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"Seeing the Impossible" or "The Impossibility of Seeing": Five Obstacles to Systems Thinking

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Abstract: Systems Thinking is one of the most powerful tools of knowledge and understanding because it teaches us to devise models that are among the most effective for improving our intelligence. Systemic models that can capture dynamism, repetitiveness, recursiveness and memory (Mella, 2008) allow us to "see the impossible", to understand how situations evolve, to anticipate the future and "see things sooner", to predict what we cannot yet "observe" in order to prepare us for what could influence our existence, to predict the future, to master complexity. Nevertheless we should not overburden Systems Thinking with thaumaturgical powers, metaphysical capabilities, or ideal or exaggerated expectations. We must be realists. In many situations, no matter how much effort and energy we put into it, building effective systemic models does not seem possible, or is strongly obstructed by several conditions that make it practically "impossible to see" reality in all its interconnections and dynamics. By using brief metaphors I want to touch on five of these conditions behind the "impossibility of seeing" that obstruct our systemic thinking with regard to understanding and predicting our world: 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) memory, the difficulty linked to structural, computational and temporal complexity I will also indicate for each of these difficulties which strategies Systems Thinking proposes to neutralize them.

Keywords: Systems Thinking, Learning Organizations, Organizational Learning, Boiled Frog, Butterfly Effect, Networking Effect

Introduction

SYSTEMS THINKING IS one of the most powerful tools of knowledge and understanding because it teaches us to devise *coherent and sense-making models* of the world – which may be explicit or implicit (Maturana and Varela, 1992) – that are among the most effective for improving our intelligence and constructing our existence (Zeleny and Hufford, 1992) and that of our descendants and fellow beings. *« "Survival learning" or what is more often termed "adaptive learning" is important – indeed it is necessary. But for a learning organization, "adaptive learning" must be joined by "generative learning", learning that enhances our capacity to create »* (Senge 2006:14).

Systemic models that can capture dynamism, repetitiveness, recursiveness and memory (Mella, 2008) allow us to "see the impossible", to understand how situations evolve and "see things sooner", to predict what we cannot yet observe in order to prepare us for what could influence our existence, to predict the future, to master complexity.

This paper aims to present the main ideas of Systems Thinking, which is considered not only as a technique but primarily as a *discipline* for efficient and effective thinking (Argyris,

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1977; Sterman,1994) and for knowledge creation, as understood by Nonaka, who believes that knowledge depends on perspectives and on individual will and that knowledge creation is an art (skill), not a science: *«The creation of knowledge is not simply a compilation of facts but a uniquely human process that cannot be reduced or easily replicated »* (Nonaka, 1994; Von Krogh, Ichijo & Nonaka, 2000).

Nevertheless we should not overburden Systems Thinking with thaumaturgical powers, metaphysical capabilities, or ideal or exaggerated expectations.

We must be realists. There are some environmental situations that create problems in applying Systems Thinking; no matter how much effort and energy we put into it, building effective systemic models does not seem possible, or is strongly obstructed by several conditions that make it practically "impossible to see" reality in all its interconnections and dynamics.

The second aim of this study is to touch on five of these conditions behind the "impossibility of seeing" that obstruct our systemic thinking with regard to understanding and predicting our world:

- *boiled frog*, that is, the obstacle deriving from temporal slowness,
- *networking effect*, or the obstacle linked to the speed of processes,
- *butterfly effect*, the obstacle from distance in space,
- *mono-directional view*, the obstacle from observational direction,
- *memory*, the difficulty linked to structural, computational and temporal complexity.

Systems Thinking Explains Social Processes

Systems Thinking was introduced by Peter Senge in his book *The Fifth Discipline: The Art and Practice of the Learning Organization* (Senge, 2006).

In his book, Peter Senge has defined a learning organization as an organization in which people at all levels, individually and collectively, are continually increasing their "pooled" intelligence (Hejl, 1984) and their capacity to produce better results (Garvin, 2000; Rheem, 1995): *«"learning organizations"* [are] *organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together»* (Senge, 2006: 3).

