Anticipation: A Bridge between Narration and Innovation

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In Memoriam: Steve Jobs

Who's afraid of non-determinism?

Everyone. No one goes to his physician prepared to accept a diagnosis that *might* be right or wrong. You don't send an e-mail that just *might* reach your addressee, or might reach someone else, or might get lost. You don't turn the key in your car's ignition under the assumption that it might not start (or at least not when you need or want it to). Innovation, which literally means *to renew*, *renewal*, is another human endeavor in which you don't want to take a risk. It might take you where you don't want to be, to situations you would prefer not to go through. For the sake of illustration, let us recall an innovation broadcasted around 1970: the nuclear pacemaker (*New Scientist*, December 1972) with batteries containing metallic plutonium 238 implanted in someone's chest. Nuclear energy was the big innovation. What better hope could a heart patient wish for?

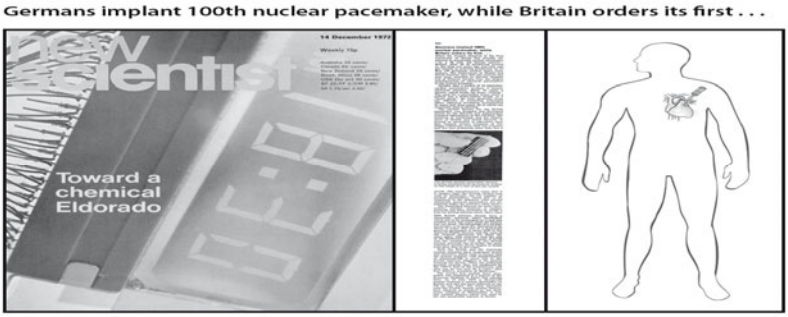

Figure 1: "The advantage of a nuclear pacemaker is its long life time," writes the author of the note in *New Scientist*, ignoring the problem of consequences to the patient.

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Then, as now, innovation was romanticized. Although, as research shows, "people are biased against creative ideas" (Mueller, Melwani and Goncalo 2011). If the nuclear pacemaker were the only example, we could still live with innovation, even if, sometimes, the costs attached to it stand in no relation to the outcome. Just for the sake of illustrating this statement, here are some examples of innovations and the narrative associated with them. Grain storage triggers the risk of insect infestation. An insecticide should not alter the characteristics of the stored grain. The narrative is simple: a fumigant – Zyklon B – was developed by Fritz Haber, a distinguished Nobel laureate in chemistry. The rest is the tragic history of millions of Jews murdered in gas chambers. The story is even more provocative: Haber was a Jewish scientist. To speed up the growth of soybeans, Agent Orange was developed. Deployed by the USA during the war in Vietnam, the chemical caused birth defects in over 500,000 people. TNT, the explosive of choice in two world wars, was developed as a yellow dye; Ecstasy for addressing abnormal bleeding. Unfortunately, the number of examples of innovation that humankind could do without is not decreasing. The reason is not only innovation euphoria – cloud computing, nanotechnology, genetic medicine, for example – but also the lack of progress in anticipating the consequences that innovation entails (Nadin 2003). As we shall see, anticipation is different from prediction (which is based on probabilities) and forecasting (based on models that try to account for randomness). The innovation narrative and the narrative of unprecedented consequences are not the same. But they are related. The few examples given above are indicative of the relation.

"Creative destruction" – only a metaphor?

Renew/*renewal* has a precise reference: there is something (an object O, a process P, an attribute A, etc.) that invites human interest to bring it up to date. Otherwise expressed: the clock of entities subject to innovation has to be reset, brought up to date. One example to make this assertion clear: the horse-drawn carriage (around the 9th century BCE), the engine-driven automobile (from Nicolas Joseph Cugnot, 1769 to Gottlieb Daimler, 1885 or Karl Benz, 1886), the hybrid car (combining combustion engine and battery-powered electricity, built by Victor Wouk in 1972, cf. *hybridCARS* 2006) correspond to moments in time that we define through the clock-based calendar. Each new moment was a resetting to new expectations and requirements. It affected not only the mechanics of moving, but also mobility. Innovation always transcends the immediate object of renewal. It pertains to the life of the people. In the case of the car, the innovation

affected culture, urban development, health, economy, manufacturing, politics, and more.

To make current, or to be ahead of time (how much?), is part of the innovation. The word *innovation* (from the Latin *novare*) as such acquires its meaning relatively late: in the 13th century in French-speaking culture; in the 16th century in the German- and English-speaking cultures. Joseph Alois Schumpeter, the famous Harvard University economist who authored a theory of economic development of capitalism, took note of the discontinuity of change resulting from innovation (*Business Cycles*, 1939). In his view of capitalism, there is a "creative destruction" process: market restructuring and the need to understand discontinuity are part of his perspective. Innovation supports the continuous reinvention of capitalism. This applies to every subject that innovation affects: production, distribution, investment, work, leisure, competition, social and political structuring. The major challenge for the capitalist is not managing the market (administering "existing structures"), but rather "making new markets (and destroying them)." The entrepreneur is "the agent of innovation. (cf. *Theory of Economic Development*, especially the German edition of 1935). Disruptions, not continuity, define capitalism. In this respect, innovation transcends the cause-and-effect sequence. Innovation is not a deterministic mechanism, but rather a process of non-deterministic reinvention, with many unpredictable outcomes (bankruptcies as well as success stories). Some were mentioned above. If we jump from nuclear batteries implanted in human bodies to the iPhone and to the innovation of financial derivatives, which led to a world-wide recession (begun in 2007 and not over as of yet), we realize that *creative destruction* (perceived as a disruption) is not just a metaphor. Some markets were destroyed; new markets were created. Some companies went bankrupt; others were saved. Therefore, to understand innovation requires that we also understand that creativity has an implicit destructive component: the new replaces something already in place. The process generates conflict. Intergenerational relations are an example extending throughout the entire history of humankind. Innovations of all kinds (how we care for offspring, education, nourishment, inheritance laws, social changes in the status of youngsters, etc., etc.) have led to many disruptions. For example, the generation of 68 was no longer willing to recognize the legitimacy of parental authority, which carried over to government authority. Their innovation was based on the narrative of challenging the rules.

