Information Anticipatory Dynamics of Empirical and Theoretical Languages of Nanostructured Evolutionary Automata

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Abstract
Exploring and comparing the elements and operations of the logical space and their physical counterparts of the nonlinear Hamiltonian, conservative and/or non-integrable, phase space in nanostructured evolutionary automata, the physical meaning of *syntactic* (*'mechanistic'*) information processing shows that self-referential syntax is fed and made self-consistent by the automaton dissipative, Steinbuch-like anticipatory semantic dynamics.
Keywords: Anticipation, Automata Languages, Biomimicry, Nanochaos, Evolution

1 Introduction

Information ist Information, weder Materie noch Energie[1].
N. Wiener [1]

Zu den klassischen Dimensionen der Naturwissenschaften,
zu Materie und Energie, trat als dritte Dimension die Information[2].
K. Steinbuch [2]

In spite of the concepts about the notion of information like those quoted above, formulated some decades ago, just recently a novel, physical notion in the classical field has been formulated for a proper description of biomimetic evolutionary systems [3, 4]. And a pathway to a fundamental, quantum mechanical agency[3] underlying the classical informational phenomenology has been started on the ground of experimental advances confirming the nonlocal character of physics and the realizability of quantum information teleportation [5]. As previously discussed [3, 4, 6] Shannonian information and abstract set-theoretic logic cannot describe biological evolution and intelligence. Even biomimetic evolutionary automata [4] cannot be interpreted through standard Information Theory developed for applications as a part of the theory of normed Boolean algebras, i.e., distributive and complementary associations, and embodied in Probability Calculus. It was shown that Brillouin's interpretation of *information* as

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[1] *'Information is information, neither matter nor energy'*

[2] *'To the classical dimensions of natural sciences, to matter and energy, information added as a third dimension'*

[3] A. Zeilinger of Vienna University, who has led the first group of physicists in carrying out successful teleportation experiments in 1998 has been reported by M. Buchanan (cf. Ref. 5) to have commented with a meaningful felicitous expression that *"information is deeper than reality"*.

negative entropy [7] is limited to systems in thermodynamic equilibrium, so that it is hardly fit for describing a physics based on and supported by far-from-equilibrium conditions (life, biological intelligence, any automaton featuring even the least biomimetic evolutionary behavior).

Accordingly, for describing in the following the *autonomous formation and evolution* in nanostructured biomimetic automata [4], capable of **learning** and **acting** not according to a pre-programmed behavior, of both an **empirical** (i.e. object-related) and a **theoretical** (i.e. descriptive) language from their *intra-specific* reciprocal exchange of time series signals consisting of coded interactions[4] [3, 4], an approach based on *physical information* will be adopted, while standard Information Theory will be applied to the case when its basic hypothesis of an *already formed* ***marks*** *inventory* – a static, time-frozen set of abstract marks – is valid. This is e.g. the case contemplated in Section 5.1. The whole information processing considered throughout this paper is supposed to occur within the realm of Steinbuch's concept of intelligent automaton [3, 4] as one capable of *simulating* its environment and *its partners* by means of increasing levels of abstraction as *collective properties* through convolution of environmental time series with its *internal anticipatory hierarchical dynamics* [4], and then of reacting in an optimal way. The nanotechnological implementation of such hierarchical-level dynamics, with the introduction of the concept of quantum holography [8] in addition to nanochaos, has been discussed recently as to the solution of some intra-level communication semantic problems [9]. Some earlier concepts concerning such *semantic automata* as opposed to syntactic automata contemplated by the Artificial Intelligence paradigm are recalled in Section 2.

2 Recalling Some Previous Concepts

Reference is to be made for details to the literature reported.

