Determinism and Chaos: A Time Perspective

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Abstract

Chaos cannot be understood without constant reference to time. A better understanding of the 3 main abstractions that we use in relation to time (Past, Present and Future) is of basic importance.

However chaos is mostly significant for our evaluation of future events: any hope for rigorously deterministic forecasting is not anymore realistic.

But in any case, the chaotic crimps into general determinism do not destroy it utterly, because no event totally escapes from the structural and functional coherence of the system in which it occurs.

Moreover, in complex systems, hierarchized levels of organization imply a hierarchy of determinisms and the most global ones impose some constraints upon the lesser ones. This leads to adaptability within coherence.

An arithmetic model is proposed and some historic and present examples are given.

As a final caveat, the uses but also the possible abuses of the concept of chaos are discussed.

Keywords: Coherence, Determinism, Forecasting, Interactions, Levels, Time.

1. Introduction

Chaos introduces an element of indeterminacy in a worldview that science considered for long time as based on rigorous causal (and generally unilineal) determinism, or, at most, on statistical determinism for numerous unconnected but generally similar events.

Chaos seems to be the global result, within complex entities, of multiple simultaneous events whose effects do propagate in non-isotropic and non-isochronic ways.

As a result, general determinism becomes blurred and forecasting remains possible only with a growing uncertainty. This is certainly what we observe in the real world.

2. Past, Present, Future

Many paradoxes and contradictions seem to spring from our misunderstanding of the evanescent nature of time.

Basically, we perceive time as an uninterrupted flow, which at any moment separates past from future.

The past seems to us somehow more real than the future, while the present is impossible to catch and stop.

In some sense however, the present, as fleeting as it may be, is our only reality: the stuff of our life is an ever flowing present, our personal eternity.

We readily understand that the future is always conditional, that we never can be sure to obtain any absolute control on what is going to happen within a second or within a century, here or at any distance.

We however believe in the existence of the past, as if it were hidden "somewhere". We easily admit that what we readily observe, (or believe we know), at this moment, is a "true" reflection of this "somewhat", hidden "somewhere".

Of course, we are able to "reconstruct" the past up to a point. We admit nowadays, also more or less easily, that those fossil bones prove that, many eons before us, there were dinosaurs, whose shape we even dare to represent. We believe that Aristotle and Julius Caesar have existed and accept as proofs the present copy of their works that we handle in our present hands. However, we are not sure about the Iliad's legendary heroes, for instance.

Our belief in the "existence" of the past, whatever this may mean, rests basically on our perception that everything present is the present result of long and sequential chains of former events. This is in fact a retrospective extension of our direct perception that what is happening just right now was "caused" by some former event. We hear a thunderclap, and a lightning forewarned it to us. And if we see a lightning, we expect a thunderclap within few seconds, would be very surprised if none was heard, and even possibly would start to enquire about this abnormality.

In this way we come to believe in cause-effect and causes-effects relations (which is not the same, as we will see) as a natural co-property of time flow. In short, we become determinists. And moreover, we tend to become mono-causal determinists: The same cause will always produce the same effect.

Thereafter, we generalize and admit that the whole of the past has been an enormous series of sequences of causes and effects, even if in many cases, we ourselves do merely reconstruct part of these sequences in a hypothetical, and dubious, way.

We also come to understand that the past is definitely out of our reach. We cannot change what already happened and, as any past event happened in a specific way, we see it as a part of one of those deterministic sequences. Moreover, through enquiry, research and logic we figure that we can make history out of the past and possibly reach what we call "historical truth".

What happens to us in our present should however make us somewhat doubtful about rigorous lineal determinism. Science progresses through controlled experiment. We would for example produce electrical discharges between the elements of a Van de

Graaff electrostatic machine. This is somehow similar to atmospheric electric discharges. However, no discharge - whether experimental or atmospheric - is exactly the same as any other. Thus, we accede to rigorous deterministic laws only by suppressing these supposedly slight and unimportant differences. This leads us to the famous "et ceteris paribus" principle, which is a very useful fiddling, but a fiddling nonetheless. Unfortunately it many times efficiently blinds us when "et ceteris non paribus".

2.1. And now, what About the Future?

We clearly understand that it is always somehow dubious or conditional. Our predictive power is limited. And it is still more limited if we try to forecast long term futures. In a similar way, our control possibilities are limited, and also more limited for the long-term future.

