

Original Paper

The Fundamental Nature of Time

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Abstract

The nature of time is intimately bound up with the nature of energy propagation, which has a long history of its philosophical understanding. Here I propose a new post-Einsteinian view of the nature of time, conceptualized as the outcome of the pure unidimensional rate of change of a process through the infinitesimal operator of differential equations. In this view, time is a local property that is generated by every individual process in the Universe rather than a fundamental dimension in which processes operate. The rate of change has an inherent “arrow of time” that does not depend on the ensemble properties of multiple processes, such as the laws of entropy, but is inherent to the function of each process, by virtue of its genesis in the Big Bang. The conventional view of time may be approximated either by aggregating the operations of large ensembles of diverse processes, or by choosing a process (such as the Atomic Clock) that has demonstrably stable temporal properties. For processes that are sufficiently nonlinear, their iterative progression may in principle lead to solutions describable as fractals, for which the integral derivation of the time variable would fractionate into a form of fractal time.

Keywords

Time, process, dimension, space-time, entropy, local, fractal



Frontispiece: Conception of a Dynamic Fractal Process. ([colorful-light-swirls-21710.jpg](#))

“The instant has no time:
and time is made from the flow of the instant”

Leonardo da Vinci (Codex Arundel, 176r)

1. Introduction

1.1 Time in Physics

Time has long been considered one of the fundamental quantities of Physics (https://en.wikipedia.org/wiki/Time_in_physics), and is treated as something that exists externally to the observer and that can be measured by a variety of devices called “clocks”. The present analysis takes a radically different view, that time is a mental or conceptual construct derived from the energetic processes of the physical world, a construct that is specific to each individual process and that is only derivable from such processes. As far as can be determined, this is a novel viewpoint that has never been articulated in its full implications in the history of philosophy, and particularly from the predominant view of Western Philosophy that time is a primary dimension of reality. It is also the only theory of time that is grounded in the Schrodinger Equation of Quantum Physics as the core definition of the nature of the energy process. Furthermore, as through-and-through process theory, it is fully compatible with the Emergent Aspect Dualism view of the universe as emergent hierarchy of processes (Tyler, 2014, 2019).

1.2 Philosophical Treatments

Remarkably, the closest philosophical treatment to that being proposed seems to be that of Aristotle, whose view on time are rarely discussed, and who differs from the predominant view in considering that change is primary to the nature of time per se. (The following quotes are from Aristotle's *Physics*, IV, 10-14.) He expresses this by saying that "time is most usually supposed to be motion and a kind of change". Much of his discussion can be interpreted as an analysis of whether time exists as a (Newtonian) dimension of reality. In this context, he explicitly rejects the dimensional concept of time: "One part of it has been and is not, while the other is going to be and is not yet." His conclusion is an equivocal "[time] either does not exist at all, or barely and in an obscure way." (I interpret this to be a reference to the infinitesimal rate of change within which the time denominator is either reduced to zero or to a negligibly small value; see below for details.)

Nevertheless, Aristotle implicitly assumes that time is a unitary and universal entity. He concludes that time is not local movement, because then it would be the movement of many things (his treatment seems to consider only heavenly bodies), and "the movement of any of them equally would be time, so that there would be many times at the same time." He concludes that, paradoxically, "It is clear, then, that time is quantity of movement in respect of the before and after", and is continuous since it is an attribute of what is continuous. He goes on to qualify what he means by "quantity": "as the extremities of a line form a quantity", and "In respect of *quantity* the minimum is one (or two); in regard to *extent* there is no minimum." Aristotle seems to be trying to say that the instant constitutes the infinitesimal transition between the extended domains of "before" and the "after".

After extended considerations, however, Aristotle accepts what would become the Newtonian position of time as an extended dimension through which change can occur: "The 'now' is the link of time, as has been said (for it connects past and future time), and it is a limit of time (for it is the beginning of the one and the end of the other)." Despite his initial denial of the existence of past and future, he here accepts them as entities, or domains, with an existence on a par with the "now", which acts as the link between the (extended domains of) past time and future time.

But Aristotle then goes further to implicate time in Boltzmannian decay processes: "A thing, then, will be affected by time, just as we are accustomed to say that time wastes things away, that all things grow old through time, and that there is oblivion owing to the lapse of time, but we do not say the same of getting to know or of becoming young or fair. For time is by its nature the cause rather of decay, since it is the quantity of change, and change removes what is."

In the statement, "all things grow old through time", Aristotle is going beyond the simple property of movement through space to prefigure the Boltzmann concept of the universality of the Second Law of Thermodynamics. He even attributes time as the causal agent of the decay: "A thing, then, will be affected by time," and "For time is by its nature the cause ... of decay." He does not elaborate this causal property in the further development of this treatise, but he seems to be endowing "Time" with

the agency of determining the direction of its arrow to the downward tendency to disorder rather than order, which is the classic pre-scientific philosophical error of imputing agency to inanimate forces.

