Architectural Analysis Based on Fractal Dimension on Diyarbakir Mosques

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ABSTRACT
When the concept of daily architecture is examined from a broad perspective, it can observe that architectural units are produced with different design criteria in each period. In terms of structural designs, the designs in which Euclidean geometry shapes - bricks, steel sections, plates - are presented with simple solutions in production and marketing, and where designs Euclid used effectively are stylistically recognized. From this point it is not hard to reach to the data that fractals in architecture are used more advanced than copying the models from nature, to fractal architecture (Jencks, 1997:14).

In this study, it was aimed to support the interpretations made on the literature data about the intuitive facts and characteristics of mosques belonging to the Akkoyunlu period in the Diyarbakır mosques with numeric data. For this, the numerical possibilities of fractal geometry have been imposed on.

First of all, the concept of fractal and its historical development, concepts of fractal design and its scope, fractal dimension and calculation methods are mentioned in the study. The architectural and historical features of the Diyarbakır mosques, which will be analysed by calculating the fractal dimension, are then discussed.

In the scope of the field study, empty ratios filled with Diyarbakır mosques belonging to Akkoyunlu period by box counting method were determined and fractal dimensions were calculated with the specified formulas. The obtained values are demonstrated in tables. In the last part of the study, the obtained fractal values are tabulated. As a result of this obtained values, evaluations were made by putting forward these results and analyses. It is thought that the studies which combine different fields such as mathematics, geometry and architecture, can provide us with different perspectives.

Keywords: Fractal Architecture, Full-Empty Rates, Box Counting Method

1. INTRODUCTION

Nowadays, architecture, with the fractal concepts which we can refer to as Chaos Theory and the geometry of the chaos, in the popular expression, has begun to shape in an irregular design environment and the effect of Euclid geometry has decreased in architecture forms. Fractal is a Latin derived word, meaning divided, fragmented. The designers who try to combine nature and order together have come to a realization that nature actually has an irregular fiction and began to use fractal geometry instead of Euclidean geometry as a means of describing nature. The most important expansion of fractal geometry is to reveal the order of chaos. The most important feature of the fractals is that they offer details evermore and every detail is not a repetition but a "self similarity". In the studies, it is seen that the smallest details in the Gothic cathedrals

from early period examples have the same characteristics with all the cathedrals (Lorenz, 2003:42).

Thus, it would not be wrong to reach a conclusion that, although the concept of fractal has entered the scientific literature in the late 1970s, there are structures made up of self-similar items in the history of architecture, suggesting that the fractals have been used in architecture for a long time.

The fact that an architectural analysis work based on fractal dimension has been performed in very small numbers up to now and the inadequacy of the studies required to use the numerical possibilities of the calculus based on the existing fractal dimension constitute the scope of our work.

2. AIM AND CONTENT

It is aimed to evaluate numerical possibilities of calculus based on fractal dimension on architecture and to investigate Diyarbakir mosques with a mathematical analysis method other than intuitive facts. The description of the Diyarbakır Mosques belonging to the Akkoyunlu period with the aid of fractal geometry, which transfers the cultural heritage from past to present, has been considered the scope of the study.

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Parlı (Safa) Mosque, Lala Kasım (Lale Bey) Mosque, Kasım Padishah (Four-legged Minaret) Mosque ve Nebi (Prophet) belonging to Akkoyunlu period in Diyarbakır constitute the scope of the study.

Whether the geometric fiction in the mosques facades is analyzed by numerical methods constitutes the problem of the study.

As the sub-problem of the study, it is discussed whether the fractal valueschange according to the directions in the facade. In addition, it has been emphasized whether the fractal values change in the facades of mosques in different periods.

It is assumed that there is a numerical ratio on the facades. And also it is assumed that numerical ratios vary according to periods.

3. RESEARCH METHOD

In the study process, initially data collection was performed by scanning sources about the subject and those sources that support the subject. Articles, theses, books and related images were used in the source research. Besides, fractal dimension concept, calculation and literature search about Diyarbakır mosques have been performed. Frontal drawings were created with the assistance of a 2 dimension drawing program through the existing frontal paintings of the designated mosques. Then, the fractal dimension of the glasses was calculated by using the "box counting method", which is one of the fractal dimension calculation methods. This calculation consists of processes;

- The two-dimensional drawing of the frontals, the linecontrol of the frontals in each square resulting from dividing the grids,
- Noting the boxe sthat have lines inside them by counting
- Maintaining the same method by gradually shrinking the existing grid system,
- As a result, comparing the number of filledbox in the first grid and the next grid by the formula below,

D = $\frac{log(x)-log(y)6}{log(z)-log(q)}$ (Bovill, 1996:194.)

D: Fractalvalue

x: Number of filled boxes counted in the next cycle

y: Number of filled boxes counted in the previous cycle
z: Number of boxes in bottom row in the next cycle
q: Number of boxes in bottom row in the previous cycle

- Calculating the fractal value of everycycle of each mosque.

4. THEORETICAL FRAME

The emergence of the fractal concept is accompanied by the chaos theorem. According to Gürsakal, chaos and fractals are related in a mathematical sense. However, while the subject of chaos is the dynamics of disorder, fractal's subject is the geometry of disorder (Gürsakal, 2007:168).

4.1. FRACTAL CONCEPT

The first person to use the fractal concept was Benoit Mandelbrot. The fractal concept is derived from a Latin adjective "fractus" by Mandelbrot. The root of the adjective fractus, meaning irregular, disorganized, divided, comes from the Latin verb "frangere" which means disintegrating (Mandelbrot, 1983:468.). In addition, since it is consonant with "fracture" that comes from the same root, meaning breaking, broke and the word "fraction", the word fractal emerged (Gleick, 2003:412.).