The narrative

But enough, for the time being, with innovation and the broad meaning of renewal. It is usually idealized, just as each birth is idealized (mothers, better than anyone else, know the risk and pain that new life entails). Nevertheless, the examples brought up are part of what can easily be called the *narrative* associated with innovation. The simplest definition of *narrative* is: a description of a sequence of events as they succeed in time. The word (again, from the Latin *narrare*) means to recount. It suggests that a record of succeeding events in time, a time series, describes what people accomplish and how. Therefore, it adds up to knowledge.

The most intuitive way to organize our own experiences is to take note of how they succeed, one after the other, along the timeline of our own activity. This inspired Gelernter (1992) to generate the *flowing stream*: nothing more than the sequence of every electronic document – mail, photo, draft, URL, notes, etc. – in the order of their reception (or in the order of their generation). It seems a simple idea, but in fact it was the innovation that changed the nature of data management in the broadest sense possible. I would have called it *the narration stream*.

If we have a record of succeeding experiences, we could try to see what these experiences have in common, and what distinguishes them. And we could try to understand them. The most telling narratives are those we experience naturally: the succession of day and night, of seasons; the succession of plant life, of animal behavior in the environment, of celestial bodies (sun, moon, stars, etc.). Innovation cannot change such sequences, although plants that flower in advance of the change in season have been created, as well as fruits that become edible earlier, animals (pets, cattle) that behave in ways that "contradict" nature. In summary: not only the artificial (what we make) is subject to innovation, but also the natural. High-performance sport is an example impossible to avoid: Oscar Leonard Carl Pistorius runs on Cheetah Flex-Foot carbon fiber transitional artificial limbs (made by a company called Ossur), competing with runners who have their natural legs. This would be the inspiring aspect. Performance enhancement through drugs is probably less inspirational (especially in view of the long-lasting consequences). The observer takes note of how humans defy the natural and acquire new means for enhanced performance. It is one thing to confront an animal in nature during its active phases (seeking food, hunting prey), and another while feeding offspring, or during sleep. The same applies to human beings: they welcome visitors, but not necessarily occupiers (in military or business guise). Narration evinces only time-significant connections. It does not report on causality. A tame animal, like the tame human being, can abruptly change its

behavior. There is no easily retraceable narration of causality as it pertains to behavior.

And the story?

As fashionable as narrativity (and other attempts to study the narrative) has become, it rarely results in a body of knowledge that makes a real difference in practical endeavors. The main reason for this is the imprecise nature of our understanding of what the act of narration is, and the knowledge that narrations embody. With the exception of Windelband (1915), almost no one has tried to define the distinction between narrative knowledge, corresponding to a historic record of change (*idiographic*), and scientific knowledge (*nomothetic*), corresponding to our attempts to describe how reality works. The idiographic captures patterns of events; the nomothetic focuses on scientific law. Of course, everyone would like to transform the uniqueness of experience captured in the narration into laws, thus opening the avenue towards automating whatever we do. To a certain extent, such attempts have succeeded: all tools are an expression of this preoccupation. In our age of digital descriptions and digital machines (which actually are programs), more progress in this direction is made. A concise formulation of the attempt described above is: to transform the art of doing things into the science and technology of doing things. It remains to be seen if the outcome is always as good as we hope.

Narration and story

For the sake of illustration: "The Queen died, and then the King died." Of course, you can substitute the generic queen and king with whomever you want (people you know, characters in books, your pet dogs). If you so desire, add a precise date for each event. Or take any successive events you kept a record of. This is narration. Temporality defines its condition: something happened after something else.

The Queen died, and then the King died – of a broken heart. Take your example (e.g., Mother died first, father died later) and add whatever the case might be: languished, committed suicide, was poisoned, etc. If your example was different – let's say: She gave birth at 4:45AM; her mother called five minutes later – your story could end with

1. after a nurse called her mother to give her the good news;
2. after she heard her daughter's voice in a dream (or thought she heard her daughter's voice in a dream, or thought she had a dream);
3. before she went to sleep (along the line of "Let me see if she gave birth so that nobody will wake me up");

etc., etc., etc. The list is open. Use your imagination. Write your own stories based on narrations you are familiar with.

Recently (Krulwich 2011), the narration of the death of Richard Feynman's wife made the rounds. The time of death (precise narration) was the time at which the clock in the room where she died stopped. Feynman, no doubt affected by the loss (he was young, she was young, they were in love – so goes the narration), would not allow the coincidence – time of death recorded on the certificate and the time the clock stopped – to obstruct his judgment. He went for the cause (later in life, he helped establish the cause of the *Challenger* space shuttle disaster). That was his story. And in this respect, science is the story into which the narration (of facts, measurements, evaluations, experiments) morphs. The apple falling from the tree, the observations of how this happens (during day or night, sunshine or clouds, noise or quiet, etc.) are the narration. Among the stories, there is one of the ever-hungry traveler (for whom apples fall), another of the reseeding of the tree (can this be the Johnny Appleseed story?), and another for Newton's theory of gravity.

While narration and story – often considered identical – have attracted the attention of many people, their significance as a substratum of life has escaped the attention of science. There is no class in narration for students of life forms and molecular biology, for future physicians and geneticists. Story was given over to writers and, eventually, filmmakers. To paraphrase none other than Abraham Lincoln: We must like stories; we make so many of them. And we like to hear them. (My wife is still working on a book entitled *Stories I Tell My Husband*.) The real surprise, though, is that narration and story play a considerable role in the dynamics of the living. Few people are aware that narration, or even stories, are exchanged at all levels of life (among cells, for example, or among neurons). It is from the embodied narration of life that we get to understand life as a narration, and further generalize to our explanations of reality.

