SOME APPLICATIONS OF FUZZY SETS THEORY TO THE DESCRIPTION OF MEMORY MECHANISMS

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Memory is a set of processes of fixation,storage and reproduction of the past experience,one of the most remarkable properties of living systems and ,first of all, the nervous system. In accordance with this definition it is customary to distinguish the following components in the mechanisms of memory: the coding /transformation / of a message into the form convenient for storage,the storage of information and its extraction. As a manifestation of one of the main characteristics of a living system information activity, the memory in all its components bears a mark of the peculiarities of determination and causality in the communication system.

Since the memory of the complex ,in particular, human systems contains a multitude of possible states of elements, it is reasonable to use the apparatus of the fuzzy sets theory and fuzzy algorithms/ Zadeh,I965,I968,I984,I986 /. Application of the fuzzy sets theory is especially useful to the pattern recognition problems, a widespread class of operations necessary in the process of reproducing and comparing the current pattern with the one fixed in memory,e.g. in classification of patterns,etc. It is well known,that most of pattern recognition systems are probabilistic or fuzzy ones /but not determinate in terms of strict Laplace determinism /. Therefore,the statistical or probability description /decision/ is useful and sufficient only in the case when the statistical information of the incoming message is really available for the recognizing subject /system /. In most of the cases,however, we deal with quite a different situation: the recognizing system has neither the complete information about the object,nor the knowledge of the probability description /distribution/ of its components. Morever, many operational concepts used in the systems of both the natural and artificial intellect in the pattern recognition problems and decision-making can not be approximated by the classical strict sets,and are an example of fuzzy sets.

The different aspects of applying the theory of fuzzy sets to the study pattern recognition or memory are considered in a number of works / Siy , Cheng ,1974, Shimura ,1975, Chorayan, 1984 /. In the case of associative memory as the distributed memory let $X^{\mu} = \{x_1^{\mu}, x_2^{\mu}, x_3^{\mu}, \ldots, x_n^{\mu}\}$ be the n- dimensional incoming pattern. These individual components of the pattern are accumulated in the memory elements in the form of the fuzzy matrix F and , if necessary, are extracted from the memory by some key pattern $Q^{\mu} = \{q_1^{\mu}, q_2^{\mu}, q_3^{\mu}, \ldots, q_n^{\mu}\}$ in accordance with the concrete value x^{μ}.

Such an approach ,in particular, may be used in the identification of the pulse pattern generated by nervous cells in the response to different signals and representing one of the probable candidates of the nervous code. The method of the integral estimation of belonging of the analyzed pattern of nerve impulses to the "standard" /taken as the analogue of the neuron impulse code of some symptoms or,in more general terms,as the "engram" of the recognized pattern,symptoms or characteristics / is realized on the basis of calculus of possibilities by operating with the concept of fuzzy sets approximating the varieties of the classes of impulse patterns of nervous cells. The resemblance and differences of the concepts of probability and possibility are considered in detail in a number of Zade's publications /I979,I98I,I984 /. The concept of possibility is the derivative of intuitive perception /in respect of the estimation of identity or compatibility of the perceived pattern with the standard contained in the information thesaurus of the receiver/ while the concept of probability is based on the frequency characteristic,proportionality relation or degree of assurance/subjective probability /. The probability and possibility possess the independent characteristics of uncertainty and as a result it is impossible to obtain the probability distribution from the distribution of possibilities of the variable and vice versa. This is reflected in the well-known statement "it's possible,but impossible".

Let Π_x be the distribution of the possibilities obtained when comparing the test pattern X with the standard Y where

$$X = \{x_I , x_2 , x_3 ,\ldots, x_n\}$$

is the n- dimensional pattern of nerve impulses,

$$Y = \{y_I , y_2 , y_3 ,\ldots\ldots, y_n\}$$

is the standard pattern represented by the fuzzy subject of the universal set U , characterized by the numerical value of the membership function $\mu(u)$ in the range $[0-I]$. Then, from the theory of possibilities it follows that $\Pi_x(u) = \mu(u)$ for all $u \in U$ $(\forall_u)$ where Π_x is the function of distribution of x . The degree of resemblance between Π_x of the test pattern of the nerve impulses, and its analogue will be determined by the result of the operation of intersection of these sets and will also take the intermediate values in the range [0-I] : $\Pi(Q) = Sup_u [\mu_x(u) \wedge \mu_y(u)]$.

The similiar situation arises when analysing the impulse pattern of the different cells of the neuron memory ensemble which stores information about the recognized pattern with the purpose of identifying the leading central elements /evidently, having the higher values of $\Pi(Q)$/ as distinct from the secondary, additional elements of the given neuron ensemble. In this case, one may use the theoretical-multiple operations of the fuzzy sets, an example the operation of concentration: Con $x = x^{\alpha}$, where $\alpha > I$. This enables stepwise reduction of the number of elements analysed and exclusion from consideration of the patterns which ,according to the individual characteristics,have low values of the membership function.

The theory of fuzzy sets may be applied to the formalization and modelling of the process of generalization during decision- making. So,at the initial stage of problem solution,the process of generalization or narrowing of the perceptive sphere comes to the fore with attention being concentrated only on the key /in view of the person making a decision / characteristics. In essence,the construction of an abstract environment model, thing or phenomenon means the formation of the fuzzy set of central neurons whose stimulation reflects the individual symptoms of an origin. The concept of fuzzy sets of central neurons as the basis of perception processes is analysed in a number of works /Chorayan,I979,I982,I984 /. If the original is some set of points,symptoms, characteristics :

$$A = \{A_I, A_2, A_3, \ldots\ldots\ldots, A_n\}$$

then ,its model may be represented as the fuzzy set :

$$a = \{a_1, a_2, a_3, \ldots, a_m\}$$

where $m < n$, and the relations of ambiguous correlation are established between the elements A_I and a_1, A_2 and a_2 , A_3 and a_3 ,A_n and a_n . The smaller is the number of characteristics under consideration / diffusion of an original ,an analogue of the operation of "diffusing of the set " Dil $A = A^{\alpha}$ where $\alpha < I$, the bigger is radius of the fuzzy subset approximating the nervous model of a real object. This results in the increase of probability that the pattern to be recognized will be included in the search. The increase of fuzziness as the indication of system complexity /Negoita ,1980 / may be also interpreted as the manifestation of the cybernetic principle of providing the necessary variety in a complex system . The increase of fuzziness leads to the increase of the system diversity and as a result provides the possibility of describing a greater number of different situations outside the system.

The diffusion of the original using its model in the structures of the brain,facilitates solution of the problem situation, solution being / D / considered as the intersection of the given fuzzy goals / g / and fuzzy restrictions /Bellman, Zadeh, 1976 / as a result of removing a number of restrictions / C / :

$$D = g_I \cap g_2 \cap g_3 \cap \ldots\ldots \cap g_n \cap C_I \cap C_2 \cap C_3 \cap \ldots\ldots \cap C_n$$

and accordingly, in terms of the values of the membership functions :

$$\mu_D = \mu_{g_I} \wedge \mu_{g_2} \wedge \mu_{g_3} \wedge \ldots \wedge \mu_{g_n} \wedge \mu_{C_I} \wedge \mu_{C_2} \wedge \mu_{C_3} \wedge \ldots \mu_{C_n}$$

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