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The Motor Wheels of Social Complexity in Today's World

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ABSTRACT

Se "osservato da una certa altezza", un sistema sociale, composto da un elevato numero di agenti di specie differenti, appare come un brulicante (disordinato) altamente dinamico sistema di individui che interagiscono con gli altri, sviluppando comportamenti individuali sempre diversi e difficilmente ripetibili in tempi successivi, producendo un cambiamento collettivo inarrestabile, nel quale continuamente viene ridisegnata la rete dei processi sociali, culturali, economici e politici; processi tradizionali sono abbandonati mentre altri processi si aggiungono, trainati da sempre nuove tecnologie e spinti dalle modificazioni dell'ecosistema. Tali forme di complessità sono favorite e sostenute dall'azione di alcune fondamentali ruote motrici della complessità: 1. Accelerazione, 2. Interdipendenza, 3. Prevalere del simbolo, 4. Comportamento combinatorio.

If "observed from a certain height", a social system, composed of a large number of agents of different types, appears as a teeming (disorderly), highly dynamic system of individuals who interact with others to produce individual types of behavior that are always diverse and unlikely to be repeated in the future. This leads to relentless collective change that continually modifies the network of social, cultural, economic and political processes. The traditional processes are abandoned while others take their place, spurred by increasingly newer technologies and changes in the ecosystem. Such forms of complexity are favored and heightened by the action of several fundamental motor wheels of complexity. I believe the following to be fundamental: 1. Acceleration, 2. Interdependence, 3. The prevalence of the symbol, 4. Combinatory behavior.

Keywords: Complex systems, Society, Acceleration, Interdependence, The prevalence of the symbol, Combinatory behavior

1 – Introduction

This study starts from the assumption that the global social system – that is, the economic, political and environmental super system – is increasingly becoming, or has already become, a "complex system" in which the individual behavior of the many subjects, or agents, that compose it, as well as that of the various nested economic and political aggregations, depends on the *behavior* and *actions* of the other individuals (and their nested aggregations), with a large number of continuous reinforcing and weakening loops. The sociologist Talcott Parsons (1951, 1971) clearly defined a social system as a network of interactions between actors.

The subject of this volume [The Social System] is the exposition and illustration of a conceptual scheme for the analysis of social systems in terms of the action frame of reference [...] The fundamental starting point is the concept of social systems of action. The interaction of individual actors, that is, takes place under such conditions that it is possible to treat such a process of interaction as a system in the scientific sense and subject it to the same order of theoretical analysis which has been successfully applied to other types of systems in other sciences (Talcott Parsons 1951, p. 3).

Niklas Luhman (1995, 1997) conceived of a "social system" as an autopoietic system (Maturana and Varela, 1980) – self-referential and self-reliant system that is distinct from its environment – in which people are connected by a network of communication processes. In his view of social systems as autopoietic systems, Luhman assigns language a fundamental role, since it permits communication among individuals (Luhman, 1995).

Words are also constellations of sounds with meaning; but they do not determine the sentences that they can produce when combined ... . With the help of speech, one may say something that has never been said before (italics in original) (Luhmann, 1997, p. 215.).

As a result, the system's dynamics as a unit are not easily observable or predictable. In fact, when "observed from a certain height" a social system made up of a large number of agents of different types appears as a teeming (disorderly), highly dynamic system of individuals who, moved mainly by personal interests, interact with the others, who in turn react to produce individual types of behavior that, like the turbulent water that forms changing eddies in a mountain stream, are increasingly diverse and unlikely to be repeated in the future, thereby producing a relentless collective change that continually modifies the network of social, cultural, economic and political processes. The traditional processes are abandoned while others take their place, spurred by increasingly newer technologies and changes in the ecosystem. The social system thus appears as a *complex* system in which the individual, collective and environmental dynamics interact through "reinforcing" and "balancing" loops (Mella 2012) that form systems of interconnected and interacting variables that are too difficult to understand and produce outcomes which are increaslingly less understandable and predictable, and thus difficult to control.
By definition, a *complex system* is composed of a large number of interacting elements, often not individually observable, whose dynamics, starting from a present state, are *intrinsically uncontrollable* and may lead to *unpredictable emerging states* (many definitions of "complexity" and "complex systems" are found in the special issue of *Science* (April 2, 1999) dedicated to "Complex Systems").

A complex system is literally one in which there are multiple interactions between many different components (Rind, 1999, p. 105).

In recent years the scientific community has coined the rubric `complex system' to describe phenomena, structures, aggregates, organisms, or problems that share some common theme: (i) they are inherently complicated or intricate [...]; (ii) they are rarely completely deterministic; (iii) mathematical models of the system are usually complex and involve non-linear, ill-posed, or chaotic behavior; (iv) the systems are predisposed to unexpected outcomes (so-called emergent behavior) (Foote, 2007, p. 410).

The "complex system" model can be applied in particular to today's global social system, in which individuals and their groups (the system's agents) differ in many respects: socio-cultural (language, religion, beliefs, habits, customs, mental models, etc.) and economic (individual wealth, economic philosophy, available resources, job skills, etc.), interacting in various ways (collaboration, competition, coordination, disorganization, peaceful, violent, etc.) and at various speeds, so that both *individual* behavior and *social collective* behavior are normally incomprehensible to the outside observer, since they do not conform to any structured model.

Many natural systems (e.g., brains, immune systems, ecologies, societies) and increasingly, many artificial systems (parallel and distributed computing systems, artificial intelligence systems, artificial neural networks, evolutionary programs) are characterized by apparently complex behaviours that emerge as a result of often nonlinear spatio-temporal interactions among a large number of component systems at different levels of organization (Honavar, 2006, online).

Complexity in natural landform patterns is a manifestation of two key characteristics. Natural patterns form from processes that are nonlinear, those that modify the properties of the environment in which they operate or that are strongly coupled; and natural patterns form in systems that are open, driven from equilibrium by the exchange of energy, momentum, material, or information across their boundaries (Werner, 1999, p. 102).

Social systems observed as units fall entirely within Humberto Maturana's and Francisco Varela's autopoiesis approach (Maturana and Varela, 1980, 1992; Varela, 1979, 1981; Zeleny, 1981; Jantsch, 1980); if "observed from a certain height" they appear as (non-organized) autopoietic systems in a closed environment that they themselves continually modify, making it even more difficult to observe regularities in individual and social behavior.

Human Beings, the entities within which they organize themselves, and other living systems, therefore, are Self-Organizing, Dynamic, Coherent and Evolving Systems. (Weis, 2008, p. 12). All biological Organisms, communities, and ecosystems, are dynamic, self-organizing, autopoietic, coherent, or complex, evolving systems—in the very same way as the complex anthropogenic systems so beloved in economics, sociology, or political science: Households, firms, governments, oligopolies, networks, markets, economic systems (regimes), and other niceties … (ibidem, pp.18–19)

Social systems are typical complex adaptive systems since they possess the characteristics typical of such systems, according to Murray Gell-Mann (1992, 1994, 1995):

The term Complex Adaptive System is used here to also refer to Complex Evolving Systems. The following extended definition will be adopted: Definition (1): A complex adaptive system (CAS) consists of non-homogeneous, interacting adaptive agents. Adaptive means capable of learning.

