Ontologies:

On the Concepts of:

Possibility, Possible, “Acaso”, Aleatorial and Chaos

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Abstract

In addressing the interdisciplinary field that is growing at the intersection between chaos theory and risk science it becomes necessary to reconsider the notion of chaos in its linkages with the notions of possible, possibility, “acaso” and aleatorial.

Aiming at such an interdisciplinary effectiveness, the present article addresses the notions of possible, possibility, “acaso”, aleatorial and chaos in terms of their respective constituent and constitutive systemic *topoi*, from the formative ontological systemic dynamics, structurally dependent upon the initial conditions of the respective systems and cognitively computed/processed by these same systems, from the perception and recognition of themselves, as individuated resonating rotative positions, in the inter-systemic web of survival.

The (inter)systemic risk is, then, addressed in connection with the chaos in the deterministic systems. An example of *Malcolm effects* and synchronized risk being researched upon for a two-dimensional nonlinear map that produces *multifractal chaos*. This allows for the signalling of conceptual linkages that occur at the intersection of chaos theory and risk science, between *homeostatic mechanisms*, synchronization and chaos.

Keywords: Possibility, possible, “acaso”, aleatorial, stochastic, *clinamen*, chaos, Malcolm effect, multifractal chaos, synchronization, risk, risk science, *multifractal self-organized criticality*.

1. Introduction

From an applied scientific standpoint, there is a pertinent importance of the study of the phenomenon of chaos that takes place in the nonlinear dynamics of deterministic systems. With the development of risk science, there arose interdisciplinary intersections between chaos theory and risk science. It is still an open matter and, perhaps, a fertile ground for future research, the matter of whether or not the theory of chaos can also provide for a building block to a mathematical approach to a science of risk that has the risk, as such, as its object, allowing for the development of a mathematical perspective on the origin of risk in the systems.

For the development of an interdisciplinary research at the intersection between chaos theory and risk science, it becomes necessary the review of the notion of chaos in its connections with other key notions with which chaos is connected, that is, it becomes necessary to consider the notions of possible, possibility, “acaso”, aleatorial and chaos in terms of their respective constituent and constitutive systemic *topoi*, from the formative ontological systemic dynamics, structurally dependent upon the initial conditions of the respective systems and cognitively computed/processed by these same systems, from the perception and recognition of themselves, as individuated resonating rotative positions, in the inter-systemic web of survival.

This is the main objective of the present work, and it is fulfilled in **section 2**. After addressing these notions, it becomes important to consider the relation between chaos and risk, in particular, the patterns of risk that emerge from *multifractal chaos* produced by the coevolutionary dynamics in coupled nonlinear dynamical systems. In **section 3**, we address this issue considering the synchronized risk of sharp jumps and changes of irregularities in a *two dimensional nonlinear map* that generates *multifractal chaos*.

In **section 4**, we draw upon the main work developed throughout the article and the results of **section 3**, in order to address some interdisciplinary issues between chaos and risk science.

2. On Possibility, Possible, "Acaso", Aleatorial and Chaos

Possibility, from the Latin *possibilitas*, *atis*, is an abstract term to designate the intelligible structure of the possible. Possible is what can be. *To can be* is that which, not being, however, is, as being able to be, and, thus, it is that which in the being is not-being, or nothing.

All things that, effectively, are, they are because they can be. *To can be* is, in the being: to be possible, and to be possible is to have, in itself, as being that is, its own possibility of being, as a dynamic power (*potere*) to be, or resonating constituent and permanently available opening (*yawning gap*[1]) (Madeira, 2009), as its own asymmetric condition of effective possibility of itself, in its own being. Which means that everything that is integrates, as fundamental constituent condition of itself, two asymmetric positions of the same being, as being of itself: being and nothing.

In the resonating rotative frontier (in Portuguese *fronteira*, from the Latin *frontariu* that means *that which is situated in front of*, as position and alterity), between the being in the being and the nothing in the same being, is situated the rotative dynamics of the ontology of the "acaso"[2], generated by the constitutive dispositional asymmetry, synthesized and metabolized by the dynamics of the being, as position of itself, as being and nothing.

The "acaso", with origin in the Latin *casus*, has the primitive meaning of cause, or reason, unknown. In the systems, the "acaso" functions as an internal spontaneous mechanism, related to the systemic material organic and linked to the vital mechanisms of aggregation and disaggregation of the same systems, this internal spontaneous mechanism is exemplifiable by that which in the systems constitutes the *arbitriu*[3] or

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[1] Poetic Edda (Kittredge, [1923], 1965, p.4):
"Of old was the age when Ymir lived;
Sea nor cool waves nor sand there were ;
Earth had not been, nor heaven above,
But a yawning gap, and grass nowhere."

[2] In English, the Portuguese word "acaso" is translated as chance, however, the word chance does not capture the semiotic roots of the word "acaso", in order to understand these roots and the meaning of the word "acaso" see the next paragraph.

[3] The Latin term *arbitriu*, cannot be confused with the notion of free will (*vontade livre*, *livre arbítrio*), the term *arbitriu* (in Portuguese *aribítrio*) incorporates, in its meaning, a deliberative systemic operativity always conditioned by the laws of structure of the system, laws that, in turn, are always conditioned by the initial formative conditions of that same system. One cannot speak of free will in regards to the term *arbitriu*, because the deliberative synthesis, that always involves choices, strategies, and effectivenesses, is always made in the systemic limits that depend upon the system's structure, which, as referred, is always dependent upon the initial conditions and laws of structure of the same system.

clinamen[4] (Epicurus) of these same systems. The "acaso" is not situated at the level of the systemic effects, instead, it is situated at the level of the causes or reasons that emerge from the dynamics of the systems, within their formative parameters, which will always depend upon the initial conditions that formed, or gave origin to the respective systems, and upon which (origins) the same systems depend as individuated entities and, thus, identities.

With radicular links at the level of the systemic effects of the dynamics of the "acaso", is situated the aleatorial[5], from the Latin *aleatorius*, with the meaning of uncertain or contingent, dependent upon the event linked to the systemic *arbitriu*, or "acaso", whose dynamics are permanently conditioned by the initial conditions that formed the system and that the system computes, as such, in order to maintain its structural integrity.

Poincaré expanded the notion of *aleatoriness*[6] to operational levels, relating it with the Greek terms *stochos*, with the meaning of target, and *stochastikos* with the meaning of skilful in the objective, or target. The difference between the two terms (aleatorial and stochastic) is located at the conjectural level of the systemic patterns signaled and configured from the perception of the patterns of rotative rhythmicity that emerge from the *aleatorial dynamics*, always dependent upon the initial conditions. The passage of the aleatorial to the stochastic is done when it is recognized the presence of *statistizable/probabilizable* structures.

It is at this point that the chaos can be signalized as a presence in the occurrence of *stochasticity* in the deterministic systems (Stewart, 1991; Prigogine, 1996), therefore,

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[4] The semantic determinism of the Greek scientific discourse was generalized as an epistemic model until Epicurus, distancing himself from the primitive atomism of Democritus, introduced the notion of *clinamen* (*declination*) as a capability, an *arbitriu* that the atoms have to deviate themselves spontaneously from their trajectories. Thus, Epicurus incorporated, in the philosophical and scientific discourse, an irreducible element of unpredictability at the epistemic level, absent up until then, with ontological and epistemological consequences about that which was considered as *criterion of truth*. Without putting into question the "general laws of nature", known at the time, the author localized a present and permanent dispositional element of constitutive arbitrariness (*arbitriu*), in any process of formation of emergent structures, as an element incorporated in the dispositional genetics of these same structures with consequences at the level of the systemic perception and cognitive processing/computation, and at the ontological level of the threat of destructuration and the opportunity of structuration, present in any physical existent, and that function as mechanisms of potential risk (linked to the mechanisms of life and death) and, thus, *undetermined*, *permanently displaced*, within the structure itself.

