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Indistinct structure of targets to formalize the tasks of dynamic objects management

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Abstract: To solve the problems of managing dynamic objects, the generalized structure of target installations has found wide application, which is a kind of heterogeneous functional network. At the same time, the formalization apparatus allows to describe the structure of the target model itself, to establish the truth of the relationship between the goals for each aspect of knowledge, to control the process of achieving the targets and the replenishment of knowledge. However, the existing means of formalizing logical-analytical activities of decision-makers are based on classical logic, which dramatically reduces the quality of decisions taken in conditions of uncertainty. The existing contradiction between the complexity of decision-making processes for managing dynamic objects and the imperfection of the formalization apparatus for solving these problems under uncertainty conditions necessitates the refinement of the means of formalization and forms the purpose of the article. The authors consider an approach to supplement the target structure with elements of fuzzy sets. The proposed formalization apparatus, called the fuzzy structure of target settings, significantly expands the descriptive capabilities, allows for initial conditions and manipulating knowledge in a wide range to obtain a solution for controlling a dynamic object, characterized by sharing the generalized structure of targets and the apparatus of fuzzy sets. The combination of these two approaches allowed, within the framework of a single formalism, to carry out the designation of the initial conditions not by rigid boundary values 0 and 1, but by any number from the range [0, 1], thus achieving a more accurate description of the properties of the modeled domain. At the same time, the rejection of the vertices of the search, algorithmic, and comparison makes it possible to significantly simplify the structure of the targets and the computational procedure on it. The description of the subject area obtained in the article due to the proposed formalization apparatus will allow, as a result of logical inference, to calculate the value of the membership function at any level of the target structure hierarchy, which will make it possible to more accurately relate the achieved and planned situations and, accordingly, make more informed decisions on managing dynamic objects.

Keywords: indistinct structure of targets, formalization apparatus, dynamic object, indistinct sets, management, functional network.

1. Problem statement

1.1 The generalized structure of targets (GST) provides targeted planning of processes to achieve a goal with dynamic objects (DO) [1, 2, 3]. The formalization apparatus (AP) allows to describe the structure of the target model itself; to establish the truth of the relationship between goals by each aspect of knowledge; to control the process of goals achievement and knowledge replenishment.

Logical-analytical activities formalization means for decision makers (DM) are based on classical logic. This feature dramatically reduces the quality of decisions made in the face of uncertainty.

Thus, the contradiction between the complexity of decision-making processes on DO management and AP imperfection for solving these problems in conditions of uncertainty necessitates the refinement of the means of formalization.

1.2. Analysis of recent researches and publications

A network model is a collection of vertices and connections between them representing the stages and sequence of their implementation during the solution of a logical-design problem [4].

Network model (NM) can be set as follows

$$S = \langle I, \mathrm{C}_1, \mathrm{C}_2, ..., \mathrm{C}_n, \Gamma \rangle,$$

Where: I – set of information units;

$\mathrm{C}_1, \mathrm{C}_2, ..., \mathrm{C}_n$ – set of links types between information units;

Γ – reflection between I and connections from a given set.

Formally, the network model is presented as follows:

$$SM = \{V, R\},$$

Where: V – set of NM vertices;

R – set of arcs.

Each vertex is described as follows

$$V = \{V_i\} = \{\langle Sem_i, UI_i, NU_i, T_i, Re\,z_i, Pr\,Oz_i \rangle\},$$

Where: Sem_i – goal of the solution search;

UI_i, NU_i – hierarchy level number on NM and vertex number on the level;

T_i – vertex type;

$Re\,z_i$ – result of the problem solution implementation (numeric or symbolic value);

$Pr\,Oz_i$ – definition procedure to get the result of the problem solving.

Generalized GST is presented in Fig. 1.

