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ON A NEW POSSIBLE CLASS OF CELLULAR NEURAL NETWORK

BY

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Abstract. In this paper, an overview concerning natural and artificial information (its generation, storage and transmission mechanisms) is intended.

Keywords: information; cellular neural network; human brain; fractal logic.

1. Introduction

Conventional digital computation methods have run into a serious speed bottleneck due to their serial nature. To overcome this problem, a new computation model, called Neural Networks, has been proposed, which is based on some aspects of neurobiology and adapted to integrated circuits. Neural Networks is a field of Artificial Intelligence, where we - by inspiration from the human brain, find data structures and algorithms for learning and classification of data. Encouraging impressive applications of neural networks have been proposed in optimization, linear and and nonlinear programming, associative

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memory, pattern recognition, computer vision (Karayiannis & Venetsanopoulos, 1993; Chow, 2007; Slavova, 2003; Ivancevic & Ivancevic, 2007).

A class of locally coupled neural networks, called Cellular Neural Networks (CNNs) were introduced (Chua & Yang, 1988a; Chua & Yang, 1988b), as a novel class of information processing systems, which possesses some of the key features of neural networks (NNs) and which has important potential applications in such areas as image processing and pattern recognition. Like a neural network, it is a large scale nonlinear analog circuit processing signals in real time. Like a cellular automata, it is made of a huge aggregate of regularly spaced circuit clone, called cells, communicating with each other directly only through its nearest neighbor. Cellular Neural Networks share the best features of these two worlds.

One of the most impressive features of artificial neural networks is their ability to learn. Although simplified, artificial neural networks can model this learning process by adjusting the weighted connections found between neurons in the network. This effectively emulates the strengthening and weakening of the synaptic connections found in our brains. This strengthening and weakening of the connections is what enables the network to learn (Karayiannis & Venetsanopoulos, 1993; Chow, 2007).

In this paper, we shall highlight the way in which a new logic (called by us *fractal logic*), can be induced in order to mimic the genetic code. Practically speaking, we discuss about a new class of cellular neural networks.

2. Results and Discussions

2.1. On Information and Wave-Corpuscle Duality

In Scale Relativity Theory, the dynamics of any physical complex system (as the human brain is) is described through variables which can be expressed through fractal functions, that is, functions which are dependent both on coordinates and on time, but also on resolution scales. Moreover, any quantity can be written as the sum between a differentiable part, *i.e*., dependent both on coordinates and time, but also on the resolution scales (Nottale, 1993; Nottale, 2011). In such context, the differentiable part is proved to be compatible only with the predictable states of the physical system, while the fractal part is proved to be compatible only with the unpredictable states of the same physical system.

The postulate through which motions are introduced on continuous but non-differentiable curves (fractal curves) solves this problem of the straight and uniform motion, meaning that on the new fractal manifold the motion is free (on geodesics). By accepting such postulate, on the basis of the model of Scale Relativity Theory, it results that the geodesics of a fractal space-time support a double representation, a stochastic, unpredictable one, described by Schrödinger

type equations and specific to the wave character, and at the same time a deterministic, predictable representation, through the fractal hydrodynamic model, which is specific to the corpuscular character. In Schrödinger's representation, only the module of the square wave function has physical significance, while in the second case we talk about average movements of some fluid particles which are submitted to a datum force, a force which is induced by the unpredictable part (non-differentiability of the motions curves) (Heisenberg, 1949).

Non-predictability, described through the non-differentiability of motion curves can be related to a Shannon-type fractal informational entropy (Weaver & Shannon, 1963; Shannon, 1948), which, based on a maximization principle, leads to an egalitarian uncertainty principle. Within this uncertainty principle, the interaction constants are specified on the basis of an Onicescu-type informational energy (Agop *et. al*, 2015; Agop *et al*., 2014; Onicescu, 1966). We mention that only the constant value of the Onicescu informational energy settles the interaction constants within the uncertainty relations. Through the maximization principle, the integrally invariant functions are simultaneously probability density and movements on constant energy curves. Practically speaking, through the principle of informational maximization, the unpredictable, wave character given by the probability density is linked to the corpuscle character given by the energy. The unpredictable part must be directly correlated to non-differentiability and it is manifested through the existence of a potential, also called fractal potential. The principle of maximization of the informational energy gives a concrete form to the force field. As a result, the informational energy not only stores and transmits the information through interaction, but also connects it directly to the deterministic part through interaction. So, practically speaking, the owner of all "mysteries" is the fractal potential, which imposes the intelligent, fractal environment and the informational energy which gives strength.

As above-specified, on the basis of the non-predictable component, one can define a fractal entropy in Shannon's sense and, starting from here, a fractal informational energy in the sense of Onicescu. By using a maximization principle of fractal entropy in Shannon's sense, one can demonstrate that, if the fractal informational energy in Onicescu's sense is constant, then the ratio between the corpuscle energy and the frequency of the associated wave is a constant at any scale resolution. Quantification at any scale resolution is thus induced. Particularly, for motions on Peano curves (of fractal dimension $D_F = 2$) and for Compton scale, the usual quantification is obtained, a situation which corresponds to quantum computers class.

