ACTIVE SEMANTIC NETWORKS IN ROBOTS WITH INDEPENDENT CONTROL

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Abstract

An approach to the construction of integral robot control systems is suggested based on the employment of information value characteristics. A method for representation of the value characteristics and their dynamics is decribed. A certain elaboration of the semantic networks idea forms the basis of the method. Specific examples illustrate the use of the suggested approach.

Introduction

Considerable specifics is inherent in problems of constructing the control systems of robots designed tor functioning in the natural environment. Here elaboration of such decision procedures proves to be necessary which can operate not only under conditions of unsteadiness and variability of initial data of the problem being solved but also under conditions of simultaneous existence of many problems whose urgency is in constant change. Hence the stringent requirements that the robot control systems be versatile and autonomous. Moreover, they must function under conditions of real time and considerable deficit of information. Approaches based on the traditional methods of decision-making, theorem proving, etc., seem to be not very effective. To the best of our belief the promising direction is associated with the development of such decision-making systems which are based on the employment of mechanisms of "inner activity" in the sense of the term meant when speaking about the motivation of human behaviour- It implies, however, the development of a method fit for the new tasks.

This paper offers the description of a possible method of the kind. A certain elaboration of the idea of semantic networks forms its basis. Ways of the method application in constructing control systems for robots are discussed and examples of specific developments are given.

Sign Systems and Information

The Chosen Approach

It is characterized by two main features. The first: we construct the robot control system on the basis of knowledge and hypotheses on processes of information handling by the human brain which affects the behaviour we would like to observe on the part of a robot. Initial hypotheses are given in [1]. It does not at all mean that we shall be engaged in the modeling of the thought or other psychic functions. It is only required that the constructed system control the robot efficiently. We use the study of psychics of an individual affecting the control only as the heuristic basis for incorporation of one or other functional subsystems or structures into the system.

The second feature consists in our employment of the semantic network, treated as a sign system, as a device for the internal representation of information in the system.

In works of different authors the semantic network appears in quite different modifications, i.e., from facilities for representing meanings of lexical units in [2] by R. Quillian to "a state-of-the-world graph" in [3] by G. Hendrix. The semantic network we deal with is an oriented graph whose nodes and arcs are marked by names of some notions. The network nodes are considered as the signs whose denotata (i.e., objects corresponding to them, actually existing in the real world) are both objects and phenomena of the environment as well as images, notions, feelings, emotions, etc, existing in the inner, psychic world of an individual being a prototype of the constructed control system. The network connections are treated as the signs whose denotata are relations actually existing among the denotata of nodes or among their concepts . Thus» the representation of interactions among essences quite different and far from one another becomes feasible in a single system and in a single language. Each sign is put in correspondence with a designatum, i.e., a notion or concept of an actual object. Nodes and connections of the semantic network are marked just by the names of these notions. What may be said about syntactics and semantics of our system is more or less obvious. Let us dwell on its pragmatics.

Pragmatic Closure

In the general sense pragmatics includes the set of relations between the sign system and its user or of sign-interpreter of the sign relations. Our sign system is, so to say, "a brain" of the device designed for autonomous functioning. Therefore, it is also an independent control system. This creates a particular situation when the sign system is, strictly speaking, its own user, its own interpreter, since it organizes its behaviour employing the sign forms of representation that exist in itself. This circumstance lends distinguishing features to the pragmatic aspect of the study of such systems. To emphasize them we define systems of that kind as pragmatically closed in contrast to the traditional systems - pragmatically open - where the sign system is something different from its user. It is, apparently, reasonable to consider the system of human thought as the pragmatically closed one. We believe that independent systems of artificial intelligence must be inevitably the pragmatically closed systems.

One of the most interesting problems treated within limits of pragmatics is that of value.