Mandelbrot stated that Euclid's geometry is inadequate to express the shape of the mountains, the shorelines, the clouds, or trees, and that many of the textures in the nature are more irregular and fragmented compared to Euclid, and that these textures can be seen in various features and in infinite numbers (Mandelbrot, 1983:464.). Understanding this difference between the geometry of nature and Euclid geometry, Mandelbrot designed and developed the fractal geometry and used it in different areas. Thus, this led to the creation of new theories by explaining many irregular and fragmented textures in our surroundings. Both the regular and irregular fractals are based on statistical data. In addition, the fractals provide information about the measures and irregularity of these textures. As a result, fractal dimension concept has emerged (Mandelbrot, 1983:468.). The fractal concept, which has been put forward and developed by Mandelbrot's ideas and works, is now used in many field studies ranging from music to physics.

4.2. HISTORICAL PROCESS OF FRACTAL

According to Gleick (2003), although the concept of chaos theorem, fractal geometry and fractal architecture was rather acceptable at the beginning of the 1980s, as experts working on chaos theory increased, some departments of the universities did not accept these studies, and some of them stipulated some severe terms. In the same period, although some journals set nuncupativerules against articles related to chaos concept, some of them published only chaos studies, on the contrary. In the mid-1980s, chaos specialists gained important positions in university management through academic publishing process (Gleick, 2003: 412.).

Ostwald (2001) defines 1989-1999 as the period of regression for fractal architecture. At the end of the 1980s, it is seen that various architectural critics criticize their colleagues for their interest in fractal geometry, non-linear dynamics and chaos theory (Kaymaz and Sezer, 2017:79).

Fractal geometry by Betsky in 1990 was expressed as a virus or parasite that destroyed the architecture, the Euclidean geometry, however, was expressed as an antibody for architecture. Hariri and Hariri also criticized fractal geometry in 1993 by resembling chaos theory and fractal geometry to "kitsch" in 1993. In the mid-1900s, Alberto Pérez Gomez, by using "Fractal Geometry and Chaos Theory" in his work, reported tha fractal geometry and science of chaos revealed his eagerside (Ostwald, 2001:74).

4.3. CONCEPTS in THE SCOPE of FRACTAL FICTION

Before mentioning fractal dimension calculation, it is necessary to deal with the most used concepts in order to understand the fractal fiction. These concepts are; self-similarity, productive algorithms and shape grammar, fractal geometry and fractal dimension (Bovill, 1996:194).

4.3.1. SELF-SIMILARITY

Fractal fictions are made up of structures that have similar properties in all dimensions. The concept of self-similarity implies a similarity relation between the smallest unit of a structural or formal fiction and the whole (Bovill, 1996:194). This structural fiction is not obliged to demonstrate the same characteristics in every dimension. This situation, while allowing the structure to be surprising and possessing similar characteristics in every dimension, enables it to demonstrate continuity in structural fiction (Ibrahim and Krawcyk, 2000:28). Thus, in a building with the same structure, it is seen that when descended into details in an object or a painting, the fiction in the whole is also in details too. We can observe these features in the Julia Set produced by mathematician Gaston Julia (Figure1) (Ibrahim and Krawcyk, 2000:32).

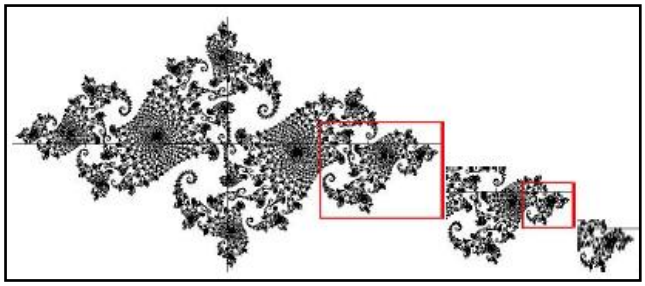


Figure 1. Julia Set (Bovill, 1996:194.)

Fractal constructions that show a similar structure can be seen frequently in the field of architecture. Especially Gothic architecture is a good example in this sense. In a single observation it can be seen that the column head of a Gothic cathedral is a smallcopy of the cathedral.

4.3.2. PRODUCTIVE ALGORITHMS AND SHAPE GRAMMAR

The concept of self-similarity, which is based on the basis of fractal geometry in nature, can also be analyzed through algorithms. The algorithm of a plant can be written in infinite repetitions, as to be appropriate for its own fiction. Therefore, an artificial plant can be created with the same form (Schmitt ve Chen, 1991:246). After each cycle with productive algorithms, it becomes possible to create similarities to the original form. Benoit Mandelbrot performed this replay in infinite numbers with his fiction, while the number of cycles in the nature was limited to 3-4 times. Productive algorithms, although based on a basic rule in nature, are limited with cycles in the order in the nature. While nature can be imitated by creating algorithms with infinite cycles, new fictions, forms can be created by abstraction. Two dimensional algorithms are designed to develop plan and frontal systems in architectural design. Productive algorithms created by fractal fictions are versatile methods used in producing architectural models in order to contribute to architectural design (Figure 2) (Schmitt ve Chen, 1991:251).

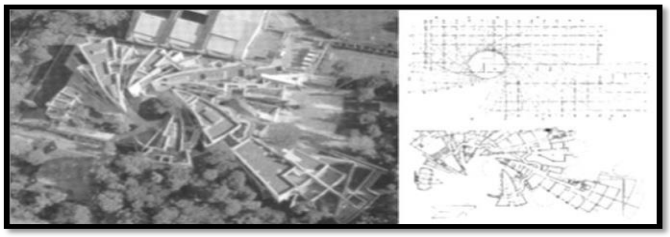


Figure 2. Zvi Hacker, Galinski School, Berlin (Jencks, 1997:17)

Another way of creating shapes is using the shape grammar. The shape grammar takes the shape first and shapes it according to the specific rules (Figure 3). Fractals that have productive algorithm, are created with shape grammar according to initial shape and a repeating rule (Stiny and Gips 1972:140).

