# Fuzzy More-Equal-Less Logic and Closed-Loop Coding-Decoding Control Semantics in Bio-Systems and Nanoinfotechnology

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**Abstract**
The aim of this paper is to show that informational control in bio-systems is possible only through the use of closed-loop coding-decoding (CL-CD) and that CL-CD is a common feature of all organized systems that induces the birth of semantics. The analysis of the nervous systems research data shows that the coding and decoding procedure uses not a binary logic, but specific logic based on the "more-equal-less" (M-E-L) principle. It is likely that similar coding principle is used in molecular signaling structures (cells and hormonal subsystems of organisms) and that the implementation of this is a kind of nanoinfotechnology. Non-categorical M-E-L logic is similar to fuzzy (*Zadeh*) logic and may be used for explanation of neurobiological and neuropsychological facts through systemic (holistic) functional organization of the nervous system and of new neuroinformational and nanoinfotechnological ideas.
**Keywords:** fuzzy neural network, "more-equal-less" (M-E-L) logic, closed-loop coding-decoding control (CL-CDC), semantics, nanoinfotechnology

## 1 Introduction

Technological Singularity concept brought up by Vernon Vinge (1993) [1] and developed by Ray Kurzweil (2005) [2] requires looking to the living world and its evolution as a kind of technology and its evolution. From this viewpoint the living systems are the natural technological systems. The development of traditional technical engineering and technologies may be explained as a general continuation of the development of the natural biosystems, produced by human brain that is a product of biological evolution.

It seems at first glance that both the natural and artificial technological systems have the same principles of the functional organization (the same functional scheme and logic). Bio-systems at organism level and at lower levels use different material structures (for example neural nets at organism level and molecular nets at cellular one) but they are the same at the functional level.

In search for the general principle of life organization, H. Maturana and F. Varela (1974) [3] raised the concept of *autopoiesis* (self-production) as an initial functional hypothesis. From this point of view life is self-producing technological system too. Technology is a broad concept that deals with tools and techniques as a whole for purposive mass serial transformations and production of matter (chemical or material technologies), energy (physical or energy technologies) and information (information technologies). Life in short time periods is a perpetual use and reproduction of natural (biological) technology, and the life in long terms is a perpetual evolutionary adaptation (through darvinistic processes by natural selection) of these technologies as a reaction to biotic and abiotic changes of environment. The life as a system is a whole of different organized complex technologies.

The latter reasoning reveals a need for an integrate life and technology science with expanded concept of technologies. The paradigm of this possible and necessary science would be based on organized systems theory. It is evident that life (functionally organized purposeful systems) is in principle different from non-living (non-organized) systems. The last systems are fully explained by physics and chemistry only – by laws explaining energy conversions and chemicals-matter transformations; these systems are properly interpreted as the traditional isolated thermodynamic systems where energy conservation and entropy increase laws work. Meanwhile, the living system is characterized by decreasing entropy or increasing of organization, which is qualitative leap in the evolution systems complexity with new technologies. Biosphere and human society (noosphere) may be represented as systems of natural and artificial technologies respectively. The biological species may be regarded as a natural technological system that lives, adapts and self-reproduces using the existing environmental resources. In biosystems of all hierarchical levels starting from cells, it is possible to allocate two, essentially different, but functionally closely interconnected natural biotechnologies: (a) material-power transformations subsystem (controlled subsystem) and (b) informational control subsystem (controlling subsystem).

Technology as a phenomenon appeared on the Earth 3-4 milliards years ago, when life (information, control, complexity and adaptivity) originated. The first technology was formed when material-power transformations and information control merged to purposeful closed-loop coding-decoding. The initial technology was based on genetic informational control and enzymatic material conversion principles. This point of view allows to interpret biological evolution as natural engineering, natural technical and technological development of biosphere. Parallelism of natural (biological) and artificial (technical) technologies is seen in such field as bionics/biomimetics.

Here concept of bio-systems as a natural technology organized on the principle of Closed-Loop Coding-Decoding Control (CL-CDC) semantics is presented. The CL-CDC concept is based on the following theories: John von Neumann' self-referring automata (1952) [4], Haviera H. Maturana and Francisco J. Varela' self-reproduction (1974) [3], James G. Miller living systems (LST) (1978) [5], Hainz Foerster' eigenbehavior and self-organization (1977) [6], Robert Rossen' concept of modeling relations (1985) [7], William T. Powers' perceptual control (PCT) (1973, 1989) [8, 9] and Howard H. Pattee' self-organization semantic closure theories [10]. The aim of the study is to reveal and formulate the general principle of functional organization and logic of the living systems and to put the biological data to systemic-graphic schemes.

The serious consideration has been paid to the information coding-decoding and control concept, as the essence for systems of natural and artificial technological procedures. The aim of this paper is to show that informational control in biosystems is possible only through the use of closed-loop coding-decoding (CL-CD) and that CL-CD is a common feature of all organized systems that induces the birth of semantics. The analysis of the nervous systems research data shows that the coding and decoding procedure uses not a binary logic, but a specific logic based on the "more-equal-less" (M-E-L) principle. It is likely that similar coding principle is used in molecular signaling structures (cells and hormonal subsystems of organisms) and that the implementation of this is a kind of nanoinfotechnology. Non-categorical M-E-L logic is similar to fuzzy (*Zadeh*) logic and may be used for explanation of neurobiological and neuropsychological facts through systemic (holistic) functional organization of the nervous system and of new neuroinformational and nanoinfotechnological ideas.

## 2 Organized or Closed-Loop Coding-Decoding Control System

The life as organized system originated when the closed-loop coding-decoding (CL-CD) functional structure composes and which determine the semantic encoding or purposeful control of the technological procedures emerge CL-CDC scheme that reflects essence of functional organization of living systems facilitates holistic understanding of life. Concepts of R. Rosen *modeling relation* are joined in CL-CDC scheme as an adaptation to explain activities of biological and social organizations.

### 2.1 Closed-LoopCoding-Decoding System

According CL-CD scheme the material system **M** of real world sphere may be represented by encoding (coding) procedure on the virtual (abstract, mathematical, formal, computer) world sphere or subsystem **V** as model of **M.** Model or formal system **V** operates with special rules (Fig.1). The coding procedure corresponds to observations, measurements, analysis, representations or reflections. Accordingly, the decoding procedure is de-reflection or synthesis of material system **M** under control of model in virtual or formal system **V**. The decoding accompanies procedures of interpretation, control, prediction, synthesis and anticipation.