Information Value

The notion of value is complex and multicomponent. However, if the study is carried out in comparatively narrow bounds of the field of pragmatically closed artificial systems, then it turns out to be possible to limit (to begin with) a volume of the information value notion including in it, at the first place, such components as significance of atoms of information, a degree of their involvement into the decision-making process, and a degree of their interconnection. Here it is of importance that information value characteristics should not be specified to the system beforehand but be determined by the system itself in the process of functioning with due account of its own state, external situation, and "motives", i.e., "subjectively". To solve this problem we introduce the notion of semantic network activity.

Representation Method

Activity in Semantic Network

Let us assume that in an environment, for instance, a stone lies on the way of a robot, that the latter percieves and recognizes it. If the robot "knows" what a stone is, then a robot marked by the corresponding word should exist in its semantic network. Let such a node exist. Thus, the stone is on the way, it can hamper the movement, it is the reality. Accordingly, information about it, hitherto stored in the memory passively, becomes significant. In the semantic network the node STONE is a "key" to this information. This is the node that must be actively used by the control system now: the reality of the stone must be transformed into a rise of a certain activity, into a growth of the value of notion of a stone. A means of this process representation used by us consists in assigning some value of a specific analog quantity - an excitation - which is a figure of significance or, in the general case, of value of the corresponding atom of information, to tne necessary noue.

We shall assume that the assignement is performed by the specific perception procedure whose way of realization will not be considered here. Thus, assume that the perception procedure has ensured some excitation of the node STONE, has escited it. One node is connected with many others in the semantic network. Let there be a connection marked by the name BELONG TO CLASS relation that goes from the STONE to the node OBSTACLE. The robot actually perceives only the stone. However, it is quite natural to require that the semantic memory give it the possibility to "understand" correctly the meaning of what is being perceived and enable it to operate with this meaning. In other words, if the atom of information STONE is significant the atom of information OBSTACLE must also become significant, as though the vaiue of the first induces the value of the second through the connection existing between them.

It is possible to reason similarly about other connections of the node STONE in the semantic network. Thus, the connection IS A PART may connect this node with the nodes MOUNTAIN or, say, SCKEE. And though the mountain or scree themselves might not yet be perceived by the robot, the value of corresponding nodes should be induced by the STONE and that will ensure the activity of the relevant information and its participation in the decision-making. The same is with connections of the type ENTAILS (for instance, RAIN-ENTAILS-BAD PASSABILITY OF SOIL), HAS, etc

A constructive representation of the value inducing process discussed is the process of excitation transfer along a connection in such a way approximately as it occurs in electric circuits or neuron structures. Here the connection has a certain weight characterized by some number. The weight is an analog quantity playing the part of the coefficient of a decrease or increase of excitation transfered along the connection or, in other words, the part of the index of correlation between value characteristics of connected nodes. Such indeces can be not only positive but also negative (as, for instance, in the string BAD STATE OP SOIL - HAMPERS - RAPID MOVEMENT)-Connections may be reinforcing or inhibiting, respectively.

Therefore, excitation of even one node can result in excitation of many others connected with it directly. Prom these others the excitation can propagate still further and, as a result, the value characteristic can be obtained by very many, in the general case by all, atoms of information stored in the network.

Activity Sources

bet us recall that we construct our semantic network not only as a system for storing the robot's knowledge on the world but also as "a model" of some individual being a prototype of the control system constructed. It enables us to include into the network fairly specific notions, such as notions of feelings, desires, aspirations, etc. The general scheme of reasoning in their derivation looks approximately as follows.

If problems that a robot faces were tackled by a man then in the given situation such and such emotional state (or an aspiration, an image, etc.) would occur in him. It follows from such and such data of the psychology (or obtained by us during a specific experiment, or, finally, it is obvious intuitively). Very good. Let us introduce a sign of this state into our network, mark it by a name of the notion of this state, and connect this sign (i.e. the node) with other nodes of the network in such a way that is based on psychology (an experiment, intuition) data.

Such a scheme permits to assimilate into a single system a set of knowledge of different kinds on psychics - the most efficient of control systems existing in Nature. This scheme does not, however, compel us to imploy in succession all such knowledge and nothing but it. We need only that is actually useful in construction of an efficient system.

