Paakat
Revista de tecnología y sociedad

# Conocimientos, caos y orden en el contexto de las TIC dentro de la sociedad de la información y del conocimiento

# Knowledge, Chaos and Order into ITCs Context within Information and Knowledge Society

http://dx.doi.org/10.32870/Pk.a8n15.328

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Received: February 18, 2018
Accepted: June 6, 2018

**RESUMEN**

El presente artículo tiene como objetivo exponer algunas ideas sobre el uso de los fractales dentro de los sistemas no deterministas como fenómenos aleatorios. El análisis ofrece argumentos para afirmar que los fractales tienen aplicación diversificada en varios campos del conocimiento, y que el estudio de los atractores y las causas aleatorias tienen un importante papel en las investigaciones científicas actuales. Las ideas expuestas en este artículo pueden ser empleadas en la docencia universitaria para una mejor comprensión por estudiantes y profesores de los sistemas dinámicos que entran en toda investigación.

**Palabras clave**
Sistemas deterministas; fractales; sociedad del conocimiento

***ABSTRACT***

*This article is aimed at exposing some ideas on the use of fractals in the nondeterministic systems as random phenomena. The analysis offers arguments to state that fractals have diversified application in many fields of knowledge and that the study of attractors and the random causes play an important role in current scientific research works. The ideas exposed in this article can be used in the university teaching for the students and professors to better understand the dynamic systems involved in every research work.*

***Keywords***
*Deterministic system; fractals; Knowledge society*

## INTRODUCTION

In the eighteenth century, French mathematician Pierre Simon Laplace, influenced by Galileo's discoveries, among others, claimed that "If the position and momentum of all the particles of the universe were known at a given instant, their future could be predicted for all future times" (quoted by Guzmán Hennezzey, 2010, p. 59). However, man, while facing different natural and social phenomena, has come to realize unpredictable facts that turned out to be more abundant and varied as knowledge and human kind developed.

In our time and fairly recently, an extensive part of the scientific community has started investigating chaos, disorder, entropy, and lately, "fractals" from the work of Polish mathematician Mandelbrot have been incorporated (Braun, 1996). We believe that the dizzying pace of the development of technology in the so-called "knowledge society", the new concepts are destined to find responses to dispel these phenomena and unpredictable facts and feed this knowledge to our society. Our purpose is to summarize briefly the pertinent ideas in this regard.

### Determinists and non-determinists

According to Laplace's claim, determinists, in their categorical definition, reduced knowledge to everything predictable. That is, while knowing the initial conditions, everything could be predicted with the passage of time. Thus, if we study the expansion of a steel bridge or other material at room temperature (27 ° C) we could determine its new length under a 40ºC summer temperature with this simple equation:

$$\Delta l = \alpha \, Li. \, \Delta t \quad (1)$$

Where Δl represents that which of the bridge has expanded or is going to expand, α is the material linear expansion coefficient and Δt is when the material is going to be heated, i.e., 13ºC, and the result is totally accurate for any temperature.

Several phenomena we face on a daily basis have accurate predictions in several fields of human knowledge. We observe that the foregoing case obeys a linear phenomenon as a great part of the phenomena within natural sciences. However, not all phenomena and facts with which man has had to interact are linear. In 1908, French physicist and mathematician Henri Poincaré starts working with mathematical non-linear systems and came to the conclusion that the world is "unpredictable by nature" (Poincaré, 1990; quoted by Lang da Silveira, 1993). From this conclusion arose two currents opposite in essence:

- **The determinists**: who sustained that "events are not unpredictable but rather we have not discovered the regularities and the laws that allow predicting them".
- **The non-determinists**: who defend the idea that chaos is unpredictable by nature, since an infinite amount of information is needed to predict events.

As authors of this paper, we adhere more specifically to the first current given the high development of mathematics – and currently of computing – the facts that could not be predicted previously and which now can are starting to abound, since the tools for developing scientific research are taken into consideration.

The fact that phenomena that had no explanation in the past and that are now part of our daily life is undeniable. Who could imagine that Maxwell's last century predictions of the existence and application of electromagnetic waves would now be an inseparable part of our daily activity, something we cannot do without?