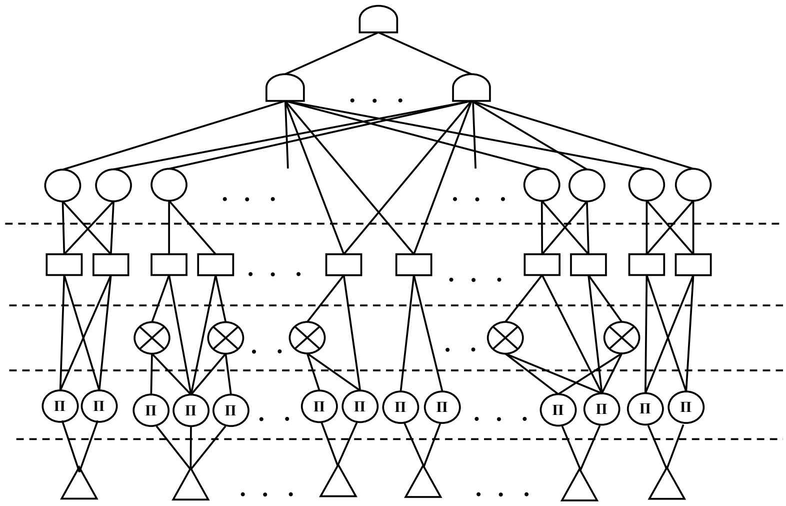

Fig. 1. Generalized network structure

The following is shown in Fig. 2:

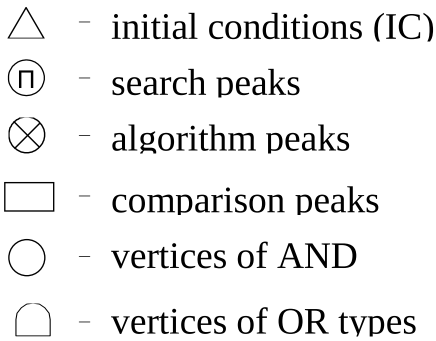

Fig. 2 Constituent structures of Generalized network structure

Use of IC determines the need to develop tools for the introduction of source data.

Search and summarization of data is implemented by processing information from the database. The results are numeric values. The results of logical-analytical activity are represented by the logical values: “true” and “false”. Vertices are used to go from numeric to Boolean values.

Vertices AND and OR are used to implement logical generalizations of the comparison results.

The initial conditions mark the initial statements on the basis of which the truth of the rule, depicted by the network model, is verified.

Such models are an alternative to predicate knowledge representation models.

NM usage advantages:

1. Simplicity of representation and processing of the network model in a computer.

2. The ability to build effective algorithms to control the correctness and completeness of knowledge formalization about the subject area.

NM disadvantage is the need to develop special procedures to display the total set of knowledge.

Knowledge processing (for formalization of which the network models are used) differs depending on the type of these models.

A well-known approach is when goals are structured and streamlined and rational options are chosen for their achievement [1, 5]. Construction of hierarchical structure of goals is also considered in the works through the relationship of necessity and sufficiency. However, this relationship determines the nature of each target separately. At the same time, the essence of the relationship between pairs of goals is not explored.

Use of GST in the development of solutions is as follows. First of all, initial conditions are indicated. On their basis, the values of the vertices of the first level are defined, then those of the second level, etc. to the vertex of the highest level of hierarchy. The value of this vertex is a response to the user or recorded for further processing.

However, the use of only values 0 and 1 for the use of DOs in the process of solutions development for IC definition and carrying out of subsequent actions on GST under uncertainty of a different nature leads to the unjustified results.

Reuter's default logic, MacDermott and Doyle's non-monotonic logic, etc. are used to overcome the incompleteness of the original data.

Probabilistic Bayesian Logic; Dempster-Shafer theory; indistinct sets and indistinct logic; confidence factors are used to display fuzziness of knowledge and their processing.

Therefore, the improvement of AP is relevant which will allow to make decisions on the management of dynamic objects in conditions of uncertainty and incomplete information.

