Time, Change & Self Organization

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> "…whatever is born or done at this particular moment of time has the quality of this moment of time." ~ C. G. Jung

Abstract

Do things change in time, or does time change things? We explore the consequences of a theory that time—given a physical interpretation independent of space—drives system change globally, identical to the way in which information drives subsystem change, locally. We conjecture that Gregory Chaitin's characterization of maximum numerical unknowability in computation maps to maximum configuration efficiency in a complex physical system.

1.0 Introduction

1.1.0 The physics of change: Time as duration.

1.1.1 In a single atom, a state change is defined as a quantum jump, an electron switching from one energy level to another. No unit of time is sufficiently small to observe this change of state, so the phenomenon is said to be discontinuous; the action apparently happens in zero time.

1.1.2 In the context of system dynamics, positive feedback is also discontinuous; i.e., one cannot determine the origin of the feedback, and the system is said to be out of control. An example is microphone-amplifier feedback, that aurally disagreeable "squeal" when one instrument is placed too close to the other. It is impossible to determine the cause of the feedback (microphone or amplifier).

1.1.3 Negative feedback, on the other hand, is a control system. As such, negative feedback resembles a continuous function, in which the rate of change is measured by intervals between chosen connected events, and time is defined as duration.

1.1.4 Newtonian (classical) physics belongs to the class of scientific theories in which time is treated as duration. In fact, such is the very basis of Newton's invention of the calculus to describe the rate of change of the rate of change (accelerated motion). Gravity—because it operates in one direction only, toward the center of mass, can be viewed as a negative feedback mechanism, a universal control system.

1.2.0 The physics of change: Time as illusion.

1.2.1 Minkowski space-time, Einstein's model for relativity, treats time as physically unreal, i.e., not independent of Euclidean space, but continuous with the ordinary space in which we measure and observe physical events. [Einstein, 1956]

1.2.2 As a consequence, Einstein knew that even the general theory of relativity was mathematically incomplete for describing a unified theory of nature, though by allowing that time is not absolute (as in Newtonian mechanics) Einstein moved conceptually closer to the empirically demonstrated quantum mechanics.

1.2.3 That is, if discontinuous energy state changes observed as jumps, as in Einstein's seminal paper on the photoelectric effect [Einstein, 1905], can be analyzed by methods of continuous functions, time can be made analytically irrelevant.

1.3.0 The physics of change: Time as information (our claim).

1.3.1 The premise of this paper is that time is identical to information, from which it follows that time has a physical basis—that is, the same characteristic that Einstein meant by "physically real" when he described the space-time continuum: "… independent in its physical properties, having a physical effect, but not itself influenced by physical conditions." [1956, p.55]

1.3.2 In a quirk of history and semantics, Einstein is known for "relativity." Actually, Ernst Mach was the true relativist and Einstein the absolutist. Nevertheless, it was from Mach that Einstein derived the mechanics in which time is an illusion (acquiring physical reality only in the notion of a continuous space-time), because in Mach, space itself is the illusion. [1956, p. 56]

1.3.3 Though Einstein's and Mach's views seem contradictory, it will be necessary for us to consider that they were both right—(i.e., neither space nor time is physically real in the domain of continuous measurement functions)—in order to get to our premise that time is information. Information is real. That is, limit and function define least action among network nodes exchanging information.

1.3.4 One reason that science conventionally considers Mach wrong, is atomic theory (which Mach never accepted). Atoms, we know, are made of mostly empty space (quantum vacuum). Space plays a demonstrable role in the quantum mechanical interactions of atoms, while Mach's purely classical mechanics predicts knowledge of the motion of any body from knowledge of initial conditions of all bodies (masses move relative to the center of all other masses in the universe). Because we know there are no such spatially closed and isolated systems in our observable world, such is impossible in practice. One settles for approximate, statistical solutions.

1.3.5 Einstein's theory is also classical. Even though he and Mach disagree on the role of space in physical interactions, they agree on the role of continuous functions in time, calculated from initial conditions (Einstein coined the term "Mach's Principle" to help explain the role of gravity in general relativity).