Systems Thinking – one of the most important instruments for organizational learning – teaches us how to construct models of a complex and dynamic reality made up of variables interconnected by causal relations that form a system.

> *«Systems thinking is a discipline for seeing wholes, recognizing patterns and interrelationships, and learning how to structure those interrelationships in more effective, efficient ways»* (Senge and Lannon-Kim, 1991).
>
> *«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: 6).

Systems Thinking is not only a technique but a discipline as well, a mental attitude, in the sense that it must be learned gradually, with practice, and continually perfected: «To practice a discipline is to be a life longer learner. You never arrive; you spend your life mastering disciplines.» (Senge, 2006: 10)

Systems Thinking is a discipline in that it proposes:

- to train us to observe reality as composed of dynamic systems;
- to provide us powerful models of description and simulation;
- to improve our ability to gain knowledge, that is to learn;
- to develop our intelligence

Due to its intrinsic logic, which observes a world of variables and of variations, Systems Thinking considers *dynamic* systems of any kind in any field (Forrrester, 1991), building models of a world of incessant movement in continual transformation and evolution.

This discipline considers not only dynamic but also *repetitive* systems, which are able to repeat their processes over time, as well as *recursive* systems, capable of interacting with themselves in the sense that their output, entirely or in part, becomes their own inputs (Mella, 2008).

Even if we are not used to observing them, recursive systems are all around us and produce most of the relevant social dynamics; they are the typical essence of biological life and collective behaviour, which are repetitive and recursive in their typical process of birth, reproduction and death, which is destined to repeat itself again and again.

The existence of a man is a chain of repetitive processes. Wakefulness is followed by sleep to allow us to face a new period of wakefulness, which requires sleep again; work is followed by rest, the office by a vacation, a discovery by new research.

Even if Peter Senge's fundamental work is relatively recent (the first edition was published in 1990), an impressive literature on the topic has already formed which, on the one hand, examines in-depth the technical aspects of Systems Thinking and, on the other, extends its application to every sector of the social sciences.

Thus, even if Senge wrote his book for entrepreneurs, managers and personnel in every type of organization, the logic of Systems Thinking can also be profitably applied to describe, understand and control social, political and economic phenomena, as well as phenomena relating to the "hard sciences".

I have provided a vast review of the logic and applications of Systems Thinking in every sector, even the physical sciences, with particular reference to control systems, in my book entitled *Guide to Systems Thinking* (Guida al Systems Thinking, 2007, Italian edition), which the reader can consult for more in-depth analysis.

There would be no arms escalation if today the production of arms were not followed tomorrow by an increase in enemy arsenals. And languages would not survive over time if their teaching wasn't repeatedly passed on from parents to children, generation after generation; we wouldn't pay taxes each year if each year we didn't produce new income; feuds wouldn't continue over time if each offense weren't followed by a vendetta; and there wouldn't even be an increase in the average temperature if day after day, year after year, there wasn't a repeat of heat emissions from industrial repetitive processes.

The systems observed by Systems Thinking are also normally systems with *memory*, since, at the end of the process, different outputs correspond to the same inputs, which refer to different moments.

The system can no longer be observed simply through the *input* and *output* variables; the variables of *state*, accumulating memory, have to also be considered at the same time.

Memory is present in almost all social, economic and biological processes.

There is memory in the populations that pass on their language, generation after generation; or in the consumers that prefer the newest products; or in firms, which learn from their successes and try to avoid past failures; or even only in my bank account that accumulates interest year after year, thereby producing higher interest; just as there is memory in my mind that grows tired and needs restorative sleep, day after day; and we know how memory is the engine behind eternal feuds between individuals and peoples, behind scientific progress and the search for new records.