1.3. Stage performance

Goal of the article Development of formal-logical apparatus built on the basis of GST to ensure the implementation of decision-making tasks for DOs management under non-stochastic uncertainty.

2. Basic material

2.1 Correctness of decision making on DOs management is based on the following provisions [6-10]:

1. The end result of purposeful activity is a set of targets. The need to achieve (relevance) target is determined by the situation. Targeted options are the means to achieve goals.

2. Achievement of current targets is ensured by the implementation of solutions.

3. Logical connections between targets and means of their achievement are taken into account when choosing a rational option.

4. The set of means to achieve the targets, their composition and interrelations should correspond to the level of knowledge about the subject area. The effectiveness of the management system is increased with the knowledge of the subject area.

In general, decision making is characterized by a list of problems $\overline{P}=(p_1, p_2, ..., p_n)$, restrictions on possible actions $\overline{O}=(o_1, o_2, ..., o_m)$ and consists in development of a set of targets $\overline{Ц}=(ц_1, ц_2, ..., ц_k)$, which is to be achieved, possible options to achieve them $\overline{D}=(d_1, d_2, ..., d_l)$ and selection of a rational set of options $\overline{D}^*=(d_1^*, d_2^*, ..., d_l^*)$, $\overline{D}^* \subset \overline{D}$ [8].

NM shall include targets expressed by some formulas. They determine the nature of the target and reflect the Aleutian and Deontic aspects of knowledge about it. The fact of the target achievement in a situation is determined by a certain characteristic function. The conjunctive and disjunctive nature of the components determines their necessity and sufficiency to achieve the target.

The relevance of ND target is characterized by the deontic aspect of knowledge and is determined by the corresponding truth of TD or FD value.

Target y is called conjunctive if

$$x_1 \wedge x_2 \wedge ... \wedge x_m \rightarrow y, \quad (1)$$

$$y \rightarrow x_1 \wedge x_2 \wedge ... \wedge x_m. \quad (2)$$

Target y corresponds to “AND” vertex in the hierarchical structure of targets (Fig. 3a) and expressions (1) and (2) are true (T_D) for it.

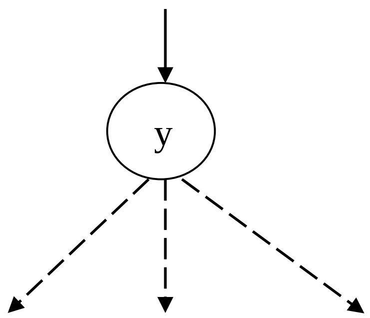

Fig. 3a Conjunctive target

2.2. The Aleutian aspect of knowledge characterizes opportunities, but not a fact of the target achievement. The target is achievable if the corresponding formula takes the value T_A.

For a variety of expression formulas:

$$x_1 \wedge x_2 \wedge ... \wedge x_m \rightarrow \mathrm{M}\uparrow y \quad (3)$$

$$\mathrm{M}\uparrow y \rightarrow x_1 \wedge x_2 \wedge ... \wedge x_m \quad (4)$$

take the values T_A, then the target y is called conjunctively attainable (Fig. 3b).

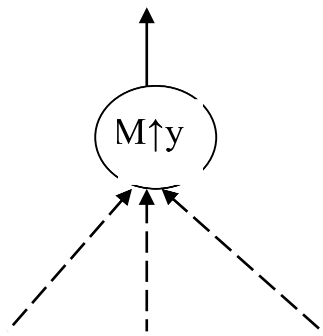

Fig. 3b. Conjunctively achievable goal

The actions of the system to move from a situation to that where y is true are indicated as $\mathrm{M}\uparrow y$.