However, there are still phenomena that currently fall in the realm of uncertainty and to define them is not an easy task. For example, let say that the border dividing two continental countries is 430 kilometers (Figure 1)

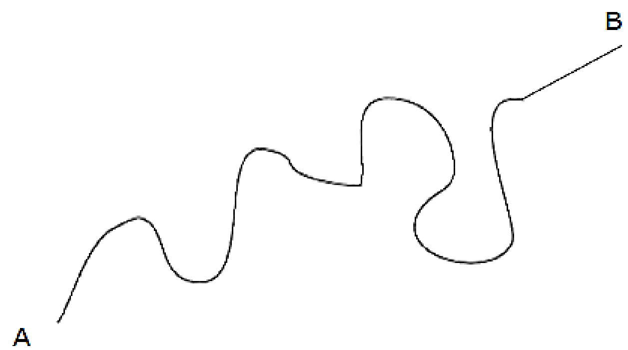


**Figure 1**. Example of the border between two countries.
Source: developed by the author.

In this case, the 430 kilometers have been measured by joining points A and B in a straight line; however, the margin of error would be immense in regard to the actual distance of the dividing line, since every time we would use a more accurate division instrument and a smaller scale, the length would increase noticeably and we would conclude that A-B is not the actual length of the border.

Therefore, the length of the border is not perfectly defined, whereas if is we measure the perimeter of a circle, a square, a triangle or of any regular geometric figure, we would obtain exact values. In the first case, we are getting closer to the "fractal" concept which we will mention further on.

Let us continue with the linear determinism and the non-determinism within this topic. Let us assume that within an extensive area, we have an initial population of 10 thousand rabbits with a 20% yearly reproduction rate.

- Within one year there would be: 10 000 + 0,2. 10 000 = +2 000 = 12 000 rabbits
- Within two years: 12 000 + 0,2. 12 000 = 14 400 rabbits
- Within three years: 14 400 +0,2. 14 400= 17 280 rabbits

Since our model responds to a linear function, searching a model is relatively easy. If in a year, we would have 12 000 rabbits, then:

12 000 = 1,2. 10 000

In two years:

14 400 = 1,2. 12 000

In three years:

17 280 = 1,2. 14 400

Therefore, our model responds to function y= 1,2. X which is a linear function type (y= k,x). As we know, these processes are identified by linear graphs that study elementary mathematics.

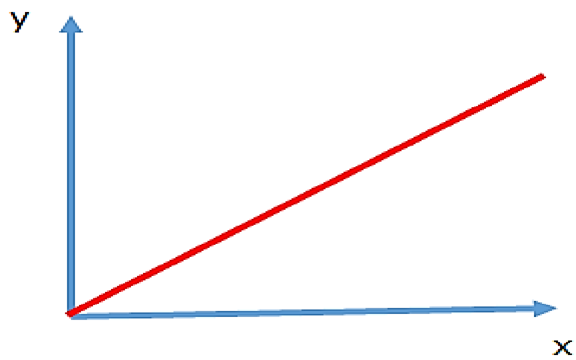


**Figure 2**. Graph of a linear system.
Source: developed by the author.

If we continue with the example and its actual behavior, there will come a time when the grass used as food would not suffice to feed the whole population enclosed in the area; therefore, the animal population would start decreasing to the point of dying out.

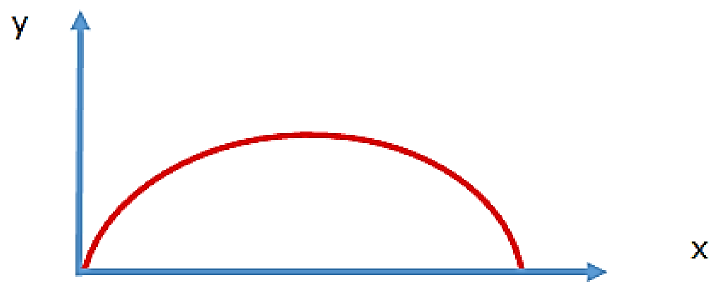


**Figure 3**. Graph of non-linear system.
Source: developed by the author.

In this case, we are dealing with a non-linear system since the population will not grow infinitely and likewise, more nature and society events will occur.

### Attractors and Random Causes. The Butterfly Effect

Currently, the field of scientific research of any branch of human knowledge must take into account all the incident factors in their field without being "surprised" by the random causes. In this paper, we try to be more explicit in what we propose through examples; however, before doing so, we define some elementary concepts.

Since our second year of high school, we are familiar with Newton's second law of math formula correctly expressed form the mathematical standpoint – but incorrectly from the philosophical standpoint – hence:

$$F= m.a \quad (2)$$

Even though we transform it in this way to analyze it in its cause and effect context:

$$a = \frac{F}{m} \quad (3)$$

Here, *F* and *m* are attractors and they correspond to independent variables, that is, as the strength and the mass vary, so does the acceleration. In this case, acceleration would be the dependent variable and which, in turn, depends on the attractors that, in turn, are independent of one another.