[5] The most often used term, in English, is random, the two terms aleatorial and random exist in the English language, while, for instance, in the Portuguese language only the corresponding term aleatório, which keeps the Latin root *aleatorius*, is used. The two terms in English can be used as synonyms, however, the term aleatorial keeps the Latin root, therefore, we used this term instead of random, in order to be able to develop some philosophical analysis of the concept.

[6] The property *aleatoriness*, in Portuguese, aleatoriedade.

as structure in the *aleatorial*, an intricate of confuse intertwining structure recognized by Poincaré in the behavior of dynamical systems (Stewart, 1991).

The term *chaos* comes from the Greek *khaos*, which refers to a primordial structure prior to all things and from where all things came, even the gods (Hesiod, *Theogony*, v.116). The *khaos* is only opposed to *order* (*kosmos*+*logos*) because the *khaos* is that which, primitively, is unknown, it is that which cannot be determined, it is that which is strange, because it cannot be perceptioned nor recognized, and, thus, cognitively processed/computed/verbalized, in the sense that each actualized living system does not have the capability to directly cognitively access to the primordial state that preceded all existing things and that was at the origin of these. The *khaos* was the vacuity, darkness, indetermination, disorder, and undifferentiated totality.

The genetic root of the term, cosmogonically trajected, allowed for a rhizomatized development of the same term, towards new meanings, agilized by mathematics (we think that agilized is a reasonable term), in what regards the attempts of conceptual synthesis to levels of pragmatic operationality.

The term was introduced, in mathematics, by Li and Yorke (1975) regarding the occurrence of complicated behavior in the temporal evolution of the logistic map. The notion was introduced through an adjectivation of the map's dynamics that, for certain parameters, showed patterns of turbulence and disorder that were usually thought to take place in systems with many degrees of freedom, but not in systems with a low number of degrees of freedom (Li and Yorke, 1975, p.985).

The adjective *chaotic* was thus introduced, by the authors, to address a non-periodic dynamics and non-quasiperiodic dynamics that showed evidence of complicated trajectories, this complicatedness being a property highlighted by the authors.

In our computational tools, because of the computational limits that impose a finite precision and, thus, the need for the rounding of numbers in computations, a simulation of the same system with chaotic dynamics, using the same initial conditions, may differ with time due to the exponential divergence of nearby orbits that amplifies the small deviations that may occur due to differences in finite precision of the software computations.

These differences may occur due to an approximation in the reading of the initial conditions, however, even if we provide for the same initial conditions and these are within the precision used by two different softwares, even though the deviation between the initial conditions for each software is null, as we shall see in the fourth section, there will still occur, for softwares with different precision levels, the accumulation of deviations between the two simulations due to the finite precision used by each software and, thus, the rounding that each software produces when it computes each iteration, these deviations are usually small but they are amplified in the same manner as a small deviation in initial conditions is amplified, this similarity is explained by the fact that the deviations between the two simulations take place within the dispositional parameters allowed for by the (same) initial conditions and by the (same) deterministic rule used by the two softwares.

To study chaotic dynamics, especially in coupled nonlinear systems, we need to simulate these systems, however, the simulations of an orbit that results from a certain initial condition may differ for each individual orbit, depending upon the "phenotypic effects" generated by the interaction between the mathematical structure and the software used, but because each orbit in a chaotic dynamics follows the same laws of structure that are determined by the underlying deterministic rule(s)[7] that guides the system's dynamics, the chaotic dynamics can be apprehended by an analysis of these laws of structure.

These laws of structure result, in particular, from the emergence of: *invariant measures* (*ergodic chaos*), *chaotic attractors* and *Lyapunov spectra*, all these are related to the underlying deterministic rule.

The occurrence of complex structures in chaos, such as attractors (see Fig.1), that are produced for certain parameters and non-negligible basins of attraction, allows a scientific approach to chaos based upon a search for the laws of structure. It is not relevant the "phenotypic effects" regarding the interaction between the mathematical rules and the software implementation of those rules that lead to differences in the simulations of individual orbits, because one is not concerned with individual orbits, but, instead, one is concerned with the laws of structure, the simulations allow a capturing of these laws of structure because different orbits obey these same laws of structure.

The ontological difference between the Greek terms *khaos* and *kosmos* is only of a cognitive nature, linked to the systemic need to perceive, interpret, understand and explain the existing things in order to survive.

[7] In the case of coupled nonlinear maps, for instance, different microscopic rules may be used for each oscillator.

Poincaré identified in chaos the multifolding of a sort of web, or net or extremely tight fabric (Stewart, 1989).

The sensitive dependence upon initial conditions can be understood by thinking about it in terms of a systemic cognition through the nonlinear deterministic rule. Two initial conditions, very close to each other, tend to lead, over time, to different histories, this is significant, since it signals that the chaotic system processes further and further details of its initial conditions.

Thus, for instance, in the case of a nonlinear map in the chaotic regime, upon each iteration the system goes further and further into the details of its initial conditions. At the end of any iteration, the system possesses a finite "knowledge" of its initial conditions, but this finite "knowledge" is expanding with the steps in the system's temporal evolution in the sense that more details are processed/computed by the system.

Thus, for instance if $x(0)$ is the initial condition of a map with chaotic dynamics, then another initial condition that differs from $x(0)$ by 0.00001 (absolute difference) will lead to an orbit that quickly diverges from the orbit that started at $x(0)$. Initially close, the two orbits diverge after a few iterations, these few iterations are the iterations needed for the deterministic rule to learn of the fifth decimal place in $x(0)$ and to be sufficiently affected by this processing such that it will diverge from another orbit that differed from x(0) by a positive or negative magnitude of 0.00001.

A theory of chaos also opens up the way to a theory of risk in deterministic systems. An example occurs when the nonlinear dynamics produce multifractal signatures in the system's dynamics. In these cases, sharp jumps may take place and the dynamics may suddenly become more volatile.

This phenomenon was signalized by Crichton (1991) under the name *Malcolm effect*, the name Malcolm referring to Chrichton's character of the mathematician specializing in chaos theory. *Malcolm effects*, thus, may take place in a chaotic system with systemic risk where a deviation in the chaotic behavior may occur towards a more volatile period characterized by extreme variations relative to the system's natural fluctuation interval. As an example, we present, next, a system of a two-dimensional nonlinear map that generates such effects in the context of *multifractal chaos*.

3. The *Malcolm Effect* and *multifractal chaos* in the dynamics of a two-dimensional nonlinear map

Let us consider the following *two-dimensional nonlinear map*[8]:

$$\begin{cases} x(t) = (1-\varepsilon)\cdot\left(a\cdot x(t-1)-(a+1)\cdot x(t-1)^3\right)+\varepsilon\cdot y(t-1) \\ \\ y_t = \left(b+x(t)^2\right)\cdot\left(r-y(t-1)\right)+x(t)^2\cdot y(t-1)^3 \end{cases} \quad (1)$$

One may recognize, in the first equation, a coupling that typically occurs in *coupled nonlinear maps* theory, where the nonlinear transformation and the coupling are separated, that is, defining f_a as the *cubic map* $a\cdot x(t-1)-(a+1)\cdot x(t-1)^3$ and taking the nonlinear transformation $x(t-1)\rightarrow x'(t)=f_a(x(t-1))$, we have:

$$x(t)=\varepsilon\cdot x'(t)+(1-\varepsilon)\cdot y(t-1) \quad (2)$$

For $y(t)$ the two *maps* $x(t)^2\left(r-y(t-1)+y(t-1)^3\right)$ and $b(r-y(t-1))$ are being added. The second *map* introduces a mean reversion, while the first contains the nonlinear update.

