NATURAL INTELLIGENCE
(Neural Networks, Information Theory and Fuzzy Sets Theory Applications to Natural Intelligence Study)

O.G.CHORAYAN

Research Institute of Neurocybernetics, State University,
B.Sadovaya 105, Rostov on Don, 344006, Russia.
Phone: (863) 2-64-83-88, Fax: (863) 2-64-52-55,
E-mail: rec@rsu.rostov-na-Donu.su

1. Neurophysiological Prerequisites.

Physiology is one of the developed branches of science storing a great amount of experimental data, general conclusions. It has a broad set of methodical approaches to study the structure and function of living organisms and its functional systems, possesses well-developed scheme of physiological specialties.The latter is determined by the differences among the examined objects, applied methods and levels of living beings organization (physiology of single functional systems, electrophysiology, evolutionary physiology and so on).These sections of physiology as a rule are based on average typical indices of cell unity, organs, tissues, systems that make smooth individual peculiarities of living beings. It is rather fair and valid on the first stage of study because for the first time it is necessary to gather and store summarized average data, to put it in order, to classify enormous number of observations and experimental results [5] .

It stands to reason that knowledge store is endless process and nowadays a great number of events need experimental and theoretical analysis with traditional methods using but now we already have a possibility to realize another important approach in physiology development connected with taking into account the individual factors.It is especially essential if we mean well-known fact of unrestricted variety of living beings in the world. As Czent-Gyorgy [6] writes there are no 2 absolutely identical cells and in the world of living organisms real range of variables among same tissues, organs, systems is so large that resulting functional peculiarities seem not compatible with generally used average physiological features.

In this extremely important problem physiology of the nervous

system as a leading information and control system of the living organism occupies definite recess.It is especially concerned with the higher forms brain physiological function (intelligent behavior). Though there is no commonly accepted definition of natural intelligence we usually mean some integral product, some result of creative thinking activity formed and maintained during human individual development showing some elements of nontrivial productive thinking, multivalued logics, biologically and socially valuable semantic information forming.There is no algorithm that allows to reach the final goal, to solve some problems of natural intelligence. These problems are characterized with the considerable uncertainty, information deficit. They are pattern recognition, decision-making, behavior planning, chess play, various examples of adaptive behavior, our, vague concepts coding, creative activity, extrapolation elements and so on.In absence of universal definition of natural intelligence for the first time it is necessary to choose composed elements, features, properties dealing with human intelligence maintaining and developing.Information thesaurus is one of the essential components of the natural intelligence. From the standpoint of this view on the intelligence the rate and efficiency of its forming are assessed in accordance with well-known four-component unity: "know- be able- act - foresee". Interrelations between the first two elements are completely defined by known aphorism " with lack of knowledge there is no mind, but with lack of mind knowledge is possible". In this connection mind is intermediary between knowledge and action as compulsory factor activating the knowledge, transforming the latter into the intelligent activity, intelligent product. It must be taken into account to elaborate psychophysiological tests aiming to clear the complex multicomponent nature of individual informational thesaurus.

Knowledge making up the information thesaurus basis is determined by psychophysiological process of pattern recognition. Pattern recognition as a main element of adaptive behavior, a compulsory element of intelligent activity is connected with the study psychophysiological basis of brain modeling constructions-standards forming (nervous models of stimulus). The latter is necessary to identify the formed image in brain structures - nervous copy of pattern with the real image, pattern, event. Dynamics of

vague in complete pattern usually examined in the experiments points to successive gradual building up of statistic and semantic information as a result of entropy removal and includes some fuzzy algorithms of search and identification [1-4] .

This process needs forming alternatives area to subsequent choosing optimal one. The alternatives area breadth guarantees the human success in searching and finding rational alternative. Sufficient variety of considered alternatives representing the maximal variety principle with the subsequent removal of redundant degrees of freedom is derivative of volume and breadth of individual information thesaurus. Structural and functional providing of this process is reached with evolutionary improvement of appropriate brain structures in close connection with ecological conditions of ancient man life and development. Apparently it is necessary to agree with known hypothesis that straight going (transfer from going by four on two extremities of our ancient ancestor) became the key element in progressive evolution of Homo sapiens not so much owing making free the upper extremities for labor as thanks to broadening knowledge horizon connecting with the eyes position changes (to see far for - ward instead to see restricted area under his legs).