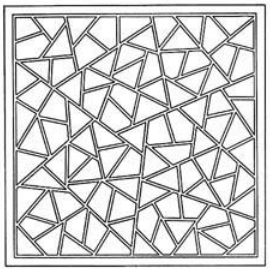


Figure3. Ice Rays (URL 1)

4.3.3. FRACTAL GEOMETRY

According to Bovill (1996), fractal geometry is a mathematical shape consisting of self-similar fictions and details that demonstrate continuity and can be observed very closely by an observer. Formations of tree branches and leaves, topographical occurrences, flooded levels of rivers and similar natural forms and rhythms indicate the continuity of self-similar forms.

Fractal geometry provides a technological possibility that can be examined from the whole of the designed composition to the smallest part. In addition, fractal geometry is capable of mathematically expressing any object (Bovill, 1996:196). For example, tree branches that are similar in shape with each other and cannot be expressed by Euclidean geometry can be expressed through fractal geometry (Figure 4).

Figure4. TreeBranches (URL 2)

4.3.4. FRACTAL DIMENSION

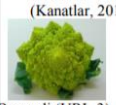
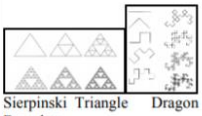
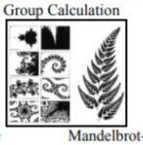
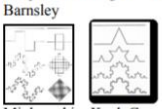
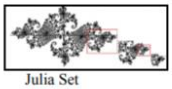
Fractal dimension is the value obtained by mathematically measuring the degree of continuity of a self-similar structure. The fractal dimension can also be used in the field of design and architectural design, which is about the control of the rhythm - repetition fiction. The fractal dimension also helps to measure the continuity of complexity in a rhythmic composition (Bovill, 1996:197).

4.3.5. FRACTAL FICTION VARIETIES

Fractals can be produced by humans as well as can be found in nature as a pure form. Biomimicry is a field that uses the means to solve problems by imitating the methods of living organisms. In addition, biomimicry is a productive fractal method used to develop creative solutions in the field of design (Gedi & Özen, Yavuz, 2018:136).

These generated fragments can be applied to various fields for use in everyday life. Fractals can be useful in many fields such as architecture, furniture design, urban scale etc. (Table 1) (Stiny and Gips 1972:142).

Table 1. Fractal Fiction Varieties

Existing Fractals in Nature	Fractals Produced with Productive Algorithms
• Up to three consecutive cycles • In any division process, the detail gradually disappears. • It is possible to see this feature in plants, in trees, in vegetables, in sea creatures and formations in sky (Kanatlar, 2012, p. 20.)  Broccoli (URL-3)  Snowflake (URL-4)  Purple Cabbage (URL-6) Oxeye daisy (URL-5)	• There can be infinite number of cycles • Same detail can be seen in all of the parts (Kanatlar, 2012, s. 20.) Fractals in Terms of Group Drawing Method Fractals in Terms of the Method Used for Group Calculation  Sierpinski Triangle Dragon Curve  Mandelbrot-Barnsley  Minkowski – Koch Curve (Kanatlar, 2012, p.26.)  Julia Set

4.3.6. FRACTAL FICTIONS IN ARCHITECTURAL DESIGN

An architectural design is not in a similar fractal structure to fractals in the mathematical form such as Koch curve. The Koch curve is made up of the continuity of self-similar textures on each scale. It is possible to examine an architectural fiction in every scale in the same way. For example, when we examine architectural fiction as frontal, it is possible to examine the structure, from the mass movements, to the fullness-emptiness proportions, even to the details of the door and the window, and finally to the continuity of the textures. Fractal characterization of an architectural composition, i.e. the approach to the building itself manifests itself in the continuity of the details seen throughout the entrance and the building.

Therefore, when an architectural structure is examined in general terms, the "concept of continuity" has a particular importance due to its role in the development of architecture. In conclusion, it can be said that when approaching a building, if observed fiction shows continuity when details are examined too, architectural fiction is formed with a "self-similar and a fractal fiction". When evaluated in this context, fractal fiction can be defined as the existence of self-similar forms that we can detail in any structure from large scale to much smaller ones (Bovill, 1996:200).

In Beaux Arts structures, while the continuity of interesting details from the smallest scale to the large scale is seen, in modern architectural examples, this continuity is not observed. However, in Frank Lloyd Wright's structures, who is a pioneer of the organic architecture and states that he is trying to build a relationship with nature, it is possible to observe the relations between a fore mentioned scales (Sala, 2005:316-318). In addition, repeating patterns in the Gothic, Renaissance, and Baroque architecture, especially in cathedral and church structures, can be seen at different scales and layers (Figure 5, 6).

Figure5. Notre Dame Cathedral, One of the Examples of French Gothic Architecture (URL 3)

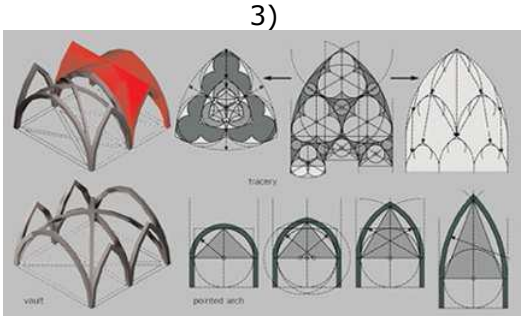


Figure 6. The Use of Similar Forms at Different Scales in the Creation of the Whole and Parts Brings A Self-Similar Structure. Pointed Arch Form Used in the Gothic Cathedral (Sala, 2005:320)

One of the examples of self-similar fiction in the Ottoman architecture is Sultan Ahmet Mosque, called also as "Blue Mosque". Different scales and layers of arches' and domes' fiction which are important elements of the period and domes and half domes that form the cover coat creates a self-similar fiction by repeating in different grades and scales (Figure 7). In addition to this, we can see similar fictions in plan scale too (Figure 8) (URL 4).

