SEMANTIC LANGUAGE AND THE PROBLEM OF GOAL FORMATION MODELLING IN HUMAN THINKING

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Abstract

Considered is the problem of goal formation modelling in human mental activity as a basis of the construction of automatic systems possessing properties of autonomy and intellectual activity. The characteristic of the psychology of goal formation is given. The necessity of use of semantic languages for modelling of independent goal formation is substantiated. The structure of semantic language based on the principles of situational control is described.

Modern formal-logical metasystems, if they are considered as means of modelling human thinking, reveal a very essential shortcoming: they do not permit a description of such an important component of mental activity as a goal formation. The most intensive creative work of the makers of programs designed for thinking modelling, if only it is brought about on the basis of existing metasystems, do not lead to construction of programs reconstituting an independent goal formation process. As a result, the automated systems proved to be, in essence, doomed to passivity: they can work only by instructions or perform reactions to stimuli known beforehand.

The creation of active cybernetic systems, i.e. those which could be able to form independently a goal, presupposes a development of language of thinking modelling corresponding to a greater extent than formal metalanguages to goal formation process regularities in intellectual human activity. One of the difficulties of creation of such a language is the absence in modern structural linguistics of means of description of mechanisms of human cognitive activity which underlie problem solving models construction. Leading with Chomsky's investigations, the works in the field of structural linguistics were directed towards the study of natural language functioning mechanisms and the construction of its formal models. Problem solving language turned out to be out of the field of vision of these works.

Investigations into thinking modelling, the results of which formed the basis of the present work, have begun in the middle of 60-thies within the frameworks of the methodology of operative thinking in big systems and the situational control based on this methodology which found at present practical application in automation of control processes, robot construction, pedagogics, etc.(1)

One of the essential prerequisities for the development of situational control was the psychological investigation into solving operative problems appearing at complex objects control (3). The essential characteristic of many operative problems is that their conditions are usually presented to man as a set of separate dynamic elements capable of moving in a discrete static space (problems of dispatcher's railway transport control, chess, - game "15" problems, etc.). The solving of these and other problems may be characterized as interaction of two components - the environment, i.e. the situation, and the process of modelling of this situation which is brought about in the head of man solving the problem. By solving the problem, the subject models, reconstitutes in his internal informational plan dynamic elements and that static system (the tracks of a railway station, the fields of chess-board etc.) on which these elements are situated. Psychological investigations suggest that such a reconstitution of situation in the internal plan occurs at the level which is essentially more abstract than information process. At informational modelling the subject abstracts himself from purely visual properties of objects, for example, when solving a chess problem, the shape of chess bishop staying on the board makes absolutely no difference to him. Each of the dynamic elements of situation is allotted first of all in informational aspect with the ability to move in the static system. Such an ability proves from the very outset to be rather an abstract conceptual characteristic. The model of some or other element of a situation in man's head embraces the multiplicity of characteristics of this element which can be characterized as its conceptual span. In problem solving the models of elements interact with each other, in other words, conceptual spans, for example, of two elements interact, so that one element becomes a predicate of another. The interaction of such kind between the models of situation elements in problem solving can be characterised as a relation between these models.

The problem solving process can be presented as a process of the construction of conceptual models of situation elements (situational concepts) and of the formation of systems of relations between them. This activity is, however, a controlled component of the problem solving process. The number of characteristics which may be revealed in some or other situations, and the number of relations which can ba aatabllahad between elements of this situation is, aa a rule, potentialIYvery great. Tha preaance of the regulator, which dlreote a cognitive process in some or other way, is characteristic of human intellectual activity. T This regulator la a goal of activity which la coded in terms of relations betwean situation elements. Inreatigationa into tha psychology of thinking testify to tha fact that goal transformation at tha different atages of statement and eolation of a problem is characteristic of man's intellectual activity. This dynamics of goal may ba observed on tha examples of wall know chess problems. Tha initial situation la given In theae problama aa a aat of separate elements aituated on tha chess board flleda. Simultaneoualy with such a situation, tha initial goal is fixed, for instance, to make tha mate to tha blacks in three moves. In such a formulation of the goal, Instructions about tha concrete actions are not given t tha subject is only informed about relations in which the cheaa figurea must be found in the final situation. In the courae of solution, this initial goal relation undergoes changes; in this case the counter-proceea la taking place: due to the conatraction of altuatlonal concepts, the initial goal la transformed into the ooncrete system of relatione which are essential for tha given situation. Aa a result of the situation model-Slin* process, the ooncrete situational al appeara, for example, not to give m poaalbilitv to the king of an advereary of retreating on certain fielda of the ehesa board. It is this altuatlonal goal that gives birth to a means of its achieving - a certain sequence of operations whioh must lead to the final situation corresponding to tha set initial goal. When this final situatlon is achieved, the problem is solved. If tha sequenoe of operations does not lead to the neceaaary result, a new altuatlonal goal is constructed and a new sequence of operationa corresponding to this goal is formed.

