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Thrice Upon a Time

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Abstract: We discuss three kinds of time: real time and virtual time as abstract constructions, and simulation time, in more concrete terms. All three discussions unroll in an ambiance of general systems paradigm, or more precisely, in the context of complex dynamical systems theory. The mathematical models utilized are those of flat Euclidean geometry, although the curved spaces of global analysis might be more appropriate. The goal of this exercise is a theoretical preparation for the virtual worlds required for the computer simulation of mathematical models for massively complex natural systems, such as those of the biosphere, the global economy, microbial ecology, human demographics, and combinations of these.

Contents

1. Introduction.

How much time do we spend thinking about time? Not a lot, generally speaking. But when we are involved in the computer simulation of complex dynamical systems, there is no escape. Here we will clarify this problem by placing simulation time, S-time, in a sandwich between two rather different things with similar names, the R-time of ordinary reality, and the V-time of virtual worlds. Throughout we will be looking at things from the viewpoint of general systems theory, GST, so a word about that first.

2. GST.

The systems movement began with Ludwig von Bertalanffy in the 1920s. During the World War 2 years, cybernetics emerged, under the influence of Norbert Wiener, Heinz von Foerster, the Macy Conferences, and so on. After the war, the retooling of the computer simulation side of military technology gave us the system dynamics of Jay Forrester and the Sloane School at MIT. Certain technical difficulties in the application of dynamical systems to the modeling and simulation of complex systems such as the world economy were removed by the advent of chaos theory in the 1960s, and a new and powerful strategy for the sciences of complex systems has emerged. The basic concepts are familiar from the popular press: whole systems cannot be reduced, their intelligence resides in their web of connections, simplicity evolves from complexity, a modicum of chaotic behavior is characteristic of life, and so on.

3. R-times.

From the GST perspective, real time is a sociopsychological construct. Each person has many times, characterized by biological oscillators and perceptual processes. In a mathematically natural process of synchronization, a few harmonically related times emerge from this ensemble of (perhaps chaotic) oscillators: biological synchrony. In a social group (herd, school, flock, etc.) a similar process of synchrony produces a consensus of a single, cosmic time: social synchrony. Even physical systems behave thus, as in a flock of pendulum clocks on the wall: physical synchrony. So you see, physical, biological, and social R-time is the outcome of a mathematical proclivity and hermeneutical process.

4. V-times.

This may seem odd, but subsystem times in a virtual world are less likely to simplexify. This is because the creators of virtuality are less clever than mother nature. Beyond force fitting systems to be enslaved by a single master clock, we should perhaps get used to multiple clocks in the made-up complex systems of virtual worlds. And why not? Multi-dimensional times are sometimes invoked in real world science. For example, signals from distant galaxies have perturbed clocks due supposedly to the red shift. Recent scientific proofs of certain paranormal phenomena such as precognition suggest models of parallel universes with phase shifted times. (Radin, Dunne) And for jet-lagged travelers, some travel clocks and wrist watches display two times. So it is not too far-fetched to propose experiments with virtual worlds in which consensual time, V-time, is a vector in a multi-dimensional Euclidean space: multiple times for multiple perceptions. Just regard this as the R-time of a system which has not yet evolved to full convergence or synchrony: an immature version of R-time.

5. S-times.

We consider now a *complex dynamical system*, or CDS. This is a mathematical model constructed from a number of dynamical schemes (dynamical systems with parameters) which have been connected into a network by coupling schemes. (Abraham) When it comes to computer simulation, it is common to distribute the models at the nodes on distinct machines of a network, each using its own simulation algorithm, and thus having its own time. These nodal models may be of any of four kinds of dynamical systems: *flows*, *cascades*, *semi-cascades*, and *symbolic dynamical systems*. Flows have continuous-time, but are simulated by a discrete-time process, through a discretization scheme, of which there are many types. Cascades, semi-cascades, and symbolic systems are intrinsically discrete-time. What is required, then, to coordinate the distributed simulation of the whole CDS, is a synchronization plan for each connection between two machines or nodes. If the CDS network contains loops, which is the usual case, it may not be possible to relate all the local times to a single cosmic time. Consideration of just three nodes connected in a loop demonstrates this restriction. In practice, a node must present the results of one tick of its own clock to an output memory register or mail drop, then hurry up and wait for its pickup by a recipient node. A whole list of outcomes may be enabled by adequate inputs to the InBoxes of the node, while nobody comes to pick up the mail. In this case, outputs accumulate in the OutBox, perhaps until it is full. Then a whole neighborhood of nodes must stall and await developments. Traffic jams on the network are another cause of nonuniform time flows. So we see that S-time is modeled by a discrete lattice in multi-dimensional Euclidean space, or perhaps, some curved manifold or Lie Group.

6. Time intervals.

In case of real, virtual, or simulation time, but especially the latter case, we may encounter situations in which the time can be estimated, yet not known exactly. The best representation of this condition might be a probability measure on the real line of time, thus, an infinite-dimensional vector. But the most simplistic representation, which we consider here, would be the enclosure of a time estimate in a closed real interval, $[a, b]$. The case of complete ignorance might be accommodated by allowing infinite values for the endpoints, but we will not go to that extreme. The closed interval, or time window, may be represented geometrically by a point, (a, b), in the euclidean plane, with $a <= b$, the case of equality corresponding to a normal time, exactly known. Thus, in all of the discussions above, the real number line of time might be replaced with the upper half plane.

7. Conclusion.

We have seen that the computer simulation of a CDS model for a complex natural system, the global economy or a microbial ecosystem for example, demands a complex S-time model. From the mathematical point of view, S-time lies somewhere between the fully converged simplexity of R-time and the arbitrarily complexity of V-time. This would still be true if S-time were continuous rather than discrete, as is the case when networks of analog devices are used in simulation. What we are proposing here, considering that one-dimensional R-time is so familiar to us all, is a training ground for S-time: V-time in intentionally immature virtual worlds.

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