1) Views as to 'information' and its 'container' different from the standard notions valid and usefully employed for telecommunication techniques start from a G. Bateson remark [10]: *Information is any difference that gives rise to a difference"*. This view was then developed arguing that an observing and an observed system are to be distinguished. It is necessary for any *mark* (the *first difference*) existing just *per se* in the observed system to become information that there exist something or someone (the *observer*) *interpreting* that mark through *interaction* with the observed system, thus creating the *second difference*. So that mark actually becomes *physical information* as an emergent property from the conjugation (convolution, compression, *simulation* and therefore *abstraction as formation of collective properties*) of external signals with the internal activity of the receptor through the dynamics mentioned in point **2)**. It is such emergence that *flows* through the parts of the physical system in question: *information is not contained in any source, which is a misleading term for what contains just a*

[4] Coded interactions are defined here as those depending on space arrangement and/or time frequency, as opposed to parametric interactions, depending on strength only; e.g., the well known relationship $E = \hbar\nu$ between an atom energy level E and the photon frequency ν embodies a coded interaction.

mark, nor is it contained in the receptor. Such images can work as *metaphors* in the case of thermodynamic systems at equilibrium, which cannot be evolutionary, and for transmission channels of telecommunication engineering, where a *one-to-one mapping*, as free from noise as possible, is sought for in order to get a very reliable copying of the message sent. *There are no simulation or abstraction, and no dynamic memories*.

2) Nanochaos and nanotechnological implementation of quantum holographic information processing throughout a hierarchy of dynamic-symbolic levels realizes the simulation capabilities mentioned: in both the quantum and classical dynamics embodying the automata capabilities, there are no algorithmic instructions, but just *learning*; no net hardware-software distinction, but just a *physical morphological-dynamical solidarity* (according to biomimetic structure-function solidarity); coupling with the environment (*partners included*) can go vertically from macro- to mesoscopic levels. The evolutionary *"cybernetic crisis"* from exponential complexity of data processing, and any *self-reference* problems are overcome by such quantum and classical dynamics. The loophole out of *abstract logical constraints* is either chaos or, in quantum holography, synchronous cooperativity by linear superposition throughout the levels, from the smallest (*the nanolevel*) to the whole nano-to-micro integrated structure-function scale[5]. To any specific evolutionary automaton a specific environment will so belong, that consists of the environmental segments valid for its own structure-function capabilities as far as simulation is concerned.

3) The automaton behavior is thus an expression of the *closed* chain of information processing

syntax ⇔ semantics ⇔ pragmatics

through its

sensing - information processing – actuating

chain made up of nano-to-micro integrated members, such behavior, as seen in the phase space of the automaton, being described by the *dissipative* process (cf. Section 3 for symbols)

$$\nabla \bullet \mathbf{f} < 0 \tag{1}$$

as opposed to the conservative process

$$\nabla \bullet \mathbf{f} = 0 \tag{2}$$

i.e. a constant volume of the flow of information for a *syntactic* information processing based on Boolean purely deductive logic. This is just a thermodynamically reversible (*isentropic*) process, *information flowing like an incompressible fluid in the phase space of the automaton*; this physical occurrence in *phase space* reflects what happens in the *logical space*: any mathematical development is just a tautology[6]. *No new information is*

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[5] Technology of *nano-to-micro integration* is now being studied intensively also as a biomimetic technology to mimick the complex information *processing-actuating* functions for robots designed for deep-space exploration, where autonomous action is of the essence.

[6] The closed character of the chain shown at point **3)** leads to the consequence that a purely syntactic process is an unphysical abstraction, useful just for grasping the qualitatively different moments making up the **solidary process** of that chain. This looks like leading to perhaps the deepest interpretation of Gödel's incompleteness theorem: that *there is semantics in any syntax indeed*, and it is this that makes

produced along the flow. This is what happens, and **must happen**, for accurate *one-to-one mapping*, in a telecommunication channel, whereas the volume in phase space for the *semantic automaton* is not invariant: it becomes shrinked so as to generate novel information and any *logico-deductive premises* for a syntax: the **'mark'** mentioned in Section 1 thus becomes a **'symbol'**.

3 List of Symbols

Symbols employed are listed here in the order of their introduction:

∇ : the vector form of the nabla operator
f : the vector form of the flow (trajectory or map) in phase space
• : the dot product
→ : if ... then
${}^{\pi}L_n$: formal empirical language with *n* as the number of elements, π as the number of predicates; *n* and π are finite positive integers
a, *b*, ... : any individual element
A, *B*, ... : predicates
¬ : negation (not *A*)
Aa : *a* has the property *A*; ¬*Aa* : *a* has not the property *A*; (*Aa*, ¬*Aa*) : a **base pair**; *Aa* a base proposition
H_{max} : maximum average information = $\log_2 z$
z : number of descriptions of a condition = 2^s
s : number of the base pairs
H[7]: average information = ${}^{z}\sum_{i=1} p_i I_i$ of the formal language ${}^{\pi}L_n$, p_i as the probability of *i*, and $I_i = \log_2 (1/p_i)$ as the information of *i*
R : absolute redundance = $H_{max} - H$
r : relative redundance = R/H_{max}
∧ : the *and* operator
∨ : the *or* operator
↔ : when and only when ... , then
${}^{\theta}H$: average information of the probability distribution set forth by a theoretical proposition into an empirical language ${}^{\pi}L_n$, with the assumption for that distribution that $p_\theta = 1, p_{\neg\theta} = 0$.
z_{ij} : the number of state descriptions that consist of the combinations of the elements of ${}^{\pi_1}L_{n_1}$ and of the predicates of ${}^{\pi_2}L_n$

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mathematics physically meaningful. Indeed, uncomputable functions are just mathematical constructs for which no physically corresponding **operation** has been found **as yet**.

[7] The term *"entropy"* commonly employed for this kind of quantities in the stochastic literature has been avoided in this context in which the deep difference and the relationships between the logical space and the thermodynamic space are stressed throughout.

$\theta_{z_{ij}}$: the number of state descriptions of a partial language that are contained in the logical space of a theoretical proposition θ
S : thermodynamic entropy
pdf : probability density function
$dS_i(t)$: entropy produced in a whole system or in one of its levels due to irreversible processes
$dS_e(t)$: entropy exchanged with the environment or with another level of the same system

4 Empirical vs. Theoretical Languages

Results of observations and measurements will form the elements of a system of fundamental propositions, comprising *any* combination of such elements; the finite set of such combinations makes up the *empirical language* of the automaton. Its evolutionary character may make the set potentially infinite, so that an inventory of the single propositions would not be possible. But models with finite elements of finite lengths could be built to represent quite accurately the potentially infinite set of an evolutionary language, so that a procedure might be devised for representing within an element inventory the amount of all elements of a forcedly limited empirical evolutionary language. Errors may creep into observations and measurements, so that the empirical language will make up a *fuzzy set* [11] enumerating the results of observations and measurements at a low grade of generalization.

A systematic connection between such empirical elements will make up a theoretical language. ***Boundary conditions***, i.e. *principles*, *space and time initial conditions*, and *correlation definitions*, all that being represented by a ***"trainer"***, will set forth the connection modalities in the automaton theoretical language. This picture of the systematic connection within the (logical) space of an empirical language can be thought of as an embodiment of Hempel-Oppenheim's scheme [12]: the concept of the logical consequence is traced back to a tautology, i.e. a proposition p follows logically from a proposition q when $p \rightarrow q$ is a tautology. Changes in the boundary conditions would change the field of application of the theoretical language within the space of the empirical language. Such boundary conditions would be set forth according to the scopes and objectives defining the field of validity of the theoretical language, like for instance the ratios of orders of magnitude of some theoretical terms: just think of an automaton operating in a hydrodynamic environment and of its envisageable multivaried performance corresponding to regimes of various Reynolds numbers. This is the case e.g. of the much sought after *autonomous microrobots* for fluid environment exploration, as is the case with "small mission systems" for planetary exploration.

Now, taking ***"semantics"*** to mean the number of propositions that might be formulated in a language by representing the events or conditions through such elements, standard Information Theory plus suitable *a-priory* or *a-posteriory* probability distributions concerning the elements of the set might be applied to the finite set of the language as the proper inventory to evaluate the information content of the language in question. This would lead to a numerical estimate of both the empirical and the theoretical language relative power, as well as to the design of *"intraspecific"* automata communication means through *linear channels* by applying the well known information theoretic techniques used in telecommunication but, **in this case**, for optimization of the problem concerning *the **identity** or at least the **satisfactorily close** approximation in the interpretation of meaning by the receiver, as compared to the intended meaning of the sender.* With the symbols set forth in Section 3, it is

$$H_{max} = {}^{n}\Sigma_{i=1}\,(1/n)\,\log_2 [1/(1/n)] = \log_2 n \qquad (3)$$

when the $p_i = 1/n$ are all equal.