***Coding*** (*encoding*) should be understood as a reflection of a real system (nature or a technological process) in an abstract virtual form on ***memory*** structures (DNA, hormones, neural networks, programs, books, *etc.*) in such from the abstract to real would by possible. The coded reflection in the memory is a model or a technological project of the real system. This model or a coded representation for control is the essence of information. Decoding is the realization of such a project or control of biotechnological procedures according information. In the process of decoding, the activated coded states of the memory structures or the projects for synthesis of reality are reflected in the dynamic states of the real world, real structures of body, *etc.*

Full closed-loop coding-decoding system consists of partially autonomic complex organized systems. There are genetic, hormonal, neural, psychical, social, robotic organized systems in the world. Dualistic material↔information equivalence manifests itself in these organized systems: signal↔information; phenotype↔genotype;

body↔soul; brain↔thought; hardware↔software; biosphere↔noosphere; social group↔management; state↔government.

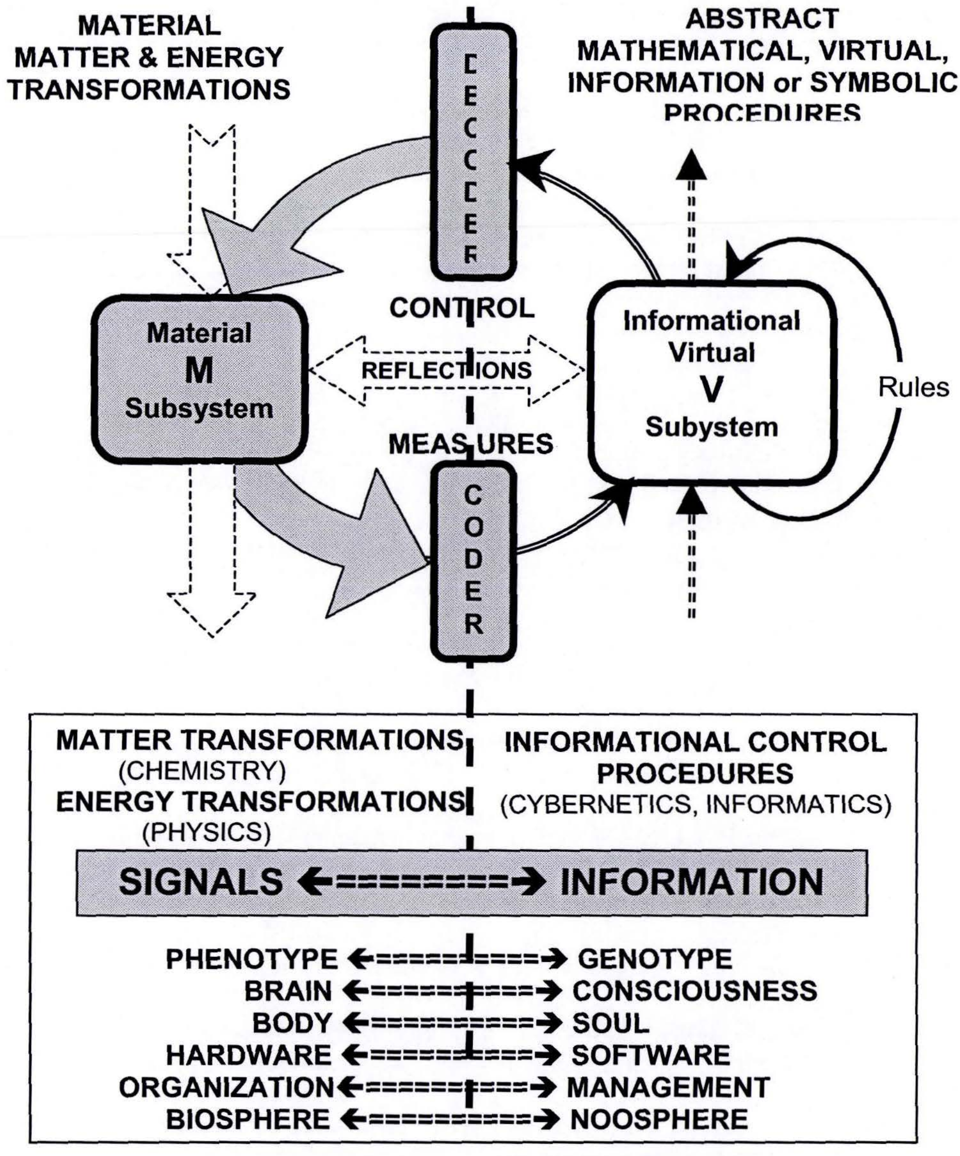



**Figure 1:** The paradigmic scheme of the organizationally closed, matter-energy-information open by closed-loop coding-decoding (CL-CD) organized systems

The systems that function according these principles are organizationally closed and informational open. Organizational closeness causes the functional compatibility of coding-decoding and functional sense (semantics) of coded reflections. Informational openness means ability to joint additional information about environment to pool of existing world models ("informational metabolism" in analogy of mater and energy conversion).

It is undoubtful that most elaborated control systems are a part of functional structure of biological organisms, because they are the result of natural evolution that developed these technologies during millions years of life history.

The systems developed by man are much more primitive and simple ones in comparison with biological systems. So it is interesting to sketch the structure of functional organization of biological organisms

## 2.2 Living Organized Systems

The living system as an organized system includes two functionally different subsystems: the controlling one (a controller) that processes the information and the controlled one that carries out transformations of matter and energy for goal-oriented actions. The controller of cell consists of genes, and the controller of multicellular organism is augmented by hormonal regulation (and animal's controller has a nervous system, in addition) (Fig. 2). In animals, this three-level structure of control linked by internal and external feedbacks to the environment forms a hierarchically organized closed-loop coding-decoding system. Coding- decoding processes multiplication of discreticaly coded genetic project of the organism are essential in reproduction of organisms. Biotechnology of reproduction becomes a rather steady bioinformation technology.

Many phenomena of living nature could be explained in the best way by using the terms of information technologies, and they in are connected with coding-decoding procedures:

1. Spores and seeds are carriers of biotechnological programmers or projects of future organisms loaded with initial supply of necessary substances and energy. The essence of the existence of plants, fungi and animals are replication, improvement and spreading of these projects.

