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Topological and Fractal Modelling of Nagara Temple Architecture: A Comparative Mathematical Study of Kandariya Mahadeva and Konark Sun Temples

Dr. Pratiksha Kadam

Statistics, K. C. College, HSNC University, Mumbai, Maharashtra, India

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ABSTRACT

North Indian Nagara temple architecture exhibits remarkable geometric sophistication through recursive tower clustering, curvilinear verticality, radial organization, axial alignment, cyclic ordering, and hierarchical spatial planning. While these temples have been extensively studied from historical, archaeological, iconographic, and cultural perspectives, their mathematical interpretation using topology, graph theory, and fractal geometry remains comparatively underexplored.

This study proposes a reproducible mathematical framework for analysing selected architectural features of Nagara temple architecture using graph-theoretic abstraction, normalized connectivity measures, fractal-inspired modelling, symmetry analysis, and spatial topology. Architectural variables including shikhara clustering, spatial connectivity, and radial organization were identified from published architectural documentation and encoded into measurable parameters. The framework is applied to two representative North Indian temples: Kandariya Mahadeva Temple, Khajuraho, and Konark Sun Temple, Odisha. Kandariya Mahadeva Temple is analysed as an example of recursive vertical clustering, whereas Konark Sun Temple is examined for its radial geometry, cyclic ordering, and astronomical orientation.

A composite parameter termed the Nagara Temple Geometric Index (NTGI) is introduced to integrate recursive geometry, spatial topology, and radial symmetry within a normalized comparative framework. The resulting values are intended as comparative mathematical indicators derived from defined architectural features rather than measures of cultural, artistic, or spiritual significance.

The proposed framework contributes to interdisciplinary research linking mathematics, architecture, computational heritage studies, and Indian Knowledge Systems. A validation pathway based on architectural plans, photogrammetry, GIS analysis, image processing, and computational feature extraction is also outlined to support future refinement and empirical verification of the model.

Keywords: Nagara Temple Architecture; Fractal Geometry; Graph Theory; Topology; Sacred Geometry; Radial Symmetry; Computational Heritage; Indian Knowledge Systems.

INTRODUCTION

North Indian temple architecture, commonly known as the Nagara style, represents one of the most mathematically expressive architectural traditions in India. Nagara temples are distinguished by vertically rising curvilinear shikharas, clustered tower forms, axial organization, geometric ordering, and hierarchical spatial progression. The visual and spatial organization of these temples suggests strong structural order, recursive proportion, and systematic geometric planning.

While Nagara temples have been widely studied from historical, archaeological, iconographic, religious, and cultural perspectives, relatively fewer studies have examined their architectural structure using modern mathematical frameworks such as fractal geometry, topology, graph theory, radial symmetry, and spatial network modelling.

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The present study focuses on two major North Indian temple systems:

1. Kandariya Mahadeva Temple, Khajuraho

2. Konark Sun Temple, Odisha

These temples were selected because they represent two complementary mathematical tendencies within Nagara architecture. Kandariya Mahadeva Temple demonstrates recursive vertical geometric clustering through grouped shikharas, whereas Konark Sun Temple demonstrates radial geometry, cyclic organization, wheel-based spatial ordering, and axial orientation.

The purpose of this study is not to suggest that the builders of Nagara temples explicitly employed modern concepts such as graph theory, topology, or fractal geometry. Instead, these mathematical frameworks are used as analytical tools for examining observable architectural characteristics including spatial connectivity, recursive tower arrangements, radial organization, and geometric hierarchy. The selected features are translated into measurable variables derived from documented architectural descriptions and plan-based interpretations, allowing comparative mathematical analysis while remaining distinct from symbolic or religious interpretations. Where possible, the selected architectural characteristics are represented through explicitly defined variables that can be normalized and compared across temple systems.

The study focuses on two representative temple systems—Kandariya Mahadeva Temple and Konark Sun Temple—which exhibit contrasting yet complementary geometric characteristics. Kandariya Mahadeva Temple is examined primarily through recursive shikhara clustering and vertical hierarchy, whereas Konark Sun Temple is analysed through radial wheel geometry, cyclic ordering, and spatial symmetry.

To facilitate systematic comparison, a composite measure termed the Nagara Temple Geometric Index (NTGI) is proposed. The index integrates normalized measures of recursive geometry, topological connectivity, and radial symmetry into a unified mathematical framework. Although the present work is exploratory in nature, the framework is structured to support future empirical validation through architectural plans, photogrammetric reconstruction, GIS-based measurements, and computational feature extraction.

LITERATURE REVIEW

The methodological emphasis of the study is on the definition, normalization, and comparison of architectural variables rather than on aesthetic evaluation. Each mathematical parameter introduced in the subsequent sections is associated with a clearly defined architectural feature and may be refined further as more detailed measurement data become available.

