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Study of Behavior of Human Capital from a Fractal Perspective

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Abstract

In the past ten years, fractal geometry has seen a meteoric rise in its use across fields. Nonlinear approaches need at least 512 observations, which is challenging to collect in the field of human capital management. As a result, we propose using a fractal interpolation approach to produce TS on the fly in this study. To mimic the original TS, we may disable the vertical scale factor and use the recommended interpolation approach.

Keywords: Human Resources, Compensation, Fractal Interpolation, and the Vertical Scale FactorIntroduction

In nature, irregular processes exist that by using Euclidean models as their basis for analysis, do not capture the variety and complexity of the dynamics of their environment. Owing to the need to develop methods more aligned to this behavior, Mandelbrot used a different approach to understand these irregularities in nature, consisting of fragments known as fractals (Mandelbrot, 1997). Use of the fractal geometric approach has grown exponentially over the past two decades. Its application ranges from economics (Mandelbrot, 1997), music (Perez, 2000), medicine (De la Rosa-Orea, 2014), topology (Vivas, 1999), physics (Aguirre 2004), astronomy (Martinez, 1999), meteorology (Morales-Acoltzi, 2015) and geology (Esper, 2005); recently, it has also been successfully introduced to the social sciences, for example psychology (Pestana, 1999), and more so, in everyday life it can be effectively applied to describe nature which surrounds us. In in the last decade, fractal geometry has been explicitly included in sciences of economic administration, as well as in areas of organization and business management, illustrating to entrepreneurs how company behavior is similar to that of a living entity which adapts to its environment (Iturriaga & Jovanovich, 2014). The human factor is the main element in management decisions. Because human capital is analyzed qualitatively, quantitative models have been proposed, such as that put forward by Iwamoto & Takahashi (2015) with data from their own company.

In the second section of the study, the theoretical foundations of fractal geometry are presented. In the third section, we describe the database and methodology. The fourth section includes numerical experiments, results and conclusions.

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Introduction

1. Theoretical Basis

By breaking down natural anomalies into smaller pieces that give birth to fractals, the fractal method is a new branch of mathematics that advances on Euclidean geometry. The essential characteristics are auto-similarity and the fractal dimension (Williams, 1997). The first means that all entities retain their original structure and global properties. To better describe natural processes, fractals reveal an incomplete dimension that goes beyond the topology of the figure under examination (Braa, 2003). You may use either complex nonlinear fractal numbers or a recursive linear fractal procedure to explain them (Mandelbrot, 1997). The main precursors of fractal theory were Cantor, Mandelbrot, Lyapunov, Giuseppe Peano, Sierpinski, Helge von Koch and Gaston Julia, some of whom contributed to this notion, prior to the establishment of fractals as currently understood. Their main contributions are explained in Table 1.

Table 1. Main precursors

Author	Contribution	Content
Georg Cantor,	Cantor set	• Take the interval [0,1], in each iteration, eliminate the segment corresponding to the central third of each interval.
Benotî Mandelbrot,	Mandelbrot set	• It is the most well-known fractal, uses a combination of a real number with a complex number.
Aleksandr Liapunov	Markus-Lyapunov fractals	• Contains topological and qualitative changes called bifurcations, derived from the logistic map, where the degree of growth changes periodically between two established values. The Lyapunov exponent λ is used.
Giuseppe Peano	Peano curve	• Curve covering an area, which is obtained by an iteration, to form a continuous curve converging to a boundary curve. • It is a special fractal, because its topological dimension is one and its fractal dimension 2, which although they are integers is considered a fractal.
Wacław Franciszek Sierpinski	Sierpinski curve	• It is constructed from a triangle, by means of homotecia, centered in the vertices of the triangle with a ratio of ½. It is similar to the set of Cantor.
Helge von Koch	Koch curve	• Continuous fractal curve that has no tangents, is obtained by methods of elementary geometry. • It is constructed by iterations where a line is divided into three, in the middle segment two more segments are inserted as an equilateral triangle.
Gaston Maurice Julia	Julia set	• Family of fractal sets, obtained by studying the behavior of complex numbers that are iterated by functions with a restriction to real numbers.

Source: Mandelbrot, 1983; Cantor, 1884; Yale, 2016; Flake, 1998

Mandelbrot described a series of problems related to risk and investments, introducing new ideas in different areas ofapplication.

A study by Gálvez Medina E. *et al.* (2009) showed that fractals are becoming important in decision making. Otherwise, complexity theory is an innovative subject, and fractal structures offer useful applications, such as an increasing the flexibility and adaptability of businesses using them.