Thus, whan dealing with tha goal formation process in hman activity, one should bear in mind regularities of appearance of two goals: initial and altuatlonal. The regularities of situational goal formation can be traoed on the baais of materials of the psychology of thinking. It is much more complicated to ascertain how the human being carries out an independent formation of an initial goal. The regularities of emerging of this goal on tha baais of independent activity are not yet revealed, since tha most spread model in the psychology of thinking la the experiment in which external goal formation takes place - the initial goal is put before the subject from the outside. In this connection, both for the psychology of thinking and for cybernetics intellectual processes which lead tha human being to an independent statement of the problem, or, in other words, to an independent formation of the initial goal are of special interest. It is tha presence of these processes that permit one speak about intellectual activity proper.

Analysis shows that initial goal formation under the influence of needs and mo tires occupies a great place in human activity. In this case the initial goal appears as a reault of combination of motivation engendered by need (for instance, strive for the satisfaction of hunger or thirst) and man's past experience.

Another variety of goal formation finds its expression in the effect of an independent statement of the problem. In this process there is a link which is in a certain sense opposed to the direct formation of altuatlonal goal in problem solving. If the situational goal turns out to ba a ooncretixation of the initial goal, then the independently stated problem appeara aa a transition from the level of initial goal suggested from the outside to higher and mora abatraot lavela. ONLY after such a upwards, tha intellectual process paaaaa on to the usual formation of a altuatlonal goal.

Inventor's activity may serve aa a typical example of how external goal formation passes on to an independent atatament of tha problem. In this case the initial goal is often suggested to the inventor by a customer from the outaide in the form, for example, of a tesk to automatze a certain indue trial operation. On the basis of an analysis of working processes in the different branches of Industry, the inventor refuses the goal suggested from the outside and propoaee his own version of the atatament and the solution of the problem, as a result of which not a separata link of the industrial system, but the system aa a whole la optimised.

The independent atatament of the problem differs from the usual formation of the situational goal by the transition to a more abstract level of consideration, which bears the title of generalisation in psychology, That la why the prooees of independent atatament of a problem, which la characteristic of higher forma of intellectual activity, may be characterised aa a generalising goal formation. This la already an internal goal formation. It is usually cannected with human work in several objeot fields and is a reault of transfer of relatione from one object field to another.

Of oourae both forms of emergence of the internal goal in human activity (motivated and generalizing goal formations) appear aa a unity, because there ia a unity or regulation or motivational

-peraonallatic and intellectual process-aa proper, The mechani of goal formation aa a function of self-regulation of mental activity makes tba human bains as an autonomous system possessing own activity. Tba problem of goal formation is ona of tba central problems in tba cybernatio theory. Tba solution of tbia problem determines in many raapecta tba lerel of practioal possibilities of automatic control BJBtime. Leading with tba fundamental works of A.Rosenblut and N.Winer the cybernetic analysis of goal formation is, however, carried out within the frameworks of theoretical bases of behavioral psychology. When working out rarlous versions of programs, goal is considered as a certain final site of a mama having a definite structure, ia to tba intellectual activity involved in achieving tba goal, it ia understood aa a movement in this maze.

The summarising book of P.Akoff and F.Rmmery devoted to the analysis of systems possessing purposefulness, yield nothing new in principle in psychology and cybernetics about goal formation, in complete correspondence with tba principles of behavioral psychology, the purposeful system ia considered in this work aa a mechanical system possessing of certain structural and functional possibilities. The external dynamic characteristics of this system connected with the choice of a behavioral pattern leading to a certain result are essential. At this approach, the ability characteristic of man to build internal conceptual models of eurrounding world ia not considered at all. As a result, it turns out to be that goal formation analysed in cybernetics is an external goal formation, ia a movement in the apace of goals which is set beforehand and forms a ready maze.

Some psychological regularities of goal formation revealed in the analysia of human mental activity may be used in working out of the theories of cybernetic systems possessing properties of activity and autonomy, for instance, the modelling of internal goal formation (characteristic of human being) in cybernetics presupposes a use of semantic language permitting a meaningful decription within a cybernetic system of the medium in which the behaviour of a cybernetic system must be formed.

Let us dwell upon the characteristic of this language more in detail. The basis of semantic language is a semiotic engendering system imnitating processes of formation, generalisations and transformations (transpositions) of relations. The operational part of tba system appear formally as three sets: (X,R,G), where X is a set of baaic concepts; R is a set of the basic binary relations between concepts; G la a set of the rules of formation of derivative concepts when goals emerge. Tba concepts of natural language such as words, expressions, sentences, etc., characterising the moat general peculiarities of functioning of objects which are essential for goal appearance play a role of baaic concepts, for instance, in tba problem of aea port control such concepts are "moorage", "storehouse" "highway", "roadstead", "cabotage harbour", etc. The vocabulary of baaic concepts for a large sea port contains about 1000 concepts of the indicated kind. The vocabulary of concepts depends on required completeness and predaion of the description of a controlled object. For Instance, control over a separate vesael is connected with the necessity of having a detailed description of concepts characterising the structure of a reasel. Such a deecription becomes unnecessary in case of control over several vessels, Here it la the concepts related to maintenance-technical characteristics of vessels that play an important role, i.e. the characteristics which determine transport possibilities of a reesel, the degree of flfcness to the performance of loading-unloading works, etc. Since in each olass of controlled systems (for example, the class of sea porta) the problems solved are of the eame type, the vocabulary of basic concepts built for one system may be used with insignificant changes for another system of this class*