In Fig.2, we present the bifurcation diagrams for x and y, with $a = 3$, $b = 0.5$, $r = 0.001$, and for different levels of coupling. We can see that while the behavior of the bifurcations for $x(t)$ show a period-doubling structure, the data for $y(t)$ show regions of chaotic dynamics near a central area, and jagged structures with high variability in the values assumed by $y(t)$, but which show a more structured dynamics, this can be seen in the attractor shapes produced for the delay plots of $y(t)$ (see Fig.3). There is a common double cone-line heteroscedastic chaotic structure that occurs near zero, but in the jagged regions of the bifurcation diagram the dynamics acquires a complex structure that is recognizable as something more than "simple" heteroscedastic noise (Fig.3(a)), such a visual distinction cannot be made, from the delay plot alone, for the chaotic dynamics near the central region of heteroscedastic chaos (Fig.3(b)).

[8] All of the simulations were made using the Software E&F Chaos, except for those that are explicitly stated otherwise.

Both delay plots, shown in Fig.3, reveal an increase in dispersion with the magnitude of $y(t-1)$, with the possibility of large jumps for $y(t)$, these are conditions capable of generating *Malcolm effects*, with clustering of variability.

Systemically, one is before two coevolving systems, this coevolution produces a high risk for $x(t)$ through the occurrence of a *synchronized Malcolm effect*. Which is visible in the attractors shown in Fig.4. Both attractors in Fig.4 show a double-T-like structure, which means that when $y(t)$ is in a region close to one of the extremes of an interval of variation of the chaotic dynamics for $y(t)$, this tends to occur in sync with large values (either positive or negative) in $x(t)$.

On the other hand, for large values of $x(t)$, $y(t)$ tends to occur in a region of high variability in the interval of variation of the chaotic dynamics for $y(t)$.[9] This signals the possibility of occurrence of *synchronized Malcolm effects*. While for large $x(t)$ (close to plus or minus 1) the variability of $y(t)$ is large, when $y(t)$ is near one of the extremes of its interval of variation there seem to be two at most four alternative possible range of values of $x(t)$ all far from zero (this is especially visible in Fig.4(a)).

The immediate question that follows is the statistical question, which concerns the risk of occurrence of high magnitudes for $x(t)$ or for $y(t)$. In Fig.5, for ε=0.01 we see that the histogram for $x(t)$ tends to concentrate at the two extremes in a form of a U-like distribution[10], on the other hand, $y(t)$ seems to generate a histogram with leptokurtosis and power-law decaying tails[11].

The fluctuations in the absolute value of $y(t)$, for ε=0.01, also show evidence of the presence of a *power law decay* (see Fig.6), after a certain threshold of large magnitudes of $y(t)$, this indicates the presence of a scale invariance in the fluctuations of $y(t)$. However, this is not the only evidence of scale invariance. Using the software Fraclab we estimated the *large deviation spectrum* for $y(t)$, for the case of ε=0.01, the result being presented in Fig.7. The spectrum shows evidence of multiscaling with a maximum near a Hölder exponent of 0.4, which is in the antipersistence region.

This means that the absolute variations of $y(t)$, scale as a *power law* with local Hölder exponents $\alpha(t,\delta)$:

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[9] This interval is wider for the case of ε=0.056 than for the case of ε=0.01.

[10] This shape occurs due to the invariant measure of the *cubic map*.

[11] The characteristic exponent for the stable law, estimated by Fraclab, was 1.5214 (0.021202), using the McColluch method, and 1.6619 using the Koutrouvellis method, both exponents are smaller than 2, which is consistent with a stable law with *power law decaying tails*.

$$\left|y(t+\delta)-y(t)\right| \propto \delta^{\alpha(t,\delta)} \tag{3}$$

There is, thus, evidence of *multifractal self-organized criticality* in the behavior of $y(t)$. This kind of process tends to produce phenomena of concentrations of volatility and large jumps, which characterize the rapid endogenous change of direction of a system's dynamics that is characteristic of *Malcolm effects*. In Fig.8, the time series, for which the spectrum was calculated is shown. The occurrence of volatility concentrations and large jumps[12], characteristic of *Malcolm effects* is very clear.

Malcolm effects tend to be produced in multifractal dynamics when a volatility clustering and jumps occur with increase in irregularities (Mandelbrot, 1997). We call the *Malcolm effects* that occur in systems with multifractal dynamics *multifractal Malcolm effects*.

Since the jumps in $y(t)$ tend to occur in sync with a large value (positive or negative) in $x(t)$, there tend to take place *synchronized multifractal Malcolm effects* in the coupled system's dynamics.

4. Risk, chaos and synchronization

It follows from the work, in the previous section, that the phenomenon of chaos, in the dynamic behavior of nonlinear dynamical systems, is linked to systemic risk.

On the other hand, the emergence of multifractal signatures, sustained by the system's dynamics, is consistent with the occurrence of a phenomenon of *multifractal self-organized criticality* or MSOC.

The systemic management of risk in the contexts of MSOC, by adaptive systems, allows for a quick adaptation but also exposes the systems to the risk of collapse due to the occurrence of *Malcolm effects*, where the systems' dynamics changes rapidly and not necessarily for the best (Crichton, 1995).

In the case of human systems, there is an additional risk when adapting to *multifractal chaos* and trying to predict the systems' future dynamics, linked to the, already mentioned, deviation in the simulation of a chaotic system by different softwares.

[12] By large jumps one should understand these in relation with the normal variations. In this case the largest jumps are near plus or minus 0.005, which is large with respect to the normal fluctuations that situate themselves near plus or minus 0.0023.

An example of a deviation is shown in Fig.9, for E&F Chaos and Excel, with respect to the cubic map. The Excel has a higher precision that E&F Chaos, which means that the computations differ, these errors accumulate and expand with the dynamic instability that is proper of a dynamics with sensitive dependence upon initial conditions.

Even though, in this case, the initial condition is the same, for the two softwares, the first iteration, for each software, already produces a deviation, both Excel and E&F Chaos differ with respect to their computation of what the following iteration should be, these (small) deviations between the two softwares computations accumulate and expand with the exponential divergence that characterizes the chaos.

This serves to show, that even if one had an equation or a mathematical model that would capture the dynamics of a system whose dynamics leads to *multifractal chaos*, that equation or model would, upon simulation, with a very high probability lose its predictive effectiveness due to the finite precision and rounding that our machines use. The system and the different human agents trying to predict the system's behavior would quickly go out of sync, which leads to a high risk of failure in predicting the occurrence of a *Malcolm effect*.

These results reveal the need to address chaos in terms of the notion of *on timeness* worked upon at CETA Research by Peter Beamish[13]. Once the system and an agent predictor cease to be *synchronized* in their rhythms, the agent predictor may be at high risk.

The exponential divergence of nearby orbits in chaos can be addressed in terms of this destruction of an *on timeness* of the different chaotic oscillators. In a collection of nonlinear dynamical systems, with low coupling, that start in initial conditions close to each other, this loss of *on timeness*, due to the exponential divergence of nearby orbits is a well known phenomenon of chaos.

However, a less known phenomenon, is the spontaneous ability of uncoupled chaotic systems to spontaneously, from time to time, synchronize and produce non-trivial patterns of synchronization, this phenomenon of emergence of *on timeness* occurs in uncoupled nonlinear maps.

[13] See: http://www.oceancontact.com/research/ps/ps114.htm, http://www.oceancontact.com/research/ps/ps112.htm.

This same phenomenon puts into question the usage of the term desynchronized to refer to uncoupled maps, or coupled maps with low coupling, a term used, for instance, by Kaneko and Shibata (1998).