Mathematical Interpretation of Indian Temple Architecture

Indian temple architecture has historically been studied through religious symbolism, iconography, sculpture, ritual systems, and dynastic development. However, the geometric and mathematical dimensions embedded within temple architecture have also attracted scholarly attention. Traditional Indian architectural treatises such as the Shilpa Shastras and Vastu Shastras emphasize proportion, orientation, symmetry, axiality, and sacred measurement systems.

Kramrisch interpreted temple architecture as a symbolic representation of the cosmic mountain and sacred spatial order [1]. Hardy discussed structural transformation and geometric organization within Indian temple forms [2]. Michell examined temple planning and symbolic architectural hierarchy [3]. Nevertheless, comparatively fewer studies examine temple structures using modern mathematical frameworks such as graph theory, fractal geometry, topology, and computational modelling.

Consequently, there remains significant scope for developing quantitative approaches that complement traditional historical and architectural interpretations while providing measurable descriptors of structural organization and spatial hierarchy.

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Fractal Geometry in Architectural Studies

Fractal geometry provides mathematical tools for studying recursive structures, scale hierarchy, and self-similar organization. Mandelbrot introduced the mathematical theory of fractals for analysing irregular geometric systems [4]. In architecture, repetitive scaling and recursive ornamentation frequently demonstrate fractal-like characteristics.

Bovill applied fractal geometry to architectural analysis and demonstrated how recursive scaling can be identified in historical monuments and traditional architectural systems [5]. Nagara temple architecture, particularly clustered shikhara systems, visually resembles recursive hierarchical organization where smaller towers repeat around a dominant central structure.

Topology and Spatial Connectivity

Topology and graph theory are increasingly used in urban analysis, spatial modelling, circulation systems, and architectural network studies. Temple spaces may be interpreted as graphs in which nodes represent architectural units and edges represent movement pathways or visual connections.

Diestel developed foundational graph-theoretic methods applicable to spatial connectivity [6]. Batty discussed spatial networks and urban topology in architectural systems [7]. Nagara temples exhibit hierarchical movement pathways, axial progression, mandapabased circulation, and structured spatial transitions suitable for topological modelling.

Beyond qualitative interpretation, graph-based approaches offer the advantage of converting architectural layouts into measurable network structures. Such representations enable the computation of connectivity indices, node centrality measures, and spatial density parameters that can be compared across different architectural systems. This characteristic makes graph-theoretic methods particularly suitable for comparative studies of temple layouts.

Astronomical and Symbolic Geometry

Several North Indian temples exhibit astronomical alignment and symbolic geometric planning. Konark Sun Temple is particularly significant because of its radial wheel geometry, solar symbolism, cyclic representation of time, and eastward orientation [9]. The monumental wheels of Konark may be interpreted mathematically through radial symmetry, circular partitioning, angular division, and periodic spatial symbolism.

Computational Heritage and Digital Documentation

Recent developments in computational heritage studies have enabled the quantitative analysis of historical monuments through digital documentation techniques such as photogrammetry, laser scanning, GIS mapping, image segmentation, and three-dimensional modelling [10, 11]. These approaches facilitate the extraction of measurable geometric features from architectural structures and provide reproducible datasets for mathematical and computational analysis.

In architectural research, digital methods have increasingly been used to investigate spatial organization, symmetry, geometric proportions, connectivity networks, and structural complexity [10, 11]. Such approaches are particularly relevant for temple architecture, where large-scale geometric forms and hierarchical spatial arrangements can be studied through computational techniques. The present study adopts a conceptual mathematical framework while identifying potential pathways for future validation using digital heritage documentation and computational feature extraction methods.

The application of computational methods to architectural heritage has demonstrated that complex spatial and geometric characteristics can be represented through quantitative descriptors. Measures of connectivity, symmetry, hierarchy, and geometric repetition have been successfully employed in studies of historical buildings, urban layouts, and cultural monuments. These developments provide a methodological foundation for extending

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similar analytical approaches to Nagara temple architecture, where hierarchical tower arrangements, radial structures, and spatial organization offer suitable candidates for mathematical modelling.

Research Gap

Existing studies on Nagara temple architecture primarily focus on archaeological interpretation, religious symbolism, iconography, historical development, and artistic expression. Although several works discuss geometric planning and proportional systems, comparatively few studies attempt to represent temple architecture using quantitative frameworks based on graph theory, topology, fractal-inspired modelling, or spatial connectivity analysis. Furthermore, limited attention has been given to the development of reproducible mathematical indicators that can be derived from observable architectural characteristics and subsequently validated through computational methods. The present study seeks to address this gap by proposing a normalized mathematical framework for analysing selected geometric and topological characteristics of Nagara temple architecture and by introducing a composite index for comparative evaluation of architectural organization.

Objectives of the Study

The objectives of the study are:

1. To analyse recursive vertical clustering in Nagara temple architecture.
2. To examine radial geometry and cyclic symbolism in North Indian temple systems.
3. To investigate spatial topology and architectural connectivity.
4. To construct graph-theoretic abstractions of temple layouts.
5. To develop a normalized mathematical framework for Nagara temple analysis.
6. To propose the Nagara Temple Geometric Index.
7. To compare recursive geometry and radial organization between Kandariya Mahadeva Temple and Konark Sun Temple.