Definition (2): An emergent property of a CAS is a property of the system as a whole which does not exist at the individual elements (agents) level. Typical examples are the brain, the immune system, the economy, social systems, the ecology, insect swarms, etc. Therefore, to understand a complex system one has to study the system as a whole and not to decompose it into its constituents. This totalistic approach is against the standard reductionist one, which tries to decompose any system to its constituents and hopes that by understanding the elements one can understand the whole system (Ahmed et al., 2005, pp. 1–2).

Complex systems are usually systems which have been created by evolution or an evolutionary process. Evolved systems which have a long historical background are nearly always complex. Complexity can be found everywhere where evolution is at work:

- in all living organisms which are subject to evolution
- in all evolving complex adaptive systems which have a long history
- in systems that have grown over a long period of time (CASG 2013, online).

The behavior "of" and "within" social systems is complex for at least three factors common to all complex systems (Andreewsky and Delorme, 2006):

1. the *complexity of structure*, produced by the presence of individual and collective memory (internal states) in agents and their subsystems and groups (von Foerster, 1960);

2. *the complexity of process*, produced by repetitive and often recursive loops that transform the system into "macro" cellular automatons which have unpredictable, chaotic and often irreversible dynamics (Wolfram, 1984; Schatten, 2004; Yates, 1990), with rules for the transition of state of the agents which are not even known as well as an internal memory;

3. the *complexity of interaction*, linked to the high number of elements in the system and to their cooperative/competitive, rational/irrational, individual/aggregative behavior (von Foerster, 1972). What we have here are multi-agent systems in which a synergetic effect is produced that can give rise to chaotic and disordered behavior, or behavior that is ordered and predictable (Section 6).

Such forms of complexity that lie behind the difficulty in understanding dynamics, change and evolution are favored and heightened by the action of several fundamental *motor wheels of complexity*; that is, characteristics and phenomena produced by and observed in the social system which often make it impossible for an observer to construct either individual or social behavior models, as shown in Figure 1.
Among the various motor wheels of complexity, I believe the following to be fundamental:

a. acceleration
b. interdependence
c. the prevalence of the symbol
d. combinatory behavior.

Precisely due to the joint operation of such phenomena, Systems Thinking (Senge, 2006; Sterman, 2000) represents the most effective logic, philosophy and technique for observing complex systems, in which it becomes increasingly difficult to perceive dynamics, change and evolution, which are too fast or too slow, as well as being one-directional (Mella, 2012). This difficulty represents the cognitive limits for understanding complexity in social systems.

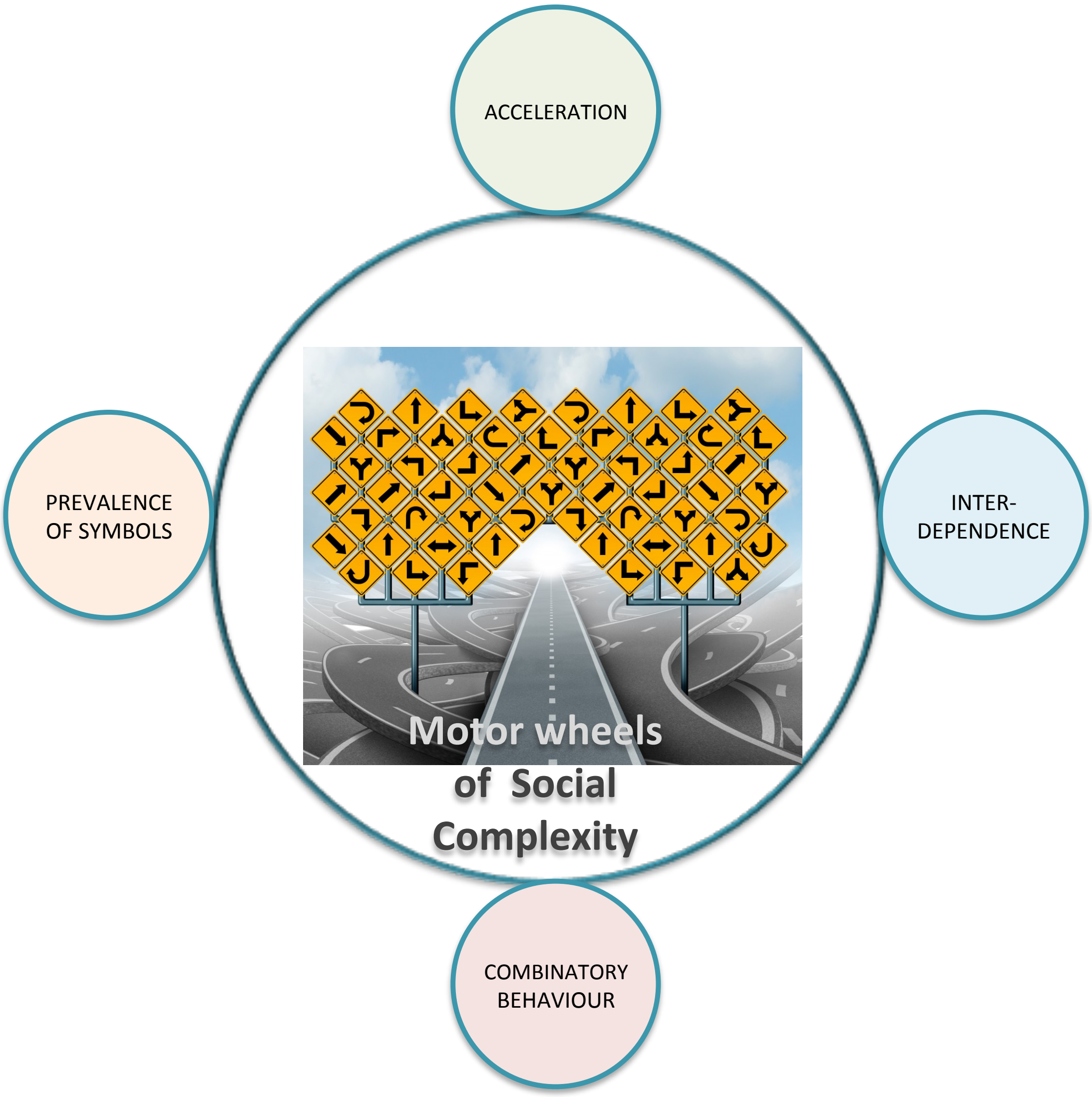


Figure 1 – The motor wheels of social complexity
[source: https://practicalaction.org/blog/practicalanswers/complexity-doesnt-have-to-be-confusing/]

In his book *The Fifth Discipline: The Art and Practice of the Learning Organization* (Senge, 2006) and in other subsequent works, Peter Senge states that Systems Thinking is not only a technique but a discipline as well, a mental attitude:

Systems Thinking [is] a way of thinking about, and a language for describing and understanding, the forces and interrelationships that shape the behaviour of Systems. This discipline helps us see how to change systems more effectively, and to act more in tune with the larger processes of the natural and economic world (Senge, et al., 1994, p. 6).

The analysis of the four *motor wheels of complexity* and the cognitive limits represent the focus of the following sections.