Figure7. Sultan Ahmed Mosque

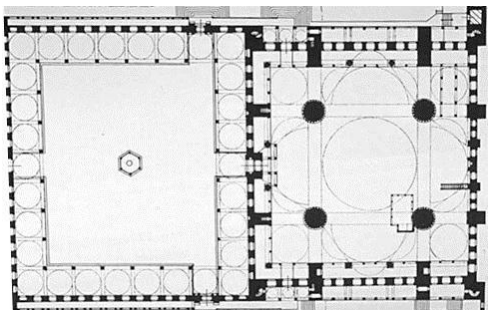


Figure8. Sultan Ahmet Mosque Plan (URL 5)

Figure9.Habitat Housing Group (URL 6)

Figure 10.MIT Dormitories (URL 7)

4.3.7. CALCULATING THE FRACTAL DIMENSION

At the end of the 1980s and in the early 1990s, with "fractal dimension" emerged with different calculation methods, it is seen that structures and surrounding of structures have begun to be analyzed (Ostwald, 2001:78).

Fractal geometry in architecture and architectural design fields is used;

- in the calculation of the fractal value of an existing design and the use of the obtained data as a method for criticism and analysis
- in using the fractal dimension in pre-design and design processes as a method and data.

Fractal dimension can be calculated with various methods.

Self-Similarity Dimension (Ds)
The self similarity dimension method is used if a similar curve is produced from repetitive parts. The measure of self similarity is measured by the relationship between the number of small parts of the original structure and the scale value in all the self similar structures (Bovill, 1996:200.).
$a=1/(s)D=(1/s)D$ (a: number of parts, s: shrinking factor)

Measured Dimension (d)
When using a measured dimension, both the measurement of which measures sequence process and the method used are important. Natural formations such as shorelines are measured through this method (Bovill, 1996:200.).

Box Counting Dimension (Db)
These two methods are not used in calculating the fractal dimension of two-dimensional complex fictions. Usually, since a two-dimensional self similar complex structure does not have a clear repeat, self similarity dimension method becomes useless. In these designs, this method is also dys functional because there are no shoreline-like curves for which measured dimension method can be used (Bovill, 1996:199.).

In this case, the box counting method emerges as the most commonly used mathematical method for computing an approximate fractal dimension of an object-texture. This method is also used in analyzing the fractal dimension of architectural fictions-textures. The box counting method takes into account the richness and repetition of detail in the examined fiction (Bovill, 1996:197).

The steps of applying the method are these:
First step is the creation of the frontal of an architectural structure. (Figure 11)

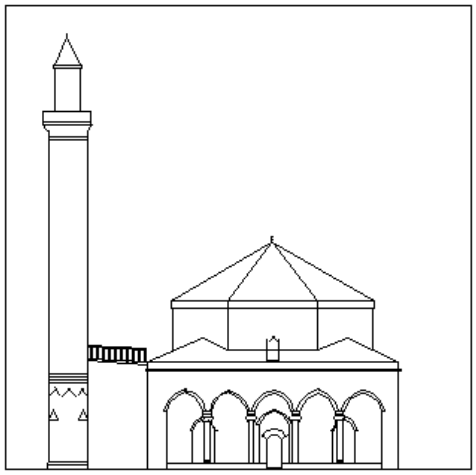


Figure 11. Ali Pasha Mosque Frontal (Diyarbakır)

Then, the two-dimensional drawing of the frontal, the line belonging to the inside of each square which is generated by dividing the grids is controlled. Boxes that have lines inside them are noted down by counting. Then, the same method is continued by gradually shrinking the existing grid system. (Figure 13, 14, 15, 16 and 17) As a result, the number of filledboxes in the first grid and the last grid are compared with the formula below (Ostwald and Vaughan, 2008: 27). Fractal value of everycycle is calculated:
D $=\frac{log(x)-log(y)6}{log(z)-log(q)}$(Bovil, 1996, p.194.)
D: Fractalvalue
x: Number of filledboxescounted in the nextcycle
y: Number of filledboxescounted in the previouscycle

z: Number of boxes in bottomrow in the nextcycle
q: Number of boxes in bottomrow in the previouscycle

