

Reimagining the image reconstruction of Candi Badut in Malang, Indonesia through geometry fractal

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i> Received July 27, 2021 Received in revised form Sept. 08, 2021 Accepted October 07, 2021 Available online April 01, 2022</p> <p><i>Keywords:</i> Fractal geometry Temple reconstruction Vastu Purusha Mandala</p> <p>*Corresponding author: Yusfan Adeputera Yusran Department of Architecture, Universitas Brawijaya, Indonesia Email: yusfan@ub.ac.id ORCID: https://orcid.org/0000-0002-2082-9153</p>	<p><i>Badut Temple is the oldest temple on Java Island and a historical relic of the Kanjuruhan Kingdom that collapsed due to natural and human factors. Therefore, this study aims to determine the suitability of the Badut Temple design drawn by B. De Haan. Based on the vastu purusha mandala philosophy, this Hindu-style temple uses repeated divisions of squares to prove that the design of the head of the temple uses Fractal Geometry with the box-counting method. The results showed that the fractal dimension index on the foot, body, and head with a ratio of 1.878: 1.870: 1.872 or be rounded up to 1:1:1. This means that the B. De Haan sketch design is similar to the existing temple. Furthermore, the ratio of the height of the foot, body, and head was 2.35:4.88:6.94 which is simplified to 1:2:3. Therefore, the Badut Temple adheres to the Vastu Purusha Mandala philosophy.</i></p>

Introduction

Many kingdoms once existed in Indonesia, leaving thousands of historical relics as proof of their existence (Achmad et al. 2014). In the 8th century, there was a kingdom called Kanjuruhan with the center of government in Malang (Ningsih 2021; Parinduri 2021). The proof of its existence is written on the Dinoyo inscription using the ancient Javanese script and Sanskrit (Subroto 2021). The main room of this temple (the main living room) contains the *Linga* and *Yoni*, which are the symbols of Shiva and Durga. In Java, the outer walls of Hindu temples contain niches where the statues are located, namely Mahakala and Nandiswara, Durga Mahisasuramardini, Ganesha, and Agastya (Lord Shiva) as the Supreme Master. However, among all the statues,

only the Durga Mahisasuramardini remains in the Badut Temple (Oktavianto 2013).

Hari, the guardian of the Badut Temple of the East Java Cultural Heritage Preservation Center (Nurchaliqu 2015), stated that this temple suffered a collapse, probably caused by natural (earthquake) and human (war) factors. It was discovered in 1921 in the form of a rock mound, and the first person to report its existence was Maureen Brecher, a Dutch controller that worked in Malang. Meanwhile, the temple was restored in 1925-1927 under the supervision of B. De Haan from the Antiquities Bureau of the Dutch East Indies. A reconstruction drawing of the Badut Temple was accurately followed during the rebuilding. The image of the reconstruction was found in the records of Oudheidkundige Dienst in Dutch which is the Bureau of Antiquities, and

there was curiosity on the correctness of the results. The original physical form was proven by analyzing the reconstruction from Fractal Geometry and juxtaposing it with the results of the existing Badut Temple.

This study conducted on the potential of Badut Temple using modern technology increases knowledge. In architecture, one of the ways to view basic patterns from mathematically complex shapes is through fractal geometry. This method divides complex shapes into pieces of geometry to obtain basic patterns. The temple is a sacred building and has a repeating pattern. Therefore, the use of fractal geometry is necessary to prove the original design of the Badut Temple as the oldest in East Java.

Fractal geometry

In the 1960s, Benoît Mandelbrot analyzed self-similarity in his writings titled "How Long Is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension" (Benoit Mandelbrot 1967). It was the development of Lewis Fry Richardson's study. Generally, Self-similarity also means resemblance, and with a visual approach, Mandelbrot gains connections from previously unrelated mathematical topics (Werner 2010). Furthermore, Green (1998), in the Senior Honors Thesis/Project (Fractal Dimension) reported that the box-counting method can be applied in geometry to obtain fractal dimensions. These dimensions are indexes that make the complexity of objects more visible. The box-counting method is very often and commonly used on objects that do not even have self-similarity. Therefore, this method can be applied to one, two, and three-dimensional objects.