As an example, one may consider the case of two uncoupled cubic maps:

$$x_i(t) = 3x_i(t-1) - 4x_i(t-1)^3 \tag{4}$$

with i =1,2.

We have simulated these uncoupled maps in Netlogo 4.1RC2, using 30,000 iterations, and discarding the first 10,000 iterations for transients, starting from different randomly chosen initial conditions and calculated the absolute differences between the two maps:

$$D(t) = \left| x_1(t) - x_2(t) \right| \tag{5}$$

A clear structure in the synchronization behavior can be seen in the delay plot of $D(t)$ in Fig.10. The histogram for the dynamics of $D(t)$, shown in Fig.11, reveals a distribution that has a decreasing shape with the increase in $D(t)$. Which indicates that the highest the value in $D(t)$ the lowest tends to be the probability of observing that deviation. The distribution seems to show a power law decay which is revealed in the logarithm of the centers of classes of the histogram plotted against the logarithm of the respective class probability (see Fig.12).

Despite an apparent counter intuitiveness of the presence of synchronization patterns in the uncoupled chaotic regime, this should come as no surprise, since despite the divergence, there is an attractor and the synchronization process occurs due to the way in which each nonlinear map explores the phase space.

In chaos, the notion of *synchronization* in *rhythm based time* and the notion of *on timeness*, both worked upon by Peter Beamish at CETA Research, appear to have an explanatory effectiveness that needs to be further explored.

A central node, in this conceptual network, is the *systemic homeostasis*. The computation that produces chaos can be linked to the *autopoietic* processing of the system, and to the mechanisms of *dynamic homeostasis*, that is, the *homeostatic mechanisms* fundamental to the systems' survival.

Such a conceptual network leads to the raising of a fundamental issue for risk science and systems science, it is the issue of the *homeostatic synchronization* between local and global, by which the emergence of *homeostatic mechanisms* of the whole living web is intertwined and inseparable from the adaptive dynamics of the local.

Local agent-specific optima are not enough, a decisional adaptiveness that favors a specific adaptive agent at the expense of the *systemic web* becomes contra-adaptive and a source of risk of collapse, especially in the case of MSOC.

There is, thus, a high risk of an adaptive failure of *schemata* that compute only the local without taking into account the interconnectedness and risk of a *living web*. If the local agent does not compute the global, it fails in anticipating problems, identifying them or even, in some cases, where the problems are identified, in solving them (Diamond, 2005). This only amplifies the risk of systemic collapse in the cases where there exists risk of occurrence of *Malcolm effects*, since, in this case, a local change, may carry significant consequences and an exposure to the risk of a global crisis, even in the cases of low coupling.

Morin's notion of *eco-self-organization* (Morin, [1977], 1997; Morin, [1980], 1999) and the notion of *eco-coevolution* where system and ecosystem coevolve in an intertwined fashion are of great value in apprehending both the adaptive drivers in interconnected webs of complex adaptive systems, as well as in an understanding of the failure to adapt that some human societies have shown throughout history.

The local evolutionary success must, therefore, be measured in terms of the relation between that local success and a global success, if a local strategy is locally apparently adaptive but globally contra-adaptive then it cannot really be considered a successful strategy, that is, evolutionary success must be considered in terms of a *glocal strategic success*.

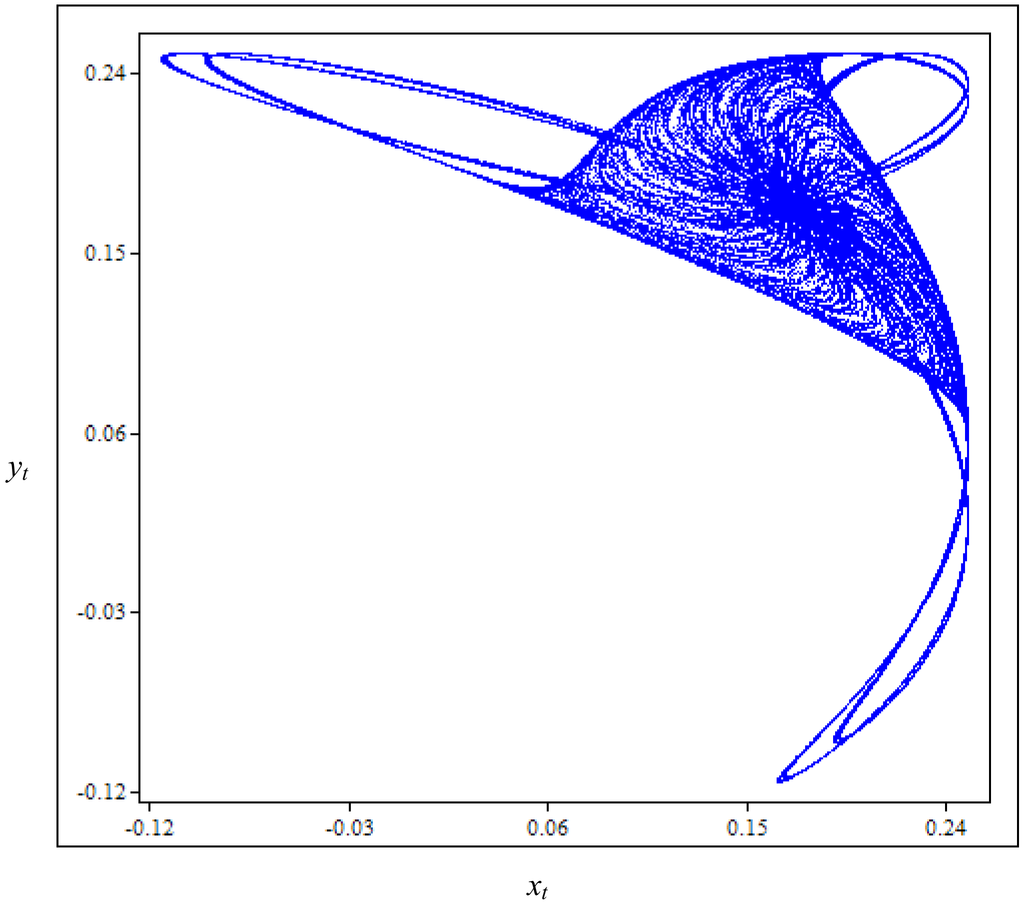
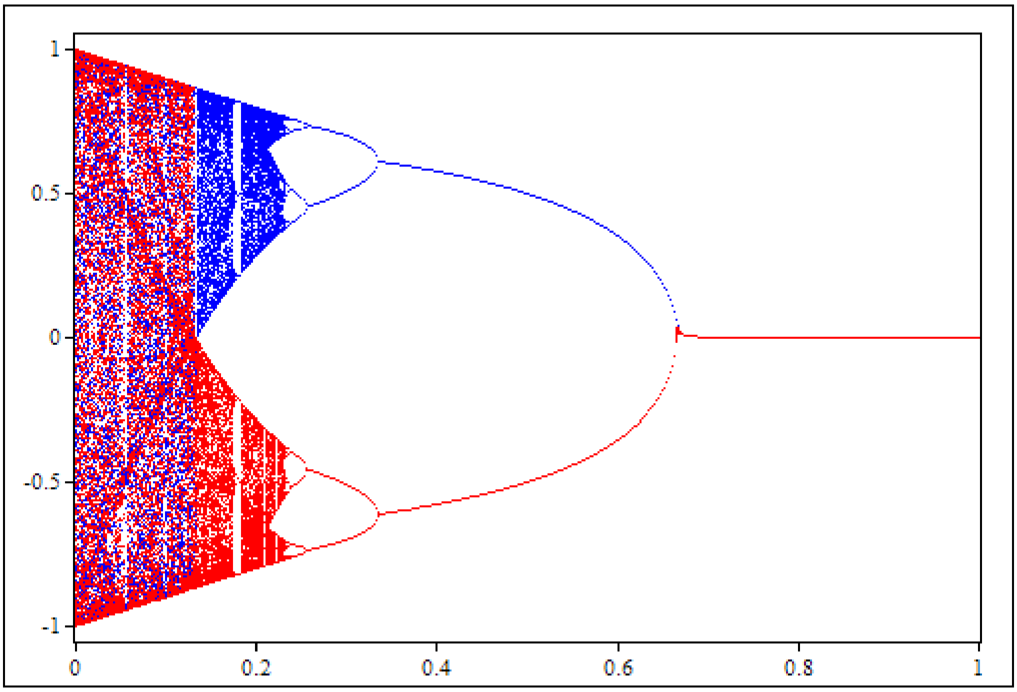


