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Fractality in Manufacturing Industry

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Abstract

Despite Mandelbrot's 1970 introduction of fractal theory, the subject of study has had a significant uptick in interest over the last decade. We assume and show that the system is fractal for Mexican manufacturing firms by analyzing time series (TS), the behavior of the variable, cost of that sold (CS), and other data. For this study, we investigated 30 Mexican stock exchange-listed firms, collecting 23 data points each firm between the first quarter of 2010 and the third quarter of 2015, for a grand total of 704. Using fractal interpolation (FI) as the means by which data in TS is generated, we narrowed the number down to 512 for each of the 30 TS. Visual Recurrence Analysis (VRA) was used to provide a description of TS 30. It is evident that 4 variables were used to explicate the dynamics of the CS system in 80% of the organizations examined.

Keywords; Fractal, Fractality, Sales Price, Manufacturers, Dynamic System, Fractal Interpolation, Cost of Goods Sold

Introduction

Fractal theory was first presented by Polish-born mathematician Benoit Mandelbrot in 1970. He described them as "a collection of forms that, by their very nature, are generated through repetition and feature intricate detail at every scale." Since they are limitless in length, cannot be differentiated, and display the fractional dimension, they are very interesting mathematically (Mandelbrot, 1982). Garnett (Williams, 1997) proposes a more succinct description, saying that they are "A line, surface, or pattern that looks the same on a wide range of scales." Studies and modeling of the inner geomagnetic field (O.A. Khachay, A.Yu. Khachay, & O.A. Khachay, 2012); Competence systems in the context of business competition (Deng, Peng, & Huang, 2009); Cerebral MRI angiography (De la Rosa-Orea et al., 2014); and many more have all been produced using a fractal approach. Inventory management in supply chain networks (Ryu, Moon, Oh, & Jung, 2013); Sustainable fractal manufacturing in mechanized processes (Peralta, Marcos, Aguayo, Lama, & Ryu, 2015); Fractal company (Gálvez, Balan kin, & Resenos, 2009); Fractal manufacturing (Ryu, Son, & Jung, 2003); Models for optimizing the logistic financial management system (Wang, Luo, The purpose of this study is to determine whether fractality occurs in the CS variable, a subsystem that has an effect on manufacturing firms' production areas. In the second, we introduce the database (DB), and in the third, we detail our research procedures. The numerical experiments and results are presented in Section 4, followed by a discussion of the findings in Section 5.

1. Base de Datos

The manufacturing environment is the focal point for the value-adding activities that take place during the processing or transformation of one or more raw materials. The goal of a factory's production managers is to keep everything running smoothly within the parameters

bounds, so that the finished product has commercially-acceptable features, but there are many factors that might influence this behavior.

The CS is the variable of interest; it shows up in the production space and includes things like labor costs, raw material costs, energy costs, depreciation charges, maintenance expenses, and so on. There were 145 firms detected in the capital series segment that were also listed on the Mexican Stock Exchange (MSE) (MSE Group, 2016).

following were selected:

- CH
- TENARIS
- AUTLAN
- AHMSA
- COLLADO
- SIMEC
- BIMBO
- HERDEZ
- ALFA
- BAFAR
- CERAMIC
- GRUMA
- BACHOCO
- CONVERTIDORA
- CEMEX
- HILASAL
- COCACOLA
- MINSA
- AC
- CULTIBA
- ELEMENT
- KIMBERLY
- LAMOSA
- MASECA
- NEMAK
- PAPPEL
- VASCONI
- VITRO
- POCHTEC
- RASSINI

2. Methodology

The 145 companies consulted for the MSE were stratified to select those involved in manufacturing; this yielded a total of 41 companies from which 30 were deemed to meet the criteria of information availability and time period (Q1 2010 to Q3 2015).

In the examined DB, 23 registers are provided for each TS, which is insufficient for the 512 data needed by the technique of dynamic nonlinear systems. In order to fulfill this criterion, four different approaches were evaluated: randomly generated numbers, the average, the geometric mean, and FI. We conclude that fractal interpolation is the most effective technique for preserving dynamic features.