The Causal Loop Diagrams

In order to make immediately and easily understandable the causal interrelationships among the variables that make up a dynamic system – understood as a pattern of interconnected and interacting variables of whatever type, size and structure (Mella, 2008) – Systems Thinking follows four basic rules:

1. search for cause and effect links between the variables (for example, A and B); the relations of cause and effect between variables can be simply represented using arrows (A → B) that unequivocally correlate their variations; the cause (input) variables (A) are written in the tail of the arrow; the effect (output) variables (B) at the head of the arrow;
2. understanding the direction of the variations between the variables; A and B have the **s**ame direction of variation (s) if increases or decreases in A result in corresponding increases or decreases in B; they have the **o**pposite direction (o) if increases or decreases in the former result in corresponding decreases or increases in the latter;
3. identify *two-way cause and effect links* between A and B and, at the same time, between B and A; in fact, in many cases two variables can be linked in the two opposite directions; the causal link must be established in each of the two opposite directions; such possible dual directions in the links form the simplest models, called *Causal loop Diagrams* (CLDs), which reciprocally connect the two variables;
4. specifying the effect produced by the loops on the variables it is composed of; there are only two basic types of loops: the *reinforcing* loops **[R]** reciprocally increase – in successive repetitions of the system's cycle – the values of the two interconnected variables, as occurs, for example, in arms escalation processes (Fig. 1); the *balancing* loops **[B]** produce the effect of maintaining relatively stable the values of the connected variables, as occurs, for example, in the causal model that links price, demand and supply in a competitive market (Fig. 2); this loop shows how, by linking two balancing loops, a system is formed which in successive cycles, produces an equilibrium; if the price falls too much then supply falls and demand rises, so that the price increases again.

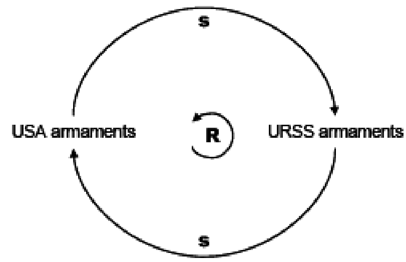

Fig. 1: Arms Escalation

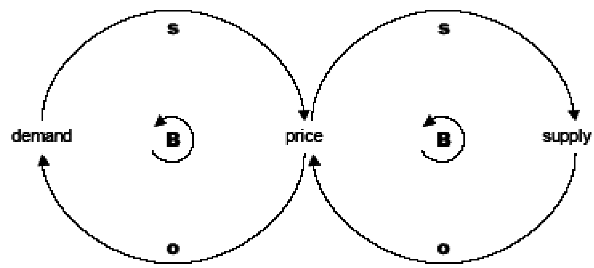

Fig. 2: Equilibrium in a Market

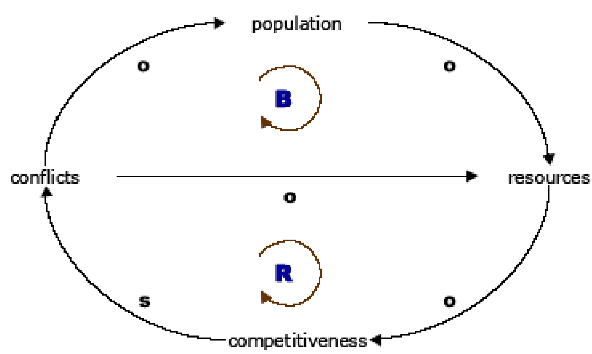

Fig. 3: Struggle-for-Life

Systems Thinking states that a dynamic world, no matter how complex, can be thoroughly described and modelled by means of various combinations of [R] and [B] loops, by inserting into the loops a greater number of variables connected in a causal relationship, or by connecting two or more loops to form more complex structures.

