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Some Interesting Features of Semantic Model in Robotic Science

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Abstract – *The present work attempts to overview semantic networks' classification and their valuable features. It is very much liable for solving knowledge management problems. The fundamental characteristics of semantic models (SM) have been discussed in a new fashion. Finally, the new technique for the construction of the robot's workspace is also explained very well due to the semantic model. It has been explained in a simple way by an algorithm and then formalized by mathematical models. The proposed work was found within a good agreement with others.*

Keywords – *Robotics, Semantic, Networks, Models, Algorithm.*

I. INTRODUCTION

When solving production and non-production purposes, systemic knowledge management remains relevant; this is solved by accumulating structured and formalized knowledge, making it possible to solve current problems and subsequent reuse. Knowledge management's primary goal is to effectively present data and information resources for decision-making [1].

Robotics is a sphere of the modern world, and special attention is paid to its improvement. Every day robots perform more and more complex tasks with total autonomy. Still, it is essential that they not only «feel» the environment but also react to it promptly to perform specific actions in the future.

There are many use cases for semantic modeling (SM). The SM in robotics allows modeling both robotic agent groups' behavior and possible changes in their environment (workspace). The workspace includes a description of geometric and other physical objects in the background and their relationship. Such a report has a hierarchical structure and, what is necessary, the knowledge presented in this way lends itself well to processing on an electronic computer.

This work will consider the semantic model of knowledge representation from the perspective, increasing efficiency for recognizing and processing information processes in the robot's workspace, obtained by technical vision systems (TVS). At present, the most effective method for gaining knowledge about the workspace of robots is vision systems. Robots typically use exteroceptive sensors such as cameras or LiDAR to detect objects in the workspace and determine their visual properties and spatial relationships. However, semantic properties of the world are often visually invisible [2].

The need for a more convenient and powerful means of domain representing has become a prerequisite for the broader application of semantic modeling. The main idea is that model represents data about natural objects and connections between them in an indirect way, which significantly facilitates access to knowledge: starting from some concepts, along arcs of relations, you can reach other ideas. In semantic modeling, there is a requirement – associativity, a grouping of information around facts, attributes, and objects. Thus, SM is a semantic interpretation of complex subject areas and logical means of formal description of real things.

II. MATERIALS AND METHODS

A. Related work

Today, there are many works devoted to SM; this is because there is explosive growth in the amount of information created by people and machines, which must effectively be present for making a specific decision.

Making a decision is not enough to analyze the subject area; specialists' reasoning process must formalize and structure their ideas about the subject area. Creation and support of functioning for any object generate several essential tasks that require a scientifically grounded approach to their solution, for example, the formation of a semantic model for the domain.

In [3] gives a good overview of process semantic network formalizing for distributed search in e-learning to synthesize a decision tree. To prepare a model for the e-learning decision tree, first-order predicate logic was used, making it possible to perform calculations both at nodes of a tree and at its edges and make decisions based on the analyses' results.

Also, attention is paid to the formalism of knowledge representation in the semantic network context in [4]-[6].

In [6], the hierarchical structures of concepts by a semantic network (IS-A, PART-OF) are described. In representation, the idea of blocking introduced problem-solving, making it possible to group vertices and arcs of a semantic network into separate structures called blocks. These structures are identified with virtual objects in the subject area of the system.

The evolution of modern robotics has given impetus to the emergence of several different related technologies. These technologies include semantic mapping. SM in robotics is represented by semantic mapping for mobile robotics tasks [7] to provide an abstraction of space and communication between person and robot. The authors paid attention to semantic mapping and analyzed existing methods.

In [8], introduced the concept of semantic navigation based on hypergraphs. Paper deals with the extraction of semantic features from raw data provided by laser scanners. Thanks to SM, the mobile robot recognizes and identifies objects in its workspace of certain classes. In [9], a general formal definition of semantic robotic maps is presented. Issues related to different design criteria, classification, and problems of semantic maps, in general, are considered.

SM of complex information collected by mobile robot at home to recognize working space is presented [10].

B. Classification of semantic networks

When formalizing semantic models, it is necessary to take into account a whole variety of semantic networks. SM allows users to model and view data at many levels, which leads to their universal acceptance.

Consider classification of semantic networks, taking into account their features.

1. By the number of relationships types:

- homogeneous networks have only one type of relationship (arrows);

- heterogeneous networks have more than two types of relationships (classical networks). Heterogeneous networks are of greater interest for practical purposes but also more difficult for researchers. Heterogeneous networks can be represented as an interweaving of tree-like multilayer structures [11], [12].

2. By purpose of relationship:

classifying – describe various hierarchical relationships between concepts. May contain taxonomic, structural, generic, and industrial relations [13];

- functional – computational models that allow describing the procedures for calculating some information units through others [13];

- scenarios – are used to describe casual relationships (causal or establishing the influence of some phenomena or facts on others), as well as relationships such as "means - result," and "tool - action," etc. [14].

