Pecularities of Semantic Nets in Control Systems

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Abstract

This paper describes the main functions of control systems of complex technological objects in the operating mode. The method of representation of information in complex objects by means of semantic nets is offered which forms a knowledge representation model of the principal components of control systems. The range of tasks requiring to be solved during the design process of control systems is analyzed. The formalism of knowledge representation is determined and procedures and communicational means of deductive inference in this formalism are worked out. A decision-making algorithm of deductive inference on semantic nets is developed. The elaborated algorithm carries out a dialogue with a dispatcher of a control system and on the basis of data analysis received from the object, generates recommendations for controlling this object. This algorithm can be used in solving a wide range of problems, such as operative-dispatch control of power systems, automotive control of complex objects and other kinds of problems which are impossible to be solved by means of formal methods.

Keywords: Colored graphs, decision-making systems, deductive inference, disjunctive, knowledge representation, predicate calculus, semantic nets

Introduction

Logical-linguistic models of control have become widespread for controlling objects with complex nature, for which classical methods of automatic control proved to be inapplicable. First, these objects possess some features which do not allow describing the structure and functioning of these objects by means of formal models using sets of logical, algebraic, differential, and other types of equations. Second, these objects themselves are continually evolving, changing their structure and functions which leads to evolving the controlling process. Third, it is impossible to formalize the objectives of controlling as the objectives themselves are changeable as well. Certainly, it might be reckoned the control problems to be unrealizable because of the absence of formalization instruments. However, the experience of experts who carry out control of these kinds of objects shows that the problem definition and its solution are still possible. One of the powerful formalization means for solving above-mentioned problems are semantic nets.

Nowadays the approach based on the usage of semantic nets in building decision-making systems becomes popular. It is used in the systems of natural language understanding, in the question-and-answer systems, and in the systems of compound objects of operative-dispatch control.

In general interpretation, a semantic net is an informational model of object domain (set of facts and assertions from the database) and has a form of a graph, the nodes of which correspond to the objects (notions) of the object domain, and the arcs correspond to the relationships among them. Syntactical (structural) knowledge, and semantic (information relevant to the given object domain) knowledge are joined in them which allows to update the knowledge quite easily, using relatively homogeneous structure.

Research in the field of semantic nets started in 1966.

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In the work of M.P. Kvillian (cited in Brachman, 1979) the author tried to represent formal semantics of English words. He introduced the term "semantic memory" for the system that was based on a formal language the expressions of which were graphs with marked nodes and arcs.

More specifically, the formal expression of this language was composed from nodes which corresponded to "word-notions" and linking these nodes "associated arcs". These arcs actually operated as pointers by means of which word-notions refer to other word-notions. This structure of mutual references gives the definition of initial word-notion. This is similar to using a wordbook in which interpretation of a given word is constructed on the sequence of words, interpretations of which are scattered in different parts of the wordbook.

Later, the concept of decomposition of semantic nets was introduced (Handrix, 1979). The nets were partitioned in separate structures, called blocks, owing to which the expressive power of semantic nets was effectively raised.

It must be noted that this idea received a wide application and further development in the knowledge representation models, particularly, in modular structures of systems, representing knowledge in the form of nets of frames (Hayes, 1977, pp. 99-107).

Methodology

Relevant method of representation of information in complex objects which forms a knowledge representation model occurs to be one of the principal components of control systems. This model is aimed to store sets of knowledge about this object domain. In the article, principal notions and principles and underlying semantic nets are introduced. A structure of semantic nets in general outline is given and the advantage of representation of knowledge about object domain in the form of semantic nets is shown. A formalism of knowledge representation, as well as communicational means and procedures of deductive inference in this formalism are worked out.

The main content

Control systems of compound objects have to work in the environment which is continually changing and updating under the impact of activities of control systems as well as of the activities independent from the system. Consequently, control systems must possess descriptions in the form of knowledge models of object domain, the set of elementary activities or operators which are alterable by human, or alterable automatically in the issue of the experience of working with such systems, and also by the general mechanism of creating and realizing the committed strategies in the form of a sequence of elementary operators.

In this connection the peculiarities of semantic representation should be noted:

1. In the semantic nets, it is possible to represent notions, events, situations as well as special methods of inference. It must be taken into account that increasing nomenclature of objects decreases homogeneousness of a net and leads to the necessity of increasing the arsenal of conclusion methods.

2. Multidimensionality of semantic nets allows presenting numerous semantic relationships linking certain notions together, notions and events in the sentence, and sentences in the text. Moreover, in semantic nets there can be reflected semantic hierarchy of special conclusion methods which determines their mutual subordination.

3. Formalization, as structural representation of semantic knowledge, makes possible to apply some super semantic to this knowledge. This super semantic reflects relative power of semantic relationships which facilitates to raise the efficiency of decision-making process in semantic nets.