Thesis 1: ***Narration is a record of change.***

Change characteristic of the living (from conception to birth, maturity, and death), and change of the physical world (mountains change, stones are "polished" by wind and water, oceans undergo cycles of ebb and flow, etc.) can be

recorded. Depending upon the resolution (how fine the grain of our distinctions) of our observations, the various narratives of change constitute a body of knowledge on whose basis science advances and technology is produced. In this sense, narrations are information about change over intervals. Given the complexity of reality, the information is always incomplete (we shall return to this idea). Moreover, the information is not associated with meaning. It only reports on changes, not on the context.

Thesis 2: ***Narrations are representations of change.***

Without entering into details, let us take note of the fact that objects $\{o_1, o_2, \ldots\}$, natural or man-made, processes $\{p_1, p_2 \ldots\}$, natural or artificial, attributes $\{a_1, a_2, \ldots\}$, of objects or processes can be described in many ways. They can be named (labeled, as the terminology of cognitive science suggests), measured, depicted in drawings, photographed, videotaped, filmed, turned into sounds, animations, etc. Words can be used (and made up if necessary) to explain what they are. These are all substitutes for something else, i.e., *representations*. Even when the real thing (object, process, attribute) is no longer within our reach, no longer actually present, we deal with its representation as it stands for the real thing. Each representation is partial. To capture everything that defines objects, processes, and attributes as they change in time is impossible, if for no other reason than because time is open to infinity.

Figure 2: Representations. The aggregate of all representations cannot capture the holistic condition of the reality represented. All representations are subject dependent. All representations are partial.

Narration is a representation corresponding to the perception of reality along the time continuum. The structure of language corresponds to the same perception. It is sequential. The sequentiality of narration corresponds to an understanding of time as a sequence of durations (between successive states of the narrated change).

Interpretation of the narration means no more or less than the attempt to reconstitute the represented from the representation. Succeeding events and their representation are, of course, not the same. Therefore, the "reconstitution" of reality from the representation is not so simple as remaking an image in a puzzle. A person's picture is a representation; the "remaking" of the person is always partial: memories of how the person behaved, moved around, spoke, are part of the interpretation. Reconstitution of the represented from a time series (a scientific method currently in use) can acknowledge the time sequence, confirming it, or challenging it. Indeed, the sequence "Queen dies, King dies after" can easily lead to a story: Queen dies because the King was unfaithful; King dies because Queen poisoned him (or had someone do it), or cursed him. In the story, information is associated with meaning (corresponding to the context). Stories often challenge the sequence: first, second, third, etc. are sometimes reshuffled in the

story (third becomes first, or second, etc.). The clock that stopped when Feynman's wife died can easily lead to a story in which the clock stops (first), the sick patient notices it (second) and takes it to mean "My time is up!" (third), and succumbs to death. When I wrote "takes it to mean," I suggested the process of associating information and meaning. The clock of narrations cannot be arbitrarily reset; the clock of stories is independent of the narration clock.

Information and meaning

Thesis 3: ***Stories are interpretations of narrations.***

The most convenient explanation of this thesis is that through stories, information is associated with meaning (Nadin 2011). The information regarding the falling apple (or the falling of anything: stones, meteorites, individuals, etc.) reveals the meaning of the physical laws, in particular the law of gravity. But it can, as well, associate the narrative to a story different in its condition from the one expressed in the theory of gravity: poetic, dramatic, religious, metaphysical. Kings fall from power, leaves float in the wind (slow falling), the fall of Rome marked the beginning of the "Dark Ages" (whose meaning is disputed by many); people who fall on account of faith lost need help to get up and get on with life; fallen angels come to earth to redeem themselves; and so on. Some are subject to confirmation through experiment; others, being unique, are not. Recall once again Feynman and the clock that stopped at the time recorded on his wife's death certificate. The narration prompted the physicist, a known atheist, to produce a scientific story: elimination of mystery, poetry, religion, etc. But similar narrations – the clock that stops exactly with the last breath of a dear person, or of some celebrity – populate culture and foster storytelling in many variations. Feynman was entirely given to the story we call *determinism*: there is a cause (e.g., a part of the clock's mechanism fails) and a subsequent effect (e.g., the clock stops) or effects, the meaning of which is expressed in scientific laws. Fighting his emotions – he was, to repeat, very much in love with his wife, as we know from his narration, his autobiography (1985) – Feynman recalled fixing that particular clock more than once. It was not in good shape, therefore it was possible that the nurse, who had to record the time of death, took the clock in her hands, checked the time, returned it to its place, disturbing the fragile mechanism. There is no way to repeat the experiment. This was not a reproducible measurement. Time is not reversible (except in equations, even those describing deterministic processes).

When clocks are more than clocks

What does all this have to do with innovation? The question is justified not only because we are focused on innovation. Imagine, for the sake of argument, a digital clock: no moving parts, nothing to get loose, not even the battery or some contacts. Imagine even a monitor connected to the atomic clock[1]. There is no reason to speculate on Feynman's take if such an interval measuring device had outputted a frozen time identical to that of his wife's death (automatically registered by the various monitoring instruments common to a hospital's intensive care unit). The narration would be more detailed, of course; and the meanings to be associated with the information embodied in the narration would also be different. What changed? Of course, innovation "refreshed," "renewed" the acquisition of information making up the record of events. This, in turn, changed the details of the narration and thus its condition: *from a relatively loose record* (mechanical clocks are not necessarily very precise, and are also difficult to calibrate) *to a tight, integrated record of a higher degree of precision*. We realize that a different narration, which means a different representation, is conducive to a different interpretation; better yet, to a plurality of interpretations. But we also realize that the speed of time plays an important role.