Fig.1 – Example of attractor generated by the two-dimensional chaotic system (Marotto, 1978; Lorenz, 1997):

$$x(t) = (1 - a \cdot x(t-1) - b \cdot y(t-1)) \cdot (a \cdot x(t-1) + b \cdot y(t-1))$$

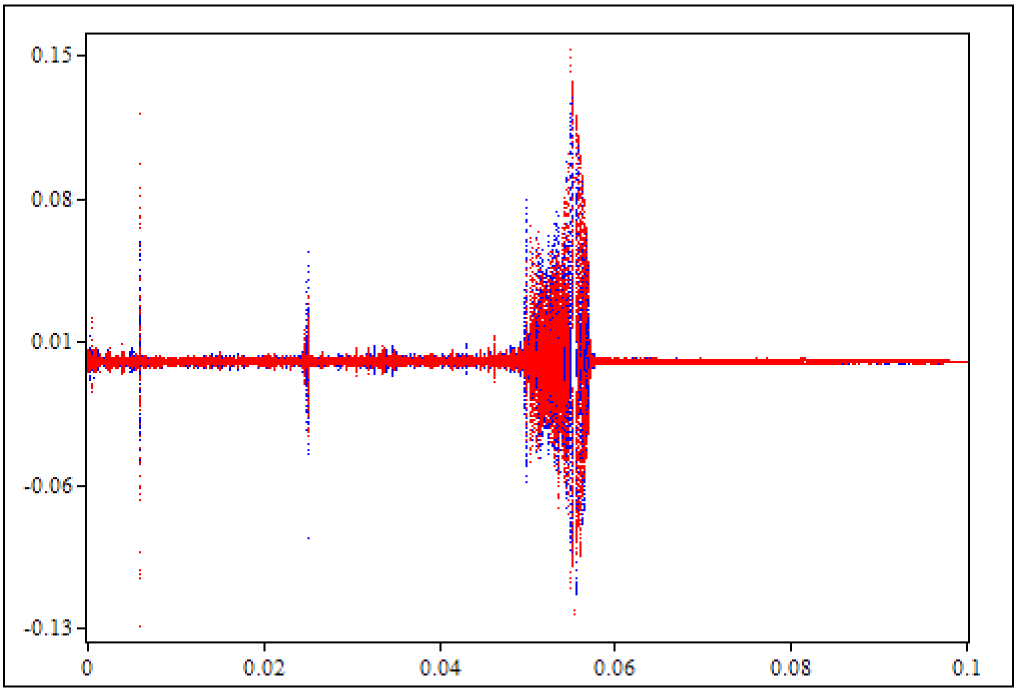
$$y(t) = x(t-1)$$

The attractor was obtained for $a = 2.5$ and $b = 2$.



ε

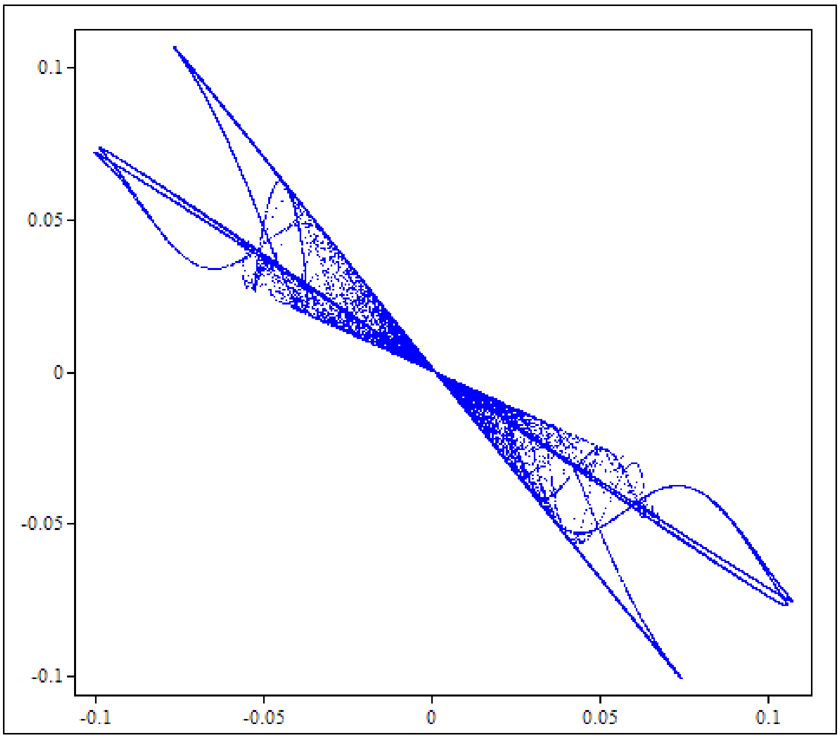
(a)



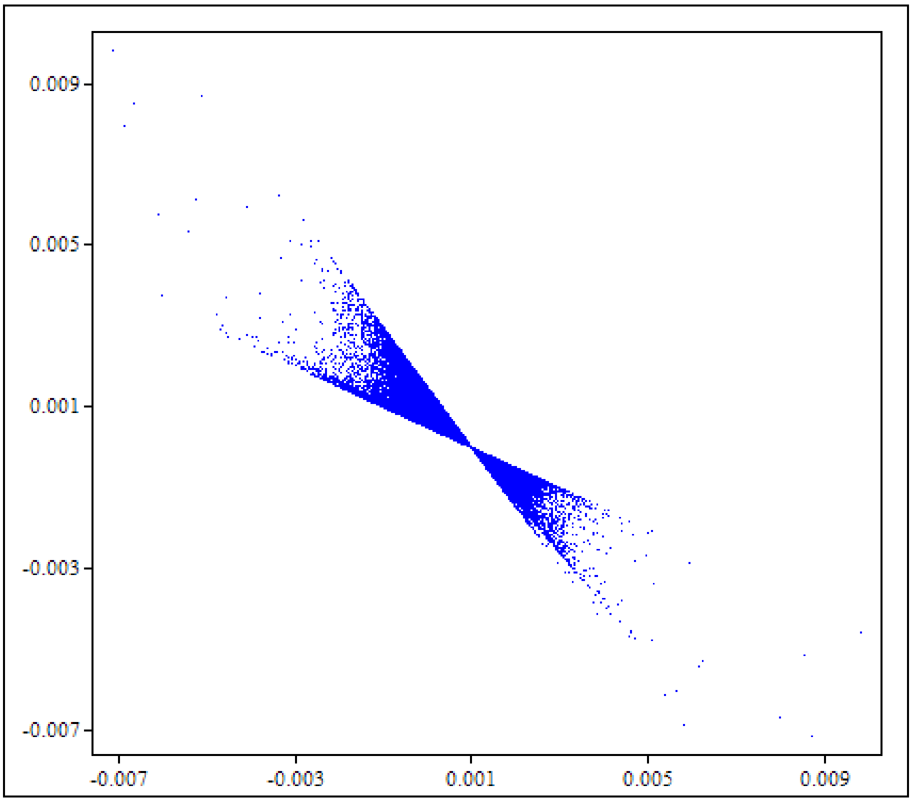
ε

(b)

Fig.2 – Bifurcation diagrams for: (a) $x(t)$ and (b) $y(t)$, with varying ε, when a = 3, b = 0.5, r = 0.001. The blue points correspond to a positive initial condition, while the red points correspond to the symmetric initial condition.