FI (Barnsley, 1988) makes it possible to generate data from a series of points, while maintaining the original behavior of the system. The general equation is:

$$(^{x}) = (^{a_n \quad 0 \quad x}_{n \quad y \quad c_n \quad d_n^{\,}}) (_{y}) + (_{\mathrm{f}}^{\,e_n}) \tag{1}$$

To calculate the parameters of the general equation, we obtained these from the following equations:

$$\overline{n} = \frac{x_n - x_{n-1}}{x_N - x_0}$$

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

$$n \quad c = \frac{(F_n - F_{n-1})/(x_N - x_0) - d_n(F_N - F_0)}{x_N - x_0}$$

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

Where:

$(x_N - x_0)$

$(x_N - x_0)$

Any real value may be used to represent the vertical scale factor represented by dn.

3. a, c, e, f are integers, this is a two-dimensional order transformation.

4. For the FI carried out here, we employed the values 0.5, -0.5, and 0.23 on a scale from [0, 1] to handle the data.

5.

6. We utilized VRA software (Kononov, 1996) to calculate the fractality of TS, and the results were the optimal flow and correlation dimension.

7.

8. Results and Discussion

TSs were submitted to two tests, arithmetic mean and geometric mean, respectively, in order to verify that they had not been manipulated. These tests were performed for the 30 companies to exemplify these operations; the analysis of the CH company is partially presented in Tabl.

Table 1. Analysis of components of the CH company system, by arithmetic mean and geometric mean

CH company		
Data	**Arithmetic mean**	**Geometric mean**
5761064		
5987630	5866017.5	5865078.522
5970971	4398815.5	4101858.882
2810001	6101192.5	6099802.643
6231414	4905579.5	4435454.991
7001158	6886807	6855550.355
7542200	7170166.5	7168174.368

The original information presents dissimilar amounts between each **TS**, for example, a company with **CS** of $ 135 14913.00, and another with CS of $ 25879.00. For this reason, it was necessary to normalize the information, dividing each data in the series by its maximum value, thus obtaining a point of comparison between the different companies.

After normalizing **TS**, the original **TS**s were graphically compared with standardized **TS**s to verify that behavior had not been affected by their properties. Figure 1 and Figure 2 show that behavior is identical in both graphs.