2. Sexual reproduction (recombination) is the diversification of these programs or projects.

3. Adaptive modifications are alternatives of programs realization.

4. Gene engineering is a purposeful insert of new individual components to the genetic programs.

5. Apoptosis is programmed cell disintegration that is necessary for most effective dismantling of some parts of organism.

6. Organism's morphogenesis is carried out under the informational control that uses hormonal signals.

7. The influence of pheromones on behavior of insects is an example of the action of informational programs by special extra-organismal signal molecules.

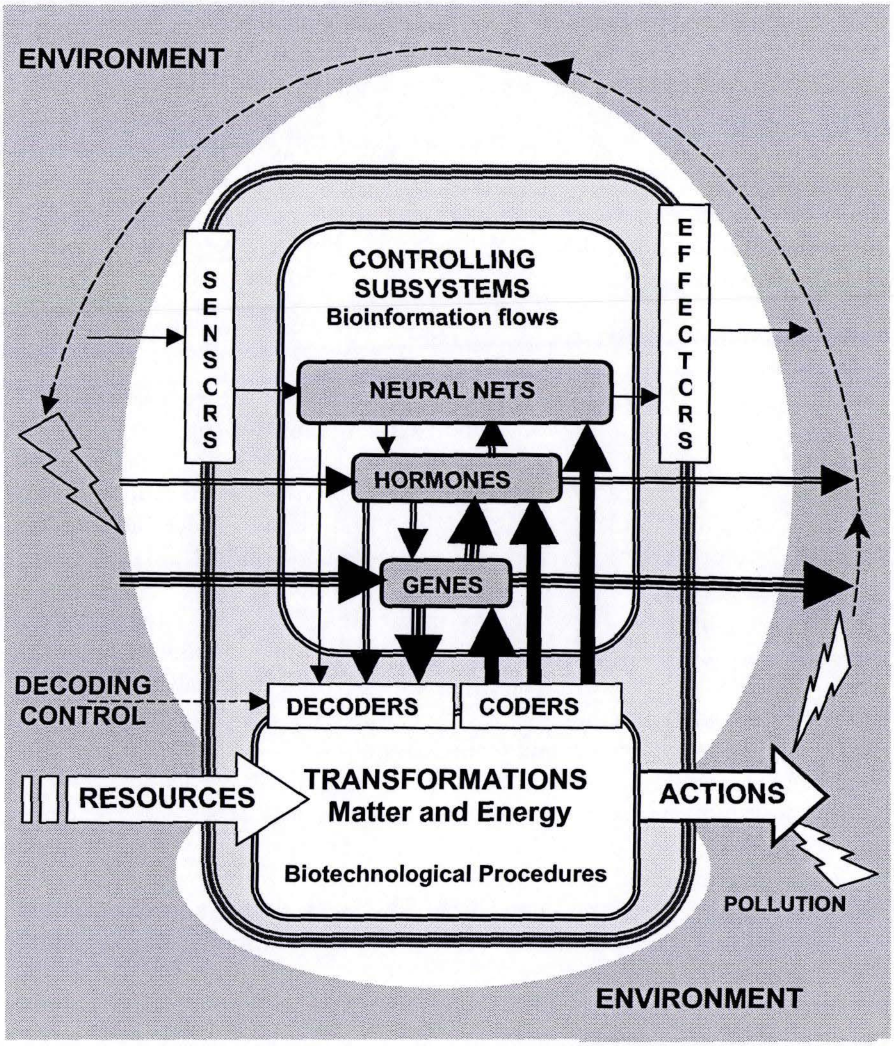



**Figure 2:** The animal as hierarchically organized closed-loop coding-decoding control (CL-CDC) system

8. Activities of the nerve system that determine the behavior of animals are the obvious products of information technologies.

9. Repetition of phylogenesis in ontogenesis (biogenetic law or theory of recapitulation) is an example of persisting evolutionary old programmes (an illustration of the evolution of information coding-decoding procedures).

Hormonal coordination of activities of multicellular organism can be explained in terms of agent theory as selective receiving of molecular signals, processing of their information, and decision-making for action. It is the activity of the coding-decoding systems. The more dynamic control of multicellular animal is carried out by the complexes of nerve cells, neural nets which receive, process and send information. Undoubtedly, the neural control of multicellular organism is a network of coding-decoding procedures.

The nerve system is a typical information coding-decoding system, which reflects and codes not only the environment of the animal, but its inner state as well. Animals control their activities according to this information and select optimal behavior.

### 2.3 Organized Control System

Control Systems Cybernetic Theory, and especially W. Powers Perceptual Control Theory (PCT) are inseparable from functional organization of Living Systems and complement CL-CD system [8, 9, 5, 11].

Even most simple organized systems based on CL-CD Control principles must have at least two CL-CD Control circuits. The first circuit reflects information about environment. In a process of development of environment model it develops the action models that encode the necessary states of environment-body (organized system) interactions. Decoding of these models is the controlling of environment through effectors. The second circuit collects information about inner environment and develops the action models for control of inner environment by means of inner effectors. Usually these two circuits work in tandem. This two circuit system corresponds to cybernetic system of combined feedforward and feedback control.

Organized systems is a case of complex system that have features of cybernetic system (purposeful system), especially if it have features of second order cybernetic system according H. von Förster [Rocha, 1996] [6]. Organized system consists of two closely connected qualitatively different subsystems – *controlling subsystem* and *controlled subsystem*. Here the controlling subsystem stores, collects, processes and sends information, and the controlled one handles the material and energy transformations.

Evolutionary cybernetic analysis of functional organization of animal nerve systems and of behavior carried out by D. Kirvelis and K. Beitas identify five levels of CD-CDC (Kirvelis and Beitas, 2004) [11]. Five levels of CL-CD control can be seen in mammals visual analyzer:

- Simple reflection;
- Multireflexic coordination and programmed control;
- Regulation and homeostasis;
- Simple perceptronic analysis;
- Analysis-by-Synthesis (A-by-S) without or with "sensory screens".

It seems that only at the fifth level of CL-CDC, i.e. A-by-S, the living systems are controlled by model-based (strong) anticipatory control, in correspondence with D. M.

Dubois [12]. At other four levels of CL-CDC, living systems are controlled by weak Rosen's like anticipatory control.