The most important theoretical contribution regarding the application of this perspective can be translated into the basic principle of Systems Thinking: *« structure influences behaviour and behaviour implies dynamics ».*

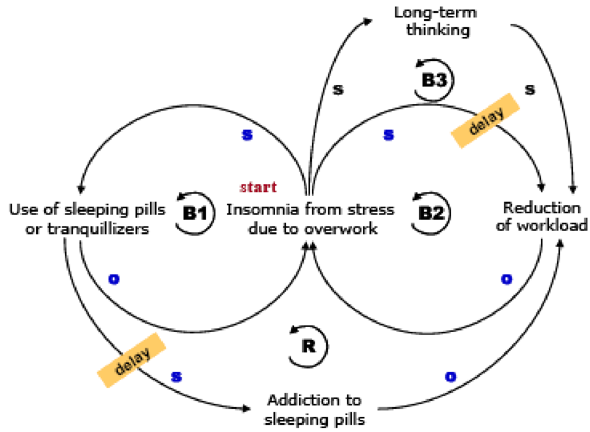

Fig. 4: Burnout from Stress

Fig. 3 represents a very simplified model of a struggle-for-life system.
Fig. 4 represents the system that describes burnout from stress; the search for short-term symptomatic solutions for stress can aggravate the problem in the long run rather than solve it.

The CLD of Fig. 5 shows the system that regulates our job and wealth aspirations.

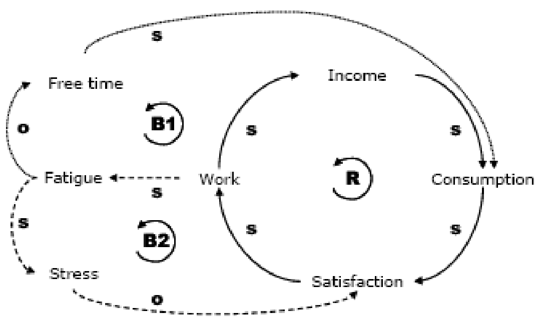

Fig. 5: Job Satisfaction

“Seeing the Impossible”, or “The Impossible to be Seen”

With its core of general principles and concepts, the Systems Thinking discipline accustoms us to “seeing the impossible”; that is, to identifying the structure that determines the trends in phenomena and produces complexity, non-linearity and memory in systems that act in all fields of human action, biological, economic and social.

This objective can be achieved by developing the necessary competencies in order to:

- perceive and recognize the circularity of phenomena,
- seeing how systems really function,
- intuit the effects of actions over time,
- feel responsible for the system’s performance,

- predict the future,
- control dynamic processes

so as to realize John Von Neumann's dream: *« All stable processes we shall predict. All unstable processes we shall control »* (Dyson, 1988, 182)

The rules of Systems Thinking can not always be applied because there are some practical obstacles that make it extremely difficult "to observe the variables", "understand the connections", "perceive the circularity and loops", "measure the effects produced by the causes"; in other words, these obstacles make it "impossible to see systems".

The most subtle, but also dangerous, of such situations occur when:

- the variables have dynamics that are too slow or fast to be observed
- the effects of the system appear in too distant a future and too vast a space to be determined
- the observer is not able to identify the connections between variables-causes and variables-effect

Five of these obstacles are particularly evident and important.

By using brief metaphors, in part taken from Senge's book, I want to highlight five of these conditions behind the "impossibility of seeing" that obstruct our systemic thinking with regard to understanding and predicting our world:

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. *memory*, the difficulty linked to structural, computational and temporal complexity

I will also indicate for each of these difficulties the strategies that Systems Thinking proposes to neutralize them.

First Metaphor: Boiled Frog. The Difficulty Arising from the Temporal Slowness of Processes

It is told that in biology laboratories the following experiment is carried out, first described by the psychologist Granville Stanley Hall in 1887 and later presented in various contexts (http://www.fastcompany.com/magazine/01/frog.html). A frog is thrown into a pot of boiling water.

If it does not lose consciousness immediately it manages, with great effort and despite being scalded, to jump out.