Vastu Purusha Mandala

Temples are sacred buildings that are often used as places of worship for gods (Soviyani 1955). Wirasanti (2016) reported that sacred space shows a series of structured signs that represent cosmic images (philosophy of the universe). From the division of temples based on the trilogy, the vertical picture of the cosmos in the sacred space is divided into three, namely Bhurloka (foot), Bhuvraloka (body), and Svarloka (head) (Situngkir 2010).

Vastu Purusha Mandala is a graphic representation of the relationship between the physical and the divine realms. Vastu refers to the physical environment, Purusha refers to energy,

while mandalas are diagrams or charts. Vastu Purusha mandala (figure 1) has a basic geometric shape, namely a square which represents the earth. The square has four sides and it serves as the symbol of the four cardinal directions (Md Rian et al. 2007).

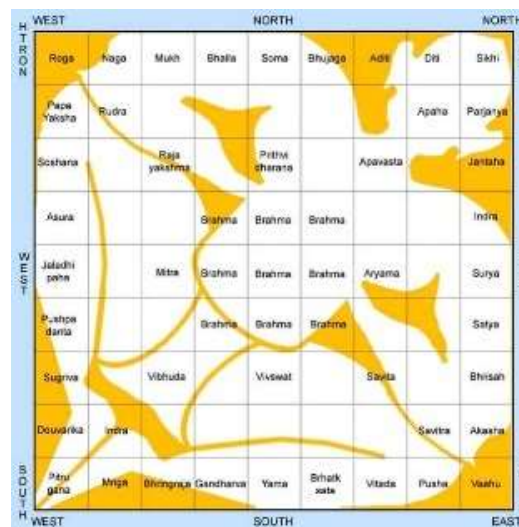


Figure 1. Vastu Purusha Mandala
Source: (Vasturaah 2017)

According to Sayekti, Amiuza, and A.S (2014), the repeating form of the natural geometry (universe) in the temple (Hinduism pattern) follows the rules of the Vastu Purusha mandala. Furthermore, the basic geometric shape in the form of a square is repeated with different sizes and forms a certain pattern. This makes the application of fractal geometry to reading sacred buildings possible.

Kanjuruhan Kingdom and Badut Temple

Kanjuruhan was a Hindu-style kingdom centered in Malang, East Java, precisely between the Brantas and the Metro River. Currently, the plains are called Dinoyo, Merjosari, Tlogomas, and Ketawanggede in Lowokwaru Sub-District, Malang. A study conducted by Oktavianto (2013) showed that Kanjuruhan is the oldest kingdom in East Java following the Dinoyo Inscription which dates to 682 Caka or 760 AD. The famous king was Prabu Gajayana, and the remains are in the form of buildings including the Badut and the Wurung Temple. Meanwhile, the word Badut is thought to be derived from the Sanskrit Bha-dyut which means the highlight of the Canopus Star or Agastya. It is estimated to be more than 1400 years old, therefore it can be called the oldest in

East Java. In 1921, E.W. Mauren Brechter reported that the condition of the Badut Temple was damaged, overgrown with trees, and covered with soil. Four years later, a year-long restoration led by B. De Haan was conducted. According to Oktavianto (2013), there are special signs that show this temple to be one of the oldest in Java. The decorations on Badut temple are in the form of Kala Makara on the gate. According to Sartono (Oktavianto 2013), the East Java BP3 Restoration Working Group Team stated that the temple was built from andesite stone with irregular tide positions because the structure was not arranged in layers.

