

Fractal Analysis of geomorphologic processes in the Linux environment using SCILAB

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Summary

The coastlines, lakeshores and natural drainage systems are the result of geomorphologic events that cannot be quantified through the simple geometry that describes a plan, a cone, a direct line or a point. The description of its alone levels of complexity can be described through a new geometry whose theoretical concepts examine the same nature of the dimensionality of an object. The Linux platform possesses all the characteristics of a stable necessary system to carry out a fractal analysis of these structures using tools of free code as Scilab. This article presents the application of the box - counting method, for the calculation of the fractal dimension of a coastal line through this free code.

Introduction

Phenomena exist in the nature that can be described, using the concepts of the Euclidean Geometry, the Calculation and the Trigonometry. These concepts are described in terms of points, circles, right lines, parabolic and other simple curves; this way, the man has learned how to see the world through the points whose dimension is equal to zero, the dimension lines one, the flat (squares and circles) objects of dimension two, and the cubic or spherical objects of dimension three. However, these mathematical concepts cannot describe the nature of an irregular body; in a more general way, of everything that possesses discontinuity or ruggedness. This fact indicates that for example, the mountains and the coastlines cannot be described by simple cones and circles, respectively. To describe the complexity of the world then, it is necessary to create a mathematical new language on the irregular thing. This work was carried out by the Polish mathematician B. B. Mandelbrot (1967) when studying the irregularity of the coast west of Great Britain, being based on the experimental results of L. F. Richardson. In this work he reached the conclusion that the measured distances of the coasts and other geographical borders depend on the scale of having measured since when measuring the longitude of a coast using segments of same longitude, it is noticed that when diminishing the size of the used segment, the

longitude of the coast increases. The analysis of the dataset gathered in the works of Richardson bore to define a potential falling relationship between the longitude of the coast and the longitude of the used segment, and whose value of the power provides information then with respect to the dimension of the coastline that for the case of that coast of Great Britain, it was of 1,25. This result agrees with the fact that its dimension should be bigger than 1 since this natural structure doesn't correspond to a regular curve and on the other hand, it should be inferior at 2, because the same one, doesn't occupy a total surface.

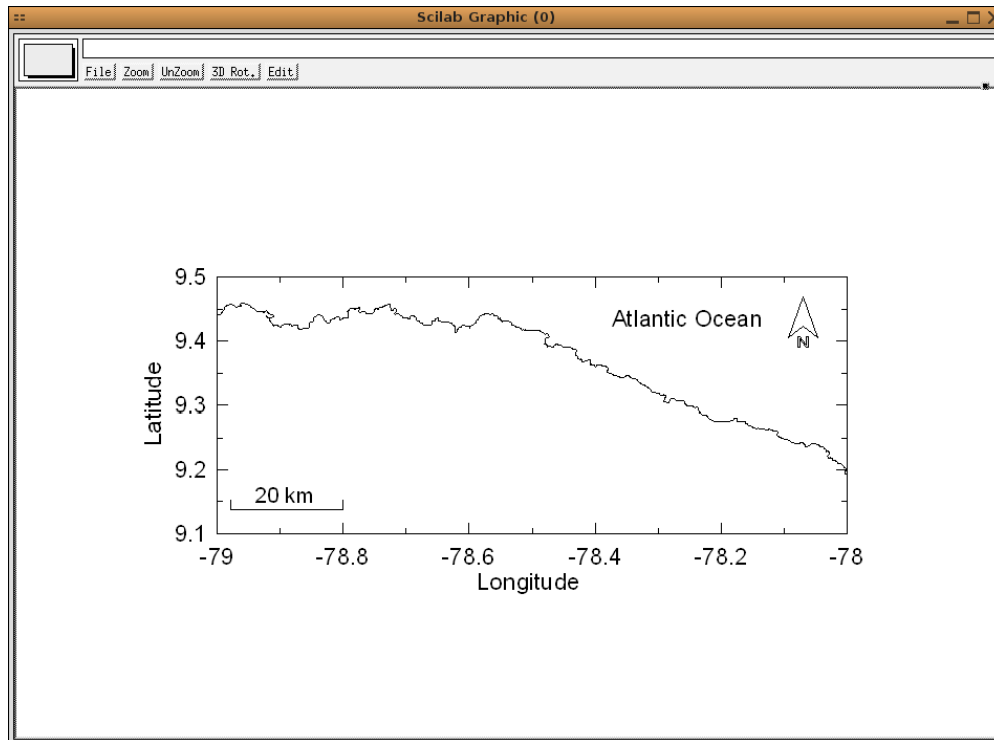
These natural structures whose dimensions correspond to fractional values are known with the name "*fractals*," and the same ones also possess another important characteristic: they are similar to different scales; this means that one part of the group resembles each other to everything, indeed. The dimension of these natural structures, well-known with the name of *fractal dimension* allows us to measure the irregularity of the same ones, that is to say, their effectiveness of occupying the space. The fractal dimension of some natural structures as the coastlines, lakeshores, or a natural drainage systems, which are the product of geomorphologic processes can be calculated, using some methods like the one of segment (previously described in the work of Mandelbrot) and the box – counting, which will be mentioned later on, and it is the object of this work.