## 3 Fuzzy More-Equal-Less Neural Logic

Organisms and other organized systems receive information (signals) necessary for behavior control. Neural nets are one of several bioinformational subsystems (genetic, hormonal, pheromonal, neural) of animal's control (Fig.2). Reflections of external environment and internal system states are transformed by receptor layers of the sense organs to neural signals; these signals are processed by parallel neural structures and used later in brain as information for remembering or control. Similar subsystems of informational control can be found in every advanced technical system (in robot, in society), which are considered to be the organized systems (Fig.3). Here the information is recorded and compared, the action plans are developed and sent as coded neural impulses to the neural control structures of effectors (executive organs). Generally, effectors are the structures that perform matter and energy transformations (e. g. muscles, glands). Effectors that are closely linked with the receptors analyzing their status and the controlling neural structures form the lowes level of CL-CD system. Organism's executive organs collect resources and change environment on purpose to realize certain motives and aims, so they are part of their own CL-CD system that is closed through effected environment and external receptor structures. It is obvious that functional activity of all organized systems is based on the informational CL-CD principles. On the level of neural subsystem these CL-CDC principles are realized by neural layered nets where neural information circulates and the main universal functional element is the neural cell - neuron.

### 3.1 Neurons and its Features

Neuromorphological studies show that the structural and functional element of the nervous system, the neuron, has a multitude of synaptic contacts with other neurons and one long process, the axon. The axon branches and impinges on neurons and other cells, making its synapses. This is how neuronal structures and neural networks are formed. Neurons come in different shapes but in most cases they may be divided into "stellate" and "pyramidal" neurons. For the sake of simplicity we assume that our neurons (quasineurons) are summators with many functional inputs and one functional output (Fig. 3).

Neuron is the collector of signals (impulse frequencies) $\mathbf{X_i}$, which has up to ten thousands inputs (synapses) $\mathbf{S_i}$ and one functional output (axon) $\mathbf{Y}$. The latter one can branch and contact through synapses with many other neurons in farther layers and with itself (Fig. 2.). The neurons' input $\mathbf{X_i}$ and output $\mathbf{Y}$ are variable excitements with approximately linear dependence (see the dotted line in Fig.3). Hence usually it is quite acceptable to approximate the static part of signal transfer by straight line.

The pyramidal neurons that are located in the cerebral cortex have additional possibilities. Their functional organization and mechanisms of action hold maybe the greatest still unrevealed secrets of nervous system. Typically the pyramidal neurons have plenty of synaptic contacts, especially on the dendrites, where the input signals are summed.

$$Y = N\left\{\sum_{i=1}^{n} S_i \cdot X_i\right\} = \begin{cases} \sum_{i=1}^{n} S_i \cdot X_i, \ if \ \sum_{i=1}^{n} S_i \cdot X_i \geq 0, \\ 0, \ldots\ldots\ldots\ldots if \ \sum_{i=1}^{n} S_i \cdot X_i \leq 0. \end{cases} \qquad Y = N\left\{\sum_{i=1}^{n} S_i \cdot X_i\right\} = \begin{cases} \sum_{i=1}^{n} S_i \cdot X_i, \ if \ \sum_{i=1}^{n} S_i \cdot X_i \geq 0, \\ 0, \ldots\ldots\ldots\ldots if \ \sum_{i=1}^{n} S_i \cdot X_i \leq 0. \end{cases}$$

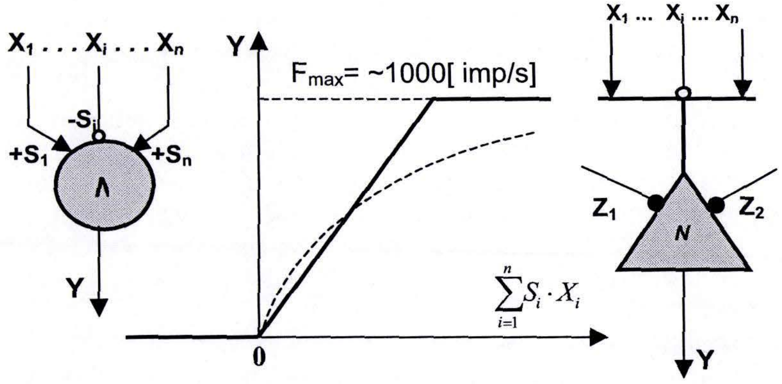


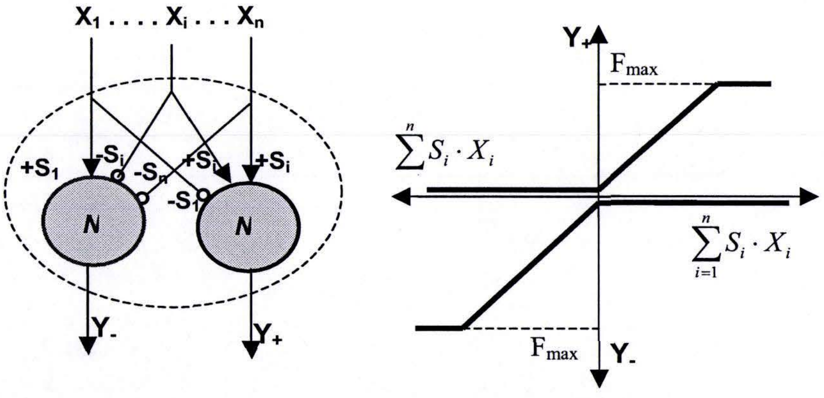

**Figure 3:** Schemes of star and pyramidal neurons, their functional characteristics and graphical picture of their neural non-linearity ***N***.

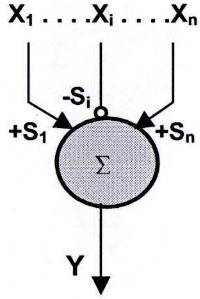
It seems that the synaptic contacts on the pyramidal neuron's body perform the suppression, which means that the pyramidal neuron transmit the positive sum of signals to the axon and to the other neurons only in case zero impulsation from any **Z** entry. Thus the pyramidal neuron responds and forwards the signals unless and until there isn't any signal suppressing on its body. It will realize universal logic operation – Peirce arrow (Dagger function).

### 3.2 Reciprocal Neurons

Neurons in neuron net can not transmit negative signals – trains of negative pulses. The system that produces signals with both signs is a reciprocal pair of neurons. Here pulses of one neuron are considered as negative ones, and pulses of other neuron – as positive ones. (Fig. 4.).