Reconstruction of Badut Temple image by B. De Haan

During the Dutch colonial period, there was a management system to protect and restore heritage objects from the kingdom in Indonesia. The relics from the Kanjuruhan Kingdom were held by B. De Haan, and a reconstruction drawing was made to rebuild the collapsed part (figure 2). This reconstruction image was found in the records of Oudheidkundige Dienst in Dutch which is the Bureau of Antiquities. The foot and body were restored, and there are several possibilities for the head. In addition, the temple head did not have a resemblance due to cracked and broken andesite stone debris. A 2-dimensional image in the form of a front view of the Badut Temple along with the main head and the entrance was obtained.



Figure 2. Reconstruction of the Badut Temple depicting B. De Haan
Source: (Torrio 2017)

The images obtained from Batukita's blog when compared with the existing conditions of the foot and body of the temple are not the same and scalable. Therefore, it is necessary to adjust the appropriate scale and size to the existing conditions to properly align the head. The current condition of the Badut Temple is only the foot and body (figure 3).



Figure 3. Existing photos of the current Badut Temple

The image of the Badut Temple reconstruction is adjusted to the size at the location to obtain more accurate measurement data.

Method

A quantitative evaluative method was conducted by approaching data processing using fractal geometry (box counting) at Badut Temple and the results were evaluated. Furthermore, the dependent variable was used in the form of a Badut Temple image (existing condition and reconstruction) and the independent variable was the fractal geometry (as a reader, using software) (Lamb 2015). Data collection was conducted through direct observation and documentation as primary data. The literature related to the study was the secondary data.

According to Md Rian et al. (2007), this box-counting method can be taken in several steps, as follows: (1) Create a square grid which is then placed on top of the image; (2) Scale the grid 'S' on the image; (3) Calculate the square grid marked by the image, and the number is called 'N'; (4) Repeat the process with the same image, but changing the size of the square grid; (5) The fractal dimension 'D' can be calculated by converting the results 'S' and 'N' into a log-line graph generated from a log-log graph; (6) Determining the fractal dimensions of the image (Tabak 2014).

Fractal Dimension Index on objects that are between one to two dimensions will bring up a value of $1 < D < 2$. Furthermore, the obtained fractal dimension shows the level of similarity in detail of the object, and the images with 1.1-1.5 indicate a low level of similarity (Risi 2015). Meanwhile, the values of fractal dimensions of 1.6-1.9 indicate a high level of similarity. For the value of 1.51-1.59, it is stated that the level of similarity is moderate. Furthermore, the similarity

of images with 1.21-1.25 or dimensions of 1.81-1.86 is visually not very distinguishable to the naked eye. In fractal dimensions 1.1, 1.2, 1.3..., 1.8, and 1.9, the difference can be seen (Md Rian et al. 2007).

The data processing stage consists of the following stages:

1. Re-imaging the measurement data of the existing Badut Temple and the reconstruction drawing by B. De Haan (using SketchUp);
2. Image analysis and the reconstruction of the Badut Temple using fractal geometry (using Fractalyse);
3. Tabulating the box counting data obtained from Fractalyse into a table to obtain the Log value of the grid size (S) and the marked grid (N);
4. Graphing numbers from Log values in line equations with the caption $x = \text{grid size (S)}$, $y = \text{marked grid (N)}$, this step is carried out using Microsoft Excel;
5. Finding the fractal dimension index of the line found in the number in front of x (coefficient).

Result and discussion

1. Badut temple data

The main image that will be analyzed is the front view of the Badut Temple. This was conducted because the comparison image was limited to the front view. However, on the floor plan, the fractal geometry was still processed therefore the data to be paired varies (figure 4 and figure 5).

