INFINITE SEQUENCES IN THE CONSTRUCTIVE GEOMETRY OF 10TH CENTURY HINDU TEMPLE SUPERSTRUCTURES

Dr. Sambit Datta
Senior Lecturer, Deakin University
sdatta@deakin.edu.au

Abstract

From its early origins to the 10th century, the Hindu temple embodied a progressive elaboration of a simple formal schema based on a cuboidal sanctum and a solid form of distinctive curvature. The architectural form of the temple was the subject of wide experimentation, based on canonical sacred texts, within the regional schools of temple building in the Indian subcontinent. This paper investigates the practice of this knowledge in the constructive geometry of temple superstructures, with attention focused on the canonical rules for deriving the planar profile of a temple using a *mandala* (proportional grid) and the curvature of the *sikhara* (superstructure) using a *rekha sutra* (curve measure). This paper develops a mathematical formulation of the superstructure form and a detailed three-dimensional reconstruction of a tenth century superstructure, based upon computational reconstructions of canonical descriptions. Through these reconstructions, the paper provides a more complete explanation of the architectural thinking underlying superstructure form and temple ornamentation.

Keywords: architectural geometry, hindu temples, mathematical sequences, digital reconstruction,

Author's Bio

Dr. Sambit Datta is a senior lecturer in the School of Architecture and Building at Deakin University, Australia. Dr. Datta's work centres on the mediatory role of geometry in the relationship between formal and abstract ideas and their material realisation in architecture. Using computer-aided design tools, he investigates the geometric ideas that shaped the genesis and evolution of Indian Temple Architecture. His current research on Asian heritage sites, supported by the Australian Research Council, unravels the formal architectonic links between temple building traditions along the trade routes between South and Southeast Asia. He teaches courses in architectural geometry, parametric modelling and design, has been a visiting scholar at the Centre for New Media, UC Berkeley, and is a director of the architecture practice, Shunya. Dr. Datta studied architecture at CEPT University (India), completed postgraduate studies at NUS, Singapore and received his doctorate at the University of Adelaide, Australia.

Construction and Canon in Temple Architecture

From its early origins to the 10th century, the Brahmanic/Hindu tradition of temple construction created a rich legacy of temples spread across India and Southeast Asia (Chandra, 1975; Chihara, 1996). During its slow dispersion, the architectural form of the temple reflected ongoing constructive and philosophical experimentation based on canonical sacred texts. In particular, the evolution of the Hindu *Cella* embodied a progressive elaboration of this prototypical schema, using a sacred constructive geometry that conveyed the syncretic Upanishadic cosmology [Chandra, 1975; Kramrisch, 1946) . The morphology of the Nâgara (latina) temple and its development can be followed from the earliest extant cellae in the fifth century to entire thirteenth century complexes and temple cities across South and Southeast Asia.

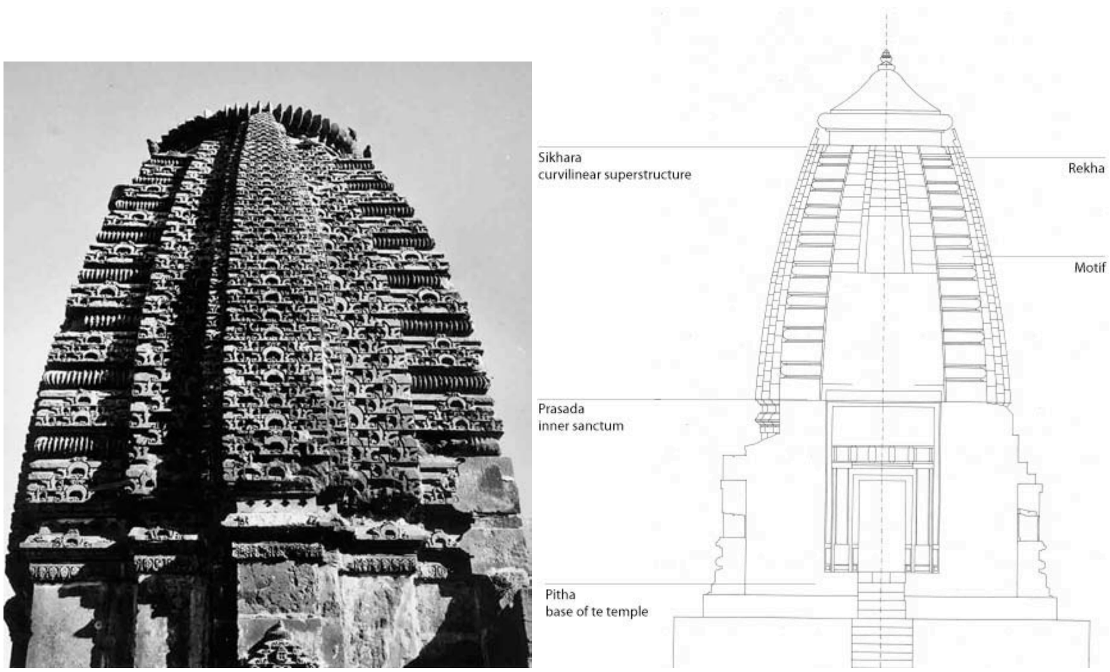

Figure 1. The basic formal scheme of a hindu temple. An example of a stone Latina temple (960 CE) from the Maha-Gurjara school of temple building, India. The superstructure exhibits a complex interplay of geometric and mathematical expression based on stereotomic principles of construction and surface articulation.