A second frog is immersed in a pot of cold water, under which a flame is lit that slowly heats the water. At first the frog feels cold, but as the water temperature gradually rises it feels like it is in paradise, and it happily basks in the warm water. The temperature rises but the frog – who knows nothing of pots, flames and researchers observing him – tries to resist the heat, perhaps in the hope the water will return to its ideal temperature.

However, inexorably the heat becomes unbearable and the frog decides the moment has arrived to jump out. His limbs, however, are numb from the heat and cannot provide him with the necessary impetus; almost always, after a couple of failed attempts, the frog remains in the water and is boiled: he becomes a boiled frog.

Lesson: some phenomena are described by variables whose dynamics is so *slow* we often cannot perceive them. Systems Thinking obliges us to consider with particular care the small and slow variations in variables, since associated with these are vital phenomena – biological as well as social – which, if not perceived at the moment they start, could cause catastrophic consequences.

We can easily see the metaphor of the "boiled frog" at work in the incapacity of policy makers to perceive and control pollution, deforestation, climate changes, immigration or depopulation, crime, the spread of drugs, and so on; and also in the incapacity of managers 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.

Systems Thinking proposes an *operational rule* which is simple though not always easy to apply: *amplify the weak signals*, thereby projecting the slow variations towards a future horizon of appropriate amplitude and, above all, be aware that the "boiled frog" is always waiting in ambush and can strike without our having the time to be aware of the process that is playing out.

Second Metaphor: Networking Effect. The Difficulty Arising from the Speed of Processes

It is told that a farmer had a pond on his property that was well-stocked with fish, and he fished from its shores on his rest days. Passing by the pond one day he saw a water-lily, but he did not give it much thought.

A couple of days later he saw four water-lilies, which pleased him. The pond, more cheerful because of the flowers, was becoming a nice place not only for fishing but also for picnicking.

After a week he saw the water-lilies had become numerous, and he thought: «I need to clean up around here; otherwise the fish will suffer». The following days saw him busy with various other chores, and when he passed by the lake again he saw it half full with water-lilies.

As he had to finish his work in the fields he thought: «In a few days I really have to remove some of those water-lilies». But it was too late by now. The water-lilies had doubled in number each night and the following day they covered the entire pond, killing fish. When the farmer returned he was forced to give up his passion for fishing.

Lesson: some processes and phenomena (usually involving accumulation and propagation based on exponential laws) are so rapid that we are not able "to see" their evolution until they have already produced their effects on the system.

A typical case where it is difficult if not impossible *to see the dynamics* of a system is the so-called *networking effect*, which operates in particular in *networks* of elements that 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.

An element initiates the propagation of two or more related elements, and this process is disseminated to other elements in the network so that – just as in nuclear fission – a cumulative dynamics occurs which is so rapid as not to permit observation while it is being produced, but only when "we see" the global effect, which usually has some undesirable aspects.

It is as if we can hear the aria sung by don Basilio, so masterfully written by Rossini, 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,* [...]*»* (act one).
> «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, […]»

We can sum up the *operative rule* suggested by Systems Thinking as follows: there is not much defence against the rapidity of the dynamics of variables; the only rule is to try to identify, as quickly as possible, the law of growth of the system and the network of interconnections among its component elements.

Third Metaphor: *Butterfly Effect*. The Obstacle of Distance in Space

It is told that the flapping of a butterfly's wings in Brazil could cause a tornado in Texas, and that many sea typhoons in the Caribbean could be caused by the flapping of the wings of a butterfly who, unawares, is floating around in a valley in the Urals.

The term *butterfly effect* derives from 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).

This effect is also known as the *Turing effect*, since Alan Turing expressed a similar idea in saying that shifting a single electron at a given time by a billionth of a centimetre could, thanks to a very long cause and effect chain, give rise to very diverse events, such as the death of a man a year later due to an avalanche or his being saved (Turing, 1950).

