Windows of Coherence: The Environment for organic substance

Yehuda Roth

Oranim Academic College of Education, Israel

E-mail: yudroth@gmail.com

Abstract. The following will introduce the A.I.E.S model, in which nonlinear maps determine the evolution of an inanimate substance to form an organic substance (Biopoiesis). We will demonstrate that when relating this model to a window of coherence that appears in the chaotic bifurcation diagram, a biological characteristics of warm-blood animate systems appears. Our model provides a mathematical platform in understanding Biopoiesis, that is, the process by which living organisms develop from inanimate matter.

I. Introduction

In the book entitled, *What is Life?*, Nobel laureate physicist E. Schrödinger states that "life feeds on negative entropy," namely, by the increase of order[1, 2]. Indeed, today life is still associated with order increasing (see examples in references [3],[4]).

At first glance, it looks as though this decrease in entropy violates the second law of thermodynamics, in which entropy always increases. However, since every living system is attached to an external environment, we can say that this reduction in entropy is always compensated by a growth of entropy in the attached thermal reservoir. As an example, we can observe an evolution of DNA molecules that have been analyzed numerically using a thermodynamic path integrals technique[5, 6]. Numeric calculations show a reduction in entropy on the account of a solvent environment.[7].

Nobel Prize-winning chemist Ilya Prigogine[8] noticed that some shapes, such as snowflakes (fractals in current terminology), possess natural order. Moreover, he described animate systems that exhibit behavior of the bifurcation type, namely, oscillation between different states. These early observations were primal clues for a generalized theory that identifies life with the evolution of nonlinear maps, such as the cellular automaton model [9, 10, 11].

Following other works, we will describe the ordering process by nonlinear maps. We will focus on a process in which inanimate systems, by reducing entropy, reproduce organic substance.

II. The nonlinear spanning map

Suppose we have a system evolving according to a nonlinear map. The system that is attached to a thermal bath is at a constant temperature T, such that, like warm-blooded animals, it is not necessarily in the reservoir temperature. Thus, our system can be out of the thermodynamical equilibrium. Yet, the constant temperature indicates that it is in a steady state.

We start with a 1-D system which evolves with an iterating nonlinear equation[12]

$$x_{n+1} = f_R\left(x_n\right), \quad \forall n \;\; \alpha_n \in [0,1] \tag{1}$$

where all values of x are within the interval $[0,1]$, and R is a control parameter that determines the map type as either regular or chaotic. We assume that the R-parameter is related to temperature, such that as R rises, so does the temperature.

If, for example, we consider the logistic map $x_{n+1} = Rx_n\left(1 - x_n\right)$, we can assume models like $R = 4\left(1 - e^{-T/\tau}\right)$ or $R = 4e^{-T_0/T}$ where, τ and T_0 are constants characterizing the animate system. The 4-factor is a constraint determined by the logistic map model.

For a large variety of maps, increasing the strength parameter R (associated with heating the system from low to high temperatures) such that the map evolves from regular toward chaotic behaviors, follows similar steps[13].
The first step (a relatively small R) is characterized by maps that converge into a single stable point, calculated as

$$x_{n+1} = x_n \equiv x^{[1]} \Rightarrow x^{[1]} = f_R^{[1]}\left(x^{[1]}\right). \tag{2}$$

For a higher level of R, the map reaches two alternating values (the Andronov Hopf bifurcation)[14], as shown in fig. 1. Yet, it is possible to redefine a map that retrieves a single

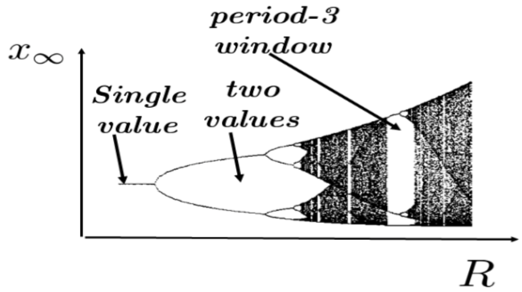

Figure 1. An example of a bifurcation diagram showing a window of coherence

stable value simply by using a double step iteration

$$x_{n+2} = f_R^{[2]}\left(x_n\right). \tag{3}$$

where $f_R^{[2]}\left(x_n\right) = f_R\left(f_R\left(x_n\right)\right)$ is the map that iterates x_n twice.
A steady value is then obtained when

$$\begin{aligned} x_{n+2} = x_n \equiv x^{[2]} &\Rightarrow x^{[2]} = f_R^{[2]}\left(x^{[2]}\right) \\ f_R\left(f_R\right) \equiv f_R^{[2]} &\equiv f_R^{[1]} \circ f_R^{[1]}, \end{aligned} \tag{4}$$

where now the superscript [2] indicates that although the map $f_R^{[2]}$ retrieves a single final value, it is composed of two basic maps.