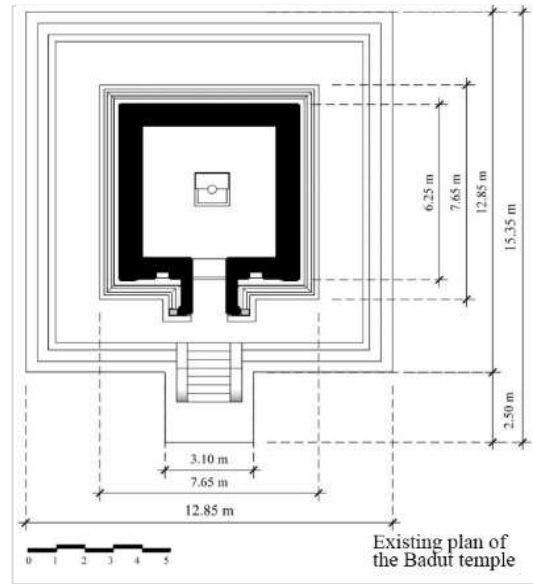
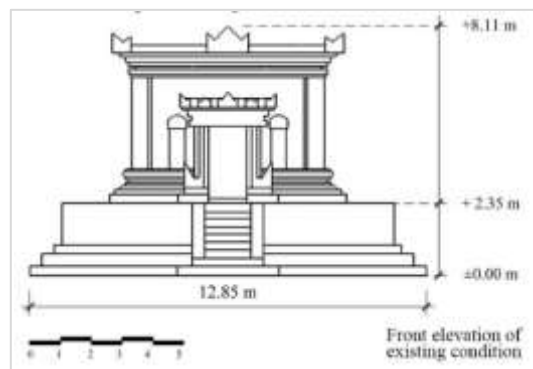


Figure 4. Existing image of the Badut temple

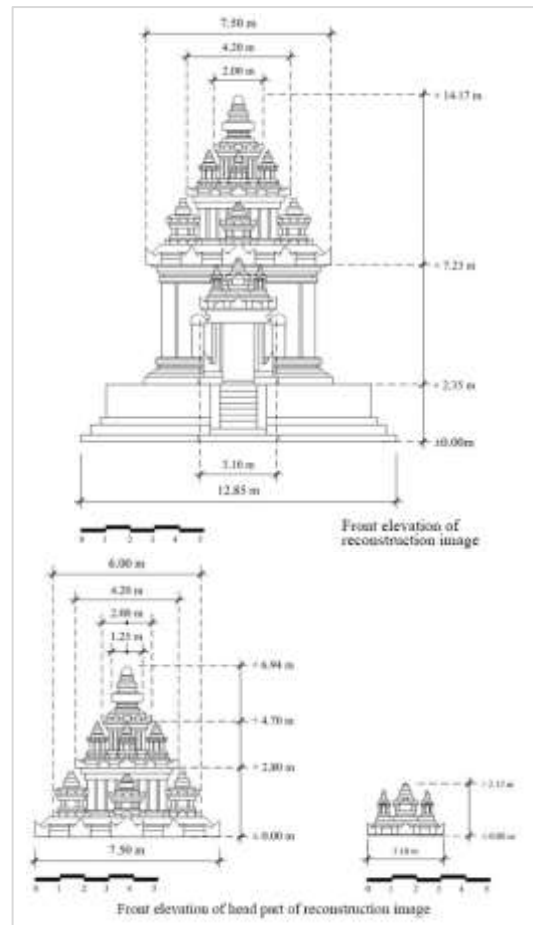


Figure 5. Re-imagining the overall reconstruction and the head of the Badut Temple by B. De Haan

2. Data analysis based on fractal geometry
a. Fractal geometry analysis on the existing Badut temple

Digital image of Badut Temple on-site, processed based on fractal geometry using the box-counting method (figure 6). The image was plotted on A3 size paper with a scale of 1:50 when processed in fractalyse software.

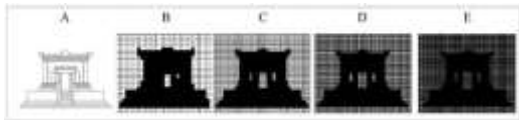


Figure 6. Application of box counting on existing appearance of Badut Temple: (A) Existing images of Badut temple; (B) Application of grid size 32; (C) Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The following is the result of the box calculation obtained on the front view.