2 – Acceleration as a motor weel of complexity

Today everything changes, but what makes the world complex is not so much the speed of change but its acceleration, which affects all aspects of our world: technology, public life, political movements and wars, the economic dynamics (Evans, 1991), as well as social aspects (Rosa, 2003).

Our ability to look forward is that much harder because of the acceleration of change that has taken place throughout the 20th century, but particularly in the last couple of decades as digital technology has changed the speed and scale of human communication (Ewalt, 2005).

For ages, social phenomena have been stable, undergoing slow changes. It is plausible that, when observing the world during the age of the Pharaohs or, two thousand years later, the Roman age, we would have witnessed an ordered, or at least complex, social system. Technological progress, military conquests, power dynamics, changes in the borders between states, and other macro phenomena were interconnected but followed an understandable order. The constraints imposed on individuals by the power system were so strong that the individual dynamics allowed for only a limited range of variation.
Up until a few decades ago, it was possible to perceive the dynamics of social and organizational phenomena, political and economic in nature, in terms of a *linear evolution*. For some years now, such linear dynamics have given way to the gradual "reinforcement" of the speed of change of all phenomena.
The "change" over time has become frenetic: the first paved roads of the Romans, which were traveled on foot or horseback, were followed by the first "motor carriages" and then the "steam-engine trains, which today have been transformed into cars, high-speed trains and planes. We are not witnessing a dynamic process at a given speed, based on constant rates of change, but an acceleration of change caused the increase in the rates of change of the different variables in the system, as recognized by Ray Kurzweil (2001) in his Law of Accelerating Returns:

An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense "intuitive linear" view. So we won't experience 100 years of progress in the 21st century — it will be more like 20,000 years of progress (at today's rate) (Kurzweil, 2001).

Referring to the model in Figure 2, let us assume that two variables, X_t and Y_t, are interconnected by a cause-effect reciprocal relation. Let us suppose that the variable X_t varies first and can be considered the cause of the subsequent variation in Y_t; the variation of the latter, however, produces a variation in X_t, so that Y_t is "effect" and "cause" of the variation in X_t, taking into account, of course, the temporal sequence. We must also consider the variation functions: f(Y) indicates how Y varies as X varies and g(X) how X varies based on variations in Y. If f(Y) and g(X) are constant, they represent the *variation rates*, or *action rates*. Let us assume that at time t_n a cause, $\Delta X(t_n)$, produces the effect $\Delta Y(t_{n+1}) = f(Y)\ \Delta X(t_n)$ at time t_{n+1}, based on the function f(Y). Let us also assume that $\Delta Y(t_{n+1})$ generates, in turn, $\Delta X(t_{n+2}) = g(X)\ \Delta X(t_{n+1})$ based on the function g(X). A loop is produced – $\Delta X(t_{n+2}) = [g(X)\ f(Y)]\ \Delta X(t_n)$ – that can repeat itself over several cycles, producing the changes over time in the values of the two variables.
In the real world, the model in Figure 2 is not an exception but the rule, as the example in Figure 3 shows. In an *interconnected world*, we must abandon *linear thinking* (*chains* of cause and effect) and accustom ourselves to *systemic thinking*, observing reality as a system of *loops* that bind all variable phenomena (Roberts, 1978; Richardson, 1991; Senge, 2006; Mella, 2012).
The *acceleration* in the variations pointed out by Kurzweil occur when the variables X_t and Y_t, which form a *loop*, not only produce the reciprocal variations but also lead to a gradual *increase in the variation rates* – f(Y) and g(X) – of the variables (or at least in one of them), as shown in

the model in Figure 3, where the variable Y also impacts the rate f(Y), based on the function k = G(Y), and the variable X the function g(X), based on the function k = F(Y), thereby accelerating the variations in the interacting variables.

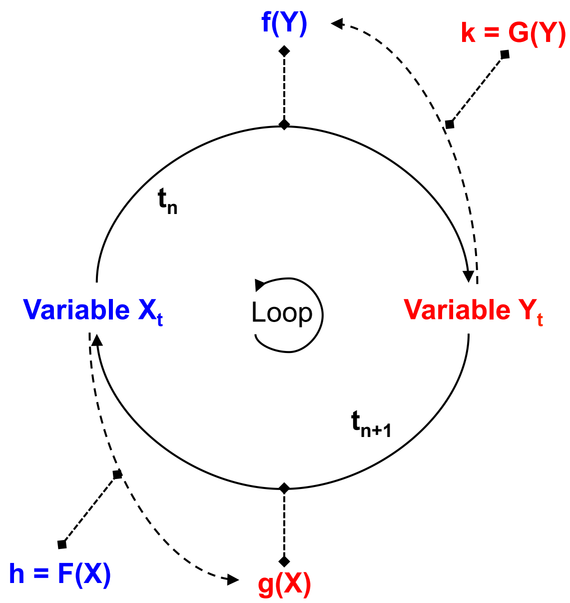


Figure 2. Loop showing the action of accelerating returns

The *accelerated dynamics* discussed above can be observed today for almost all the most relevant *social variables*, which entails three relevant consequences that make the perception, understanding and explanation of individual dynamics and/or isolated events complex.

a) The *contraction of time* in the variation of the accelerated variables is the first clear consequence of acceleration (Demartini and Mella, 2011); therefore, the change in structures, processes and models, and in any other cultural context of reference, becomes increasingly faster, thereby disorienting agents and decision-makers; yesterday's decision-making criteria no longer apply for the same decisions today. Moreover, the information needed to make decisions and act changes with increasing speed, which makes it impossible to verify the correctness of such decisions, producing at the same time an increasingly frantic search for new information. Unfortunately, even fake news increases at an accelerated pace, and the acceleration in the speed of circulation of men, goods and, above all, information reduces *reaction times*, making it also necessary to accelerate forecasts and decisions. All of this increases the risk of failed forecasts, even in the short term, as well as the risk of acting based on incorrect, false and unverifiable information.

b) The *expansion of the room for action*, which is the immediate consequence of this increasing acceleration, leads to the broadening of the areas that can be observed and reached through individual, group or organizational actions. An understanding of large-scale phenomena requires knowledge of what occurs in increasingly wider areas, thereby favoring the globalization of behavior, especially that of organizations (corporations, non-profit organizations, nations). However, this leads to the saturation of the environment; that is, the entire environment becomes a niche in which everyone acts in an atmosphere of growing competition, which leads to conflicts. Not only do the observations have to become more timely, but the variety of phenomena to observe also increases.

c) The *information* regarding the states of systems loses its importance and gives way to the information on dynamics; the information on the structure of the systems (static or with slow dynamics) gives way to contingent information, with a limited temporal and spatial validity, so that the reliability of this information is not always verifiable before its use for decision-making purposes. In conclusion, stability gives way to permanent contingency, which makes it necessary and urgent to change our patterns of perception of the dynamics of all phenomena (www.accelerationwatch.com/accelerationstudies.html). For this reason, an outside observer has no choice but to judge the dynamics of the macro social system produced by a complex system, along with its individual agents, as disordered and unpredictable (Smart, 2012).