2.3. The target is disjunctive (Fig. 3c), if:

$$x_1 \vee x_2 \vee \ldots \vee x_m \to y, \tag{5}$$

$$y \to x_1 \vee x_2 \vee \ldots \vee x_m. \tag{6}$$

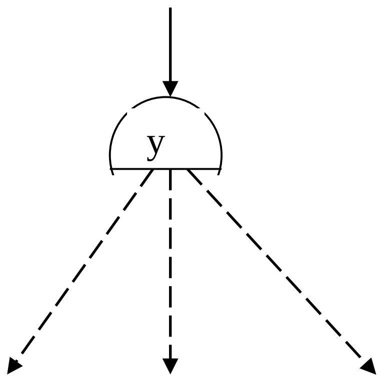

Fig. 3c. Disjunctive target

If the following formulas (T_A) are truth:

$$x_1 \vee x_2 \vee \ldots \vee x_m \to \mathrm{M}\uparrow y, \tag{7}$$

$$\mathrm{M}\uparrow y \to x_1 \vee x_2 \vee \ldots \vee x_m, \tag{8}$$

then the target will be disjunctively achievable (Fig. 3d).

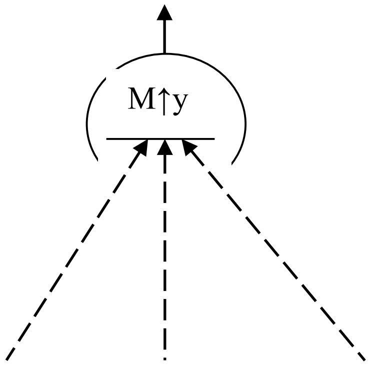

Fig. 3g. Disjunctively achievable target

The truth of each component of expressions 1 and 2 is a required condition for the truth of a conjunctive target. The truth of at least one of the formulas 5 and 6 is a required and sufficient condition for the truth of a disjunctive goal, regardless of knowledge aspects.

However, the need and the possibility of achieving the targets are not identical. That is, the considered means for describing targets based on NM are not enough. Consider the characteristic function of the following form to link the actual processes and the objectives described by proposed AP [11]:

$$\vec{\varphi}(\alpha,t) = \mathop{\wedge}_{i=1}^{n} \varphi_i(\alpha,t) \equiv \varphi_1(\alpha,t) \wedge \varphi_2(\alpha,t) \wedge \ldots \wedge \varphi_n(\alpha,t)\,, \qquad (9)$$

Where, α – situational variable describing the state of the problem environment; t – moment of time; $\varphi_i(\alpha,t) = \begin{cases} \varphi_i(\alpha,t), \\ \sim \varphi_i(\alpha,t), \end{cases}$ – elementary logical formula expressing a certain state of the problem environment.

Pragmatic truth T_P of elementary formulas $\varphi_i(\alpha,t)$ are determined on the basis of information about the observed signs of the situation α.

2.4. Thus, Deontic T_D, Aleutian T_A and pragmatic truth of T_R occur for each NM target. They characterize the necessity, possibility and fact of the target achievement, respectively (Fig. 4).

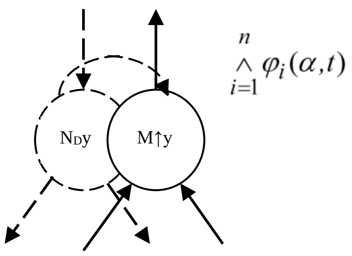

Fig. 4. Unity of Deontic, Aleutian and pragmatic truth of the target

In combination, the dual nature of "AND" and "OR" vertices in no way resolves the contradictions in the designation of the initial conditions.

The use of four-valued logic – “true”, “false”, “indefinitely” and “contradictory” as well as of eight- or sixteen-digit logics, does not solve the problem in principle. Finally, an unambiguous decision is made (often rude and incorrect) about assigning the value 0 or 1 to the IC as a result of definition.

A possible way to go out of this impasse is an attempt to combine the structure of targets and indistinct sets within a single apparatus and to get indistinct GST.

Collection of ordered pairs is called as indistinct subset A of a set X [4, 12]

$$A = \{(x, \mu_A(x))\}, \forall x \in X\;, \qquad (10)$$

where $\mu_A(x)$ – membership function.