For a higher value R, the map terminates with four alternating values that give rise to the *four-rank map* $f_R^{[4]} = f_R^{[2]} \circ f_R^{[2]}$. Increasing R further, the same splitting continues until the map reaches the chaotic regime, in which it is impossible to redefine maps that stabilize at a finite single value.

In general, we define $f_R^{[m]}$—a *map of rank m* (m stands for "map"')—as

$$f_R^{[m]} = \underbrace{f_R^{[1]} \circ f_R^{[1]} \circ \ldots}_{\leftarrow\ m\ times\ \rightarrow} = f_R^{[m/2]} \circ f_R^{[m/2]}. \tag{5}$$

Although we expect a chaotic behavior at high R, the bifurcation diagram shown in fig. 1 shows a much more complex behavior than just a simple division of period multiplications (1,2,4,...values), and chaos [15]. Amongst all the chaos, we find a stable period-3 orbit as shown in fig. 1. More windows of 5-period and 6-period are also found. Thus, in order to redefine the 1-rank map to retrieve a single stable value, we apply the appropriate rank map such as the 3-rank map $f_R^{[3]}(x_n)$.

III. The Animate state and the inanimate ensemble

Suppose we have a large dimensional Hilbert space spanned by a basis of states that are labeled by the states $|i\rangle$. Among this basis of states exists a unique single state, such as a DNA molecule or other organic substance that is associated with a single state $|\Omega\rangle$. This Hilbert space can be composed as a tensor-product of many spaces defined by different ingredients of the organic substance. The organic substance-state $|\Omega\rangle$ is defined to be unique as it defines the animate system, like a DNA molecule. All other states are related to an inanimate ensemble of states $|\bcancel{\Omega}\rangle$, defined as $|\bcancel{\Omega}\rangle = \sum_{i\neq\Omega} a_i\,|i\rangle$, where the $\{a_i\}$-set selections determine the ensemble. To generalize our model further, we allow the coefficients a_i to be time dependent and complex. They can also be temperature dependent and random. Thus, except for the single organic substance state, $|\Omega\rangle$, all other complexities are introduced through the inanimate states ensemble.

Defining possible sets of the $\{a_i\}$ coefficients, it can be seen that $\forall\ \{a_i\}\quad \langle\Omega|\bcancel{\Omega}\rangle = 0$, meaning that there is a pronounced distinction between the two concepts, being in the ordered organic substance state $|\Omega\rangle$ rules out the possibility of being part of an inanimate ensemble and vice-versa.

Using a Gröver-type state[16, 17], we present the A.I.E.S (Animate Inanimate Ensemble of States) model through a state ensemble $|n\rangle_{\bcancel{\Omega}}$ such that

$$|n\rangle_{\bcancel{\Omega}} = \alpha_n^{[p]}\,|\bcancel{\Omega}\rangle + \beta_n^{[p]}\,|\Omega\rangle\,. \tag{6}$$

The coefficients $\alpha_n^{[p]}$ and $\beta_n^{[p]}$ generate the state-time evolution as determined by the nonlinear map, where the superscript $[p]$ is the p-rank map. The coefficient s's subscript at $|n\rangle_{\bcancel{\Omega}}$ defines each state in the ensemble through the selection of $\{a_i\}$, namely, the $|\bcancel{\Omega}\rangle$-state.

For each $|\bcancel{\Omega}\rangle$, we expect the coefficients $\alpha_n^{[p]}$ and $\beta_n^{[p]}$ to behave as follows:

(i) Normalization condition
$\left|\alpha_n^{[p]}\right|^2 + \left|\beta_n^{[p]}\right|^2 = 1.$

(ii) Biopoiesis[18]
The process for which organic compounds, such as a DNA molecule, arise from inorganic matter through natural processes. For a p-rank map that converges into a single value, all states (most of them are inorganic), will line up to form the organic substance as represented by the state state $|\Omega\rangle$.

In order to fulfill these two conditions, we suggest a state of the form

$$\begin{aligned} &|n\rangle_{\bcancel{\Omega}} = \sqrt{\Delta x_n^{[p]}}\,|\bcancel{\Omega}\rangle + \sqrt{1-\Delta x_n^{[p]}}\,|\Omega\rangle \\ &\Delta x_n^{[p]} \overset{\text{def}}{=} x_{n+p} - x_n. \end{aligned} \tag{7}$$

It is seen that for a map that converges into a single value, $x_{n+p} \rightarrow x_n$, we find that $\forall \aleph \quad \lim_{n\to\infty} |n\rangle_{\aleph} = |\Omega\rangle$.