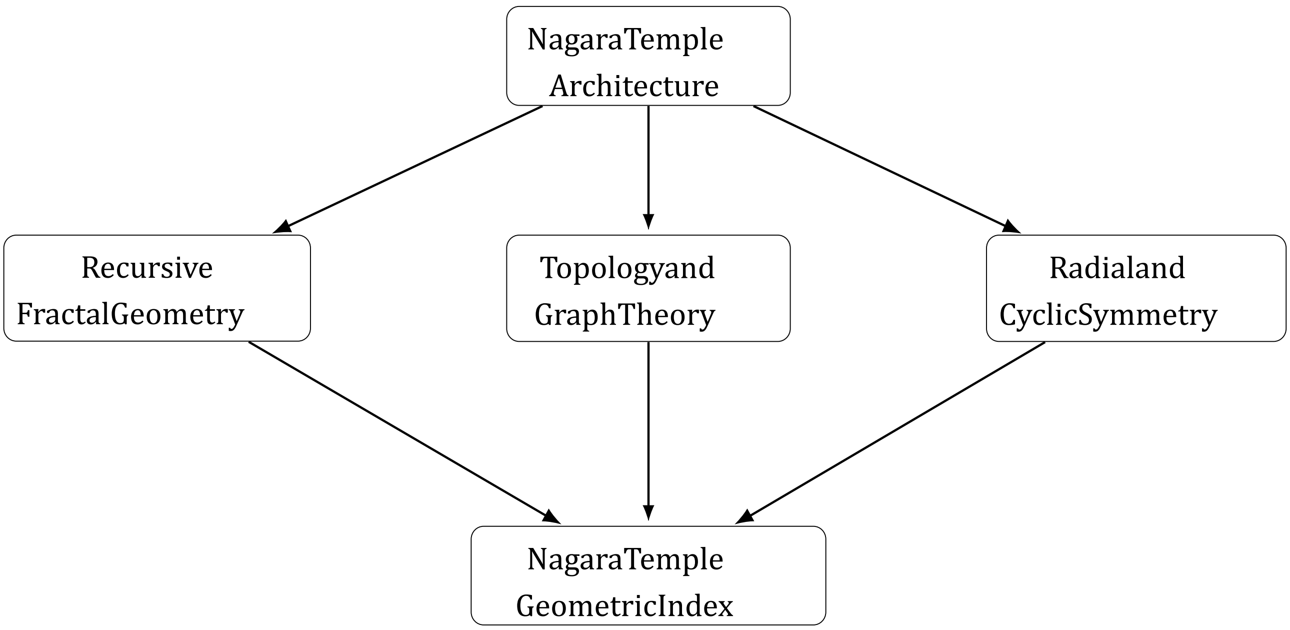

Figure 1: Proposed mathematical framework for analysing selected features of Nagara temple architecture.

Architectural Background of the Selected Temples

Kandariya Mahadeva Temple

Kandariya Mahadeva Temple, located in the Khajuraho Group of Monuments in Madhya Pradesh, is one of the finest examples of mature Nagara temple architecture. The temple is dedicated to Shiva and is known for its high central shikhara, clustered miniature spires, sculptural abundance, and strong vertical movement. It belongs to the Chandela period and is generally dated to the eleventh century CE [8, 2, 3].

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Parameter	Value
Location	Khajuraho, Madhya Pradesh
Approximate period	c. 1025–1050 CE
Dynasty	Chandela
Architectural style	Nagara
Main deity	Shiva
Main shikhara height	Approximately 31 m
Main mathematical feature	Recursive clustered shikhara system
Orientation	East-facing

Table 1: Kandariya Mahadeva Temple Details

The temple exhibits vertical hierarchy, recursive clustering, axiality, progressive elevation, and repeated miniature shikhara forms. Smaller tower elements cluster around the main tower, creating an impression of geometric growth toward a central vertical peak.

Konark Sun Temple

Konark Sun Temple, located in Odisha, is one of the most celebrated examples of KalingaNagara architecture. It was constructed in the thirteenth century CE and is dedicated to Surya, the Sun God. The temple is conceived as a monumental solar chariot with twelve pairs of elaborately carved wheels and symbolic horses [9, 3, 2].

Parameter	Value
Location	Konark, Odisha
Approximate period	13th century CE
Dynasty	Eastern Ganga
Architectural style	Kalinga-Nagara
Main deity	Surya
Wheel structures	24 monumental wheels
Symbolic form	Solar chariot
Main mathematical feature	Radial geometry and cyclic symbolism
Orientation	East-facing

Table 2: Konark Sun Temple Details

The temple exhibits radial geometry, cyclic symbolism, solar orientation, axial planning, and mathematical ordering through its wheel structures. The wheels may be interpreted as geometric representations of time, periodicity, circular symmetry, and solar movement.

