Electrical ANN Circuits (1-ports) and Schrödinger's "What is Life?"

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Abstract—The motivation for the present work came from the book [1], "What is Life?", in which (Chpt. 6 for details and the Preface) Erwin Schrödinger argues (see http://whatislife.stanford.edu/LoCo_files/What-is-Life.pdf) that the decrease of the entropy, and not the energy supply, is the most important aspect of our feeding (eating). Regarding this stress on the preservation of structure, which is discussed in [1] strongly but intuitively, without any structural entropy defined, we suggest a very simple modeling representing some circuits by means of 1-ports. Using, as in [1], very little of biological information, we apply the algebraic concept of ideal that represents here the preservation of a certain type of the structure, which seems to fit both the growing (or surviving) biological structures, and the "Thevenin contraction" of circuits. We also extend the scope of vision suggested in [1] by observing that our informational "feeding" and "digestion" are not less important than the physiological ones, and if this "feeding" is not proper, or this "digestion" is not possible, this causes health (mental) problems. As the result of this position, the not-understood recent "days of violence" are seen here as an almost natural human response to the information that is given by radio, TV, etc., in such a form that it cannot be normally treated, i.e. it cannot order (or be ordered in) our mind. The volume of the excited part of the brain and the entropy of the logical system treating the information received, are thus strongly increased. This extension of [1] makes the unique outlook on life, suggested some 70 years ago, more adjusted to the problems of modern life, more system-oriented and instructive.

I. INTRODUCTION

Already the simple fact that the logarithmic function appears in the mathematics of entropy shows that entropy is an additive function of the different parts of the system in focus and thus of the space (volume) occupied by the system. This makes, in principle, entropy relevant for description of different spatial structures that sometimes are homogeneous and simple. It is difficult to directly define "structural entropy", but we are motivated by the creative thought of Erwin Schrödinger, insisting in [1] that the most important result of our feeding (eating) is not receiving energy, but negative entropy, i.e. decreasing/limiting the entropy of our body during development the body's inherent structures, or not letting these structures be destroyed. Some molecules are periodically supplied with food to be ordered in the structures. Any destruction, or disordering, or complication (all structural concepts) is associated with increasing entropy, and it is even said in [1], in terms of statistical entropy, that the entropy's maximum [critical complexity would be better] means death. Thus, e.g., the Gaussian bell-shaped (i.e. with the point of the maximum involved) distribution is irrelevant here because for statistical distributions $S = k \ln P$, and maximum of probability $P$ means maximum of entropy $S$, i.e. certain death.

It may be said that, as regards the physiology, [1] answers the question it asks by: "Life is preserving the existing (given) simplicity", while from the more narrow positions of the present constructive attempts, life is correct absorption of correct molecules by the existing structures that grow and survive.

In our opinion, the structural point of view of [1] is a decisive step forward towards some system-theoretic understanding of life. Obviously, this point of view is as relevant for plants as for humans, and in a degree even for crystals growing [this is typical for life] from proper solutions; however, today we have to also consider the needs of high intelligence. The latter is discussed in Section IV as a direct extension of the intuitive argumentation and the line of thought of [1] in the direction of intellectual life seen here as an organic necessity in creation and preserving of some appropriate logical structures of knowledge, having not too high entropy.

First, let us try to define "structural entropy" of a very simple formation via some elementary circuit analogy, using the concept of affine nonlinearity (ANN) and the algebraic outlook introduced in [2].
II. ONE-PORT AS AN "IDEAL": A DESCRIPTION TOOL

Both the ability of a living organism to absorb material from surrounding media without an uncontrollable increase of the bodies entropy, i.e. while preserving its inherent structures, and the possibility of sequential reducing different linear circuits to Thevenin's 1-port [2], can be interpreted as an "absorption" (inclusion in itself) of some elements. Let us try to develop or formalize some such circuit-biology parallelism, by associating this "absorption" with the mathematical "ideal".

By ideal we mean (see also the Appendix in [2] and compare with the precise definition in [3], which employs the usual arithmetic multiplication) a subset $Q$ of a set $P$, such that a defined interaction (e.g. a circuit design procedure) between any element of $Q$ and any element of $P$ becomes an element of $Q$. Writing this interaction of the elements of the sets as the "product" $QP$ (actually, this is $qp$ where $q \in Q$ and $p \in P$, but here we shall write capitals even next to symbol 'e') and assuming that such interaction actually takes place, we express the real processes as the basic "absorbing" feature $QP \in Q$ (see schematic Fig.1) of the ideal. For $QQ \in Q$ (a group operation) the process is most simple for the circuits, but for the biology only $Q(P \setminus Q) \in Q$ should be relevant.