The described method application allows In an active semantic network to represent structures corresponding functionally to the structure of human motivation mechanisms and including notions that describe needs, aspirations, sets towards smth., etc.

The nodes corresponding to such notions can be excited in the network primordially and their excitation value can change comparatively slow. It is, so to say, the absolutely valuable information determining the global set of the systems. From them excitations propagate on all other nodes of the network giving them some initial "set" value. This initial distribution ie superposed by another constantly changing distribution generated by work of the perception procedure and reflecting situations in the environment. Both these processes undergo a constant mutual influence. Thus, a sequence of some specific perceptions can change the excitation of nodes corresponding, for instance, to feelings and influence the activity of one or other motives through them. Such a process of mutual influence determines "the subgectiveness" of information value characteristics.

Activity Regulators. SRI

One of the activity regulators are the network inhibitory connections whose influence on each of the nodes opposes constantly to the exiting influence of the reinforcing ones. A trend, realized by functional characteristics of the node, to a spontaneous decrease of its own excitation in absence of input effects ("the memory") is another regulator. However, the special System for Reinforcement and Inhibition (SRI) is the basic mechanism of network activity regulation.

The SRI principal purpose is to provide the domination of one atom of information over all others at each time instant. SRI affects the positive excitation feedback in the network giving an additional excitation to the node most active at this moment and inhibiting all the others proportionally. SRI - is a dynamic system constantly switching its extra activity from one node to another changing here the level itself of an additional excitation and inhibition.

The SRI construction reflects the adopted by us ideas about the attention mechanisms structure whereas the SRI role in network operation is compared with that of attention in the thought process. This comparison serves as one of the instruments of both the analysis of processes taking place in the network and the synthesis of the network itself in that part of it which is based on psychology data-

An important role in the network activity regulation belongs also to the learning and self-organization processes securing a constant change of weights of the connections available, occurrence of new connections, change of forms of functional characteristics of nodes (their "memory", in particular), as well as "a growth" of the network on account of occurrence of the new nodes corresponding to new notions that are formed in the network. Development of all these processes is determined by a character of final results of behaviour generated by the network and is directed to keeping an optimal relation of excitations of the special nodes PLEASANT and UNPLEASANT reflecting the general estimate of state of the motivation sphere.

DeciBion-Making

The method of building, employing and the composition of the suggested network are sufficiently specific to justify introduction of a special term for the designation of semantic networks with an activity of the decsribed type. Let us call them M-networks. The M-network is only a device for solving particular problems. Specific control systems built as M-networks and possessing SRI are defined as M-automata-

Let a robot control system be constructed as the M-automaton. Consider basic processes taking place in it during its functioning.

The perception procedure transfers into the network information about a current situation of an environment by the exciting of corresponding nodes. It is obvious that not all M-network nodes may be excited by this procedure. Those of them whose excitation is controlled by the perception procedure are called the receptor ones. Thus, the node STONE was a receptor one in the above example.

Prom the receptor nodes the excitation transfers into the network where mixes with excitation going from permanently active nodes representing inner motives of the system. Value characteristics of all atoms of information stored in the M-network are formed as a result. The process of excitation propagation is controlled by SRI. A certain image, a notion, a feeling, etc., is "singled out by the attention" and dominates at each time moment. It is, so to say, "a thought" of the system. Continuous switchings of SRI form a flow of such "thoughts", while the switchings themselves appear as associative transfers. Nodes that are not singled out and are, accordingly, inhibited by SRI compose "a subconsciousness" of the system to which additional excitations inflow constantly along connections from the nodes singled out by SRI and where a continuous "competition" takes place for the "attention" capture. In the network during these processes stable excitation centers come into being, exist a certain period, and disintegrate, which can be also sluggish, and latent, and "realizable". From time to time the flow of these processes is perturbed by a new portion of excitations brought into the network by the perception procedure when external situations change. Therefore, the distribution of excitations in the network is dynamic, i.e., continuous correction and reestimation of the value of information available is performed in the "thought" process.