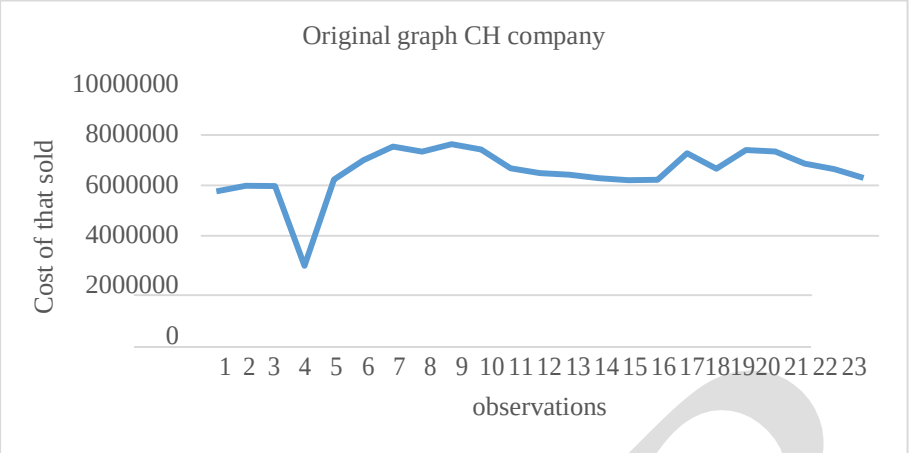


Figure 1. Graph of the cost of that sold by the CH company

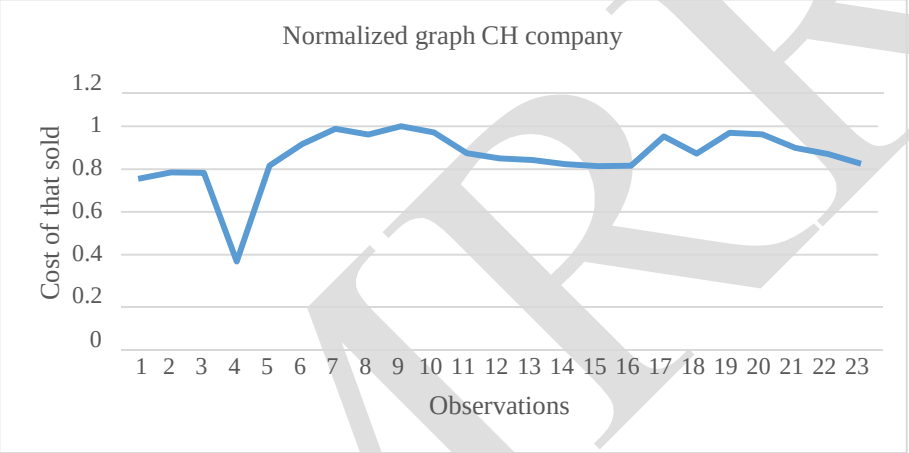


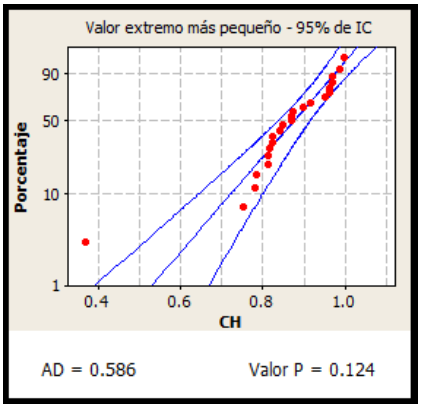
Figure 2. Graph of the cost of that sold after being normalized

We employed VRA software to check for TS fractality, which required us to build data-driven hypotheses from the facts at hand.

1) To produce a random number from a given distribution.
2) To produce information based on an average value.

Thirdly, to provide information based on its geometric mean.
Fourthly, to produce information through fractal interpolation.

The first option takes into account three characteristics to establish which distribution the TS modifies. Using graph, P-value, and Anderson-Darling (AD), we selected and tested the hypotheses for distributions with smaller AD. Since P(0.124) > 0.05 and AD(0.586) > 0.586 were obtained for CS, it may be concluded that TS is of the smaller end-value type



distribution.

Figure 3. The graphic behavior for the cost of that sold by the CH companies and the P and AD tests

After determining the distribution to which **TS** belongs, five hundred and twelve random numbers were generated in Minitab, while maintaining the distribution of the original **TS** (Figure 4).

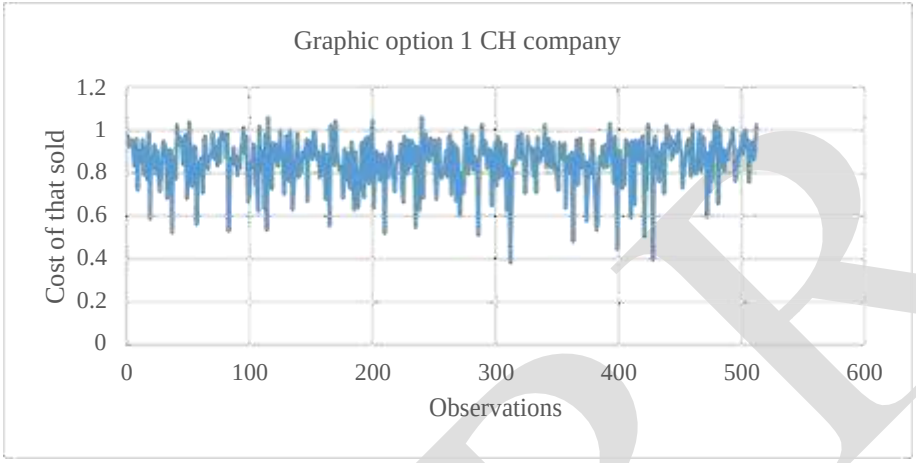


Figure 4. Graph of the numbers generated by the distribution system of the CH company