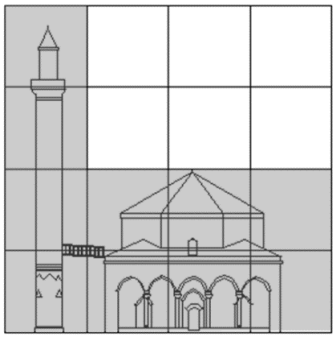


Figure 12. 1st Cycle 4x4

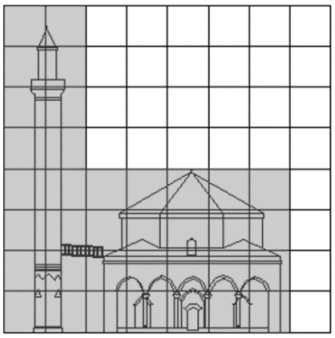


Figure 13. 2nd Cycle 8x8

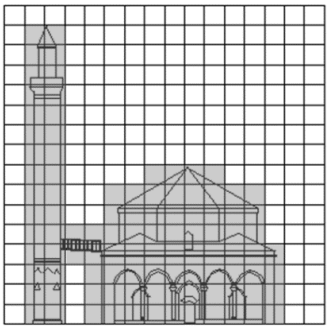


Figure 14. 3rd Cycle 16X16

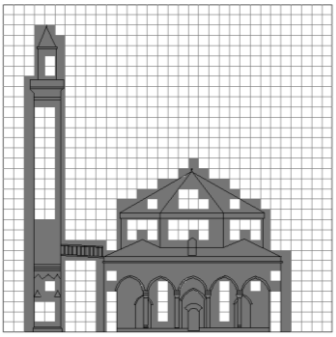


Figure 15. 4th Cycle 32x32

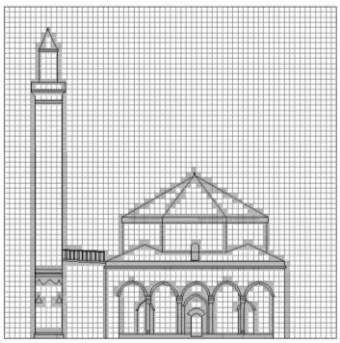


Figure16. 5th Cycle 64x64

Table 2. Number of Boxes in Cycles

Number of cycle	Size of grid	Number of fullboxes	Number of empty boxes
1	4x4	12	4
2	8x8	36	28
3	16x16	100	156
4	32x32	230	794
5	64x64	621	3475

Table 3. ObtainedFractalDimensions

Ali Pasha Mosque				
Cycles	**1-2 Cycles**	**2-3 Cycles**	**3- 4 Cycles**	**4-5 Cycles**
Fractal Dimension	1,6	1,47	1,2	1,43
Average fractal dimension	1,9			

5. RESULTS

Parlı (Safa) Mosque, Lala Kasım (Lale Bey) Mosque, Kasım Padishah (Four-legged Minaret) Mosque ve Nebi (Prophet) Mosque belonging to Akkoyunlu period in Diyarbakır are examined within the scope of the study (Figure 17) (Table 4).

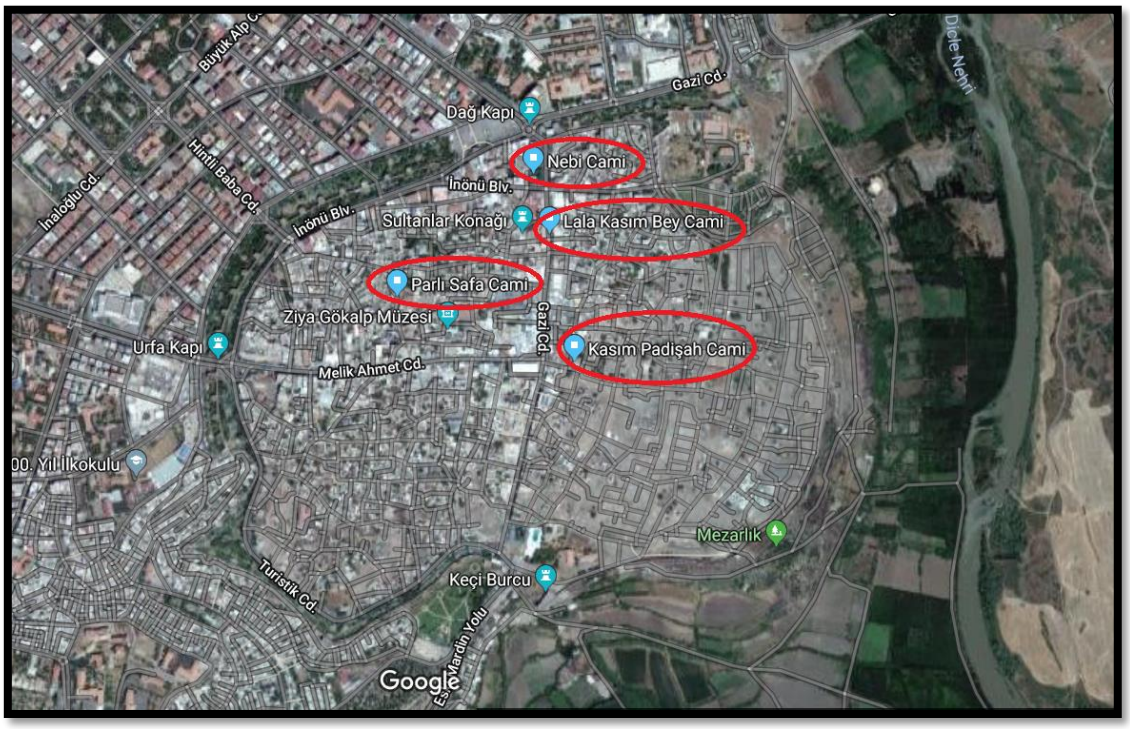


Figure 17. Mosques Belonging to Akkoyunlu Period Chosen within the Scope of the Study (Google Earth, 2018).

Tablo 4. Diyarbakır Mosques and Their Periods within the Scope of the Study

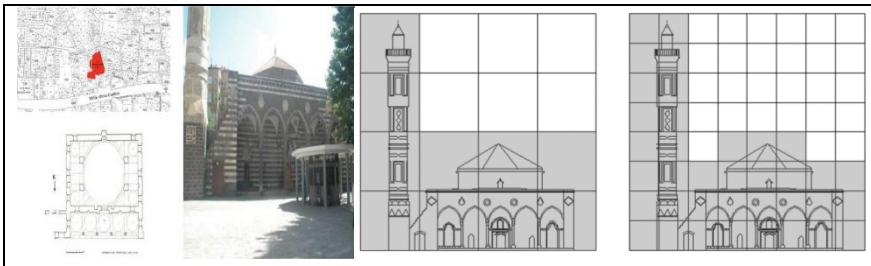
Name of the Mosque	**Date**	**Period**
Parlı (Safa) Mosque	3 rdquarter of the 15th century	Akkoyunlu
Lala Kasım (Lale Bey) Mosque	1st quarter of the 16th century	Akkoyunlu
Kasım Padishah (Four Lagged Minaret) Mosque	- 1500	Akkoyunlu
Nebi (Prophet) Mosque	Beginning of 16th century	Akkoyunlu