IV. windows of coherence-The environment for organic substance generation

Ergodicity can be related to chaotic maps[19]. The ergodic hypothesis is fundamental to the definition of the thermodynamic equilibrium. We can therefore say that in a high temperature range, our system tends to reach a thermodynamical equilibrium, namely to be in a chaotic state. However, observing bifurcation diagrams for a variety of maps, we find that even with a large R, there are narrow regimes ("windows"') for which the map exhibits a regular behavior (see Fig. 1).

Observing a p-rank map converging into a single value $x^{[p]}$, we notice that there are infinite possibilities for selecting initial conditions for the state $|n\rangle_{\aleph}$. However, under the appropriate p-rank map, it reduces to the ordered organic substance state, thereby reducing entropy. At first glance, it looks as though this behavior violates the second law of thermodynamics. However, since our analysis assumes the system to be attached to an external thermal bath, we can say that this reduction in entropy is always compensated by a growth of entropy in the attached thermal reservoir. In other words, a system based upon a window of coherence always emits heat that is absorbed by the environment.

One cannot ignore the similarity between this high temperature windows of coherence and warm-blooded animals systems. They both operate in a very narrow temperature spectrum ($\sim 35^oC - 42^oC$ in the human body) so as to increase order. Let us add by saying that all of these characteristics require an "internal engine" and other temperature regulation systems (such as sweating in the human body) to maintain this narrow temperature spectrum. When those regulating systems stop functioning, the system temperature lines up with the environment temperature, thereby terminating the organic substance reproducing process.

V. Discussion

We proposed the A.I.E.S model, in which an organic substance was presented by a state. After introducing the state $|n\rangle_{\aleph}$, which is the organic substance state in superposition with the inanimate ensemble of states, we introduced the state evolution as determined by a nonlinear map. In our model, the strength parameter R was assumed to be related to the temperature of the organic substance system. However, it possible to re transform the strength parameter R to depend on other parameters such as the Ph- level. We showed that in an environment induced by a window of coherence and by tracking the evolution of the nonlinear maps, the disordered inanimate ensemble reproduces an ordered organic substance, thereby reducing entropy and emitting heat. Such a system can survive only in a very narrow spectrum of temperatures in which the window of coherence is defined.

Our A.I.E.S model allows the existence of many particles states even at a spectrum of high temperatures. Thus, the A.I.E.S model can be implemented in other fields, such as quantum computers, operating at high temperatures.

References

[1] Schrödinger E., *What Is Life?* (Cambridge University Press 1992).
[2] Luke A.J. O'Ne *What is Life? The Next Fifty Years: Speculations on the Future of Biology*, (Cambridge University Press, 1997).
[3] Morowitz H. J., *Beginnings of Cellular Life: Metabolism Recapitulates Biogenesis*, (Yale University Press, 1992).
[4] http://www.panspermia.com/seconlaw.htm
[5] Joli M. , *Journal of Physics: Conference Series* **410**, (2013) 012038
[6] Zoli M., *Phys. Rev. E.*, **79**, 041027, (2009); M. Zoli, *Phys. Rev. E.*, **81**, 05191, (2010)
[7] Joli M., *J. Chem. Phys*, **141**, 174112 (2014)

[8] Prigogine I., *From Being To Becoming*, New York: W. H. Freeman and Company, (1980). p 123.
[9] Wolfram S., *Statistical Mechanics of Cellular Automata.* Reviews of Modern Physics **55 (3)**, (1983).
[10] Andrew I., *Cellular Automata: A Discrete Universe*, (World Scientific, 2001) ISBN 9789812381835.
[11] Andrew I., Halpern P., *Complex Systems*, **1** (1987)
[12] Roth Y. 2015, *J. Phys.: Conf. Ser* **574**, 012085 (2015)
[13] J. Awrejcewicz J. and Hagedorn P., *Nonlinearity, Bifurcation and Chaos - Theory and Applications*, (InTech, 2012).
[14] Marsden J. E., McCracken M., *The Hopf Bifurcation and its Applications*, (Springer-Verlag, 1976)
[15] Gilmore R., Lefrank M., *The Topology of Chaos.* (New York, USA. John Wiley Sons 2002).
[16] arXiv:quant-ph/0301079
[17] Roth Y., *SOP Transactions on Theoretical Physics*, **1**, Number 1, pp.23-26, (2014)
[18] Lal A. K., *Astrophysics and Space Science*, **317** 267-278 (2008)
[19] Eckmann J. P., Ruelle D., *Review of Modern Physics*, **57,3**, (1985)