While there are thousands of variations, essentially every temple in the Brahmanic/Hindu tradition can be understood through principles outlined in canonic Sanskrit texts (*shastras*) such as *Mayamata* and *Agni Puranas* (Kramrisch,1946). These texts provide sets of prescriptive rules that touch on all aspects of temple construction, from site selection, formal typology and location of sculptural elements, to ornamental details. The architectural elements described by such shastras are based on a number of geometric figures known as *mandalas*, and it is from these ritual and cosmic diagrams that temple plans and superstructure have been generated (Meister, 1979).

Anga	Part of the body
Caturanga	The subdivision of the ground plan into four offsets (catur is Sanskrit for four)
Caturguna	The subdivision of the vertical measure into four parts.
Latina	A term used to decribe the curvilinear profiles of Nagara superstructures
Maha-Gurjara	A regional school of temple building from Western India.
Mulasutra	Sanskritic term translated as root measure or base module.
Nagara	Sanskritic term describing a regional variant of Indian temple architecture
Pitha	The first course of the tiered base of the temple
Prasada	The central body of the temple. The term refers to a palace.
Rekha	Refers to a curved line
Shastras	Ancient texts dealing with codified knowledge
Sikhara	The superstructure of a Nagara temple
Silpashastra	Texts dealing with knowledge of the arts
Sulbasutras	Specific texts dealing with the ritual and geometry of Vedic fire altar construction. Also used in the layout of temple plans
Upanishads	Philosophical texts that constitute the core principles of Hindu thought
Vastushastra	The body of knowledge (shastra) dealing with habitable sites and the spirit of place

Table 1. Explanation of Sanskritic terminology and technical terms used in the paper.

Studies of Indic temple geometry have demonstrated the correspondence of canonical descriptions of constructive geometry with the base plans of surviving monuments. However, as these temples were built in dynamic, ever-changing cultural, physical and sectarian contexts, the actual practice of this knowledge was the subject of wide experimentation over several centuries within regional schools of temple building (Meister, 1976; Meister, 1979; Hardy, 2002). Thus, while the shastras (canonical texts) may have been prescriptive, a multitude of interpretations and variations were possible within the canonical rules. Indeed, this ambiguous relationship between strict canon and subtle experimentation presents many challenges in relating the idealized geometry models to extant temples (Bafna, 2000).

To understand the mathematical principles underpinning temple architecture, it is necessary to rigorously examine the geometries at play in the formal foundation of Indian temple architecture, the early Nagara cella. The formal schema of the cella comprises (Figure 1) the base (*pitha*), an inner sanctum (*prasada*) and, later, a superstructure of distinctive form (in particular the curvilinear *sikhara* of the northern Indian Nâgara tradition). The morphology of the Indian temple and its progressive geometric complexity can thus be followed from the earliest extant cellae in the fifth century to entire thirteenth century complexes and temple cities across India and Southeast Asia (Meister, 1976; Datta, 1993). Textual and graphic descriptions of two- and three-dimensional propositions governing the conception, composition and construction of temples are offered in the literature.

The traditional study of Indian architecture is usually cast under the rubric of *vastushastra* or *silpashastra*. Vastushastra refers to the body of knowledge (shastra) dealing with habitable sites and the spirit of place. It is from this primary literature that ideas governing traditional architecture are drawn. Ancient writings on Vastushastra are spread through a diverse body of texts ranging from such philosophical texts as the *Upanishads*, to technical manuals encoding artisanal knowledge like the *Brhat Samhita*, *Mansara*, *Mayamatam* and *Vastusutra* Upanishad.

Varahamihira's *Brhatsamhita* (Bhatt, 1981), a sixth century treatise on astrology and astronomy, offers valuable evidence on the use of mandala geometry for the layout of buildings (Meister, 1976). The Mansara (Acharya, 1980) is commonly held to be the most comprehensive and representative text on ancient Indian architecture. Dagens' (1994) translation of Mayamatam and the Vastusutra Upanishad (Boner et al, 2000) provides summaries of this body of literature. Scholars have attributed the technical descriptions of constructive geometry to the various *sulbasutras* (Meister, 1979). While these ancient texts serve as a primary reference for temple scholars, secondary modern references (Kramrisch, 1946; Dhaky, 1961; Chandra, 1975) offer access to and interpretations of their ideas. Kramrisch (1946: 437-442) provides an accessible listing of traditional texts relevant to vastushastra. For a detailed examination of these and other texts, see Bafna's (2000) discussion on the sources of evidence for temple architecture.

The superstructures of latina temples have a distinctive curvilinear form composed of a series of motifs (Figure 1). The surface geometry of these shrines results from intricate mathematical and geometric expression based on stereotomic techniques (Kramrish, 1946; Meister, 1979). This paper investigates the practice of this knowledge in the constructive geometry of temple superstructures in the tenth century.

