it makes to move up one’s eyes automatically to the main tower above sanctuary and from that travel up through the finial to the axis of cosmos (Fig. 11b). This highest point of the shikhara above sanctuary is believed as the ultimate point of liberation from the physical world.

The beauty of shikhara lies behind the proportions of the arrangement of replicas. In Hindu temples the repetitions of the towers are not arbitrarily, but follow some rules and proportions for the welfare of the society as well as the universe. Its proportions have deep significance; because if the temple is constructed according to the mathematical system properly, then it can function in harmony with the mathematical basis of the universe. Almost in every Hindu temple in North India, the rule of repetition of towers is almost the same. On the shikhara above the sanctuary of Kandariya Mahadev temple, the second larger tower is just half in size of the main central tower and the shorter towers are one-third and one-fourth in size of the main tower. Placing of the smaller towers on the elevation is such that the peaks of each smaller tower pointing towards the summit of main central tower, makes the impression of unity in infinity towards cosmic axis.

It turns out that the stratification of the towers above the sanctuary follows the golden sequence as the basic rule for arrangement. Let’s take the distance between two peaks of main tower and second tower as a side of a square (ABCD). Then, an arc is drawn whose center is located at M point and radius is MA (Fig. 12). The arc touches the peak of third tower and intersects the extension of a line DC at point G. Then, a square (EFGC) is drawn by taking a line CG as a side. Now the square (EFGC) is copied as FHIG whose side GI determines the distance between third peak and fourth peak. Again a second arc is drawn from a point O by taking the radius OF which touches the peak of fifth tower. It produces a new square (JKLI). Interestingly, the peaks of alternative towers, i.e., the peaks of first, third and fifth towers also obey the golden ratio, where the distance between peaks of first and third towers determines the square (XYGD) and that of third and fifth towers determines the square (UVLG).

Another significance of such arrangement of smaller towers on the shikhara of Kandariya Mahadev temple is the man’s perception for seeing the whole body of shikhara in its self-similar parts from any location of view (Fig. 13). This fractal property is also reflected from the degree of details in each part of shikhara.

One can experience the same level of details of the whole body of shikhara in its self-similar parts. To analyze the consistency of details or roughness of whole shikhara and that of its parts more concretely, "box counting method"
has been applied to the images of those parts for calculating their fractal dimensions. For the experiment, all three images are taken as the same size of 37 mm x 52 mm having the same resolution 80 pixel/cm. For the experiment ‘Box Counting Demonstration’ software has been employed for counting the marked boxes. By taking the grid sizes 24, 12, 6 and 3, marked boxes has been counted (Figs. 14–16). Then by applying the grid sizes and their respective numbers of counted boxes in a log–log graph the following results have been obtained (Tables 3–5 (Graphs 3–5)):

From resulted graphs of above three figures (Figs. 14–16), it is observed that the fractal dimensions of those three images are 1.84, 1.83 and 1.80, respectively which are high fractal value and almost the same. As discussed before, the level of details having these fractal dimensions are not distinguishable in naked eyes and shows the high level of details. Accordingly, it is concluded that the degree of details of the whole body of shikhara and its self-similar smaller parts are high and uniform. At the same time it is observed from the graphs that in each case all the points lies on a straight line, i.e., the resulted curve is a smooth straight line in the graph which shows that in each part of the shikhara degree of details is uniform. Therefore, it can be said that from any viewpoint there is a consistency of the richness of details in the whole body of shikhara.

Now the same experiment has been done with the front elevation by the same process. By employing the same computer software (Box Counting Demonstration) on the front elevation (Fig. 17) the following results are obtained shown in Table 6 (Graph 6).
From the slope it is obtained that it has fractal dimension 1.87 which is higher but near about similar to that of whole shikhara (above sanctuary) and its self similar parts within the shikhara (i.e., ‘a’, ‘b’ and ‘c’ in ‘Fig. 13’), and its resulted smooth straight line in the graph describes its uniformity of details. Thus it is observed that not only from the distinctive part, shikhara, but also from the whole elevation one can experience the consistent degree of details from anywhere outside.