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Sources of Architectural Data

The architectural information used in this study was compiled from authenticated heritage documentation, UNESCO World Heritage records, published architectural literature, and standard reference works on Indian temple architecture [8, 9, 3, 2, 1]. Particular attention was given to documented descriptions of temple layouts, shikhara organization, wheel geometry, spatial sequencing, and architectural hierarchy.

For Kandariya Mahadeva Temple, architectural information regarding shikhara clustering, vertical composition, plan organization, and spatial progression was obtained from UNESCO documentation and published studies of Nagara temple architecture [8, 2, 3]. For Konark Sun Temple, information regarding wheel geometry, radial organization, symbolic chariot planning, and orientation was obtained from UNESCO documentation and architectural analyses [9, 3].

To facilitate mathematical modelling, architectural features were converted into measurable variables. These variables were derived from documented architectural descriptions, published plans, elevation drawings, and visually identifiable structural components reported in the literature [2, 3, 8, 9]. The conversion process was designed to provide a consistent basis for comparative analysis across the selected temples.

Architectural Variable Definition and Coding

For reproducibility, each mathematical component used in the NTGI framework was associated with a specific architectural feature. Table 3 summarizes the variables and their interpretation.

Variable	Symbol	Architectural Interpretation
Recursive shikhara units	N_r	Number of visually identifiable subsidiary shikharas participating in clustered tower formation
Total structural units	N_t	Total number of major and minor tower elements considered in the analysis
Number of graph nodes	V	Distinct architectural spaces such as sanctum, mandapas, gateways, platforms, and corridors
Number of graph edges	E	Physical or functional connections between architectural spaces
Symmetric radial sectors	n_s	Radial sectors exhibiting geometric symmetry
Total radial sectors	n_t	Total number of radial sectors considered in the analysis

Table 3: Variables and their interpretation

The coding procedure was based on published architectural descriptions, plan-based interpretation, and documented structural features. All variables were normalized before inclusion in the NTGI framework to facilitate comparison between temple systems of different scales and architectural complexity.

The variables selected for the present study do not represent exhaustive architectural measurements. Rather, they were chosen to capture specific characteristics associated with recursive hierarchy, spatial connectivity, and radial organization. Future studies may refine these variables through direct architectural measurement, image-based extraction, or computational geometry techniques.

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Model Assumptions and Validation Scope

The proposed framework is intended as a quantitative interpretation of selected architectural characteristics observed in Nagara temple systems. The mathematical parameters are derived from architectural features that can be identified from published plans, documented descriptions, and future measurement-based datasets. The framework is exploratory and comparative in nature, but it has been structured so that each parameter can be refined using empirical measurements as more detailed architectural data become available.

1. Temple spaces may be abstracted as graphs where nodes represent architectural units and edges represent pathways.
2. Recursive shikhara clustering is represented through a fractal-inspired geometric parameter intended to capture hierarchical repetition and structural organization within the temple superstructure.
3. Radial wheel geometry at Konark Sun Temple may be analysed using circular symmetry and cyclic partitioning.
4. The numerical values used in the present study represent normalized comparative indicators derived from documented architectural characteristics and are intended to demonstrate the proposed methodology rather than establish definitive archaeological measurements.
5. The proposed NTGI framework measures selected mathematical characteristics only and does not evaluate artistic, religious, spiritual, or cultural value.
6. Certain numerical parameters are modelling assumptions requiring future validation through architectural measurements and computational analysis.

Component	**Interpretation**	**Future Validation**
Recursive fractal parameter	Vertical hierarchical clustering	Image analysis, photogrammetry
Topological connectivity	Spatial pathway organization	GIS and architectural plans
Radial geometry parameter	Cyclic wheel symmetry	Geometric measurement
NTGI framework	Comparative normalized index	Larger dataset validation

Table 4: Model Assumptions and Validation Scope

The assumptions adopted in the present framework are intended to provide a mathematically consistent basis for comparative analysis rather than definitive architectural measurements. As additional datasets become available, the parameters may be recalibrated and validated using direct geometric measurements, digital reconstruction techniques, and computational heritage methodologies.

Mathematical Framework

Graph-Theoretic Representation

To represent temple layouts in a mathematically tractable form, the architectural organization of a temple may be abstracted as a graph. In this representation, distinct architectural spaces are treated as nodes, while physical, visual, or functional connections between these spaces are represented as edges. Such graph-based representations enable the quantitative analysis of spatial connectivity and provide a foundation for comparative architectural studies.

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Definition 1. A temple graph is defined as

$$G = (V,E), \tag{1}$$

where V represents temple components such as sanctum, mandapas, gateways, wheel structures, platforms, and corridors, while E represents movement pathways or structural connectivity.