Even if it may sound improbably, the *butterfly effect* is always lurking, and it manifests itself in many forms: a truck travelling slowly along a stretch of highway can cause a slowing of traffic that blocks the flow of connected stretches of highway, thereby causing a kilometres-long line even on a distant stretch of highway. A local student protest that blocks traffic on a London street can cause a traffic jam involving the entire city. Resentment among leaders of minor parties can lead to a political feud that brings down the government. The wrong word whispered at a party at a friend's house can ruin a marriage. A small border incident in some part of the world can produce an escalation that leads to a war of devastating proportions. A modest variation in the number of animals in a given population can produce devastating effects and lead to the extinction of other populations linked to it.

Lesson: there are systems – composed of a very high number of variables linked by *nested loops* contained in other *loops* – so complex that even an insignificant variation in one of the variables is enough to produce enormously vast effects in others in distant 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.

Systems Thinking suggests this *operational rule*: do not limit yourself to seeing the "forest" – the entire system – but instead *zoom in* toward the "trees", their "large branches" and "small branches" (their constituent parts) while considering increasingly minute variables that can give rise to the initial variations with effects that are difficult to foresee and which are produced by the interconnections at increasingly vaster levels.

We must not forget "to see" the action of the *loops* of interconnections in recursive phenomena. While Lorenz and Turing "see" only in one direction, Systems Thinking must go further and exploit the power of the *Uroboros* (Mella, 2008), asking not only whether butterflies, by fluttering their wings, can cause climate alterations but also if such alterations might not make butterflies extinct; and in that case, what fluttering of wings would there be to produce new typhoons?

Fourth Metaphor: Mono-Directional View. The Obstacle of the Observational Direction

It is told that the mayor of a pleasant mountain town was desperate. Every afternoon at about the same time the road from the valley to the mountain top suddenly filled with cars, forming a slow-moving line several kilometers long which just as suddenly disappeared.

He put the town experts to work to monitor the traffic flow. They found that strangely the average number of vehicles per minute that passed was far greater at other hours of the day; and yet traffic lines did not form. To clear up this mysterious behaviour of the traffic flow, observers were stationed along the entire road at regular intervals.

They found to their surprise that every afternoon a car passed along the road at the same time going at normal speed with an elderly couple aboard. When the car got close to the top of the mountain it slowed down and went very slowly for a couple of kilometres: by creating a "bottleneck" for the drivers behind them, the elderly couple caused the traffic jam. Traffic flowed smoothly again when they resumed their normal speed.

When called in by the mayor, the elderly driver said: «I know nothing of the traffic you're referring to. I never saw any. We've been taking this road for weeks and when we are at the top we slow down because we never tire of the view from the top, which is always covered in snow. Believe me: we've never seen any traffic». Since they had never been given any tickets the only option open to the mayor was to widen the road with a passing lane near the top and to build a turnout where drivers could stop to admire the panorama.

Lesson: often we "*look*" in one direction only and cannot "*see"* the variables taking place at our backs or in other directions; at times we even prefer to ignore these. The observer adopting a mono-directional view is inside a limited system and ignores, or wants to ignore, the fact that this system is part of a larger system. Observing the small system in only one direction makes it easy to ignore the larger system that is stretching out in the other directions.

For example, those who resort to deforestation to gain cultivable land for their survival (looking ahead) do not (or do not want to) see the damage this causes the ecosystem (looking back). If we substitute "deforestation" with "whale hunting", "waste pileup", "building dams on large rivers", etc., we obtain the same result: those who only "look" ahead do not "see" behind themselves.

Systems Thinking suggests a simple *operational rule*: trying to *zoom in* by placing oneself *outside* the observed partial system and looking for the *loops* with the other subsystems helps to overcome the obstacle to correct systemic observation. What systems thinking can never prevent is the desire to consciously turn one's gaze elsewhere in order not "to see".