Thus, in an extended treatment of time over four chapters of his *Physics*, Aristotle manages to espouse in some way most of the diverse historical positions on the nature of time, although he is consistent in highlighting the special nature of the “now”, or present instant, that has the unique role of forming the transition between the past to the future. In this sense, he treats change as a transition from a prior state to a following state, and implicitly accepts the “now” as being a compound concept. However, throughout the variants of time that he considers, he adheres to the concept of time as being a unitary and universal entity that underlies all reality as an indivisible, though inchoate, essence—“there is the same time everywhere at once”. On this level, Aristotle is adhering to a Platonic view of time as an abstract essence underlying all aspects of the universe, though in emphasizing its Heraclitan nature of change rather than simple being, he is diametrically opposed Plato’s view of time as an eternal, immutable dimension of realization. On the other hand, his frequent invocation of “before” and “after” as extended domains comes close to this time-as-eternal position.

In summary, Aristotle takes so many mutually contradictory positions on the nature of time that his treatment amounts to an airing of all the inherent paradoxes of time without providing a convincing resolution for any of them.

2. Analysis

2.1 A Formal Resolution of the Nature of Time

The concept of time that I will develop here, on the other hand, matches the simplicity and precision of Leonardo da Vinci in the header quote in treating the “instant”, or the present moment, as primary and unitary, with time understood as the “flow” or dynamic evolution of this instant. To set the stage, we may consider Zeno’s Paradox, which was developed as a refutation of the notion of time as process. In considering how long it would take a frog to jump to the edge of a pond, Zeno points out that there can be no change in an infinitesimally small subdivision of time, and therefore that time is an illusion because in the limit it is static and the domain of time is eternal. This was the view of Zeno’s philosophical mentor, Parmenides, and in opposition to his main rival, Heraclitus, for whom the flow of time was, indeed, fundamental.

Zeno’s logic can be inverted by considering not time *per se* but time in a compound as rate of change of space over a given period of time. Now the change is built into the ratio of space to time in the form of the irreducible concept of *rate of change*. If the rate of change is subdivided into its spatial and temporal components, it may be viewed as expressing the immutability of each of these domains, but if it is taken as a fundamental unit of a process as such, it becomes the essential element of the Heraclitan concept of flux as the core concept of the nature of reality.

If time is the simple entity of rate of change, how can this simple entity of infinitesimal duration have the form of agency, or inbuilt dynamic? This is best understood through the differential calculus of

Leibniz and Newton, who indeed start with the same concept of the discrete change—the binary compound discussed by Aristotle. In their mathematical treatment of the **derivative operator**, dt , both Leibniz and Newton go through the same process as Aristotle does, of considering the before and after states, S_1 and S_2 , bounding the infinitesimal dt operator (although dissociating it from necessarily being the present moment, to being any moment under consideration). They then assume continuity of the state change dS from S_1 to S_2 , through the interval between before and after, allowing them to shrink the interval to its limiting value of zero while retaining the ratio dS/dt as a defined quantity, which Newton symbolizes by the instantaneous notation \dot{S} . That is, rather than being the ratio of two things, each of which is defined by the two ends of its range, the essence of the infinitesimal calculus is that, when the range is shrunk through the infinitesimal to zero, both the range and the ratio lose their differential qualities and become a unitary essence—an *instantaneous* rate of change that no longer has a defined time interval. Thus in differential equations, time has been transcended by the concept of a pure unidimensional concept of rate of change. In this way, the differential calculus is generally accepted as a valid procedure for defining the instantaneous derivative \dot{S} of a process, from which the process as a whole can be constructed by the inverse procedure of **integration**.

Expressed in mathematical notation:

$$\dot{S} = \lim_{dt \rightarrow 0} dS(t)/dt \quad (1a,b)$$

$$S(t) = \int \dot{S} dt$$

Here it is proposed to base the analysis of time on the same concept, that the essence of time is, in fact, the instantaneous Newtonian derivative \dot{t} (or what Leonardo calls “the instant”). Rather than thinking of this derivative as a point in the predefined domain of (Platonic) time, the novelty is to consider the instantaneous derivative itself as the fundamental essence, and the concept of extended time as the outcome of the integration process operating through this instantaneous derivative. This is a more formal analysis of Aristotle view that time either does not exist or only barely; it exists only as an aspect of a rate of change, but taken to the infinitesimal limit where it is a unitary concept in which the time aspect evaporates into the instantaneous rate of change.

Just as we can envisage the process S under the condition that the interval of time analysis shrinks to zero, we can equally express the instantaneous time \dot{t} in terms of the condition that the process shrinks to zero

$$\dot{t} = \lim_{dS \rightarrow 0} dt/dS \quad (2a,b)$$

$$t = \int \dot{t} dS$$



Figure 1. Depiction of Leonardo da Vinci as Heraclitus, the Weeping Philosopher, with Donato Bramante (the painter of this picture in 1486) as Democritus, the Laughing Philosopher. This may be the first depiction of the world as a cartographic globe. (Pinacoteca di Brera, Milan.)