(a)



(b)

Fig.3 – Delay plot for $y(t)$, for a = 3, b = 0.5, r = 0.001 and: (a) ε=0.056 (near a jagged region), (b) ε=0.01 (near a central region).

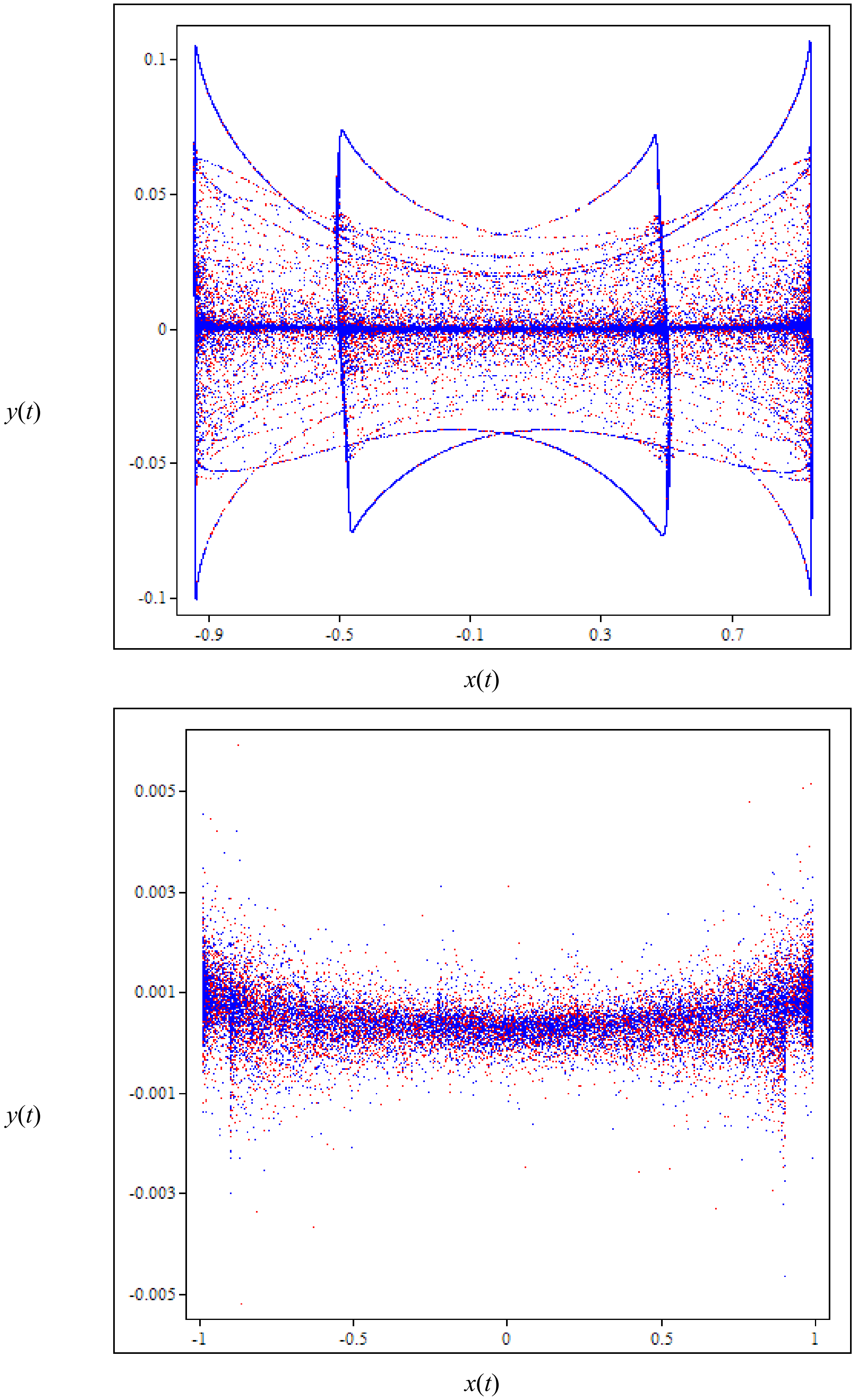
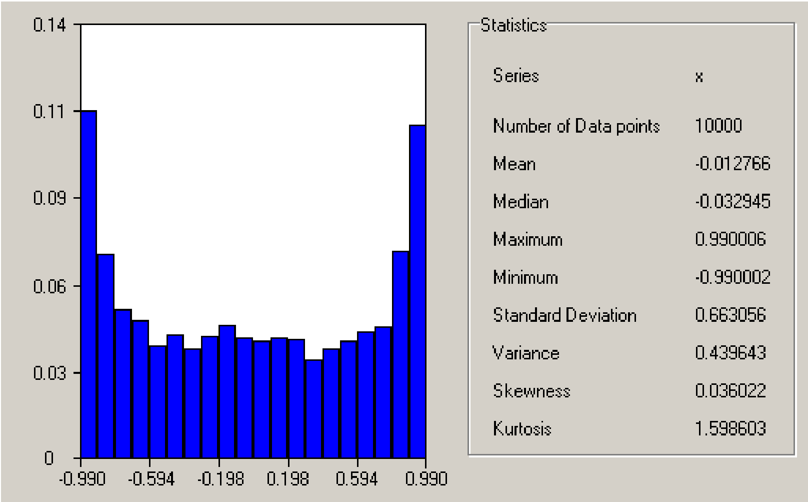
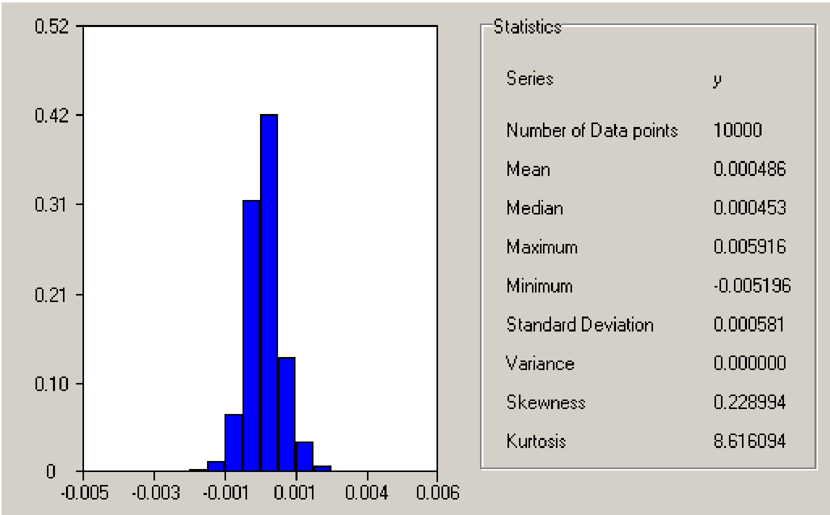


Fig.4 – Phase space plots for a = 3, b = 0.5, r = 0.001 and: (a) ε=0.056, (b) ε=0.01.



(a)



(b)

Fig.5 – Histograms for $a = 3$, $b = 0.5$, $r = 0.001$, $\varepsilon = 0.01$, obtained for a simulation with 20,000 iterations, the first 10,000 data points being removed for transients.