Even at times and without any previous warning, some quite unexpected and "improbable" event is going to erupt suddenly: an earthquake, a stock market crash, for instance. Clearly, something about the future remains concealed to our perceptions and supposedly rational common sense.

In short the future as well as the past, even if in a different way, are imaginary dimensions of our consciousness.

This leaves us with the riddle of the present.

The present moment is the bridge from past to future, the only fleeting instant when "reality" (whatever we mean by this word) can be grappled with.

Let us see, through some examples, what this means practically.

In Physics, Heisenberg's indeterminacy principle, states that we cannot at the same moment, know perfectly the position and the movement of any particle. The particle moves within, or better, as a wave, but if we interfere with it, the wave "collapses" and disappears, while we observe the particle in a precise position. But, presto, at the very next moment the particle is again on the move, it is again hidden within a - different - wave.

The French biologist P. Vendryes (1956) explored the riddle of decision making. The past was settled, once and for all. The future is the imaginary multi-dimensional field of probabilities and possibilities. At this moment, we are poised to decide, i.e. to select a defined move that will suppress for the next moment all the possibilities,... but one. When doing this, we collapse the field of probabilities, selecting one and only one. In this way, we suppress any uncertainty as the next future moment transits toward the past through our present action.

In Prigoginian thermodynamics terms (1982), in any dissipation process, as the widely and increasingly fluctuating system becomes more and more unstable, there is a <u>critical moment</u> when the new structure becomes irreversibly established. This is "nucleation", in Prigogine's terminology (1982).

In all of these examples, the transit from future toward past through a present moment corresponds to an irreversible elimination of all probabilities, but one, and to a definitive selection event.

We must still however be cautious. While the future of any system or process can be represented as a space of probabilities, this does not mean that anything may happen. The general shape of this inverted funnel of probabilities ever more open toward the farther future strictly depends on the sequence of the past events. This means that not anything is possible, or, in other words, that some kind of restrictive determinism does really operates: we do not live in an incoherent world, but merely in an evolutionary one that admits innovation, within the limits of what we could call "historical coherence". So we have a Hamletian problem: To be or not to be determinists.

3. Order, Disorder and Coherence

A complex system (a redundant expression, this one) is the playground of many simultaneously interacting elements. The system must maintain a permanent capacity for adaptation, i.e. it must remain adaptable, i.e. remain able to shift towards different behaviors.

But it must also maintain itself coherent. This implies that the characteristic interactions and relationships among its functional parts should remain generally permanent within defined limits. In shorthand, the system must be autopoietic, i.e. be able to reproduce its elements and their characteristic interrelations. This is however the global result of a colossal number of small local actions within the system and is, moreover subject to environmental action.

Already in the 18th Century Leibniz stated that any change in one element in an entity has the potential to modify all the other elements.

However, the intrinsic mechanism of this process is generally overlooked, and mainly so is the necessary time dimension in the propagation of effects.

In any system at any moment numerous local events take place simultaneously, each of them triggered by some input received from the environment or from some other part of the system. However, propagation of the effects of these multiple local events is not instantaneous. This implies that for some time most of the other parts of the system will undergo no change. Moreover, propagation is neither isotropic, nor isochronic. Accordingly, any event will affect different other parts of the system in different ways and with a different time lag. The effect of one event may even be felt various times through more or less direct or indirect propagation paths, as any system can be conceived as an interacting network. Even a destructive (or constructive) event may not manifest its totally devastating, or organizing, effects immediately as for example a tsunami, or the explosion of a nova or supernova, or a partial cerebral hemorrhage, or the invention of the airplane or the computer.

Consequently, no local internal or external event instantaneously affects, and much less destroys the global determinism of the system's behavior: it merely disturbs it to some extent.

Moreover, strongly perturbing local effects tend to trigger negative feedbacks from other parts of the system, thus avoiding or circumscribing aleatory behavior.

It should also be observed that very complex systems generally possess a hierarchy of meta-controls at various levels. This type of structural-functional organization limits the effects of local perturbations.

The kind of perturbations described above is multiple and repetitive. As a result, the global determinism is constantly disturbed again and again and the disturbance cannot be calculated in real time because the only perfectly workable model of the system would be the system itself...