The neurons of reciprocal pair have the same structure of synaptic connections, just their signs are opposite, i. e. the coefficients of correspondent synapses are equal but have the opposite signs. In biological neural networks the sign of neural signal is defined by type of synapse at end. Such a pair of neurons is a linear algebraic "space/time integrate" where one neuron of the pair sends signals **$Y_-$** about negative sum of incoming signals **X** and the other neuron of the pair sends signals **$Y_+$** about positive sum of incoming signals **X**. When the sum of synaptic coefficients with the same synaptic sign is less then **1** (e. g. **$\Sigma S_+ \leq 1$** for exciting synapses) neuron's function always is in linear phase but can not be maximally **$F_{max}$**.




$$Y = \begin{cases} Y_- = \begin{cases} \sum_{i=1}^{n} s_i \cdot x_i, if \sum s_i \cdot x_i \leq 0, \\ 0, if \sum s_i \cdot x_i \geq 0, \end{cases} \\ Y_+ = \begin{cases} 0, if \sum s_i \cdot x_i \leq 0, \\ \sum s_i \cdot x_i, if \sum s_i \cdot x_i \geq 0. \end{cases} \end{cases}$$

**Figure 4:** The pair of reciprocal (inverse) neurons – linear algebraic summator and its characteristics

In that case the pair of reciprocal neurons realizes the scalar product of entry vector **X** and entry vector of synaptic connections **S** or, in other words, estimates the correlation of these vectors by value **Y**. When both neurons have the threshold **Θ**, this algebraic "space/time integrate" is non-linear and have insensible zone ± **Θ**.

### 3.3 More-Equal-Less Logics as Fuzzy Logic Neural Networks

The features of reverberated objects filtrated by two neurons' continuous entry signals of opposite signs and their magnitude expressed by intensity of neuron's excitation *Y* can be further processed by means of fuzzy logic. The merest neuronal structures that realize elementary operations of fuzzy logic are shown in Fig. 5.

Neuron which has one exciting and one suppressive entry realizes the conditional difference or informs about the elementary inequality saying that **$X_1 > X_2$**, and presents the expression of this inequality on outlet **Y**. Such neuron which has one suppressive entry **X** and one exciting entry with constant $\mathbf{F_{max}}$ realizes logical inversion $\mathbf{Y = F_{max} - X}$ which corresponds to one of the most important operations of traditional logic, namely the negation **Y = notX.**

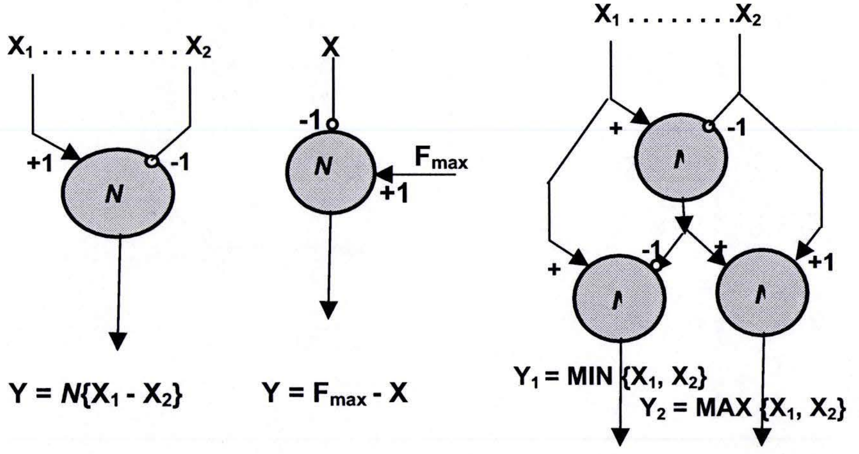



**Figure 5:** Neuronal structures that realize the main operations of continuous (neuronal, analogical, syncretic, fuzzy) logic

The structure of two similar neurons can perform other principal elementary operations of continuous or fuzzy logic – conjunction (logical multiplication) or disjunction (logical addition). In neuronal fuzzy logic they are expressed as follows:

$$\mathbf{Y = MIN\{X_1, X_2\} = N\{X_1 - N\,[X_1 - X_2]\,\} = N\{X_2 - N\,[X_2 - X_1]\}} \text{ (conjunction)},$$
$$\mathbf{Y = MAX\{X_1, X_2\} = N\{X_1 + N\,[X_1 - X_2]\} = N\{X_2 + N\,[X_2 - X_1]\}} \text{ (disjunction)}.$$

Selection of minimal value is understood as fuzzy conjunction and selection of maximal value is understood as fuzzy disjunction. It is obvious in the logical analysis of two features; however the same conception is also applied in the fuzzy logical analysis of multiple featured neuronal structures.

As stated above, the principal operation performed synthesizing neuronal fuzzy logic's **MIN** and **MAX** structures is $\mathbf{N\{X_i - X_k\}}$ and it is realized by separate neuron. It is seen clearly when minimum and maximum separation procedures of multiple entries' neurons are written down:

$$\mathbf{MIN\{X_1, X_2,...X_n\} = N\{X_1 - N[X_1 - N(X_2 - N(X_2 - ....)]\}},$$
$$\mathbf{MAX\{X_1, X_2,...X_n\} = N\{X_1 + N[X_1 - N(X_2 - N(X_2 - ....)]\}}.$$

It is obvious that the same neurons are necessary to realize the negative of multiple entries, namely inversion, when neuron-invertor is set for every entry. (It is worthy to note that complete neural network has such invertors only in the primary receptor structures where only the positive signals dominate. In the further neuroinformational procedures the inverted and non-inverted signal vectors function in parallel.)

It all goes to show that the basic neuronal fuzzy logic's operator is element-neuron which performs the "**more**" and "**less**" comparisons. It is understandable that various schemes performing any functions of fuzzy logic can be synthesized from such neuronal structures. There can be even synthesized such schemes as "**uncertain**", "**equal**", "**indefinite**" and similar ones that are disclaimed by traditional categorical logic stating that there are only two possible variants "yes" or "no", and no third variant is possible.

It is this particular feature which differentiates categorical logic from fuzzy logic and makes the latter closer to behavior of animals and humans. It can be easily interpreted by schemes of neuronal structures' possible functioning. It is undoubtedly well demonstrated when conditional operators **IF** used in computer programming language are realized by means of neurons.