There are nodes in the M-network which correspond to notions of those real actions that a robot is able to carry out in an environment: EXECUTE TURN *TO* THE LEPT.TAKK OBJECT X, etc. *Let* us define such nodes as effectory. There are also nodes corresponding, so to say, to generalized actions, e.g., AVOID ENCOUNTER WITH OBJECT Y (no instructions here how to avoid). As a rule, connections with greater weight are established from nodes of that type to the effectory ones- If SRI single out an effectory node or node of generalized action in the process of M-automaton functioning and if such node begins to dominate over the others we say that the system has made an appropriate solution. If SRI singles out an effectory node it is interpreted by the system as a command that the corresponding real action be executed by the robot. We shall assume that the corresponding action is executed by some execution procedure. Depending on the specific robot construction and specialization this procedure may have an access to subsystem of direct control of its actuators, manipulators, etc.

Thus, the general structure of processes realized by the M-automaton is as follows. The perception procedure reflects information about an external situation into the M-network. The process goes of reestimation available in the network- Checking of the environment state is performed during this process. A decision is made at some instant and the execution procedure realizes an appropriate action. It results in a change of environment, the new situation is reflected into the M-network, and the whole cycle is repeated. During multiple repetition of such cycles the robot's behaviour is being formed.

Specific Developments

Refinement and investigation of the described approach was carried out by creation and study of possibilities of a number of functioning M-automata realized as digital computer programs. As an object of modeling the information handling processes performed by a man when organizing a purposeful motor behaviour in static natural environments were selected. On the one hand, these processes are sufficiently complex to ensure the check of "a strength" of the applied methods, on the other hand, a number of interesting practical problems - in particular the control of robot motion - are reduced to the problem of purposeful motion organization. The developed M-automata imitate actions of a robot in an environment with objects that are to a various extent useful or dangerous to it. Motives of the robot behaviour depend on its striving for self-preservation and achievement of a global goal. The robot studies the environment, chooses a motion objective, constructs a plan for its achievement, and then fulfils it, performing actions-steps and actions toward transformation of the environment, comparing obtained results with the planned ones, amplifying and correcting the plan in accordance with existing situations.

The detailed description of all developed M-automata is given in the monograph [4] and works [5,6]. There are developments of technical realization of the robot control system [5,7].

M-Networks and Neuron Ensembles

There exists one more independent way of the suggested method argumentation.

It is associated with treatement of M-network nodes as elements corresponding to ensembles of neurons in cerebral cortex. Such ensembles, the idea of which ascends to Hebb [8], are treated here as cortical information models of elements of an individual's inner and external world. In this case the M-network appears as an apparatus for the description of an integral inner (cortical) model of a world of a man and the M-automata as psychophysiological and psychological cognition models. A number of our investigations is completed within a such interpretation [1,9]. Simultaneous existence of two independent to such an extent processes is, in our opinion, quite an interesting fact. It allows, in particular, to suggest (not but speculatively for the time being) that processes of activity of cells and greater brain formations studied by neurophysiologists may be described adequately as processes of execution of procedures of subjective estimation and reestimation of elements of the inner world, i.e., procedures which underlie the behavioural reactions formation. When developed a such approach would serve the cause of narrowing the gap between sciences studying the brain and behaviour.

Conclusion

Semantic networks are traditionally employed to represent a system knowledge on the world in artificial intelligence systems. We endeavoured to use them in representing our own knowledge not only on the world but on mechanisms of behaviour formation, too. Having preserved the constructivity of information presentation we gained an opportunity of using the developed apparatus in artificial systems, in robots in particular. Having introduced the notion of semantic network activity we obtained the possibility to imitate the inner activity or motivation of a robot. Processes of motives-knowledge interaction were represented in the dynamics of information value characteristics. Complexity and diversity of behaviour forms which were observed during the experimental study of the developed M-automata convince us in the efficiency of the used approach and in expedience of its practical employment in efforts to develop integral robots. This may offer great possibilities of representation of complex and intimate behaviour mechanisms knowledge on which may be drawn from the psychology.

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