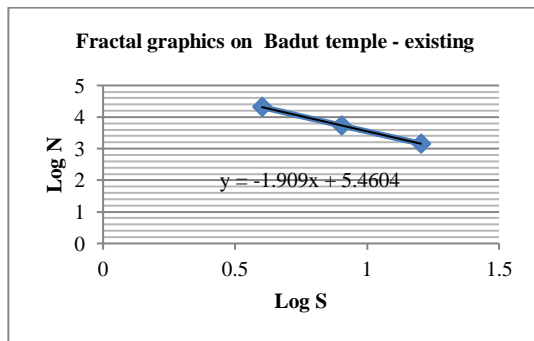


Figure 7. Graph of 1.909 fractal dimension

In processing data from the front view of the existing Badut Temple, the fractal dimension index was 1.909. Numbers that appear in the can be categorized in a very high level of similarity (figure 7 and table 1).

Table 1. Fractal geometry calculation data for the existing front view of the Badut Temple

Grid (S)	N	Log S	Log N
32	390	1.50515	2.591065
16	1442	1.20412	3.158965
8	5374	0.90309	3.730298
4	20709	0.60206	4.316159

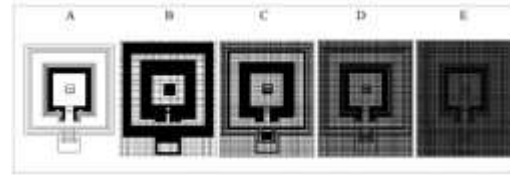


Figure 8. Application of box counting on the existing plan of the Badut Temple: (A) Image of the Badut Temple plan; (B) Application of grid size 32; (C) Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The results of the boxes calculation obtained by the plan (figure 8 and 9, table 2).

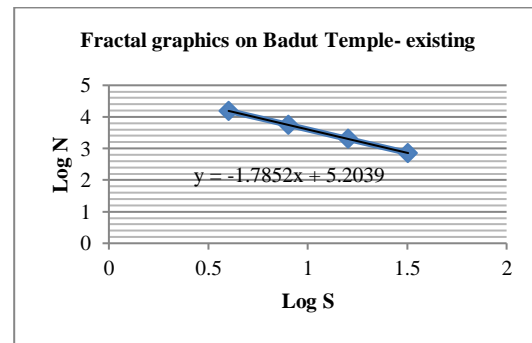


Figure 9. Graph of 1.785 fractal dimension

In processing data from the front view of the existing Badut Temple, the fractal dimension index was 1.785. Numbers that appear in the line can be categorized with a high degree of similarity.

Table 2. Fractal geometry calculation data for the existing plan of the Badut Temple

Grid (S)	N	Log S	Log N
32	716	1.50515	2.854913
16	1989	1.20412	3.298635
8	5591	0.90309	3.747489
4	15427	0.60206	4.188281

b. Fractal geometry analysis on the Badut Temple reconstruction

The digital re-image of the Badut Temple reconstruction was processed based on fractal geometry using the box-counting method (figure 10). Meanwhile, the image was plotted on A3 size paper with a scale of 1:50 when processed in fractalyse software.

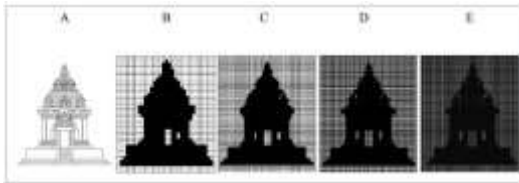


Figure 10. Application of box counting on appearance of Badut Temple reconstruction: (A) Badut Temple image; (B) Application of grid size 32; (C) Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The box calculation results on the front view of the Badut Temple reconstruction (figure 11 and table 3).