### 3.4 Neuronal Structure – the Operator of Arithmetical Conditions

The operator of arithmetical condition used in programming languages is expressed as follows:

**IF (arithmetic-algebraic function) $m_1$, $m_2$, $m_3$ .**

It means that if performing computational procedures the arithmetical value calculated according to algebraic expression is negative, the further operation will be performed considering the address $\mathbf{m_1}$ indicated in the program, if the value is positive, the operation will be performed considering the address $\mathbf{m_3}$, and if it is equal to zero, the operation will be performed considering the address $\mathbf{m_2}$.

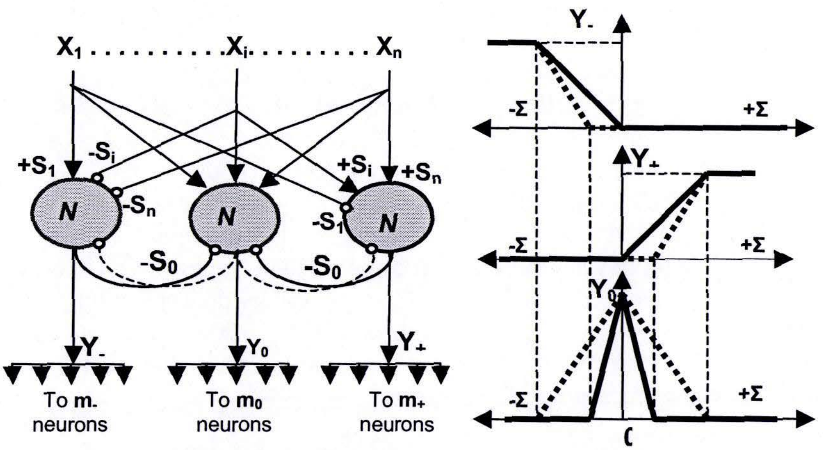



**Figure 6**: Neural structure – the operator of arithmetic condition
**IF (Arithmetic expression $\Sigma s_i x_i$) $m_-$ , $m_0$ , $m_+$**

This conception exhibits such actions as "**less**", "**more**", "**equal**", which are naturally performed by neurons or unsophisticated structures of some neurons. Even the pair of reciprocal neurons (Fig. 6) performs "less" **(Σ< 0)** and "more" **(0<Σ)** operations when the first neuron sends signals to one group of neurons and the second neuron sends signals to another group of neurons. They can not generate the signals and act on the same groups of neurons simultaneously.

Fig. 6. demonstrates the complete neuronal operator of arithmetical condition designed for perpendicular net of neurons. The neuron located between the reciprocal neurons of the pair will be excited only if both the reciprocal neurons are still, i. e. both of them fulfill condition $\Sigma s_i x_i = 0$. If one of the reciprocal neurons is excited, the middle neuron will be extinguished by intense suppression $-S_0$ of one of the reciprocal neurons.

The middle neuron which has zero or indefinite identification status can also suppress both of the reciprocal neurons. Such an interaction of three neurons realizes the function given below:

$$Y = \begin{cases} Y_-, IF \sum S_i \cdot X_i < 0, \\ Y_0, IF \sum S_i \cdot X_i = 0, \\ Y_+, IF \sum S_i \cdot X_i > 0. \end{cases}$$

The features of fuzzy logic are apparently demonstrated by the presented diagrams of all three neurons' reactions. The excited neuron $Y_-$ means "less", $Y_+$ – "more" and $Y_0$ – "uncertain" or "equal".

### 3.5 Neuronal Structure – the Operator of Logical Conditions

The operator of logical condition used in programming languages is expressed as follows:

**IF (Logical function) Arithmetic-algebraic expression**

It means that arithmetic value according to algebraic function will be given only if logical function is "**YES**". Otherwise the arithmetic-algebraic function is ignored.

The neural structure which realizes the operator of logical condition is demonstrated in Fig. 7. Logical functions can be realized by pyramidal neurons which are connected with each other by inhibitory connections. Two pyramidal neurons connected in series by inhibitory connections realize the double negation, subsequently as a result of it forms the proposition. Several suppressions converged in one pyramidal neuron realize the Pirs arrow (Dagger function), which is expressed as follows:

$$.NOT. [Z_1 .OR. Z_2] = .NOT.Z_1 \& .NOT.Z_2 .$$

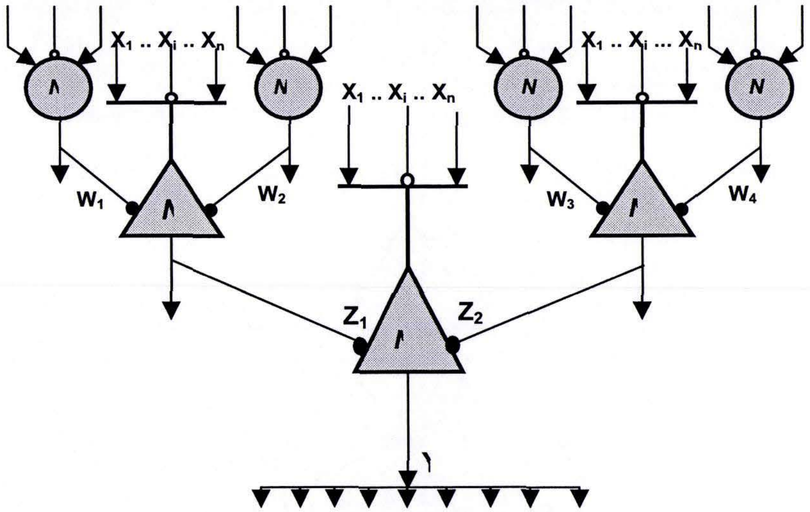



**Figure 7**: Neural structure – the operator of logical condition

If star neuron transmits information about the features of reverberated object by signal batches **W** and transfers them to the suppressive entries of primary pyramidal neuron, which transfers them further to the suppressing entries of following pyramidal neuron, then such a neuron will realize the described function:

$$Y = \begin{cases} N\left\{\sum_{i=1}^{n} S_i \cdot X_i\right\}, when[W_1.OR.W_2]\,\&\,[W_3.OR.W_4] = .YES., \\ 0, when[W_1.OR.W_2]\,\&\,[W_3.OR.W_4] = .FALSE. \end{cases}$$

The excited neuron **Y** will act on corresponding groups of neurons by its connections and perform the selective procedure of information processing and transmission. Generally speaking (in conception of computer technique) such neuron is called the neuronal microprocessor functioning by principles of hybrid computer as pyramidal neuron allows consonantly integrate analogical and logical operations. It can form much more complex concepts than star neuron.