The elements of the set *R* characterise spatio-temporal and other relations which are established between concepts in problem solving, lor instance, an "object I is a part of an object I"; an "object X is an element of a claae Y"; and "object X movee towards an object I"; an "object X ia situated over an object X without being contiguous with it", etc. As distinguiahad from the basic concepts, the baaic relations are of a more universal character and practically do not chemge whan passing on from the solution of one problem to another. The results of analysis of many concrete control problems in the different classes of complex systems (technical, socio-economic, biological, etc.) showed a community of relations used in them. As a result, a universal vocabulary of basic relations containing about 200 elements was constructed. The derivative concepts are formed from the baaic concepts and basic relations in terms of thsee engendering grammars: correlational, oategorial and transformational, This semantic language was used for describing the goal formation process whan controlling over industrial systems

The set of microgoals of the problem to be solved ia enumerated in terms of correlation grammar. The idea of ezpresaing the sense of concept by the set of ether concepts which are in certain relations to a certain concept underlies this grammar. For instance, the concept "cargo hatch" is in the simplest case defined as a set of concets: "quadrangular deck opening" and a "device for hermetic shutting", which are in relations to the determining cencept, respectively: an "object X is an element of a class Y" and an "object X has in its composition an object Y". Formally the goals are written down in terms of syntagmatic chains representing an expression of the following kind:

$$(X_a^i \vec{r}_1 X_b^j) \wedge \ldots \wedge (X_e^k \vec{r}_2 X_d^j) \wedge \ldots \wedge (X_m^q \vec{r}_e X_n^u)$$

where i, j, u are the orders of derivation of concepts, arrows →, ← indicate the orientation of relations. Owing to the fact the real relations between objects of the problem to be solved are reflected in the structure of goal being as its sense, the adequacy is ensured of the structure of goal to the structure of situation. The rules of output, in terms of which the set of microgoals is enumerated, are written down in syntagmatic chains in which the elements X_a^i, $X_b^j, \ldots X_n^u$ play a role of object variables. The formation of relations between basic concepts is brought about on the basis of structural identification of concepts and object variables. If there is a rule $X_1 \vec{r}_1 X_2$, where X_1 is a "passenger ship", X_2 is a "free passenger moorage", r_1 means that an "object X moves towards an object Y", then one of the possible goals, which may be formed with the aid of this rupe, is: $X_i \vec{r}_1 X_j$, where X_i a "passenger ship" "Russia", X_j is a "free passenger moorage", since the concepts X_1, X_2 have structural entry into the concepts X_i, X_j, respectively.

The rules of goal formation are determined in terms of the classes of concepts characterising problem requirements. The structure of concepts being a part of rules of formation of goals in a sea port control problem contains the information about cargo, the technological scheme of its processing, instructions about the ways and methods of works, etc. The number of rules of correlations grammar for real big systems control problems (transport, computer, industrial, etc.) reaches several hundreds. The formal comparison of the structures of goals constructed in correlation grammar permits an ascertainment of the character of logical connections between goals and a construction of structural-equivalent classes of goals. The construction of classes of goals is brought about in terms of categorial grammar. The idea of combination in one class of goals having similar fragments accurate to isomorphism underlied this grammar. The characteristic of the class is the generalized structure (macrogoal) entering into the sttructure of each goal of the class. The macrogoals are formed in computer memory as a result of programs of generalizations and decisions made on computer by man knowing the control goal and the evaluative functional corresponding to this goal. The enumeration of sequences of goals at set time intervals as well as the transposition of relations at these intervals is carried out in terms of transformation grammar. The rules of output represent substitutions of the kind $X_i \rightarrow X_j$, where X_i, X_j are goals. The rule is considered as applied to the goal X_k, if X has entry into X_k. The realization of the rule is brought about by the substitution of X_k for X_i. The process of transformation of goals in a real problem continues untill the next goal hits the class fixed beforehand or the set interval of extrapolation is exausted. The formed sequence of goals plays a role of problem solving. When controlling over objects, such sequences correspond to the plans of functioning of objects at set time intervals. In the process of realization of a plan on a real object, the difference is fixed between the real situation and the situation formed in the language. If this difference exceeds a set magnitude, then the correction of the plan is made. Analysis shows that the use of semantic language permits an advancement in cybernetic goal formation modelling, i.e. permits a reconstitution of some essential features of internal goal formation.

The realization of semantic language on a computer is brought about in terms of a module system of mathematical provision. This system is used at present for solving problems of control over complex objects, the formation of data banks for decision-making, the generalized models of external world, integral robots, etc. The accumulated experience in maintenance of this system testifies to its sufficient efficiency and universality. The variable part of the system, when passing on to a new class of problems, makes up 20% on the average.

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