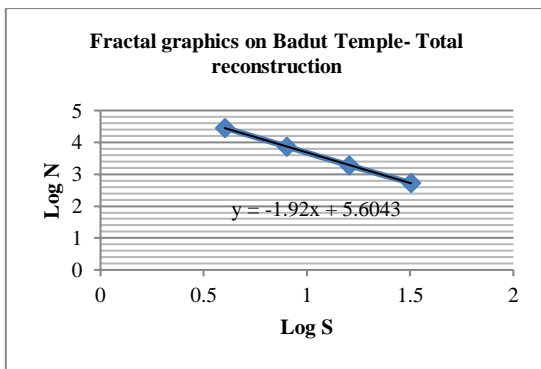


Figure 11. Graph of 1.920 fractal dimension

In processing data from the front view of the Badut Temple reconstruction, the fractal dimension index was 1.920. Numbers that appear can be categorized in a very high level of similarity.

Table 3. Fractal geometry calculation data for the Badut Temple reconstruction

Grid (S)	N	Log S	Log N
32	529	1.50515	2.723456
16	1910	1.20412	3.281033
8	7339	0.90309	3.865637
4	28523	0.60206	4.455195

c. Fractal geometry analysis on the ratio of the foot: Body: Head of the Temple

To determine the similarity between the foot and body as well as the head of the Badut Temple obtained from B. De Haan, the fractal geometry analysis was conducted separately according to the parts of the temple.

The existing digital image was processed based on fractal geometry using the box-counting method (figure 12).

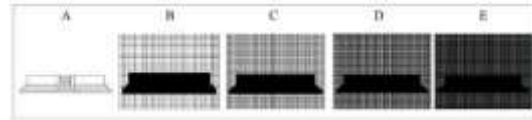


Figure 12. Application of box counting on the foot of the Badut Temple: (A) Image of Badut Temple foot; (B) Application of grid size 32; (C) Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The box calculation result at the foot of the Badut Temple (figure 13 and table 4).

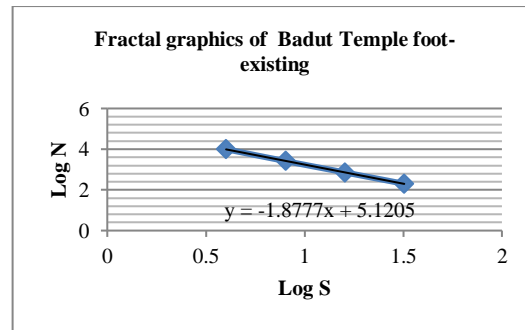


Figure 13. Graph of 1.878 fractal dimension

In processing data from the front view of the foot on the Badut Temple reconstruction, the fractal dimension index was 1.878. Numbers that appear is categorized in a very high level of similarity.

Table 4. Fractal geometry calculation data for the Badut Temple foot

Grid (N)	s	Log N	Log S
32	199	1.50515	2.298853
16	720	1.20412	2.857332
8	2602	0.90309	3.415307
4	9932	0.60206	3.997037

The existing digital image of the Badut Temple on the body was processed based on fractal geometry using the box-counting method (figure 14).

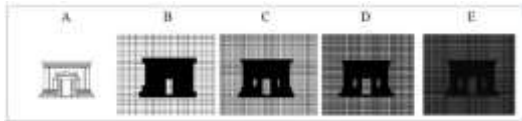


Figure 14. Box counting application on the body of Badut Temple: (A) The image of Badut Temple body; (B) Application of grid size 32; (C) Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The box calculation results on the Badut Temple body (figure 15 and table 5).

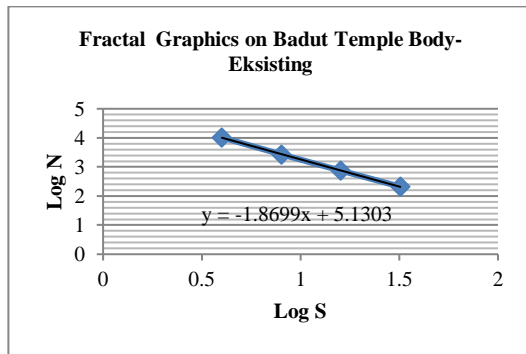


Figure 15. Graph of 1.870 fractal dimension

In processing data from the front view of the foot on the Badut Temple reconstruction, the fractal dimension index was 1.870. The numbers that appeared is classified in a very high level of similarity.