For

$$r = R/\,H_{max} \text{ it is } r = (H_{max} - H)/\,H_{max} = 1 - H/\,H_{max}\,; \qquad (4)$$

the **relative redundance** r is thus a measure of the *"lack of importance"* of information represented by a mark inventory, and is a maximum when a given mark in the inventory comes sure, whereas all other ones surely do not come into play. This concept of redundance in the *logical space* will appear as an *essential ultimate condition* for evolution in the *dissipative evolutionary space*, with a similar structure as to its dependence on asymmetries in the probability distribution, but with a definite physical meaning [3] whose actual embodiment into a thermodynamic function will be shown to be a problem (Section 6.1), as also is the numerical evaluation of the function itself.

This notion of redundance can be applied not just to the maximum average information of the mark inventory, but also to the average information of a second inventory through which the first one is coded, so as to obtain the redundance r_c of the code in question:

$$r_c = 1 - H/H_c. \qquad (5)$$

An optimal code is that with zero r_c, i.e. with $H = H_c$.

5 Empirical Languages in a Logical Space

The possibility of *"intraspecific"* communication as it is dealt with here means that any problems of semantic nature [9] throughout the individual members of a class of automata sharing similar hyerarchical dynamical structure-functions have been overcome. So a logical, physically non-dissipative space will be employed for formalizing the empirical language into a theoretical language and to remark their essential features and reciprocal interactions. The nanoscale physical embodiment of the logical space dynamic occurrences will be discussed in Section 6.

5.1 Formalizing Empirical Languages

The symbols listed in Section 3 allow an empirical language to be formalized within the Boolean/Shannonian logical space into a formal language ${}^{\pi}L_n$. For instance, a proposition space can be built for describing qualitatively the state of an ideal gas g through the predicates *"high" P, V,* and *T*, respectively its pressure, volume and temperature. The base propositions are *Pg*, *Vg* and *Tg*, while $s = 1 \bullet 3$, ${}^{\pi}L_n = {}^{3}L_1$, and $z = 2^3 = 8$ gives eight state descriptions:

$$Pg \wedge \ Vg \wedge \ Tg \tag{6}$$
$$Pg \wedge \ Vg \wedge \neg Tg \tag{7}$$
$$Pg \wedge \neg Vg \wedge \ Tg \tag{8}$$
$$Pg \wedge \neg Vg \wedge \neg Tg \tag{9}$$
$$\neg Pg \wedge \ Vg \wedge \ Tg \tag{10}$$
$$\neg Pg \wedge \ Vg \wedge \neg Tg \tag{11}$$
$$\neg Pg \wedge \neg Vg \wedge \ Tg \tag{12}$$
$$\neg Pg \wedge \neg Vg \wedge \neg Tg \tag{13}$$

while the empirical law $pv = constant$ can be expressed by the non-equivalence $\neg(Pg \leftrightarrow Vg)$. Moreover, through probability theory theorems, e.g. Bayes's law, *a-priory* and *a-posteriory* probabilities and the corresponding semantic information with particular probability distributions for specific applications can be attained (e.g., hypotheses with unknown *"truth value"*, hypotheses within ${}^{\pi}L_n$ that a predicate A in a proposition $Aa_1 \wedge Aa_2 \wedge ... \wedge Aa_i$ also applies to the remaining elements in the proposition $Aa_{i+1} \wedge Aa_{i+2} ... \wedge Aa_{i+n}$, i.e., hypotheses directly coming *from within the empirical language*, or any *theoretically stated propositions*, i.e. indirectly coming hypotheses or hypotheses not linked to a well established logical relationship with experimental data, etc.).

5.2 Empirical/Theoretical Language Interaction Dynamics

As is stressed above, the *probability distribution of propositions* is a determining factor for information and redundance. As shown below (cf. Section 3 for symbols), 1) a probability distribution in an empirical language can be affected by a theoretical language; 2) a metric for the information content of a theory can be established; 3) an information conservation law can be formulated; 4) redundance is affected by successive introduction into ${}^{\pi}L_n$ of theoretical propositions $\theta_1, \theta_2, ... , \theta_i$; 5) redundance can be affected by an enlargement of the empirical language:

1) $H = {}^{n}\sum_{i=1} p_{\zeta i} \bullet I_{\zeta i}$ for a determined probability distribution over the $z = 2^{n\pi}$ descriptions of state ζ_i. With ${}^{\theta}p_{\alpha}$ as the probability of a proposition determined by means of the theoretical proposition space θ, and with the same notation for the information I of α, taking ζ^{θ} to mean the descriptions of state in the theoretical language space θ which are numbered from $i = 1$ to $i = z^{\theta}$, and as the member with ${}^{\theta}p_{\zeta\neg\theta} = 0$ because of

$$lim_{x \to 0} [x \bullet log_2 (1/x)] = 0 \tag{14}$$

does not enter the average information, it is

$${}^{\theta}H = {}^{z^{\theta}}\sum_{i=1} p^{\theta}_{\zeta^{\theta}_i} \bullet I^{\theta}_{\zeta^{\theta}_i} \tag{15}$$

2) the redundance of the formal **empirical** language ${}^{\pi}L_n$ can be taken as a measure of the **information content of a theory**:

$$r^{\theta} = 1 - {}^{\theta}H / {}^{\theta_0}H = 1 - {}^{\theta}H/H_{max} \tag{16}$$

3) being any theoretical language subject to a previously collected set of observations and experiments *at a given level of description*, as well as to its experimental validation, and being the observed physical system unaffectable by the complete language consisting of the empirical and the theoretical parts, we have

$$H \equiv H_{theoretical} + H_{empirical} = \text{constant } \textbf{for a determined level of description} \quad (17)$$

4) ${}^{\theta_0}H = H_{max}$ when through a theory no description of a state is excluded and no decision within a base pair is supplied, so that ${}^{\theta_0}r = 0$; introducing $\theta_1, \theta_2, \dots, \theta_i$, it is

$$0 = {}^{\theta_0}r \leq {}^{\theta_1}r \leq {}^{\theta_1 \wedge \theta_2}r \leq \dots {}^{\theta_1 \wedge \theta_2 \wedge \cdots \wedge \theta_i}r \leq 1 \quad (18)$$

up to the limiting case ${}^{\theta_\infty}r = \dots {}^{\theta_1 \wedge \theta_2 \wedge \cdots \wedge \theta_i}r = 1$

5) on addition of new *individual elements* or *predicates* to an empirical language, for the ${}^{\pi}L_n$ consisting of the ${}^{\pi_1}L_{n_1}$ plus ${}^{\pi_2}L_n$, i.e. of the combination of the respective elements of the first one and of the predicates of the second one, setting forth

$$z = 2^{(n_1 + n_2)(\pi_1 + \pi_2)} = z_{11}\, z_{22}\, z_{12}\, z_{21} \quad (19)$$

we have, with ${}^{\theta}z$ as the number of state descriptions of the *full* language that are left open by a proposition θ so that

$$^{\theta}z = {}^{\theta}z_{11}\, {}^{\theta}z_{22}\, {}^{\theta}z_{12}\, {}^{\theta}z_{21}, \quad (20)$$

$$r^{\theta} = 1 - \log_2 z^{\theta} / \log_2 z = 1 - (\log_2 {}^{\theta}z_{11} + \log_2 {}^{\theta}z_{22} + \log_2 {}^{\theta}z_{12} + \log_2 {}^{\theta}z_{21}) / \log_2 z \quad (21)$$

In this analysis, a point has now been reached that allows a relationship to be set forth between the logical space as formed above and the phase space corresponding to the physics of its structure and operation. This relationship would be a guide for the nanostructure design of the automaton in implementing its nanoscale reversible logic possibly formalizing any dissipative anticipatory, Steinbuch-like "simulation behavior" ultimately supported, as a self-organization process, by *physical information redundance* that, as shown in the following, can be measured by an *actual* thermodynamic function or by its *extrapolated* value.

6 Deep Logic

From the well known Brillouin's views [7] about H expressed in thermodynamic units, we have S + H = constant. But, as argued in the following, it is to be recalled that S is a state function, i.e. one defined just for equilibrium states. This will set a problem with the actual numerical evaluation of the *ultimate evolutionary condition* (as argued in Section 6.1) in general and for the automaton languages as well. Moreover, for a full information processing in the logical space, we would have $\Delta S = -\Delta H$ and, as the process in the *logical space* is tautological, i.e. no *new* information, as *information not already contained in the initial conditions*, is generated, it is $\Delta H = 0$, i.e. the process in the *phase space* is isentropic ($\Delta S = 0$).