Thesis 4: ***The clock of narration and the clock of interpretation are different.***

The clock of narration corresponds to the rhythm of events in the physical world. The clock of interpretation projects into the physical world rhythms characteristic of the change in the living, in particular, rhythms associated with interpretation. When we react to something, the reaction time affects performance. When we imagine things in the future, we have the convenience of controlling the rhythm of time. Indeed, as events unfold in time, the gravity-based machine that measures the interval corresponding to the movement of celestial bodies serves as a reference. This is the meaning of the information delivered by clocks. The living is affected by intervals in the environment of existence; but the living also introduces its own rhythms into reality. Saccadic movements, the foundation of sight, have a rhythm different from the heartbeat and neuronal connections. Birds in flight or the slow fall of leaves are other examples of particular time scales; the heartbeat of animals is extremely varied.

[1] An atomic clock uses an electronic transition frequency in the microwave, optical, or ultraviolet region of the electromagnetic spectrum of atoms as a frequency standard for its timekeeping element.

Time characteristic of life is not reducible to intervals. As a matter of fact, there is no proof that time scales uniformly. In other words, time at universe scale, where we refer to phenomena that happened way in the past (even millions of years ago), and time at the nanoscale, where we refer to very fast interactions, might be different in more ways than order of magnitude. The narration of phenomena from the remote past – let's say star explosions – and the narration of current phenomena of extreme dynamics (such as fermentative metabolism, and earthquakes) are different to the extent that they appear to us as associated with different realities (Lara *et al.* 2009). Being a record of change, each narration is a representation of the dynamics of reality. Each interpretation of a narration is a story: the meaning we associate with the information on record. A faster clock, such as the clock of interpretations, is what it takes to evaluate the possible consequences of the phenomena on record in the narration. In other words, the future itself is nothing but the outcome of a faster clock. As a virtual reality, this future depends on the rate of change expressed by the clock. We refer to possible futures – plural! – because we can build clocks with various speeds: from very slow to extremely fast. Each such clock allows us to investigate the future *not as a probability*, but *as possibilities* (often negating probabilities). This is where innovation takes place.

If the information in the narration is continuously subjected to interpretations from the future, facilitated by the faster clock, its meaning becomes *anticipation*. The Haicheng, China earthquake (February 4, 1975) was anticipated on account of massive human observation of animal behavior. As a consequence, the impact of the earthquake – a physical phenomenon still impossible to avoid –was mitigated by preparatory measures: large segments of the population were evacuated; electricity was interrupted in advance, in order to avoid accidents, water delivery was stopped. As good as this sounds, it gives only a partial description of the story. Anticipatory processes are non-deterministic. The Sichuan, China earthquake (May 12, 2008) was not predicted, although observations (like those in Haicheng) were accumulated. The narration that was meaningfully interpreted in 1975 was not adequate some 30 years later, and the number of victims (not to mention the damage) was huge. If you visit NASA's website (NASA Science, Science News), you can read about new methods for "predicting" earthquakes. One is based on detecting temperature variations of the Earth's surface—which was one among the variables observed in China. The innovation associated with the narrative observed does not automatically become successful. Remember: the goal is to transform the uniqueness of the narration (the idiographic) into laws (nomothetic) generalizing the interpretation. There is no guarantee that this goal can always be met, because the non-deterministic and

the deterministic are different in nature. Statistics allow for some generalization, but they do not replace the real.

Fast or slow, clocks are deterministic. They are machines. Interpretations, involving faster clocks, pertain to a reality that is no longer the reality of the phenomena represented by the narration, but of interpretation processes. At the low end of the living – simple forms of life, no cognition, but always a memory substratum – the output of the interpretation process is patterned behavior (the monocell is phototropic; it anticipates the consequences of exposure to light, even if it has no awareness). At the high end, the human being is defined by complexity across its various scales of existence (from the cell level to the whole that defines a unique profile). Narrations are transmitted among cells. These are records of actions validated from one level to another.

New ways of thinking

Interpretations can vary along the continuum from coherent to incoherent. A second example, in addition to that of the earthquakes in China, should help in explaining the idea I am trying to articulate. My intention is to suggest that obsession with a reductionist cause-and-effect course of action, which generalizes expectations associated with the laws of physics (sometimes involving statistics), has to be transcended. We'd better start thinking about alternatives.

The cell is the constitutive "particle" of the living. Cells continuously exchange information. More precisely, they exchange meaningful information, i.e., narrations. Based on this example, which involves many components (physical, chemical, and biological in nature), life unfolds from its inception to death. I learned from an eminent scholar in molecular biology (Professor Harry Rubin, Emeritus, University of California – Berkeley) that cells undergo their own cycle of renewal. By now, this knowledge is relatively unquestioned (see Orford & Scadden 2008 as only one example). Moreover, cancerous cells are almost permanently present in the organism. Scientists have tried very hard to discover the circumstances under which these cells multiply and thus lead to the condition called cancer (of which there are so many variations). This condition has a simple narrative: the mechanical growth of cancerous cells that in the final analysis exhaust life resources. Given the narration, that in the past almost always ended in death, various innovations – e.g., surgery, radiation, alternative healing methods, drug-based treatments—were advanced. Physicians specialized in the domain (oncology); clinics have been built; everyone hopes to find the miracle cure (and get the Nobel Prize). The most prominent innovations are the attempts at surgical removal of the cancerous growth, medication to halt

proliferation, establishing a "firewall" (where laser treatment comes into the picture) for containment. All these methods are based on the deterministic model of cause-and-effect associated with grueling chemotherapy (radioactivity comes into play again), itself a major innovation that has helped save many lives. Albeit, no cure for cancer has been discovered or invented. Rubin realized that the question to be asked is not "How do we get rid of something as organic as life itself, without getting rid of life at the same time?" His data, collected over many decades, show that as long as healthy cells surrounding cancerous cells keep the latter in check, no cancer develops. My own hypothesis is that stimulating anticipatory capabilities, characteristic of the living, is probably the answer. Instead of dwelling on the innovation expressed in pills and surgery, let us examine the narration exchanged by cells, and identify under which circumstances healthy cells no longer recognize in advance the dangers associated with the unchecked proliferation of cancerous cells.