Table 5. Fractal geometry calculation data for the Badut Temple body

Grid (S)	N	Log S	Log N
32	210	1.50515	2.322219
16	748	1.20412	2.873902
8	2705	0.90309	3.432167
4	10291	0.60206	4.012458

Digital re-image of the reconstruction of the Badut Temple on the main head processed was based on fractal geometry using the box-counting method (figure 16).

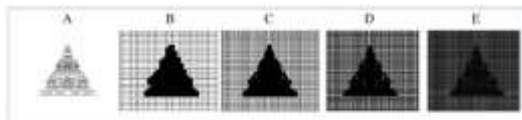


Figure 16. Application of box counting on the head of the Badut Temple: (A) Image of the main head of the Badut Temple; (B) Application of grid size 32; (C)

Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The calculation results of the main head of the Badut Temple reconstruction box is shown in figure 17 and table 6.

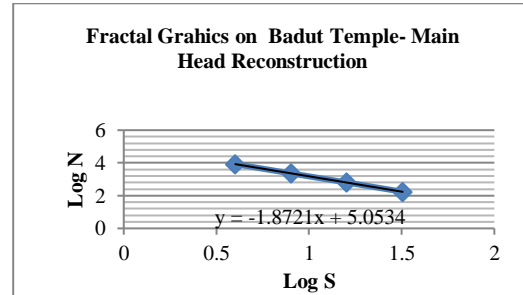


Figure 17. Graph of 1.872 fractal dimension

In processing the data from the front view of the main head of the Badut Temple reconstruction, the fractal dimension index was 1.872. Numbers that appear can be categorized with a high level of similarity.

Table 6. Fractal geometry calculation data for the head of the Badut Temple

Grid (S)	N	Log S	Log N
32	172	1.50515	2.235528
16	634	1.20412	2.802089
8	2277	0.90309	3.357363
4	8491	0.60206	3.928959

Digital re-image of the Badut Temple reconstruction at the head of the entrance processed was based on fractal geometry using the box-counting method (figure 18).

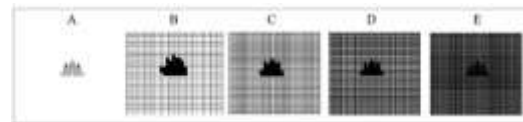


Figure 18. Box counting application on the head of the Badut Temple entrance: (A) Image of the head of the Badut Temple entrance; (B) Application of grid size 32; (C) Application of grid size 16; (D) Application of grid size 8; (E) Application of grid size 4

The box calculation results on the Reconstruction of the Badut Temple at the head of the entrance (figure 19 and table 7).

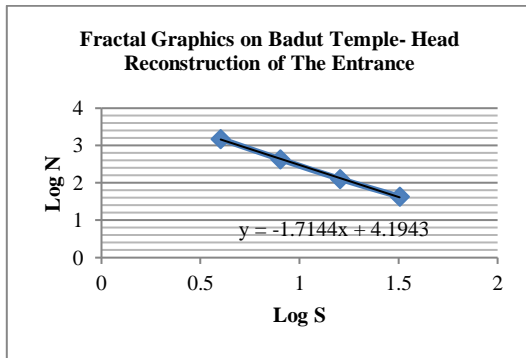


Figure 19. Graph of 1.714 fractal dimension

In processing the data from the front view of the main head reconstruction on the Badut Temple, the fractal dimension index obtained was 1.714. Numbers that appeared can be categorized with a high level of similarity.

Table 7. Fractal geometry calculation data for the head of the Badut Temple entrance

Grid (S)	N	Log S	Log N
32	43	1.50515	1.633468
16	128	1.20412	2.10721
8	429	0.90309	2.632457
4	1509	0.60206	3.178689

The ratio obtained from the comparison of fractal dimensions of the foot: body: head of the Badut Temple was 1.878: 1.870: 1.872. The comparison showed that the highest difference is only 0.008 and can be simplified to 1:1:1. Meanwhile, for the main head with that of the entrance, there was a difference of 0.158.

