TWO NEW PRINCIPLES OF BRAIN ACTIVITY

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ABSTRACT

Two new principles – purposefulness and prediction are formulated in this work. These principles, from the one side, are consequences of new mathematical results, which overcome some false paradigms in mathematics and computer science and, from the other side, they are the principles of two physiological theories: the Theory of Functional Systems of Brain Activity (TFS) by P.K. Anokhin and the Information Theory of Emotion (ITE) by P.V. Simonov. Thus, these principles give us conceptional bridges between the new mathematical results and two physiological theories. The principles generate two new formal models of brain activity: the hierarchy of "weak" formal systems and the structural set of all possible probabilistic regularities, which give us a maximal precision of prediction. Both these models were further synthesised in the joint formal model of brain activity, which explains all properties of these physiological theories and some other theories.

Keywords: Mental Models, Brain, Prediction, Knowledge Discovery, Philosophy of Mind, Neural Networks.

1. PURPOSEFULNESS PRINCIPLE.

The Purposefulness Principle [7,9].
This principle has risen as a result of clarification of the notion of task, which provides a new approach to the foundations of mathematics and revision of D. Hilbert's program [1]. We will say that we have a meaningful task if we have a criterion of the task solution in the sense that for every possible solution we can uniquely decide if this solution is a real solution of this task or it is not. In the mathematical theories it is commonly supposed that we have a decision of task if we have a proof of this decision. But the proof is not a criterion of whether the task is solved. To have a criterion it is necessary to determine for every given proof if this proof is a real proof of the task or if it is not. Let this criterion of being solved, task and possible proofs be formalized in some formal system S. In this case, what requirements the formal system S must fulfil in order for us to have the possibility to formulate meaningful tasks in S, i.e. for every task and proof in the frame of S we can uniquely decide if this proof is a proof of this task or it is not? This question was formally investigated in the work [1]. It was proved that only in "weak" formal systems S, which don't include arithmetic, we could set a meaningful task. It leads to the following revision of D. Hilbert's program: "Consequently, for the decision of any meaningful task we have no rights to select from any theory so large a fragment that it will not be a "weak" system. ... But for "weak" systems we cannot prove Gedel's theorem on incompleteness, so the question about consistency ... is not so sharp any more, as for the initial D. Hilbert's program. In this sense the theorem (from [1] - E.V.) says that the revision of D. Hilbert's program, corresponding to the new paradigm, is radical and probably leads to a solution of epistemological crisis in foundations of mathematics." [1]. Thus, the formulated notion of task is a principle of construction of mathematical theories.
Let us generalize the notion of task so that it may be applied to brain activity. The notion of purpose is more general than the notion of task. We cannot achieve the purpose if we have no criterion of its achievement, otherwise we may always consider that the purpose has not been achieved yet. So we can set the purpose only if we have a criterion of its achievement. Further, we can define the notion of result: result is the fact that the purpose is achieved and the criteria of achievement are satisfied. The notion of the result is the main notion of the physiological Functional Systems Theory of Brain Activity (in comparison with all the other known physiological theories).

Functional Systems Theory of Brain Activity [4,5,10].
"Perhaps, the most dramatic moment in the history of investigations of brain activity... is the moment when attention is directed to the action itself but not to its results ... we may think that the result of the "grasping reflex" must not be an action by itself but the totality of all afferent irritations, which corresponds to the properties of a grasped object (result of grasping - E.V.)" [10, p. 27].
The other main notion of TFS is the notion of a functional system: "The main postulate of the Functional Systems Theory is the proposition that the leading system formation factor, which organizes the organism's functional systems of any level is helpful for the organism's ... adaptation result. It is the result ... that makes the "mobilization" of all central and executive formations in the functional system" [10, p.34-35].
The organization of functional systems in purposefulness behaviour is performed in accordance with two principles: by consequence and hierarchy of results. The con-

sequence of results follows the "dominant" principle: at all times there is only one dominant requirement with a corresponding functional system, which demands satisfaction at that time for the survival of an organism. All the other functional systems relative to this dominant functional system line up in the hierarchy in accordance with the principle of "hierarchy of results": the hierarchy of functional systems is a consequence of the interaction of results, when the result of one functional system is included as a component in the activity of another functional system. For example, if a rabbit has a dominant food seeking functional system, then the normal level of oxygen in the blood and the normal level of the other metabolic constants will be changed. These changes automatically make active those functional systems, which maintain a normal level of these constants and so on.

Thus the organism decides its tasks by use of consequences and hierarchy of results and corresponding tasks. Therefore the mathematical model of brain activity that may resolve these tasks and that follows from the Principle of Purposefulness must be the sequence and hierarchy of "weak" formal systems [7,9].

2. PREDICTION PRINCIPLE.

Information Theory of Emotion by P.V. Simonov.