Let me explain the alternative thinking I suggest. The narration that leads to cancer is part of the larger narration called *life*. Cells exchange narrations relevant to their continuous reproduction. They interpret narrations received. When the interpretation shifts, their own functioning is affected. The narration becomes the story we call cancer. In terms of anticipation, the question relevant to the cancer story is the following: When and why does the anticipatory function of healthy cells diminish? This, of course, brings the immune system to mind. For those focused on innovation, we know that laser surgery replaced the scalpel. In our days, computer-assisted surgery removes surgeons from the position of total control (and the expected artistry) they once had. Their new role is to monitor and interpret the "narration" of a very precise action that humans cannot perform (degrees of precision in the range not afforded by the human eye, and even less by the hand).

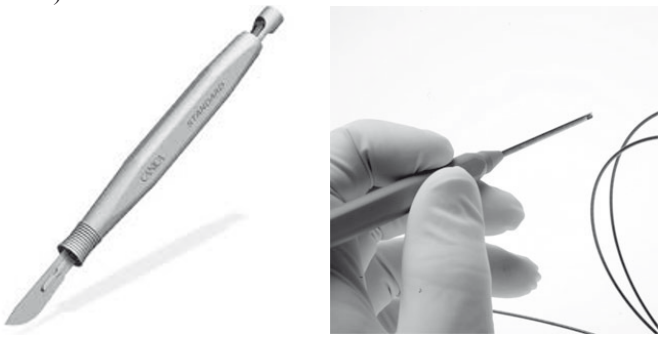

Figure 3: From the scalpel to the bendable laser scalpel

Can machines innovate?

The question could have taken a more provocative form: "Can machines generate narrations?" Followed, unavoidably, by the more drastic question: "Can machines tell stories?" As a matter of fact, some of the fiction sold at airports and bus stations is written by programs. Machines are very good at permutations: take a narration and produce similes. Machine-produced books are variations on a theme within a given structure. It costs less to generate this kind of "fast book" (similar to the technology of fast food production) on a computer than to employ a scribe. (In the past, scribes did exactly the same thing, paid close to nothing in the monasteries where they lived.)

More often than not, on various networks, we exchange messages with artificial intelligence (AI) agents. In search of a wife or husband ("life partner," as the current formula goes), a person searches through matchmaking e-businesses (advertising their services all over the world), and follows the prescribed path. Matchmaking is essentially an exchange of narrations: $life_1$, $life_2$, $life_3$, …$life_i$. Human nature is such that individuals tend to put themselves in a better light. Matchmakers of the past took narrations entrusted to them and made them more enticing (the proposed match is younger, richer, more attractive). Today, a seeking man or woman can end up exchanging narrations with AI procedures, under the assumption that he/she is in touch with other human beings. Automatically, misrepresentations (age, weight, height, earnings) are weighted and a second narration, parallel to the fictitious profile, is automatically generated. Matching becomes an issue of algorithms and procedures. When all is "digitally" ripe, the selection for the man seeking a match, or for the woman seeking life companionship, is made available for interpretation. Real men and women and virtual characters, a mixture that the receiver is not aware of, test each other. Here is where each makes his or her story, by opening a dialog, exchanging information, chatting. More and more possibilities of remote interaction are becoming available in the Web 2.0 world. The innovation of matchmaking – a serious business worth billions of dollars – is the result of many narrations, and even more stories, that have had good and less than good outcomes. Even some of the people involved in the innovation – that is, fully aware of some of the deterministic mechanisms at work – have made their choice in the space of virtual relations (Paumgarten 2011).

Of course, this in itself does not answer the question of automated innovation, not to say automated narration and storytelling. We have seen that the clock of narration corresponds to the rhythm at which objects, processes, and attributes change. An object o_1 (Peter, 38 years old, divorced, father of three, undergoing treatment for alcoholism) becomes o_2 (still Peter, but now 35, single, likes to jog)

over a certain interval. For the matchmaking, this change is consequential. The difference in the condition of the two (difference o_1, o_2) is indicative of the depth of change. The AI procedure infers from all the data, true or false, submitted by Peter (or whoever claims to be Peter) to a more realistic narration. It shares this processed narration with candidates who, according to the matchmaking algorithm(s), are deemed appropriate. In simple terms: a machine (the aggregate of procedures and programs) extracts knowledge from the narrations and evaluates the probability of a match.

On the conceptual level, we deal with probable changes of objects, processes, and attributes. A process p_1 becomes the new process p_2 over a certain interval. (Even processes age. Some are preprogrammed to "die" at a certain time; others come to life at a predefined time. The various bots that make our life miserable behave like this.) Attributes A $\{a_1, a_2, a_3, \ldots\}$ are also expressive of change: changes in skin color, for example, can be interpreted as symptoms by qualified physicians. When everything changes, the narration becomes complicated.

Narrations representing change in the physical world can never be more complicated than the processes for which they stand as a record. Complex systems, such as the human being, or nature as a whole, undergo change at many levels. The record of change is indicative of the complexity of the system, but also of how complex the changes are. The narration of high fever—associated with a cold or the flu – represents some aspects of the functioning of the human thermostat, but also much more than that. The physician always wants to know when the fever started, for how long it has lasted, and if the patients, associates it with something in particular (diet, stress, over-exertion, exposure, unsanitary habits, etc.). Ideally, if he could obtain a continuous record, the physician would be able to make more than the usual reductionist determination: infection, inflammation, cold, influenza, or similar. In complex systems, variables are unfathomably related.