These two equations are now the precise expression of Leonardo's two statements about the "flow of the instant". The derivative equation embeds the notion that the instant is the limit when the time interval is taken to zero, while the integral equation expresses how the nature of a process through time can be derived from the continuous integration of the individual instants. The important issue in this connection is that, since S is a variable function of t as normally conceived, \dot{t} is also a variable function of S . Consequently, Leonardo's concept is that time is something generated by a process (just as sausages are generated by a sausage machine). If the generation process is regular, the outcome of that process will be regular, like a string of sausages of the same size. If, however, the process is subject to some form of variable boundary conditions, the resulting outcome will itself be variable (like sausages of varying length).

2.2 Lagrangian Intrinsic Coordinates for Time

One form of dependence of the time dimension on the prevailing conditions was famously introduced by Lorenz in 1895 and incorporated by Einstein in his Theory of Relativity, in which the definition of time depended both on the velocity of travel and on the gravitational field. In the present view, the time dependence on the prevailing conditions is not restricted to the process of the propagation of electromagnetic radiation, as in the Theory of Relativity, but is applicable to all processes of any description, each proceeding at their own pace defined by the instantaneous derivative of the process, and defining their own time their progression is expressed.

Of course, the Einsteinian view of time that, though uniform, it is distorted by the velocity of a moving body according to the nonlinearity specified by the Lorenz equation,

$$t_v = t \cdot v / \sqrt{\frac{c^2}{v^2 + c^2}} \quad (3)$$

where v is the velocity of the moving body and c is the velocity of light, which applies independently in every local motion frame. This formulation may be regarded as a particular case of the general dependence of time on the local process of motion, where that is the particular case for uniform motion. In the general case of any kind of process, the equations are of similar form:

$$\frac{\dot{S}}{dS} = f(S, \bar{S}) \quad (4)$$

where $f()$ is any form of nonlinear function that characterizes the process and \bar{S} is the environment of S .

To reiterate, eqs. 2b and 4 specify the concept of a function that can depend on its derivative, and can be expressed in the coordinates of the derived function itself. This concept is not novel, but was developed by Joseph Louis Lagrange in the 18th century. Lagrangian mechanics consist of Newtonian mechanics translated into the local spatial coordinate frame of the function being specified, (i.e., the viewpoint of a traveler along the path of the function, not of some external coordinate frame).

This equation specifies that the Lagrangian derivative $\frac{\dot{S}}{dS}$ of the function S is some function of S itself and the environment with which it interacts.

$$t = \int \frac{1}{\bar{S}} dt \quad (5)$$

However, as usually conceived, Lagrangian mechanics is still embedded in a uniform flow of Newtonian time; in other words, it still treats time as an external dimensional platform in which the processes take place. The daVincian view of time, that time is generated by the flow of the instant, places its conception firmly at the viewpoint of the traveler through the process, as the surfer rides on

the crest of the wave. This conception takes the Lagrangian to the next level, freeing it not only from the spatial coordinate frame, but also from the linear domain of Newtonian/Einsteinian time to generate its intrinsic function of both space and time as the instant unfolds.

3. Philosophical Consequences

3.1 Time as Process

We may extend the daVincian focus on time *per se* by realizing that the “instant” is still an abstract entity that retains a mystical aura of a generative power that rolls out the flow of time as we experience it. Just as Aristotle views time as an abstract essence that permeates the universe, so Leonardo in his capsule statement does not go beyond the abstract notion of time *per se* to probe its full essence. This same issue is, in fact, a widespread in philosophy in general, that by naming some concept it reifies that concept into a status corresponding to other named concepts, thus imbuing it with parallel qualities that may be inappropriate when considering its fundamental essence. A good example is the Aristotle’s arbitrary and unsupported assumption that time is both unitary and universal. Just as Einstein’s Relativity revolutionized physics by recasting those assumptions for the nature of space (while retaining the dimensional notion of time), we may take the radical path of by recasting those assumptions for the nature of time.

This viewpoint can be seen to derive from Heraclitus, whose philosophy was that the core of everything is “change” and that the fundamental element of nature is fire. While the other three elements of ancient philosophy (earth, water and air) are identifiable substances, fire is unique in being a dynamic *process* rather than any kind of *substance* per se. Heraclitus’ view of nature has therefore been characterized by the phrase “All is flux (πάντα ῥεῖ)” (Simplicus, ~540). This view comes closer than that of any philosopher of seeing the fundamental essence of the universe as energy, and the inherent flux of that energy as the defining process of our existence.

This reconceptualization is already formalized in eq. 2a,b, in which time t is derived from the concept of the process governed by \dot{E} . Here, therefore, the nature of the process defines the nature of the time derived from it. If it is a rapid process, the time derived from it will pass rapidly, and conversely for a slow process. Importantly, if it is a variable process, the time derived from it will be variable in nature, as in the Lagrangian extension to the time domain, and conversely for an invariant process. The implication of this conceptualization is that **time is entirely relative to each process in the universe**. That is, it is relative to unfolding activity of each subatomic particle, atom, molecule, cell, organism, star, and coherent body of any kind.