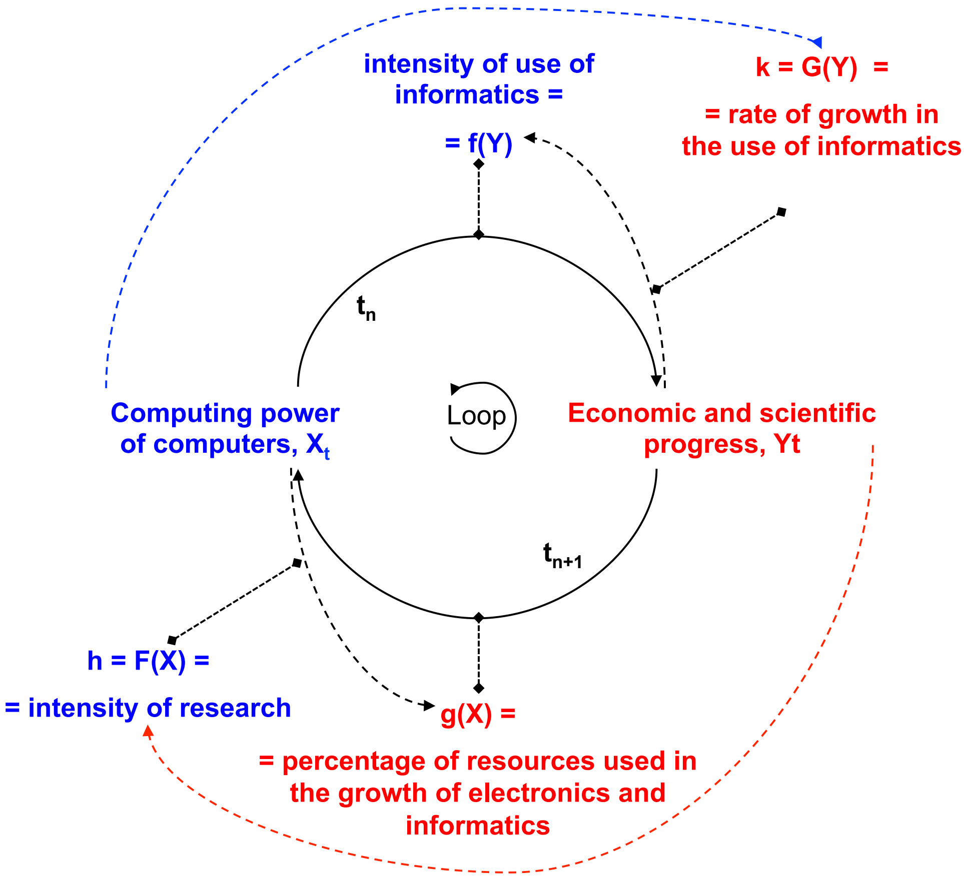


Figure 3. Loop showing the acceleration of developments in electronics and informatics

3 – Interdependence among variables as a motor wheel of complexity

Today everything appears connected due to the existence of multiple relations among variables. The variables in an environment that varies at a low and constant speed are almost always linked by cause-effect relations, thereby forming *causal chains* that are simple to *observe* and *control*. In an accelerated world we see evidence of the shifting from open causal chains to systemic interaction, in which the dynamics of phenomena are no longer definitively oriented but instead present circular dynamics that can be represented as loops, as shown in Figure 4, where we can intuitively grasp the complexity of the dynamics involving the 5 interacting variables (Mella, 2012).

The variables that compose the social system and the environment not only change in an accelerated manner, but their variations become interdependent, forming a unitary dynamic system (Mella, 2012, ch. 2), in the sense that the dynamics of a variable interferes with that of the others through multiple reinforcing or balancing loops, thereby forming vast systems which are complex and difficult to describe, analyze and simulate (Senge, 2006, Ch. 5).

To understand how the interactions among the variables produce complex dynamics, Figure 5 shows a simulation of the model in Figure 4, which has been simplified by ignoring the variables A and B – which otherwise would have resulted in even more complex results – under the assumption that the two loops go in directions R and B. Figure 6 presents the dynamics of the variables X, Y and Z produced by 4 tests undertaken to evaluate the effects of changes in the initial values and in the action rates.

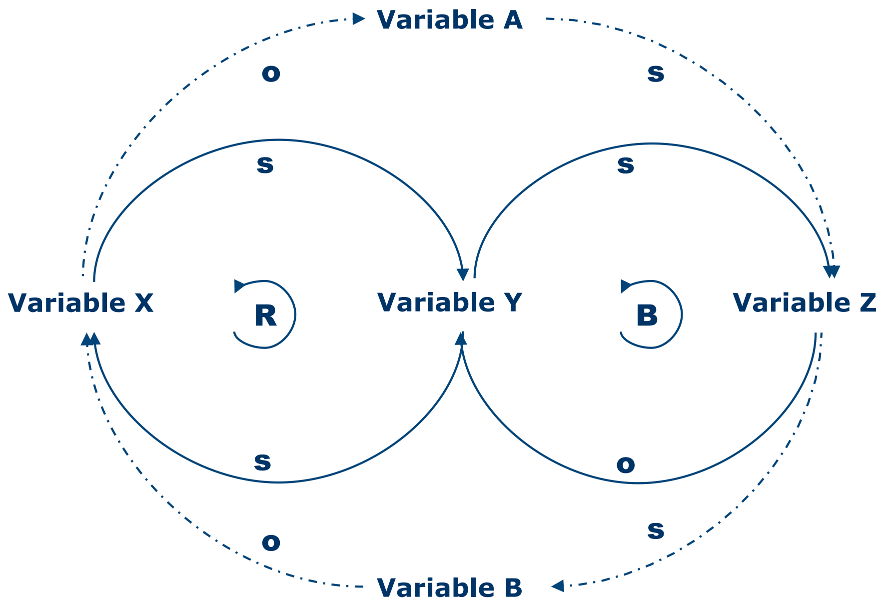


Figure 4. Circular connections as interconnected loops

The existence of *complex dynamic systems* represents perhaps the main reason for the extreme difficulty in understanding the dynamics of individual phenomena, since the dynamics of any single phenomenon depends on the loop structure it is a part of, either as a cause or an effect. The observer is forced to adopt a holistic and holonic perspective (Koestler, 1967; Wilber, 2000; Mella, 2009), which increasingly blurs the distinction between variable and system and between system and environment. Every system belongs to a supersystem, and the reality observed appears as a *supersystem* of connected and nested *supersystems* (Figure 7) that becomes a "global", and thus "closed", system which must be studied as a whole and whose behavior becomes counter-intuitive due to the loops and delays.