Table 3

<table>
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<tr>
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Fig. 16. Box counting operation of the smaller part of shikhara ‘Fig. 13c’. Extreme left—Smaller part of shikhara, ‘Fig. 13c’; (a) grid size 24; (b) grid size 12; (c) grid size 6; and (d) grid size 3.

Graph 3. Fractal dimension 1.84.

Graph 4. Fractal dimension 1.83.

Graph 5. Fractal dimension 1.80.

These unique fractal characters on the whole body of shikhara above the sanctuary of Kandariya Mahadev temple are born by the process of iteration from a single central tower which is known as unipratiti. Shikhara of Adinatha temple (900 A.D.) as the unipratiti and the shikhara of Paraswanatha temple (950 A.D.) as the result of third iteration of unipratiti are the evidences for production of the shikhara of Kandariya Mahadev temple. In this process, self-similar smaller towers are generated along its four sides. Then again it produces smaller towers around its three sides outwards. It continues up to five steps and gets the final form of whole shikhara as multipratiti (Fig. 18). Motifs of shikhara are the lotus petals. Shikhara is also the image of lotus blossom which symbolizes the creation as it sprouts from Vishnu’s navel. It is the symbol of purity. The budding of multipratiti shikhara as the iteration follows the process of germination of lotus flower from its bud and at the same time this process is guided by the shape of foundation (Figs. 19 and 20).

5.3. Details

The abundance of details in the temple of Kandariya Mahadev not only makes the temple highly fractal in terms of roughness, but also displays the theme of godly beings who are the important characters in Hindu cosmology and philosophy. Numbers of figures displaying sexual gestures on the temple fabrics symbolizes the creation. In other words, the smallest details of the temple carry the concept of creation. Naked eyes go to the tiniest details up to some level, but the story or the images of the gods makes a passage of spiritual journey for the ‘third eye’ (power of imagination) to perceive further to the eternity. Though geometrically the details are not the exact repetitions of its parent body of the temple, but it repeats the same concept/theme of the body.

Tiniest figures give the impression of paramamu (atom), the smallest time unit, the consciousness which acts as the

Table 6

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Graph 6. Fractal dimension 1.87.

Fig. 17. Box counting operation of the front elevation. Extreme left—front elevation; (a) grid size 24; (b) grid size 12; (c) grid size 6; and (d) grid size 3.

Fig. 18. Elevations and plans of: (a) Shikhara of Adinatha temple (900 AD); (b) Shikhara of Paraswanatha temple (950 AD); and (c) Shikhara of Kandariya Mahadev temple (1050 AD).
microcosm of the largest time unit, cosmos. Like the exterior, the interior of Kandariya Mahadev temple is also full of figuristic and floral details in which figuristic details protects the sanctuary from demons and floral details depicts the cosmic events. On the ceiling of this temple, the floral pattern of panels is most noteworthy for depicting the cosmos where, again, fractal takes the main role for depiction. Here the combination of some ceiling panels makes the pattern such a way that it seems the flowers are blossomed from buds recursively. From each bud four petals are bloomed then from four petals eight petals are generated and again from this eight petal-flower a 12 petal bloom is born. Here the bloom depicts the creation of universe from the lotus bud sprouting from the navel of Vishnu. Each bloom from a single bud is stratified by making the level difference. These differences of levels and concentric floral patterns make a passage for the spiritual journey to the unit ness of infinity and thus help the man to practice for getting the ultimate liberation (Fig. 21).

analyze the consistency of degree of details in the whole structure, the ‘Box Counting Demonstration’ software has been employed. In this case, the image size of a part of ceiling details has been taken as $50 \text{mm} \times 50 \text{mm}$ with the resolution $80 \text{pixels/cm}$ (Fig. 22). By taking the grid sizes 16, 8, 4 and 2 the following results are obtained as shown in Table 7 (Graph 7).