3.2 Universal Time

Thus, time is the process of unfolding of the energetic process of any defined entity in the universe, as expressed in eq. 2a,b, which can be different for every different kind of energy in the context of its energy landscape. Nevertheless, in a universal sense this particularized process could be considered to be the universe as a whole. This is, in fact, a viewpoint considered by Aristotle: “Some assert that [time]

is the movement of the whole ... [or] the sphere itself ... on the ground that all things are in time and all things are in the sphere of the whole.” However, he dismisses this line of thinking with a brusque: “This view is too naive for it to be worthwhile to consider the impossibilities implied in it.”

With the expansive logic of Physics, we can nevertheless resuscitate this view to define the S in eq. 2a,b as the universe as a whole, to give us a cosmic definition of time that could approximate the generic concept of time as employed throughout conventional physics. In other words, all the subprocesses in the universe would average out to an essentially uniform overall process, approximating the abstract concept of time on which conventional physics is based. In this way, we could return both Aristotle and contemporary physics to their core assumptions of a universal concept of time, but on the firm philosophical basis of their derivation from the daVincian framework of a generative conception of time as the “flow of the instant”.

3.3 Relation to the Schrödinger Equation

The primary form of energetic process in the universe is light, which has a long history of its philosophical understanding. Lucretius in the early days of the Roman empire had a clear view of light as a wavefront, or film, propagating from the source into the eye, a view that continued through Robert Grosseteste in the 13th century, and Leonardo da Vinci in the 15th century. However, the concept of energy was first formulated in 18th century by Emilie de Chatelet, who derived the mathematical formulation for its conservation across the kinetic and potential forms of energy from empirical experiments (du Chatelet, 1741). This conservation principle was then embodied in the fundamental process equation in generalized coordinates by Hamilton and Jacobi (Jacobi, 1842-3),

$$\frac{\partial S}{\partial t} = \mathcal{L} - \frac{\partial \mathcal{L}}{\partial \dot{q}} \dot{q} \quad (6 \text{ a,b})$$

where S is the upper limit of the action integral of the system taken along the minimum action trajectory of the system, q is its coordinates, and the Lagrangian, \mathcal{L} , is defined by

$$\mathcal{L} = T - V \quad (7)$$

with T being the total kinetic energy and V the total potential energy of the system.

The Hamilton-Jacobi Equation is a particular form of eq. 1a that specifies how the (instantaneous) rate of change energy depends on the immediately preceding energy state. As reformulated in quantized form by Erwin Schrödinger in 1925, it forms the underlying basis of Quantum Physics, from which all energetic processes are derived.

From the present viewpoint, the key aspect of the equation is that it is *recursive*, in that the derivative of the energy function is defined in terms of the current net energy state, which in turn is derived from applying the derivative to determine the infinitesimal increment towards the subsequent energy state (as represented in the general form by eq. 1b). Thus, the whole process is fundamentally an evolution from any given initial landscape through the subsequent states defined by the recursive nature of the equation.

As an aside, it is important to realize that the quantized nature of the Schrödinger Equation is applicable only to the detection process of energy absorption by matter. As the basis for energy propagation and the standing-wave structure of the energy that constitutes matter, the universe would grind to a halt if these processes were governed by quantized energy packets (like a cart with square wheels!). It must use the continuous form of integration of the derivative, as in eq. 1b, in order to account for the fundamentally continuous oscillatory nature of atomic structure. Quantum physics thus has an inherent paradox in its defining equation, beyond the commonly express paradox of light being analyzable both as a particle and a wave. The wave nature itself is only possible in time if the wave function is a continuous rather than quantized energy function.

3.4 The Arrow of Time

The standard approach of physics is to maintain that there is no fundamental arrow of time. The equations of physics, such as General Relativity (Einstein, 1915) or Quantum Field Theory (Witten, 1988) treat time as an unsigned dimension and operate equivalently forwards and backwards in time. The usual approach to the arrow of time is to consider that it is not a property of individual particles but of the organization of ensembles of particles, as governed by the Second Law of Thermodynamics (Lebowitz, 1993). This law implies that average disorder always increases, such that it is the ensemble processes instantiate a directional arrow of time toward increasing entropy. This formalism is, however, inherently problematic in that, while overall disorder increases, it is subject to local fluctuations such that some regions of material configurations experience increasing order (i.e., decreasing entropy), at least for certain periods. An example is the organization of living organisms, which take advantage of the entropic metabolic processes to build cellular structures of increasing order, such as pumping hearts and thinking brains. Does this mean that the arrow of time reverses in those regions? This is an absurd notion in relation to the space-time continuum at the heart of contemporary physics, in which time is a uniform dimension independent of the processes taking place within it. Moreover, the boundary between symmetrical time is fuzzy and indefinite. Can two particles have disorder? Three? At what point does the entropy concept kick in? Given these indeterminacies, the conventional view of the arrow of time is incoherent and self-contradictory.