5.1. PARLI (SAFA) MOSQUE

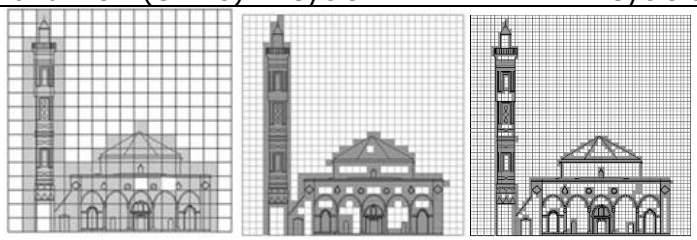
Parla (Safa) Mosque is an artifact belonging to the Akkoyunlu Period in the 3rd quarter of the 15th century. The fractal value calculation for this mosque is as follows (Table 5.)

Table 5. Fractal Value Calculation of Parlı (Safa) Mosque

Name of the Mosque	**Date**	**Period**
Parlı (Safa) Mosque	3rdquarter of the 15th century	Akkoyunlu



Parlı (Safa) Mosque's plan and view (URL 8)1st.Cycle 4x4 2ndCycle 8 x8



3rdCycle 16x16 4thCycle 32x32 5thCycle 64x64

Number of cycle	Size of grid	Number of fullboxes	Number of empty boxes
1	4x4	10	6
2	8x8	37	27
3	16x16	107	149
4	32x32	292	732
5	64x64	818	3278

Number of boxes in cycles				
Parlı (Safa) Mosque				
Cycles	1-2 cycle	2-3 cycle	3-4 cycle	4-5 cycle
Fractal Dimension	1,9	1,53	1,47	1,48
Average Fractal Dimension	1,59			
Obtained Fractal Value				

Calculations of Parlı (Safa) Mosque

(1x2) Cycle

$$\frac{\log(37)-\log(10)}{\log(8)-\log(4)}=\frac{1.57-1}{0.9-0.6}=\mathbf{1.9}$$

(2x3) Cycle

$$\frac{\log(107)-\log(37)}{\log(16)-\log(8)}=\frac{2.03-1.57}{1.2-0.9}=\mathbf{1.53}$$

(3x4) Cycle

AVERAGE: 1.58 $\frac{\log(292)-\log(107)}{\log(32)-\log(16)}=\frac{2.47-2.03}{1.51-1.2}=\mathbf{1.47}$

(4x5) Cycle

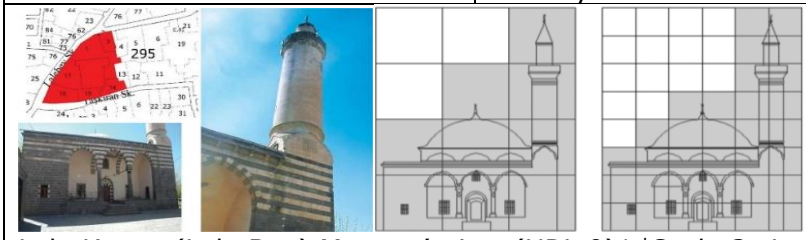
$$\frac{\log(818)-\log(292)}{\log(64)-\log(32)}=\frac{2.91-2,47}{1.81-1.51}=\mathbf{1.46}$$

5.2. LALA KASIM (LALE BEY) MOSQUE

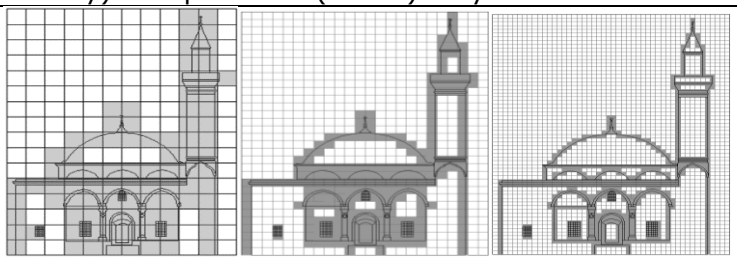
Lala Kasım (Lale Bey) Mosque is an artifact belonging to the Akkoyunlu Period in the 1stquarter of the 16th century. The fractal value calculation for this mosque is as follows (Table 6).

Table 6. Fractal Value Calculation of Lala Kasım (Lale Bey) Mosque

Name of the Mosque	**Date**	**Period**
Lala Kasım (Lale Bey) Mosque	1st quarter of the 16th century	Akkoyunlu



Lala Kasım (Lale Bey) Mosque'sview (URL 9)1st Cycle 3x4 2nd Cycle 6 x8



3rd Cycle 12x16 4th Cycle 24x32 5th Cycle 48x64

Number of cycle	**Size of grid**	**Number of full boxes**	**Number of empty boxes**
1	3x4	9	3
2	6x8	34	14
3	12x16	89	103
4	24x32	238	530
5	48x64	602	2470

Number of boxes in cycles

Lala Kasım (Lale Bey) Mosque

Cycles	1-2 cycle	2-3 cycle	3-4 cycle	4-5 cycle
Fractal Dimension	1,93	1,4	1,43	1,33
Average Fractal Dimension	1,52			

ObtainedFractal Value

Calculations of Lala Kasım (Lale Bey) Mosque

(1x2) Cycle

$$\frac{\log(34)-\log(9)}{\log(6)-\log(3)}=\frac{1.53-0.95}{0.78-0.48}=\mathbf{1.93}$$

