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An Interface Design for Calculation of Fractal Dimension

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ABSTRACT Partially insufficient is the modelling of irregular and complex forms using Euclidean geometry. On the other hand, fractal geometry allows irregular complex forms and structures to be expressed in mathematical terms. While fractal geometry appears to be irregular in nature, when analyzed, it is the structures in which a regular form is replicated throughout the picture. The fractal dimension is a numerical value of that form, showing the levels of complexity of shapes or objects in nature. It appears as the signature of many things. The method used in this analysis when measuring the fractal dimension is the method of box counting. It appears as the signature of many things. The method used in calculating the fractal dimension in this study is the method of box counting. A user-friendly interface is developed using the MATLAB GUI to more easily investigate and analyse biological, medical, architectural, geographical, astronomical etc. images of this method. The fractal dimension can be easily calculated by the user-friendly interface.

KEYWORDS
Fractal Geometry
Fractal Dimension Calculator
Box-Counting Dimension Method
User Interface

INTRODUCTION

The shapes commonly used in Euclidean geometry are integers such as 1, 2 or 3. These shapes are like line, circle, triangle, polygon, cone, cylinder. However, with the Euclidean geometry, it is not possible to express the complex structures in nature mathematically İlhan (2019); Uyar and Öztürk (2017). As a reason, it is not a realistic approach to try to express the shapes or objects that exist in nature with mathematically lines, square, rectangular, circle, and sphere geometry with smooth shapes. Unlike the forms of Euclidean geometry, the fractal geometry developed to describe nature better; includes recessed, jagged, twisted, fragmented, complex shapes Genç (2019). For instance there is no sphere-shaped cloud or cone-shaped mountain on earth. Therefore, new methods of defining and modelling forms that do not fit Euclidean geometry are needed Uyar and Öztürk (2017); Ufuktepe and Aslan (2002). The concept of Fractal geometry was introduced by Mandelbrot to model shapes that do not fit Euclidean geometry. The term fractal is a Latin word and means fragmented, divided and broken Genç (2019). Fractal is a general name given to complex shapes with the ability to repeat or resemble itself, in the field of mathematics. Defines the term fractal as a shape consisting of whole-like parts. For this reason, when looking at the overall shape, there are similar structures in the shape. Consequently, the shape pieces in a fractal structure are identical to each other and to the whole shape. As a result, fractal can be considered as duplicates of this similarity Genç (2019); Erdoğan (2017). Although there are repeating structures in fractal geometry, these structures may have a feature that is constantly growing or shrinking Falconer (2004). In this case, the concept of fractal dimension comes up there. Each small piece is a copy of the whole piece or the like. The fractal dimension shows a measure of self-similarity Erdoğan (2017); Brown and Liebovitch (2010).

Fractals can be formed by repeating geometries that have a similar shape, as well as repeating geometries with shapes that are not randomly similar to them. In this case, fractal structures are divided into different categories Genç (2019). Fractals are divided into three categories: self-similarity, semi self-similarity and statistical similarity Yılmaz (2013). Fractal shapes with a geometric structure formed by random repetition are usually found in nature. But these repetitions have a limit Sertöz (1996).

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Fractal geometry is used in many fields from medicine, economy, biology, engineering, architecture, music, astronomy, geography, physics to art. Especially the fact that an object is composed of parts that are the same as a whole or the irregularity of the whole can be noticed by careful consideration. For example, when the coastline of the land is examined, there are recesses and protrusions in any part of the coast, just like in the whole Uyar and Öztürk (2017). Fractal structures such as this are rivers, rivers, clouds, branching of trees Genç (2019), leaf patterns Genç (2019), snowflakes Genç (2019), capillaries, lung bronchi, faults ÖNCEL and ALPTEKİN (1995), turbulent flow Cınbarcı (2016), nerve fibers Genç (2019) or hurricane Genç (2019) etc. examples can be given ÖNCEL and ALPTEKİN (1995).

When looking at the application areas, fractals are used in a very wide range. Uyar et al. they used fractal geometry in the study of landforms Uyar and Öztürk (2017). Bayrak et al. in their study, they performed fractal analysis on thyroid ultrasound images Kırcı and Bayrak (2019). Li et al. performed fractal analysis using the box counting technique for the iris recognition process Yu *et al.* (2005). Sezer et al. measured the strength of some materials using fractal analysis Sezer *et al.* (2007). Oncel et al. investigated seismic activity in fault lines by fractal analysis for earthquake research ÖNCEL and ALPTEKİN (1995). Erdogan et al. used fractal analysis to analyze financial data Erdoğan (2017). Ge, on the other hand, made a Phd study on fractal geometry, which is also one of the fields of art, effective in the ceramic department Genç (2019). In addition, there are many studies in the literature regarding the use of fractal geometry in the study of architectural structures Alik (2015); Ediz and ÇAĞDAŞ (2010a); Değirmenci (2009).