4. On each stage of problem solution, we can neatly separate the complete knowledge of a system (complete semantic net) from the current knowledge – activated section of a semantic net in which some operations (processes of comprehension, conclusion, etc.) are performed.

It is essential to take into consideration that structuring of general semantic knowledge is a great advantage of semantic representation, but this representation is often at a disadvantage in representation of purely structural relationships, easily realizable in predicate calculus (logical links, quantifiers of generality and existence) or in the procedural representation (parallel processes, hypothetical worlds, dynamic events).

That is why quite a number of contemporary researchers in the area of knowledge representation prefer to embed some procedural and declarative representation into semantic representation for the purpose of combining their advantages in a new, mixed representation.

We are raising the problem of the development of complex system facilities aimed at providing the possibility of automatic synthesis of control semantic systems of complex technological objects of certain class. Principles of decision-making and methods of conclusion in concerned systems will be based on the algorithms of deductive inference, user procedures, searching methods in the databases, etc.

Let us define the semantic net on the logical level as disjunctive, and on the physical level – as a set of colored graphs.

Let us consider the principal range of tasks which demand to be solved in the design process of control systems:

1. Determination of formalism of a semantic net as a logical level representation of knowledge which is accessible to the developer of the particular control system.

2. Development of the high level language for the developer of the system to describe synthesizing system by means of a semantic net.

3. Development of means of translation from the high level language, in the result of which a software package, ready to function in the operating mode of the system, is elaborated.

4. Development of means of communication with the database; means of control and management of solution process, and other facilities of the software support.

5. Development of a knowledge engineering subsystem, allowing receiving control actions in certain systems.

6. Development of dialogue facilities using a system and interfaces with objects and so on.

The initial items of semantic nets are types, constants,

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object variables and simple frames (Rossopoulos, 1977).

We give a special consideration to the development of formalism of knowledge representation in the form of a semantic net, facilities of communication with a database, and procedures of deductive inference in this formalism.

A decision-making and complex technological object control system performs two functions: carries out a dialogue with a dispatcher and on the base of data analyses, received from the object, generates recommendations for controlling this object. Decision-making in the system is performed by means of specially developed algorithms of deductive inference on semantic nets.

The class of objects to be considered for control systems z can be described as a W set of its states Ω_z. The state of an object ω_z^i in a certain moment of time ($\omega_z^i \in \Omega z$) will be

$$\omega_z^i = < \prod^i, G^i >$$

where $\prod^i = < \pi_1, \dots, \pi_n >$ – is a set characterizing the object status values; $G^i = < U^i, R^i >$ – a structure of an object, represented as a graph. Here $U^i = \{U_1^i, \dots, U_m^i\}$ is a set of graph nodes to which the objects are matched. These objects are parts of z, $(\forall(U_j^i \in U^i) \rightarrow U_j^i SQNZ)$, $j = \overline{1,m}$ and R^i – is a set of relationships, reflecting the links among elements of the set U^i, and SQN – is a relation "part-whole".

Each status π_e can get meanings from a certain set of acceptable value Ω_{π_e}, where $e = \overline{1,n}$.

Each object U_j^i from the set U^i in its turn is defined similarly, as z, and it is matched with a set of states, $\Omega_{U_j^i}$. In $j = \overline{1,m}$ its turn, $\Omega_{U_j^i} = < \prod_{U_j^i}^i, G_{U_j^i}^i >$, etc.

This kind of structure can have some levels ordered by SQN, besides that there are a number of objects characterized only by a vector $\prod_{U_j^i}^i$.

Thus, the state of an object is characterized with a fixed set of values of all its statuses, with a certain structure, and with status values of its parts.

A set of states for each object is defined by the area of status definitions, and by the structure. The sets of permissible values of statuses are supposed either as finite or some finite-dimensional Euclidean spaces.

Consider the peculiarities of semantic nets serving for knowledge representation in control systems:

1. Initial elements of semantic nets are types, constants and object variables. Different relations are introduced, such as "set-subset" and "part-whole" (SQN hierarchy), and the operation of coloring the semantic nets.

2. The semantic net is described in the form of a set of semantic units of knowledge representation – with fragments called frames.

3.Each frame is predestinated for description of a certain set of elements of a system characterized with areas of status definitions, ways of their calculation, and each of them has its own structure from the set of structures. Principal classes of control system objects and principal classes of solutions in the given system are organized as frames.

Logical conception of a semantic net is based on the following notions.

The element of the system T is a value defined as a triad $T = < \tau, \prod, G >$, where τ – is a type of the element, $\prod$ – a set of values of its statuses $< \pi_1^\tau, \dots, \pi_n^\tau >$, from the area $\Omega_1^\tau \times \dots \times \Omega_n^\tau$ (Ω_i^τ – is a definitional domain of the statuses of a given element); G – is a structure of the element of a graph nodes of which are the elements $T_1^{\tau_1}, \dots, T_r^{\tau_r}$, called the parts of the element T^τ, and the relations $P_1^\tau, \dots, P_l^\tau$, among the given elements, defined separately for the element of the given type.