2.2. Computational Models Inspired by Human Brain Neuronal Networks

Complex systems theory enables a holistic approach concerning brain structure and human brain functions. Many phenomena with complex patterns and structures are widely observed in the brain. These phenomena are some manifestations of a multidisciplinary paradigm called emergence or complexity. They share a common unifying principle of dynamic arrays, namely, interconnections of a sufficiently large number of simple dynamic units can exhibit extremely complex and self-organizing behaviors (Jackson, 1992; Stonier, 1990; Yockey, 1992; Wicken, 1987).

Artificial neural networks are inspired by the biological nervous system, in particular, the human brain. One of the most interesting characteristics of the human brain is its ability to learn. We should note that our understanding of how exactly the brain does this is still very primitive, although we do still have a basic understanding of the process. It is believed that during the learning process the brain's neural structure is altered, increasing or decreasing the strength of its synaptic connections depending on their activity. This is why more relevant information is easier to recall than information that has not been recalled for a long time. More relevant information will have stronger synaptic connections and less relevant information will gradually have its synaptic connections weaken, making it harder to recall.

The increased availability of computing power has not only made many new applications possible but has also created the desire to perform cognitive tasks which are easily carried out by the human brain. It become obvious that new types of algorithms and/or circuits were necessary to cope with such tasks. Inspiration has been sought from the functioning of the human brain, which led to the artificial neural network approach. One way of looking at neural networks is to consider them to be arrays of nonlinear dynamical systems that interact with each other.

The highly interdisciplinary nature of the research in CNNs makes it very difficult for a newcomer to enter this important and fascinating area of modern science. This permits the mathematical modeling and analysis of networks of neurons from the viewpoint of dynamical complex systems.

Under certain restrictions, cellular neural networks (CNNs) come very close to some Hamiltonian systems, they are potentially useful for simulating or realizing such systems. They show how to map two one-dimensional nonlinear lattices, the Fermi-Pasta-Ulam lattice (1965) (Chua & Yang, 1988a; Chua & Yang, 1988b) and the Toda lattice (Toda, 1981; Toda, 1983), onto a CNN. For the Toda lattice, they show what happens if the signals are driven beyond the linear region of the piecewise-linear output function. Though the system is no longer Hamiltonian, numerical experiments reveal the existence of soliton solutions for special initial conditions. This interesting phenomenon is due to a

special symmetry in the CNN system of ordinary differential equations. If one is only interested in the signals associated with Hamiltonian systems, and not in conserving the energy in individual circuit elements (nonlinear inductors and capacitors), then such systems can be built as analog circuits, which implement some signal flow graphs.

Considering that the nervous impulse transmission through brain neuronal network is achieved on continuous but non-differentiable curves, in Scale Relativity Hydrodynamic variant (with constant arbitrary fractal dimension), "information" (through states density) is "stored" and "transmitted" by spatial-temporal cnoidal modes. These modes can be assimilated to a one-dimensional Toda network and by mapping, to a cellular neural network. Cnoidal modes double periodicity generates differentiable-non-differentiable Toda pair and further by mapping, differentiable-non-differentiable cellular neural network pair. In such conjecture, a topological method can be applied since the admissible number of fractal kinks (cnoidal modes degeneration for the case of non-linear "functionality" regime) is determined by the topological properties of the symmetry group associated to the differential equation of these modes. In this way, two distinct states are thus established for each of the components of the pair. This induces in total four distinct states, as stipulated by the human genetic code. These four distinct states could substantiate a new type of logic, which we call *fractal logic*.

Pairs' coherence specifies that information's "storage" and "transmission" is achieved by specific algebraic languages.

Unlike the electronic calculator which has a hard structure divided by artificial algorithms, the spectral component corresponding to the hardware particles, has the same artificial behavior, without having the fractality of the natural development. As a result, there is no consistency between the cellular network of the substance and the spectral one. The development of the neural network is performed according to fractal criteria, the same as for all the other parts and systems of the human body. Consequently, the spectral field created by the undulation of the particles of the neural network is consistent, allowing the information to be processed inside the neural network and also in the spectral field (Hilbert space), where there are the a-spatial and a-temporal components which enable the memory and also the complex component that allows the possibility of multidimensional processing which can explain the superior psychic processes, the conceptualization, the semantics, the abstracting.

Therefore, at any scale there are the two types of realities that coexist, the differential one and the non-differential one, highlighted by the hydrodynamic and stochastic theories. Another major difference between the electronic calculator and the human brain is the analogical feature of psychic processing, unlike the digital signal processing. Analog signal processing is enhanced by the topology configuration character of the processing, being not only a numeric processing, but also one determined by the geometric topology.

2.3. Information as an Expression of Topological Transformations

Related to the above statements from the previous section, "topology" proves to play a fundamental role in the definition of a fractal logic, so, the paradoxes highlighted by quantum mechanics in the first half of the 20th century include, apart from the uncertainty relations (Heisenberg, 1949), a strange involvement of the observer in developing quantum phenomena. The Copenhagen school avoided to attribute a significance to these observations, but today they must be researched also from a philosophical and methodological aspect. Anyway, these facts suggest that the splitting into subjective and objective information is artificial and that they should be regarded as aspects of the same phenomenon. In order to uphold this idea, we must take into consideration another paradox of quantum mechanics, which is just as exciting and linked to the entanglement phenomenon, which, as a result of repeated experiments, highlighted a reality which is hard to infer, that is, that all the particles which interacted at a certain point remain connected.