Star neurons form initial concepts filtering according to the principle "**more**", "**less**", "**equal**", whereas pyramidal neurons interconnect those concepts by logical "suppression" or Pirs arrow's functions and thus form superior concepts. Since star neurons-accumulators operate by analogical signals, their switchover from suppression to excitation and vice versa is not pronounced and such feature enables to attribute them to fuzzy sets and fuzzy logic. Examples of the simplest neural structures given here help to understand the possibilities of much more complex neural nets, i. e. the functional organization of parallel neural structures operating by multidimensional signal vectors.

### 3.6 Neural Network – the Analyzer of Multidimensional Signals

As mentioned above, nervous system is the net of many thousands of neurons functioning in parallel and the abundance of parallel channels of information which start at receptors and end at effectors with collateral informational interactions as well.

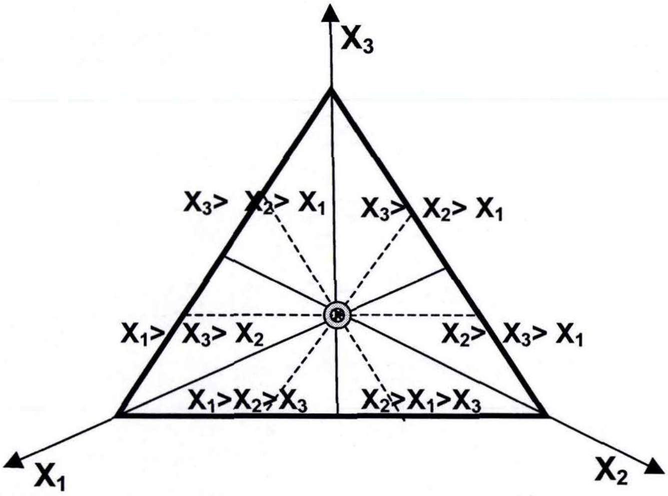



**Figure 8**: Three-dimensional positive-feature vectors situated according to **more-equal-less** fuzzy logic geometric picture. In middle $\mathbf{X_1=X_2=X_3}$

Therefore, after getting to know the possibilities of elementary neural net, it is essential to design the possibilities of neural analyzer with more complex and numerous entry signals. The neuroscheme of three-feature fuzzy analyzer given in Fig. 9. also fairly clear demonstrates the possibilities of **n**-dimensional analyzer of neural signals.

When multidimentional positive-value signal from n+1 entries is analyzed, first of all it is recomented to compose neuron analyzer of $\mathbf{[(n+1)n]/2}$ elementary reciprocal pairs of neurons, which would analyze tehe signals interrelationships of every entry pairs by principle "**more-less**", i.e., the excited would become only that neuronwhich receives more intense signal to its exciting synapsis. It is obvious that altogether there can be $\mathbf{(n+1)!}$ States of analyzing structures which corresponds to the permutational combinations of the quantity of entry signals and to the respective number of reciprocal chains of primary neural analyzer. This analyzer is differenciator and every $\mathbf{N\{X_i - X_k\}}$, $\mathbf{N\{X_k - X_i\}}$, neuron of its reciprocal pair "cuts" the space of entry signals by hyperplane to two symmetric pieces which pass through the central axis "all equal" $\mathbf{\{X_1 = X_2 = \ldots X_i = \ldots = X_{n-1}\}}$, devide the plane $\mathbf{X_i0X_k}$ through its middle and pass throgh all other axes as well (Fig. 8.). Such neuronal analyzer subdivides all the positive quasi-octant to $\mathbf{(n+1)!}$ symmetric sectors and every of them match the direction of entry signals' vectors, which in its turn fulfills the corresponding inequable alignment according to the value of signal $\mathbf{X_k > X_i > X_{m-1} > \ldots > X_n > X_j}$. Hereafter the neural net can be organized by means of pyromidal neurons and their inhibitory connections in such way that the corresponding pyromidal neuron would be excitaded only in that case if entry signals' vectors lies in that sector. It is posible to form **$N_1 = (n+1)!$** pyramidal neurons wich would identify a single concept.

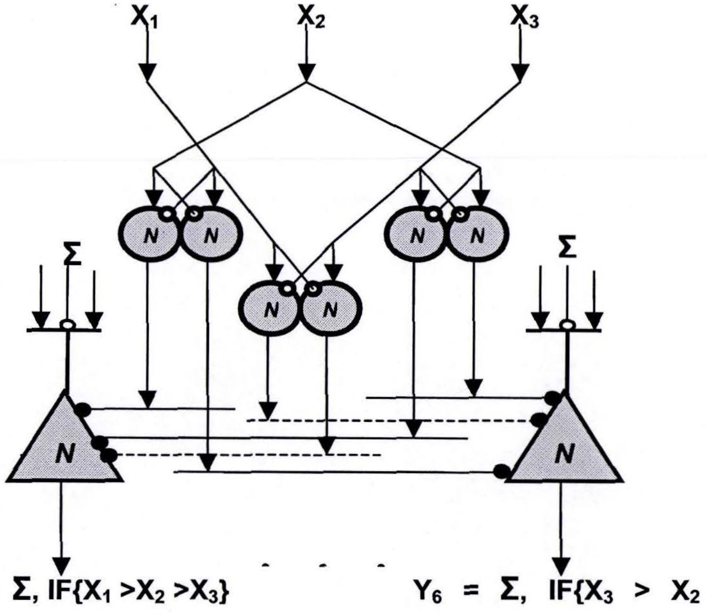



**Figure 9**: Fuzzy neural network which identifies positive three-dimensional entry vectors according to the more-equal-less logic (3! = 6 possibilities)

The gist of neuroinformatics is realization of logical operations by means of neural structures. In those cases when neurons filter the features of objects reverberated in receptors and estimate their expression by means of continuous values, their logical analysis must be performed by methods of continuous logic. There are a lot of various variants of continuous logic called differently: infinite, continuous, neuronal, analogical, syncretic, fuzzy logic, etc. It is relevant to various hybrid computers, informational technologies as well as neuroinformatics. There are plenty of algebraic algorithms for their realization, e. g. **R**-functions (Rvachiov, 1967) [13], neural logic (Kirvelis, Pozin, 1967) [14], fuzzy logic (Zadeh, 1969) [15]. For the neural structures it is the easiest to apply the neural logic expressed in algebraic terms, which virtually expresses the main features of all mentioned logics.