Studying quantitative variables that explain economic development can generate scenarios which will facilitate decision-making, thus eliminating biases caused by subjectivism, and increasing the performance and progress of organizational objectives. This can promote: savings, greater knowledge about the company and the establishment of

development strategies to increase their competitiveness (Bonatti, 2007). The studies mentioned are concentrated in Table 2.

Table 2. Analysis of previous studies

(Author, year)	Article	Analysis
(Iturriaga & Jovanovich, 2014)	Fractals, economy and business	• It establishes the possibilities of application of fractal geometry; To the economy, organization and administration of companies, analyzing the feasibility of the same. •Highlights; That by having a greater technological development, companies react more quickly to changes in the environment, this is favorable to detect self-similar patterns at different levels.
(Iwamoto & Takahashi, 2015)	A Quantitative Approach to Human Capital Management	• Provides a quantitative technique to support decision makers through the objective assessment of human capital management. • The study is carried out in two phases, projecting the increase of profits generated by the company: • Selection and formulation of the factors, which are represented by the main component and its factor analysis. • Value added is defined, adjusting the index to the characteristics of the company's personnel and production, constructing a model to identify the factors of human capital management, through a multiple regression.
(Williams, 1997)	Chaos theory tamed.	• Contains; Antecedents, concepts and characteristics of the chaos, focused on people without experience in this field. • Part of simple concepts, to more complex in different areas of study.
(Braña, 2003)	Notes "Introduction to fractal geometry"	Contains the historical development on the fractals, explaining the most known models and their characteristics: self similarity and fractal dimension; Types of fractals (linear and non-linear), as well as the best-known examples.
(Mandelbrot, 1997)	In Fractals and Scaling in Finance	It shows that the price movement maintains an invariant of scale, manifesting itself from a small period of time (5 minutes), per day and monthly. • Compares the study with several types of distribution; Random, normal, Brownian. • Price movement is cyclical, but its length can not be determined over time, this means that it will not be able to decide when it starts and when it ends. • Models based on current prices do not work in the long term, such as some trend systems. • It indicates, that to use the indicated mathematical tools, a suitable financial model can be elaborated.

(Gálvez Medina E. *et al.* 2009)	Fractal approach applied in the administration	Shows aspects such as; The evolution of management theories and the versatility of application in the sciences: they favor their integration to explain the applications of the fractal approach in the administration to have matching characteristics. • Fractal factory. Its objective is the development of companies, adaptable to the metaphor: organizations are living organisms with the possibility to grow and adapt. • Fractal company. Evolution of the fractal company, applying more coherent knowledge, show results of scientific work and technological developments based on the logic of fractal theory.
(Bonatti,2007)	Biases and Pitfalls in Decision Making	• Explains behaviors, perceptions, and failures that affect decision making. • Classify the types of negative behaviors in decision making.

2. Data Base

First, we need to construct a database (DB) that includes a time series for the "wages" variable. One thousand pesos is the usual monetary unit of analysis based on INEGI's Monthly Survey of Manufacturing Industry (Encuesta Mensual de la Industria Manufacturera, EMIM) from 2007-2015 (covering 108 observations). This sum is the result of adding together payroll taxes, industrial profits, and social security. They are categorized as a "fractal company" since their patterns of conduct are exposed by looking at their time series. The idea of fractals is intrinsic to the logic behind the most trustworthy applications of knowledge.Methodology

The lack of records in the DB raises serious questions about how to finish the TS for the observed variables. The aim in this study is to complete a TS of salaries with just 108 observations while adhering to the approach associated with the analysis of non-linear dynamic systems, which needs at least 512 data (Barnsley, 2014). The following section describes experiments performed to model the behavior of the human resources-relevant "wages" variable.

Non-linearity, caused by continuous feedback and unaffected by external or internal factors, necessitates the use of fractal geometry and non-linear dynamic systems inside businesses (Guzman, 2016).

In order to minimize issues with the relative handling of values with multiple digits, data is first normalized for the purpose of numerical experiments. This was accomplished by dividing the TS by the largest absolute number, yielding values between zero and one.

Following Barnsley (2014), the model for fractal interpolation is produced from five equations, the first point relates directly to the observed interpolated point. Five parameters, determined by the equations 2-5 and by the observed **TS,**were included.