(2x3) Cycl e

$$\frac{\log(89)-\log(34)}{\log(12)-\log(6)}=\frac{1.95-1.53}{1.08-0.78}=\mathbf{1.4}$$

(3x4) Cycle **AVERAGE:**

1.52 $\frac{\log(238)-\log(89)}{\log(24)-\log(12)}=\frac{2.38-1.95}{1.38-1.08}=\mathbf{1.43}$

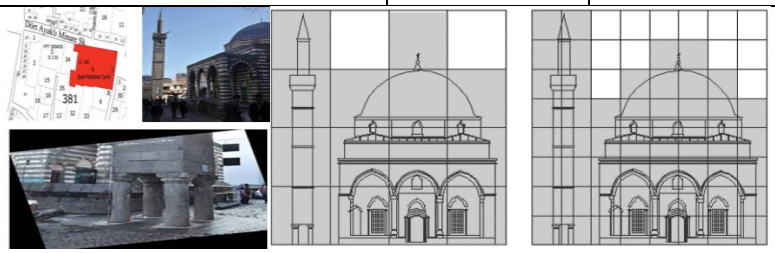
(4x5) Cycle $\frac{\log(602)-\log(238)}{\log(48)-\log(24)}=\frac{2.78-2.38}{1.68-1.38}=\mathbf{1.33}$

5.3. KASIM PADISHAH (FOUR-LEGGED MINARET) MOSQUE

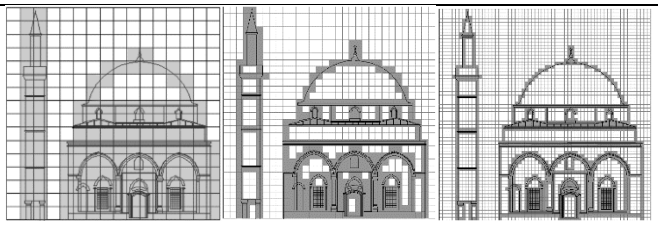
Kasım Padishah (Four-legged Minaret) Mosque is an artifact belonging to the Akkoyunlu Period in 1500s. The fractal value calculation for this mosque is as follows (Table 7.)

Table 7. Fractal Value Calculation of Kasım Padishah (Four-leggedMinaret) Mosque

Name of the Mosque	**Date**	**Period**
Kasım Padishah (Four-leggedMinaret) Mosque	1500's	Akkoyunlu



Kasım Padishah (Four-leggedMinaret) Mosque (URL 10) 1stCycle 4x4 2ndCycle 8 x8



3rdCycle 16x16 4th Cycle 32x325thCycle 48x64

Number of cycle	**Size of grid**	**Number of fullboxes**	**Number of emptyboxes**
1	4x4	14	2
2	8x8	52	12
3	16x16	151	105
4	32x32	397	627
5	64x64	854	3342

Number of boxes in cycles

Kasım Padishah (Four-leggedMinaret) Mosque				
Cycles	1-2 cycle	2-3 cycle	3-4 cycle	4-5 cycle
FractalDimension	1,9	1,54	1,4	1,1
AverageFractalDimension	1,49			
ObtainedFractal Value				

Calculations of Kasım Padishah (Four-leggedMinaret) Mosque

(1x2) Cycle $\frac{\log(52)-\log(14)}{\log(8)-\log(4)} = \frac{1.72-1.15}{0.9-0.6} = \mathbf{1.9}$

(2x3) Cycle $\frac{\log(151)-\log(52)}{\log(16)-\log(8)} = \frac{2.18-1.72}{1.2-0.9} = \mathbf{1.54}$

(3x4) Cycle **AVERAGE: 1.49**

$\frac{\log(397)-\log(151)}{\log(32)-\log(16)} = \frac{2.6-2.18}{1.51-1.2} = \mathbf{1.4}$

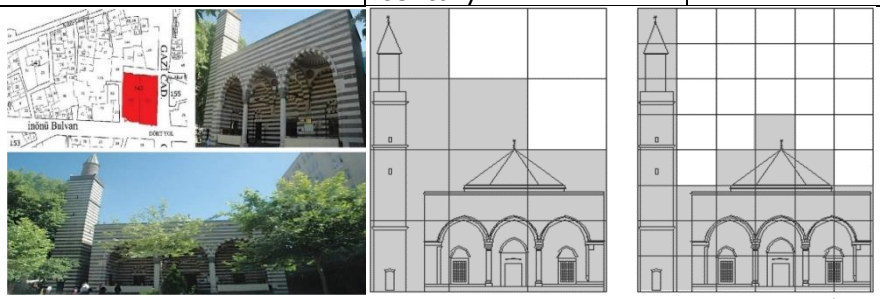
(4x5)Cycle $\frac{\log(854)-\log(397)}{\log(64)-\log(32)} = \frac{2.93-2.6}{1.81-1.51} = \mathbf{1.1}$

5.4. NEBI (PROPHET) MOSQUE

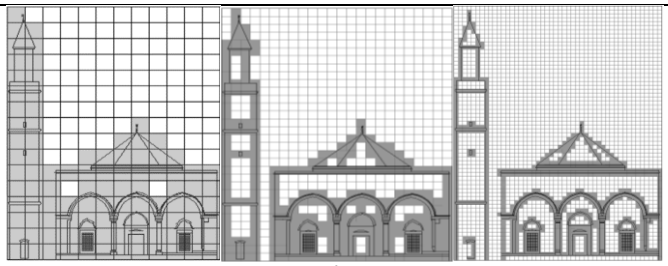
Nebi (Prophet) Mosque is an artifact belonging to the Akkoyunlu Period at the beginning of 16th century. The fractal value calculation for this mosque is as follows (Table 8.)