"Summarizing the results of our experiments and information from literature, we arrived in 1964 at the conclusion that emotion is human beings' or animals' brain reflection of a need (of its quality and quantity) and probability of satisfaction of this need"[6, p.20]. Emotions are the integral parameter, which is the basis for decision making. Emotions reduce all variety of purposes to only two of them: achievement of positive emotions and elimination of negative emotions: "Since positive emotion attests to coming close to a purpose, and negative emotion attests to going away from a purpose, an organism tends maximize the first state and minimize the second one" [6, p.28]. These two purposes have a subjective criterion of their achievement, which appears in emergence of emotions. Thus, after introducing the parameter of probability of purpose achievement, the main purpose of the brain activity becomes the achievement of the previous two purposes. And only after choosing one of them, the brain sets the task to achieve the corresponding particular purpose, which gives a sequence and hierarchy of more concrete tasks. Let us consider the mathematical theory in the frame of which we can formalize this main purpose of brain activity.

Inadequacy of Axiomatic Approach to Knowledge [3,8,9].

Let us consider how we can calculate an estimations of prediction (and not only prediction) in such areas as Philosophical Logic, Artificial Intelligence, Expert Systems, Decision Making, Probability Logic and so on. All these areas unconditionally take for granted the axiomatic approach to knowledge: It is assumed that we may indefinitely apply the logical inference to knowledge and that the logical inference of new knowledge from existing knowledge is a main purpose of knowledge. The probabilistic, fuzzy, reliability and other different estimations of knowledge must be calculated after the logical inference is done.

Let us consider the works, where these estimations are calculated. The estimations of prediction are considered in the works [11-17]. There are works where probability (uncertainty, fuzziness, reliability, etc.) is considered as a value of truth of propositions and the process of inference is considered as so-called "quantitative deductions" [11,12,17]. In spite of sufficient progress in developing of such formal systems, all of them are founded on an axiomatic approach to knowledge. Analysis of changing of probability estimation in the inference process shows that estimations always decrease and, as a rule, they decrease essentially, and these estimations can't be enhanced. It follows, that unlimited application of inference process to knowledge is impossible, so that it leads to knowledge with unrestrictedly small estimations of probability, which can't be considered as knowledge. Let us show that this situation is not just coincident. It follows from the subordination of the Prediction Principle to the Purposefulness Principle in the axiomatic approach to knowledge.

Subordination of the Prediction Principle to the Purposefulness Principle in the Existing Paradigm.

As we said, the mathematical model of the brain, which follows from the Principle of Purposefulness, must be the sequence and hierarchy of "weak" formal systems. This model is a logical model of purpose achievement, such that the purpose may be either achieved or not achieved. This particular logical scheme of results achievement is considered in all the above mentioned areas. The probabilistic (fuzzy, reliability and other) estimations of knowledge are calculated **after** the logical inference is done. So the axiomatic approach to knowledge is an equivalent to the preference of the Purposefulness Principle to the Prediction Principle. But contrarily in the brain activity the brain first achieves the maximal value of probability estimations and only **after that** does it achieve the concrete purpose with the corresponding sequence and hierarchy of results. We need to understand that the brain isn't a logical mechanism but prediction mechanism. Let us consider how we can avoid the axiomatic method in formalisation of the main purpose of brain activity.

Prediction Principle.

The first step in formalization of the Prediction Principle was made in "quantitative deductions," where the truth values were generalized to continuous values. But the second step wasn't done: if we generalize the truth values we need to generalize inference rules, because the inference rules retain the truth but not the new continuous values. So we need to define such inference that can retain the new continuous values.

Let us do the second step and consider the computability from the point of view of the "semantic" approach to programming [2]. The idea of semantic programming implies that the computational process (which generalizes the logical inference) may be considered as the computation of truth values (including the possible use of logical

inference) of propositions on some model (algebraic system). From this point of view we can consider the process of computation not only as computation of truth value, but also as computation of the **maximal value** of probability, uncertainty, fuzziness, reliability, etc. We will call such an inference a **semantic inference.**

For the purpose of prediction we will define the **semantic probabilistic inference** [3,9]. This inference begins with the rule of the form P $\Leftarrow$ (the premise of the rule is absent) and continues by constructing the "refining" graph by adding some predicate (conjunction of predicates) to the premises of any graph rule so that the conditional probability $\mu(P/P_1\&...\&P_k)$ becomes strictly greater. Moreover, every graph rule must be a **probabilistic regularity**, which means it is impossible to delete any predicate (conjunction of predicates) so that the conditional probability becomes no smaller that the previous one. Let us denote the set of all probabilistic regularities as ***PR***. It was shown that this inference does not need any inference rule. It is proven in [3] that this inference is a generalization of logical inference. Moreover, this inference is stronger than the logical inference in the following sense: it is proven in [3] that for any proof of some predicate P from ***PR*** and some data D there is only one rule in ***PR*** which predicts P on D with better estimation than by means with this proof. In [3] it is also proven that using the probabilistic inference we can receive all "the best for prediction" rules, which have maximal values of conditional probability. Furthermore the probability estimations will rise in the process of this inference, whereas they are decreased in the logical inference.

Prediction Principle.

The brain can discover the set ***PR*** of all probabilistic regularities. It's argued in [9] that the brain fulfils this presupposition on all levels of its work from neural up to decision-making.

In works [8,9] it is shown that all properties of TFS and ITE may be explained by this principle. The structure of information processes in the brain, which gives the structure of predictions in the brain and corresponding structure of the set ***PR*** was described in [9].

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