Although data were generated from the analysis of the original information, the new **TS** does not maintain the same pattern of behavior, so it is considered that this is not an adequate option with which to complete the required number of the sample.

The second option shows the generation of data by the arithmetic mean, and Figure 5 shows that the points obtained are positioned on the line of the original **TS**.

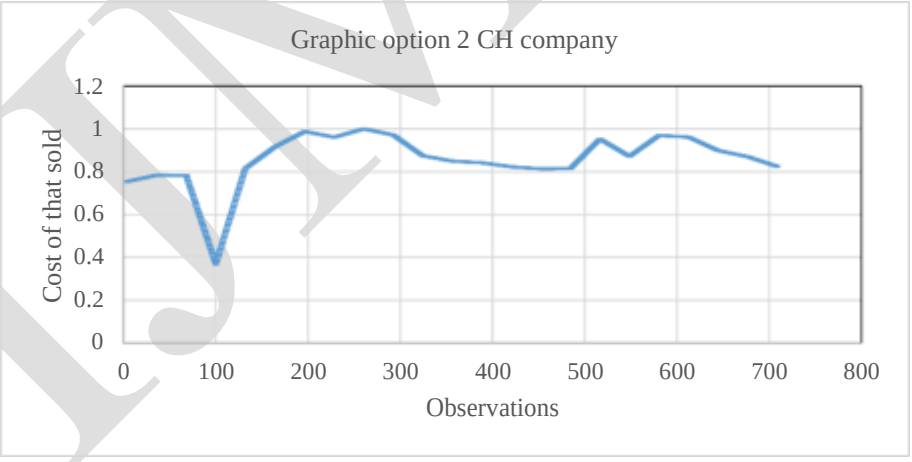


Figure 5. Graphic data for numbers generated by arithmetic mean for the CH company

The third option generates data using the geometric mean, showing that they maintain the same shape as the original **TS** (Figure 6), with the peculiarity that when plotting both options, the data tend to adjust to a straight line.

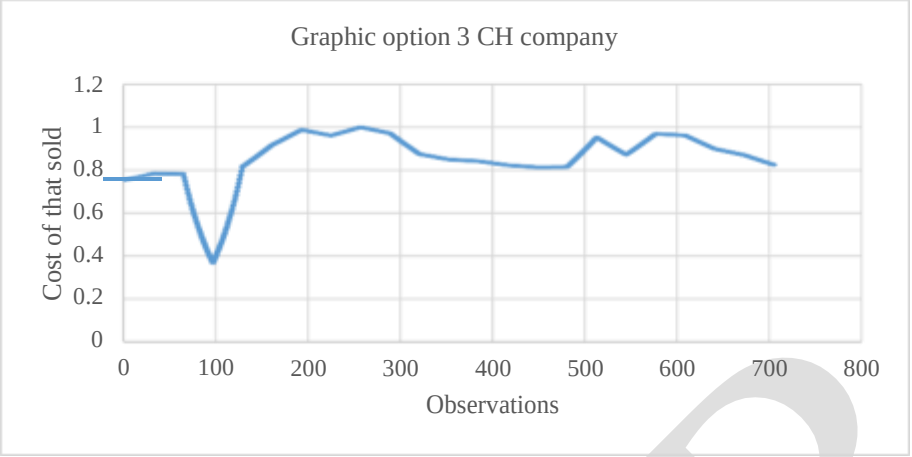


Figure 6. The graph generated by creating data using the geometric mean

The fourth option refers to fractal interpolation, observing that the data obtained manifest the same behavior as the original **TS** (Figure 7).