Comparative analysis of Geometry: Discussion

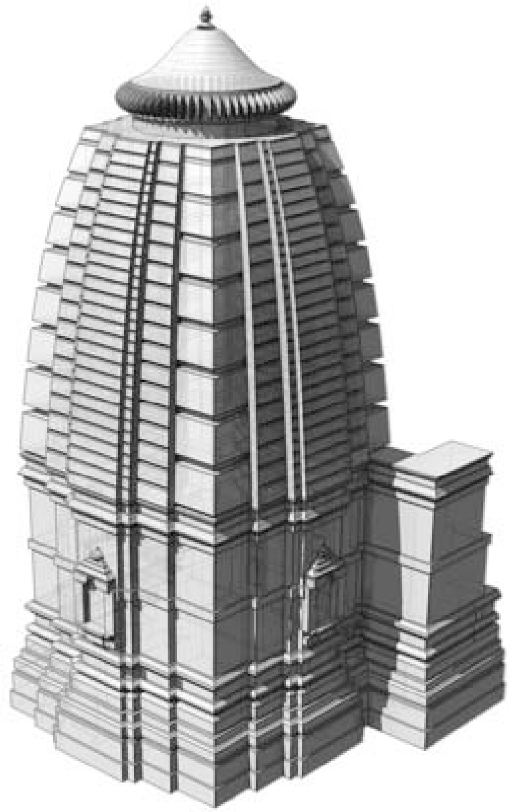

Figure 2. 3D reconstruction of the Temple of Ranakdevi, Wadhwan. The superstructure geometry is modelled using the geometric progression for scaling and curvature of individual units.

Computational modeling provides a robust methodology for researching the genesis and evolution of geometry in temple architecture. The fragmented discontinuity of textual accounts, lack of graphical representations and heavily eroded early remains make the process of establishing the lineage of formal continuity difficult. In this context, computation presents an attractive methodology for capturing, analyzing and comparing partial geometry models from textual and graphic descriptions and specific temple sites spread over time, geography and culture. For example, form models can be derived from data recovered from existing temples, two and three-dimensional idealized geometries can be reconstructed from textual canons (shastras) and these models can be analyzed and compared to yield new knowledge on the role of geometry in the genesis and evolution of temple architecture over time.

This paper describes the computation of three distinct geometries in understanding the construction and conception of temple superstructure, as represented by the three dimensional reconstruction in Figure 2. First, a generic skeletal model of the superstructure using rule-based computation is generated (Figure 4). Second, detailed models of individual motif geometry from temples are recovered using close range photogrammetry, and a tiling procedure based on the sum of infinite sequences is described (Figure 5). Finally, the superstructure geometry is developed by combining the first and second computations to generate a three-dimensional solid model of the surface geometry (Figure 6).

The reconstructions present new possibilities for interpreting the formal and geometric basis of temple form, demonstrating how the computability of a global geometry can form the basis for comparative analyses of a multitude of temple superstructures that are derived from the same constructive canon. Further, the parametric variation of generated global models allows for a rapid evaluation of the geometric similarities and differences between multitudes of samples. The advantage of this process is that changes in any stage due to revision of assumptions or testing of alternatives can be easily propagated between the models. Further, since the models of the surface geometry are based on generic constructions, they can be easily transferred to other, similar forms such as related but different schools of temple building can be easily incorporated in any stage, whether due to revision of assumptions or the testing of alternatives. In placing a specific temple between its possible antecedents, the use of constructive geometry as a generator allows the study of the evolution of temple architecture form over time as a series of related instances of arising out of similar techniques. The application of this method to comparing the base and superstructure (Datta and Beynon, 2008).

Superstructure Geometry

Archetypal forms of superstructure can be computed from generic descriptions of geometric construction using rule-based generation. Textual and graphic descriptions of mathematical and geometric constructions described in the literature (Dhaky, 1961; Meister, 1979) are codified in the form of shape rules and constructive methods to generate classes of formal three-dimensional geometry corresponding to the two-dimensional canonical descriptions. The three-dimensional form of the superstructure is based on encoding two control profiles: the horizontal plan profile and a vertical curved profile (Figure 3). The derivations of the curved profile (rekhasutra) is based on Kramrisch’s (1946) interpretation of the canonical procedures for laying out curves.