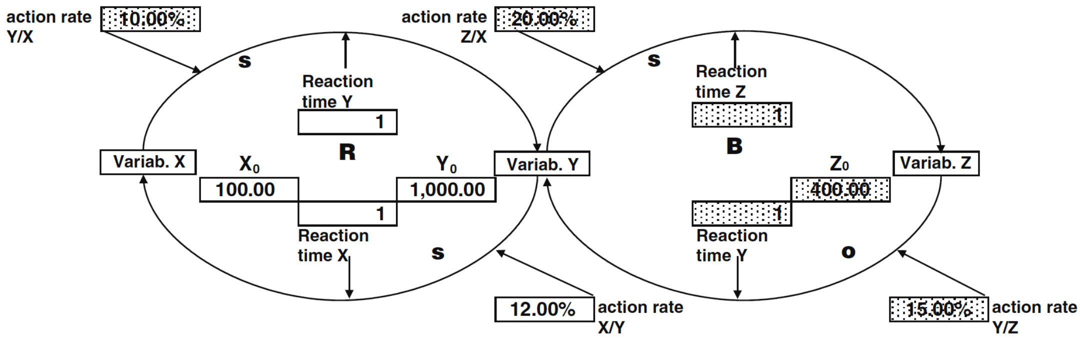
The global systems (general holistic perspective) accentuate the complexity since the interconnection and the interaction of variables produce very relevant consequences:

a) The *temporal extension* of the effects of the system: due to the action of many delays, the responses to the causes may be produced after a very long period, thus making it difficult to perceive the correlation between causes and effects:

Delays between actions and consequences are everywhere in human systems ... Unrecognized delays can also lead to instability and breakdown, especially when they are long" (Senge, 2006, p. 88).

b) The *spatial extension* of the effects: the effects are revealed over increasingly vaster spaces, and it becomes difficult to perceive their connection with the causes; the increase in the speed of change and the interconnections among the loops can produce the butterfly effect, which will be considered in Section 6.

... an insignificant variation in one of the variables (the flapping of a butterfly's wing) is enough to produce enormously vast effects in others distant in time and space. The problem is not "seeing" the final effects (tornadoes and typhoons) but perceiving the variations which are minute and distant in time" (Mella, 2012, p. 31);



	Variab. X			Variab. Y					Variab. Z		
time	X	rate Y/X	ΔY	Y	rate Y/X	Δ Z	rate X/Y	Δ X	Z	rate Y/Z	Δ Y
0	100.0	10.00%	10.0	1,010.0	20.00%	202.0	12.00%	121.2	602.0	15.00%	-
1	221.2	10.00%	22.1	941.8	20.00%	188.4	12.00%	113.0	790.4	15.00%	-90.3
2	334.2	10.00%	33.4	856.7	20.00%	171.3	12.00%	102.8	961.7	15.00%	-118.6
3	437.0	10.00%	43.7	756.1	20.00%	151.2	12.00%	90.7	1,112.9	15.00%	-144.3
4	527.8	10.00%	52.8	642.0	20.00%	128.4	12.00%	77.0	1,241.3	15.00%	-166.9
5	604.8	10.00%	60.5	516.3	20.00%	103.3	12.00%	62.0	1,344.6	15.00%	-186.2
6	666.7	10.00%	66.7	381.2	20.00%	76.2	12.00%	45.7	1,420.8	15.00%	-201.7
7	712.5	10.00%	71.2	239.4	20.00%	47.9	12.00%	28.7	1,468.7	15.00%	-213.1
8	741.2	10.00%	74.1	93.2	20.00%	18.6	12.00%	11.2	1,487.3	15.00%	-220.3
9	752.4	10.00%	75.2	-54.7	20.00%	-10.9	12.00%	-6.6	1,476.4	15.00%	-223.1
10	745.8	10.00%	74.6	-201.6	20.00%	-40.3	12.00%	-24.2	1,436.1	15.00%	-221.5
[omissis											
91	-1,821.8	10.00%	-182.2	533.1	20.00%	106.6	12.00%	64.0	-336.4	15.00%	66.5
92	-1,757.8	10.00%	-175.8	437.8	20.00%	87.6	12.00%	52.5	-248.8	15.00%	50.5
93	-1,705.3	10.00%	-170.5	334.6	20.00%	66.9	12.00%	40.1	-181.9	15.00%	37.3
94	-1,665.2	10.00%	-166.5	225.3	20.00%	45.1	12.00%	27.0	-136.9	15.00%	27.3
95	-1,638.1	10.00%	-163.8	112.1	20.00%	22.4	12.00%	13.4	-114.5	15.00%	20.5
96	-1,624.7	10.00%	-162.5	-3.2	20.00%	-0.6	12.00%	-0.4	-115.1	15.00%	17.2
97	-1,625.1	10.00%	-162.5	-118.5	20.00%	-23.7	12.00%	-14.2	-138.8	15.00%	17.3
98	-1,639.3	10.00%	-163.9	-231.6	20.00%	-46.3	12.00%	-27.8	-185.1	15.00%	20.8
99	-1,667.1	10.00%	-166.7	-340.5	20.00%	-68.1	12.00%	-40.9	-253.2	15.00%	27.8
100	-1,707.9	10.00%	-170.8	-443.3	20.00%	-88.7	12.00%	-53.2	-341.9	15.00%	38.0

Figure 5. Simulation of the dynamics of interacting variables forming interconnected loops
(source: Mella, 2014, p. 30)

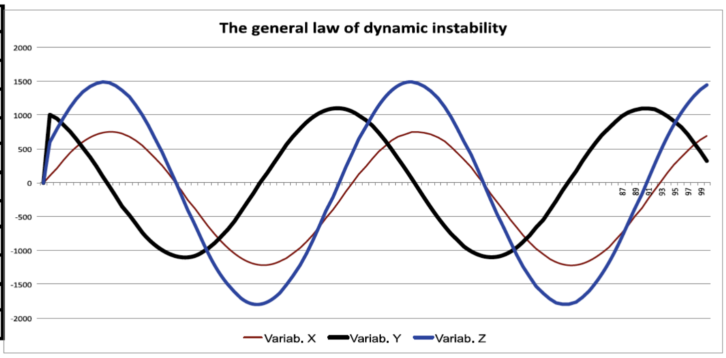
c) *Irreversibility*: the behavior of systems becomes irreversible since this modifies the environment and, in turn, is modified by the environment as part of an interaction that is never repeatable under the same conditions;

d) *Memory*: dynamic systems have a memory that makes it difficult to understand the form of the correlation between inputs-causes and outputs-effect and to make observations about the dynamics of the future states; as a consequence, the output-effect of any variable does not depend directly on input-cause but on the state of the system, whose dynamics depend on the input based on the relation: "input→state→output", or: "cause→memory→ effect":

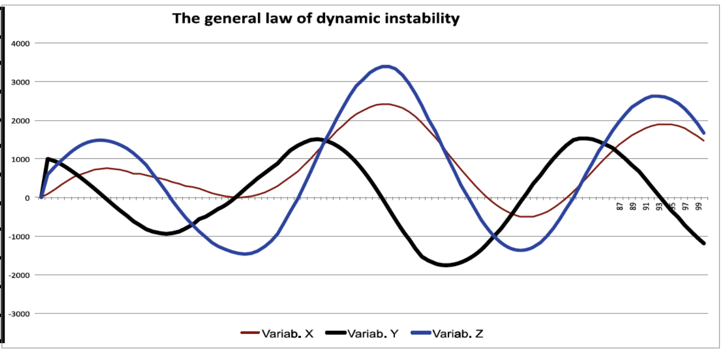
… even simply structured dynamic systems present an intrinsic complexity when they are systems with a memory; the internal states that form the memory uncouple the inputs from the outputs to produce a chain of changes in state that can extend the number of and length of time necessary for the calculations required to describe the system beyond any limit" (Mella, 2012, p. 33).

e) *Non-linearity*: the above characteristics give rise to and spread an important new phenomenon: non-linearity often impedes any attempt at perceiving an order, a dynamics in any ordered sense. Easily observable simple linear phenomena that evolve in an orderly way give way to apparently disorderly phenomena, which is clearly a consequence of the complexity of the system. Not only do we move from *ordinary* to *differential equations*, from the *first* to the *second derivatives*, but we observe a non-linear response in the multiple variable functions, which are interrelated through *feedback*.