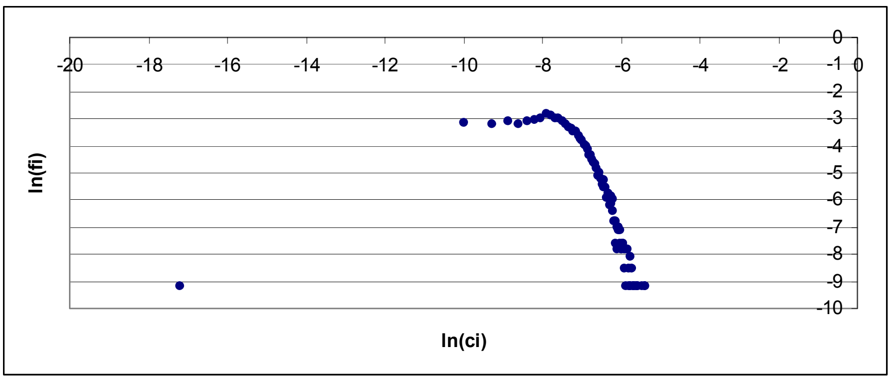


Fig.6 – Plot of the logarithm of the class centers against the logarithm of the relative frequencies, for the histogram of Fig.5(b).

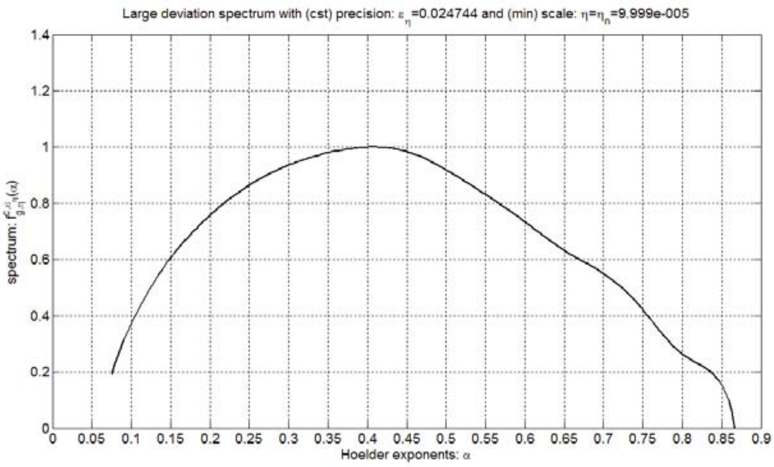


Fig.7 – Large deviation spectrum for the data of Fig.8.

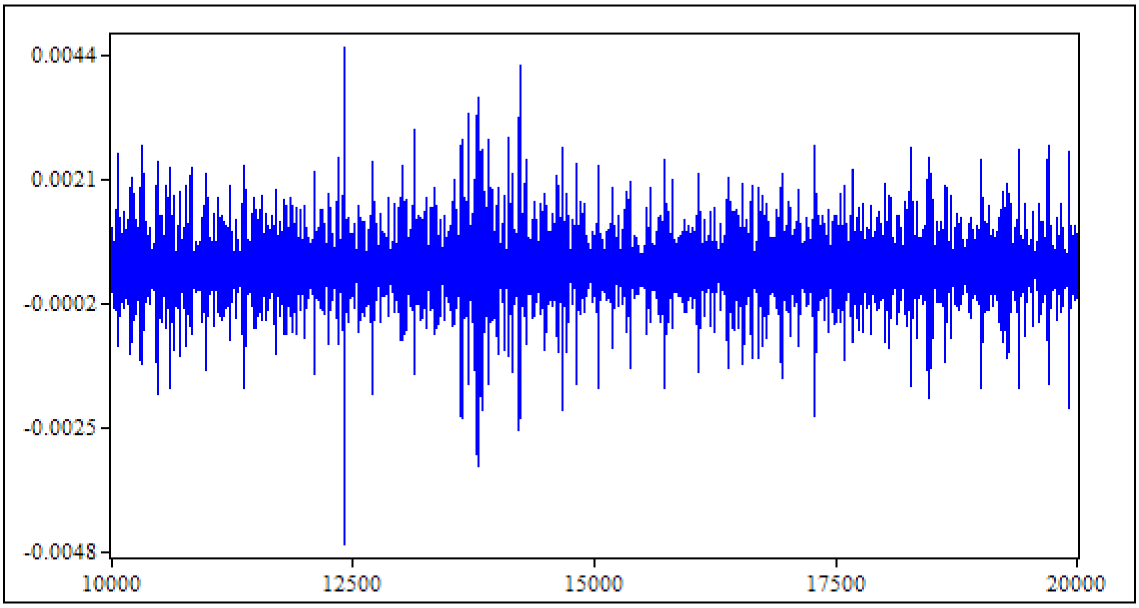
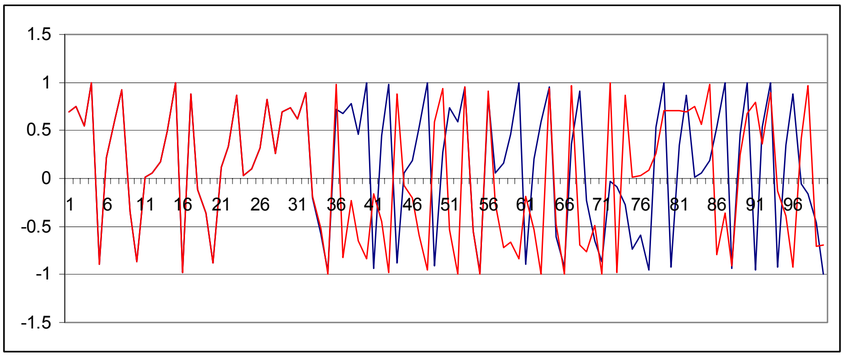
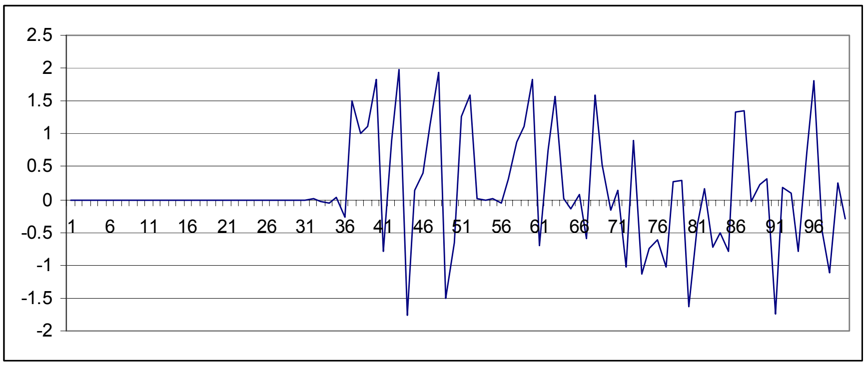


Fig.8 – Time series plot with 20,000 iterations for $y(t)$, taken from a simulation with 30,000 iterations, the first 10,000 iterations being removed for transients. Parameters: $a = 3$, $b = 0.5$, $r = 0.001$, $\varepsilon = 0.01$.



(a)



(b)

Fig.9 – Two simulations of the *cubic map* $x(t) = 3x(t-1) - 4x(t-1)^3$ starting from the same initial condition for E&FChaos (blue line on graph (a)) and for MS Excel (red line on graph (a)). Even though the two softwares start from the same initial conditions they eventually go out of sync due to the finite precision and rounding used by each program. The graph (b) shows the growth in the deviation between the two maps, it is similar to the growth of the deviation between two iterations of the *cubic map* that start from initial conditions initially very close to each other, there is a good reason for this, the deviations between the computations performed by the two softwares are initially very small because the differences in the rounding used by each program are small, it is the accumulation of small differences that is quickly amplified by the exponential divergence of nearby orbits.