In the present conceptualization of time, conversely, the arrow is provided by the process of the derivative operator operating within any system. While the differential equation specifying the behavior of any system is reversible in principle, each process gets started at some point and can only continue in that starting direction. Although each process may have evolved out of a prior process, the fundamental direction of the sequence of processes is set by the initial conditions of the whole sequence, namely the Big Bang. Thus, according to the present conceptualization, all subatomic particles, atoms, molecules, cells, organisms, astronomical bodies, galaxies, and superclusters each have an individual arrow of time inherited from their origin in the Big Bang, regardless of how they are related to an ensemble of increasing or decreasing disorder among its components (Note 1). It may be a long haul of billions of years back to the origin that determined the direction of the differential equation

roll-out that defines the particular process, but that process is nevertheless ineluctably directional and cannot be reversed, once started. Thus, in this conception, time's arrow does not depend on some arbitrary construct of what elements to include in the ensemble, but is specific to each individual process.

This conceptualization helps to provide a formal basis for new views of the arrow of time promulgated by philosophers such as Maudlin (2012), that it is a fundamental asymmetry of the time dimension, distinguishing it from the symmetry and interchangeability of the spatial dimensions. His derivation of this directionality of time's arrow is essentially the Moorean position that it is the common-sense view that everyone would maintain from everyday experience (Moore, 1925). It is self-evident that time flows by its nature, but nothing more can be said to derive the essence of the directional flow. The concept proposed here, that all of reality consists of the flow of energy in its variety of forms puts this evidence from human experience of a firm philosophical foundation, that reality is flow "from the ground up". In this view, the equations of physics are symmetric abstractions of an inherently asymmetric process that devolves to a symmetric equation for analysis of the simplest cases, but the general case.

3.5 The Multiplicity of Process Time

On the other hand, the process concept of the time derivative as the core generator of time, as developed herein, carries with it the negation of the concept of time as a unitary dimension so central to the conventions of contemporary physics. If time, as we understand it through the integral form of eq 4b, is derived from the processes generating the value of the instantaneous derivative, the relativity of time so derived applies to every process that generates it, and in particular to every consciousness; indeed, to every level of description of the process, since processes are complex and subject to multiple levels of description. Moreover, the time defined by each process will vary with the current rate of that process level, as it speeds up or slows down with the various influences at play in the process. Thus, the common understanding that subjective time as experienced by conscious humans passes more quickly or more slowly in particular circumstances represents the valid definition of time for that (subjectively accessed) process. This is the full relativity of the inherent concept of time. From the point of view of each process, time derives from the fluctuating activity of that process, as experienced by that process (if it is capable of internal experience, as are the processes of our brains).

Thus, time is not the uniform dimension of the physics abstraction, but the concrete playing-out of the vagaries of each local process throughout the Universe. As above, one can attempt to recover that universal abstraction by considering the net functioning of all the processes throughout the universe, but this is defeated in practice by the limitations of light transmission, and does not remove its inherently process-defined basis. As in the practice of physics, one can also attempt to "measure" time by focusing on highly regular processes that are subject to minimal perturbation by external influences, but this is merely imposing the Platonic concept of time as the regular basis domain of other physical processes on the empirical paradigm. It is not removing the fact that this is a theoretical choice of how

to proceed in understanding the chaos of processes that constitute the Universe. Ultimately, Newtonian, or Einsteinian, time is no more real than any other abstract concept (such as God, or morality); the time specified by Physics is just a convenient metric in which to characterize processes, not an absolute external reality.

The unavoidable consequence of this derivation is that the entire corpus of large-scale General Relativity theorization of the nature of space-time geometry and the small-scale Quantum Field Theory of subatomic particles has to be reconceptualized in terms of the local generation of the time dimension for each elemental component of the system (rather than as one of the uniform dimensions within which the systems operate). The present philosophy of time thus requires the dismantling of centuries of theoretical physics based on the externalized concept of time, first as an independent (fourth) dimension alongside space, then as an integral component of a distortable space-time continuum. In the process concept of time, there is no uniform substrate of time; time is an individual consequence of the operation of each local process.

The closest to a uniform convention for time would be to consider the syncytium of all particles of one type, such as electrons. The uniform nature of electrons as a class of particles implies that they would all operate in a uniform fashion across the universe, except where perturbed by other forces or fields. Indeed, the perturbation by the various forces would be a basis for some kind of relativistic distortion that could be developed into an alternative theory of relativity. But, rather than a distortion of some notional—and one could say implausible—concept of the “fabric” of space-time, it would now become a distortion of each kind of syncytium of local energy fields, giving a more concrete basis from which to develop a formal theory than the implausible basis of a distortable “fabric” of space-time.