The size of the temple obtained was reviewed following the results of the reconstruction images that have been declared to have high similarities starting from the foot, body, and head. Based on the reconstruction drawing by B. De Haan, the vertical head size was 6.95 meters. Furthermore, the condition of the existing Badut Temple has a vertical foot and body size of 2.35 meters and 4.9 meters respectively. The size ratio from the vertical foot: body: head ratio was 2.35:4.88:6.94, and the ratio is simplified to 1:2.08:2.95 or rounded to 1:2:3.

Referring to the fractal dimension difference column (table 8), the results of the total reconstruction showed a difference of 0.011. This figure can be interpreted that the level of similarity between the Total Reconstruction of the Badut Temple and the existing clown Temple is

very high. Additionally, the difference in the main roof reconstruction was 0.037 which can be stated to be very small. The reconstruction on the roof of the entrance was 0.195 and probably stated to have a bigger difference than the total and the main roof.

Table 8. Differences in reconstruction fractal dimensions against the existing Badut Temple

No	Badut Temple	Fractal Dimension	Fractal Dimension Difference
1	Existing	1.909	0
2	Total reconstruction	1.920	0.011
3	Main roof reconstruction	1.872	0.037
4	Entrance roof reconstruction	1.714	0.195

Referring to the fractal dimension difference column (table 9), the results of the total reconstruction showed a difference of 0.135 which revealed to be quite large when compared to the front view image. Meanwhile, the difference in the main roof reconstruction of 0.087 is declared to be quite small. For the reconstruction on the roof of the entrance of 0.071, it is stated to have the smallest difference compared to the total and the main roof.

Table 9. Differences in reconstruction fractal dimensions against the Badut Temple plan

No	Badut Temple	Fractal Dimension	Fractal Dimension Difference
1	Floor plan	1.785	0
2	Total reconstruction	1.920	0.135
3	Main roof reconstruction	1.872	0.087
4	Reconstruction of the entrance roof	1.714	0.071

Conclusion

The use of fractal geometry showed a high similarity from the results of the ratio and comparison of the current state of the Badut Temple with the reconstruction. The ratio showed that the fractal dimension number of the foot: body: the head is 1.878:1.870:1.872 with the largest difference of 0.008 which means almost 1:1:1. Meanwhile, in the comparison of the Total Reconstruction of the Badut Temple by B. De

Haan to the existing condition, the smallest difference number was 0.011. Therefore, it can be concluded that the similarity of the fractal dimensions is also very high. This number indicates a very high similarity of fractal dimensions. Meanwhile, in the vertical measurement of the temple, the foot: body: head ratio is 1:2:3. This can strengthen the use of the Vastu Purusha Mandala rule in the establishment of the temple. From these ratios, it can be concluded that the Badut temple has vertical proportions with the longest head, middle body, and shortest legs.

In conclusion, the front view image Reconstruction by B. De Haan has a fairly high similarity with the Badut Temple when viewed from the calculation of Fractal Geometry. Therefore, the reconstruction on the head of the temple is true, and the repeating square pattern of the Vastu Purusha Mandala located from the temple plan (base) is also related to the reconstructed image. This relationship is obtained from the division of the temple based on the three domains with a ratio of fractal dimensions at the foot: body: head of 1:1:1. Furthermore, the ratio of the fractal dimensions proves that different image objects have a high degree of similarity.

A repetition pattern enriches the knowledge, especially in the visible part of the building according to the data used. This is based on geometric shape in the form of a square and a vertical foot: body: head in the ratio of 1:2:3. This is consistent with efforts to search, study and evaluate the architectural form of a religious building which has become important as part of the treasury of historical conservation theories (Yusran and Hadinata 2019).

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Author(s) contribution

Yusfan Adeputera Yusran contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

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