Linux is a similar operating system to Unix for personal computers, distributed in a free and independent way that supports a wide spectrum of applications or programming packages. The versatility of this platform in fractal analysis has been reported by some authors (Gangé, 2002). Knowing the main characteristics of the Linux atmosphere, as its stability before the execution of simultaneous several applications, compatibility and connectivity (just to mention some); we intend to calculate the fractal dimension of a coastline of the Isthmus of Panama (Central America) using a Scilab code, based on the box – counting method.

Study of a coastline as a result of a geomorphologic process

A coastline is the result of certain geomorphologic processes, that is to say that it is a universal characteristic of the terrestrial landscape. These processes give place to the fact that a coastline presents certain grade of complexity, and as a result, a small portion of the same one, can be considered as an image to scale completely reduced, if it is about speaking in statistical terms. Due to this peculiar characteristic of these natural forms, the same ones can be described through the Fractal Geometry.

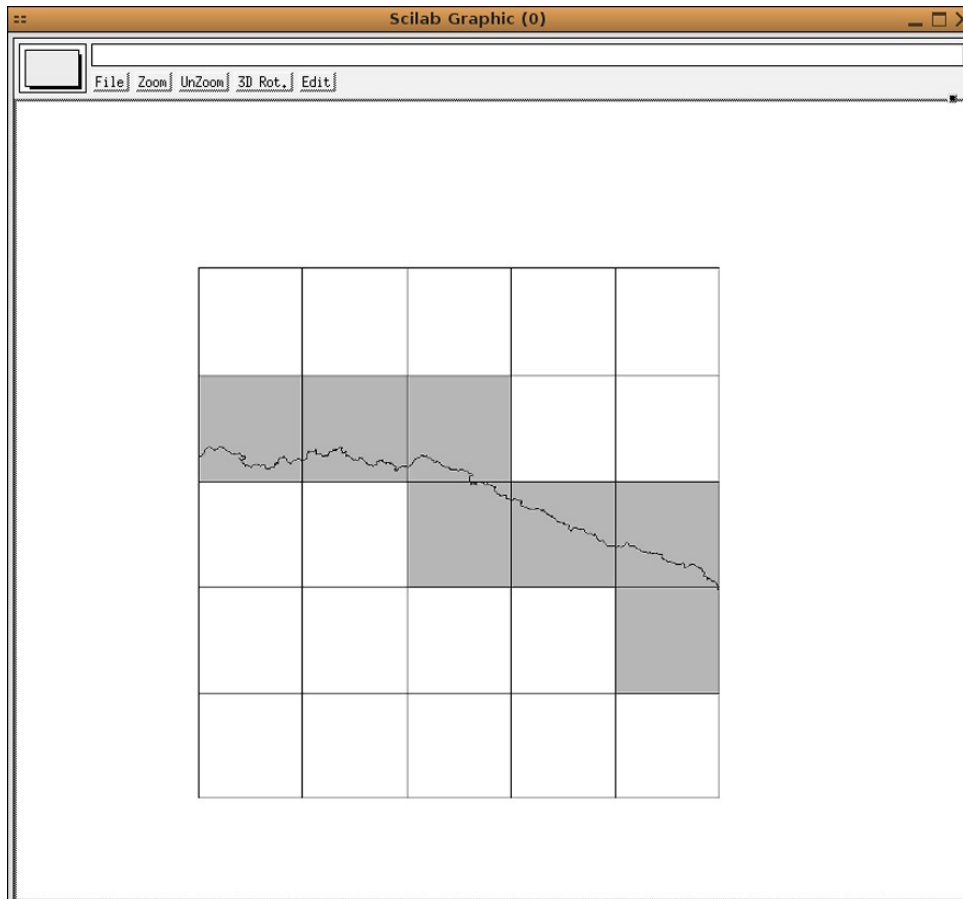
An example of this fact illustrates the coastline of the oriental section of the Isthmus of Panama (Central America), which is part of a volcanic formation. This coastline was discharged of the National US Geophysical Data Center website (NGDC.)