Example of construction for different DO flight altitudes is presented in Fig. 5.

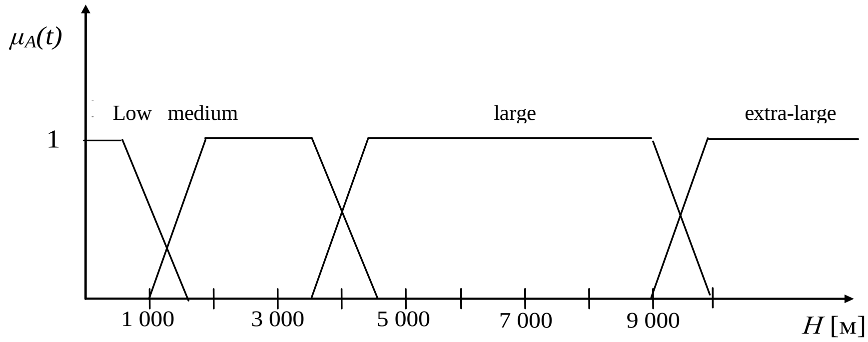

Fig. 5. Linguistic "height" variable

2.5. Linguistic variables are divided into numeric and non-numeric. Numeric is a linguistic variable for which the base variable is defined on a numeric set. Thus, the linguistic variable "Height" is numeric and its value (indistinct variables) are indistinct numbers. Each indistinct variable in fig. 6 conditionally corresponds to the trapezoidal membership function. Thus, the indistinct variable "average" is defined as:

$$\text{‹ average } \{(1000|0),(2000|1),(3500|1),(4500|0)\}.$$

Now any vertex of a nanosecond can have any value from the interval when the initial conditions [0, 1] are indicated. Known operators can be used in the process of determining the values of the membership functions of the vertices of subsequent levels: Zadeh max-min, Mamdani min, Arithmetic, Larsen Product, Boolean, Bounded Product, Standard Sequence, Drastic Product as well as Gougen and Godelian.

The outcome of the procedure is to obtain indistinct solution. The specific solution is obtained by converting the solution (indistinct subset) to a scalar.

Thus, GST and its logical inference are greatly simplified.

First, the transition is performed from the rigid boundary values 0 and 1 to more "soft" values of the membership function from the range [0, 1].

Secondly, GST itself is simplified. There is no need in search, algorithmic and comparison vertices.

Thirdly, the result of the logical conclusion on GST with the use of one of its known or modified procedures is a certain value of the membership function at any level of the hierarchy of the target structure allowing to make an unambiguous decision to achieve the target with a dynamic object.

Conclusion

Thus, a mathematical tool is proposed to formalize decision-making tasks for dynamic objects management which is distinguished by sharing the generalized structure of targets and the apparatus of indistinct sets. The combination of these two approaches allowed, within the framework of a single formalism, to carry out the designation of the initial conditions not by the rigid boundary values 0 and 1 but by any number from the range [0, 1]. Thereby, more accurate description of the properties of the simulated subject area is achieved.

The refusal of the search, algorithmic and comparison vertices greatly simplified the structure of the targets and greatly simplified the computational procedure.

A more accurate description of the subject area at the expense of the proposed formalization apparatus will allow, as a result of logical inference, to obtain the value of the membership function at any level of the target structure hierarchy which will make it possible to more accurately relate the achieved and planned situations and, accordingly, make more informed decisions on dynamic objects management.