1.3.6 We cannot reconcile quantum mechanics with classical mechanics, because quantum events don't happen continuously in time; what we observe is purely interpreted in a mathematical model, a geometric event-space of discontinuous, statistical functions ("rolls of the dice.").

1.3.7 We rely on continuous functions—a map of small step changes—to give up information on probable states in the near term, with ever lessening confidence for accurate prediction in the long term, as chaos sets in.

Suppose that we are able to stand this model on its head:

1.3.8 Consider some arbitrarily chosen future state space as the initial condition—consider the present state as chaotic. We would find that this model is dual to the second law of thermodynamics—energy flow toward disorder—because what we perceive as movement toward a future state is exactly the same as the future state movement toward the present. We already know that we choose the present state only by convention; what would be the difference, though, if we reversed the convention? Does this reversal of the time arrow commute?—we shall see that it does not commute, the consequence of which is that change driven by a physical interpretation of time increases the availability of useful information (i.e., the potential for negative feedback) in the present state, from the future. Positive feedback informs the future state.

2.0 Method

2.1.0 Information flow & temporal direction.

2.1.1 A future state trivially contains more information than a present state; i.e. the application of negative feedback (control) depends on being able to exploit the added information as it is revealed in steps. Conventionally, we predict future states from continuous function models based on initial conditions in the present—and assume that the present possesses less, but more ordered, energy while probable future states are energy-rich though more disordered.

2.1.2 We will consider the present state "information-poor." We use this term to describe our relative ignorance of what initial conditions favored this state over an infinity of probable states.

2.1.3 We term "information-rich" those future spaces by which time plays an active role in information flow to the present, an information-rich space having no orientation in time—i.e., no preference for chronological order. For example, theories of general relativity and quantum mechanics are information-rich in that they contain and predict more information about the world than the algorithmically uncompressed world reveals. Here, we refer to theories on the complexity of information due to A.N. Kolmogorov and Gregory Chaitin. [Chaitin, 2005]

2.1.4 The direction of information flow from information-rich to information-poor spaces, therefore, is identical to information entropy famously described by Claude Shannon and analogous to mathematical models of energy entropy (Carnot, Clausius). [Shannon, 1948]

2.1.5 We conventionally consider that our present initial condition is the starting element in an ordered chain and that future states follow inductively from this assumption—colloquially speaking, energy and information flow "downhill" from a chosen ordered state toward disorder. Increasing disorder of energy means that one has proportionately less energy available for work; increasing disorder in Shannon's context means that one has proportionately less information available for coherent communication. These models are empirical. We measure increases and decreases in energy or information within the boundary conditions defined by continuous functions. "Downhill" flow from the perspective we suggest, is from a random field of complete probable future states to a partially ordered present. In other words, we don't choose a present state to be assumed continuous with future states—we observe a partially ordered present state discontinuous from random time-driven events flowing to the present. We have theoretical support from algorithmic information theory (Chaitin):

2.2.0 ***Chaitin's remarkable number,*** Ω.

2.2.1 [Chaitin, 2005, pp 201-203] has discovered a linguistically and computationally defined number, Ω (Omega), the halting probability of a universal Turing machine. Chaitin calls it a "dangerous" number, because its value is unknowable in principle. This is significant: while we already know that most numbers are in fact, unknown, and likely to remain so, the "maximally unknowable" Ω is infinitely complex, its precise value dependent on the choice of computer, or program, running the algorithm.

2.2.2 So we conjecture that if the choice of computing machine determines the outcome of a present computation—the future result resting in a future computer maximally unknowable in the present—then the result *exists* in a context of information-richness, and what we know of the result is information-poor. In other words, an infinite number of future computing machines calculating an infinite number of results based on the same algorithm for computing Ω, gives us for every finite computing machine in the present a unique infinite result of infinite complexity that is self-similar to the infinite set of all results on an infinite number of future computing machines. The aggregated result is infinitely self-similar, in other words.