What finally remains of a system's determinism is a kind of global envelope embedding many possible alternative states. This is exactly what should be awaited as a frame for any system that must be adaptable and, at the same time, maintain it global coherence.

It should be at last recognized that "pure" determinism, as well as "pure" randomness are merely ideal limit cases of all possible behaviors of systems, corresponding the first to strictly lineal systems, and the second to completely non-systemic degraded order.

4. Chaos in Action

Let us now try to get a feeling of chaos in action. As a first example, let us suppose a system whose behavior is cyclical. And let us suppose that its process variations are submitted to three distinct periods of for instance 3, 4 and 6 seconds (or minutes, or years, or millennia). Obviously, if immune to external disturbances, the system will repeat the same behavior every 12 seconds (or minutes, etc...) and its behavior will be easy represented graphically.

However, if the distinct periods are for example 13, 43 and 101 seconds (or minutes, etc...) the system will repeat its behavior only after 56459 seconds (or minutes, etc...), provided for no external interference during such a long span of time. As a result, the global determinism remains hidden for the short time witness, who merely observes apparently random fluctuations and cannot reconstruct the whole picture.

The situation turns still more difficult when many different but interrelated elements interact simultaneously, each one with its own rules of behavior.

This was demonstrated from 1892 on by Poincaré who showed the impossibility to compute exactly the future positions at some instant of three celestial bodies whose initial positions and velocities are known, by using anyone of the usual functions: linear, trigonometric, exponential, and their combinations. He moreover demonstrated that a three bodies system might well be unstable. Much more so is the case of an n-bodies system, as was dramatically demonstrated recently by the Shumaker-Levy 9 comet's destructive plunge into Jupiter (1998).

An everyday example is the sometimes seemingly aberrant behavior of the stock market. In his 1994 book on "Complexification", John Casti (1994) shows that "the stock market is not a random walk, but rather is a fractal with trend-reinforcing behavior... in direct contradiction to the cherished Efficient Market Hypothesis (EMH), which describes the market as a roulette wheel without memory" (3, p. 257). Casti's calculations demonstrate that stock markets have at the same time a fractal and cyclical behavior. The cycle time he found out is different for each market: form 30 months for Britain to 60 months for Germany. What could be the rationale underlying these unsuspected regularities?

The most probable set of hypotheses is that the stock market reflects different types of behavior at different levels that can be understood either as a bottom up or a top down phenomenon. The activities of the jobbers and the impulses or unpredictable needs or whims of individual traders dominate daily trading. This is practically probabilistic as well as unpredictable. However, daily trading is embedded within more permanent financial and economic features: Short term fluctuations of some indexes (prices, basic rate, employment, etc...) act as more general orienting frames for all the traders and produce weekly, or monthly variations superimposed on daily operation. In turn, the general expectations about the economic cycle will become a wider extend frame for medium term variations.

The market is also submitted to the invisible hand of internal feedbacks. Bullish or bearish trends tend to drive it to excessive highs or downs (at different levels), which brings it to intrinsic - but not precisely known - inferior or superior limits of global stability. At this point, negative feedbacks of psychological nature replace the positive ones, producing a reversal of the trend (short, medium or long), that can eventually be sudden and, in cases, catastrophic. However, all these movements remain within the limits of probable secular trends, as could be for example the Kondratieff wave of 50-60 years.

5. Conclusion

While one must be careful to avoid metaphorical abuses of the chaos notion, as occured in the past with catastrophe theory, with indeterminacy confused with uncertainty, and even with popular interpretations of relativity, it remains obvious that chaos is a frequent and important feature of our everyday life. Its relations with bottom up and top down processes is inherently connected with the fractalization of many of them and the resulting self-similarity at different levels. It goes a long way to explain, through the effects of the multiple simultaneity of many events, the apparent cracks in determinism as commonly understood. It also explains the deeper problems of forecasting. It helps us to understand the physiological and psychological aspects of our perception of time in its past, present and future dimensions and of the effects of this perception on our worldview. Accordingly, it should become an intellectual and mental tool for a better understanding and management of many of the complex situations that we must live through in our days. And it should not remain merely a more or less esoteric theory, out of reach of our deciders. On the contrary, we have a responsibility to translate it in practical terms - without betraying it - into every realm of life.

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