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Нечеткая структура целевых установок для формализации задач управления динамическими объектами

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Аннотация: Для решения задач управления динамическими объектами широкое применение нашла обобщенная структура целевых установок, являющаяся разновидностью неоднородной функциональной сети. При этом аппарат формализации позволяет описывать структуру самой целевой модели, устанавливать истинность отношений между целями по каждому из аспектов знаний, контролировать процесс достижения целевых установок и пополнения знаний. Однако существующие средства формализации логико-аналитической деятельности лиц, принимающих решения, базируются на классической логике, что резко снижает качество принимаемых решений в условиях неопределенности. Существующее противоречие между сложностью процессов принятия решений по управлению динамическими объектами и несовершенством аппарата формализации для решения указанных задач в условиях неопределенности обусловливают необходимость доработки средств формализации и формирует цель статьи. Авторами рассматривается подход, позволяющий дополнить структуру целевых установок элементами нечетких множеств.

Предложенный аппарат формализации, названный нечеткой структурой целевых установок, существенно расширяет описательные возможности, позволяет означать начальные условия и манипулировать знаниями в широком диапазоне для получения решения на управление динамическим объектом, отличающийся совместным использованием обобщенной структуры целевых установок и аппарата нечетких множеств. Объединение этих двух подходов позволило в рамках единого формализма осуществлять означивание начальных условий не жесткими граничными значениями 0 и 1, а любым числом из диапазона [0, 1], чем достигается более точное описание свойств моделируемой предметной области. При этом отказ от вершин поисковых, алгоритмических и сравнения позволяет значительно упростить саму структуру целевых установок и вычислительную процедуру на ней. Полученное в статье описание предметной области за счет предложенного аппарата формализации позволит в результате логического вывода вычислить значение функции принадлежности на любом уровне иерархии структуры целевых установок, что позволит точнее соотносить достигнутые и запланированные ситуации и, соответственно, принимать более обоснованные решения по управлению динамическими объектами.

Ключевые слова: нечеткая структура целевых установок, аппарат формализации, динамический объект, нечеткое множеств, управление, функциональная сеть.

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Нечітка структура цільових установок для формалізації завдань управління динамічних об'єктів

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Анотація: Для вирішення завдань управління динамічними об'єктами широке застосування знайшла узагальнена структура цільових установок, що є різновидом неоднорідної функціональної мережі. При цьому апарат формалізації дозволяє описувати структуру самої цільової моделі, встановлювати істинність відносин між цілями по кожному з аспектів знань, контролювати процес досягнення цільових установок і поповнення знань. Однак існуючі засоби формалізації логіко-аналітичної діяльності осіб, які приймають рішення, базуються на класичній логіці, що різко знижує якість прийнятих рішень в умовах невизначеності. Існуюче протиріччя між складністю процесів прийняття рішень з управління динамічними об'єктами і недосконалістю апарату формалізації для вирішення зазначених завдань в умовах невизначеності зумовлюють необхідність доопрацювання засобів формалізації і формулює мету статті. Авторами розглядається підхід, що дозволяє доповнити структуру цільових установок елементами нечітких множин. Запропонований апарат формалізації, названий нечіткої структурою цільових установок, істотно розширює описові можливості, дозволяє означати початкові умови і маніпулювати знаннями в широкому діапазоні для отримання рішення на управління динамічним об'єктом, що відрізняється спільним використанням узагальненої структури цільових установок і апарату нечітких множин. Об'єднання цих двох підходів дозволило в рамках єдиного формалізму здійснювати позначення початкових умов не жорсткими граничними значеннями 0 і 1, а будь-яким числом з діапазону [0, 1], чим досягається більш точний опис властивостей модельованої предметної області. При цьому відмова від вершин пошукових, алгоритмічних і порівняння дозволяє значно спростити саму структуру цільових установок і обчислювальну процедуру на ній. Отриманий в статті опис предметної області за рахунок запропонованого апарату формалізації дозволить в результаті логічного висновку обчислити значення функції приналежності на будь-якому рівні ієрархії структури цільових установок, що дозволить точніше співвідносити досягнуті і заплановані ситуації і, відповідно, приймати більш обґрунтовані рішення з управління динамічними об'єктами.

Ключові слова: нечітка структура цільових установок, апарат формалізації, динамічний об'єкт, нечітка множина, управління, функціональна мережа.

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