The connectivity degree of a node v is defined by

$$C(v) = \deg(v). \tag{2}$$

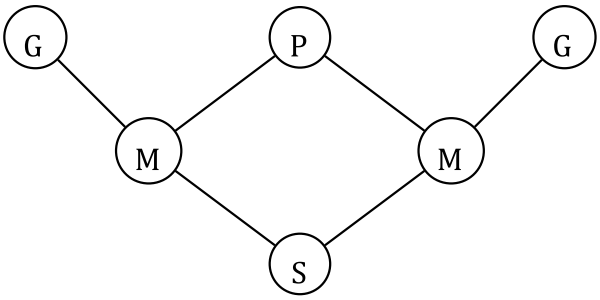
The adjacency matrix is represented as

$$A = [a_{ij}], \tag{3}$$

where

$$a_{ij} = \begin{cases} 1, & \text{if two spaces are connected,} \\ 0, & \text{otherwise.} \end{cases} \tag{4}$$

The adjacency matrix provides a compact representation of temple connectivity and facilitates the computation of graph-based measures such as connectivity density and spatial organization. Although simplified, this abstraction captures the primary structural relationships between architectural components.



S: Sanctum, M: Mandapa, G: Gateway, P: Platform

Figure 2: Simplified graph representation of Nagara temple spatial connectivity.

Topological Connectivity Parameter

The normalized topological connectivity parameter is defined as

$$T = \frac{2|E|}{|V|(|V|-1)} \tag{5}$$

This formulation corresponds to the standard graph density measure commonly used in network analysis and provides a normalized indicator of spatial connectivity within the temple graph.

Since

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$$0 \leq |E| \leq \frac{|V|(|V|-1)}{2}$$

(6)

it follows that

$$0 \leq T \leq 1. \tag{7}$$

Higher values of T indicate stronger spatial connectivity within the selected graph abstraction.

Recursive Fractal Modelling

The clustered shikharas of Kandariya Mahadeva Temple suggest recursive geometric organization.

Definition 2. The recursive fractal parameter is defined as

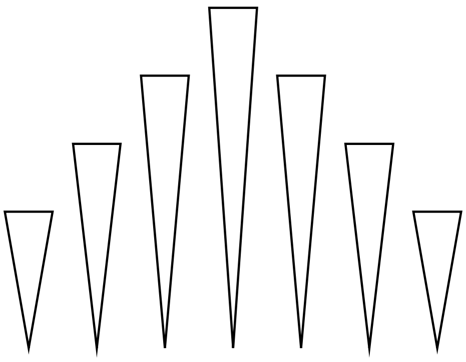
$$F = \frac{N_r}{N_t}, \tag{8}$$

where N_r denotes recursively repeating structural units and N_t denotes total structural units considered.

The parameter (F) provides a normalized measure of recursive architectural repetition. In Nagara temple architecture, subsidiary shikharas frequently occur in clustered arrangements surrounding a dominant central tower. The ratio therefore estimates the relative contribution of repeating structural elements within the observed tower hierarchy. Although simplified, the parameter permits comparison across temple systems of different scales by reducing the measure to a normalized interval between 0 and 1.

Radial Geometry and Cyclic Symmetry

Konark Sun Temple demonstrates strong radial organization through wheel structures and cyclic partitioning.



Recursive clustered shikhara abstraction

Figure 3: Recursive vertical clustering inspired by Kandariya Mahadeva Temple.

Definition 3. The radial symmetry parameter is defined as

$$R = \frac{n_s}{n_t}, \tag{9}$$

where n_s denotes symmetric radial sectors and n_t denotes total sectors.

The parameter (R) quantifies the degree of radial organization present within a selected architectural feature. For Konark Sun Temple, the monumental wheel structures provide a natural basis for radial partitioning. A larger

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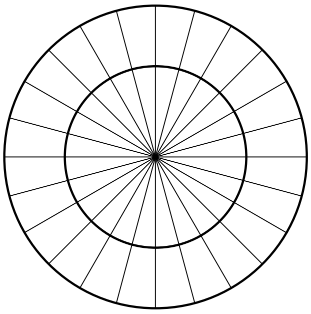
proportion of symmetric sectors produces a higher value of (R), indicating stronger geometric regularity and radial order.



Radial wheel abstraction inspired by Konark Sun Temple

Figure 4: Radial geometry inspired by Konark Sun Temple wheel structures.

Nagara Temple Geometric Index

The proposed composite mathematical parameter is defined as

$$\mathrm{NTGI} = \alpha F + \beta T + \gamma R, \tag{10}$$

where:

- F = recursive fractal component,
- T = topological connectivity component,
- R = radial symmetry component.

The NTGI is formulated as a weighted linear combination of three normalized architectural characteristics: recursive geometry, topological connectivity, and radial symmetry. The use of normalized parameters ensures that each component contributes on a common scale, thereby allowing meaningful aggregation within a single comparative index.

The weighting coefficients α, β and γ represent the relative importance assigned to the three architectural characteristics.

The weights satisfy

$$\alpha + \beta + \gamma = 1, \tag{11}$$

with

$$\alpha, \beta, \gamma \geq 0. \tag{12}$$

The non-negativity condition ensures that each component contributes positively to the composite index and prevents cancellation effects between different architectural characteristics.