We cannot ignore the fact that all narrations exchanged within the organism are autonomic. Cells do not have secretaries to take note of how the smallest variations in the environment translate into changes that require the finest tuning imaginable. Moreover, there is a lot of anticipation that affects the process. Cognitive science made us aware of the fact that seeing – which we take for granted as long as it is in order – is the result of anticipations that allow us to "ignore" a lot of what makes the world visible. If we could process all the richness of the visual universe, the "price we would pay," i.e., lower performance, would make it impossible to adapt to changing environments. "The brain is futural" (Morton 2011). The observation continues: A lot of memory is proleptic. (Kant used the word *proleptic* to describe anticipation. In other words, memories are used not to dredge through the past but to anticipate. Bill Benzon

(in a private e-mail conversation, September 4, 2011)[2] completed the thought: You move through the world. Right? What you see will change as a function of your movement. Vision is computationally expensive. The visual system is primed to anticipate changes in visual input attributable to our own motion.

This is where the question of the innovation machine falls into place. The living "knows" a lot about the world even without having experienced it. Genetic information is continuously transmitted; and there is interaction, in particular the interaction of minds (Nadin 1991). Our minds generate a lot of information – mainly as possibility scenarios. Can machines emulate this non-deterministic functioning? If we expand the understanding of machines so as to integrate the living, the answer is easy to give. Of course, integration of the living and the non-living is not trivial. There are no narrations in the "life" of a stone, in the "life" of water (running or still), of fog, of mountains. This has to be explained. The life of the stone – a metaphor, of course – is the change of the stone over time. However, stones are not born and don't die. They are transformed by the elements (wind, heat, water, etc.), i.e., through physical processes. In this transformation, there is no narration from a stone's atom or molecule to another. Energy exchange is all there is. The same holds true for mountains, water, air, etc. But there is the narration that the living generates of events related to how stones, water, fog, and mountains change over time. If a machine could report on change in the world, it could as well generate narrations. There are observation stations (on the moon, at the North Pole, in Antarctica, on California's fault lines) that generate records of change made of large streams of data. And there are machines that process such data records based on instructions reflecting our understanding of phenomena. They generate information from the data. Eventually, they issue warnings (based on previously acquired knowledge).

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[2] "Given that our eyes move as we move, it follows that the visual world will change in a way that is precisely matched to our path of motion. As we move straight ahead small distant objects will become larger and larger, thereby taking up more and more of our visual field, until they reach their maximum apparent size and then disappear off the margin of the visual field.
Similarly, if we move our head to the right, say, to track a running horse, stationary objects will move to the left in the visual field while the horse itself will be relatively stable in the center. Since organizing a sharp visual image takes precious fractions of a second, the brain primes the visual system for these movements by sending preafferent signals anticipating the visual effects of our movement (Freeman 1999a, 1999b, 2000; cf. Gibson 1979, 206 ff., 227 ff.)."

What kind of narrations do machines generate?

We have already seen that narrations are time records of change. However, change can as well be the outcome of deterministic processes (the narration associated with gravity explains falling down) or non-deterministic processes (the triggering of cancer cell growth). Given their different condition, it is justified to examine whether machines can generate narrations of both types of change.

Thesis 5: ***Machines can narrate deterministic processes.***

Enough has been written about the "9/11" narration of the terrorist acts to make a rehash of the tragic events unnecessary. (The Japanese *kamikaze* of WWII were precursors to the same narration of suicidal acts of destruction.) The aggregate of records of flights, real-time video, random taping, photographs, cell phone calls, and much more actually make up the narration. Those who plotted the criminal act designed it for maximum impact not only in terms of destruction and loss of human life, but also in terms of media impact. This narration has been analyzed to a high level of detail by official commissions and various agencies (dealing with emergency response, construction codes, fire extinguishing, medical care, trauma handling, and so many other related aspects). A huge effort was undertaken from the perspective of avoiding any future terrorist incident (small or large scale). These are all interpretations, that is, stories in which the clock of real-time events is superseded by the "story clock," which is a collection of clocks (some faster than the others).

The reason I bring up this example is because of another story with one outcome as its goal: to change the narration. This is the story of the *Truthers*, who hijacked the narration and keep trying to rewrite it. (There are "truthers" for almost everything that ever happened.) Please take note of the following: the record of an event, the description of an event, and an event's interpretation can remain close or can differ in an extreme manner. The basis for the infinite interpretation is the lack of correspondence between the clock of events and the clock of the story. Within the organism, it is not unusual that narrations are misinterpreted. (High fever is but one example.) However, the coherence of life makes the requirement of establishing a connection between the record (narration) and its interpretation necessary. Persons with six fingers (or with seven toes), or born with missing parts exemplify what happens when the record is faulty, or interpretations go wild. Pistorius, the "Blade Runner" was born with congenital absence of the fibula. This is the narration. When he was eleven months old, his legs were amputated half way between his knees and ankles. This is the interpreted narration: the absence of the fibula made the amputation necessary. The artificial

limbs (carbon fiber, Flexfoot, etc.) are the innovation. The meaning is not arbitrary. The Truthers are deniers of the narration, or given to speculative plot interpretation. For whatever reason – and there are theories (i.e., stories) about such reasons – they rewrite the information in order to match the meaning they decide the event should have. Mythomaniacs of all kind populate the world and exercise their right to be heard. There is no innovation to be expected from such narrations; it is always fruitless (even if at times they attract funds from legitimate or illegitimate sources) .

If misinterpretation had no practical consequences, the effort to address the issue would be, at best, of academic relevance (or irrelevance). But it all leads to our focus on innovation. The fact that airplanes, meant to transport human beings, were given the function of rockets to hit buildings brings up the need for prevention. So far, prevention translates into expensive (and often absurd) checking of who will have access to a flight (and the politics associated with prevention). Passengers who do not appear trustworthy (whatever that means) are kept at bay or at least discouraged from seeking a place on airplanes. (And everyone else is required to give up convenience, and sometimes more, for the sake of security.) Of course, nobody wants to have suicidal criminals on airplanes – neither for flying into buildings nor for blowing up the plane in mid-air. So much harm is possible, in so many forms (even plastic knives, which replaced metal ones from the coach cabins, can be used in a criminal manner). The required innovation has not yet been considered (to the best of my knowledge): a program that would not allow an airplane to become a weapon[3].