Fifth Metaphor: Too Much Memory. The Difficulty from Computational Complexity

It is told that many brilliant graduates in cybernetics asked the famous cybernetician, Ross Ashby, to be able to work with him in his department. In order to choose the most motivated graduates, Ashby gave them a simple automaton composed of a container with batteries equipped with two on/off switches and two lamps, with very few internal states, asking them to come back the following day, but only if they were able to give a correct description of what happened to the lamps when the on/off switches were pushed in all possible combinations. The following day almost all returned.

Satisfied, he gave them a second automaton with a higher number of internal states, inviting them to come back after a week if, in the meantime, they were able to describe it. Only a few returned and these received a third automaton, a "machine" more difficult that the others, with multiple inputs and a number of internal states. The graduates were asked to come back with a description, this time without any time limits.

After many weeks only one returned, and the master, incredulous, asked him if he had completed the description. The persevering candidate dejectedly shook his head and said: «I don't think it's logically impossible to describe this automaton, but I believe no human could succeed in only one lifetime». Satisfied, Ashby invited him to join his department since the young graduate had understood the insurmountable problem concerning the complexity of systems with memory.

In order to understand the extreme behavioural complexity of a system with memory it is enough to consider the incredible number of behaviours [input-states-output] that a machine with memory can produce.

This form of complexity has been well described by Heinz von Foerster (1991: 130), 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».

Lesson: even simply structured 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. Moreover, Systems Thinking must often deal with such difficulties (Mella. 2008), appearing impotent in "*seeing*" a "forest" whose trees cannot be "*observed*".

According to systems thinking the only *operational rule* to follow is to reduce a system characterized by computational and structural complexity into more elementary systems with a less difficult approach, and to examine the dynamics of these subsystems. The complex dynamics must be made to derive, within the limits of *acceptable approximation*, from those of the observed subsystems.

Conclusions

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 offers hope, since it represents an instrument of learning in order 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 systems whose dynamics are, by their nature, difficult to perceive, model or control.

This paper has considered five such difficulties, which have been presented in the form of metaphors.

Some processes are so slow that we are not able to perceive their dynamics; by the time we become aware of their effects it is too late to control them and we end up like a *boiled frog* (first metaphor).

At other times processes are so fast, explosive and exponential that by the time we become aware of them there is no time to undertake any control, and we end up like the pond suffocated by the *water-lilies* (second metaphor).

Some processes derive from the concatenation of a large number of loops, which are contained in other loops of varying size, so that their macroscopic effects 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 (third metaphor).

If we only look ahead and observe a restricted corner of the world we cannot understand what is happening behind us, even at a certain distance. The *mono-directional view* blocks us 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).

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*, we could insert the same inputs all our life, or all the life of the universe, and continue to observe outputs that are always different. The greatest challenge to complexity is understanding and mastering such systems (fifth metaphor).

These five difficulties are insurmountable. The only remedy is to understand their existence and sharpen even more our attention and sensitivity. They pose a great challenge: to set up "sensors" that signal in advance the start of phenomena that are difficult to observe and understand, so that we are not unprepared when we have to suffer their effects.

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About the Author

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Born in Pavia, graduated in March 1969 with a first class degree in Industrial administration, in 1985 I won a chair as a full professor and lectured in Business Economics and Administration at the Faculty of Economics of Pavia. In 1986 I was elected Head of the Department of Business Research at the University of Pavia. From 1987-88 to 1992-93 I was Dean of the Economics Faculty at the University of Pavia. Since it was founded in 1990 I have been the scientific Director of the Masters in Accounting, Budget and Financial Control in profit organizations, set up by the University of Pavia. In 1997 I became Co-ordinator of the Doctorate in Business Research at the University of Pavia. In 2000 I created the scientific web site www.ea2000.it. My interests also deal in the fields of Complex and Holonic Systems and of Networks. In 1997 I have proposed the Combinatory System Theory, described at the web site: www.ea2000.it/cst.

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