From the slope it is obtained that it has fractal dimension 1.78 depicting high degree of details and its smooth curve as straight line depicts the uniformity of details in the panel.

Fractal pattern of the plan of Kandariya Mahadev temple, replicas of detailed towers, and rhythmic growth of horizontal friezes, create a harmony of fractal characters in the whole complex. High level of details in everywhere of the temple adds fractal flavor of roughness throughout the structure.

Fractal dimensions of the plan of Kandariya Mahadev temple, its elevation, parts of the elevation and smaller details are ranging from 1.7 to 1.8, which confirms the high fractal value of the whole temple complex from any view.
Whereas the smooth curve in the log–log graph for each part of the temple confirms the uniformity of details in the temple structure from any point of view by naked eyes.

To sum up, Hindu temple is not the abode of God but the form of God and since it was strictly suggested to be the microcosm of cosmos, all Hindu temples have the common basic characteristics along with some unique features. These unique features of Hindu temples, exhibited fractal properties and complex form, act as the signature of Hindu art and architecture. This paper has presented Kandariya Mahadev temple at Khajuraho as the icon of Hindu temples.

Modern architecture lacks fractalness and complexity, and carries the "simple and brute forms." But Jencks [24] believes that there has been a ‘paradigm shift’ in the contemporary architecture. According to him “fractals, wave forms and the structure of the cosmos will be resonated with the new buildings” which indicates the replication of Hindu temples but in a different way. In this paper Hindu temples evidence the deep relationship between the fractal geometry and the deepest truth, which is being rediscovered in the contemporary architecture. Thus, the ‘past’ present in the future and ‘future’ contained in the ‘past’ [16].

Although, in modern architecture some buildings such as Frank Lloyd Wright’s prairie houses and Antonio Gaudi’s buildings reflect the fractal characteristics with their gentle and organic complexity, but their key element of complexity were shaded by the trend of “simple and brute forms” of the modern architecture. However, temple architecture was not strongly influenced by the modern architecture and continues its strong and strict guidelines of design by reflecting traditional fractal properties. Perhaps, Lotus temple (1986) in Delhi for the Baha’i communities is an exception that sheds a new light of the possibility of using the fractal geometry wrapped by modern form, of course by achieving its religious, philosophical and functional requirements. After coining the term ‘fractal’ and setting up some mathematical formulas, now it has a great possibility to experiment about the refining of conventional temple-form or searching for new form of complexity related with Hindu cosmology with the consideration of ritual guides.

The decline of using the fractal geometry in modern architecture became soon eradicated by the strong affection towards the chaos and complexity in contemporary architecture. For searching the new, complex, fractal and chaotic forms in the contemporary architecture, on the one hand, manual experiments of architectural elements with the fractal geometry are extensively practiced. On the other hand, by adopting the theories of folds, fractals, chaos, complexity and algorithms, ‘computer architecture’ has been developed that translates the theories into the architecture [13]. Accordingly, the fractal geometry not only analyzes

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Graph 7. Fractal dimension 1.78.

For example, by using the drafting tools, fractal geometry has been applied manually for the plan of Zvi Hecker’s Galinski School of Berlin (1995). In the plan Zvi Hecker manifested sunflower by arranging the classrooms as the repetition of bent triangular petals of various scales with their spiraling ‘celestial construction’, reflecting the dynamic beauty of Tornado and spiral rhythm. Besides, Lab Architects’ Federation Square at Melbourne (2002) is another example where ‘computer architecture’ produced the elegancy and complexity of fractal on the facade by using the right-angled triangle as a single motif and the Pinwheel grid, thus enhancing the beauty of complexity in the architecture, and harmonizing the building with the complex pattern of city fabric.

the old buildings and the existed urban patterns and growth, but also helps to create a countless unimaginable forms and patterns for finding new possibilities of space as well as aesthetic in contemporary architecture.

Acknowledgment

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References