Figures 1 Digital Map of the oriental area of Panama (1:250 000) that shows a coastal extracted line from the website of NGDC, National US Geophysical Data Center.

The box – counting method

One of the methods more used nowadays to carry out a fractal analysis of geomorphologic processes is the box - counting one (Turcotte, 1997). This method consists on superimposing the image of a coastline for example with a mesh of square boxes (it is normal to use diverse meshes with boxes of different size). Then, the number of boxes N of lineal dimension r is counted that contain the image under study. The repetition of this process for other meshes of different sizes in r will generate a dataset of N versus r that when representing them in a double log graph, it will give a direct line whose slope will correspond to the value of the fractal dimension (D), of the natural image that one studies, as a result. The previous thing mentioned obeys the concept of fractal set where: $N = c / r^D$, where c , corresponds a constant of proportionality and D , the fractal dimension of the natural structure under study.

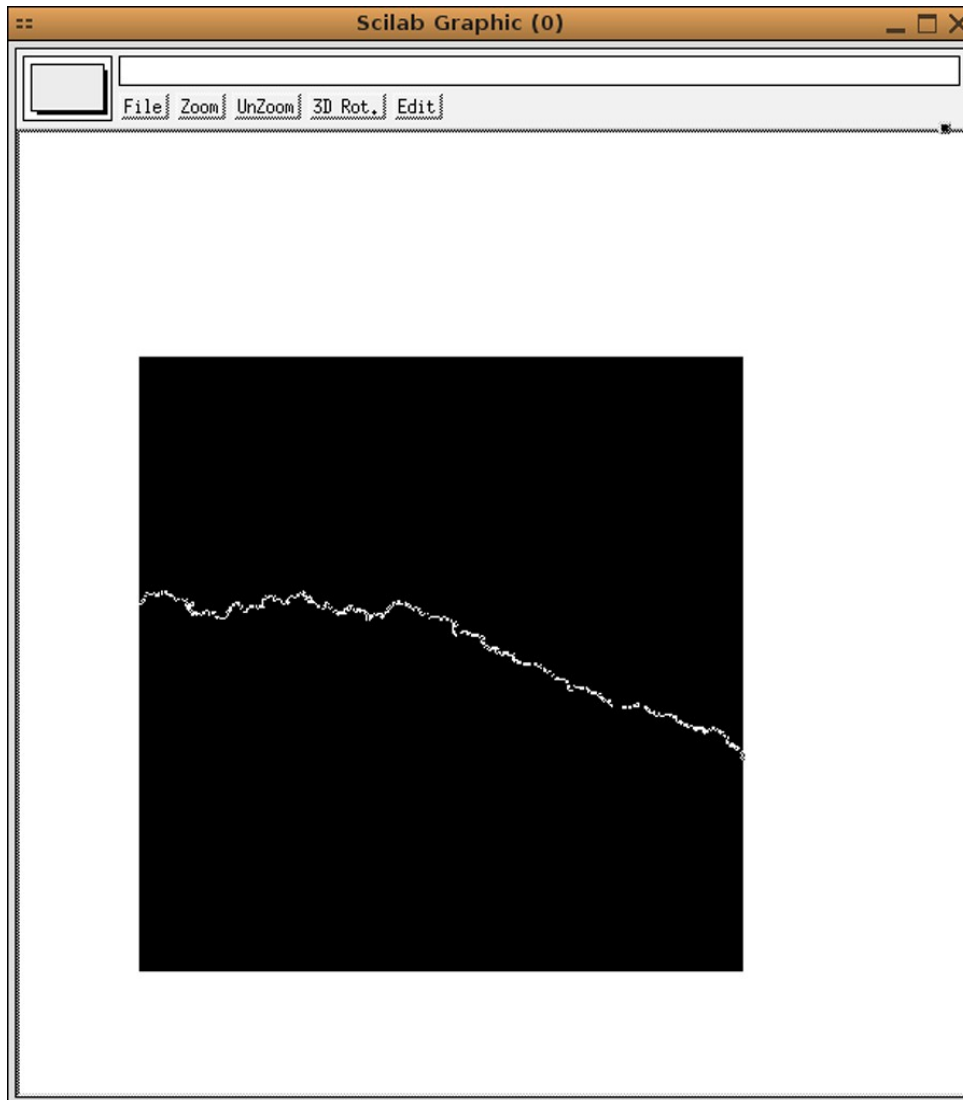


Figures 2 Image of the coastline of Figure 1 superimposed with a mesh of 25 square boxes. The boxes with gray bottom contain the natural image.