Table 8. Fractal Value Calculation of Nebi (Prophet) Mosque

Name of the Mosque	**Date**	**Period**
Nebi (Prophet) Mosque	Beginning of 16th century	Akkoyunlu



Nebi (Prophet) Mosque'sview (URL 11)1st Cycle 3x4 2nd Cycle 6 x8



3rd Cycle 12x16 4th Cycle 24x32 5th Cycle 48x64

Number of cycle	**Size of grid**	**Number of fullboxes**	**Number of emptyboxes**
1	3x4	9	3
2	6x8	27	21
3	12x16	99	93
4	24x32	278	490
5	48x64	731	2341

Number of boxes in cycles				
Nebi (Prophet) Mosque				
Cycles	1-2 cycle	2-3 cycle	3-4 cycle	4-5 cycle
FractalDimension	1,8	1,9	1,48	1,4
AverageFractalDimension	1,59			
ObtainedFractal Value				

Calculations of Nebi (Prophet) Mosque

(1x2) Cycle $\frac{\log(27)-\log(9)}{\log(6)-\log(3)} = \frac{1.43-0.95}{0.78-0.48} = \mathbf{1.6}$

(2x3) Cycle $\frac{\log(99)-\log(27)}{\log(12)-\log(6)} = \frac{2-1.53}{1.08-0.78} = \mathbf{1.9}$

(3x4) Cycle **AVERAGE: 1.59**

$\frac{\log(278)-\log(99)}{\log(24)-\log(12)} = \frac{2.44-2}{1,.8-1.08} = \mathbf{1.46}$

(4x5) Cycle $\frac{\log(731)-\log(278)}{\log(48)-\log(24)} = \frac{2.86-2.44}{1.68-1.38} = \mathbf{1.4}$

The fractal values which are obtained as a result of these fractalcal culations vary between 1.43 and 1.6. According to calculations, fractal dimensions are as follows (Table 9.).

Table 9. Fractal dimensions of mosques belong to Akkoyunlu Period in Diyarbakır

Name of the Mosque	**Average Fractal Dimension**
Parlı (Safa) Mosque	1.58
Lala Kasım (Lale Bey) Mosque	1.52
Kasım Padishah (Four-legged Minaret) Mosque	1.49
Nebi (Prophet) Mosque	1.59

6. CONCLUSION

When mosques are evaluated within the scope of "When the value is near 1, it is regarded as a sign for simplicity and regarded as a sign for complexity when the value is near 2" (Bovil, 1996:198) statement, it can be said that Kasım Padishah (Four-legged Minaret) Mosque is the simplest (1.49) and Nebi (Prophet) Mosque is the most complex (1.59) one in terms of frontals.

These mosques, their fractal dimensions of which are calculated with box counting method, Parlı (Safa) Mosque, Lala Kasım (Lale Bey) Mosque, Kasım Padishah (Four-legged Minaret) Mosque ve Nebi (Prophet) Mosque belong to Akkoyunlu Period. Having quite close fractal dimensions in Parlı (Safa) Mosque (1.58), Lala Kasım (Lale Bey) (1.52) Mosque, Kasım Padishah (Four-legged Minaret) (1.49) Mosque ve Nebi (Prophet) (1.59) Mosque supports the statement of "There is a common sense of being similar and composition unity in architectural elements of Akkoyunlu structures" (Doğan and Doğanay, 2017: 659.). The Ottomans benefited from Akkoyunlu Mosques in Diyarbakir. The mosque form of Akkoyunlular developed in its own conditions in that region, found its balance and could be continued in the new period; that is, these constructions of Akkoyunlu period were interpreted in Ottoman architecture. Lala Kasım (Lale Bey) Mosque is stated as a good examplefor the intersection of the regime change (Tuncer, 1996:35.). In the same way, this mutual interaction also exists in the Nebi (Prophet) Mosque, which was built at the end of the Akkoyun period and in the first years of the Ottoman Empire. It is also said that Parli (Safa) Mosque, an Akkoyunlu Mosque, is pioneer to the type of plans develope dby Sinan the Architect in the architecture of the Ottoman Mosques (URL 12). The closeness of the fractal dimensions that are concluded as a result of the calculations in these mosques belonging to Akkoyunlu period supports this mutual interaction.

With this study, it is thought that calculation of numeric possibilities based on fractal dimension can form a mathematical analysis method by using it in architecture field, besides intuitive facts. It has been observed that the concept of Fractal Dimension can be used as a method in architectural analysis besides measuring objects and structures in non-Euclidean geometry. As a result of the analyses, the intuitive facts on the frontals of the Diyarbakır Mosques were analyzed mathematically, and the structures were examined together with their architectural periods and characteristics. Through the analysis, similarities and interactions between different styles are revealed.

In the study, fractal geometry and fracta ldimension were used to support the numerical data in the literature. However, the fractal geometry and fractal dimension can be used for different purposes, such as designing a new fiction by using existing principles in a fractal design. In this study, fractal dimension calculations made by box counting method can be performed more comprehensively with advanced computer technologies. These existing possibilities can be developed to analyze larger structures in a more comprehensive way.

As a result, fractal geometry and fractal dimension can be used to numerically analyze and evaluate existing intuitive data, to contribute to the design as a supportive method

and to examine textures, buildings, even cities. Through this study, it is seen that the characteristics of these mosques belonging to their periods and the interactions of these periods can be supported with numerical data with data that are discerned intuitively and already existing in literature belonging to Diyarbakır Mosques. It is thought that the studies which combine different fields such as mathematics, geometry and architecture, can provide us with different perspectives.

The fractal method can be used in order to analysis the facades of buildings with numerical system. And also some values can be obtained by the directions and build period of them.

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