2.2.3 Infinite self-similarity is critical information. This fact informs us that the problem of predicting the outcome of some highly complex physical events—e.g., protein folding—is tractable to complex systems science. That is, we should in strongly polynomial time be able to, using the principle of infinite self-similarity, calculate the outcome of any finite state whose global properties are known (or arbitrarily chosen) but whose sequence of convergent events is locally uncertain. We conjecture strongly polynomial time solutions because of the property of Ω that Chaitin terms "self delimiting." If self delimitation corresponds to the self organizing principle of self-limitation, locally computable finite results should correspond to global results even if these exist in non deterministic polynomial time (NP). The algorithm should reduce to a sorting algorithm to detect the locally shortest metrics at any defined instant in the field of possible metrics.

3.0 Result

3.1 Consider a network of Omega-calculating machines so that each machine is a node; the combination of unique results at each node produces self-reinforcing information on the changing state of the network. *N* nodes exchanging information, analyzed over sufficiently short intervals, and compared to a physical model of protein folding, should approximate the desired sequence to arbitrary accuracy.

3.2 Because each discrete sequential event has a finite range, information boundaries should correspond to cardinal directions of 3-space for a 6-dimensional , 2-point boundary, finite analysis. [Casti, 1996] A model of dynamic centrality [Braha—Bar-Yam, 2006] in which dominant nodes exchange position continuously, reveals that high network connectivity is sensitively dependent on time. To exploit this characteristic, in order to extract accurate information about a present action from a future state, one treats the network as a self organized system exhibiting infinite self similarity—each interval in which a singularity forms is a new initial condition. Because we now know, as a result of Perelman's proof of the Poincare' Conjecture, that singularities of the topological positively curved 3-manifold are extinguished only in finite time [Anderson, 2004]—then if time is an *n*-dimensional infinitely orientable metric on a self-avoiding random walk, a network of random-output computers (Ω calculating machines) corresponds to quantum time intervals randomly orienting in an infinite dimensional (Hilbert) space—in which the principle of self-similarity forces an ordered direction of continuous time in the limits of the 3-manifold. [Ray. 2006]

3.3 In other words, the output of each machine is sensitively dependent on the machine's orientation in *space*—the idea being that the 3-space time vector at any node is uniquely rectified in the process of the *n*-space self avoiding random walk. One models a folding sequence on the continuously changing rectilinear path disclosed by the state of the entire network, under an assumption of maximal efficiency, which defines a least path. Such a path depends on the topology of the subsystem at the interval observed, not on the measure characteristics of the network of system nodes. We find that in self organized systems:

i) Observable are already pared to essentials.
ii) Time dependent subsystems evolve at different rates.
iii) Subsystems cooperate, with self similar results, that define the system.

3.4 We base our conjectures on results sponsored by NECSI and of which we choose to focus on two articles, [Braha—Bar-Yam, 2006] previously mentioned and [Bar-Yam, 2004].

3.5 In a seminal paper [Bar-Yam, 2004] challenges the long held notion that the problem of bounded rationality—i.e., individual human (or, abstractly, individual node) limitations to acquire sufficient information for central control decisions—might be solved or mitigated by information technology integrated vertically into the system (hierarchical up and down, rather than lateral, communication). [2004, p. 40]

3.6 Bar-Yam reveals that distributed control—lateral information—increases variety. Increased variety increases the coordination strength of the network; i.e., “In considering the requirements of multi-scale variety more generally, we can state that for a system to be effective, it must be able to coordinate the right number of components to serve each task, while allowing the independence of other sets of components to perform their respective tasks without binding the actions of one such set to another.” [2004. P. 41]

3.7 The independence of time metrics in an *n*-dimensional system where time flows on a self avoiding random walk satisfies the multi-scale variety requirement. What we mean, is that the connectedness of the network is preserved in self-similar components that perform cooperative functions independent of the observed state of the system. Subsystems are self delimiting. Thereby, an analytically continuous complex system is tractable to analysis using the tools of discrete functions. This is an obvious crucial requirement for computability.