The standard approach to the “measurement” of time (a phrasing that assumes it to be a physical property that can in principle be measured), is to choose some stable process such as the resonance of a cesium atom as an “Atomic Clock”. It may seem that the concept of temporal stability implies an understanding of time to be the underlying variable within which to assess the stability over time. However, this is not the case, because multiple processes may be compared with each other. If two people are asked to “keep time” independently of each other, implying that at least one of them is an unstable process. However, if the procedure is repeated with two stable processes such as atomic resonators, they will be shown to remain in phase with each other over long intervals of time (as defined by the processes of the human measurers). Thus, their process stability can be established without reference to an extended time dimension (only to a local phase estimation, and we can say that we will choose to use their signature events (the number of phase peaks) as a yardstick for the stability of any other process (such as the human stream of consciousness) without recourse to the concept of an underlying domain of universal time.

3.6 Time as Fractal

This concept of process time leads to surprising structural implications of a fractal nature. The essence of fractals is that they are recursive, folding back on themselves in the domain that they inhabit. The classic example of a fractal is a 1D process that moves forward or backward in equal steps at random (or drawn from a symmetric statistical distribution of step sizes), known as a 1D random walk. The binary (1, -1) random walk has the classic property of a $1/p$ distribution of run-lengths p of going forward and backward, and the corresponding $1/f$ frequency distribution when transformed to the frequency domain (spatial frequency, or temporal frequency, according to whether the dimension is space or time). The process tends to drift away from its starting point with the square root of the number of steps but is certain to eventually return to its starting point, and to do so repeatedly as it progresses (Polya, 1921). Thus, the 1D random walk is essentially recursive in nature.

A 2D random walk is the classic case, and is still certain to ultimately return to its starting point. However, the general case in nature as we experience it is for processes to proceed in three dimensions (such as atoms in space, or objects in our interactive environment). For a 3D random walk, the probability of returning to any given starting point falls to only 34%, with the complementary probability of 66% of the path drifting away from the starting point forever. And this is an upper bound for the probability of finding any other point in the process space. With increasing dimensionality of the process space for more complex processes, such as a brain, the probability of reaching any particular state progressively diminishes; this probability decreases (slowly) to 0.19, 0.13, 0.10, 0.09, and 0.07 as the dimensionality of the process space increases from 4 to 8 dimensions (Montroll, 1956). In other words, if a turbulent process has more than 5 independent parameters, there a greater-than-90% chance that its behavior will get lost in its parameter space and never exhibit any particular form of behavior.

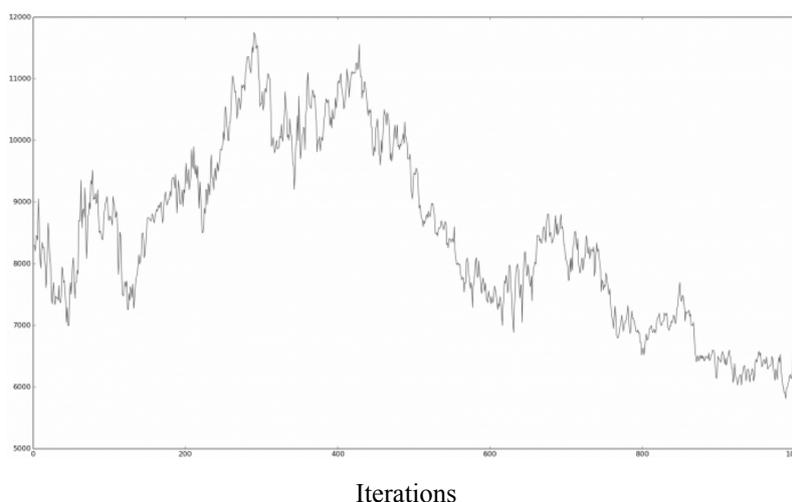


Figure 2. A One-Dimensional Random-Walk Fractal

(<http://www.turingfinance.com/hacking-the-random-walk-hypothesis/>)

To reiterate, the idea is that time is not an independent dimension but is an outcome of the evolution of a process specified by a differential equation from an infinitesimal change kernel, dt . Time is derived from the integral of dt . In the simplest form of process, the integral of dt is just t , so a simple process can generate a linear dimension of time as it evolves through the integral, in the classic math formula. But the world is full of nonlinear processes, such as the Navier-Stokes equation for turbulence. As these processes roll out to generate their time “integral”, they do all kinds of wild things such as generating vortices that wrap around themselves in self-similar spirals and fractal structures.