An example of the application of this method is illustrated in the Figures 2, which shows the coastal line of the Figures 1 superimposed with a mesh whose square boxes possess a longitude (r) of 22,5 km. The number of boxes (N) that contains this coastline is equal to 7. The mesh possesses 25 boxes in total.

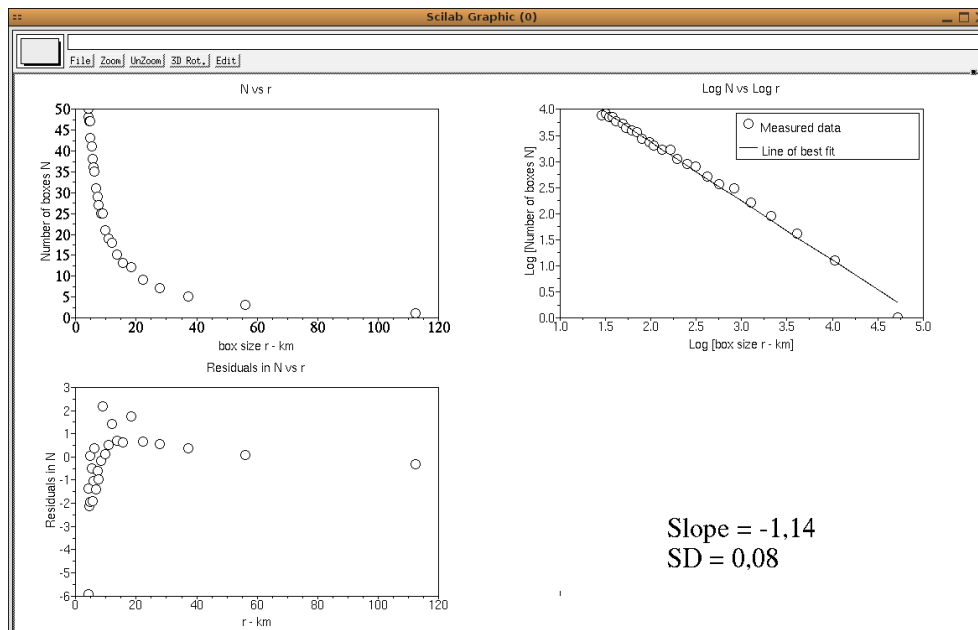
The Scilab code in Linux environment

Scilab corresponds to a very powerful and interactive atmosphere of free programming for the numeric calculation; it is a scientific package that possesses a group of tools for the manipulation of matrices, treatment of signs, transformation of Fourier, graphic representation, etc. (Dalrymple, 1995; Chancelier, 2002). This programming atmosphere was developed by INRIA and of ENPC in Unix environment, for the applications of industrial type and like a strong investigation tool (development and test of algorithms.)



Figures 3 Recognition of the edges of the coastline of Figure 1.

In this last aspect, it is possible to use Scilab, for the quantification of the fractal dimension of images corresponding to this type of natural structures. The initial part of the code consists on the recognition of the image to try and its edges; the same one consists of the toolbox of images of Scilab and the commands **imread**, **imshow** and **edge**. The second part contains the relating tools to the counting of the square boxes which define: the dimension of the image in both axes, the iteration process for the diverse sizes of these boxes (**xEnd**, **xStart**) and finally, the regression process that gives us as a result, a graphic representation of N vs r with their respective residuals. The Figure 3 illustrates the recognition of the image to try.



Figures 4 First graph representing N in function of r, second image of the logarithm of N in function of the logarithm of r and lineal adjustment of this; and third image presenting a graph of the residual ones in N and the logarithm of r.

The group of images of the Figure 4 represent 3 graphics: the first one, corresponds to a graph in lineal scale of the number of counted boxes that contain the edge of the image under study, N in function of the lineal dimension of same r; the second one presents the same result as the previous graph, but in logarithmic scale, it also shows up the adjustment for least squares, and the third figure that shows the residuals in N in function of r.

The experimental results obtained in this study demonstrate the feasibility of the tools of Scilab in the recognition of this type of images, which are the product of specific geomorphologic events. Thanks to the commands of Scilab, the fractal dimension of the coastline of the oriental section of the Isthmus of Panama, could be calculated ($D = 1,14 \pm 0,08$).

Finally, the graph of the residuals in N demonstrated that the adjustment carried out on the obtained data in this analysis is the appropriate one.

Conclusions

If our interest is focused on the fractal analysis of certain natural structures corresponding to the result of geomorphologic processes, Scilab offers the necessary tools to generate codes able to calculate the D fractal dimension, of those structures. The Linux environment is an attractive and versatile platform for the development of this kind of analysis that are of great interest in earth sciences.

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