$x \quad a_n \quad 0 \quad x \quad e_n$

$$w_n(y) = (c_n \quad d_n)(y) + (f) \tag{1}$$

$$a = \frac{x_n - x_{n-1}}{n} \tag{2}$$

$x_N - x_0$

$$e = \frac{(x_N x_{n-1} - x_N x_0)}{n} \tag{3}$$

$x_N - x_0$

$$c_n = \frac{(F_n - F_{n-1})/(x_N - x_0) - d_n(F_N - F_0)}{} \tag{4}$$

$x_N - x_0$

$$f_n = \frac{(x_N F_{n-1} - x_0 F_n)}{(x_N - x_0)} - d\,\frac{(x_N F_0 - x_0 F_N)}{(x_N - x_0)} \quad (5)$$

d_n represents a vertical scale factor that can be any real number.

a, c, e, f are real numbers, known as a transformation to two dimensions.

3. Results and Discussion

In Figure 1, the original series is compared to the standard, in order to verify that the wage variable does not vary. In Figure 1a, a periodic increase is observed. This occurs at the end of each year, rewarding the workers in the form of Christmas bonuses and bonuses for productivity, among other benefits. It also indicates a positive trend in economic conditions in the country, in the form of increases in minimum wage and inflation.

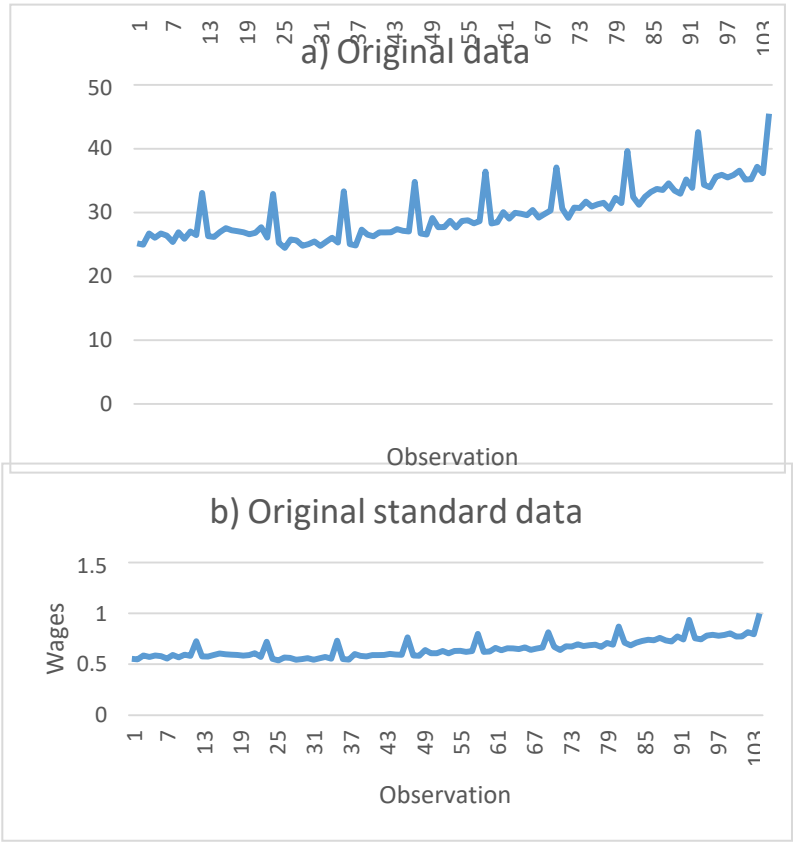
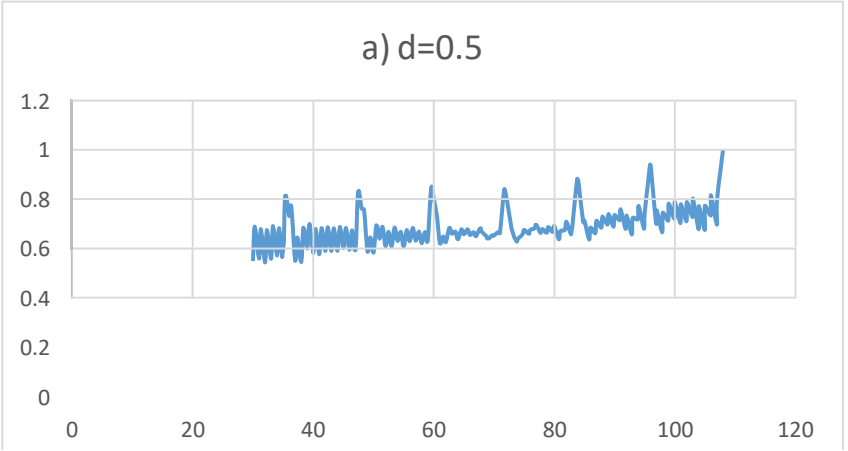
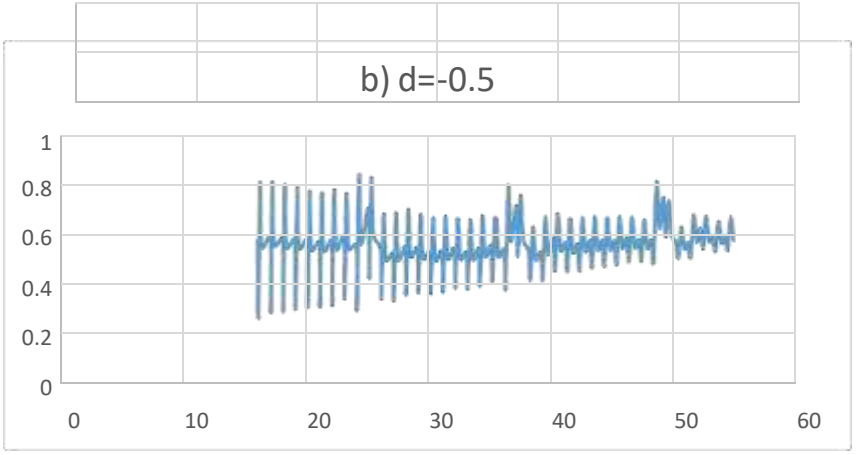