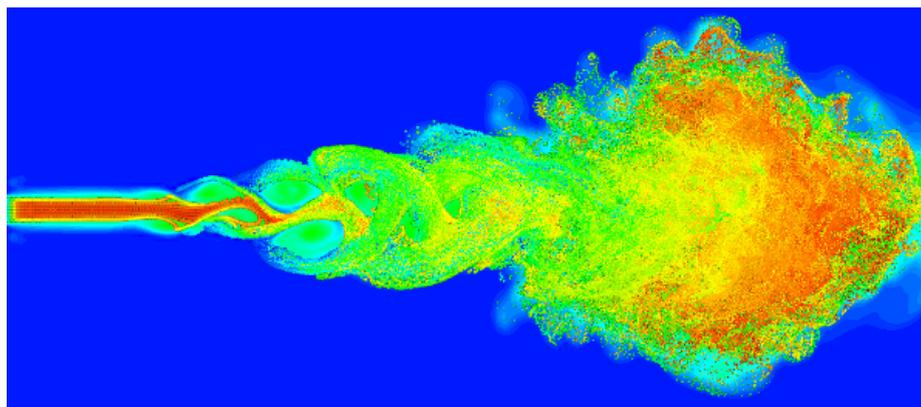


Figure 3. Simulation of the Fractal Nature of Turbulence in Three Dimensions (Projected to Two)

So rather than viewing time as a Cartesian dimensional basis in which things take place, the implication of the daVincian concept is to view time as the coordinate-free Lagrangian that tracks the evolution within the process and is defined by each process as it evolves. The Lagrangian is a key transformation to coordinate-free specification that operates “inside” the process rather than outside it, so that rather than just the process being fractal in a Cartesian space-time, the Lagrangian space-time becomes itself fractal through the process evolution.

The best-known fractal is the Mandelbrot set (Brooks & Matelski, 1981), generated by the limits of recursive equation:

$$Z_{\text{new}} = Z_{\text{old}}^2 + C \tag{8}$$

with the arrows indicating the recursion relations embedded in the equation.

A sample from the resulting map is shown in Figure 4, illustrating that the hypercomplex form of the fractal solution to this extremely simple recursion equation has numerous forms of self-similarity over indefinitely many scales of comparison. Although examples may be generated of the solution structure for any choice of initial parameters, it is impossible to write the equation for the complete solution. It simply has to be generated through iteration to determine its properties. The key to its complexity is the

nonlinear operation of the squaring term on the z variable. Without this nonlinearity, the solution space would be a simple second-order feedback system.

The fractal function is thus an object lesson as to the nature of the ramifications of a recursive equation such as the Schrödinger Equation, which has essential the same feedback structure as shown for the Mandelbrot equation (eq. 8). The implication is that the iterative progression of the Hamilton-Jacobi/Schrödinger Equation, which is often considered to underlie the whole of physics (Feynman, 1985), is liable to generate fractal solutions under appropriate initial conditions (Domany et al., 1983; Rodnianski, 2000; Johnson & Ordonez, 2011; Chen & Olver, 2013). One example is reproduced in Figure 4.

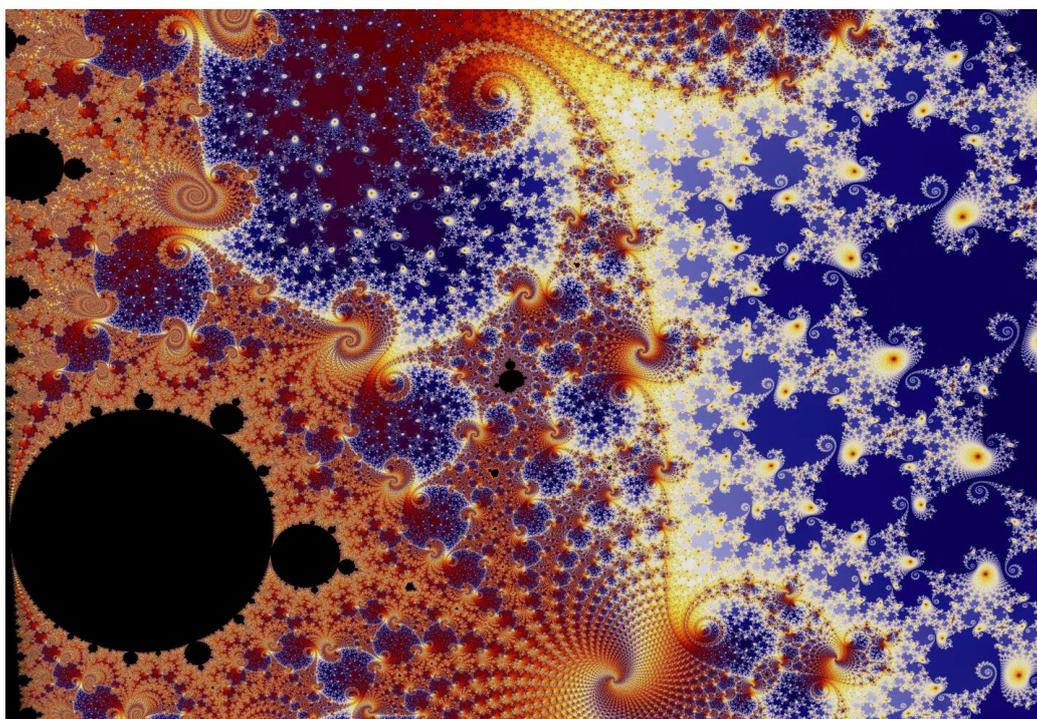


Figure 4. A Sample of the Infinite Solution Space of the Mandelbrot Equation. Coloration indicates the iterative sequence convergence value, with black indicating where the solutions tend to infinity

In the present context, the issue is what are the implications for the nature of the (process-specific) time derived from this kind of fundamental physical process. If time does indeed need to be derived for each local process, rather than being an abstract Platonic domain, then time itself must have a fractal nature, folding back on itself in indefinitely ramifying complexity.