The decisive role of organizing determinant brain cell structure perfection is underlined with the fact that during ontogenetic individual intelligence development is associated with nerve cell construction complication and not with its amount increasing- there is no new formation of nerve cells since individual birth. It is good to have the filled brain but it's better to have the well organized brain.

2. Neurocybernetic and Bionic Prerequisites.

The distinctive peculiarity of neurocybernetics modern stage is priority of practical usage of bionic studies results to construct, to build effective artificial control and communication systems simulating the wonderful features of high constructive and energetic efficiency and reliability. A neural network is a collection of neural populations. A neural population is a group of neurons accomplishing the same function.These neurons are usually (but necessarily spatial neighbors). Connections between them are very dense. In fact every neuron is connected to all other neurons of the

same group. The connections may initially have a random strength or may follow a fixed spatial distribution. They consequently change with experience according to some learning rule for example Hebbian learning.Similar populations are connected in parallel, whereas populations of different hierarchical levels are cascaded in a layered fashion. Connections between populations are not random but genetically determined or developed early in ontogeny.

Neural network apparently offer great potential and promise. There is hope in the control community of being able to achieve control objectives which have not been attained before.

On the goals of neural networks in communication is to make communication engineers aware of what neural networks are and how they could be applied to communication systems in the future. For this purpose it is necessary to show how ideas from communication, specifically information theory can help elucidate what is going on in natural neural networks. Because synthetic and neural networks performance, or promise to perform, very demanding operations of decision, recognition and computation based on their network structure, it is not surprising that ideas from communication help analyze and understand neural networks.

As known today brain activity principles (parallel processing of information, optimal neuron cell and subcellular architecture, effective ways of information reception, transmission, handling, effective algorithms of decision-making in conditions of essential uncertainty, neural networks learning algorithms), so the new future results of experimental and theoretical brain studies need practical realization in schemes, models, acting technical selfcontrol elements and systems in various spheres of human being (industry, culture, education, medicine).

Just solving these problems is associated with the period of intelligence revolution that humanity expects in near future [8]. Understanding that is traditional for modern computers possibility of successive information processing seems exhausted is one of the decisive motives of neuroinformatics, intelligent robotics systems studies intensification. It is defined with the fact that the rate of computer functional elements is closed to top speed determined by fundamental physical rules. It explains sharp increasing interest to unique creative capabilities of human brain, natural intelligence.

Property of emergency inherent to neural network not occurring in composed nerve cells has important meaning for intelligent functions.For example we can consider associative memory, adaptive learning, abstract generalized model building. The higher forms of creative intelligent activity performed by human on the ground of decision-making processes are the fuzzy algorithms of purposeful acts [1,3,10,11,13,15,16,22,23]. Therefore elaboration of tests envisaged occurrence of fuzzy logics elements inherent to human thinking activity has an important meaning. These tests include the tasks intended to discover predisposition to certain type of human nervous activity, resistancy to unfavorable environmental influences, capability to nontrivial thinking, capability to make decision in problem situation under uncertainty [1-3] .

The distinguishing property of human intelligent activity is absence of precise description, strict formalization. According to N. Wiener [14] words the main advantage of human brain is his capability to handle with vague concepts. Vagueness, Fuzziness is a fundamental property of human thinking. Fuzziness in our reasoning in our behavior is not weakness it is index of our strength our essential acquisition during evolutionary process.In complex dynamic environmental conditions it is very hard to survive and successfully develop if individuals carefully estimate variety of external stimuli clearly assess the aftereffects of our actions, seek and find, choose the best alternative action. If additionally to take into account that such clear estimation, calculated is usually impossible it becomes understandable that human thinking under uncertainty is sooner life standard than exclusion.

Underlining restriction of human cognitive ability Kauffmann [9] sharing Eccles' view [7] writes that our cognitive behavior is reached owing to the models, concepts and rules approaches which are not absolutely truthful forever. Human advantage in comparison with the computers (in spite the speed of computer information handling more than 1 million operations in sec instead human rate only a few operations in 1 sec) is provided by human ability a priori reject a great amount of alternatives being nonessential for given goal. It makes man not only today but in near future competitive in decision of every complex tasks requiring nontrivial approach realizing in essential environmental uncertainty. It warrants necessity of human

inclusion in man-machine systems maximally using advantages computers (in rate of elementary mathematical operations) and human capability to decision-making in vague conditions under information uncertainty.