Figure 1 a) Original data series b) Standard data set between 0 and 1

The interpolation was conducted in three phases: firstly, scale invariance (**SI**) 0.5 was used to increase the frequency of the **TS**, 2a; secondly, the noise generated by expansion was reduced using a coefficient -0.5, 2b; and finally 0.23 was employed as **SI**, 2c.





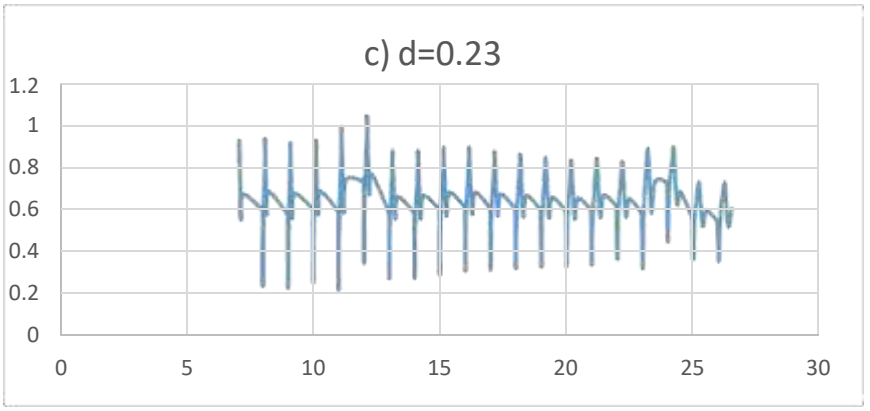


Figure 1. Interpolation phases with standard data

To demonstrate the effect of **SI** in the interpolation, an experiment was carried out, which only modified to a minimal extent; by hundredths, as shown in Figure 3. This factor modified the behavior of the variable, only influencing the inclination of the abscissa line and controlling the extent of variability.

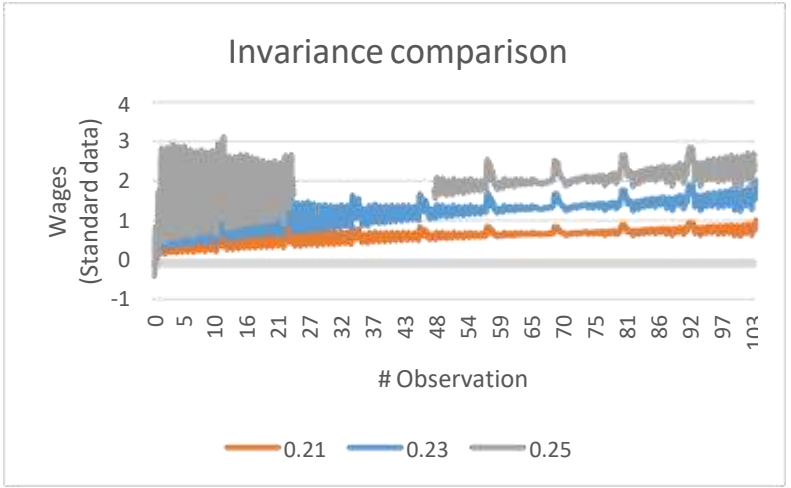


Figure 3. Interpolation phases with standard data

Figure 4 shows that the arithmetic and geometric interpolation, only places some points within the original data, however, the fractal interpolation generates data so that one can observe the natural behavior of the variable being studied; thus if this uses an **SI** = 0, behavior continues perfectly without varying from the original. Thus a test for the proposed interpolation scheme, aims to check whether it recovers or simulates the original data, considering a null **SI**.