For the baseline model,

$$\alpha = \beta = \gamma = \frac{1}{3}. \tag{13}$$

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In the absence of empirical calibration data, equal weighting is adopted in the baseline model so that no individual geometric characteristic is preferentially emphasized.

Thus,

$$\mathrm{NTGI} = \frac{F+T+R}{3} \tag{14}$$

Under the equal-weight assumption, the NTGI represents the arithmetic mean of the three normalized components. Consequently, higher NTGI values indicate a greater combined presence of recursive hierarchy, spatial connectivity, and radial organization within the selected architectural framework.

The NTGI should be interpreted as a comparative indicator rather than an absolute measure of architectural quality, cultural significance, or aesthetic value.

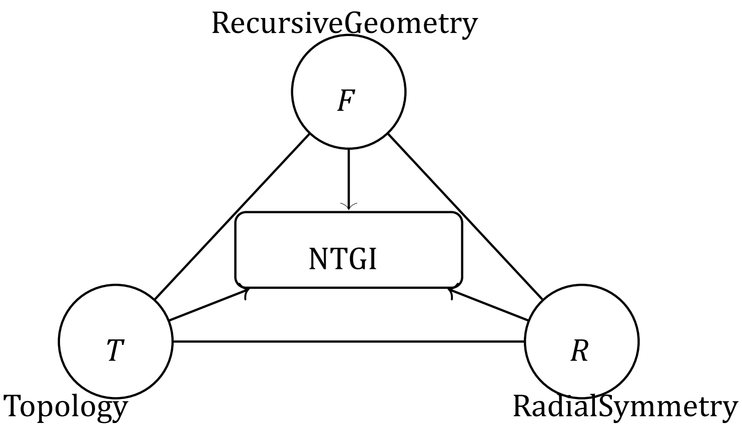

Figure 5: Triangular representation of the three mathematical components contributing to NTGI.

Numerical Modelling

Parameter Estimation Framework

The numerical values used in the present study were obtained as normalized indicators derived from the architectural characteristics identified in Sections 4 and 5. Since comprehensive measurement datasets are not presently available for the selected temples, the values should be interpreted as comparative modelling estimates intended to demonstrate the proposed framework rather than definitive archaeological measurements.

The estimation process considered three principal characteristics: recursive shikhara clustering, spatial connectivity represented through graph abstraction, and radial organization represented through geometric symmetry. All parameter values were normalized to the interval [0,1] to facilitate comparison between temple systems.

Temple	**Recursive Geometry (F)**	**Topological Connectivity (T)**	**Radial Symmetry (R)**
Kandariya Mahadeva Temple	0.78	0.52	0.88
Konark Sun Temple	0.62	0.66	0.95

Table 5: Normalized parameter values used in the NTGI framework.

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Kandariya Mahadeva Temple

For Kandariya Mahadeva Temple, the recursive geometry component was estimated within the proposed normalized framework as

$F_K = 0.78$. This value reflects the pronounced clustering of subsidiary shikharas around the dominant central tower. The topological connectivity component was estimated as:	(15)
$T_K = 0.52$. while the radial symmetry component was estimated as:	(16)
$R_K = 0.88$.	(17)

Therefore, these values indicate a temple system characterized by strong recursive hierarchy and substantial geometric regularity.

$$\mathrm{NTGI} = \frac{0.78 + 0.52 + 0.88}{3}$$

Hence,

$$\mathrm{NTGI}_K \approx 0.727. \qquad (19)$$

The resulting value reflects the strong recursive hierarchy and geometric regularity exhibited by the clustered shikhara system of Kandariya Mahadeva Temple.

Konark Sun Temple

For Konark Sun Temple, the recursive geometry component was estimated as:

$$F_C = 0.62, \qquad (20)$$

reflecting a comparatively lower emphasis on recursive tower clustering. The topological connectivity component was estimated as

$$T_C = 0.66, \qquad (21)$$

while the radial symmetry component was estimated as

$$R_C = 0.95. \qquad (22)$$

The high radial symmetry value reflects the prominence of wheel-based geometry and cyclic spatial organization within the temple complex.

Thus,

$$\mathrm{NTGI} = \frac{0.62 + 0.66 + 0.95}{3}$$

(23)

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Hence,	
$NTGI_C \approx 0.743$.	(24)

The slightly higher NTGI value reflects the strong contribution of radial symmetry and spatial organization associated with the wheel-based geometry of the Konark Sun Temple.

The comparison suggests that Kandariya Mahadeva Temple exhibits stronger recursive vertical clustering, whereas Konark Sun Temple demonstrates stronger radial geometry and cyclic ordering.

Sensitivity Analysis

Alternative weighting schemes may also be considered.