3. By participation (arity) degree of concepts in relationships [15]:

- Binary relations (only two concepts connect). Such ties are pretty convenient and straightforward from the point of view representing on the graph in the form of an arrow between two ideas;

N-ary (it is determined that relations are used and connected with more than two objects) in practice. They are more complex because it can be confusing to represent all relationships on a graph.

4. To size:

- to solve specific problems, for example, those are solved by artificial intelligence systems;

- sectoral scale should serve as the basis for the creation of specific systems, without claiming to be of universal importance [16];

- global semantic network. In theory, such a network should exist since everything in the world is interconnected. Perhaps someday World Wide Web will become such a network [15].

5. By type:

- assertion networks – designed to assert propositions are intended to state recommendations. Most data in an assertion network is genuine unless it is marked with a modal administrator. Some assertion systems are even considered as a model of reasonable structures underlying characteristic semantic natural languages [17];

definitional networks emphasize and deal with the only subtype or relation between concept type and newly defined subtype. A producing network is referred to as a generalization hierarchy. It supports the inheritance rule for duplicating attributes [18];

- executable network – contains mechanisms that can cause some changes to the network itself by incorporating some techniques, for example, such as attached procedures or marker passing which can perform path messages, or associations and searches for patterns [17];

- implicational networks – uses implication as to the primary connection for connecting nodes. Also, these networks are used to explain patterns of convictions, causality, and even deductions [18];

- learning networks – these are networks that build and extend their representations by acquiring knowledge through examples. Contain mechanisms in such networks brings changes within the network itself through expression by securing information. A classic example could be like, changing a new report from an old system by including and excluding nodes and arcs, or by changing numerical qualities called weights, and connected with arcs and nodes [16], [18];

- hybrid networks – networks that combine two or more of previous techniques, either in a single network or in a separate but closely interacting network hybrid network, have been created to implement ideas regarding human cognitive mechanisms. In contrast, some generally are developed for computer performance [17], [18].

6. By type of relationship:

- symmetrical (for example, synonymy and antonomy);

- asymmetric (for example, "part-whole", "cause-effect", "opposite", etc.) [19].

7. By type of knowledge description about upgraded objects:

The intensional network contains intensional knowledge and describes the general structure of the modernized subject area based on abstract objects and relations, generalized representatives of certain classes of objects and relations. For example, objects such as a production site, load, the part can be generalized concepts of meanings set, from which names set of specific production sites (turning, press, etc.), terms set f goods (workpiece, cassette), parts classes set (bolt, shaft, nut, etc.) [15], [20];

- an extensional semantic network that describes extensional knowledge about objects is being modernized, and as it were, a «photograph» of its current state.

8. By type hierarchy:

- static semantic hierarchy models (conceptual graphs). Informalism of conceptual graphs, a particular class of concepts is distinguished – proposition. Concept «proposition» includes one or more conceptual graphs, which allows one to define meta-statements [21];

- dynamic semantic hierarchy models. Data model and semantics of objects with active roles (taking into account that entered data can change and be replenished). Here are some fundamental characteristics for semantic data models:

a. Representation of unstructured objects – as low-level or primitive types that are not constructed through lower-level types' aggregation. Strings, integers, and reals are examples of low-level types [21], [22];

b. Relationship Representation. A relationship is presented as an entity if the relationship of two or more objects conceptually describes a distinct model object [21], [22], [23];

c. Hierarchies of Relationships. An important technique used in semantic networks is hierarchy or classification systems. Domain ontology is represented in the form of hierarchy, at the root of which is concept/object, and in nodes – its nomenclature;

d. Derivation / Inheritance. How semantic model is presented makes it easy to conclude due to the hierarchy of inheritance between levels (inheritance of attributes);

e. Abstractions Present. Most traditiona1 data models provided only one means of representing data. Semantic models, using abstractions, enable users to model and view data at many levels.

III. METHODOLOGY FOR DEVELOPING A SEMANTIC MODEL OF ROBOT'S WORKSPACE

A semantic model in robotics can describe relationships between any object, for example, detected and identified in an image.

In recognizing and identifying information entered using a technical vision system, it will determine the geometric characteristics of objects and their belonging to a particular class. Data obtained allows one to identify semantic links between individual objects and correspondence of detected links to standard descriptions (templates). The preceding was proposed to investigate the possibility of using semantic models to determine meaningful and semantic relationships between objects in the robot's workspace during the assembly process.

Constructing semantic networks process consists of identifying objects and building a model itself. A method is proposed for making a semantic model of the robot's working space based on information of TVS, the algorithm of which is shown in fig. 1.