Therefore, this linear equation "governs" the deterministic state of this system which is also linear. However, as we have seen in the example of the rabbits in nature, facts not subject to linear systems abound, and there are other random causes that powerfully intervene and may distort the attractors' role.

This occurs frequently in the non-prediction in time and space of natural cataclysms such as cyclones, typhoons and earthquakes, the unexpected fall of the stock market at regional and world levels; viral and bacterial diseases with countless probable causes; pests that destroy crops; floods and droughts; the decline of academic and behavioral performance of a group of students; among other facts that could be used as examples.

In regard to attractors and random causes, the so-called "butterfly effect", introduced to the scientific community in 1972 by Edward Lorenz, is currently drawing strength (Barzanallana, 2016). Statements such as "The simple flap of a butterfly's wings in a Chinese desert may set off an earthquake in Costa Rica", is based on Lorenz's approach. This statement even though it is clearly exaggerated, is worth analyzing. Let us take Compañy's (2010) example, and assume that we release a small marble from the top of a flat slanted roof as shown in Figure 4.

Even the smallest variation given to the sphere with the fingers will put it off track and it will fall in an undetermined place, i.e., every time we release it, it will be impossible to predict the exact place where it will fall. Imagine a hunter aiming his riffle at a deer 200 meters away; by inclining the barrel a tenth of a millimeter, the bullet may deflect sufficiently and avoid reaching the animal since any small variations in the initial conditions may lead to drastic variations in the results.

**Figure 4**. Marble released from a roof.
Source: taken from http://pasosenlarena.blogspot.com/2010/07/

In this case, our margin of error could have been caused by the hunter with the small initial deflection; however, there are other random factors such as air, ambient temperature, etc. Therefore, within a research whatever the branch may be, we have to be clear with systems consisting of many components and not isolate or let random causes overlap or distort the attractors' role. In this regard, there are computer programs that did not exist before which take into consideration the variables to use in a system and discard those that barely affect the results of the forecasts prepared in advance.

## Determinism and predictability

We frequently hear the word chaos associated to a constant disorder, something irreparable and strange which has no solution. The strength of the word *chaos* causes misinterpretations or generalized interpretations. More than 40 years ago, when the “Science of Chaos” was introduced, it soon became known as the “deterministic chaos” to differentiate it from the purely coincidental chaos (Scott, 1991; Lang da Silveira, 1993; Sametband, 1999).

The term *complexity* is currently used when studying those non-linear phenomena. Let us illustrate a case, for example, an electric spark that ignites in a barn:

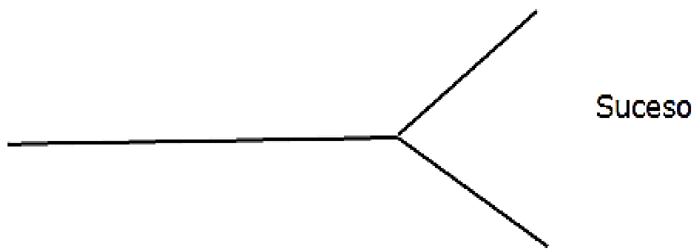


**Figure 5**. Scheme of a linear fractionation before an event.
Source: developed by the author.

A slight unnoticeable even has arisen, however it can ramify with time as a multiplier effect:

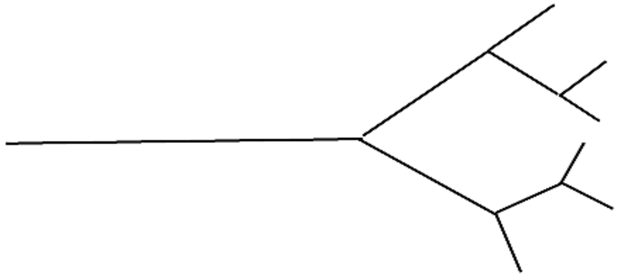

**Figure 6**. Scheme of ramification of an event.
Source: developed by the author.

Random factors:

- Presence of wood, straw, etc.
- Presence of oxygen
- Absence of people in the surroundings
- Farmer's disorganization
- Not having extinguishers at hand

When designing the barn, the concurring multiplier effect these factors entail may not have been taken into consideration. Therefore, there will come a time when these countless collateral events and the amalgam of lines that these events represent will be unpredictable.

For all scientific facts, whether natural or social, this zone is called the "chaos zone". It is present in every dynamic system whatever its nature (physical, chemical, biological, social, etc.) and it is extremely sensitive to the values of its initial conditions as we have seen in the marble example.