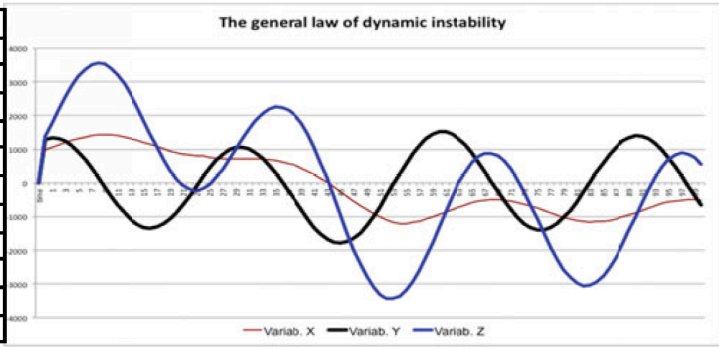
Test 1	
X0 =	100
Y0 =	1.000
Z0 =	400
g(Y/X)=	10%
g(Z/Y)=	20%
g(Y/Z)=	15%
g(X/Y)=	12%
r(X) =	1
r(Y) =	1
r(Z) =	1
NO disturbances	



Test 2	
X_0=	100
Y0=	1.000
Z0=	400
g(Y/X)=	10%
g(Z/Y)=	20%
g(Y/Z)=	15%
g(X/Y)=	12%
r(X)=	1
r(Y)=	1
r(Z)=	1
YES disturbances	



Test 3	
X0 =	1.000
Y0 =	1.000
Z0 =	1.000
g(Y /X) =	30%
g(Z /Y) =	30%
g(Y /Z) =	15%
g(X /Y) =	20%
r(X) =	1
r(Y) =	1
r(Z) =	1
YES disturbances	



Test 4	
X_0 =	1.000
Y_0 =	1.000
Z_0 =	1.000
g(Y/X)=	10%
g(Z/Y)=	0%
g(Y/Z)=	0%
g(X/Y)=	3%
r(X)=	1
r(Y)=	1
r(Z)=	1
NO disturbances	

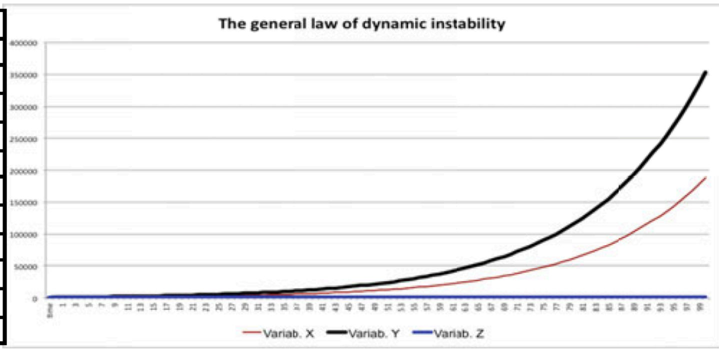


Figure 6. Simulation tests showing the effects of different initial values and action rates of variation in Figure 5 (source: Mella, 2014, p. 31)

Therefore, the system of variables that interact through loops and the connections among these loops, which are often nested, more and more frequently leads to *disorder* and to *oscillating*, in many cases *chaotic*, *dynamics*. There are no operational models to understand and control the disorder in the micro behaviors of the agents in complex systems, even if Hermann Haken, the founder of Synergetics, has introduced the idea of *order parameters* for understanding the average dynamics of the agents in a system. A complex system formed by a multiplicity of elements whose micro behavior cannot be individually observed, can give rise to "macro phenomena" that are observable and, in many circumstances, not describable.

To describe collective behavior we need entirely new concepts compared to the microscopic description. … In more complicated systems quite other "modes" may appropriately describe spatio-temporal patterns or functionings. ... It will turn out that equations governing self-organization arc intrinsically nonlinear. From those equations we shall find in the following that, "modes" may either compete, so that only one "survives", or coexist by stabilizing each other. Apparently the mode concept has an enormous advantage over the microscopic description (Haken 1983, p. 14).

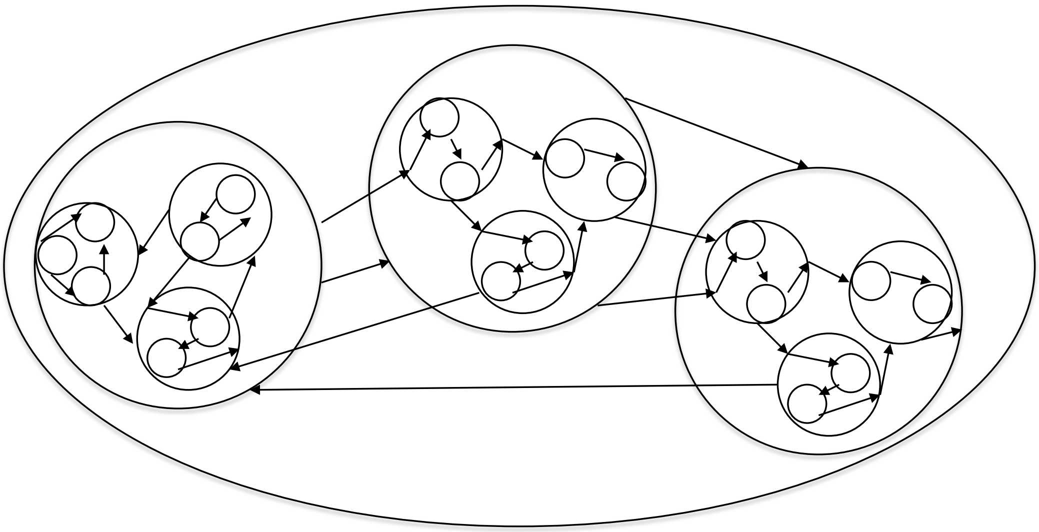


Figure 7. Supersystem of nested supersystems of loops

4 – The prevalence of the symbol as a motor wheel of complexity

It is necessary today to be aware that social systems have produced an accelerated and usually complex transition of *needs* into *aspirations*. Needs decrease as they become satisfied, and for this reason they are in a sufficiently stable quantity, while aspirations by nature do not admit an upper limit to satisfaction, but are instead highly dynamic. In advanced economies, needs are usually satisfied, and man's economic behavior is mainly directed at goods that can satisfy aspirations. The shift from needs to aspirations also implies that from "quantity" to "quality". Large quantities of goods are not needed to satisfy aspirations; what is needed are goods of high quality. Quality advances with the increase in the variety of the aspirations the "wealthy" man seeks to satisfy, which immediately draws our attention to the inevitable shift from "utility" to "value", and thus from the basic value of useful goods to the symbolic one of goods that satisfy aspirations. In advanced economic systems, where man lives in "wealthy", *highly-competitive* environments, we observe an important effect: the search for *utilitarian* aspects of actions and their results are subordinate to that for the *symbolic* aspects; behavior becomes mainly symbolic – understood as "*a person's capacity to respond to or use a system of significant symbols*" (Faules and Alexander, 1978, p. 5) – in which the "abstract" gets the better of the "concrete", the "ideal" of the "material".
When observing the global social system we must be aware that an increasingly larger percentage of decisions and actions – individual or collective – are motivated by a *symbolic*

motive more so than by a *real cause*, with the accelerated shift, normally chaotic, from the material to the immaterial, from need to aspiration.