1. Analysis of robots working space content is carried out to highlight the main elements of semantic network.

2. All objects are in a workspace and, with the help of classifiers, belong to certain classes; that is, they are recognized and identified, and for this, you first need to determine the type of these elements.

Object identification – during the learning process, the classifier remembers each product's geometric features (holes, corners, threads, etc.). In the course of scanning images by robot's TVS, the geometric characteristics of objects are compared with those stored in memory. When all properties match, the object is assigned the appropriate name of the specific class, and the coordinates of the assumed center are determined.

As an example, an object can be identified as a «nut» if it has a thread, 6-sided shape (fig. 2a), or as a «bolt» if the object has semicircular/countersunk / 6 sided / cylindrical head shape, cable, and cylindrical rod (fig. 2b).

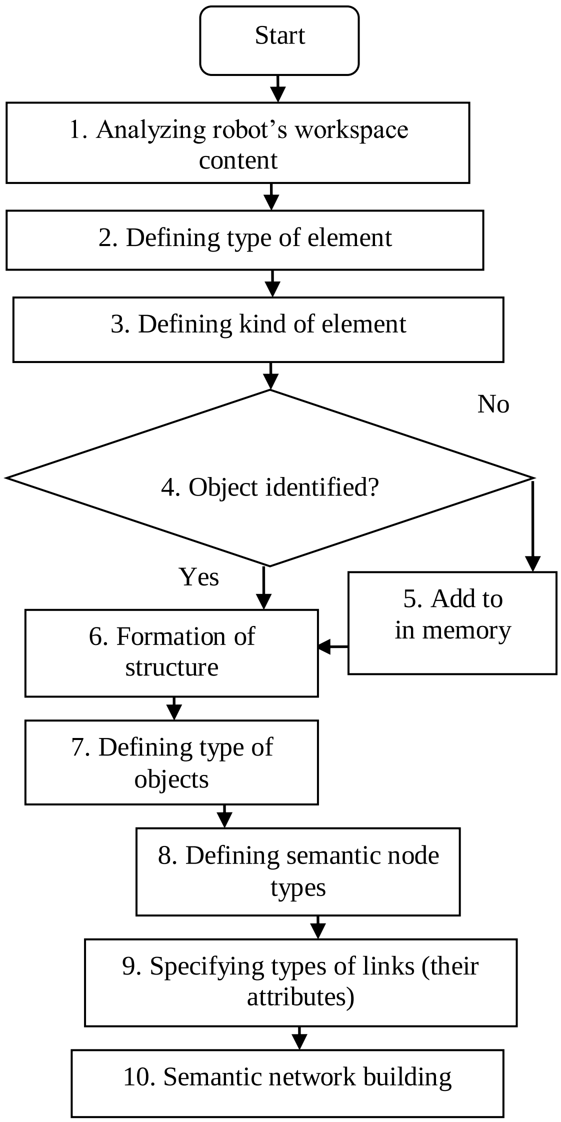
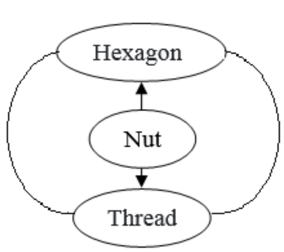
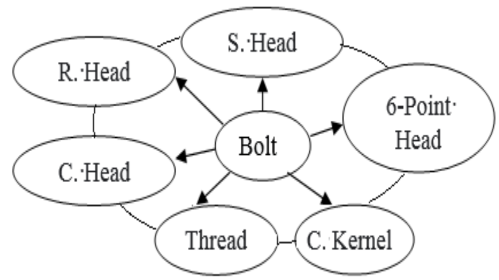


Fig. 1: Algorithm for semantic model of robot's workspace constructing



a)



b)

Fig. 2: Identification of objects (such as a fastener) by individual characteristics

3. Determination of elements type and their possible values.

4. Check for object identification. If characteristics of an object are not found in memory, they need to be added there (point 5).

6. Formation of structure – highlight levels of elements hierarchy, form links, indicate their direction.

Information obtained in this way is the initial one for constructing a robot's working space; it can be represented as a model (1), including certain semantic connections between objects.

The general presentation principle of the initial object description is that it consists of many elements. Therefore, to represent description object (D_{or}), one should:

$$D_{or} = (D_o, D_{po}, D_e), \quad (1)$$

where

D_o – determination of objects kind, D_{po} – description of concept objects properties, D_e – description of element.

7. Determination of objects kind – elements of semantic network can be formalized as:

$$D_o = (Vr, Ar), \quad (2)$$

where

Vr – vertices, Ar – arcs.

Vertices can be represented as:

$$Vr = (Cn, Pr, Ev), \quad (3)$$

where

Cn – concepts, Pr – events, Ev – properties.