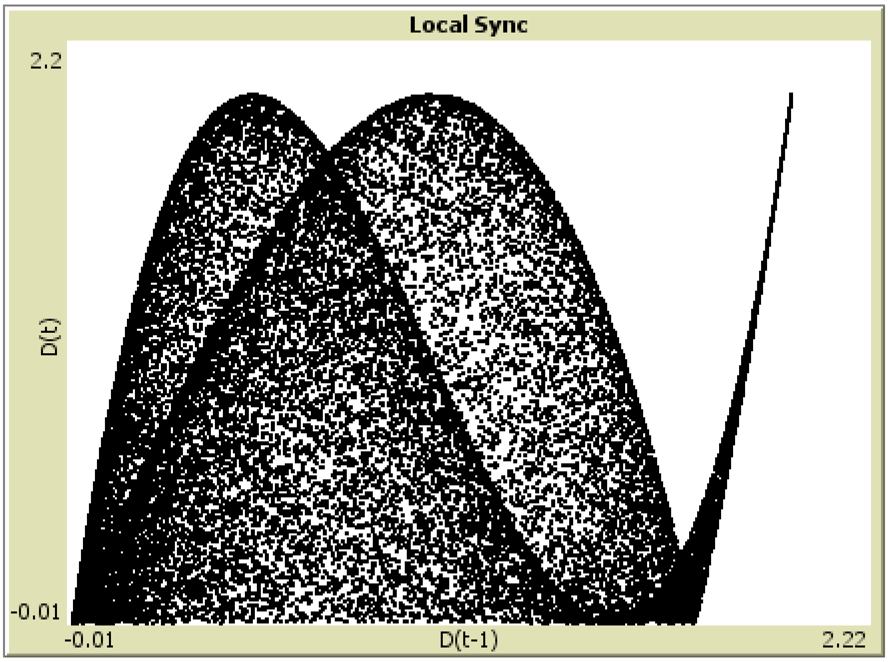


Fig.10 – Delay plot for $D(t)$.

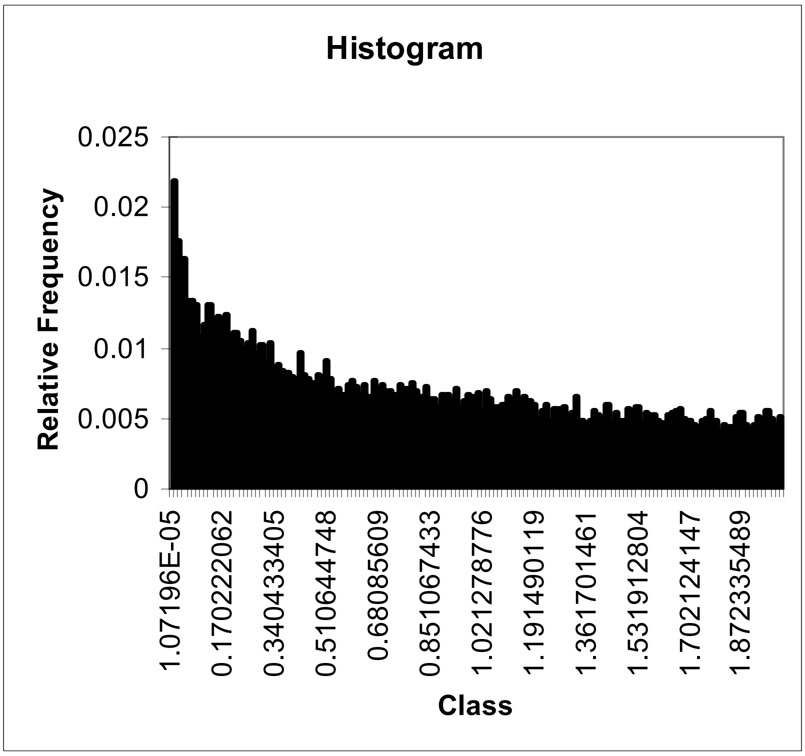
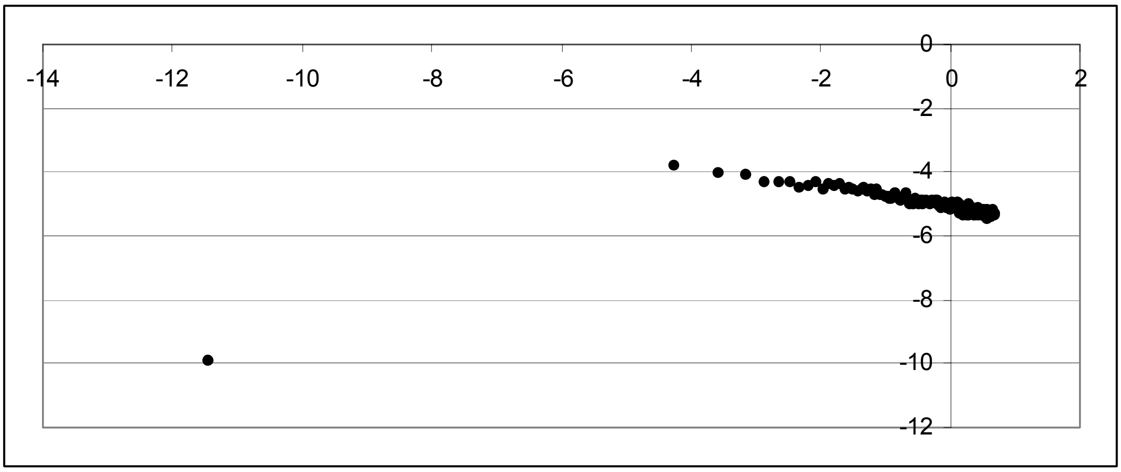
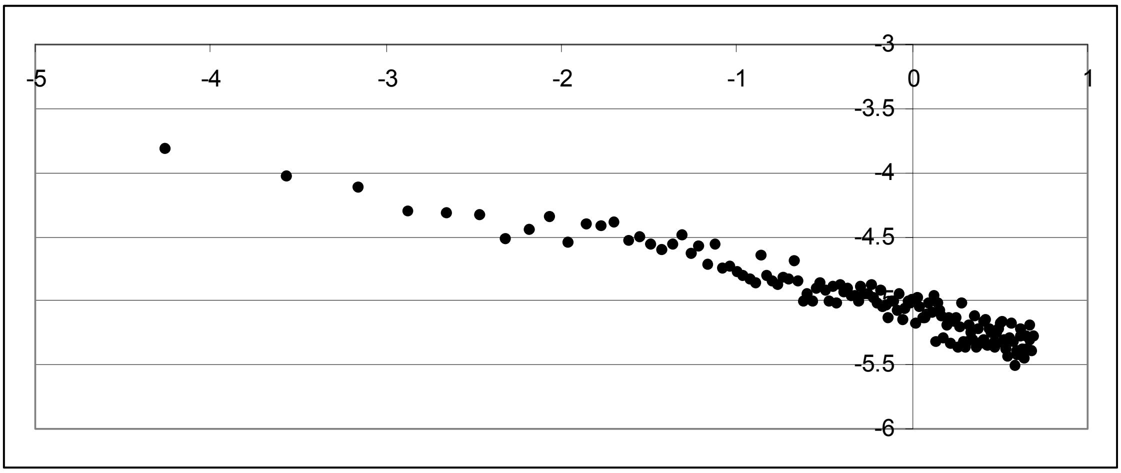


Fig.11 – Histogram for the dynamics of $D(t)$.



(a)



(b)

Fig.12 – Logarithm of the center of class against logarithm of the frequency for the previous histogram: (a) the whole histogram; (b) detail of the power law scaling region.

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