In recent years, interface programs have been widely used in education, research and development or preparing toolboxes to speed up and facilitate operations. There are many literature studies prepared with MATLAB Guide User Interface (GUI) used for the development of interfaces Vardhana *et al.* (2018); Kis *et al.* (2019); Hanhan and Sangid (2019); Pham *et al.* (2019); Jara-Muñoz *et al.* (2019); Huang (2019); Folch-Fortuny *et al.* (2016); González-Martínez *et al.* (2018); Calusdian and Yun (2019); Mazivila *et al.* (2018); Elwaseif *et al.* (2017); Fidan *et al.* (2019); Boz and Çimen (2017). When these studies are examined, it is seen that MATLAB program is one of the basic tools in designing interfaces. Since the MATLAB GUI program uses the advanced analysis and graphics features of MATLAB, they have a very flexible and useful structure. The MATLAB program can communicate with different programs, as well as allowing many toolboxes to be used in the background Arifoğlu (2013).

A user-friendly interface has been built in this study to perform the calculation of a desired image by fractal dimension. Using the developed interface, biomedical, medical, astronomical, artistic, geological, biological, engineering, architecture etc. Thanks to the user-friendly interface, the fractal size obtained in the studies will be easily calculated and displayed.

MATERIAL AND METHOD

Fractal geometry is an approach used to recognize, model and analyze complex objects in nature Ediz and ÇAĞDAŞ (2010b). The development of new measurement methods, called fractal analyzes, has been on the strategy with the emergence of fractal geometry Yılmaz (2013); Ediz and ÇAĞDAŞ (2010b). Fractal analysis made it possible to examine not only the shapes of shapes or objects, but also systems and processes Erdoğan (2017). Therefore, the numerical values produced using fractal analysis provide information about the complexity levels of events in nature. Some fractal structures that are produced in computer environment and exist in nature are given in Figure 1-11 Genç (2019); Cınbarcı (2016); Alik (2015); Ediz and ÇAĞDAŞ (2010a); Değirmenci (2009). In the images from Figure 1-12, fractal structures are repeated iteratively according to the specific rule. These fractal structures are interwoven, created by simple rules. The pictures in Figure 8-10 are fractal structures in nature. In addition to these, there are fractal structures in digital media. An example of these structures are the images in Figure 11 and Figure 12. In addition, the flow diagram is given in Figure 13 in order to better understand the processing steps in the fractal dimension calculation.

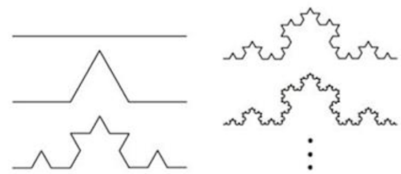

Figure 1 Koch spline Genç (2019); Alik (2015); Ediz and ÇAĞDAŞ (2010a); Değirmenci (2009)

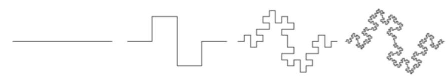

Figure 2 Minkowski spline Alik (2015)

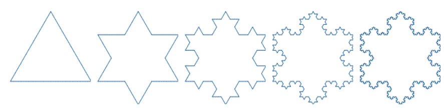

Figure 3 Koch snowflake Genç (2019); Alik (2015)

Image Processing

For the calculation of the fractal dimensions to be applied, the image has to be converted to binary format, which is two levels. Because of this, the image that has been obtained should be converted from RGB form to gray format and then to binary format Cimen *et al.* (2018); Solomon and Breckon (2011); Çimen *et al.* (2018); Gonzalez *et al.* (2004). There are different ways in which the image is converted from RGB to gray. The first is done on equality 1, whereas the second is achieved on equality 2.

$$I[m,n] = \frac{I[m,n,1] + I[m,n,2] + I[m,n,3]}{3} \tag{1}$$

$$\begin{aligned} I[m,n] &= 0.2989 \times I[m,n,1] + 0.5870 \times I[m,n,2] \\ &+ 0.1140 \times I[m,n,3] \end{aligned} \tag{2}$$

Conversion of the image to binary format is done with the equation in equation 3 Cimen *et al.* (2019). In this study, since the gray levels of the images are between 0-255, the threshold value was chosen as 128.