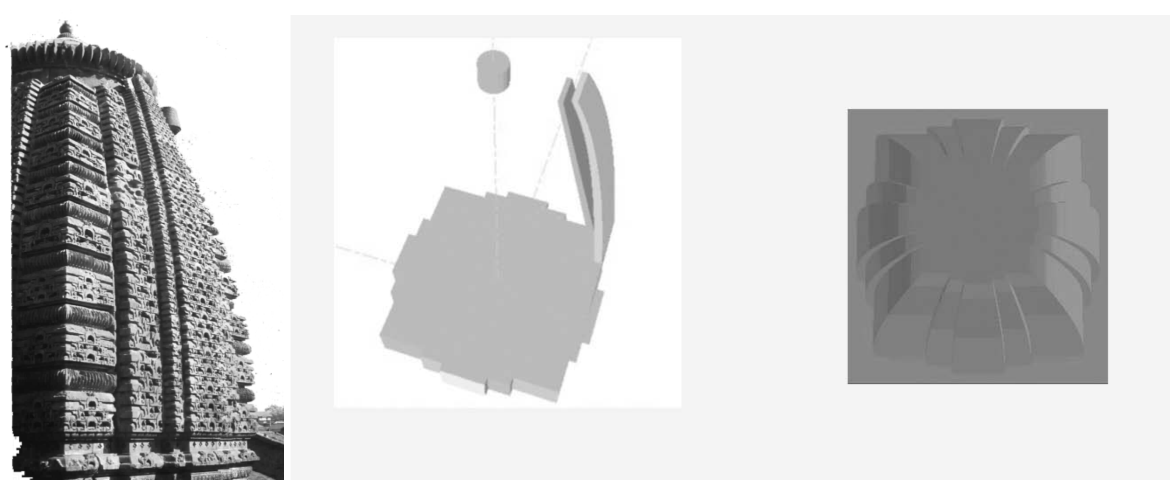

Figure 3. Left: Surface geometry of the temple of Ranakdevi at Wadhwan with three offsets (four faces) showing the curvature. Middle: A generated example showing a base with three offsets, central axis and geometric envelopes of the central spine (offset). Right: Top view of a generated example showing the global model of the surface geometry.

Horizontal and vertical control geometries of the surface are derived from textual (canonical) accounts in the temple literature. The horizontal profiles are computed using a set of shape rules derived from the literature on temple geometry (Meister, 1976; Meister, 1979; Meister, 1986). The vertical profile is based on descriptions (Kramrisch, 1946; Dhaky, 1961) provided in scholarly texts (explained in detail in the next section on curvature). The generation of geometric form with this technique allows a large class of profiles, and by extension superstructure forms to be explored.

The global model is then subdivided into four component motifs, corresponding to the four faces (Figure 4). Each component motif is developed in detail using close-range architectural photogrammetry (Streilein et al, 1998; Debevec et al, 1996). Finally, the global surface is tiled with the detailed component motif models. The reconstruction approach developed by the author (Datta, 2001) comprises the following steps:

- a global model of the superstructure using rule-based generation;
- local models of motif geometry;
- parametric tiling model combining the above.

The computation of each of the above is described in the following sections using the surface geometry of the temple of Ranakdevi in Wadhwan (Figure 1) as an exemplar.