3.8 If, as we assert, time is identical to information—and if information flow is as we have conjectured, from information-rich spaces to information-poor spaces—at least two conclusions hold:

> i) Rationality is bounded at each node by the length of the time interval, and not by a limitation on the availability of information. After all, an information-receiving node in a self-similar system, given infinite time, possesses infinite information.
> ii) Exchange of information among nodes will be distributed among changing centers, as demonstrated in [Braha—Bar-Yam, 2006], i.e.:

3.9 “Dynamic centrality” [Braha—Bar-Yam, 2006] acknowledges the role that time plays in network analysis.

3.10 Truly remarkable, though, is that the states observed in any one interval are independent of the aggregated state, i.e., the sum of states over the life of the observation. Thus, these self similar states comport with multi-scale variety in leading the state of aggregated change “…without binding the actions of one such set to another.” This suggests that random movement of the time metric—analytically continuous and discretely embedded in the complex system—drives a process deterministically by random motion.

4.0 ***Discussion***

4.1.0 ***Future randomness determines present order.***

4.1.1 "Deterministically random" has the appearance of contradiction. However, recall that Ω is the result of algorithmic input, defined even if unknowable.

4.1.2 The sticking point is that if, as we claim, time is a physical agent driving change, the discontinuous and random reorienting of that complex metric on a scale of measure zero generates random information in an information-rich future state (*n*-dimensional Hilbert space [Ray, 2006])

4.1.3 The present state, information-poor, is shaped uniquely by random *n*-dimensional motion. Though it is tempting to say, therefore, "the future shapes the present," that is not what we mean—i.e., though the states are discontinuous, no "unseen hand" is necessary to order the relation. The necessary condition is least action. We agree in principle with Peter Atkins' metaphor, "infinitely lazy creator." [Atkins, 1992]

4.1.4 Singularities are prohibited on a scale where time is measured continuously in a complex function model. Perelman's proof of the Poincare´ Theorem [Anderson, 2004], supported by the geometric foundation laid by William Thurston and strengthened by Richard Hamilton, informs us that the walk of time across the manifold of our physical experience is self avoiding. Therefore, the subsystems resulting therefrom, " …(allows) the independence of other sets of components to perform their respective tasks without binding the actions of one such set to another." Multi-scale variety is a very powerful idea, in that time-dependent components [Braha—Bar-Yam, 2006] are self-similar without being necessarily continuous with the changing system (consistent with Perelman's technique of Ricci Flow with surgery; i.e., getting past the singularities globally). Stasis—or neutral feedback—is the aggegrated smoothly continuous property of a complex system on the large scale, while changes in the system spike sharply from "below," as a coordinated critically massive action of subsystems. Models such as Eldredge-Gould Punctuated Equilibrium [1972] and Per Bak's mathematical model of the same phenomena [Bak, 1996], capture the empirical result. We aim to capture the small scale where the result is not smoothly continuous.

4.2.0 ***This way and that way.***

4.2.1 Complex phenomena driven by simple time parameters—i.e., changes in growth and acceleration on a linear plot with high connectivity to the information rich future state—should be tractable to complex analysis.

4.2.2 We conjecture that a complex function model with high network connectivity to infinitely random real input (Ω) has the capacity (in strongly polynomial time) to produce a maximally efficient representation of a self assembled object (e.g., a folded protein).

4.2.3 We conjecture that "Maximally unknowable" and "maximally efficient," are dual. Consider the classical physics problem, of determining the most efficient path from a point on Earth to a point on the moon. The problem reduces to a 2-point boundary value problem in 6 dimensions. [Casti, 1996] That is, from infinite paths that a vehicle traveling between those points could take, one path guarantees the least time, least fuel (energy).

4.2.4 Complex systems science does not have the advantage of real continuous function calculations that the classical problem has. The generalized problem, however, is the same: design a control that compels a path between two points by least action, least energy. "Least" in a complex system is not always apparent; it is, however, always present. That is, in fact, what the frozen moment of time that we call "the present" actually means: the least of all possible moments.

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