If recursive geometry is prioritized:

$\alpha = 0.50$, If radial geometry is prioritized:	$\beta = 0.25$,	$\gamma = 0.25$.	(25)
$\alpha = 0.25$, If topology is prioritized:	$\beta = 0.25$,	$\gamma = 0.50$.	(26)
$\alpha = 0.25$,	$\beta = 0.50$,	$\gamma = 0.25$.	(27)

Thus, the NTGI model provides flexibility for different architectural interpretations.

To evaluate the influence of weighting choices, the sensitivity of the index may be expressed as

$$\Delta \mathrm{NTGI} = \mathrm{NTGI}_i - \mathrm{NTGI}_j,$$

where NTGI_i and NTGI_j denote index values obtained under different weighting schemes.

Mathematical Justification and Proofs

Proposition 1. The NTGI framework is bounded between 0 and 1.

Proof. Since

$$0 \le F,T,R \le 1, \tag{28}$$

and

$$\alpha + \beta + \gamma = 1, \tag{29}$$

with nonnegative weights,

$$0 \le \mathrm{NTGI} \le 1. \tag{30}$$

Hence the index is normalized. □

Proposition 2. Recursive tower clustering increases the fractal-inspired parameter F.

Proof.

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Since

$$F = \frac{N_r}{N_t},$$

with $N_t > 0$, increasing the number of recursively repeating shikhara units while keeping the total number of structural units fixed increases the value of F.

Therefore, recursive tower clustering contributes positively to the fractal-inspired parameter F. □

Proposition 3. Radial partitioning contributes positively to cyclic symmetry.

Proof. As the number of symmetric radial sectors increases, the parameter

$$R = \frac{n_s}{n_t} \tag{32}$$

approaches 1. Hence, highly ordered wheel geometry contributes positively to radial symmetry. □

RESULTS AND DISCUSSION

The proposed framework offers a mathematical perspective on selected geometric characteristics of Nagara temple architecture. Although the two temples considered in this study belong to the same broad architectural tradition, the analysis suggests that they achieve architectural complexity through different geometric strategies.

Kandariya Mahadeva Temple is characterized by its prominent clustered shikhara arrangement, where numerous subsidiary towers rise around the central superstructure. This hierarchical arrangement contributes to a strong recursive geometry component and creates a visually unified upward movement. From a mathematical viewpoint, the temple demonstrates how repetition and hierarchical organization can be represented through normalized geometric measures.

In contrast, Konark Sun Temple derives much of its geometric character from radial organization. The wheel structures, circular forms, and ordered spatial arrangement contribute significantly to its radial symmetry component. Rather than emphasizing vertical clustering, the temple expresses geometric order through cyclic patterns and spatial regularity.

The NTGI values obtained for the two temples are relatively close, indicating that both structures exhibit substantial geometric organization despite their contrasting architectural forms. Kandariya Mahadeva Temple achieves this through recursive hierarchy, whereas Konark Sun Temple achieves it through radial symmetry and spatial connectivity. This observation highlights the diversity of geometric expression within the Nagara architectural tradition.

The results should be interpreted as comparative mathematical observations rather than definitive assessments of architectural value. The framework is intended to provide a structured approach for analysing selected geometric characteristics and may be refined further through measurement-based studies and computational validation.

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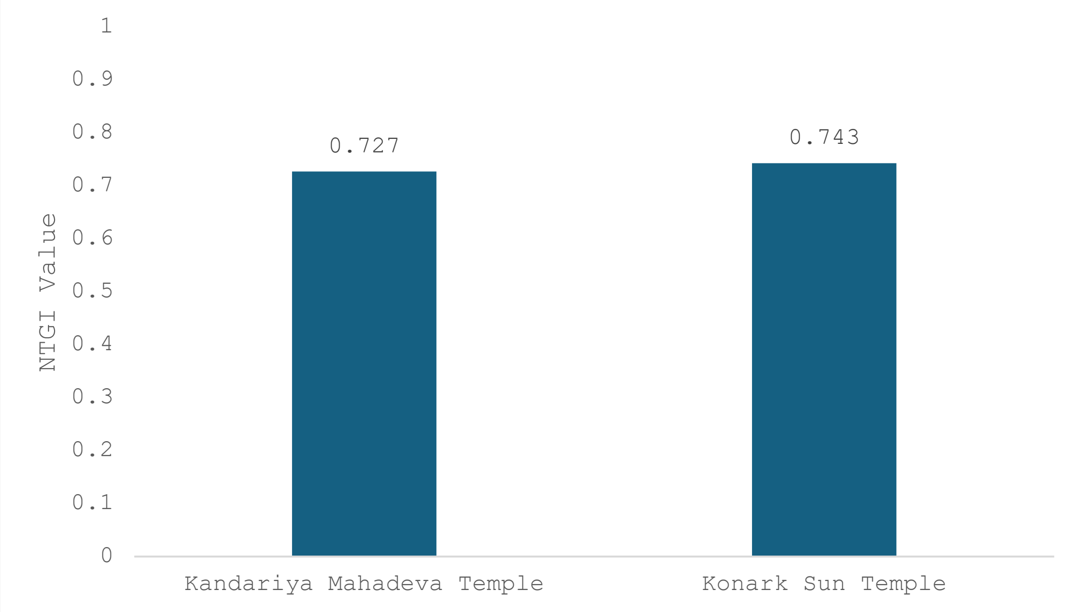

Figure 6: Comparison of NTGI values for Kandariya Mahadeva Temple and Konark Sun Temple under the equal-weight baseline model.