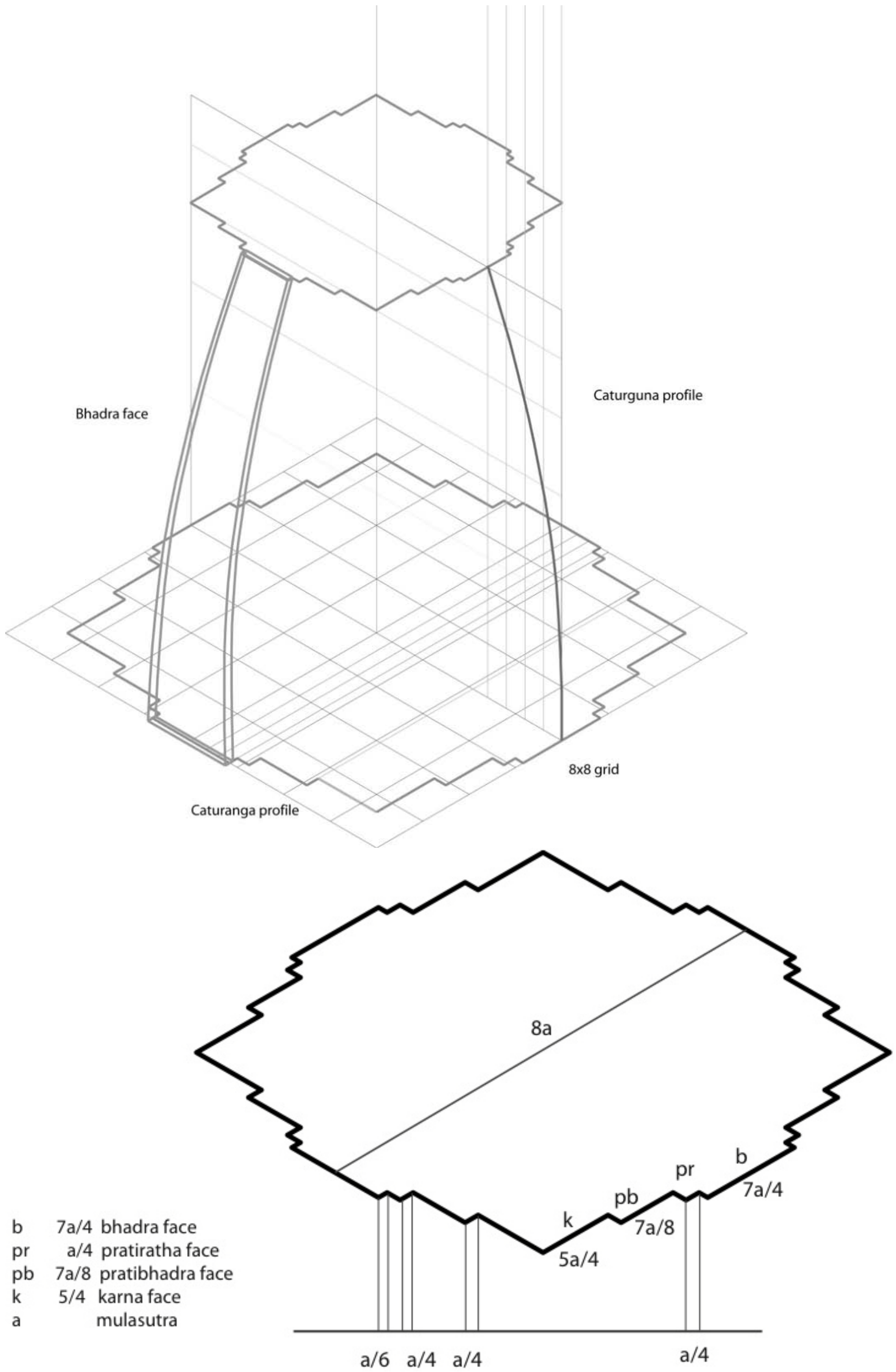

Figure 4. The superstructure geometry is controlled by two horizontal closed profiles in plan and an open curved profile in section. The horizontal profile (caturanga) is offset into four faces based on a proportionate subdivision of the ritual 8x8 grid (bottom). The rules for computing these profiles are described in the literature (Meister, 1979; Datta, 2001). The curve measure (caturguna) is derived by joining points of intersection in the vertical grid in the XZ-plane (top). The rekha (curve measure) is shown on the bhadra face of the superstructure. The top profile (skandha) is divided into 6 part parts and the bottom profile (caturguna) is 10 parts of the mulasutra (root measure).

The Ground Plan

Embedded in the plan of most temples is a ritual grid diagram of 8 x 8 = 64 squares (mandala), prescribed for temple building in the Brhat Samhita (Bhatt, 1981) and later texts (Meister, 1976). This grid is used to generate the ground plan and control measure in the configuration of stone temples. For example, Meister (Meister, 1979) shows how the horizontal profile depends on the number of offsets (angas) and the proportional relationships between each offset are derived from the recursive subdivision of the sixty-four square grid. Based upon field measurements, the basic module (mulasutra) of the ritual grid is a=660mm. The horizontal profile has three offsets (four faces, caturanga) and these are sub-measures of the basic module – a, a/4, a/4 and a/6, respectively. The width of the offsets in terms of the basic module (mulasutra) are 5a/4, 7a/8, a/4 and 7a/4 respectively. Using these measurements, the plan profile of the temple may be computed (Figure 4).

Description of Curvature

The vertical profile is based on the extrusion of the profile of the ground plan in the vertical direction (Datta, 1993). The extrusion in the vertical direction is based on a curved profile (rekha), which establishes the degree of curvature of the superstructure and controls the overall geometry of the superstructure (Figure 3). Following Kramrisch (1946) and Dhaky (1961), Datta (1993) has developed a mathematical procedure to generate the curvature based on textual descriptions. This procedure is dependent on the height of the superstructure, the number of vertical units chosen for each offset and the choice of an integer (one of 3,4,5,7) for controlling the degree of curvature. In the example reconstruction used in this paper, the integer chosen is 4 (caturguna, or four-fold division). A detailed description of the derivation of curvature is provided by Datta (1993).

In actuality, each offset has a different number of units, and hence a different rhythm. For simplicity, we treat the entire superstructure as a single unit (Figure 4). Following Kramrisch (1946), the rules for deriving the rekha are summarised as follows:

If the base profile (ritual grid) is divided into ten parts, then the width of the top of the superstructure or skandha, is six parts, the height being given (multiple of mulasutra). This establishes the extent of the bottom and top profiles (Figure 4).
If the integer chosen for the curve is 4 (caturguna), the height is H, and then the successive vertical divisions are: H/4, 1/4 (H - H/4), 1/4(H - 3H/4), up to n terms, where n is the number of units [11-13].
As described above and shown in Figure 3, the global geometry of the superstructure can thus be characterized by the following:

- generating a horizontal base profile in the XY-plane based on rules for dimensioning the 8x8 grid and its proportionate subdivision into offsets;
- generating a vertical curved profile based on rules for dimensioning a vertical grid in the XZ-plane and its proportionate subdivision into stone units.

This method of reconstruction is significant because of the state of decay of existing artifacts. As the profile creation process is computed from parametric rules based on canonical description, a large class of profiles, and by extension, superstructure geometry, can be explored. The advantage of this rule-based generation of profiles based on parameterized rules is that the same set of rules can be used to generate "best-fit" constructive models that correspond to field measurements and observations of surviving monuments. The rule based model generation process allows temple scholars to conjecture on the range of possible measures that may have been used to derive the ground plan and superstructure geometry of related monuments.