$$y[m,n] = \begin{cases} 1 & y[m,n] \geq Threshold \\ 0 & y[m,n] < Threshold \end{cases} \tag{3}$$

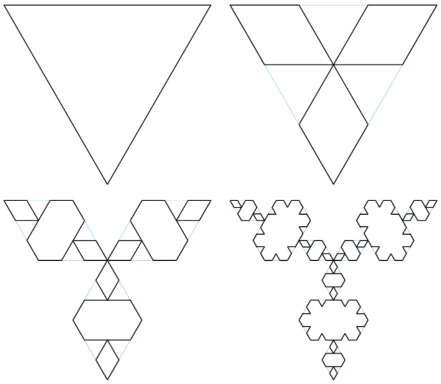

Figure 4 Inversed Koch snowflake Genç (2019); Alik (2015)

Figure 5 Cantor cloud Genç (2019); Alik (2015)

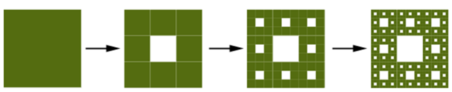

Figure 6 Sierpinski spline Alik (2015)

Figure 7 Sierpinski triangle Genç (2019); Alik (2015)

Figure 8 Broccoli and barnsley leaf Cınbarcı (2016); Alik (2015); Ediz and ÇAĞDAŞ (2010a)

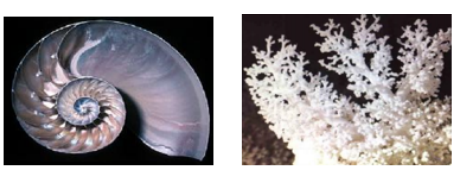

Figure 9 Snail shell and lung airways Alik (2015); Ediz and ÇAĞDAŞ (2010a); Değirmenci (2009)

Figure 10 Turbulances in fluids Genç (2019); Cınbarcı (2016)

Figure 11 Digital fractal structures Alik (2015); Değirmenci (2009)

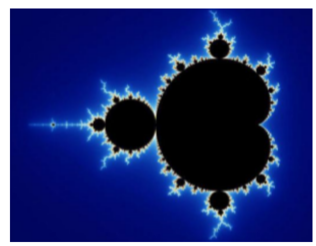

Figure 12 Mandelbrot Set Genç (2019); Cınbarcı (2016); Alik (2015); Değirmenci (2009)

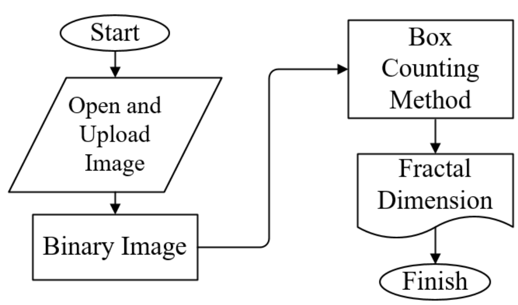

Figure 13 Flow chart of process

Box Counting Method

Box counting is a method used to calculate fractal dimension. In this method the number of pieces is calculated as much as the number of boxes that are needed to fully scan a shape. In practice the area of the standard boxes placed on the object covering the object is determined by counting. The calculation of the fractal dimension is based on the gradient (change) of box sizes. This method has begun to be developed by counting fully or partially filled cells. This method is applied in the study, the partially filled boxes used were counted. Fractal size analysis is performed by counting the boxes on the image and applying it to equation 4. N_i used in Equation 5; ith iteration is the number of filled boxes that partially or completely cover the shape on the object or image by dividing the image into boxes.

$$D_{i+1,i} = \frac{log_2(N_{i+1}) - log_2(N_i)}{log_2(2^{i+1}) - log_2(2^i)} \tag{4}$$

The locations of the boxes obtained according to the iterations on the image, the numbers and the fractal dimensions of the boxes are given in Figures 14 and 15. As in 1, 2 and 3 iterations the fractal dimensions of the binary image given as an example is in the objects, empty boxes are counted as 0. In the 3th iteration, empty boxes are formed, which are drawn in white squares as the box size is reduced. While the number of empty boxes is 4, the number of full boxes is 60. In Figure 15, it can be seen that the box