Scientific interest to the problem of fuzzy thinking especially arose after the first Zadeh's publications [17-21] on fuzzy sets, fuzzy algorithms. Theory of fuzzy sets and fuzzy algorithms is founded on the idea that the key elements in human thinking are the classes of objects in that transition from belonging to non-belonging from membership to non-membership is the continuous gradual process and logics of cause-effect relations in human thinking differ from the classic formal logic. The class of objects permitted possibility of partial membership is approximated with fuzzy set. Fuzzy set is described by the membership function having number values in the range (0-1) in accordance with the membership degree of this object to given set. Fuzzy set A of universal set U is characterized by membership function μ_A(u) which describes each element with some number in the interval 0-1 characterizing its belonging to set A.

Algebraic operations on fuzzy sets provide human ability to approximately information assessment continuously arriving to the brain. The latter selects the information that is necessary for approximately correct decision. Fuzzy algorithms are rather effective to reach vague fuzzy goals. Because fuzzy set has not a clear-cut boundaries it has not also single-valued probability distribution. Methods of fuzzy set theory essentially differ from the methods of probabilistic theory: in theory of fuzzy set more simple concept membership function corresponds to the concept of statistical pro-bability in probability theory but both concepts have identical nu-merical values in the range 0-1.

Fuzzy sets have some properties that permit to make some algebraic operations being important to human thinking processes. There are: intersection of fuzzy sets $A \cap B$ (it is necessary to find common composed elements of two or more compared objects, events); concentration: Con A = A^α (corresponds to logic operation described with adverb very); dilution : Dil A = $\sqrt{A}$ (corresponds to logic procedure described with adverb more or less).

Fuzzification is often used methodical approach to handle with

vague information. For example when we want to be more careful and not to make thoughtless conclusion or action we use the words more or less, slightly, to some extend, and so on.

Algebra of fuzzy sets allows to make approximate inference on the ground of fuzzy logic excluding the categorical results, reasoning; our inferences are becoming more soft, more acceptable for broad number of cases, problem situations.

We must consider the theory of fuzzy sets as a considerable step to make nearer the classic mathematical accuracy of real world events. The fuzzy sets theory does not call to substitute the probability theory and statistical theory, it only fills omission in structural uncertainty field where it is impossible to apply correctly probability theory, statistical methods. The fuzzy logic may be defined as algebraic system in which set of truthful meaning compose the closed range (0-1) and logical operations may be described as result of appropriate set-theoretic operations: union, intersection, concentration, complement and so on.

Treatment of fuzzy data in expert systems comes to 2 basic processes: presentation of fuzzy information in knowledge base data and procedure of vague foundations and fuzzy rules. The knowledge base data are presented in the forms of productive thinking of the type: if .. then . and mechanism of inference in conclusion processes uses known rule "modus ponens".

The fuzzy logic increases our capability to solve the problems when we deal with the tasks that are too complex and too vague to apply the classic mathematical and statistical methods.

3. Some Applications of the Information Theory and Fuzzy Sets Theory.

a. Adaptation of Information Theory to Solve Expert Assessment Problems.

Method of expert assessment is one of the widespread approaches to estimate education systems efficiency. As a rule in expert systems with number assessment linguistic variables (terms and concepts of natural language – the main communication means) are used. Quantitative specification of natural language words is rather complex problem.

Let's consider a case of expert assessment of necessity

additional inclusion of some branch of science into a list of compulsory school disciplines according to a program of professional education.Let's we have 7 indices of assessment (A, B, C, D, E, F, G) and appropriate assessments made using the terms of linguistic variable on the scale from yes to no with intermediate meanings : most probable yes, sooner yes than no, maybe yes, maybe no, sooner no than yes, most probable no.