As shown in Figure 6, the NTGI values of Kandariya Mahadeva Temple (0.727) and Konark Sun Temple (0.743) are relatively close, suggesting that both temple systems exhibit substantial geometric organization despite emphasizing different architectural characteristics.

Applications of the Study

The proposed framework may be useful in:

- Computational heritage studies
- Digital reconstruction of monuments
- AI-assisted architectural interpretation
- Mathematical modelling of sacred architecture
- Spatial network analysis
- Heritage-based STEM education
- Comparative studies of Indian temple systems

Novelty of the Study

The novelty of the study lies in:

- Integrating fractal-inspired geometry with Nagara architecture.
- Introducing radial geometry analysis for temple wheel symbolism.
- Developing the Nagara Temple Geometric Index.
- Applying graph-theoretic abstraction to temple connectivity.
- Providing a normalized mathematical interpretation of North Indian temple systems.
- Connecting mathematical modelling with Indian Knowledge Systems and computational heritage.
- Establishing a reproducible framework linking architectural observations with normalized mathematical descriptors.
- Providing a foundation for future validation through computational heritage techniques including photogrammetry, GIS analysis, and image-based feature extraction.

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Limitations of the Study

The study develops a conceptual normalized framework rather than a field-measured archaeological model. Certain numerical values are modelling assumptions requiring future validation through architectural drawings, LiDAR mapping, image analysis, and computational extraction methods.

The proposed NTGI framework measures selected mathematical characteristics only and should not be interpreted as a measure of artistic, religious, cultural, or spiritual value. Since only two temple systems are considered, broader generalization requires a larger dataset of Nagara temples.

A further limitation of the study is that the parameter values are based on normalized modelling estimates derived from documented architectural characteristics rather than direct field measurements. Future investigations incorporating architectural surveys, digital reconstruction, and computational feature extraction may provide more precise parameter estimation and broader validation of the proposed framework.

Future Scope

Future studies may include:

- LiDAR-based geometric validation
- GIS mapping of temple plans
- Computational extraction of fractal dimensions
- AI-based classification of temple styles
- Comparative studies between Nagara and Dravidian systems
- Astronomical alignment modelling
- Image-processing-based measurement of shikhara clustering
- Development of automated NTGI computation using computer vision and image-processing techniques
- Construction of a larger temple geometry dataset for comparative analysis across multiple Nagara temple systems

CONCLUSION

Nagara temple architecture demonstrates remarkable mathematical richness through recursive vertical hierarchy, radial geometry, symbolic ordering, and spatial topology. The present study proposes a normalized mathematical framework for interpreting selected features of Kandariya Mahadeva Temple and Konark Sun Temple using graph theory, topology, fractal-inspired modelling, and symmetry analysis.

The analysis suggests that Kandariya Mahadeva Temple exhibits stronger recursive clustering, whereas Konark Sun Temple demonstrates stronger radial geometry and cyclic organization. The proposed NTGI framework contributes to interdisciplinary research connecting mathematics, architecture, computational heritage studies, and Indian Knowledge Systems.

The present work should be viewed as an initial step toward the development of quantitative approaches for analysing Indian temple architecture. Future studies incorporating direct architectural measurements, digital heritage documentation, and computational geometry techniques may further refine the proposed framework and extend its applicability to a broader range of temple systems. Such approaches may contribute to a deeper quantitative understanding of the geometric principles embedded within India's architectural heritage.

REFERENCES

1. Kramrisch, S. (1946). The Hindu Temple. University of Calcutta, Calcutta.
2. Hardy, A. (1995). Indian Temple Architecture: Form and Transformation. Wiley Academy, London.
3. Michell, G. (1988). The Hindu Temple: An Introduction to Its Meaning and Forms. University of Chicago Press, Chicago.
4. Mandelbrot, B. B. (1982). The Fractal Geometry of Nature. W. H. Freeman, New York.

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5. Bovill, C. (1996). Fractal Geometry in Architecture and Design. Birkhäuser, Boston.
6. Diestel, R. (2017). Graph Theory. 5th ed., Springer, Berlin.
7. Batty, M. (2013). The New Science of Cities. MIT Press, Cambridge.
8. UNESCO World Heritage Centre. Khajuraho Group of Monuments. World Heritage List Documentation.
9. UNESCO World Heritage Centre. Sun Temple, Konark. World Heritage List Documentation.
10. Remondino, F. (2011). Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. Remote Sensing, 3(6), 1104–1138.
11. Stylianidis, E., & Remondino, F. (2016). 3D Recording, Documentation and Management of Cultural Heritage. Whittles Publishing.