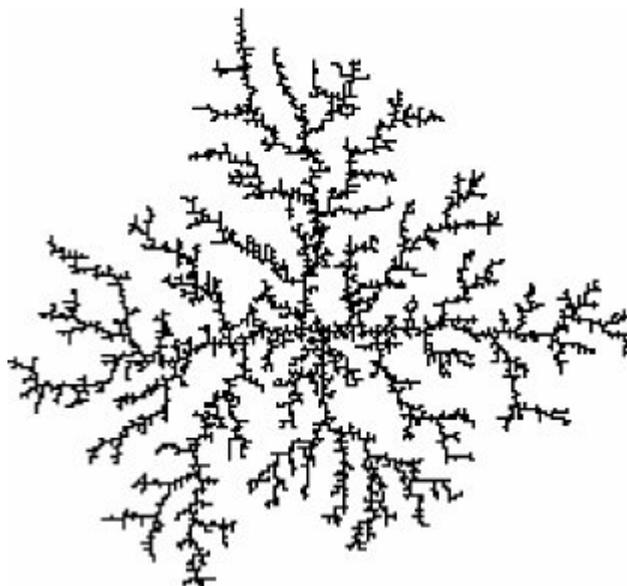


Figure 5. Fractal Generated by Quantum Diffusion-Limited Aggregation through the Schrödinger Equation (from Johnson & Ordonez, 2011)

3.7 Fractal Time in Context

There have been many speculations about the elaborated nature of time, that it may evaporate at the event horizon of a black hole, or be subject to wormhole shifts allowing the velocity of light to be transcended, or have higher-dimensional loops that allow cyclic return to the same point in time (the Ground-Hog-Day Effect). However, none of these time aberrations have the complexity of fractal time, since they all operate on time as a unitary, one-dimensional local entity (even though it may be a one-dimensional curved line). Processes in general are not so locally restricted. The quantum-physical process of a propagating wavefront, though generally analyzed in terms of a plane wave in a uniform medium, can readily encounter inhomogeneous media and split into multiple differential components that cross paths and intersect. Although the intersections would be purely linear (additive and non-interacting) in the vacuum, such intersections in nonlinear media can indeed interact and generate further wavefront subcomponents, reminiscent of the fractal behavior in Figure 4. Whereas a process consisting of a defined particle can only take a single path, however elaborate, a wavefront can exhibit true fractal behavior (reminiscent of the proliferating broomsticks in the Disney “Sorcerer’s Apprentice”, which multiply progressively with every blow of the axe). While this may not be the typical form of behavior of wavefronts in everyday experience, it is part of the vocabulary of their potential behavior under sufficiently nonlinear conditions, even when defined by as simple a nonlinearity as the Mandelbrot equation.

Again, since time is defined as the integral of any developing process over the space traversed by the wavefront (eq. 5), the time defined by such a fractal process will itself take on a three-dimensional

fractal character, potentially splitting into multiple temporal subcomponents propagating through 3D space with independent individual behaviors. Thus, the elaboration of this view of time as deriving from the instantaneous derivative of each potentially complex, nonlinear process in the universe brings time itself into the fractal domain of three-dimensional turbulent dynamic processes.

4. Conclusion

Although time has long been considered one of the fundamental quantities of Physics and is treated as something that exists externally to the observer and that can be measured by a variety of devices called “clocks”, the present analysis takes a radically different view processes as fundamental, with time derivable from the integral of the differential equations specifying each process. In this view, time is a mental or conceptual construct derived from the energetic processes of the physical world, a construct that is specific to each individual process and that is only derivable from such processes. As far as can be determined, this is a novel viewpoint that has never been articulated in the Western Philosophical view of time as a primary dimension of reality. Furthermore, the present concept of time as inherently a process (rather than an extended dimension). In this respect, it is fully compatible with the Emergent Aspect Dualism view (Tyler, 2014, 2019) of the universe as constituted entirely of processes, in an emergent hierarchy from the subatomic level to the conscious processing of the human mind. It is also the only theory of time that is grounded in the Hamilton-Jacobi/Schrodinger Equation of Quantum Physics, which, when applied to a sufficiently nonlinear physical process, can lead to the fractionation of outcomes that is describable as “fractal time”.

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Note

Note 1. This proposal does not attempt to resolve the conundrum of the origin of the Universe *per se*, which remains a subject of heated debate (Finster, Smoller & Yau, 1999; Wolkover, 2019).