Another interesting relationship *between the two spaces* can be drawn from that equation if we consider the *pdf* of a fluid expanding isentropically from a small cell within a finite volume. Now $\Delta H = 0$ means that the initial information about the *pdf* within the cell **must** be found unchanged within the full final volume after expansion.

But, as the fluid within the volume looks like uniform throughout, the initial information looks like lost. The introduction of a *finer scale of observation* will show that the final information is just the same as the initial one. Indeed, with the phase space volume divided into 2^r cells, $H = \log_2 2^r = r$; with the same number of cells, information in the final state seems disappeared. At this level of description the final state is fully indeterminate and no information is needed to specify it. But let us consider now a finer scale of division of the entire volume for description of the *pdf*, e.g. $2^{r'}$, with $r' = nr$; the full volume will thus be $2^{nr/n}$, so that again $H = r$. This means that the "macroscopic information" has gone into "microscopic information", such terms being relative to the scales in question, so that **at any level**, according to the *general* equation

$$S + H = \text{a constant} \quad (22)$$

with

$$H \equiv H_{\mathbf{macroscopic}} + H_{\mathbf{microscopic}} \quad (23)$$

for an isentropic information processing it is

$$H_{\mathbf{macroscopic}} + H_{\mathbf{microscopic}} = \text{a constant} \quad (24)$$

This relationship in the phase space reflects exactly the relationship in the logical space

$$H \equiv H_{theoretical} + H_{empirical} = \text{constant } \textbf{for a determined level of description} \quad (25)$$

the introduction of the "finer scale of observation" reflecting just the considerations under the points 4) and 5) (addition of further *individual elements* and/or *predicates*) in Section 5.2.

If the fluid in question is an ideal gas, it will be a physical system behaving like the abstract logical Turing's machine, and will present the same well known "halting problem"; indeed, being *a fully Hamiltonian chaotic system*, if *prepared in a given state* (respectively, if the machine is fed with an *algorithm* and *initial conditions*) there will be no way to **foresee in a finite time** whether this purely mechanistic (*'syntactic'*) automaton will reach a certain state (respectively, whether the machine will accomplish its assigned task) and stop: *we could just wait and see*. It is the *"dissipative character"* of a system, i.e. its capability of creating order inside itself by rejecting entropy into the environment, that allows it to escape the halting problem and any other logical paradoxes [3, 4], i.e. to escape *self-reference* by featuring *self-consistency* (attractors). The self-referential formal languages of timeless logic making up the syntax of the automaton and resulting from nondissipative processes (cf. Section 6.2) **must** rely on the dissipative dynamics of it for their evolution.

The following sections will discuss further basic *logic-related physical properties* in addition to such observations for the nanoscale embodiment of the automaton dynamic hierarchy carrying out iterative, recursive, incursive and hyperincursive information processing, by working according to the closed chain mentioned at point **3)** of Section 2 and to the dynamics discussed throughout the literature mentioned in Sections 1 and 2.

6.1 'Relative Redundance' as the Ultimate Evolutionary Condition

The entropy change dS(t) of the nanostructured multi-level system is

$$dS(t) = dS_i(t) + dS_e(t); \quad (26)$$

in **any** evolutionary system, it must be $dS_e(t) < 0$ and $|dS_e(t)| > dS_i(t)$ with the result $dS(t) < 0$ so that the whole nanostructured system will support itself and even evolve against the degrading action of noise and continuing to fulfill the interlevel or the system/environment condition

$$|dS_e(t)| > dS_i(t) \tag{27}$$

just if its redundance

$$r = 1 - [S(t)/S_{max}] \tag{28}$$

increases as a result of the fact that S_{max} as the maximum entropy corresponding to the maximum number of complexions **at equilibrium** grows faster than S(t). This is possible just if either the number of nanoscale units or the number of degrees of freedom through which the self-organization processes occur increases with time. Flexible nanomechanical components capable of adding to their mechanical deformability and other kinds of mechanical motion also the motion of electrons and ion currents, with molecular reactions involving the transfer of atoms, massive group of atoms and molecules, all working on upper-rank codes and hierarchically organized through feedforward – feedback *coded interactions*, would satisfy that criterion in the dissipative phase space of the automaton. This would also be the condition and the physical support for satisfying the criterion for redundance *r* discussed in Section 5.2 for the conservative logical space: the higher the information content of a theoretical language the higher its explanation potential.