All these paradoxes that quantum mechanics imposed, along with the wave-corpuscle duality, determined a new approach in physics, mathematics and in the scientific approach in general. If during the 20th century it was studied from the elementary particles' point of view, of the wave component from the spectral viewpoint and materially under the form of substance and energy, the information was not treated at its true value, according to the role it has in quantum mechanics. The information technology era, as well as the complex systems theory, with the chaotic aspects in which information has a potential character, but which explains the dynamic evolution patterns of the system which is highlighted in the phase space, have imposed the comeback on the role of information at quantum level. An analysis of the particle behavior in the wave-corpuscle duality can be regarded from the fractal space-time perspective, with the unpredictable and non-linear evolution, allowing that, on the basis of Shannon's information theory (Weaver & Shannon, 1963; Shannon, 1948) we connect it to entropy and further to informational energy in the sense of Onicescu. There still remains an essential question: where can we search for and find the information in this quantum dynamics. It must be present both in the wave structure and in the particle properties. This connection cannot be made otherwise than in the phase component of the wave, which is to be found in the spinning of the particle and which allows for the transfer of information from the spectral reality to the corpuscle one, as the Fourier transform demonstrates. The phase is given by the magnetic component of the electromagnetic field and represents the unpredictable, potential part, described by the complex function of Schrödinger's wave formula, as these characteristics can be explained both through the fractal theory and through the topological transformations supported by the phase from the electromagnetic wave, respectively by the spin from the particle description.

Complex numbers proved to be the most suitable in describing the rotation movement around its own axis, but this model is a dynamical one, which supports transformations at the level of topological dimension through successive passage from the topological dimension 0 (of the point) to the topological dimension 1 (of the line) etc. The dimensional dynamics, from 0 to infinite, which is realized in our reality up to 3 dimensions, can be performed multi-dimensionally in the complex field of psychic reality (through the fractal potential).

Thus, an infinite dimensional complex space is organized, which explains the difficulty of highlighting the informational component. The successive passage through the Euclidean, fractal and topological dimension determines a quantitative but also qualitative dynamics of energy. The moment this qualitative diversity is expressed, is given by the moment of topological transformations at every level. This practically-unlimited diversity provides also quality along with quantity to energy in its dynamics. From the complex systems theory perspective, we can find in the above-described phenomena the main characteristics specific to complex systems: non-linear dynamics, fractal geometry, with a potential latent informational energy, along with a dynamics of a practically-infinite diversity, obtained through topological transformations within the complex space of the phase. In this sense, Stoica *et al*., 2015; Duceac *et al*., 2015a; Duceac *et al*., 2015b; Doroftei *et al*., 2016; Nemeş *et al*., 2015; Postolache *et al*., 2016; Ştefan *et al*., 2016 presented consequences of topological transformations in biological systems.

The topological transformations are not dependent on scale; they have the same qualitative information, no matter what the reality level is, which makes the information ubiquitous, just as the substance and energy both at microcosm level and at macrocosm level.

3. Conclusions

Information represents codified energy which is expressed under the form of patterns, structure patterns, initiated by attractors which activate in the phase space, between the chaotic and the structured part. The information is stored in the spectral space and expresses the patterns in the structure of atoms, molecules, macromolecules and cells. It has a potential existence which is expressed through substance and energy in certain conditions of local coherence. Information is to be found in the complex space of the spectral field of the wave phase. As a result, this complex space is everywhere and at any level of reality. The space of physical reality is intertwined with the complex space generated by electromagnetic waves. From the mathematical viewpoint, this space is infinite dimensional as it may contain the whole information in the Universe. At quantum level, this overlapping is done through collapsing the wave in the complex space of the wave phase level and it is transmitted to the

complex space of the spin rotation, thus transferring the whole information. This phenomenon is specific to the reality from the level of the whole cognoscible Universe, as electromagnetic waves exist anywhere and also at every level of the reality, including the human brain. Thus, the brain has access both to the real and the complex space, as it manages to become aware both of the physical reality through analyzers and instruments, which are the prolongation of analyzers, but at the same time to become aware of the complex reality which represents a source of creation, inspiration and knowledge, beyond what is offered to us through the perception of analyzers.

In this sense, various dynamics imposed by means of information on the biological systems were recently given by Duceac, 2015; Duceac *et al*., 2016; Păvăleanu *et al*., 2016; Velenciuc *et al*., 2016; Duceac *et al*., 2017.

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ASUPRA UNEI POSIBILE NOI CLASE DE REȚELE CELULARE NEURALE

(Rezumat)

În această lucrare, realizăm o prezentare de ansamblu asupra subiectului informației naturale şi artificiale (sunt vizate mecanismele de generare, stocare şi transmitere).