Events can be described as:

$$Pr = (Ta, Ro), \quad (4)$$

where

Ta – action type indication, Ro – indication of roles that objects play in this action.

Properties are used to clarify concepts and events and can be expressed through:

$$Ev = (Ev_{cn}, Ev_{ev}), \quad (5)$$

where

Ev_{cn} – properties for concepts (describe their features and characteristics: size, material, color, etc.), Ev_{ev} – properties for events (duration, time, location).

8. Definition of nodes semantic types, an indication of their attributes.

Can only be built a semantic node at the very end of semantic analysis. That is, the main goal of semantic analysis is the construction of semantic nodes.

9. Indication of types of links (their attributes).

Key links – allow you to build a hierarchy of concepts in the network, in which nodes of lower levels inherit nodes properties of higher levels. This transfer mechanism determines the effectiveness of semantic networks.

In semantic networks, there are these types of links:

- functional connections (usually defined by verbs «produces», «influences» ...);
- quantitative (more, less, equal ...);
- spatial (far from, close to, behind, below, above ...);
- temporary (earlier, later, during ...);
- attributive (have a property, have a value);
- logical (AND, OR, NOT);
- linguistic.

10. Building a semantic network based on a robot workspace model.

Input information for building a semantic model is identified objects of robot's workspace.

Let there be set of objects $X = \{X_0, X_1, X_2, ..., X_n\}$, visible with TVS, и $R = \{R_0, R_1, R_2, ..., R_m\}$ – many semantic connections between these objects.

Then semantic network can be represented as:

$$SN = X' \times R', \quad (6)$$

where

$X' \subset X,\ R' \subset R.$

For example, after identifying object S, we get: concepts set eCn, which are entities, and concepts set eR, expressing relationship between other concepts.

First of all, from candidates set eCn, it is necessary to select key concepts set – eK.

Next, you should highlight received candidates for key concepts, and then highlight context.

Thus, from candidates set eCn, it is necessary to remove elements of key concepts set eK, as a result of which set of relations and secondary concepts eM – eCn / eK will be obtained.

The task is to select a subset of relations (associations), where relationships of type: dependence, subordination, and aggregation relation can act as an association of critical concepts with other concepts.

Thus, after analyzing connections between concepts, we obtain elements of relations set eR.

Each of the elements of the relations set will be associated with a particular key concept, creating of elements descriptions set:

$$S_i = (e_i, Re_i), \quad (7)$$

in which elements of sets Re_i are elements of set eR.

Describes of elements are not yet complete since aspects of the set eR are not associated with secondary concepts.

It is necessary to search for secondary eR concepts – concepts referred to by associations.

Semantic description of a product obtained in this way will consist of many elements that describe the general representation of subject area state without concepts that reflect entities and relationships. In general, the network can see in fig. 3.

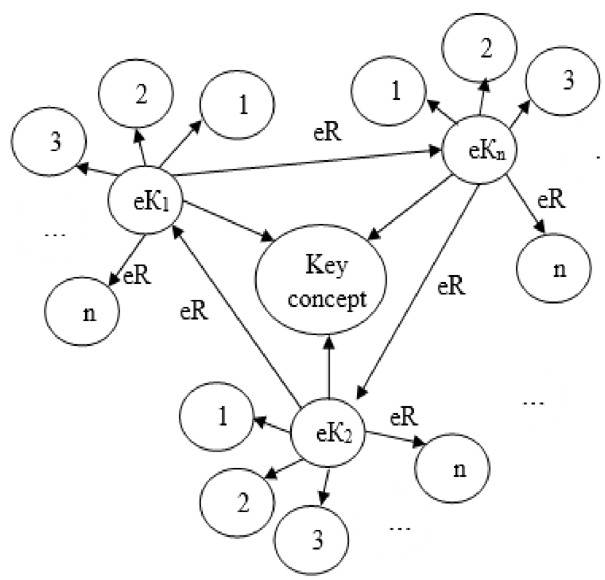


Fig. 3: The semantic communication network of concepts

After TVS, with specially trained classifiers, identifies objects of workspace, connections between these objects are determined; objects are compared with templates of semantic networks in memory. When specific characteristics coincide, the appropriate template is selected. Information about this enters the decision-making system, where the correct robot command is assigned to complete the assembly of a part.

IV. CONCLUSION

The article provides an overview of semantic networks' classification features, which must be considered when solving knowledge management problems. Characteristics fundamental for semantic models are discussed. A technique for constructing a semantic model of the robot's workspace during the assembly process is proposed, represented by an algorithm, and formalized by mathematical models. The proposed technique is the basis for structuring information in developing a database and knowledge base for information support of procedures for objects searching in the robot's workspace during assembly to improve recognition and information processing efficiency. The proposed technique can become the basis for technology of creating general ontology from private ones.

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