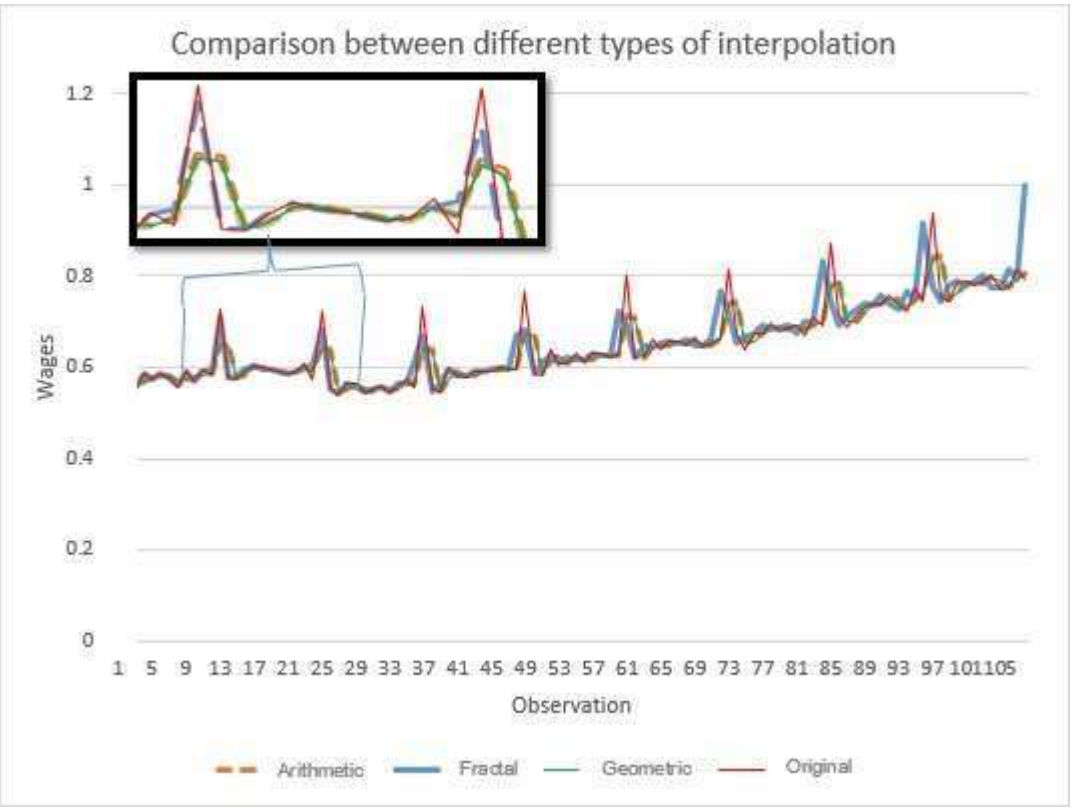


Figure 4. Graph of achieved interpolations

Another numerical experiment that enabled us to meet our goal, involved building a **TS** with more than 512 values, maintaining the dynamic behavior originally identified.

4. Conclusions

It is often challenging to have a "complete" DB that satisfies the standards of the theory of dynamical systems when undertaking research with a social component represented by salaries. As a result, the DB needed to be finished up using linear, nonlinear, and fractal interpolation methods. While the arithmetic and geometric interpolations tried their best to mimic the investigated system's behavior, they were unable to fully capture the dynamic nature of the original TS (with the exception of fractal interpolation). That is, fractal interpolation made use of the fact that processes are fractal to demonstrate SI, which allowed them to preserve the observable dynamic invariants.

Our use of fractal theory yielded the expected result—an increase in the total number of observations—but no substantive change to TS itself. Similarly, fluctuations, as well as gains and declines, are honored, even whether they are very large or little.

In accordance with the anticipated findings of the research, this study allowed us to correctly assess the degree of fractality present in human capital and make informed judgments in the industrial industry.

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