Making from the ephemeral an industry, which becomes the leading one in France in terms of capitalization. Lvmh is not only a world luxury giant but the largest Franch company in terms of market value. Its 156 billion euros of market value is 8% higher than the giant French energy company Total (144 billion). Oreal, with its perfumes and creams, is in third place in the Cac40 with 115 billion, the same amount as Danone (43 billion), Renault (26 billion), Michelin (21.6 billion) and Peugeot (18 billion) put together. Now that it has split off from Puma to become a high-end company, even Kering is in strong ascendancy (+30% since the beginning of the year, equal to 60.5 billion), even surpassing the insurance giant Axa (55 billion) and on the heels of another famous French brand Hermès (62.8 billion in stock market value) (Bennewitz, 2018, online).

This phenomenon produces extremely complex dynamics, and the process of observation and understanding must identify the symbolic determinants of behavior more so than the rationality factors in a system of ever wider, more dynamic and more complex relations. In social systems, symbolic messages prevail over messages of substance (Mills, 2002), which leads to a change in the scale of needs and of the value of goods aimed at satisfying these needs, and as a consequence to a change as well in the collective culture and vision, generating various forms of investment in the vision (Senge, 2006, p. 193) or antagonism towards it.

We are surrounded by a lot of practices, from seemingly insignificant behaviours like pressing the start button of our iPod to larger movements like flying to an exotic honeymoon in Thailand. What is important is that these practices have meaning to us, that we know how to interpret them. Culture is basically this interpretation system which we use to understand all those daily extraordinary signifying practices around us. A culture as a concept is like a fish immersed in water – we do not always appreciate this power until we encounter a different environment, where suddenly many of the assumptions we have taken for granted about the clothes we wear, the food we eat, the way we address others, and so on, no longer seem to apply. The effect of encountering such differences can be so great that the term 'culture shock' is not an exaggeration (Solomon et al., 2010, p. 507).

5 – Combinatory behavior as a motor wheel of complexity

Social systems develop collective phenomena which are the essence of life at any level, both for human beings – who operate in populations, tribes, associations, teams, social units, and so on – and for animals, which operate in crowds, hordes, flocks, flights, herds, schools, and so on.
When an individual is part of a collectivity, his behavior is no longer autonomous with respect to the macro behavior of the collectivity, even if the collective behavior derives from the "combination" of the individual behaviors. In fact, the collective dynamics of any social system does not derive from the free and self-determined activity of single entities, individuals or organizations, which act *locally*, but from the "combined" action of those agents who, though operating individually and apparently autonomously, produce collective macro effects that then constrain the same individual behavior in a long-lasting loop between the micro and macro behavior and effects. If this occurs, then a social system becomes a *Combinatory* system in which the individuals undertake actions guided by macro variables, which they themselves produce, that refer to the collectivity:

A "combinatory system" is defined as any collectivity made up of a plurality of unorganized similar agents (or elements) producing analogous micro behaviors and showing, as a whole, a macro behavior and/or a macro effect, whose dynamics are created by a micro-macro feedback

action. If, on the one hand, the macro behavior of the system derives as a whole from the combination, appropriately specified, of the analogous behavior (or effects) of its similar agents (hence the name combinatory system), on the other hand the macro behavior (or the macro effect) determines, conditions or directs the subsequent micro behavior, according to a feedback relation between the micro and macro behavior or effects.
The existence of micro-macro feedback thus leads to an essential consequence: the macro behavior (or effect) of the system cannot be considered a mere sum of the micro behavior (or effects) of its elements; the micro-macro feedback causes "emerging" types of macro behavior (or effects) which are not included in advance in the operating program of the agents' behavior and are attributable to the unit (Mella, 2017, p. 9).

The action of combinatory systems leads to an important methodological consequence: the individual actions of the individual elements that compose a Combinatory System, and that act in a locally independent manner, do not in fact represent the free expression of their will, since they are directed, without these elements being aware of it, by the global action of the system itself, as part of a typical invisible hand which regulates agents' behaviors (Mella, 2017).
The observation of the individual micro behaviors is further complicated by the fact that they are affected by the macro effects the agents themselves produce by acting in a combinatory way, which gives pause for reflection: is it possible for rational micro behavior to produce an irrational macro behavior, one that can even cause catastrophic effects for the entire system? The answer is yes: individuals – ignoring the existence of a link between individual actions and collective outcomes – produce micro behavior that, from the local point of view, optimizes the micro effects but that, from a global point of view, can generate a collective macro effect which at times is damaging and capable of breaking up the system (Mella, 2017).
There is no rationality in a couple that tries to dance in the opposite direction to the rotation produced in a ballroom, attracting ire and shoves from the other couples; thus, it is not free to decide in that way. Similarly, it would be irrational for an entrepreneur not to take into account a production innovation, thereby damaging his own firm; he is not free in that way, unless he is willing to forego some competitiveness. And if a university researcher is free not to follow a new scientific discovery, he is equally free to continue to be eliminated from competitions for university posts. Can we call this behavior rational?

6 – Conclusion. The role of systems thinking

Will men, collectivities, social groups and organizations be able to survive in an increasingly complex world they themselves have created; an increasingly dense, vast, interconnected and fast world in which the variables form ever larger and more intricate loops that give rise to non-linear dynamics? Will men and collectivities survive deforestation, species extinction, climate changes, global warming, contagions, pandemics, escalations of actions and reactions, feuds and wars? Will they be able to activate the loops to produce the improvement in productivity, quality and civic sense necessary to guarantee progress in living conditions?
Systems Thinking (Senge, 2006; Mella, 2012) represents an instrument to understand the world and its complexity, to throw light on its interrelations and dynamics, whether short- or long-term. Nevertheless, at times Systems Thinking, despite its cognitive power, is difficult to apply to processes or complex systems whose dynamics are, by their nature, difficult to perceive, model or control. The most important difficulties in observing social systems through Systems Thinking are the following:

1. *boiled frog*, that is, the obstacle deriving from temporal slowness,
2. *networking effect*, or the obstacle linked to the speed of processes,
3. *butterfly effect*, the obstacle from distance in space,

4. *mono-directional view*, the obstacle from observational direction,
5. *Short-Term, Local and Individual Myopia Archetype,* the difficulty that comes from preferring immediate and individual benefits that cause collective disadvantages in the long term,
6. *memory*, the difficulty linked to structural, computational and temporal complexity.