Infinite sequences: A mathematical formulation

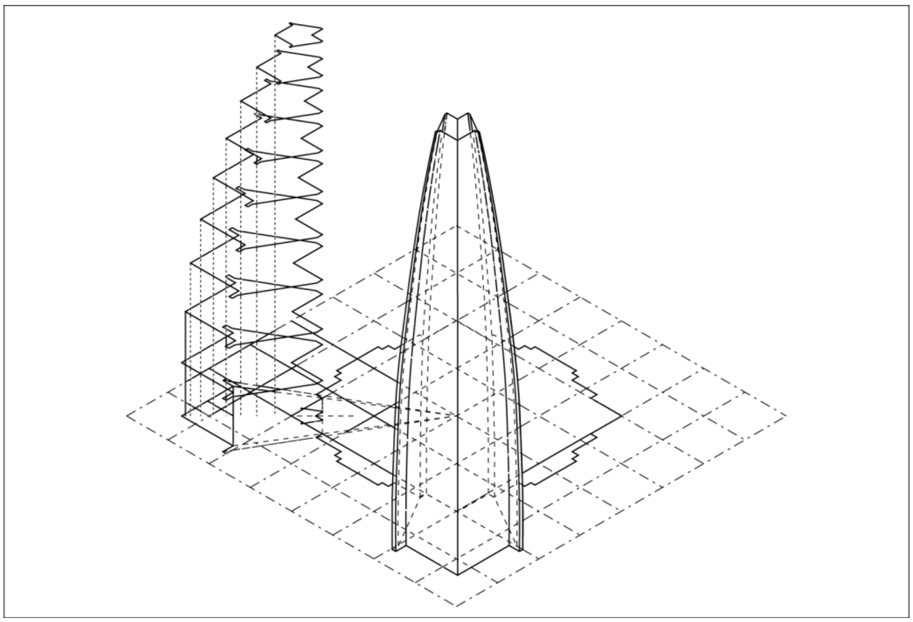

Figure 5. Analysis: The corner geometry of the superstructure is subdivided into constituent units based on a series progression. A tiling function is used to scale each constituent unit in the series with self-similar motif geometry.

Having established a computational method for the ground plan geometry and basic superstructure form, the detailed modeling of each of the facets and their geometry is described in his section. As discussed, the caturguna profile defines the generation of the lata portion of the sikhara while the critical profile in establishing the degree of curvature of the latas of a sikhara is the rekhasutra or curve measure(Figure 4). However, each lata (see temple surface in Figure 1) is made up of a sequence of scaled motifs.

The surface of the superstructure is composed of a series of carved motifs that exhibit a progressively diminishing sequence of self-similar forms. While no guide exists in the canonical literature on how these sequences are handled, two clues are available in the mathematical and cosmological texts. First, the notion of shunyata (nothingness) and the infinitesimally small occupies a central place in the syncretic Upanishadic cosmology. Second, the preoccupation with and knowledge of shredhishektras (mathematical series) are evident in vedic mathematical texts.

A method for generating the latas based on the description of the derivation of the rekha (Kramrisch, 1946; Datta, 1994) is developed in this section. The bounding (skeletal) geometry of the corner offset (karna) is tiled with scaled copies of the unit of carving. The parametric surface is developed using the global model as a skeletal surface tiled with a sequence of scaled units using the local geometry of the motif (Figure 5). This forms the basis for the repetitive tiling of the surface using a scaling function based on the curve profile shown in Figure 4. The tiling procedure is dependent on the height of the sikhara and the number of vertical units chosen for each lata. In practice, each lata would have a different number of units, and hence a different rhythm. For simplicity, in this paper, we treat the entire superstructure as a monolithic unit.

We can formalise this subdivision process as follows:

$$(\alpha^0 = H), \alpha^{(n+1)th} = \frac{1}{R} \cdot \{\alpha^{nth} - \alpha^{(n-1)th}\}, R \in \{3, 4, 5, 7\} \qquad \textit{Eq 1}$$

Where R is the curve measure, H is the height of the superstructure.

Although the problem of deriving the curvature may be solved by geometric construction, and certainly was solved in this way by the ancients, a more intriguing formulation is possible. To find out how the cella superstructure may represent a finite encoding of the infinite, we cast the height of the sikhara and the properties of the rekhasutra as a geometric sequence using the remainder subdivision algorithm (Eq 1). Further, we can define the problem as one of determining the height of the mth unit in a given progression of n terms using the height of the superstructure as the finite sum of an infinite geometric sequence. In the following sections, we convert the constructive steps into a summation series of an infinite sequence of terms.

The first term of the progression is H/4, and the common ratio, r = 3/4. From the common ration of the series represented in Eq 2, we can generalize the derivation of a common ratio r, for a given R.

$$\frac{H}{4}, \frac{3}{4} \cdot \frac{H}{4}, \left(\frac{3}{4}\right)^2 \cdot \frac{H}{4}, \left(\frac{3}{4}\right)^3 \cdot \frac{H}{4}, \ldots, \left(\frac{3}{4}\right)^{n-1} \cdot \frac{H}{4} \qquad \textit{Eq 2}$$

To rationalise the subdivision of the sikhara height H, we use the common ratio r, which is independent of the height (Eq 3), and express the height H of the sikhara as the sum of n terms of a geometric progression.

$$r = \frac{R-1}{R}, R \in \{3, 4, 5, 7\} \qquad \textit{Eq 3}$$

The sum of n units of a geometric progression, H being the height of the sikhara, a being the first term and r the common ratio, can be rewritten as,

$$\alpha + \alpha \cdot r + \alpha \cdot r^2 + \ldots + \alpha \cdot r^{n-1} = H \qquad \textit{Eq 4}$$