Elements without structure are called the basic elements. The type τ of the element of system is defined by the frame to which this element relates. The elements of similar type are joined in the sets of elements of type τ; the sets of elements create frames or named sets within the frames in the same way.

Each named set is associated with the set of logical conditions, defining the validity of characterizing object of a given set. As each element is characterized with its structure, the given set of conditions is to be a certain generalized graph, including: a) a list of conditions which must be satisfied by the statuses of the given element; b) a structure, defining a certain sub-graph, nesting into a sub-graph structure of the element under consideration which is necessary for assigning this element to the given set; c) conditions which must be satisfied by the statuses of the parts (SQN-descendants) of the given element, etc.

Conditions, appropriate to the statuses of the given element are given by conjunction of the characteristic predicates, designated subsets of Cartesian products of domain of definition of corresponding statuses.

Designated subsets in the subspaces of the statuses are also defined inside the frames using addressing to the user procedure, immediate definition, or the specific operators.

So, inside the frame F_τ it must be defined:

- Statuses of elements of the given frame, their domain of definition, and computational shortcuts;
- Possible elements of the frame structure;
- Designated sets M_i^τ, appearing the sub domains of Cartesian products of a number of domains of status definitions of elements of the given frame, together with the methods of recognition, relatively towards given sets.
- Designated sets M_i^τ of elements which are the subset of the given frame together with the methods of recognition, relatively towards the given sets are represented as the conjunction of certain conditions;
- Additional conditions about sets M_i^τ, as, for example, a definition of a frame F_τ as a disjunctive of a number of similar sets.

Each set of conditions, setting a characteristic predicate of a certain set M_i is interpreted by the system as an issue of calculation performer of each condition. As there are conditions, demanding calculation of the characteristic predicates of the designated sets inside other frames, in which calculation of each of them may be ambiguous, the general method of problem solving in the given case has the form of AND_OR tree (bringing the task to subtasks).

Each frame consists of intensive and extensional parts. Intensive part is a set of descriptions of condition sets, allowing checking whether the certain element is a part of the given frame. Written in the high level languages these conditions must be translated into some procedure implementing checking the acceptability of the status values and the element structure. The extensional part of a frame – is a certain area in the database where particular examples of elements from the frame are kept along with their values of statuses and structure.

A semantic net must carry out the following functions:

• Answer the information requests of a dispatcher;

• At the request of a dispatcher to solve the decision making problem, or find the control activities.

Incoming to the semantic net request from outside will cause generation of inner questions, appropriate to generating the subtasks, essential for receiving the final answers. Each inner request will cause addressing to the procedures in the net, solving the given subtask, or reducing it to the simpler subtasks. The answer to the request will be a list of elements, satisfying incoming conditions, or a list of control activities, leading to the desired result. In the description of any frame, the possibility of generating the answer is foreseen. If there are different ways of solutions for subtasks, planner, representing a system module, calling from the networking program before any point of branching, itchooses one of the branches. The criteria of choice are estimations of time study on solution task, using each possible method. If the solution is not received for the chosen branch, the planner returns to the point of branching; incidentally, the choice of the following branch is made on the basis of changed time estimations.

Conclusion

One of the principal parts of the control systems of complex objects is a means of information representation. All the knowledge about the problem domain must be kept in the knowledge representation model.

There are the following classes of knowledge representation models: declarative, procedural and special.

In the declarative representation there is a close-cut separation between the procedures of search for solutions, which leads to the exhaustive search, and the procedures of optimization of this search for the purpose of reduction of this exhaustive search. Efficiency of searching is low because it must be handled the complete description of the system states.

In the procedural representation some algorithmic languages are used with embedded tools of automatic search for solutions (PLANNER, CONNIVER, QA4, KRL, FRL). In the procedural representation the structural knowledge is separated from the semantic knowledge. This makes it difficult to use the knowledge, especially in real control systems.

Semantic nets are free from the above mentioned deficiencies.

The main characteristics of semantic nets are the following:

1. Descriptions of the objects from the object domain are derived using natural languages;

2. All the knowledge including incoming facts as well as certain specialized methods of solution, are accumulated in the relatively homogenous structure of memory;

3. On the semantic nets there are defined a number of more or less unified semantic relations among objects which correspond to unified methods of inference.

In the present paper it is described an algorithm of deductive inference on semantic nets for decision-making in the control systems of complex objects which can be used in solving a wide range of problems.

Using semantic nets in the control systems of complex objects will increase the power of control systems because of their ability to describe dynamic processes with a glance of experience in working with such systems.

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