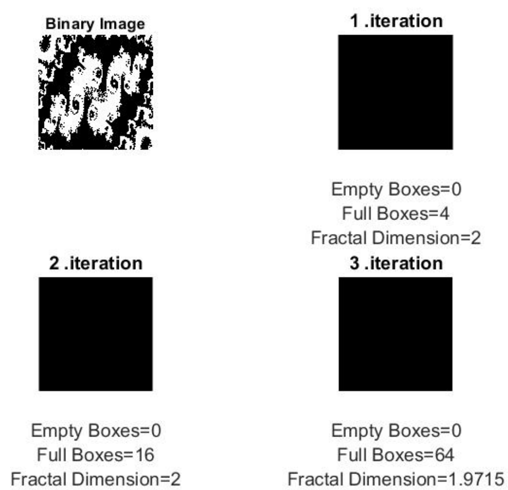

Figure 14 Number of boxes counted and Fractal dimensions for 1-3th iterations

size shrank even more in the 4th iteration The details become more clearly evident in the binary image. Images of filled and empty boxes calculated in iterations 4, 5, 6 and 7 are given in Figure 10. Table 1 is given for the number of full and empty boxes obtained from iterations.

As can be seen from Table 2, when the numbers of filled and empty boxes obtained from iterations are substituted in equation 5, fractal dimensions are obtained for each iteration. In this study, the fractal dimensions obtained for only 7 iterations of the selected image are calculated in order to reduce the processing load and give more importance to the visuality.

MATLAB GUI INTERFACE

Matlab GUI provides the opportunity to prepare an interface that users can use easily for purposes such as increasing the clarity,

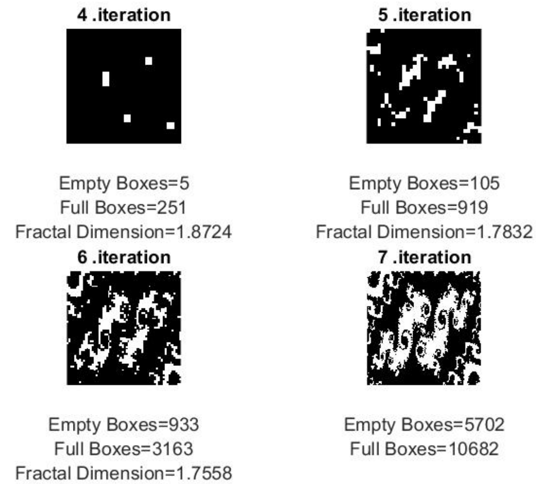

Figure 15 Number of boxes counted and Fractal dimensions for 4-7th iterations

visualizing the data by facilitating the operations. The interfaces prepared enable the processing and visualization of the data in an interactive way with the user, so that many operations can be carried out quickly. For this reason, the interfaces prepared are widely used in computer assisted education, research and development. There are two stages in interface preparation. In the first stage, it is the interface that the user will use directly. The interface draft is created by moving the items to the screen opened as in Figure 16. The second stage is the user event functions in which the operations that are requested by the user in relation to the items are performed. Although these functions are .m files, they are the part that the user who wants to perform or calculate against each event on the interface is not directly seen by the user.

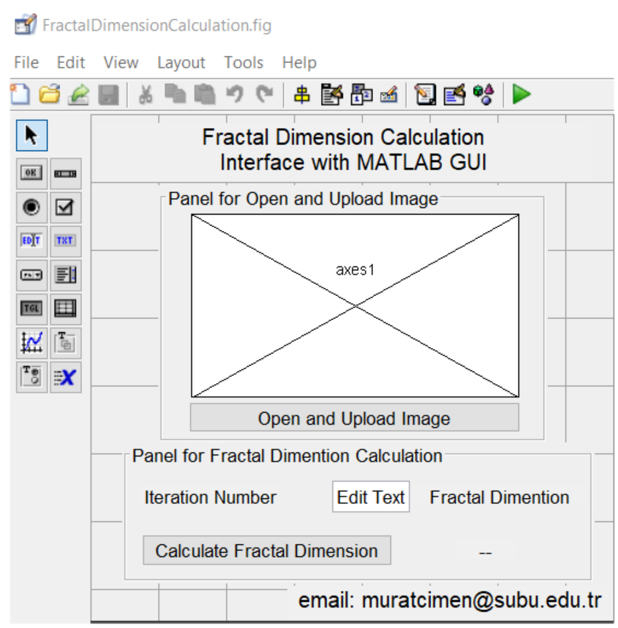

Figure 16 Matlab GUI Interface preparing

Table 1 Number of counted Boxes for each iteration

Iteration Number (N)	Number of Empty Boxes	Number of Full Boxes
1. Iteration (N1)	0	4
2. Iteration (N2)	0	16
3. Iteration (N3)	0	64
4. Iteration (N4)	5	251
5. Iteration (N5)	105	919
6. Iteration (N6)	933	3163
7. Iteration (N7)	5702	10682