Rewriting (Eq 5), we can derive the first unit, if the number of terms, n and the common ration r are known.

$$\alpha \cdot \frac{(1 - r^n)}{1 - r} = H \qquad \textit{Eq 5}$$

Finally, the height of the lata unit m can now be derived as the mth term of a geometric progression whose first term is a (Eq 6) and common ratio is r (Eq 3),

$$\alpha = H \cdot \frac{(1-r)}{1-r^n} \qquad Eq\ 6$$

Using (Eq 7), we can determine the height of any unit given the rekha, number of units in a lata sequence and the height of the sikhara, all of which are specified in the canon.

$$l^{mth} = \alpha \times r^{m-1} = H \cdot \frac{(1-r)}{1-r^n} \cdot r^{m-1} \qquad Eq\ 7$$

As described previously, the rekha, R is chosen from the set {3,4,5,7} and the common ratio of the progression r fixed from (Eq 3). The next step is to determine the number of units, n. Finally, (Eq 7) is used to assign the heights of each unit of the sequence. While the vertical height of each unit is fixed, the top of each unit is scaled by a uniform scale factor that is derived from the rekha construction. The mathematical generation of a caturguna sikhara, on a caturanga base is shown (Figure 6).

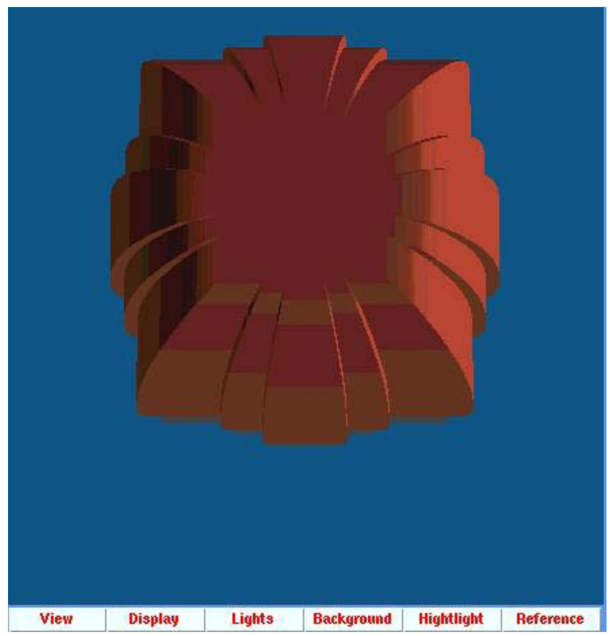

Figure 6. A caturguna-caturanga superstructure generated to an arbitrarily large set of terms shows how the infinite sequence converges toward a limit.

The tiling function is based on the sequential subdivision of the curved surface. The tiling geometry of the corner offset of the superstructure in this temple comprises 8 units. The first (lowest) unit, the last unit and the remaining 6 units follow in a series progression. The tiling corner spine is computed by recursive subdivision of the global geometry using this series formulation of the scaled motifs. The bounding box of each unit is computed from a set of parameters that control the global model such as the initial starting unit, number of units, scale factor and type of progression. These are then tiled within the enclosing geometry of the corner spine (Figure 4). This process rationalizes the degree of curvature derived from the rule-based curve generation into planar facets that approximate the curvature. Thus the explicit derivation of the curvature of the form as shown in Figure 4 is now replaced by a family of polygonal tiles related by a function of the underlying series mathematics. Using this mathematical formulation, it is now possible to derive the motif geometry directly from this model by a simple substitution rule that maps the bounding box of each unit to the specific geometric size of the tile shown in Figure 5. The resultant model gives the final superstructure geometry where each tile in the series is a self-similar scaled version of the motif model geometry (Figure 2).

Conclusion

This research attempts to ‘read’ geometries embedded in temple remains through computational geometry, an approach that may be contrasted with Robin Evans’ theories on geometry in architectural making (Evans, 1995). In his work, Evans uses a series of translations to track the development of architectural form through projective geometry. The building-as-object is cast, through a series of drawings, to the finished product – a projection informed by how architecture develops through the translation of drawing into building, representation into actuality. The particular challenge of my research is the opposite, the translation of building through the geometric and proportional clues present in its surviving form back to its description.

As Affleck and Kvan (2005) observe, the majority of virtual heritage projects attempt to create in the computer a realistic representation of their subject. This is an attempt not so much to recreate a temple form, but to uncover how its architecture was developed. By comparing its formal properties with models from which it may have been derived, advances in computation provide new ways to explore, analyze and explain the genesis and evolution of these historical artifacts. For example, in the temple superstructure example described here, the use of the ritual grid – well known in the layout of temple plans – was projected into the vertical plane to decipher the compositional structure of the superstructure, including the derivation of the curve measure. The use of series mathematics, well known from temple literature (Datta, 2001; Datta, 2005) was used to develop the tiling models. The complexities of the surface geometry could be explored and repetitive models obtained through generation and parameterization. The example demonstrates the above principles in the context of one type of tenth century superstructure, one that follows the profile of the offset in plan, and a curve in section. Thus, computation of spatial information plays a fundamental role in plotting any links between extant architectural remains and the principles of geometrical and architectural composition as presented in the texts. Representation of the building through the series of computed points is not only a device for aiding visualization but a deep description of its underlying geometry, a reverse analogue to the traits that Evans describes as the “instructional device” for the complex cutting of French renaissance stonework. Through a comparison of the relationships between cosmology, geometry and physical form using computational methods, in these early sites with both Indian and Southeast Asian models, it is intended that the generative role of geometry within the architectural historiography of Brahminic temples can be clarified and more fully developed.