This sets a limit between the possibility of predicting the future and the initial conditions since the majority of predictable phenomena respond mathematically to linear differential equations such as those used in physics. However, as computers made their appearance, the problem of non-linear systems has been addressed and considerable progress has been made in this regard.

In the times of Laplace and under the Newtonian determinism, science believed in the linearity of all events; the tools necessary to elucidate many phenomena were not available; these appeared later as society and their interaction with men developed (Lang da Silveira, 1993). The foregoing has given rise the two tendencies mentioned at the beginning of this paper and which are currently beginning to clear up some doubts.

## The study of fractals

A fractal is a geometric object which basic structure, fragmented or irregular, repeats itself at different scales. In 1975, Polish mathematician Benoît Mandelbrot studied and proposed this term which derives from Latin *fractus* which means broken or fractured (Braun, 1996; Talanquer, 2000).

Hence, many natural structures are fractal type. The key mathematic property of a genuinely fractal object is that its fractal metric dimension is a not an integer unlike the regular geometric figures. An interesting aspect of fractals is that they possess two characteristics that are still being studied:

- They are self-similar (they repeat themselves)
- They present mathematical recursive algorithms

Figures 7, 8 and 9 show some examples of nature. Figure 7 shows how a peacock's feathers constantly repeat themselves in recursive patterns.

**Figure 7**. Peacock feathers.
Source: taken from https://es.gizmodo.com/

**Figure 8**. A snail spiral.
Source: taken from https://es.gizmodo.com/

**Figure 9**. Snowflakes seen through a microscope.
Source: taken from https://es.gizmodo.com/

Bonilla Oconitrillo (2013) claims:

> During these twenty centuries the topic has been addressed by artists who seemingly have always understood that reality is one only, that body and skin are one only, mutually needed to function regardless of being analyzed separately.
> Fractals immediately connect with the theory of chaos and the dynamic systems, and this brings us closer very rapidly to a slightly more harmonious and integral comprehension of reality (p.1).

Unlike the geometry used in the past (based on rectangles, circles, triangles, ellipses, etc.), this new geometry describes sinuous curves, spirals and filaments that wind around themselves producing elaborated figures and which details are lost in the infinity.

Therefore, we can understand fractal geometry as *the geometry of nature*, *chaos* and *order*, with forms and sequences that are locally unpredictable but globally ordered in contrast with the Euclidian geometry that represents objects created or ordered by man and, are of course totally predictable.

## Ordering chaos

By knowing in a general way some aspects of previous concepts, even though consequences are not predicted, we can expand our epistemological basis to better understand the dynamic systems that go into every research. Therefore, we summarize the following:

- From Albert Einstein we consider a four-dimension space (x, y, z, t) in real life; these dimensions, applied to mathematics, can be much more.

- As systems are converted into non-determinists, technology, on the other hand, is developing to predict more accurate results.

- Even though chaos cannot be predicted accurately, current studies take the phenomenon into account in order to avoid it.

The foregoing offers several current examples: several years ago, at airports with major air traffic, there were several inexplicable cases of plane crashing at takeoff with no apparent cause. Subsequent investigations confirmed that a zone of turbulence would form at the end of the wings of the aircrafts, and if another plane would takeoff next and passed through this turbulence zone, it “would stall”.

After knowing the chaotic results of the investigation of the chaos zone where it is impossible to work, measures were taken to avoid producing said chaos zone in current aviation. The International Aeronautical Commission set forth a rule that establishes a three to four minute-delay between aircraft takeoff, time sufficient for the vortices in the wings of the plane taking off to dissolve before the next aircraft may take off, thus, avoiding a tragedy.

Another example can be found in tropical cyclones. Meteorological institutes have a forecasting department where, through the collection of previous data, a “cone of possible trajectory” is established, which indicates the possible zones affected and the place where the hurricane must go through with a high probability prediction. Of course, relevant measures are taken in this regard.

In time past, these chaotic events irremediably surprised us with their catastrophic consequences, but, thanks to the technologic development, the seasonal zones affected have diminished in both social spheres and in the field of natural phenomena. Therefore, some scientists, philosophers and sociologists appeal to the phrase “order chaos” not only in reference to predictions but also in their attempt to unravel their particularities through the study of those complex dynamic systems.

## Conclusions

This brief study constitutes a summary of facts that, even though they are there for everyone to see, sometimes, we do not realize their importance although we are at the mercy of their consequences. Many authors have addressed the main topic of this study with sufficient depth; however, several communities among which the university students still do not know about this topic.

It also applies to most fields of knowledge. Therefore, it would be useful for university students and professors to have some informative knowledge in this regard so they may understand the role current technologies play in scientific research by analyzing a topic efficiently.

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