The capabilities of learning and of anticipatory behavior can thus be given a mesoscopic-level identification through the evolutionary changes in degrees of freedom of nanostructures. However, there would be a problem with actually determining a physical macroscopic agency for giving *r* a numerical value in case of those far-from-equilibrium systems that cannot be described through the *"local equilibrium"* concept [13]; this would be surely the case with the flexible nanomechanical hardware made up of macromolecules and supramolecular structures envisaged here, due to the long relaxation times for mechanical equilibrium in long-chain molecules. It is suggested here that the extrapolated values for S(t) could be obtained for such full non-equilibrium condition through the free energy measured by the recent *"Jarzynski's equality"* [14] and its thermodynamic relationships with entropy.

6.2 A Basic Look at Mesoscopic Nondissipative Logic

Nanoscale processes in which dissipation strongly depends on the velocity of relative motion across the hills and cols of the potential energy nanoscale landscape can be envisaged for realizing levels featuring no energy dissipation [15]. *Conservative nonlinear dynamics*, mainly if it involves complex polynomial potentials, in spite of the very simple structure of the nano-oscillators will generally show a very complex behavior. Syntactic information processing thus occurs. If a point of instability exists, with bifurcation and possibly chaos, a mean field approximation is no longer valid. A given level in the hierarchy can give rise to novel levels or to full chaos which would be equivalent to broad-band noise, down to a loss of statistical correlations that amounts to the acquisition of the degrees of freedom of the level underneath in the level hierarchy.

This would mean the mixing of the two levels and destruction of their *logical modalities* with respect to the oncoming time series of signals, from the environment or from any other level. *"Intermittency"* might also set in, with regular or periodic behavior interrupted by chaotic bursts; far from bifurcations, i.e. in the mean field regime, cross-correlations with signals from a level underneath or from the environment would be possible, with formation of *collective properties* (*"abstraction"*). For instance, a meso-scopic embodiment might be realized according to these lines of the so-called *"hyper-incursive machine"*, which is based on recursive bifurcation leading to chaos and order-to-chaos repeated transitions and is discussed in [16].

7 Conclusion

Grasping the biomimetic evolutionary character of an automaton, which is rooted in the closed chain

syntax ↔ semantics ↔ pragmatics

whose embodiment relies on its chain of

sensing – information processing – actuating

as a *biomimetic hardware-wetware* made up of nano-to-micro integrated members, and whose activity can give rise to the empirical and theoretical languages dealt with above, requires renouncing any *reification* of the **single members** of the chain. Here reification is meant in Mahner & Bunge's sense [17] *"Reification is the incorrect conception of properties, relations, or concepts as entities having* ***autonomous*** *existence. ... Examples are the structuralist idea that structures precede the corresponding structural things, or that* ***processes*** *are detachable from, or prior to,* ***things*** *– a well known tenet of* ***process*** *metaphysics."* Indeed, biomimicry, like e.g. the evolutionary character of any system, implies the mimicry of biological *structure-function* ultimate solidarity. Accordingly, as to the Steinbuch-like anticipatory dynamics of empirical and theoretical languages, which consists of evolutionary processes, the grasping of the *essential difference* between the empirical and the theoretical language means not to reificate the process of applying standard Information Theory to the case when its basic hypothesis of an already formed inventory of marks is valid, i.e., once both languages are formed, so that a *static, time-frozen set of abstract marks* can be identified, and finite models and finite sets of boundary conditions can be set forth to deal with the equations as relative. Indeed, this moment comes from a dynamic self-organization activity, whose repre-sentation both in the logical and the thermodynamical (or, more generally, physical) space shows the larger *evolutionary power* of a theoretical language with respect to the corresponding empirical language, so stressing their **essential** physical outcomes. Such representation also allows their interaction dynamics to be investigated, and supplies a physical characterization of *purely syntactic* processes, like those going on in Artificial Intelligence systems, whose "intelligence" shows thus essentially different from biological intelligence. Moreover, the genuinely biomimetic capabilities of **"learning"** and of **"anticipatory behavior"** can thus be given a molecular-level identification through the evolutionary changes in degrees of freedom of nanostructures, e.g. the nanoscale components and devices [18] envisaged for some smart autonomous systems.

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