In brief, the computational approach described in this paper results in the creation of multiple partial three-dimensional models of superstructure geometry. It is envisaged that these models will be useful for supporting the comparative analysis of superstructure geometry of temples from related temple building traditions (e.g. within South and Southeast Asia);
piecing together the genesis and evolution (over time) of the geometric experimentation within specific schools of temple building (e.g. Maha-Gurjara, Chandela, etc.); and
explaining the complex and problematic linkages between canonical prescriptions of ideal form with the analysis of data recovered from surviving monuments.

There is a broader question raised by this inquiry. Considering the philosophical and mathematical concepts revealed by this method of reconstruction, were ancient Hindu temple builders grappling with a method for encoding a notion of infinity through their use of geometric sequences?

Bibliography

1. Chandra, P. ed, Studies in Indian Temple Architecture, American Institute of Indian Studies, Varanasi, 1975.

2. Daigoro Chihara, Hindu Buddhist Architecture in Southeast Asia, E.J. Brill, Leiden, 1996.

3. Kramrisch, S., The Hindu Temple, Vols 1 & 2. University of Calcutta, Calcutta, 1946.

4. Meister, M. W., “Construction and conception of mandapika shrines of central India.” East and West, New Series, 1976, 26, 409-418.

5. Meister, M., “Mandala and practice in Nagara architecture in northern India,” Journal of American Oriental Society, 1979, 99(2), 204–219.

6. Hardy, A., “Sekhari Temples,” Artibus Asiae, 2002, 62 (1), 81-138.

7. Bafna, S., “On the idea of the Mandala as a governing device,” Journal of the Society of Architectural Historians, 2000, 59(1), 26-49.

8. Meister, M., “On the development of a morphology for a symbolic architecture: India,” Anthropology and Aesthetics, 1986, 12, 33-50.

9. Michell, G., The Hindu Temple: An Introduction to its Meaning and Forms, London, 1977.

10. Dhaky, M., “The chronology of the Solanki temples of Gujarat,” Journal of Madhya Pradesh Itihasa Parishad, 1961, 3, 1-83.

11. Datta, S., Geometric Delineation in the Nâgara Cella: Study of the temple of Ranakdevi at Wadhwan, Thesis, School of Architecture, CEPT. Vastu Shilpa Foundation, Ahmedabad, 1993.

12. Datta, S., Modelling Sikhara form in the Maha-gurjara idiom, Michael Ventris Research Report, Institute of Classical Studies, Cambridge and Architectural Association (AA) London, 1994.

13. Datta, S., “Infinite Sequences and the Form of Cella Superstructures,” in The Proceedings of the Third International Conference on Mathematics and Design, Deakin University, Geelong, 2001, 106–112.

14. Streilein, A., Niederöst, M., “Reconstruction of the Disentis monastery from high resolution still video imagery with object oriented measurement routines.” International Archives of Photogrammetry and Remote Sensing, Vol. XXII, Part 5, 1998, 271–277.

15. Debevec, P., C. Taylor, and J. Malik:, “Modeling and rendering architecture from photographs: A hybrid geometry and image-based approach,” in Proceedings of SIGGRAPH 1996, 1996,11–20.

16. Datta, S., “On Recovering the Surface Geometry of Temple Superstructures,” in Bhatt, A., ed., Proceedings of the 10th International Conference on Computer Aided Architectural Design Research in Asia, TVB School of Habitat Studies, New Delhi, Volume 2, 2005, 253-258.

17. Evans, R., The Projective Cast: Architecture and Its Three Geometries, Cambridge, Mass.: MIT Press, 1995.

18. Affleck, J. and Kvan, T., “Reinterpreting Virtual Heritage,” in Bhatt, A., ed., Proceedings of the Tenth Conference on Computer-Aided Architectural Design Research in Asia, TVB School of Habitat Studies, New Delhi, Volume 1, 2005, 69-178.

19. Datta S. and Beynon, D. (2008) Compositional Connections: Temple Form in Early Southeast Asia, *History in Practice, Society of Architectural Historians Australia New Zealand,* Geelong, Australia [DVD Publication]

20. Bhatt, R. (1981). *Brhat Samhita of Varahamihira* (Vol. 1 & 2). New Delhi: Motilal Banarsidass.

21. Acharya, P. (1980). *The architecture of the Mansara* (Vol. 2). New Delhi: Manohar Publishers.

22. Dagens, B. (1995). *Mayamata: An Indian treatise on Housing Architecture and Iconography*. New Delhi: Sitaram Bhartia Institute of Science and Research.

23. Boner, A., Ram Sarma, Sadasiva, & Baumer, B. (2000). *Vastusutra Upanisad:the Essence Of Form In Sacred Art(skt. Text, Eng. Tr. & Notes),* . New Delhi: Motilal Barnasidass.