After reviewing the above options, we decided to use fractal interpolation.

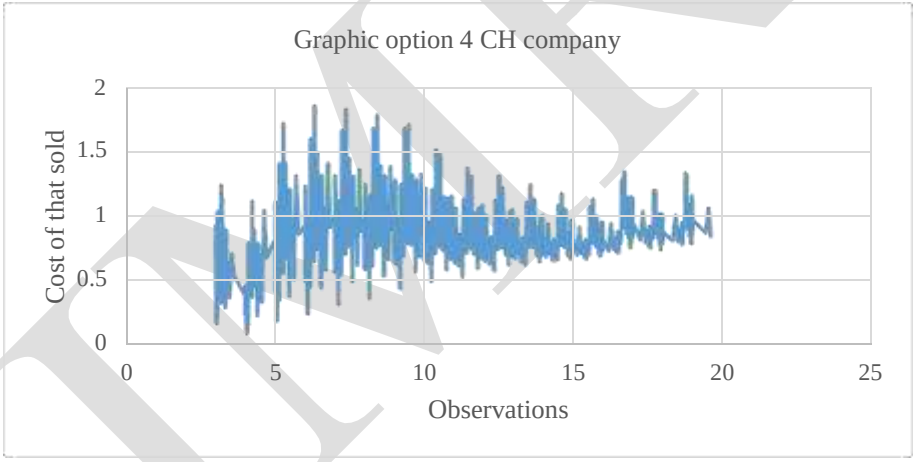


Figure 7. The behavior of the data created using fractal interpolation of the CH company

We performed the **FI**s of the companies being studied and with the information obtained and using the **VRA**, we obtained the Tao (**τ**), which is the value that indicates the sensitivity of **TS**. Other data provided is the correlation dimension (**D**), which shows the point of convergence, and also provides information about the number of variables, which can explain the system and from which Table 2 is constructed.

Table 2. Results from the analysis using VRA, which prove that manufacturing companies manifest fractal behavior

COMPANY	τ	D	COMPANY	τ	D
AUTLAN	1	3.67	MASECA	3	3.29
BAFAR	1	3.62	BIMBO	1	3.25
CONVERTIDORA	3	3.62	BACHOCO	1	3.24
RASSINI	1	3.58	ALFA	3	3.21
HILASAL	3	3.47	POCHTEC	1	3.19
LAMOSA	3	3.46	SIMEC	3	3.18
MINSA	3	3.43	KIMBERLY	3	3.14
CEMEX	3	3.42	GRUMA	3	3.07
COCACOLA	3	3.42	COLLADO	3	3.01
TENARIS	3	3.39	ELEMENT	3	2.94
HERDEZ	1	3.36	AC	1	2.92
CERAMIC	1	3.36	VASCONI	1	2.75
CH	3	3.35	VITRO	3	2.71
AHMSA	3	3.34	PAPPEL	1	1.69
NEMAK	1	3.3	CULTIBA	1	1.66

Information in Table 2 shows that:

- Manufacturing companies present fractal behavior in the **CS** system.
- The dynamic of the **CS** system, explains 80% with four variables.
- Comparing their **τ**, companies can be divided into two groups, those with **τ**=1 and those with **τ**=3.

9. Conclusion

A new window is created for the investigation of system dynamics when the fractal idea is taken into account, since there are many processes that cannot be understood via a purely linear lens. Manufacturing firms use fractal geometry to consistently replicate processes like the one described in this article's analysis of the CS variable. The idea is to obtain a methodology that enables systematic analysis of the operation of organizations, which can be viewed as dynamic entities that change with time in a systematic way, maintaining increasing and decreasing scales, representing figures in showy occasions like dust of Cantor, butterfly wings, snowflakes, and The Sierpinski triangle, among others. Our non-linear numerical experiments have considerable potential for use in the industrial sector in the future.

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