At this juncture, let's return to Schumpeter and the "creative disruption" model that, in his view, encourages the entrepreneur to be innovative. It sounds more than cynical to consider the events of 9/11 as a creative disruption. But I would be less than candid if I were not to see in the broad picture a narrative quite consonant with that of capitalism. For that matter, wars are often interpreted as "engines" of change. (And there are some people who consider that wars play a "creative" role: just think about drones, new weaponry, new strategies, new policies, etc.) So much science and technology are involved, along with so many individuals; so much time resetting takes place. The destruction caused by wars – and nobody should rush to justify them – is followed by what capitalism

[3] Nadin, Mihai, in an e-mail (March 20, 2003) to DARPA, stated: "If the possible action description is represented in a possibility/probability database, it becomes a realistic expectation that neural networks could model all kinds of possible events and attract attention to conditions under which these could take place. Moreover, we could add to the specifications of an airplane, such as piloting program with built-in limitations on certain operations that would prevent planes from flying into vertical structures or taking the plane to the nearest airport if the pilot is disabled.

likes most: new needs, new markets, increased consumption. The narration of war and innovation is probably stronger than that of providing aid to people in need of food, medicine, shelter, and clothing.

Through its condition as a record, narration is an-ethical, that is, free of ethics. Stories are testimonials to the ethics of interpretation. They embody values characteristic of those who tell them. Innovation, as a change in the record that constitutes the narration, is not unlike the story synchronized to the ethics of innovators. The nuclear battery of 40 years ago, the Chernobyl disaster, and the tragedy of an earthquake and a tsunami that destroyed a large section of Japan have in common not the technical innovation (or lack thereof), but an ethics of compromise that overwrites respect for the human being. Anticipation, as a bridge between the an-ethical narration and the inevitable ethical condition (or lack of it) of every innovation, is expressed in what are called consequences of our ideas and acts (Bode 2002).

The innovation machine

For those connected to the Internet (and who is not?), the experience of "creative destruction" and the associated disruptions" is a daily event. As a matter of fact, everyone using digital machines, i.e., programs, has the same experience. Updates come in as we watch a movie (the benefits of online cinema), calculate our taxes, play a game. Usually, so we are told, performance will improve and, most important, since we are subjected to more threats, risks related to security are addressed. Imagine what would happen if electricity distribution or water delivery, not to say sewage treatment, would be updated in "real time" at the frequency at which browsers, readers, players, and cell phone apps are updated. The former are "hard" machines: electricity is distributed within large networks involving high voltage lines, transformers, circuit breakers; in regard to water and sewage, we see what happens when pipes break or flow control mechanisms (valves) need to be repaired. There is literally a mess. Our machines are more and more "soft" and, presumably, intelligent. The fact that each update involves programming (probably done in India and tested in China) does not fully account for the innovation it represents. As a matter of fact, there is no living supervisor who selects you, or someone else, as the receiver of the "creative destruction", i.e. disruption message. Programs check on programs, and everyone checks on all of us (while we debate privacy and related issues characteristic of the past), and the market is kept alive and active.

Updates are usually free (actually, paid for in advance when we acquire the product). But the appearance is misleading. The innovation cycle of the digital

age is shorter and shorter. This is part of the unavoidable narrative of the post-industrial age. Within this model, human-based innovation becomes too expensive. Thus, for every aspect of innovation that can be automated, machines are conceived that, like the matchmaking procedures, generate "matches" to the most recent hacker attacks, to "phishing" expeditions, to hijacked browsers, to all the bots supposed to take over our machines and work in the background for the benefit of those who seek instant gratification for their "creative" talents.

Thesis 6: ***An innovation machine has at least two clocks.***

An innovation machine consists of a narration (subject to renewal) – objects, processes, attributes – generated in real time (subject to the clock C_n), and a model of itself unfolding in faster than real time (subject to the clock C_m).

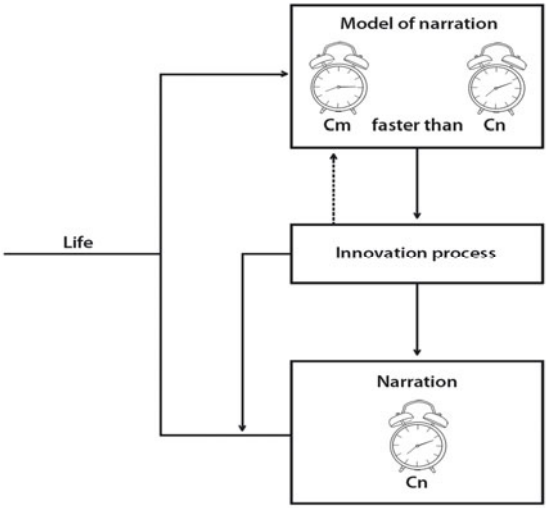

Figure 4: An innovation machine. Model of itself unfolding in faster than real time. The clocks C_n and C_m correspond to the time of narration and to the time of the model.

Narration: Pistorius is born with congenital absence of the fibula – real time.
Model: In the absence of the fibula, legs are amputated – real time.
Innovation: Given the narration, the model (interpretation, i.e., story), a blade-based replacement of legs and feet is desired (the Ossur product) – faster than the real time of the narration.

To further explain, let's take a look at the narration we can call the toaster: To keep bread fresh for a longer time, exposing it to fire (heat) proves useful. Over time, many attempts have been made to do exactly that: bread slices are attached to a simple contrivance and brought close to fire. As electricity became available, heated elements proved more appropriate to the goal. The narration changed: to obtain the feeling of fresh bread (warm from the oven), to obtain the taste of crisp crust; to come up with new dishes. All these narrations are associated with innovations. The real-time process is toasting (at various intensities). The faster-than-real-time is the generation of new expectations.