Some processes are so *slow* that we are not able to perceive their dynamics in a reasonable span of time, also given man's life expectancy. When we become aware of their effects, it is too late to control them, and we end up like a *boiled* frog, an experiment first described by the psychologist Granville Stanley Hall in 1887 and later presented in various contexts (http://www.fastcompany.com/magazine/01/frog.html). When immersed in a pot of *slowing heating* water, a frog does not realize that the heat numbs his limbs, so that he ends up being boiled. We can easily see the metaphor of the "boiled frog" at work in social systems observing the incapacity of policy makers to perceive and control pollution, climate changes, immigration or depopulation, crime, the spread of drugs, and so on; and also in the incapacity of companies to perceive the slow rise of competitors, the loss of market share, the slow march of products toward the declining phase of their life cycles, the slow deterioration in organizational efficiency. Similarly, we find ourselves today drowning in the plastic that has invaded land and sea (Mella and Pellicelli, 2018).

At other times, some processes and phenomena (usually involving accumulation and propagation based on exponential laws and acceleration) are so explosive and accelerated that we are not able "to see" their evolution until they have already produced their effects on the system. When we become aware of them there is no time to undertake any control. A typical case where it is difficult if not impossible *to* perceive the dynamics of a system is the so-called *networking effect*, which operates in social systems when interconnected agents propagate some information, or effect, at too high a speed to be observed, as in the case of phenomena spreading by word of mouth or pandemics.

It is as if we can hear the aria sung by don Basilio, so masterfully written by Gioachino Rossini – Italian composer noted for his operas – in The Barber of Seville:

«Slander is a breeze – It is a gentle gust of wind – which unnoticed, subtly, lightly – softly, slightly, sweetly – begins to spread a whisper. [...] Eventually it breaks forth, explodes – spreads and multiplies – to produce an explosion – like a cannon shot – an earthquake, a storm, [...]» [original: «La calunnia è un venticello - Un'auretta assai gentile - Che insensibile sottile - Leggermente dolcemente - Incomincia a sussurrar. […] Alla fin trabocca, e scoppia, - Si propaga si raddoppia - E produce un'esplosione - Come un colpo di cannone, - Un tremuoto, un temporale, […]» (act one: http://www.librettidopera.it/zpdf/barb_siv.pdf).

In particular today we are forced to interact with increasingly intelligent robots guided by the speedy progress of artificial intelligence, without having time to acquire the proper knowledge and culture to interact with them.

As observed in Section 3, most processes in the global social system derive from the concatenation of a large number of loops, which are contained in other loops of varying size and nested many times over, so that the macroscopic effects of the global system are the result of the action of micro effects produced by miniscule loops, often distant in space from the observation point. When, in a far-off land, a butterfly flutters its wings it can unleash a chain of vortices which, gradually strengthening themselves, can set off a storm in another part of the world. This is known as the *butterfly effect*, a term coined by the physicist Edward Lorenz who, in 1979, stated that if the theories of complex systems and chaos were correct, then the fluttering wings of a butterfly would be enough to alter climate patterns, even permanently (www.nemesi.net/farf.htm).

If an individual agent only *looks ahead* and observes a *restricted corner* of the world, he cannot understand what is happening behind him, even at a certain distance. In complex social systems, the *mono-directional view* blocks the agents from understanding the interactions and dynamics of events. There is nothing else to do but accustom ourselves to observing our world at 360 degrees (fourth metaphor).

Another difficulty that often characterizes individual behavior in social systems and that often has incomprensible effects based on normal principles of rationality for collectivities is that which derives from the action of the "Short-Term, Local and Individual Myopia Archetype" shown in Figure 8. Here, each individual-agent tends to prefer the *repetitive behaviour* that brings *short-term*, *individual* and *local* advantages, ignoring the *long-term*, *collective and global* disadvantages that such behaviour can produce (Mella and Pellicelli, 2018). Following an individual but *myopic* rationality principle, the agents selfishly or through ignorance prefer their own advantages even if their repetitive behavior is linked to great future global and collective disadvantages in the long-run. Global warming, the spread of plastic waste, running out of sites for waste disposal are examples of the consequences of this archetype.

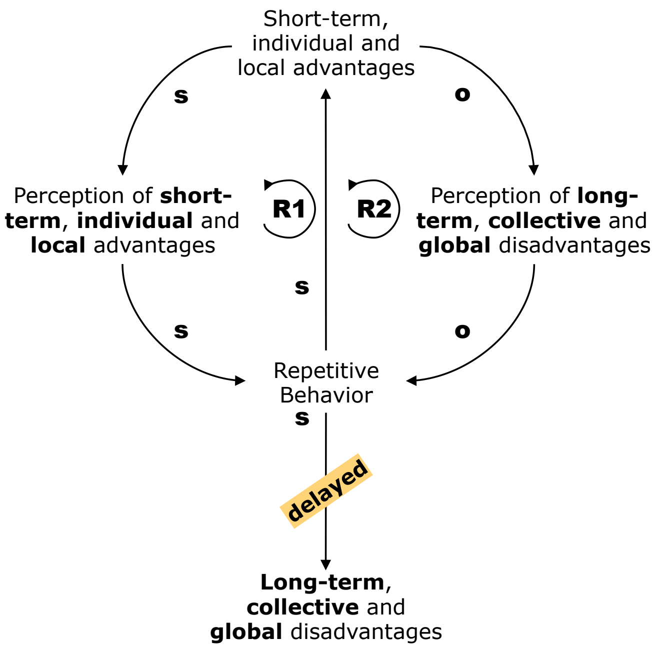


Figure 8. "Short-Term, Local and Individual Myopia Archetype"
(source: Mella, 2012, p. 236).

Our willingness to apply Systems Thinking encounters an often insurmountable obstacle in structural and computational complexity. In a structurally complex system with *internal states*, and thus *memory*, such as in the global social system, we could insert the same inputs all our life, or the entire life of the universe, and continue to observe outputs that are always different. The greatest challenge to complexity is understanding and mastering such systems. This form of complexity has been well described by Heinz von Foerster ((2003, p. 143), the father of "second-order cybernetics", who views a machine with memory – defined as non-trivial – as a complex system deriving from the interconnection of machines without memory, or trivial machines (which in Systems Thinking represent the elementary processes between two variables based on a cause-effect relation).

«In any case, the number that can be constructed under such conditions is not astronomical. It is meta-astronomical! If we have only two *inputs* (A and B) and two *outputs* we can construct 2^{16}, that is, 65,536 different AB machines. Producing these 65,536 machines is quite difficult; however, it is still doable. If we have a fast computer we can get all the possible machines in around two minutes. But suppose we want to calculate the number of machines with *four inputs* and *four outputs* (a machine of the ABCD type). The number of different ABCD machines is 2^{8192}, that is, 10^{2466}. The age of the universe calculated in microseconds is 10^{28}. This means that if we had a fast computer that could calculate one machine each microsecond, we would need a time period of 10^{2438} times the age of the universe to calculate the number of possible ABCD machines. You are strongly urged not to undertake a similar enterprise. You would lose your shirt, your money, and everything else».

These difficulties are inevitably found in social systems considered as complex systems. They are insurmountable (Mella, 2012). The only remedy is to be aware of their existence and to hone even more our attention and sensitivity.

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