Fig. 1: The basic feature of ideal is interpreted as absorption of the "surface"-formations $QP$ by the set $Q$, i.e. the fed biological structure grows from the new molecules taken from $P$. On the circuit side, $Q$ means "Thevenin contraction" (Fig. 2 and 4) of some linear (with external sources) formations $P$, or $QP$.

Let set "Q" include simple structures associated with Thevenin's equivalent. Actually, the form of the Thevenin's equivalent is kept in our mind, and this information (not only the very hardware realization), semantically, also belongs to "Q". However, the "memory" of the live body regarding its structure is based only on the existing structure. Thus, a first structural element (the "instructing branch") in the parallel connections of Figs. 2 and 4, is needed, as representing the structural code of $Q$.

Remark 1: That some information about $Q$ is needed for the decrease of the entropy is just as with the known intellectual action of "Maxwell's Demon" in the field of statistical entropy. Our circuit-designer, simplifying the structures and thus decreasing the structural entropy as (Fig.2→Fig.4), can be named "Thevenin's Technician".

Remark 2: We have chosen $Q$ and $QP$ to be parallel connection, since this connection seems to be most relevant to the basic physical interactions (via molecules' fields giving the information) during the creation of a biological structure. However, some other circuit structures could also be considered for a modeling using a unique feature of 1-ports. Namely, since each branch is also a 1-port, some recursive, fractal 1-port topologies and structures [4] can be easily created. This could imitate the action of a genetic code, or self-reproduction of a structure.

While on the circuit side, for performing $QP \in Q$ we already have to have some $Q$, -- that in the left-hand side of the inclusion $QP \in Q$ (see Figs 2 and 4), also on the biological side we see $Q$ as some given structure into which the material particles one receives by eating have to be properly included.

Existence of the "ideal" is equivalent to the possibility of growing, in each case.

III. ON THE PROTOTYPE FOR A "STRUCTURAL ENTROPY"

By itself, the initial joining of a material particle, received by eating, to a biological structure (meaning, in the modeling, extending a circuit) makes this structure more complicated and increases the entropy.
The food has to be such that the body could reasonably quickly simplify this overall structure by including the added particle into the already existing structure. (Then, in the model-system, no external source(s) are present.) Simplifying (ordering) the whole construction, this inclusion decreases the entropy. See Fig. 3 illustrating the whole process.

Consider the circuit of Fig. 4(a) which is the n-branched, "healthy" (i.e. absorbed by Q) continuation of the configuration of Fig. 2.

![Fig. 3: S(t)](image)

Fig. 3: $S(t)$

Fig. 4 (a,b): The simple parallel "structure" as Q. See eq. (1), for $E_o$ and $R_o$ such that (b) is, as a 1-port, equivalent to (a). If $E_{Thk} = E$ and $R_{Thk} = R$, $\forall k \in (1,2,...,n)$, then the affine nonlinearity defined by eq. (2) is (see (3)) proportional to $n$, i.e. can represent the entropy of the structure, which justifies our focus on this nonlinearity. It needs to be stressed that the "structure" in focus is (a), while (b) $(QQ \subseteq Q)$ represents $Q$.

It follows from Kirchhoff's laws, that if in Fig. 4

$$E_o = \frac{\sum_{k=1}^{n} (E_{Thk} / R_{Thk})}{\sum_{k=1}^{n} 1 / R_{Thk}}$$  \hspace{1cm} (1a)

and

$$R_o = \left( \sum_{k=1}^{n} 1 / R_{Thk} \right)^{-1}$$  \hspace{1cm} (1b)

then, as the 1-port, circuit of Fig. 4(b) is equivalent to circuit of Fig. 4(a). If all the sources in Fig. 4(a) are similar, equal to some $E$, and also all the resistors are similar, equal to some $R$, then, in this homogeneous case, (1) gives $E_o = E$ and $R_o = R/n$.