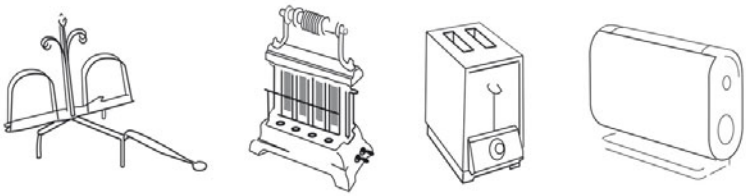

Figure 5: From the fireplace toaster to the Porsche toaster: changed narration, changed design.

The designer's mind, addressing new expectations, works faster than the toaster. The toaster's clock corresponds to the physical process: introduce the slice of bread, adjust to the desired degree of toasting (light, medium, dark), press down the handle. The clock of the design process corresponds to imaging, associations, formulating alternatives, etc. For digital products, the model of the process and the model of the machine itself are also digital. The two clocks are related. The faster the prediction component, the higher the possibility of generating alternative ideas. Therefore, an innovation machine needs an evaluation procedure.

One clock keeps track of the machine's output – let's say word processing, computer graphics, database, e-mail, among other examples. Under the aegis of this clock, performance is recorded as a narration. Interference in the functioning – such as accidental power supply failure, hardware errors; or intentional interference from outside, intelligent agents, hackers, etc. – becomes part of the narration. In order to evaluate the output, the machine needs a projection, into the future, of what it should actually be (desired performance). To compare the real output to an ideal output implies that the second clock has to be also the clock of the process evaluation. In all fairness, updates for security improvement reasons are not the only innovations disseminated in real life over the networks. Quite often, new algorithms are implemented with the aim of optimizing processes. From various parts of the world, better design of processes and improved per-

formance programs found their way to the users. Renewing objects, processes, and attributes in ways that are more possible in our days than in the past accelerates the production cycle. Given the fact that proprietary solutions – embodied in competitive products – have to address the broadest possible market, innovation translates the narrative of higher profits into the creative destructions and associated disruptions it brings about. The model of the niche product – a small section of the market – is less profitable than the model of products for the global economy. This, of course, is part of the narration of a universal means, which the digital is.

In the past, innovation meant renewal of a specific aspect of the narration of human activity. Windshield wipers on automobiles[4] are an example of what innovation meant in respect to the characteristics of a product of wide public interest. The narration develops from "window cleaning" to "intermittent wipers." In contrast to windshield wipers, today's downloads on the computer in charge of a car's functioning represent a different approach: the soft aspects of the car's functioning are affected, this means GPS-based functions, cruise control, monitoring of emissions, etc. Each innovation, whether past or present, juxtaposed two models: reality (of the product) and future (how the product should be altered, modified, renewed in view of higher performance, reliability, security, etc.). The two models were connected through evaluation procedures. Each model had its own clock: real-time functioning vs. desired future functioning. Each evaluation results in new narrations.

A logical question, that goes beyond the scope of this text, is whether an innovation machine can innovate itself. It is rather much the same question as whether machines can generate narrations – and the answer was positive in respect to deterministic change. Furthermore, whether a story machine is possible – and the answer was left open. At our current level of understanding what is needed to interpret narrations and to associate meaning with them, it is rather doubtful that deterministic processes can have non-deterministic outcomes. But science is never a limiting endeavor. There is no science in stating the impossible and declaring No! Therefore, the understanding of anticipation as a bridge between narration and innovation is rather an invitation to cross the bridge and to continue exploring human creativity.

PS: Reviewing this article extended to the day Steve Jobs died. I met him in 1983-1984 – doing work on the user interface for Lisa, a computer well ahead of its time (as was the Xerox Star that inspired it). David Hodge made the contract

[4] Along the timeline: 1903 (Mary Anderson), 1911 (Gladstone Adams and Whitley Bay), 1919 (Willliam M. Folberth), 1963 (Robert Kearns, intermittent wipers), 1970 (Citroën, rain-sensitive intermittent wipers).

with Apple possible, Thomas Ockerse (my colleague at the Rhode Island School of Design) joined me in the project.

The reason for this note on my interaction with Steve Jobs is connected to the subject of this article. Indeed, the so-called iconic interface, which I treated from a semiotic perspective (Nadin 1988), is a clear illustration of the ideas submitted in this text. During my first encounter with Jobs, I argued that interface is a sign (or supersign). Today I will argue that interface is a narration: the re-creation on the computer screen of the office, an environment familiar to those who would make the computer the most important component of their activity. For this narration to be convincing, representations called *iconic*, i.e., representations based on likeness (cf. Peirce on icons as representations), were used. Moreover, I insisted on the networking capabilities of Lisa – which the subsequent Mac machines unfortunately did not have.

Steve Jobs had his problems with my methodology (and his ways of expressing himself were rather direct). He was impatient, theory did not interest him, he wanted to see results. The same happened years later (1987-1988) when he developed NeXT, a high-end workstation, also ahead of its time (and which I was convinced would be a success). I congratulated him on the innovation, and on accepting my suggestion to involve the renowned designer Paul Rand in developing a *language* for the product. This language could stimulate new narrations. One of the NeXT-based narrations is the world-wide web. Tim Berners-Lee, at CERN, used a NeXT machine to write the first browser – which is yet another narration, superseding the office metaphor. Indeed, narrations have a life of their own; they unfold, like the stories in the 1001 Arabian Nights.

I am not sure that I want to turn to writing down memories, but I did not want to miss the occasion to pay my respects to a person dedicated to innovation. After the two famous Steves (Jobs and Wozniak), garages are no longer just for parking cars.

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