In special series of tests definition using the expert assessment method the next number meaning of these terms are found: yes - 1.0, most probably yes - 0.83 , sooner yes than no - 0.66, maybe yes, maybe no - 0.5 , sooner no than yes -0.34, most probably no - 0.17, no - 0. Then the probability of intermediate meanings of linguistic variable rate setting standard meaning are: yes -0.29 ; most probablu yes - 0.24; sooner yes than no - 0.19; maybe yes, maybe no - 0.24; sooner no than yes - 0.09; most probably no - 0.05; no - 0. In this case according to Shannon theory of statistical information [12] the initial entropy of this assessment system is calculated by the next way:

$$H_{init} = 0.29 \log_2 0.29 - 0.24 \log_2 0.24 - 0.19 \log_2 0.19 -$$
$$-0.09 \log_2 0.09 - 0.05 \log_2 0.05 = 2.39 \text{ bit.}$$

Accordingly rate setting entropy value is :

$$2.39/7 = 0.34 \text{ bit.}$$

As result of expert test study let's have the next probabilistic estimation of intermediate linguistic variable meaning, calculated with above-mentioned manner (A - 0.83 , B - 0.34, C -0.83, D - 0.34, E - 0.66, F - 0.66, G - 0.83). Then empirical entropy for expert groups is calculated in such a manner:

$$H_{emp} = - 3 (0.18 \log_2 0.18) - 2 (0.15 \log_2 0.15) -$$
$$- 2 (0.16 \log_2 0.16) = 1.45 \text{ bit .}$$

Accordingly rate setting entropy per element of the system is :

$$1.45 / 7 = 0.21 \text{ bit .}$$

Therefore examined expert group brings in the system essential information decreasing its entropy. The value of this approach is estimated with entropy removal:

$$H_{init} - H_{emp} = 0.34 - 0.21 = 0.13 \text{ bit.}$$

It means that the system becomes more informative, therefore examined expert system declares for proposal - inclusion of the school discipline into the education program.

Experience of wide and successful usage of information theory in many branches of science in combination with new promising theory of fuzzy sets and fuzzy logics allows to hope that it will be successful in experts assessment of education and research in current problem solving. Taking into account expert assessment subjectivism of variety individual views even among the specialists it seems that indicated approach aiming problem situations analysis under essential information uncertainty may be useful to solve these research tasks.

b. Adaptation of Information Theory and Theory of Fuzzy Sets Methods to Analysis of Natural Intelligence Constitutives

On the ground of literature review some experiments series with expert assessment comparative value of the intelligence definition methods natural individual gifts a scheme of intelligence estimation using tests methods was developed. In three series of experiments on different students contingents (mathematicians, psychologists, biologists) intelligence semantic area was constructed. Non-trivial thinking, associative thinking, decision-making ability, some kinds of productive thinking, abstraction elements, symbols signs handling, intuition and extrapolation behavior are considered as essential intelligence components. Level of cognition, memory volume and structure, genetic factors, inductive and deductive thinking, attention factor are considered as modifying factors of natural intelligence. Number values presented by membership function values are calculated using subjective probabilities, characterized meaning and role of considered factors in total individuals intelligent activity.

Information analysis of experimental data is realized using Shannon's equation for empirical entropy [12]:

$$H = - \sum_{i=1}^{n} P_i \log_2 P_i \ ,$$

where P_i - probability measure, calculated on the ground of membership function values.

To make range classification in accordance with value of examined properties of natural intelligence intersection and concentration operations with fuzzy sets are developed:

$$A_1 \cap A_2 \cap A_3 \cap \cdots \cap A_n = Min[\mu_{A_1}(u), \mu_{A_2}(u), \ldots, \mu_{A_n}(u)]$$

where $A_1, A_2, \ldots, A_n$ - fuzzy sets approximating some single properties of natural intelligence,

$\mu_{A_1}(u), \mu_{A_2}(u), \ldots, \mu_{A_n}(u)]$ -corresponding number values of membership function.

To take into account the differential meanings of examined intelligence properties concentration operation is suggested:

$$Con\ A = A^{\alpha}$$

where α - value coefficient of examined property. Then according to intersection operation we receive a new sequence of analyzed properties that differs from previously estimated sequence.

It seems that the suggested analysis may be used as an useful adequate method of many problems study connected with analysis of the information nature , logic of creative human intelligent activity.

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