# 4 Discussion on the Bio-Systems Nanoinfotechnology

The CL-CD control with functional semantics and M-L-E logic can be seen not only in physiological macrolevel of organisms, but also in the lowest level of molecular cell structures, i.e. at nanotechnological level. Example of molecular control of cyclic cell activities is presented below and in Figure 10 [16, 17].

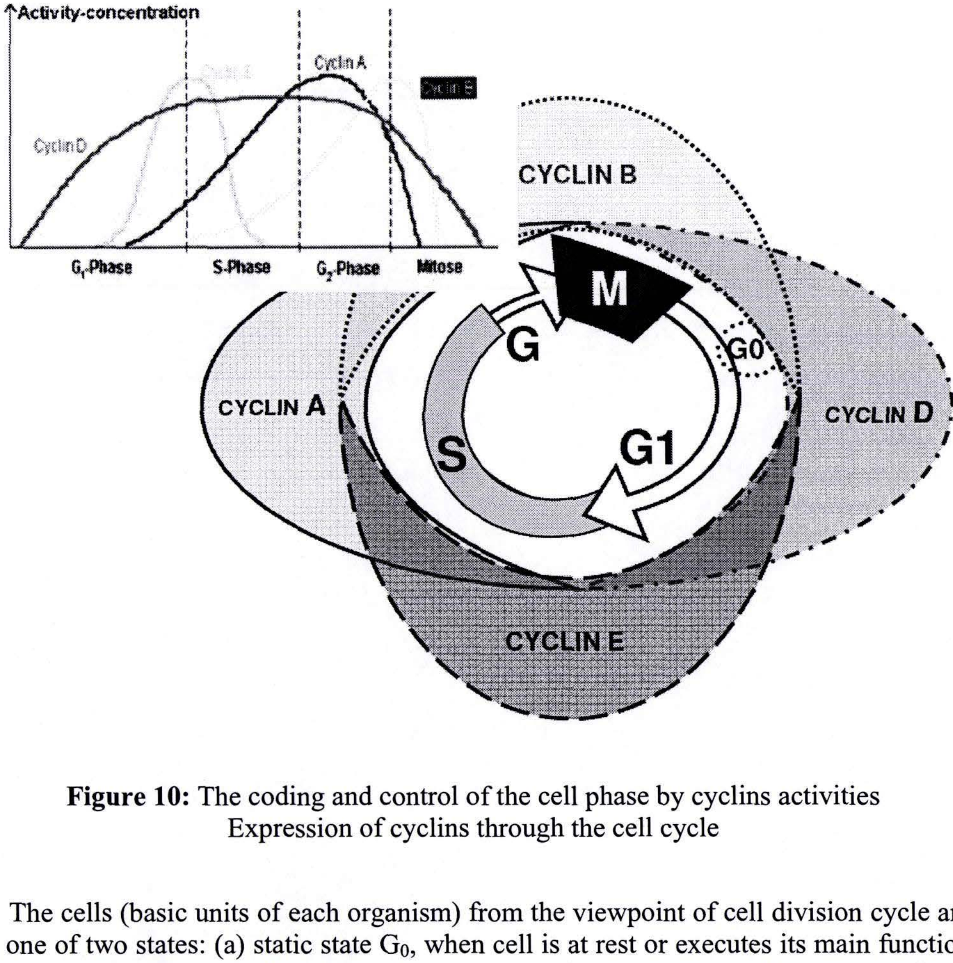



**Figure 10:** The coding and control of the cell phase by cyclins activities
Expression of cyclins through the cell cycle

The cells (basic units of each organism) from the viewpoint of cell division cycle are in one of two states: (a) static state $G_0$, when cell is at rest or executes its main function (but not participate in cell divisions) or (b) dynamic state, when cell is in one of cell division phases ($G_1$, S, $G_2$, M). The state off cell depends on presence of special proteins cyclins that control cell behaviour in cell divisions. In absence of cyclins the cell is in non-divisive state ($G_0$ phase). The presence of cyclins means that cell is in one of phases of dynamic (divisive) state. The high concentration of cyclin D means that cell division cycle is active. Concentrations of cyclins change periodically where curves of cyclins concentrations are shifted and peak concentrations of cyclins E, A and B do not coincide. For example, the peak of cyclin E means beginning of S phase (replication of DNA), peak of cyclin A – beginning of $G_2$ phase, peak of cyclin B – beginning of M phase (mitosis). Cyclins the concentrations of which increases bind to cyclin-dependent kinases and switch intracellular events of mitosis and transition of cell from one phase of cell division to next phase. It seems that the cyclic ranking according to the activity levels of the procedure determines the physiological cell phase or coding.

The adoption of the cell phase is determined by 5 different cyclins. Maybe the more detailed molecular biology studies will reveal up to 5! = 120 phases in cell division cycle. This future fact would suggest that biological cells in a molecular level of technology are controlled by molecular techniques based on more-less-equal fuzzy logic principles. Similarly, the physiological state of the multicellular organisms may be controlled by ranking-coding molecular activity of the hormones.

Because the signal molecules that control technology of biochemical processes are of nanosizes, and because artificial biological/biochemical methods are being developed for current nanotechnology it is considered that signalling molecules for coding-decoding of information and other control structures may be based on more-less-equal logic. It would be implementation of CL-CDC principles at nanoinfotechnological level.

This more-less-equal (M-L-E) coding logic can be effectively adapted to the new nanophotonics information technology [18, 19].

# 5 Conclusions

1. Theoretical investigations of the functional organization of nervous systems of animals have shown that bioinformational procedures acquire semantics level (sense) only when they use CL-CD (closed-loop coding-decoding) principle.

2. The functional interpretations of the experimental data of neuromorphological, neurophysiological and neuroethological-neuropsychological research of animal and human neural structures demonstrate that the informational activity of the neural systems is based on neuronal networking that implements "more-less-equal" logic (nearly related to fuzzy logic) but not simple binary "yes-not" logic.

3. Theoretical comparative analysis of the information coding-decoding procedures in the neurostructures and similar procedures in intra- and intercellular signaling molecular structures (such as cyclins in cells and hormones in plants and animals) for a system control and signal coding has shown that the logic of the "more-less-equals" can be a common bioinformational coding-decoding method that can be applied in the nanoinfotechnology also.

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