Let us define quantitative affine nonlinearity as

$$ANN^e = \frac{E}{R_o},$$  \hspace{1cm} (2)

i.e. as the ratio of the nonlinear (constant) term of the characteristic $v(i) = E \pm R i$ to the linear term, for some standard value $i_o$ of $i$. Then, for Fig. 4(b), in the "homogeneous" case of the similar branches in Fig. 4(a):

$$ANN^e = \frac{E_o}{R_o} = n \frac{E}{R_o} \sim n. \hspace{1cm} (3)$$

For $n \to \infty$, we have $R_o = R/n \to 0$, and Fig. 4(b) becomes only the battery $E$, whose voltage is completely independent of the current. In this case, the asymptotically infinite extreme $ANN^e$ means nonlinearity of the battery (or a voltage hardlimiter).

Qualitatively, these conclusions around (3) remain correct also in the non-homogeneous case.

To define a "structural entropy" for this simple model, we have to consider that the branches (identical or different) in Fig. 4(a) can be in any sequential order, which introduces the factor $n!$ of the statistical realization of $Q$. Since for $n \gg 1$ the factor $\log n! \sim n \log n \sim n$ reflects the usual additivity of entropy with respect to the physical volume occupied by the system, one should consider whether or not $ANN^e \sim n$ could characterize some entropy as $S \sim ANN^e$.

However, we have to further explain why the position of [1] is so important.

IV. THE "STRUCTURAL-ENTROPY" OUTLOOK OF [1] APPLIED ALSO TO "INFORMATIONAL FEEDING"

Our life, to be simply described, as Schrödinger wanted, is not only the processes like food digestion associated with an intensive energy conversion and purposed to be physiologically healthily conducted by the body. Our ability to treat ("digest") the information is as important for our mind, as our ability to digest food for our body, and keeping the correct structure of thinking with a not too high entropy, is much more important for us than receiving a lot of information (compare the latter to intensive energy supply in the physiological case). It is well known to teachers what the correct informational feeding is, but the general actual situation is not good, and the extension of the argument of [1] in the...
direction of human intellect is not only legitimized, but also timely.

Indeed, the numerous existing (not our) interests supported by information means (radio, TV, Internet, etc.) fill our minds with much "gossip" often causing us to worry. The present opinion is ([5], however, gives a deeper discussion) that the recent, not understood "days of violence" are a result of missing by the society the point of "correct informational feeding", and the defined hooligans exhibit, in fact, a normal human wish to destroy the media/society that make their thoughts disordered, increasing the entropy of the thinking/logical system. Of course, low entropy of the system is necessary for one to remain "alive" in the sense of normal coexistence with the information media, which includes, in particular, the ability to communicate with one's mother or child.

The importance of the information being received is not most essential here. The point is the change in the complexity (entropy) of the logical structure of the work of the excited part of the brain, and in the needed space for this excited part. The received signal increases entropy; the logical treatment decreases it. The correctly presented information has to be such that we are able to treat it and internalize it, i.e. to extract it from our general perception of the received signal. We should not receive the information without this extraction, i.e. without correctly connecting the new knowledge with what we already know, just as when a physical structure is created, as was discussed. We "organically" need information in order to treat ("digest") it; this is also "life", some basic "physiology" of our logic, which will be never changed. Radio, TV, etc., have to learn how to make the information they want to record in our minds treatable for many. Thus, some proper pedagogical and psychological censorship or supervision, at a level that might be compared to that of the medical control of the usual feeding, has to be applied by the editors. In our opinion, this argument directly follows from the motivating book [1].

For a definition of the entropy of the logical system, work [6] should be relevant. One sees that the logical complexity (entropy) of such a system should very quickly increase with an increase of the number of inputs. However, today, electrical brain activity can be experimentally measured, e.g. [7], and our reaction to broadcasting, etc., i.e. our "digesting" of the actually given intellectual "food", can and should be carefully studied.

V. CONCLUSIONS

1. We tried to connect, via the concept of structural entropy, the basic physiology as it is discussed in [1], with the basic circuitry. It was interesting to observe that the criterion of complexity/entropy can be connected with affine nonlinearity [2]. One notes that not just the simplest $E-R$, also the $E(s)-Z(s)$ circuits might be similarly considered for a modeling in the domain of the Laplace variable. As well, the given modeling might be also extended from the ohmically-resistive/conductive circuits/structures to the magnetic and dielectric circuits/structures, with the proper sources.

2. We argue that the position of [1] associated with the concept of structure is relevant not only for physiology or botany, but also for human psychology that also is our "life" to be explained. We thus try to understand the real causes for the problem of the organized hooliganism of the "days of violence", thus trying to contribute to solving this problem by suggesting making the work of the informational means more scientifically based (and thus more humane). Hopefully, a system science researcher, concerned with the society life and dangers, can appreciate this.

REFERENCES