Table 2 Fractal dimension calculation each iteration

$$D_{2,1} = \frac{log_2(16) - log_2(4)}{log_2(2^2) - log_2(2^1)} = 2$$

$$D_{3,2} = \frac{log_2(64) - log_2(16)}{log_2(2^3) - log_2(2^2)} = 2$$

$$D_{4,3} = \frac{log_2(251) - log_2(64)}{log_2(2^4) - log_2(2^3)} = 1.9715$$

$$D_{5,4} = \frac{log_2(919) - log_2(251)}{log_2(2^5) - log_2(2^4)} = 1.8724$$

$$D_{6,5} = \frac{log_2(3163) - log_2(919)}{log_2(2^6) - log_2(2^5)} = 1.7832$$

$$D_{7,6} = \frac{log_2(10682) - log_2(3163)}{log_2(2^7) - log_2(2^6)} = 1.7554$$

When the developed interface works, the screen opens as in Figure 18. The screen that opens works as shown in Figure 17 according to the flowchart. After starting the program, it is checked whether "Open and Upload Image" button is pressed to load the image as in the first comparison. In the second comparison, it is checked whether the "Calculate Fractal Dimension" button is pressed to calculate the Fractal Dimension. If pressed, the value of the fractal dimension is calculated by the box counting method according to the number of iterations on the screen, and then it is displayed. The result of a sample application is given in Figure 19.

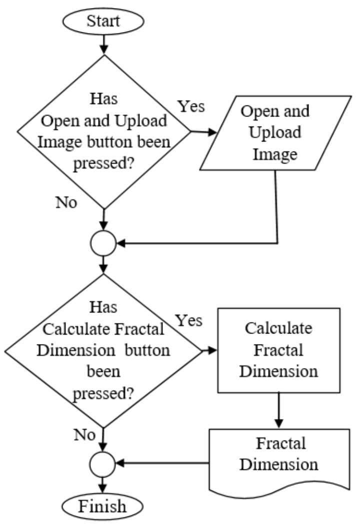

Figure 17 Flow Chart of Fractal Dimension Calculation Interface Program

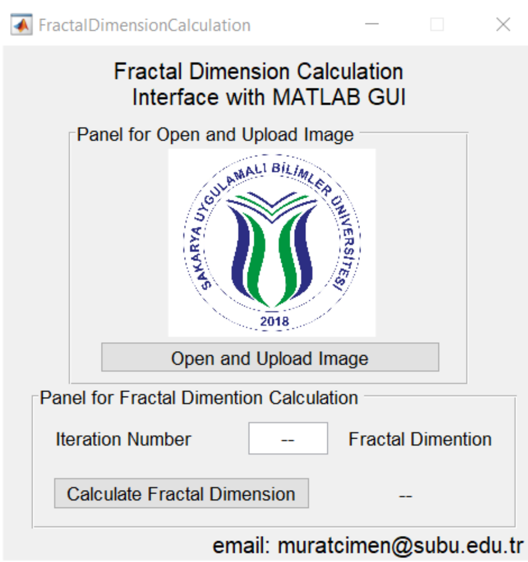

Figure 18 Matlab GUI Interface

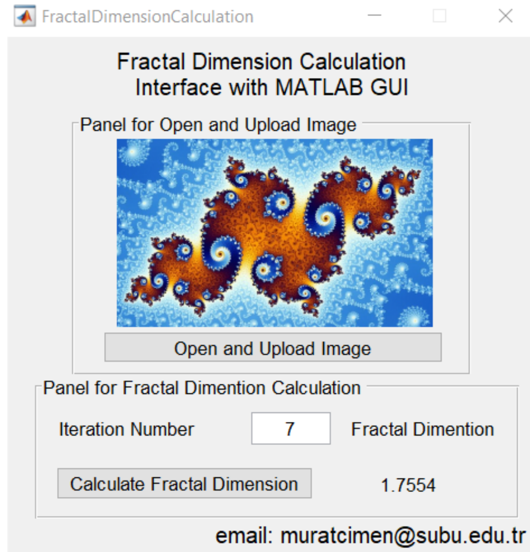

Figure 19 Matlab GUI Interface calculated a fractal dimension of a sample image

CONCLUSION

In this study, an interface design has been realized in MATLAB GUI program in order to calculate the fractal size of a desired image. To calculate the fractal dimension the desired image is added to the screen in this interface program. Then it provides calculation of the image's fractal dimension. Thanks to the user-friendly interface created, it has allowed the examination of the image to be analyzed in many fields from medicine to biology, architecture to geology, engineering to art. This study benefits both education, research and development.

Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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